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Money Stock Measurement

History, Theory and Implications

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In This Issue . . .

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President's Message

The Federal Reserve Bank of St. Louis has long emphasized the central role of monetary aggregates in the conduct of monetary policy. Appropriate long-run growth of the supply of money is essential to attaining the principal goal of monetary policy—price stability—which, in turn, is necessary to maximize sustainable growth in the economy. And the monetary aggregates have, in fact, played important roles as indicators of monetary policy in connection with the actions leading to the deceleration of U.S. inflation over the last several years.

Translating the abstract scientific concept of "money" into a measurable empirical counterpart has often been controversial. Obviously, a monetary aggregate must include the exchange medium of the economy, including currency and checkable deposits. The spending plans of households and firms are also affected by and reflected in the quantities of other liquid assets that they hold. How many of these should be included in a monetary aggregate? And, by what criteria should they be selected?

Studies of the measurement of money tell us that the answers to these questions change through time. Financial innovation changes institutional arrangements and practices, forcing us to revise our measures of money. In some cases, new financial instruments such as money market mutual funds are added to the monetary aggregates. In other cases, increasing similarity among financial institutions may require a major change in the institutional coverage of the aggregates. We experienced both of these phenomena in the 1970s. Technological progress continues to cloud our measures of money by reducing the transaction costs of quickly exchanging one asset for another.

Our staff in St. Louis has contributed in a number of ways to the measurement of monetary aggregates. Thirty-three years ago, William Abbott's revised M1 monetary aggregate appeared in the *Federal Reserve Bulletin*. Twenty-five years ago, the St. Louis adjusted monetary base first appeared in this Bank's *Review*. Through widely circulated publications such as *Monetary Trends and U.S. Financial Data*, Homer Jones and his successors have disseminated monetary aggregates data to a worldwide audience of analysts and researchers.

Research at St. Louis has also examined the policy implications of linkages between various monetary aggregates and nominal economic variables. This year, for example, marks the 25th anniversary of publication in the St. Louis Fed's *Review* of Leonall Andersen and Jerry Jordan's seminal research linking the growth of nominal income to the growth of the M1 monetary aggregate.

Today, some suggest that the monetary aggregates may no longer be useful guides for monetary policy. The weaker-than-anticipated growth of M2 during the recent economic recovery and expansion has brought to the forefront once again issues regarding the measurement, modeling, and continued policy usefulness of monetary aggregates. I am hopeful that the presentations and discussions presented at this conference will improve our understanding of the issues involved in measuring money and the implications of alternative measures for the conduct of monetary policy.

Thomas C. Melzer
President and Chief Executive Officer
Federal Reserve Bank of St. Louis

Editor's Introduction

Monetary aggregates have played a prominent role in policy research at the Federal Reserve Bank of St. Louis for more than 25 years. The Bank's 18th annual Economic Policy Conference in October 1993 brought together a variety of evidence on the interaction between the use of monetary aggregates in policymaking and measurement of the money stock.

The first session of the conference addressed issues in the construction of monetary aggregates. Milton Friedman and Anna Schwartz have noted that measurement of the stock of money in the United States is an activity almost as old as the republic itself. Their well-known histories of these data, however, largely precede both the first modern monetary aggregates published by the Federal Reserve in 1960 and the aggregates used today in macroeconomic research. In the first paper presented at the conference, Richard Anderson and Kenneth Kavajecz review the history and construction of the Federal Reserve's monetary aggregates.

Following a broad introductory discussion of definitional and statistical issues, Anderson and Kavajecz trace the history of the Federal Reserve's monetary aggregates since 1943. They describe in detail the sources of data used in building the current aggregates, cautioning the reader that a wide variety of data are received and incorporated into the aggregates throughout the year. Because various Federal Reserve publications are released at different times, observations on a monetary aggregate in one publication may differ significantly from observations in another. Moreover, data in different issues of the same publication more than a year apart may not be comparable since the monetary aggregates are benchmarked each year to incorporate additional incoming data and new seasonal adjustment factors. The authors find that these annual benchmarks often significantly change published growth rates for the monetary aggregates, although the size of the revisions is small except for the most recent years. The authors conclude with a summary of the Federal Reserve's use of monetary aggregates as monetary targets.

The article is followed by a unique timeline compiled by Kenneth Kavajecz that traces the history of the Federal Reserve's monetary aggregates from 1960-93. The date of each change in definition and benchmark revision is included, as well as descriptions of many special events that affected the monetary aggregates. Of general interest to all readers, the chronology will be invaluable to researchers working with high-frequency data on the monetary aggregates.

In his commentary, Charles Calomiris proposes a number of reasons why empirical economists should be concerned about the construction of the monetary aggregates data that they use in their research. Since tests of many hypotheses in modern macroeconomics require long time series of data, researchers may be at risk by ignoring issues such as changes in sampling and seasonal adjustment procedures used by the data constructors. Further, the construction of long time series is complicated by the Fed's frequent retrospective revisions and redefinitions of the monetary aggregates. Calomiris also notes that the redefinitions discussed by Anderson and Kavajecz call into question the usefulness of the monetary aggregates for testing many propositions in macroeconomics. If the redefinitions are motivated by a desire to make the new aggregate better track economic activity, then the redefined aggregates may not be suitable for tests of the structural stability of macroeconomic relationships, including money demand.

A number of economists have argued over the last 15 years that simple-sum monetary aggregates of the type published by the Federal Reserve Board are not defensible in terms of either economic aggregation or statistical index number theory. These researchers have suggested a number of alternative measures of the money stock including the Divisia monetary aggregate proposed by Barnett and the currency-equivalent aggregate suggested by Rotemberg. In the conference's second paper on the policy implications of differing measures of the money stock, K. Alec Chrystal and Ronald MacDonald compare the indicator properties of simple-sum aggregates to those of alternative measures of money in seven industrialized countries.

The authors' first set of tests is based on a variant of the classic St. Louis reduced-form equation for nominal output. Perhaps as might be expected, the results show little difference between the indicator properties of narrow simple-sum and Divisia aggregates. For broader aggregates, however, the Divisia aggregates are generally found to be preferable to simple-sum aggregates. Next, the authors conduct a series of sophisticated multivariate causality tests based on estimated error-correction models. These tests also suggest that Divisia aggregates are preferred to simple-sum aggregates, although the results are not so strong as to find that a Divisia aggregate has significant indicator value when a simple-sum aggregate does not. In a test on U.S. data since 1980—a period of extensive financial innovation—the authors find particularly strong support for the superior indicator properties of a Divisia M2 index relative to the simple-sum M2 aggregate.

In his commentary, Charles Nelson notes that the authors' specification of the St. Louis equation for the U.S. is not comparable to that for their other countries, with the former better seen as a structural demand equation and the latter as reduced-form equations. For the U.S., although differences between results based on alternative various M1 and M2 aggregates may be reasonable, he finds puzzling the sharp differences among results for M1 and Divisia M1 and M1A when one might have expected the three aggregates to closely resemble each other.

Nelson also questions the authors' causality inferences drawn from their estimated error-correction models. Emphasizing that monetary aggregates enter the error-correction models through both the first differences of their growth rates and the error-correction terms (which are specified in growth rates rather than levels), he suggests that Chrystal and MacDonald's emphasis solely on the significance of the coefficients on the first differences of growth rates may be misplaced. Strong significance of the error-correction terms in some equations suggests more of a role for monetary aggregates than the authors perhaps recognize.

The papers presented in the second session addressed a pair of econometric issues in measurement of monetary aggregates. Financial assets, like other goods, are demanded by households because they yield a flow of services. This simple insight suggests the potential value of analyzing the demand for money in the context of a multivariate expenditure system, rather than as a single isolated demand equation. Despite its intuitive appeal, the expenditure system approach has had limited acceptance due to a number of shortcomings. Most prominent perhaps has been uncertainty regarding the correct functional form. This uncertainty has led to widespread use of flexible functional forms able to furnish (at least) a second-order approximation to the true unknown function at (at least) one point.

The Fourier flexible functional form proposed by Gallant solves the approximation problem by providing an arbitrarily accurate global approximation to any unknown function and its partial derivatives. Expenditure systems based on this functional form typically have been static, however, limiting their usefulness with economic time series data. Douglas Fisher and Adrian Fleissig propose and compare two dynamic extensions of the Fourier functional form. Their estimates of dynamic expenditure systems that include monetary assets suggest that the dynamic models are more consistent with the data than the Fourier static model. In particular, the dynamic models seem to provide much sharper estimates of the elasticities of substitution between the various types of monetary assets held by households.

No econometric model can be all things, but James Swofford concludes in his commentary that Fisher and Fleissig have done a commendable job of achieving the goals they set forth for their model. Their dynamic extension of the Fourier functional form is an important contribution, likely of value to many future researchers. He notes, however, that although their elasticity estimates are plausible, many readers may find them difficult to interpret. The reader who is primarily interested in understanding household money demand may miss entirely the importance of estimating expenditure systems if authors, including Fisher and Fleissig, fail to provide a thorough discussion of their findings. Swofford also concludes that Fisher and Fleissig's model fares laudably well against the very demanding criteria proposed by Carl Christ at last year's St. Louis economic policy conference.

The next paper addresses the relatively new topic of supply-side monetary aggregation. Measured money stocks in most economies are primarily composed of inside money or, in other words, of the liabilities of profit-maximizing firms. The supply-side aggregation conditions applicable to the monetary services produced by these liabilities differ from those more commonly studied in the demand-side monetary aggregation literature. Recognition of the risk and uncertainty facing these intermediaries further complicates aggregation, since existing economic aggregation conditions and index number theory (such as that for Divisia monetary aggregates) have usually considered only cases of perfect certainty. William Barnett and Ge Zhou introduce to the literature a stochastic model of monetary services production by banks under uncertainty. In the model, banks are treated as neoclassical competitive firms that maximize the present value of expected utility. The banks contract for deposits and real factor inputs (labor, for example) at the beginning of each period. During the period, three variables—the economy's average price level, reserve requirement ratios for each deposit type, and the ex post realized rate of return on loans—are determined by random processes not controllable by the firm. The empirical results support the hypothesis that the banks' deposit liabilities are weakly separable from purchased real factor inputs such as labor. A comparison of the Divisia, simple-sum, and currency-equivalent monetary aggregates to the model's estimated exact monetary aggregate suggests that the ability of the Divisia index to track the exact aggregate is little diminished under uncertainty. This conclusion is invariant to whether the exact aggregate is constructed from model estimates based on alternative assumptions of risk neutrality and risk aversion.

In his commentary, William Brainard notes the increasing importance of studies of the supply of monetary assets. Unlike simpler times, when the money stock could be well measured by summing currency and demand deposits, today's relatively low costs of substituting among a wide variety of financial assets makes less certain both the measurement and control of monetary aggregates. Brainard notes, however, that the dynamic structure of the model may not be as rich as the authors suggest. In particular, the period-by-period balance sheet constraint imposed by Barnett and Zhou as equation 2 prevents the model firm from carrying retained earnings (or losses) forward. Each period, the firm's available resources include only the deposits and real inputs contracted for at the beginning of that period plus a fixed amount of capital; in turn, all earnings must be paid out to the owners of the firm at the end of the period since the balance sheet constraint prevents any from being carried forward into the next. He suggests that the apparent dynamic structure of the profit function in their equation 3 arises because Hancock's profit function, equation 1 in Barnett and Zhou, differs from the cash flow that the firm will in fact receive in each period, conditional on its decisions and the stochastic nature of the economy. This reservation aside, the richness of Barnett and Zhou's paper is reflected in the numerous extensions proposed by Brainard for future researchers.

In a response to Brainard, Barnett and Zhou present additional results clarifying the dynamics of their model. The model requires some type of temporal separability restriction on either the discounted profit stream or the intertemporal utility function to avoid the intractable problem of estimating a system of simultaneous Euler equations. The formulation employed by Barnett in previous work, and preferred by Brainard, appears as but one of a number of alternative separability hypotheses. The relative plausibility of the hypotheses remains a subject for further empirical research.

Papers at the conference's final session once again turned to the implications of alternative measures of the money stock for the conduct of monetary policy. Monetary policymakers often rank price stability first among their goals. During the 1970s, central banks worldwide adopted growth targets for monetary aggregates that they hoped would guide them toward price stability. In many countries, however, initial optimism became disappointment as Goodhart's law—that the behavior of a monetary aggregate will change when the central bank targets its growth—seemed to prevail. Jerome Stein studies whether Goodhart's law has applied with equal force in the United States to all measures of the money stock. Working with the dynamic model he developed with Infante in the 1980s, Stein demonstrates that the short-run stability of the linkage between inflation and money growth is apparent only when the model includes a variable representing the state of the economy, measured in his model by the difference between the current and long-run equilibrium unemployment rates. In that case, the growth of M2 arises as a good indicator of movements in both inflation and unemployment. Further, M2's indicator properties appear superior to those of statistical index number monetary aggregates, including Divisia M2, the currency-equivalent aggregate CE, and a Divisia CE aggregate. Regardless of its indicator value, a monetary aggregate must be controllable before it can be chosen as a policy target. Stein concludes that none of the broad monetary aggregates are sufficiently controllable to be used as targets. He finds, however, that adjusted bank reserves appear to be an acceptable target for control of the inflation rate.

Although monetary aggregates may be valuable indicators of the stance of monetary policy, they are not necessary for central banks to achieve price stability. Agreeing with Stein that the long-run inflation rate is largely determined by growth of the money stock, Frederic Mishkin notes that Federal Reserve policy has supported a relatively low, steady inflation rate during the last decade without strict adherence to any monetary target. He suggests that the highly dynamic nature of Stein's model might help explain the relatively poor showing of M2 per se as an indicator for individual variables such as inflation and real output while being a valuable indicator for nominal GDP. Since real output growth accelerates more quickly following a monetary shock than inflation and later tends to slow while inflation accelerates, cyclical movements in M2 may be more closely correlated with both short- and long-run movements in nominal GDP than with either inflation or real output separately. At the same time, Mishkin finds troubling the poor fit of the model to quarterly data which may indicate that Stein's empirical surrogate model is not capturing well the dynamic interactions prominent in the SM theoretical model. Also puzzling are the very different conclusions reached by Stein and by Chrystal and MacDonald regarding the relative indicator properties of simple-sum and Divisia M2. Finally, Mishkin emphasizes that the omission of rational expectations from Stein's model prevents him from analyzing the importance of credibility in policymaking. Announced targets for monetary aggregates might help prevent sharp jumps in inflationary expectations by signalling the public that the central bank is serious about achieving its inflation targets. In this event, monetary aggregate targets might help the central bank stabilize the inflation rate even when measurement of the monetary aggregate is uncertain or monetary aggregates are not highly controllable.

The conference concluded with a panel discussion of the role of monetary aggregates in feedback rules for the conduct of monetary policy. Monetary aggregates have historically been constructed to guide monetary policy. The introduction of rational expectations into macroeconomic models emphasized that the feedback rules by which policymakers adjust growth of monetary aggregates are an important part of the structure of the economy.

In the panel discussion, Michael Boskin suggests that Federal Reserve actions under Alan Greenspan, and to some lesser extent under Paul Volcker, should be viewed as a rules-based policy. He sees the Fed as setting out a strategy whereby its actions in most periods are governed by pursuit of its goal of long-run price stability, rather than by a feedback rule based on a monetary aggregate. Temporary deviations from pursuit of the goal are permitted for exigencies that are well understood by the public. Further, in his view, the Federal Reserve will never find satisfactory any policy rule that includes only a small set of monetary aggregates or similar indicacor variables.

Behavioral rules arise naturally as solutions in decision-theoretic models. Could a monetary policy rule based on monetary aggregates arise as the solution to a decision problem? The second panelist, Philip Dybvig, proposes a complete prototypical decision framework for the Fed, including an objective function, control variables, constraints and a well-defined information set. Although too much of the structure remains unknown to obtain explicit solutions, he concludes that future research on the value of monetary policy rules and the role of monetary aggregates might usefully be guided by such a framework.

Some researchers have argued that monetary aggregates have little value as either policy targets or indicators. If so, discussion of their measurement seems vacuous. The third panelist, Bennett McCallum, concludes the conference by suggesting that monetary aggregates are indeed irrelevant to the conduct of monetary policy. In his framework, the central bank's main job is to keep nominal GDP growing smoothly at a noninflationary rate. Even when the penultimate goal is price stability rather than stable growth of nominal output, he argues that we know much better what growth rate for nominal GDP is likely to be consistent with long-run price stability than we do the appropriate long-run growth rates for M1 or M2. McCallum's research suggests that directly targeting the growth of nominal GDP through control of the monetary base is preferable to targeting any monetary aggregate, no matter how measured.

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April 8, 1994

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A Historical Perspective on the Federal Reserve's Monetary Aggregates: Definition, Construction and Targeting

"...the Federal Reserve should use as an intermediate target that monetary total (aggregate), or those totals, through which it can most reliably affect the behavior of its ultimate objectives — the price level, employment, output, and the like. Which total or totals best satisfy that requirement depends in turn on (1) how accurately the total can be measured; and (2) how precisely, and at what costs including unwanted side effects, the Fed can control the total; and (3) how closely and reliably changes in the total are related to the ultimate policy objectives.

"In general, though by no means uniformly, the broader the concept, the greater the problems of measurement and control."

Improving the Monetary Aggregates (Report of the Advisory Committee on Monetary Statistics), 1976, p. 7.

DATA ON THE MONETARY AGGREGATES are the fundamental raw material of research in many facets of economics and finance. Money demand modelling, measurement of money stock announcement effects, tests of the rationality of preliminary money stock forecasts and financial market efficiency, and comparison of alternative seasonal adjustment procedures are just a few such areas. Monetary aggregates also are used by Federal Reserve System staff in formulating policy alternatives for the Federal Open Market Committee (FOMC). Perhaps no government data are more important or more widely used in economic and financial research than the monetary aggregates. Often unappreciated by researchers, however, is the extent to which the appropriate use of monetary aggregates data is intimately connected with changes through time in the data's definitions, construction, revision and publication. A failure to appreciate the interdependence of time, data, definitions and procedures may adversely affect or vitiate research and policy conclusions.

This paper discusses the construction, publication and evolution of monetary aggregates data since the inception of the Federal Reserve System in 1914. In opening their seminal volume on U.S. monetary data, Friedman and Schwartz (1970) set a similar objective:

> This book attempts to provide a comprehensive survey of the construction of estimates of the quantity of money in the United States — an activity that dates back almost to the beginnings of the Republic. The survey covers sources, methods of construction, and the end product. (p. 1)

Friedman and Schwartz present a consistent time series of monetary aggregates based on their own data for 1867-1946 and Federal Reserve data through the mid-1960s. This paper and the companion timeline (Kavajecz, 1994) extend Friedman and Schwartz by reviewing the construction and publication of the Federal Reserve's monetary aggregates from 1960 through 1993. We focus on the years since 1960, the period for which the Federal Reserve Board staff currently publishes official monetary aggregates. The interested reader will find few (if any) available descriptions of the Federal Reserve's monetary aggregates comparable to Friedman and Schwartz's narrative.

The evolution of the monetary aggregates as economic statistics has been influenced by both economic thought and statistical practice.[1] Structural change in financial markets and the introduction of new financial instruments require periodic redefinition of the monetary aggregates to accurately reflect the portfolio choices available to households and firms. Never defined nor constructed in the abstract, however, monetary aggregates exist largely as indicators and/or targets of monetary policy. Thus, to an unknown but perhaps considerable extent, selection of the definitions of the monetary aggregates has been based on the relative ability of alternate aggregates to predict economic activity. Prior to 1980, commercial banks furnished most transaction deposits and their nontransaction deposits seemed to be the closest substitutes for money. In turn, the Federal Reserve's monetary aggregates emphasized both the distinctions between types of deposits and between commercial banks and thrift institutions. The narrower M1 and M2 aggregates first published in 1971, for example, included only deposits at banks, while thrifts were included in M3. These distinctions were preserved in 1975 when M3 was revised and M4 and M5 were introduced.

Perceived breakdowns in the historical relationship between a monetary aggregate and economic activity, reflected, say, in a putative permanent shift in its velocity, may lead to calls for redefinition of the aggregate. Such pressures on M1 and M2 (as initially defined in 1971) were apparent throughout the 1970s. Reinforced by accelerations in inflation and a shift by some macroeconomists toward increased emphasis on the monetary aggregates, these pressures led in early 1974 to the appointment of the Advisory Committee on Monetary Statistics, chaired by professor George Bach of Stanford. By 1980, the Depository Institution Deregulation and Monetary Control Act (DIDMCA) permitted a redefined set of monetary aggregates to be constructed from a greatly expanded, much richer and much more costly flow of data than had ever previously been available. The new aggregates also seemed to have more stable relationships to economic activity. Published analyses at the time of the 1980 redefinition cited with approval the lack of trend in the velocity of the new M2 relative to the old measure, although they stopped short of proposing a less variable long-run velocity as a choice criterion.[2] Although such pragmatic redefinition seems clearly to be in the spirit of Friedman and Schwartz[3], it may account for at least some part of the ex post stationarity of the GNP velocity of M2 (as currently defined) identified by Hallman, Porter and Small (1991).

The ideal monetary aggregate would be composed of assets that are capital-certain (or

[1] We do not discuss in this paper the work on aggregation theory and related monetary aggregates such as the Divisia and MQ aggregates. These were consistently labelled by Board staff as experimental and not adopted for policy analysis. The interested reader is referred to Barnett (1980) and Spindt (1985).

[2] Simpson (1979, 1980). Other descriptions of the construction of the Federal Reserve's monetary aggregates include Broaddus (1975), Duprey (1982), Lawler (1977) and Walter (1989).

[3] See especially chapter 4.

nearly so), highly liquid and closely related to economic activity. Narrow monetary aggregates composed primarily of medium of exchange seem to satisfy at least the first two criteria acceptably well, while broader aggregates do so somewhat less well. Broader aggregates often include assets that are capital-uncertain or, in other words, assets whose market values vary with market interest rates, the pace of economic activity, or expectations of such variables. Broad monetary aggregates are uniformly defined to include the nominal (face) value of capital-uncertain assets rather than the market value, however. Small time deposits included in the non-M1 component of M2, for example, may be taken to be capital-uncertain when there are penalties for withdrawal before maturity.[4] Money market mutual fund (MMMF) shares, also included in the non-M1 component of M2, appear capital-certain to their holders even though the market value of the funds' assets varies inversely with market interest rates. So long as the MMMFs satisfy a variety of Securities and Exchange Commission rules (including restrictions on the maturity of the funds' assets) and short-term market interest rates don't move too rapidly, the funds need not pass through changes in the market value of their assets to shareholders. The market values of money market instruments included in very broad aggregates such as M3 and (the seldom used) L vary considerably more, however. Such instruments include negotiable large time deposits included in the non-M2 component of M3, and most items included in the non-M3 component of L. Monetary aggregates defined to include the nominal rather than market value of these assets necessarily omit some actual portfolio constraints faced by firms and households, who must necessarily substitute among financial assets at market rather than nominal values. Including these assets in monetary aggregates at market values, however, would cause the *measured* size of the aggregate to vary with market rates. This might reduce the usefulness of the aggregate as an indicator of the impact of policy actions. A policy action that reduced reserve availability could reduce not only the quantity of money demanded as market interest rates increased, but also the apparent quantity "supplied" as prices of the included money market instruments fell. The indicator properties of movements in such capital-uncertain monetary aggregates for economic activity have not been established.[5]

The statistical issues in building monetary aggregates also are formidable. If cost were no object, an ideal monetary aggregate would be built from daily observations on all its components at all financial intermediaries. In fact, cost/benefit tradeoffs figure prominently in both data collection and the definition of the aggregates. The Congress has mandated that a cost/benefit analysis be part of each application for renewal of major deposit reports, typically required every three years. Reporting burden is generally to be kept as low as possible while obtaining adequate data for the conduct of monetary policy. This position has led to deposit reporting strategies based on survey sampling wherein deposit coverage and reporting frequency vary by size of institution.

Most of these issues have largely been omitted from the literature on money demand. As fine a work as Laidler's (1993) classic text on money demand fails to discuss the definition, construction or revision of monetary aggregates, except to acknowledge Friedman and Schwartz's research. Nowhere is the reader warned of the potential pitfalls in monetary aggregates data awaiting the unwary. This problem arises largely from the difficulty and high cost to researchers of locating relevant institutional details. This paper attempts to reduce that cost.

SOURCES OF MONETARY AGGREGATES DATA

Throughout U.S. history, every definition of money has been composed primarily of the liabilities of private financial institutions, both notes and deposits. During most periods, these financial institutions have been subject to government regulation. In turn, the primary sources of current and historical monetary aggregates data are government reports filed by these financial institutions.

4Under Regulation Q, depositories were required to impose early withdrawal penalties. Many institutions have chosen to continue such penalties even in the absence of Regulation Q. On the demise of Regulation Q, see Gilbert (1986). The liquidity of time deposits has varied through time. Prior to Reg Q, some time deposits were indistinguishable from modern savings and transaction deposits; see Friedman and Schwartz (1970), p. 76–7.

5The difficulties of interpreting monetary aggregates that include capital-uncertain instruments are prominent in proposals to include bond and equity mutual funds in a redefined M2. See, for example, Collins and Edwards (1994) and Orphanides, Reid and Small (1993).

The Federal Reserve's first published monetary aggregate appeared in 1943 in Table 9 of *Banking and Monetary Statistics*. The table showed currency, demand deposits and time deposits for June call dates from 1892 to 1922 and for June and December call dates from 1923-41. The sum of currency and demand deposits was defined as "the supply of money" or "means of payment," although it was noted that time deposits often were used for current payments "...during the 1920s." Subsequent data were published in the *Federal Reserve Bulletin*.[6] Later, Copeland and Brill (1948) presented a series based on the last-day-of-the-month consolidated condition statement of the banking system. In 1949, the Board began monthly publication of this series.

The first modern monetary aggregate based on averages of daily data, labelled M1, was constructed by William Abbott and Marie Wahlig of the Federal Reserve Bank of St. Louis and appeared in the *Federal Reserve Bulletin* in 1960 (Abbot, 1960); a revision was published in 1962 (Abbot, 1962). Building monetary aggregates from daily data is important because seasonal patterns within a month may cause data for individual days to be unrepresentative of both the month's average level and the aggregate's trend growth rate. Abbott and Wahlig's data, which began in 1947, reflected available deposit reports and were shown at half-monthly and monthly frequencies. Member banks had begun reporting in 1944 averages of daily data at the middle and end of each month. Data for nonmember banks and mutual savings banks (MSBs) were estimated from Federal Deposit Insurance Corporation (FDIC) call reports, although the precise interpolation method is not stated.

Monetary aggregates data subsequently were published on the Board's statistical release, known as the *J.3* and entitled *Demand Deposits, Currency, and Related Items*, twice a month from November 1960 through July 1965. The release included averages of daily data at half-monthly and monthly frequencies, seasonally adjusted, and at weekly, half-monthly and monthly frequencies, not seasonally adjusted.[7] The most recent data included on the release predated the publication date by two weeks.

The *J.3* was succeeded by the current release, known as the *H.6* and entitled *Money Stock, Liquid Assets, and Debt Measures*, on July 30, 1965. It shows averages of daily figures at weekly and monthly frequencies. A revised monetary aggregates series based on weekly averages of daily data beginning in 1959 was later presented by Fry, Beck and Weaver (1970).[8] The current definitions of the monetary aggregates were largely established in 1980; see Kavajecz (1994) and Simpson (1979, 1980). At the time of the redefinition, monetary aggregates based on the new definitions were constructed back to 1959. Details of their construction are discussed in the appendix.

For researchers, monetary data extracted from individual issues of the *J.3* and *H.6* releases provide contemporaneous estimates of the monetary aggregates based on a well-defined information set: the data available to Board staff as of the publication date. These statistical releases allow a researcher interested in announcement effects or the policy formation process of the FOMC to observe Federal Reserve Board staff estimates of the level of the money stock at each point in time, or permit a researcher interested in market efficiency or the "rationality" of initial money stock estimates to study the timing and extent of revisions to initially published data. The statistical releases are not very useful for longer-run studies, however, because the information set underlying the release changes each week as Board staff receives both new data and revisions to previously reported data. Further, the definitions of the monetary aggregates have changed through time.

While the Federal Reserve Board has published a number of historical volumes, each with unique features making it a valuable source of data, use of these data also is complicated by varying definitions and observational frequencies. Ideal historical data would be computed at similar frequencies under consistent definitions. The two most comprehensive volumes, *Banking and Monetary Statistics* and *Banking and Monetary Statistics 1941-1970*, were published by the Federal Reserve in November 1943 and September 1976,

[6]For details, see the introductory notes to section 1 in *Banking and Monetary Statistics* and the notes to chapters 1-4 in *Banking and Monetary Statistics 1941–1970*.

[7]Member banks began reporting daily data each week in December 1959. For years after 1959, the weekly data were prorated to obtain monthly and half-monthly frequencies.

[8]Some independent researchers have attempted to build monetary aggregates data for earlier periods using current definitions. For a careful discussion of the issues, see Rasche (1987, 1990).

respectively.[9] Observational frequency differs across data series, with various data at monthly, weekly or daily frequencies. There are also important conceptual distinctions through time in the data, such as the difference between member and nonmember banks and the difference between thrifts and commercial banks. When using data from other sources in conjunction with the *Banking and Monetary Statistics* volumes, researchers should appreciate that data published subsequently are not strictly comparable, since more recent publications incorporate further revisions to the data.

A closely related publication, and the yearly counterpart to the *Banking and Monetary Statistics* volumes, is the *Annual Statistical Digest*. The *Digest* is released at the end of each year and contains data for the previous year. The Board's *Annual Report* also contains information about the monetary aggregates, but the information tends to be more descriptive than numerical. These publications provide a long-run, consistent perspective of the monetary aggregates over their respective published date ranges, since within each issue of each publication the observations are based on a single, consistent information set. They perhaps are less appropriate, however, for lines of research where the hypotheses depend on the information set used in constructing the money stock estimate, since the date the estimate was formulated is not explicitly given.

Similar concerns suggest that data sets constructed from various issues of the *Federal Reserve Bulletin* may not be suitable for a variety of research. Board staff have published components of the monetary aggregates, such as demand deposits and currency, in the *Bulletin* since its inception in May 1915. In February 1944, the staff first showed demand deposits and currency in the same table, foreshadowing the later M1 monetary aggregate. While the *Bulletin*'s current Table 1.10 (first published in its present form in January 1977) descends from the 1944 table, the data published in this table through the years are not a consistent time series due to definition changes, reporting changes, annual benchmark revisions, and reestimation of seasonal adjustment factors. At the same time, the *Bulletin* is an excellent resource for tracking the various changes that have occurred in the definitions and construction of the monetary aggregates through time. Due to its somewhat longer time span, data extracted from various issues of the *Bulletin* illustrate how the monetary aggregates have evolved; occasional articles have presented detailed information on changes in the monetary aggregates. Unfortunately, like many other Federal Reserve historical publications, the *Bulletin* does not specify the date at which the estimates were made, that is, the time-indexed information set on which they were based. In general, data in the *Bulletin* precede by two months the *Bulletin*'s publication date, but at times it has been longer. Since monetary aggregates data appear with differing lags in various System publications (for example, 10 days on the *H.6*), data from different sources may be based on quite different information sets even when the dates that they first appear in print are close together. This suggests that, in general, a database built from one Federal Reserve source or publication should not be updated from another.

Finally, a publication that presents comprehensive, consistent time series is *Money Stock Revisions*.[10] This publication is offered to the public early in each year as a supplement to the issue of the *H.6* release that incorporates the Board staff's annual benchmark revisions, including reestimated seasonal adjustment factors. The publication presents a comprehensive set of monetary aggregates data, beginning in 1959 for monthly data and in about 1975 for weekly data.[11] Unlike other Board staff publications, the information set and definitions used in constructing the data are well-defined, making the data ideal for longer-run studies. Note, however, that since each year's publication uses that year's current definitions — and the definitions of the monetary aggregates and their components have changed through time — the data may differ significantly from previously published data.

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[9]The 1943 edition of *Banking and Monetary Statistics* was reprinted in August 1976. See also the Board's corrected 1959 reprint of *All-Bank Statistics.*

[10]The title of this publication has changed somewhat through time. It currently is produced by the Money and Reserves Projections Section of the Division of Monetary Affairs. Prior to 1988, it was produced by the Banking Section of the Division of Research and Statistics. Prior to 1993, the printed publication was offered to the public as a supplement to the issue of the *H.6* release that contained the newly benchmarked monetary aggregates data; data in machine readable form were sold by the National Technical Information Service of Springfield, Virginia. In 1993, the publication and associated data were first offered for sale by Publications Services at the Board of Governors.

[11]Subject to the availability of the particular series. See Table 2 for the availability of specific series.

DATA COLLECTION

The data collection process is the foundation of the construction of monetary aggregates data. The collection of data useful for the monetary aggregates has changed (and improved) dramatically during the last eight decades. We present here a brief outline of the principal data inflows to the Federal Reserve during a small number of distinct periods over which data collection and publication practices differed significantly.

1915-43

The data collected during this period have been extensively documented by Friedman and Schwartz (1970), chapters 12-15. Beginning in 1923, data for all member banks are available. From April 1923-December 1928, the Federal Reserve collected and published deposits as of a single day each month; from January 1929-March 1944, monthly averages of daily data; after March 1944, averages of daily data were collected twice a month. Data also continued to be reported each week on Wednesday by a sample of several hundred weekly reporting banks that held a majority of bank deposits. Data for nonmember banks and for MSBs were available on call reports.

1944-80

Averages of daily member bank deposit data were collected twice a month through December 1, 1959, when weekly averages began to be collected. Regular publication beginning in November 1960 of monthly money stock figures on the *J.3* release necessitated estimates of the monetary liabilities of nonmember banks. Nonmember bank data continued to be collected on call reports, typically two per year until 1960, when thereafter four per year were required.

1980-Present

Perhaps the least appreciated aspect of the Monetary Control Act of 1980 was a significant improvement in the quantity and quality of data flowing to the Federal Reserve. A watershed in data collection, the act empowered the Federal Reserve System to impose reporting requirements on all depository institutions with reservable liabilities above a prescribed minimal amount. The act significantly eased estimation of the money stock, as deposit reporting by financial institutions became nearly universal and was no longer a function of membership status or charter type.[12] Two years later, in the Garn-St. Germain Act, Congress mandated that the Federal Reserve establish guidelines to ease reporting burden borne by financial institutions while maintaining adequate coverage of the outstanding monetary liabilities of the banking system. In response, a system of reporting categories was established wherein the reporting burden — measured by frequency of reporting and number of items reported — depends upon both total deposits and reservable liabilities.

Under this system, the Federal Reserve Board staff each year establishes a cutoff level of total deposits and an exemption level of reservable liabilities. Increases in both levels are indexed to the year-over-year increase in aggregate deposits at all depository institutions as calculated from second quarter (June 30th) call reports.[13] Table 1 summarizes the System's reporting categories and the type/frequency of report submitted by financial institutions in each category for 1992, 1993 and 1994.[14] The deposit cutoff and reserve exemption levels were established at $25.0 and $2.4 million, respectively, beginning January 1985. These have subsequently been indexed each year, based on 80 percent of the growth in aggregate deposits, except in 1988. In that year, Board staff research suggested that little accuracy would be sacrificed, and a significant reporting burden reduced for smaller institutions, by increasing the deposit cutoff more rapidly. The deposit cutoff, which had automatically increased in January to $30 million from the previous year's $28.6 million,

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[12]In particular, thrift institutions and nonmember banks began reporting deposits weekly to the Federal Reserve.

[13]A zero reserve requirement ratio applies to the reserve exemption amount of deposits. The reserve exemption amount is not to be confused with the low reserve tranche. The tranche allows a lower 3 percent reserve requirement ratio to be applied to some portion of deposits, while a higher ratio (currently 10 percent) applies to the balance. Both the reserve exemption amount and the low reserve tranche are indexed. For 1993, the reserve exemption and low reserve tranche amounts are $3.8 and $46.8 million, respectively. For 1994, the amounts are $4.0 and $51.9 million, respectively.

[14]Values for each year are typically published in the respective January issues of *Federal Reserve Bulletin*. Values for 1992, 1993 and 1994, for example, appear on pp. 36-7, 18 and 23-4 of the January 1992, 1993 and 1994 issues, respectively.

Table 1

Depository Institution Reporting Categories 1992–94 by Deposit Cutoff and Reserve Exemption Amount

Amounts effective as of January 1992 (1993) [1994]		**Reserve Exemption Amount** reservable liabilities	
	Deposit Cutoff total deposits	if more than $3.6 ($3.8) [$4.0]	if less than $3.6 ($3.8) [$4.0]
	if more than $44.8 ($44.8) [$44.8]	the institution must file the FR2900 report weekly	the institution must file the FR2910Q report quarterly
	if less than $44.8 ($44.8) [$44.8]	the institution must file the FR2900 report quarterly	the institution might be exempt from reporting

Note: All figures are in millions of dollars.

was raised in September to $40.0 million. Several thousand smaller banks were exempted from weekly reporting by this change.

Institutions that file the FR2900 at a *weekly* frequency (Table 1, the upper left-hand box) report daily levels for about a dozen deposit and nondeposit liabilities. Institutions falling in the other boxes have a sharply reduced reporting burden. Institutions that file the FR2900 at a *quarterly* frequency (the lower left-hand box) report the same items but only for a single week each quarter (the week that contains the third Thursday in the last month of the quarter). Institutions that file the FR2910Q (upper right-hand box) report weekly average data on fewer items for one week each quarter. Institutions in the lower right-hand box of Table 1 are exempt from filing reports with the Federal Reserve if and only if Federal Reserve staff are able to accurately obtain required data from other sources, such as call reports.[15] For institutions other than weekly reporters (all categories except those in the upper left-hand box), Federal Reserve Board staff must estimate their deposits during the periods between reports. In 1992, daily data were received each week from approximately 9,100 financial institutions, about 30 percent of all depositories. These data comprised about 90 percent of the aggregate deposits included in the monetary aggregates (the balance being estimated), or, including nondeposit liabilities, about 80 percent of the aggregate liabilities of financial institutions included in the monetary aggregates.

Construction of weekly values of broad monetary aggregates such as M2 and M3 also relies on a variety of weekly reports of data for nondeposit liabilities such as repurchase agreements (RPs), Eurodollar deposits, and reports from nonbank financial institutions such as MMMFs. The numerous sources and reports used by Board staff in the construction of the monetary aggregates are shown in Table 2. In general, broader aggregates such as M2 and M3 are less precisely measured than M1 because a larger proportion of the data included in the aggregate is either not reported directly to the Federal Reserve, and/or is reported less frequently than the data included in M1. In addition, a larger number of various nonmoney stock items are netted out of the broader aggregates.

In the non-M1 components of M2 and M3, MMMF shares have been among the more complex items. A dynamic industry characterized by rapid growth, new funds have frequently appeared and old ones vanished. In addition, funds may merge, change names or change investment objective by, say, lengthening the maturity of their assets to become a short-term bond fund. All these events complicate accurate

[15] If not, the institution is required to file an annual report.

Table 2

Information about the Definition, Availability and Source Data for the Monetary Aggregates

This table provides information on the construction of the monetary aggregates M1, M2, M3 and L as of October 1993. Readers are cautioned that some definitions and data sources may differ in earlier periods. Each aggregate reflects the amounts of the designated assets held by the nonbank public, which includes households, businesses and government entities other than the U.S. Treasury. Assets issued in the U.S. are included whether they are held by foreign or domestic residents. Certain dollar-denominated assets issued abroad and held by U.S. residents also are included. The aggregates are constructed by consolidation rather than aggregation, such that the liabilities of one money stock issuer that are held by another issuer within the same aggregate cancel each other. For example, the amount of large time deposits held by money market mutual funds is subtracted from gross large time deposits in building M3, because these deposits are both a liability of one money stock issuer (banks) and an asset of another (money market mutual funds).

Monetary aggregates published by the staff of the Board of Governors as of October 1993 were:

M1 = currency + checkable deposits;
M2 = M1 + certain nontransaction deposits and other liquid assets;
M3 = M2 + certain assets that are either less liquid and/or issued in large denominations; and
L = M3 + certain money market instruments.

Federal Reserve System reports are referred to below by the prefix FR and reports of the interagency Federal Financial Institutions Examination Council by the prefix FFIEC. Call reports are administered by the FFIEC, a joint agency including the Federal Reserve, the Federal Deposit Insurance Corporation (FDIC), the Treasury Department and the National Credit Union Administration (NCUA). Complete report titles and reporting frequency are shown only the first time a report is cited; references thereafter are abbreviated.

		NSA published data begin		
Money Stock Component	**Definition**	**monthly**	**weekly**	**Source of Information**
M1 =		1/59	1/6/75	Federal Reserve Board staff have judged that adequate data are not available before these dates to construct monetary aggregates based on current definitions.
(+) Money stock currency =	Currency held by the nonbank public (in other words, held outside the U.S. Treasury, Federal Reserve Banks and the vaults of depository institutions).	1/59	1/6/75	
(+) Currency in circulation	Currency held outside the U.S. Treasury and Federal Reserve Banks.			Federal Reserve Statement of Condition (internal Fed balance sheet) (FR34), daily; Treasury and Mint Reports on currency and coin in circulation.
(−) Vault cash	Cash held by depository institutions (including cash in automatic teller machines).			Report of Transaction Accounts, Other Deposits and Vault Cash (FR2900), from weekly and quarterly reporters; Quarterly Report of Selected Deposits, Vault Cash and Reservable Liabilities (FR2910Q); Annual Report of Total Deposits and Reservable Liabilities (FR2910A); Consolidated Reports of Condition and Income (call reports) (FFIEC 031, 032, 033, 034), quarterly, last business day of the quarter. The FR2900 is the core report for the monetary aggregates. More than 9,000 financial institutions file the FR2900 report weekly following their Monday close of business, each report containing daily deposit data for the preceeding week. Some smaller institutions file the FR2900 report only for one week each quarter. See the text for discussion.

Money Stock Component	Definition	NSA published data begin		Source of Information
		monthly	weekly	
(+) Travelers checks	Outstanding amount of U.S. dollar-denominated travelers checks issued by nonbanks (checks issued by banks are included in demand deposits).	1/59	1/6/75	Monthly Report of Travelers Checks Outstanding (FR2054), last business day of the month; weekly data are interpolated from seasonally adjusted monthly data.
(+) Demand deposits adjusted =	Demand deposits at all depository institutions in the U.S. other than those due to other depositories (including money market mutual funds [MMMFs]), the U.S. government, and foreign banks and official institutions, less cash items in the process of collection (CIPC) and Federal Reserve float.	1/59	1/6/75	
(+) Gross demand deposits	Deposit liabilities of banks payable on demand; time deposits with original maturity of less than seven days; travelers checks and money orders that are the primary obligation of the issuing depository institution.			FR2900; FR2910Q/A; call reports
(−) Demand deposits due to depository institutions, foreign banks and official institutions, and the U.S. Treasury				Weekly Report of Assets and Liabilities for Large Banks (FR2416), includes about 160 large banks, weekly, close of business Wednesday; call reports for other depositories, quarterly, last business day of quarter.
(+) Other money orders	Money orders and official checks issued by nonbank subsidiaries of bank holding companies.			Weekly Report of Money Orders and Similar Payments Instruments issued by Nonbank Subsidiaries of Bank Holding Companies (FR2053), close of business Monday.
(−) Cash items in process of collection	Third-party payment instruments (checks) redeemable in immediately available funds if presented today.			Same as gross demand deposits; all checks being collected are deducted from demand deposits regardless of the type of account wherein the deposit was made.
(−) Float on the Federal Reserve				FR34
(+) Other checkable deposits	NOW and automatic transfer service (ATS) accounts at commercial banks, U.S. branches and agencies of foreign banks, and Edge Act corporations; NOW and ATS accounts at thrifts; credit union share draft balances; and demand deposits at thrifts.	1/63	1/6/75	FR2900; FR2910Q/A; call reports, quarterly

Money Stock Component	Definition	NSA published data begin: monthly	NSA published data begin: weekly	Source of Information
Non-M1 component of M2 =		1/59	1/5/81	Adequate weekly thrift data are not available before 1981; see Appendix 1 for discussion of monthly thrift data for 1959–80.
(+) Savings deposits, net =	Passbook and statement savings deposits plus money market deposit accounts (MMDA) other than those due to general purpose and broker/dealer money market funds, foreign banks and official institutions and the U.S. government. MMDAs are a special type of savings account that permits a small number of third-party payments per month.	1/59 12/82* (*MMDAs)	11/3/80 12/20/82*	MMDAs were first authorized in December 1982; separate savings and MMDA data were collected until September 1991. Thereafter, only a single combined series has been collected.
(+) savings and MMDA deposits at banks and thrifts	Deposit or account in which the depositor is not currently, but may be at any time, required by the financial institution to give written notice of intent not less than seven days prior to withdrawal.			FR2900; FR2910Q/A; call reports
(−) savings and MMDA deposits due to foreign banks, foreign official institutions and the U.S. Treasury				FR2416; call reports
(+) Adjusted small time deposits =	Deposits, including retail repurchase agreements (RPs), issued in amounts of less than $100,000 with original maturities of seven days or more, less all IRA/Keogh retirement account balances at banks and thrifts.	1/59	11/3/80	
(+) gross small time deposits				FR2900; FR2910Q/A; call reports
(+) retail RPs at commercial banks and mutual savings banks (MSBs)	Retail RPs are issued in small denominations most often to households and small businesses.			Monthly Survey of Selected Deposits (FR2042), last Wednesday of the month.
(+) retail RPs at savings and loan associations				Office of Thrift Supervision, quarterly thrift balance sheet
(−) IRA/Keogh balances at commercial banks and MSBs				FR2042
(−) IRA/Keogh balances at savings and loan associations				Office of Thrift Supervision, quarterly thrift balance sheet

Money Stock Component	Definition	NSA published data begin monthly	weekly	Source of Information
Non-M1 component of M2 = (continued)				
(+) Share balances in general purpose and broker/dealer MMMFs	MMMFs are certain types of investment companies that agree to abide by the SEC's Rule 2a-7 and a variety of other regulations regarding the types and maturities of allowable assets. Shares in these funds may be held by households, businesses and various institutions.	1/74	2/4/80	The Investment Company Institute (ICI) voluntarily collects information for the Federal Reserve. Weekly and monthly reports cover both the funds' liabilities (shares) and assets. The amounts of individual assets held by MMMFs are important because most assets—including RPs, Eurodollars, large time deposits and Treasury bills—are netted from the monetary aggregates during the consolidation of M2, M3 or L. Data are labeled by Federal Reserve staff as the Weekly (Monthly) Report of Assets of Money Market Mutual Funds [FR2051a (FR2051b)]; Weekly Report of Assets for Selected Money Market Mutual Funds (FR2051c); or the Weekly Report of Overnight Eurodollars for Selected Money Market Mutual Funds (FR2051d). The ICI data are as of close of business on Wednesday. The Wednesday level is included in the aggregate for the week ending the following Monday. For example, M2 and M3 for the week of January 10, 1994, contained data on MMMF shares as of Wednesday, January 5.
(+) Overnight RPs, net =	One-day and continuing-contract RPs issued by all depository institutions to other than depository institutions, MMMFs and foreign official institutions.	11/69	1/6/75	
(+) gross overnight RPs	RPs as of close business, one day each week			Report of Selected Borrowings (FR2415), for commercial banks, weekly, close-of-business Monday; Weekly Report of Repurchase Agreements on U.S. Government and Federal Agency Securities with Specified Holders (FR2415t), for thrifts, close of business Monday
(−) overnight RPs held by MMMFs				FR2051a, c
(+) Overnight Eurodollars, net =	Eurodollar deposits with original maturity of one day issued by foreign branches of U.S. banks worldwide to U.S. nonbanks (U.S. addresses other than depository institutions and MMMFs)	2/77	12/31/79	
(+) gross overnight Eurodollars				Report of Selected Deposits in Foreign Branches held by U.S. Addresses (FR2050), weekly reporting of daily data, close of business Monday; Monthly (Quarterly) Report on Foreign Branch Assets and Liabilities [FR2502, (FR2502s)], last business day of the period
(−) overnight Eurodollars held by MMMFs				FR2051a, c

Money Stock Component	Definition	NSA published data begin		Source of Information
		monthly	weekly	
Non-M2 component of M3 =		1/59	1/5/81	
(+) Large time deposits, net =	Deposits issued by banks and thrifts in amounts of $100,000 or more with initial maturities of seven days or more, other than those held by MMMFs, other depository institutions, and foreign banks and official institutions	1/59	11/3/80	
(+) gross large time deposits				FR2900; FR2910Q/A; call reports
(−) large time deposits due to foreign banks and official institutions, and the U.S. Treasury				FR2416; call reports, quarterly
(−) large time deposits held by MMMFs				FR2051a, c
(−) mortgage-backed bonds at savings and loan associations	Mortgage-backed bonds are reported as a reservable liability on the FR2900. They are not deposits, however, and, hence, are subtracted from the monetary aggregates.			Office of Thrift Supervision, Statement of Condition (call report), quarterly
(+) Term RPS, net =		10/69	1/6/75	
(+) gross term RPs	RPs issued by all depositories with original maturities greater than one day, other than continuing contract and retail RPs and RPs issued to other depositories and foreign banks and official institutions.			FR2415
(−) term RPs held by MMMFs				FR2051a, c
(+) Term Eurodollars, net =		1/59	12/31/79	
(+) gross term Eurodollars	Eurodollar deposits due to U.S. nonbank addresses with maturity longer than one day at all foreign branches of U.S. banks and at offices of non-U.S. banks in the U.K. and Canada			FR2050; FR2502; data furnished by the Bank of England and Bank of Canada.
(−) term Eurodollars held by MMMFs				FR2051a, c

Money Stock Component	Definition	NSA published data begin		Source of Information
		monthly	weekly	
Non-M2 component of M3 = (continued)				
(+) Shares in institution-only (I-O) MMMFs, net =		4/74	2/4/80	
(+) shares in I-O MMMFs, gross	MMMFs that under SEC guidelines require large minimum investments (typically $50,000 +) and sell shares only to sophisticated investors and institutions, thereby gaining exemption from certain SEC accounting rules. These shares may be held by households, businesses or institutions.			FR2051a, c
(−) overnight RPs and Eurodollars held by I-O MMMFs	Note that term RPs and Eurodollars held by MMMFs were netted above.			FR2415 for banks; FR2415t for thrifts
Non-M3 component of L =		1/59	NA	
(+) Bankers acceptances, net =	Bankers acceptances held by the nonbank public other than accepting banks, Federal Reserve Banks, foreign official institutions, Federal Home Loan Banks and MMMFs.	1/59	NA	
(+) gross bankers acceptances				Monthly Survey of Eligible Bankers Acceptances (FR2006), monthly, last day of the month; call reports, quarterly
(−) acceptances held by Federal Reserve Banks				FR34
(−) acceptances held by MMMFs				FR2051a, c
(+) Commercial paper, net =	Commercial paper held by the nonbank public other than MMMFs.	1/59	NA	
(+) gross commercial paper				Report of Commercial Paper Outstanding Placed by Brokers and Dealers (FR2957a), weekly, Wednesday; Report of Commercial Paper Outstanding Placed Directly by Issuers (FR2957b), weekly, Wednesday and last day of the month
(−) commercial paper held by MMMFs				FR2051a, c

Money Stock Component	Definition	NSA published data begin monthly	weekly	Source of Information
(+) Short-term U.S. Treasury securities, net =	Treasury bills and coupons with remaining maturities of less than 12 months held by the nonbank public other than depositories, Federal Reserve Banks, MMMFs, and foreign banks and official institutions.	1/59	NA	
(+) gross short-term Treasuries				Monthly Statement of Public Debt, U.S. Treasury Department
(−) Federal Reserve Bank holdings of short-term Treasuries				FR34
(−) MMMF holdings of short-term Treasuries				FR2051a, c
(+) U.S. savings bonds	U.S. government savings bonds held by the nonbank public.	1/59	N.A.	Monthly Statement of Public Debt, U.S. Treasury Department

SOURCE: Compiled by the authors from published and unpublished Federal Reserve documents.

measurement of the aggregate amount of MMMF shares held by the nonbank public. Retirement accounts (IRA/Keogh) at banks, thrifts and MMMFs also have sometimes been nettlesome. These deposits, netted from the monetary aggregates, are not collected in the same manner as other deposit data included in the aggregates. As shown in Table 2, retirement balances at banks are collected in the FR2042 report. This report surveys fewer banks less frequently than the FR2900 report that provides most deposit data. Retirement balances at MMMFs are collected by the Investment Company Institute from member mutual funds and, like data for commercial banks and thrifts, lags somewhat behind the reporting of deposits and other liabilities included in the aggregates.

Measurement problems also arise regarding Eurodollars and RPs. High-quality timely data are available on the overnight Eurodollar component of M2 because these deposits are largely held at Caribbean branches of U.S. banks.[16] Term Eurodollars held in foreign branches of U.S. banks are reported on approximately the same basis. Term Eurodollars, however, also are held extensively at non-U.S. banks in England and Canada, not subject to Federal Reserve reporting. The Bank of England and the Bank of Canada collect quarterly data for U.S.-dollar denominated deposits due to U.S. nonbank addresses. Although aggregate totals are given to Federal Reserve staff, data for individual banks are confidential and, hence, can neither be checked nor edited by Federal Reserve staff.[17]

For RPs, the problem is more a conceptual issue than a matter of data reporting. Overnight RPs are included in the non-M1 component of M2 because, at least in part, they are an attractive alternative to holding transaction balances. RPs with maturity of more than one day also, of course, may serve the same purpose. RPs with a maturity longer than one day, however, are reported as term RPs and included in the non-M2 component of M3. An investor who accepts a two-day RP contract rather than a sequence of two, one-day contracts may reduce the size of M2 without any economic significance. It seems likely that much of the predictable part of such switches, say, due to holiday weekends, is captured in the seasonal adjustment factors. The balance remains as statistical noise.

Overall, weekly first-published values of M2 and M3 shown on the current H.6 release are based about 80 percent on data that are reported weekly, with the balance estimated from lesser frequency reports.[18]

MAJOR OPERATIONS BY BOARD STAFF THAT AFFECT THE MONETARY AGGREGATES

In addition to the principal sources of data, well-informed researchers should be aware of the more important revision practices and schedules used by Federal Reserve Board staff that affect the continuity of the data. Benchmarks, seasonal factor reestimation and definition changes may have significant impacts on the monetary aggregates and, correspondingly, on research employing that data.

Benchmark Revisions

All monetary aggregates data are subject to a "benchmark" revision annually. In its most general form, a benchmark of the monetary aggregates by Board staff would be (ideally) a measurement of the universe of money stock issuers and their holdings of monetary liabilities. A benchmark serves three main purposes. First, it allows Board staff to incorporate deposit data on institutions that are exempt from reporting directly to the Federal Reserve. These data are obtained either from bank and thrift call reports or from other annual reports filed by the institutions. Second, it allows the incorporation of corrected/revised data submitted by depository institutions throughout the year. Third, it allows staff to update estimates of some nondeposit components of the aggregates.

Depository institutions generally submit revised deposit data throughout the year. Such

[16]In fact, these deposits are recorded in New York while being legally booked through "nameplate" branches in the Caribbean (so-called because the office largely consists of a brass nameplate).

[17]In addition, few statistics are available for coverage ratios, error rates, and so on.

[18]Detailed estimates of such coverage ratios are prepared about every three years and furnished to the Office of Management and Budget as part of the reauthorization process for the report. See Walton and others (1991).

data from weekly reporting institutions are incorporated into the monetary aggregates published on the *H.6* release only during the first three weeks following the week in which the report was due, that is, the four most recent weeks shown on the *H.6* release. Deposit data submitted after that time are held in abeyance and incorporated at the annual benchmark, along with data received from institutions that report only once per year. (Deposit data received from quarterly reporting institutions are incorporated when received during the year, as are nondeposit data received from many sources. See Table 2.) This three-step process begins with aggregation of all deposit data reported by financial institutions during the past six or seven years. Next, data are matched to call reports for all depository financial institutions to identify missing institutions (if any) and obtain deposit levels at the call dates for those institutions exempt from filing deposit reports with the Federal Reserve. Finally, miscellaneous data collected during the year regarding items not covered by deposit reports are incorporated.

Benchmarks constitute a clear break-in-series for monetary aggregates data, changing significantly not only past data but altering the base upon which new estimates will be published during the coming year. Since 1964, a benchmark of the monetary aggregates has been done at least annually. In recent years, Board staff have published the benchmark data prior to the February Humphrey-Hawkins testimony of the Federal Reserve Chairman before Congress. From 1974 through 1980, however, benchmark revisions of the monetary aggregates were conducted approximately every quarter. The increased frequency of benchmarks addressed a concern, raised by the Bach Commission, that the methods used at the time to estimate nonmember bank deposits could introduce a bias into the monetary aggregates. It was felt that more timely benchmarks would serve to keep the Federal Reserve's estimates more closely aligned with the true, unobserved figures. This was not a new concern, however, and in fact all benchmarks prior to the Monetary Control Act had focused heavily on nonmember bank deposits, since these institutions were not required to report to the Federal Reserve.[19] The power to enforce near-universal reporting that was endowed on the Federal Reserve by the Monetary Control Act obviated the need for frequent benchmarks after 1980. Today, benchmarks focus on special items not covered on deposit reports.

The effects of these revisions on quarterly growth rates of the monetary aggregates are shown in the first page of Table 3. The columns of the table correspond to the annual benchmarks published in early 1986-93. Each entry in the table is the change in the annualized growth rate of the corresponding monetary aggregate during that quarter due to revisions of the underlying source data. The largest revisions due to any benchmark occur in the most recently completed year, shown as the shaded areas in the table. Revisions for prior years, not shaded, are smaller. While not following a consistent pattern, the data suggest that any particular quarter may be revised significantly, especially for the broader aggregates. In part, the latter are related to the higher percentage of nondeposit components in those aggregates.

Seasonal Adjustment

Seasonal adjustment of the monetary aggregates has long been an important area of research. The FOMC formulates its monetary policy in terms of seasonally adjusted data, and both the public and policymakers often take recent movements in adjusted data as indicating the underlying trend growth rate of the monetary aggregates.

Seasonal adjustment methods attempt to separate recurring calendar-related patterns in data (due to, say, calendar dating, payroll schedules, tax filing deadlines, and so on) from random shocks and the underlying trend. In general terms, the data generating process for the monetary aggregates is assumed to be well represented as the product of three components: a time-varying trend, a time-varying seasonal and an irregular.

Each year, Board staff publish revised seasonal factors for most historical periods and projected seasonal factors for the upcoming year. With few exceptions, these seasonal factors are based on, and published simultaneously with, the an-

[19]The quarterly deposit data reported on the call reports by nonmember banks also were not without problems. The definitions of "deposits" differ somewhat between the Fed's Regulation D and the call report instructions, making the data not fully comparable. For earlier analyses of the effect of benchmark revisions, see Lang (1978) and Simpson and Williams (1981).

Table 3

Page 1: Revisions to Previously Published Quarterly Growth Rates of the Monetary Aggregates (s.a.) Due to Benchmark Data Revisions

Year of annual benchmark (usually published in February; see Kavajecz, 1994)

Periods	1986			1987			1988			1989			1990			1991			1992			1993		
	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3
1984 Q4	0.4	0.6	−0.2	0.4	0.5		−0.6	−1.2		0.1	0.0		−0.1	0.2		0.0	−0.1		0.0	0.0		0.1	0.1	
1985 Q1	0.1	−0.4	−1.0	−0.2	−0.3		−0.4	−0.1		0.0	0.0		0.0	0.0		0.0	−0.1		0.0	0.0		0.0	0.0	
Q2	0.1	0.3	−0.3	0.2	0.0		−0.1	0.2		0.0	0.0		0.1	−0.1		−0.1	−0.2		0.0	0.0		0.0	0.1	
Q3	0.1	0.0	0.0	0.1	0.2		0.0	0.2		0.1	0.1		−0.1	−0.1		0.0	−0.2		0.0	0.0		0.0	0.1	
Q4	0.6	−0.1	−0.6	0.5	0.8	0.5	0.2	−0.1		−0.1	−0.1		0.0	0.0		−0.1	−0.1		0.0	0.0		0.0	0.0	
1986 Q1				0.1	0.0	0.0	0.1	0.7		0.0	−0.5		0.0	0.0		0.0	−0.1		0.0	0.0		0.0	0.1	
Q2				−0.1	−0.7	−0.4	0.5	0.6		0.1	0.1		0.0	0.0		0.0	−0.1		0.0	0.0		0.0	0.0	
Q3				−0.1	−0.2	−0.1	0.4	0.5		−0.1	0.0		0.0	0.0		0.0	0.0		0.0	−0.1		0.0	0.0	
Q4				−0.1	−0.1	0.1	−0.1	−0.1	−0.5	0.0	−0.1		0.0	0.1		0.0	0.0		0.0	0.0		0.0	0.1	
1987 Q1							−0.1	−0.2	−0.4	0.3	0.1		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Q2							0.4	0.1	0.3	−0.2	0.0		0.0	0.1		0.0	0.0		0.0	0.0		0.0	0.0	
Q3							0.0	0.0	0.0	0.1	0.3		0.0	0.3		0.0	0.0		0.0	0.0		−0.1	−0.1	
Q4							0.2	0.0	0.1	0.1	0.3	0.2	0.0	0.1		0.0	0.0		0.0	0.1		0.1	0.1	
1988 Q1										0.0	0.1	0.1	0.1	−0.1		0.0	0.0		0.0	0.0		0.0	0.1	
Q2										0.2	−0.2	0.0	−0.1	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Q3										0.2	−0.3	−0.3	0.0	−0.3		0.0	0.1		0.0	0.1		0.0	0.1	
Q4										0.0	−0.1	−0.1	0.0	0.3	0.4	0.0	0.0		0.0	0.0		0.0	0.0	
1989 Q1													0.3	0.1	0.0	0.0	0.2		0.0	0.0		0.0	−0.1	
Q2													−0.1	0.0	0.1	−0.1	0.1		0.0	0.1		0.0	0.0	
Q3													0.1	0.3	0.1	0.1	0.1		0.0	0.1		0.0	−0.1	
Q4													0.1	0.3	0.0	−0.1	0.1	0.4	0.0	0.1		0.0	−0.1	
1990 Q1																0.3	0.0	0.1	−0.1	0.0		0.0	−0.1	
Q2																0.3	0.4	0.4	−0.1	0.1		0.0	−0.1	
Q3																0.0	0.2	0.2	0.1	0.3		−0.1	0.1	
Q4																0.0	0.1	0.0	0.2	0.1	0.0	0.0	0.0	
1991 Q1																			−0.1	0.1	−0.1	0.2	0.1	
Q2																			0.2	0.0	0.2	−0.1	−0.2	
Q3																			0.1	0.5	0.2	−0.1	−0.1	
Q4																			−0.1	0.7	−0.2	−0.2	−0.1	−0.1
1992 Q1																						0.2	−0.4	0.0
Q2																						0.2	0.1	0.7
Q3																						−0.1	−0.2	−0.3
Q4																						0.0	−0.1	−0.2

Note: These revisions do not include effects due to revisions in seasonal adjustment factors and/or changes in definitions.

Table 3 (cont.)

Page 2: Revisions to Previously Published Quarterly Growth Rates of the Monetary Aggregates (s.a.) Due to Revisions to Seasonal Adjustment Factors

Year of annual seasonal review (usually published in February, along with benchmark data revisions)

	1986			1987			1988			1989			1990			1991			1992			1993		
Periods	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3
1984 Q4	0.9	0.0	-0.3	-0.6	-0.3		0.1	0.0		0.0	0.2		0.7	0.1		-0.1	-0.1		-0.1	0.0		0.1	-0.1	
1985 Q1	-0.6	0.0	0.4	0.8	0.6		0.0	0.1		0.0	-0.1		-0.2	0.0		0.0	0.1		-0.3	0.0		0.3	0.0	
Q2	0.2	0.7	0.6	-0.3	-0.3		-0.1	0.2		0.0	-0.3		0.0	0.1		0.1	0.1		0.1	0.0		-0.2	0.0	
Q3	-0.6	-0.7	-0.6	-0.4	-0.2		0.1	-0.3		0.0	0.2		-0.2	-0.1		0.0	-0.1		0.2	0.0		-0.2	0.0	
Q4	1.1	0.1	-0.4	-0.3	-0.3	0.0	-0.1	-0.1		0.3	0.4		0.1	-0.1		-0.1	-0.1		0.0	0.0		0.1	0.0	
1986 Q1				1.0	1.0	0.1	0.1	0.2		-0.3	-0.3		-0.2	0.0		0.0	0.0		-0.3	-0.1		0.2	0.0	
Q2				-0.2	-0.4	0.1	-0.4	0.2		0.0	-0.4		0.4	0.3		0.1	0.2		0.0	0.0		-0.1	0.0	
Q3				-0.7	-0.3	-0.4	0.4	-0.3		-0.1	0.3		0.0	0.1		0.0	-0.1		0.2	0.0		-0.1	0.0	
Q4				-0.1	-0.2	0.1	-0.1	-0.2	-0.2	0.6	0.6		-0.5	-0.3		-0.2	0.0		0.1	0.0		0.1	0.0	
1987 Q1							0.1	0.3	0.4	-0.5	-0.4		-0.1	0.2		0.0	-0.1		-0.2	0.0		0.1	0.0	
Q2							-0.6	0.2	0.1	0.0	-0.5		0.7	0.4		0.3	0.2		-0.1	0.0		-0.1	0.0	
Q3							0.6	-0.2	-0.3	-0.3	0.3		0.1	-0.2		-0.2	-0.2		0.2	0.1		-0.1	0.0	
Q4							-0.2	-0.2	-0.2	1.0	0.7	0.7	-0.9	-0.5		-0.1	0.0		0.1	0.0		0.1	0.0	
1988 Q1										-0.6	-0.7	-0.3	-0.1	0.3		0.0	-0.1		-0.2	-0.1		0.0	0.0	
Q2										-0.1	-0.6	-0.5	1.1	0.5		0.4	0.3		-0.2	-0.1		0.0	0.0	
Q3										-0.2	0.5	0.1	0.1	-0.3		-0.3	-0.2		0.4	0.2		-0.1	0.1	
Q4										1.1	0.9	0.6	-1.3	-0.6	-0.6	-0.1	0.0		0.1	0.0		0.1	0.0	
1989 Q1													0.0	0.4	0.2	0.0	-0.1		-0.3	-0.1		-0.2	-0.1	
Q2													1.3	0.5	0.6	0.4	0.4		-0.3	-0.2		0.0	0.0	
Q3													0.2	-0.3	-0.1	-0.4	-0.3		0.5	0.3		0.1	0.2	
Q4													-1.6	-0.8	-0.6	0.0	0.0	-0.5	0.0	0.0		0.0	0.0	
1990 Q1																0.1	-0.2	-0.1	-0.4	0.0		-0.4	-0.3	
Q2																0.4	0.5	-0.1	-0.3	-0.4		0.1	0.1	
Q3																-0.4	-0.3	-0.3	0.6	0.4		0.7	0.4	
Q4																-0.1	0.0	0.6	0.2	0.0	0.2	-0.3	-0.1	
1991 Q1																			-0.6	0.0	-0.6	-0.8	-0.4	
Q2																			-0.2	-0.4	-0.2	0.3	0.1	
Q3																			0.6	0.6	0.6	1.1	0.6	
Q4																			0.2	0.0	0.2	-0.4	-0.2	-0.3
1992 Q1																						-1.2	-0.5	-0.2
Q2																						0.6	0.1	0.3
Q3																						1.4	0.7	0.4
Q4																						-0.7	-0.5	-0.3

Note: These revisions shown do not include effects of benchmark data revisions to and/or changes in definition.

Table 3 (cont.)

Page 3: Revisions to Previously Published Quarterly Growth Rates of the Monetary Aggregates (s.a.) Due to Changes in Definition

Year of redefinition (published at time of benchmark and seasonal review)

	1986			1987			1988			1989			1990			1991			1992			1993		
Quarters	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3
1984 Q4																								
1985 Q1																								
Q2																								
Q3																								
Q4																								
1986 Q1																								
Q2																								
Q3																								
Q4							0.4	0.0	0.0															
1987 Q1							0.1	0.0	0.0															
Q2							0.4	0.0	0.0															
Q3							0.3	0.0	0.0															
Q4							0.2	0.0	0.0															
1988 Q1																								
Q2																								
Q3																								
Q4													0.0	−0.1	0.0									
1989 Q1													0.0	−0.1	0.0									
Q2													0.0	−0.1	0.0									
Q3													0.0	−0.2	0.0									
Q4													0.0	−0.1	0.0									
1990 Q1																								
Q2																								
Q3																								
Q4																								
1991 Q1																								
Q2																								
Q3																								
Q4																								

Note: These revisions shown do not include effects due to benchmark data revisions and changes in seasonal adjustment factors.

Source: Data shown in shaded areas are taken from the issues of the Federal Reserve Board's *H.6* statistical release, published after the annual benchmark. See Kavajecz (1994) for exact dates. Other data shown are the authors' calculations from annual issues of *Money Stock Revisions*.

nual benchmark data.[20] Monthly seasonal factors are estimated by a variant of the Statistics Canada X11-ARIMA method.[21] In the first step of this method, the observed data are extended by the addition of one or two years of forecasts. The forecasts are obtained via an ARIMA model that includes exogenous intervention variables for each month and, in some cases, a small number of special events.[22] In recent years, intervention variables have been included for events such as the impact of the 1986 Tax Reform Act on the levels of liquid deposits in early 1987 and the dramatic surge in M1 that occurred during Hurricane Gloria's sweep up the east coast of the United States in September 1985. Seasonal factors are then obtained by applying standard X11 algorithms to the lengthened series.

Weekly seasonal factors are estimated via a two-step process. In the first, initial estimates of weekly seasonal factors are obtained from an unobserved-components time series model.[23] In the second, these initial estimates are modified via a quadratic programming model such that averages of a particular path of seasonally adjusted weekly data equal the previously estimated monthly seasonal pattern.[24] Projected weekly seasonal factors are obtained in a similar manner, subject to judgmental adjustment by Board staff for events such as unusual calendar dating and holiday effects that are not captured by the statistical models.

Like other aspects of the monetary aggregates, the methods used for seasonal adjustment have evolved over time. From 1955 — when the first seasonally adjusted numbers were published — through 1981, seasonal adjustment was done using the classic Census X11 procedure.[25] In 1982, the X11-ARIMA procedure proposed by Dagum was adopted to reduce well-known potential problems due to the use of truncated moving-average filters near the ends of the sample.[26] Other features that have been added to improve the estimation include trading day effects, payment schedules and holiday dating.

Following recommendations of the Advisory Committee on Monetary Statistics, the Federal Reserve publishes both seasonally adjusted and unadjusted data. The weekly *H.6* release, for example, currently includes adjusted data for four monetary aggregates and 25 components, and unadjusted data for the four aggregates, 26 components and 11 related miscellaneous series. Most of the adjusted components are furnished for ease of analysis, however, and are not used in construction of the monetary aggregates. Seasonally adjusted M1 is constructed as the sum of four separately adjusted components: currency, travelers checks, demand deposits and other checkable deposits (OCDs). The non-M1 component of M2 and the non-M2 component of M3 are adjusted as a whole, with adjusted M2 equal to the sum of adjusted M1 and the non-M1 component of M2; M3 similarly is formed by summing M2 and the adjusted non-M2 component of M3.

Early each year, Board staff forecast seasonal adjustment factors for the monetary aggregates during the coming year. These projected factors are published on the *H.6* release at the same time as the benchmark data, and are not revised during the year on the basis of incoming data.[27] Hence, published monetary growth rates throughout the year are based on ex ante fixed seasonal factors that incorporate no information received during the current year. Thus, it perhaps is not surprising that revised seasonal factors for the most recently completed year may differ significantly from those that were forecast a year earlier. Revisions to the monetary aggregates due to revisions to seasonal fac-

[20] The very few exceptions in which the seasonal review was completed and published after the benchmark are noted in Kavajecz (1994).

[21] See Farley and O'Brien (1987).

[22] See Box and Tiao (1975).

[23] The statistical model has been developed over a number of years; see Cleveland and Grupe (1983), Pierce, Grupe and Cleveland (1984), and Cleveland (1986). The model allows for a noninteger number of weeks during the year and other effects. Statistically, it seeks to estimate trend, seasonal and irregular components of a time series that is sampled at a frequency which differs from the fundamental frequencies of the data generating processes for its components.

[24] See the appendix to Farley and O'Brien (1987) for details of the algorithm.

[25] See Pierce and Cleveland (1981).

[26] While X11 uses two-sided moving-average filters for most observations, the filters must be truncated near the ends of the time series. This effect tends to increase the size of the revisions to the most recent year's seasonal factors when they are reestimated the following year. Further, it also tends to underestimate the degree of seasonality near the end of the sample. Extending the sample via ARIMA model forecasts seems to attenuate both problems. See Dagum (1983).

[27] Experimental estimates of concurrent seasonal factors, updated using incoming data, were published as an appendix to the H.6 for several years but never incorporated into any official monetary aggregate. The Board's committee of experts on seasonal adjustment had recommended exploration of concurrent factors; see Pierce and Cleveland (1981). A similar recent review at the Bank of England (1992) suggested that concurrent adjustment might reduce the size of subsequent revisions.

tors, shown on the second page of Table 3, often have exceeded those due to either revisions to underlying source data (shown on the first page of the table) or to changes in definitions (the third page of Table 3).

Although the concept of seasonal movements in data may be fairly straightforward, there is no generally accepted statistical definition of seasonality. "True" seasonal factors are never observed nor measured, even with error. Thus, seasonally adjusted monetary aggregates necessarily retain a significant subjective component, even in the long run. Lindsey and others (1981) notes that the adjusted monetary aggregates have tended to become somewhat smoother through time as their seasonal adjustment factors have been subjected to successive annual revisions. Although he attributes this to increases in our knowledge about, and precision in, estimation of the seasonal adjustment factors, an alternative hypothesis is that the seasonal component is absorbing more of the irregular component, leaving an adjusted time series that more closely resembles its trend component.

Changes In Definitions

Although financial innovation has been an important factor, the evolution of the Federal Reserve Board staff's definitions of monetary aggregates primarily has been governed by economists' changing empirical perceptions of the appropriate concept of money.[28] In the 1960s, economists' focus on the medium of exchange function of money made M1 the principal aggregate. As empirical relationships for M1 appeared to break down in the 1970s and attention turned once again to the role of liquid near-moneys, some suggested that multiple monetary aggregates might collectively reveal more information about the stance of monetary policy with respect to economic activity. The Federal Reserve responded by creating the monetary aggregates M2 and M3 in 1971, and M4 and M5 in 1975.

Despite the increasing attention focused on near-moneys, the multiple definitions of the monetary aggregates during the 1970s continued to reflect legislative distinctions between the asset and liability powers of banks and thrifts. These distinctions faded after passage of the Monetary Control and Garn-St. Germain Acts, permitting a new set of nested definitions such that M1 became a subset of M2, and M2 a subset of M3.[29] By internalizing within M2 opportunity-cost-induced shifts of funds between medium-of-exchange and liquid near-moneys for all intermediaries, this design enhanced the usefulness of M2 as an intermediate policy target through better estimates of a (nominally) stable demand curve for M2.[30]

Since monetary aggregates data first appeared on the *J.3* statistical release in 1960, the broad monetary aggregates (roughly corresponding to M1, M2, M3) have been redefined about a dozen times. Changes have ranged in magnitude from the massive redefinition in February 1980 to small additions and subtractions such as the inclusion of nonbank travelers checks in June 1981. Whenever a definition change is put in place, Board staff recompute all historical data for the monetary aggregates and components under the most recent definitions.[31] Available Federal Reserve publications, including *Money Stock Revisions*, show monetary aggregates data solely in terms of current definitions. For researchers studying Federal Reserve behavior, "knowing what money was" at a particular time is complicated by changes in definitions as well

[28]Our view is that many of the theoretical arguments for the inclusion and/or exclusion of specific assets are ex post rationalizations of workable empirical definitions. The same argument is, of course, made by Friedman and Schwartz (1970).

[29]There are a few qualifications to this characterization. From 1980-87, a portion of the vault cash and demand deposits held by thrifts had been included in M1 (but not in M2 and M3), while the balance was excluded (none of the vault cash and interbank deposits held by commercial banks were included in the aggregates). In 1988, the treatment of these items for thrifts was changed to be comparable to that for banks. Similarly, in constructing M3, a variety of netting items are deducted, such as large time deposits at commercial banks held by M2-type money market funds. In general, in moving from narrower to broader aggregates, any asset held by a money stock issuer (say, a money market fund) that was issued by another money stock issuer (say, a commercial bank) is netted out of the broader consolidated monetary aggregate.

[30]For discussion, see Simpson and Porter (1980).

[31]The 1980 redefinition, for example, required Board staff to "rebuild" M2 for years prior to 1980 with an expanded set of thrift deposit data. Some details are discussed in the appendix.

as by the annual benchmark and seasonal review process.

Definitional changes perhaps are usefully summarized in three categories. First, there is the inclusion (or, less often, exclusion) of an existing money market instrument or depository liability.[32] A prominent example is the addition in 1980 of general purpose and broker/dealer MMMFs to the M2 aggregate.[33] While M2 was recomputed on a consistent basis for all prior periods following the redefinition, conceptually this is a nontrivial change. During the 1970s, when the first surge in money market fund growth occurred, the contemporaneous M2 aggregate excluded money market funds; shifts by households into the funds were (in principal) embedded in the elasticity of M2 with respect to its opportunity cost and reflected in shifts in the income velocity of M2. Researchers using the redefined M2, however, see an aggregate that internalizes these shifts, has a smaller interest elasticity, and different velocity behavior. Of course, the importance of this change in definition for analysis of Fed behavior is mitigated by the FOMC's emphasis on M1 during the period. Other examples are the inclusion in M2 of retail RPs (which were basically uninsured small time deposits exempt from Reg Q) in 1982, the exclusion of retirement accounts from the monetary aggregates in 1983, and the addition of term Eurodollar deposits to M3 in 1984. While the last had been discussed earlier, inclusion of the deposits had to await a reliable source of data.

The second type of definition change is the inclusion of a new money market instrument or depository institution liability. In some cases, the new instrument or deposit may simply reflect the removal of a prohibition against that type of deposit or of a ceiling on a deposit offering rate (Regulation Q ceilings). To the extent that deregulation or the authorization of new instruments permanently changes the behavior of depositories, its affect on the monetary aggregates is similar to a change in definition. Examples include the authorization of NOW accounts nationwide in 1980, the introduction of money market deposit accounts (MMDAs) in 1983, and the major discrete steps in the phaseout of Regulation Q that occurred in 1982, 1983 and 1986.[34] In many cases, this type of deposit account was *already* included in the aggregates (both OCDs and MMDAs are types of savings deposits). The authorization of these new instruments, largely born of deposit interest rate controls, likely induced unusual transitory volatility in published data during the period when money may be shifting between components and may also have permanently changed the income and interest elasticities of the monetary aggregate.[35]

The third type of definition change is reclassification of the liabilities of different types of financial institutions. Prior to the 1980 redefinition, deposits at banks and thrift were included in separate monetary aggregates. Deposits at thrifts were included in M3 and M5 while comparable deposits at banks were included in M2 and M4. The 1980 redefinition restructured the monetary aggregates to combine similar types of deposits at commercial banks and thrifts. Although strongly motivated by the increasing similarity of the deposits offered by banks and thrifts during the 1970s, some economists counselled against the pooling of bank and thrift liabilities in the new aggregates. Their arguments were based largely on the joint product nature of depositories. To the extent that firms and households tend to purchase a bundle of services from a single institution rather than separate products from a number of institutions, there may be value to aggregation by institution-

[32]The precise definition of M1 has changed several times due to changes in the treatment of demand deposits due to foreign commercial banks and official institutions. Included in M1 prior to 1980 (see Kavajecz, 1994), these deposits were excluded thereafter following recommendations of the Advisory Committee on Monetary Statistics. See Advisory Committee on Monetary Statistics (1976), p. 4, or Farr and others (1978). These changes also complicate building M1 based on current definitions for years prior to 1959; see Rasche (1987).

[33]Tax-exempt general purpose and broker/dealer MMMFs, excluded in 1980, were added in February 1983.

[34]See Kavajecz (1994) for details. More obscure examples include certain assets sold by depositories with recourse, bank investment contracts (BICs), and bank deposit notes (the latter classified as a deposit under Federal Reserve Regulation D but not by the FDIC). Brokered deposits provide another example. Although a bank or thrift might receive a deposit of a million dollars (or more) from a broker, the amount of the deposit is included in M2 as a small time deposit if the deposit is placed entirely for the benefit of individuals. In this manner, the development of the brokered retail CD market could potentially have affected the apparent interest elasticity of M2 by altering the behavior of its small time deposit component.

[35]There is no doubt this was the case in 1983, when the FOMC decided to rebase its target growth rate ranges for the year following the introduction of MMDAs. The implications of deregulation during the 1980s, including the demise of Reg Q, for money demand models are discussed by Moore, Porter and Small (1990).

al type rather than by product. In response, the Board adopted the recommendation that, to every extent feasible, data for banks and thrifts should be published separately so as to permit such analysis. This argument is similar to Friedman and Schwartz's position that financial assets may appropriately be aggregated if they are sufficiently close substitutes in either demand *or* supply.

Overall, annual revisions to the monetary aggregates due to revisions to source data, seasonal factors and definitions render treacherous any attempt by a researcher to update or extend previous studies by mixing differing vintages of monetary aggregates data. One recent empirical study (Dewald, Thursby and Anderson, 1986) found in an extensive computer simulation experiment that empirical results may be highly sensitive to the mixing of different vintages of data, including data on the monetary aggregates. A complete chronology of revisions and redefinitions of the monetary aggregates is shown in Kavajecz (1994).

CONCLUSION: THE MONETARY AGGREGATES AS MONETARY TARGETS

We conclude our historical examination of the Federal Reserve's monetary aggregates with a summary of their use as monetary policy targets. The FOMC's target and monitoring ranges for the aggregates are shown in Table 4.[36]

Targeting of monetary aggregates began with House Concurrent Resolution 133 in 1975, later formalized in the Humphrey-Hawkins Act of 1978 as an amendment to the Federal Reserve Act. From 1975 through 1978, the committee rebased each quarter its annual four-quarter target range for the monetary aggregates. The resulting base drift in the committee's targets has been controversial.[37] Since 1978, the committee has set one, fourth-quarter-to-fourth-quarter range each year except 1983. Authorization of MMDAs in late 1982 led to a surge in M2 growth as aggressive bidding by depositories against money market funds apparently drew nonmonetary balances into M2. (Recall that taxable general purpose and broker/dealer MMMFs had been included in M2 in 1980 and that MMDAs, a type of savings deposit, were always included in M2. M2 was redefined slightly in February 1983 to include tax-exempt general purpose and broker/dealer money market funds.) The committee subsequently reset its 1983 target ranges using a February-March base.

While relatively narrow through the early 1980s, target ranges widened during the decade as an accelerating pace of innovation in financial markets apparently complicated money demand forecasting and money stock control. The range for M1 was widened to 4 percentage points in 1983 and to 5 points in 1985. Citing uncertainty regarding the demand for M1 and its relationship to economic activity, the committee did not set a target range for M1 in 1987 or beyond.[38]

The target range for M2 similarly was widened over this interval, although it has remained at its current width of 4 percentage points since 1988. In part, the widening of the range in 1988 reflects the increased difficulty of forecasting the demand for M2 during an era of turmoil in financial markets, including the restructuring of the thrift industry, capital and earnings difficulties at commercial banks, and a restructuring (deleveraging) of household and firm balance sheets.

The monetary aggregates during most years have grown within their target ranges, as shown in Figures 1 and 2. Growth often has run well toward the upper or lower bounds of the cones, however, suggesting that the midpoint of the committee's target range may not always be the best forecast of an aggregate's growth.

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[36]Target and monitoring ranges differ in terms of the strength of the implied policy reaction function. In general, deviation of an aggregate from a target range suggests a somewhat stronger policy response than deviation from a monitoring range, ceteris paribus.

[37]For contrasting views, see for example Axilrod (1982), Broaddus and Goodfriend (1984) and Walsh (1986).

[38]"Monetary Policy Report to the Congress," *Federal Reserve Bulletin*, April 1987.

Table 4

Growth Cones for the Monetary and Credit Aggregates (percent annual rate)

Date established	Base period	Span	Target and monitoring ranges: M1	M2	M3	Bank credit proxy
Apr.75	Mar.75	Mar.75–Mar.76	5.0 – 7.5	8.5 – 10.5	10.0 – 12.0	6.5 – 9.5
Jun.75	Jun.75	Jun.75–Jun.76	5.0 – 7.5	8.5 – 10.5	10.0 – 12.0	6.5 – 9.5
Jul.75	75Q2	75Q2 – 76Q2	5.0 – 7.5	8.5 – 10.5	10.0 – 12.0	6.5 – 9.5
Oct.75	75Q3	75Q3 – 76Q3	5.0 – 7.5	7.5 – 10.5	9.0 – 12.0	6.0 – 9.0
Jan.76	75Q4	75Q4 – 76Q4	4.5 – 7.5	7.5 – 10.5	9.0 – 12.0	6.0 – 9.0
Apr.76	76Q1	76Q1 – 77Q1	4.5 – 7.0	7.5 – 10.0	9.0 – 12.0	6.0 – 9.0
Jul.76	76Q2	76Q2 – 77Q2	4.5 – 7.0	7.5 – 9.5	9.0 – 11.0	5.0 – 8.0
Nov.76	76Q3	76Q3 – 77Q3	4.5 – 6.5	7.5 – 10.0	9.0 – 11.5	5.0 – 8.0
Jan.77	76Q4	76Q4 – 77Q4	4.5 – 6.5	7.0 – 10.0	8.5 – 11.5	7.0 – 10.0
Apr.77	77Q1	77Q1 – 78Q1	4.5 – 6.5	7.0 – 9.5	8.5 – 11.0	7.0 – 10.0
						Bank credit
Jul.77	77Q2	77Q2 – 78Q2	4.0 – 6.5	7.0 – 9.5	8.5 – 11.0	7.0 – 10.0
Oct.77	77Q3	77Q3 – 78Q3	4.0 – 6.5	6.5 – 9.0	8.0 – 10.5	7.0 – 10.0
Feb.78	77Q4	77Q4 – 78Q4	4.0 – 6.5	6.5 – 9.0	7.5 – 10.0	7.0 – 10.0
Apr.78	78Q1	78Q1 – 79Q1	4.0 – 6.5	6.5 – 9.0	7.5 – 10.0	7.5 – 10.5
Jul.78	78Q2	78Q2 – 79Q2	4.0 – 6.5	6.5 – 9.0	7.5 – 10.0	8.5 – 11.5
Oct.78	78Q3	78Q3 – 79Q3	2.0 – 6.0	6.5 – 9.0	7.5 – 10.0	8.5 – 11.5
Feb.79	78Q4	78Q4 – 79Q4	1.5 – 4.5	5.0 – 8.0	6.0 – 9.0	7.5 – 10.5
Feb.80	79Q4	79Q4 – 80Q4	4.0 – 6.5(M1B)	6.0 – 9.0	6.5 – 9.5	6.0 – 9.0
Feb.81	80Q4	80Q4 – 81Q4	3.5 – 6.0(M1B)	6.0 – 9.0	6.5 – 9.5	6.0 – 9.0
Feb.82	81Q4	81Q4 – 82Q4	2.5 – 5.5	6.0 – 9.0	6.5 – 9.5	6.0 – 9.0
						Debt
Feb.83	83Feb/Mar	83Feb/Mar-83Q4	—	7.0 – 10.0	—	—
Feb.83	82Q4	82Q4 – 83Q4	4.0 – 8.0	—	6.5 – 9.5	8.5 – 11.5
Jul.83	83Q2	83Q2 – 83Q4	5.0 – 9.0	NC	NC	NC
Jan.84	83Q4	83Q4 – 84Q4	4.0 – 8.0	6.0 – 9.0	6.0 – 9.0	8.0 – 11.0
Feb.85	84Q4	84Q4 – 85Q4	4.0 – 7.0	6.0 – 9.0	6.0 – 9.5	9.0 – 12.0
Jul.85	85Q2	85Q2 – 85Q4	3.0 – 8.0	NC	NC	NC
Feb.86	85Q4	85Q4 – 86Q4	3.0 – 8.0	6.0 – 9.0	6.0 – 9.0	8.0 – 11.0
Feb.87	86Q4	86Q4 – 87Q4	NS	5.5 – 8.5	5.5 – 8.5	8.0 – 11.0
Feb.88	87Q4	87Q4 – 88Q4	NS	4.0 – 8.0	4.0 – 8.0	7.0 – 11.0
Feb.89	88Q4	88Q4 – 89Q4	NS	3.0 – 7.0	3.5 – 7.5	6.5 – 10.5
Feb.90	89Q4	89Q4 – 90Q4	NS	3.0 – 7.0	2.5 – 6.5	5.0 – 9.0
Jul.90	89Q4	89Q4 – 90Q4	NS	NC	1.0 – 5.0	NC
Feb.91	90Q4	90Q4 – 91Q4	NS	2.5 – 6.5	1.0 – 5.0	4.5 – 8.5
Feb.92	91Q4	91Q4 – 92Q4	NS	2.5 – 6.5	1.0 – 5.0	4.5 – 8.5
Feb.93	92Q4	92Q4 – 93Q4	NS	2.0 – 6.0	0.5 – 4.5	4.5 – 8.5
Jul.93	92Q4	92Q4 – 93Q4	NS	1.0 – 5.0	0.0 – 4.0	4.0 – 8.0

The FOMC first set desired longer-run growth targets for M1, M2, M3 and the bank credit proxy at its meeting on April 14-15, 1975. On February 15, 1977, ranges for the monetary aggregates were added to the Domestic Policy Directive sent to the Open Market Desk at the Federal Reserve Bank of New York. On April 18, 1978, the range for bank credit was added to the Domestic Policy Directive.

NC: Not Changed

NS: None Specified

Figure 1
M2 Historical Target Ranges

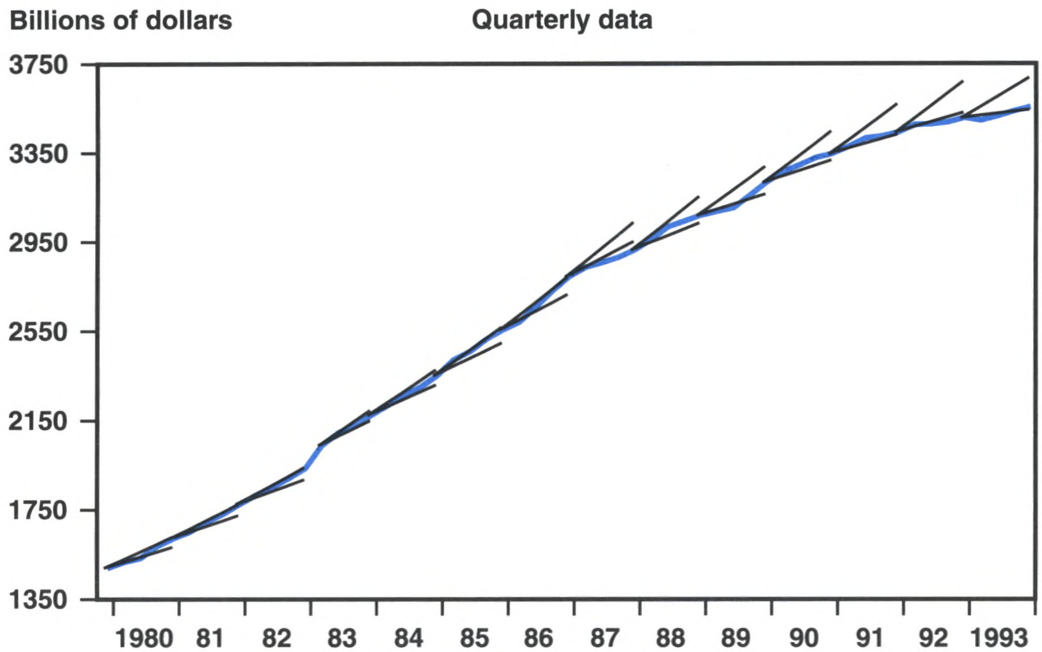
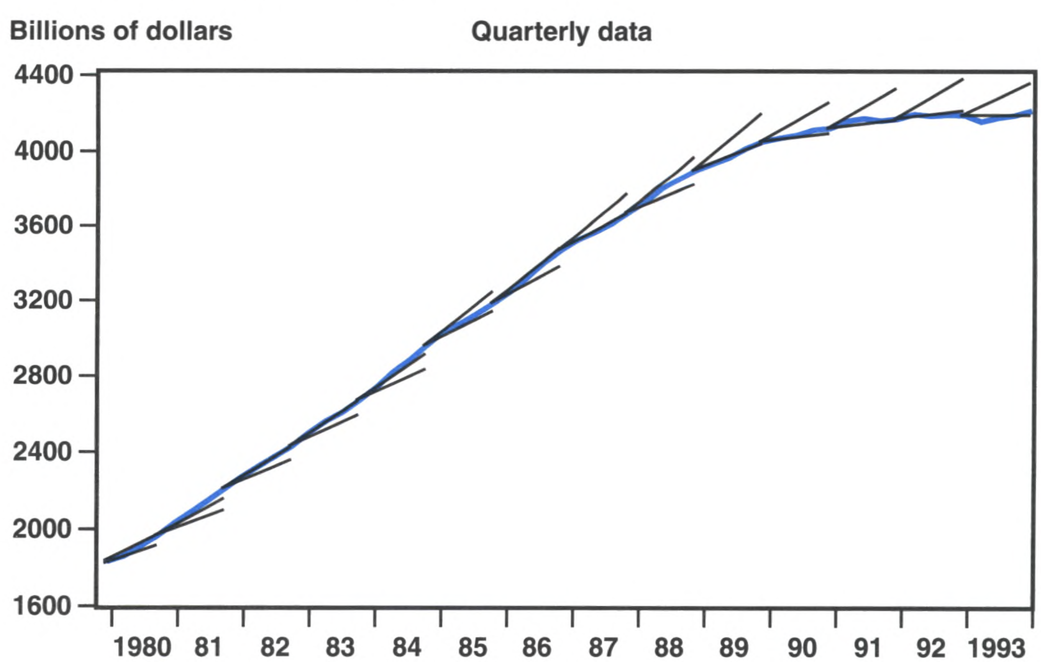


Figure 2
M3 Historical Target Ranges



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Appendix
Building Historical Monetary Aggregates 1959-80

The 1980 redefinition of the monetary aggregates confronted Board staff with the daunting task of building comparable historical data. In some cases, large amounts of additional data needed to be collected. In others, various estimates and approximations had to be made since required historical data had not been collected in the needed detail, at the desired frequency, or on the basis of consistent definitions. Although the data sources available as of 1977 have been described elsewhere, little has been written about the earlier data.[1] This appendix, based on published and unpublished material, summarizes available information about the data sources and methods used to construct monetary aggregates for years prior to 1980.

Monetary aggregates are built by consolidation of data, not addition. Consolidation requires not only data on the types and amounts of outstanding liabilities of financial intermediaries but also data on the ownership of such liabilities by other money-stock-issuing institutions, the latter being netted from the aggregate during consolidation. So far as possible, the discussion below reviews available data on both items.

DEPOSITS INCLUDED IN M1

Most commercial bank deposit items were available at least twice a year from call reports. Demand deposits had been reported by member banks since well before 1959. Call report data were available quarterly from all banks beginning in 1961, when quarterly call reports became required by law.

Daily data on OCD accounts were available for member banks. End-of-month data beginning in September 1972 for other New England financial institutions were obtained from the Federal Reserve Bank of Boston.

MSBs issued two types of demand deposits. One was used for regular third-party payments, that is, it was checkable. The other consisted mainly of escrow balances, not used for regular payments. Only the first is included in the monetary aggregates. Separation of the two types of deposits prior to 1980 was based on month-end data collected by the FDIC during an 18-month survey conducted from July 1975 to December 1976. The survey data themselves were included in M1 for the 18 months they were available. Before and after this period, data on total demand deposits reported on semiannual or quarterly call reports were multiplied by the average ratio of checkable to total demand deposits during the survey period. Monthly data were obtained by interpolation.

Share draft balances at federal credit unions were obtained from the National Credit Union Administration (NCUA) as of month-end for May-September 1976. Thereafter, only end-of-quarter data were available. No data were available on share drafts at state credit unions. For total credit union savings deposits, as of July 1977, federal credit unions held 55 percent of savings deposits; their share of share draft accounts is unknown.

Under the 1980 definition of the monetary aggregates, demand deposits at commercial banks due to thrifts, foreign banks and foreign official institutions are subtracted from total demand deposits in building M1 (see Table 2). Demand deposits at U.S. commercial banks due to foreign commercial banks and official institutions were available weekly (on Wednesday) for weekly reporting banks since May 1961, and quarterly or twice a year from call reports for all banks since (at least) 1959.[2] M1-type deposits at foreign-related institutions were available as of the last Wednesday of the month since November 1972 (beginning in 1977, Edge Act corporations reported only quarterly, but other institutions continue to report monthly). For earlier years, estimates were based on data

[1]Beck (1978) describes data available in 1977 and refers to unpublished memoranda for earlier sources and methods. Our discussion here draws from unpublished Federal Reserve Board memoranda by Neva Van Peski and Darwin Beck, and from Van Peski (1979). We thank them for helpful comments while absolving them of responsibility for remaining errors or omissions.

[2]The report form filed by weekly reporting banks had been revised in 1961 and 1966 to improve coverage of these items; see the introduction to chapter 4 in *Banking and Monetary Statistics 1941–1970.* Ironically, these data were originally collected from weekly reporting banks so that they could be added back into the monetary aggregates after being removed during earlier adjustments. Following the 1980 redefinitions, these reported data were used to remove the same items from the new aggregates.

taken from the Annual Report of the Superintendent of Banks in New York and for Edge Act corporations from call reports submitted twice a year to the Federal Reserve Bank of New York.

Deposits due to thrifts were handled in various ways. For MSBs, demand deposits at weekly reporting (commercial) banks (FR2416 reporters) due to MSBs were available for each Wednesday since May 1961. Quarterly or semiannual data for all commercial banks also were available on call reports since before 1959. These deposits were netted out of M1. For credit unions, demand deposits at all commercial banks due to credit unions were estimated to equal 0.03 percent of total year-end credit union assets for each year through 1974. After 1974, they were taken to equal the "cash" item in the annual reports of the NCUA. (No adjustment was made for credit union vault cash, also included in this item.) For savings and loan associations (S&Ls), demand deposits at commercial banks before 1973 were assumed to be a constant fraction of the item "cash on hand and in banks" reported annually in condition statements issued by the Federal Home Loan Bank Board (FHLBB); we do not know the value of the fraction used. Beginning September 1973, semiannual call reports are available in March and September from the FHLBB.

DEPOSITS INCLUDED IN THE NON-M1 COMPONENT OF M2

Savings Deposits

The savings deposit component of M2 includes deposits at commercial banks, MSBs, S&Ls and credit unions. As usual, construction of monetary aggregates requires both gross deposit amounts and, as a netting item, the amounts of deposits held by other money stock issuers. Monthly savings deposit data generally were available beginning in 1968. For prior years, savings deposits often were estimated as a constant share of total deposits, the share itself being estimated from data available circa 1968. The following paragraphs discuss estimates for each type of depositary.

For commercial banks from June 1961 through June 1966, total savings deposits were taken from semiannual and quarterly call reports; monthly values were obtained by interpolation. For July 1966 through January 1968, savings deposits at member banks were estimated from monthly summary reports submitted by the Federal Reserve Banks (FR422). Beginning January 1968, member banks reported daily savings deposits each week. Monthly nonmember bank data were obtained by interpolation of quarterly call reports.[3] The number of data items required as netting items in consolidation is small since commercial banks were not permitted to offer savings accounts to profit-making businesses (including other depositories) prior to November 1975. Thereafter, data regarding savings deposits due to domestic and foreign banks and foreign official institutions were available on Wednesdays for weekly reporting banks and for all banks on quarterly call reports since March 1976. (Note that this corresponds to current practices shown in Table 2.)

We have been unable to clarify precisely which data were used from 1959-67 for MSBs. From 1959-67, total deposits were available on a month-end basis from the National Association of Mutual Savings Banks (NAMSB), but no separate savings deposit series was available. For 1968-71, savings deposits were estimated using total deposit data and a deposit breakdown collected in a quarterly survey by the FDIC.[4] Beginning in December 1971, month-end savings deposits were published by the NAMSB. Month-average data (to correspond to averages of daily data, so far as possible) were constructed by averaging month-end data.

[3]The discussion in this appendix is somewhat more precise than what we have been able to document. From July 1966 through January 1968, for example, Board staff wrote that "nonmember bank data were estimated using ratios generated from call report data...," but they do not say precisely how this was done or which ratios were used. The staff memos do note that nonmember bank data continued to be taken from call reports after January 1968, and that monthly values were obtained by interpolation of quarterly call report data.

[4]Unfortunately, we have been unable to locate a description of the estimation procedure.

Two netting items were needed for MSBs: savings deposits at MSBs due to the U.S. Treasury, and savings deposits held by MSBs at commercial banks. Both series were available on call reports beginning in March 1976. Different approximations were used to generate data for prior dates. U.S. Treasury deposits were in fact zero for all months prior to November 1974, the first month MSBs were permitted to offer interest-bearing savings deposits to governments. Government deposits were assumed to be $1 million in November 1974 and all intermediate months were obtained by linear interpolation. Similarly, savings accounts held by MSBs at commercial banks were assumed to be $1 million in November 1975 and intermediate months through March 1976 were obtained by interpolation.

For S&Ls, total deposits for all operating S&Ls from 1959 to June 1968 were obtained from the Federal Savings and Loan Insurance Corporation (FSLIC).[5] Beginning in July 1968, month-end savings deposits at all federally-insured S&Ls became available from the FSLIC. For the earlier period (1959 to June 1968), savings deposits were assumed to equal total deposits multiplied by the July 1968 ratio of savings to total deposits. Month-average data were obtained by averaging month-end data.

Savings deposits held by S&Ls at other depositories, netted out in consolidating M2, were available semiannually beginning in September 1973 from the March-September reporting system release published by the FHLBB (essentially a semiannual call report). Values for prior months were obtained by linear interpolation between an assumed zero in December 1967 and the September 1973 value of $19 million.

Credit union shares were obtained on a month-end basis from NCUA.[6] Month-average data are constructed by averaging month-end data. Deposits of credit unions at other credit unions, netted out in consolidation, are available annually for federal credit unions from the year-end report of the NCUA beginning in December 1968; values for prior years are assumed to be zero.[7] Similar data for state credit unions were estimated by multiplying total assets at state-chartered credit unions by the ratio of such inter-credit-union shares to total assets at federal credit unions.

Small Time Deposits

The small time deposit component of M2 includes bank and thrift deposits under $100,000 with an original maturity of seven days or more. U.S. Treasury deposits and deposits of thrifts with commercial banks and other thrifts are netted out in consolidation.

For commercial banks, small time deposits were computed as a residual by subtracting two series, savings deposits and time deposits of more than $100,000, from reported data on total time and savings deposits. Total time and savings deposits at member banks had been reported weekly since 1959. Small time deposits at nonmember banks were estimated by multiplying small time deposits at small member banks by the ratio of small time deposits at nonmember banks to small time deposits at small member banks on call report dates.[8]

Time deposits due to the U.S. Treasury and due to MSBs were netted from the non-M1 component of M2 in consolidation. For weekly reporting member banks, these data were available on Wednesday since 1959 and 1961, respectively (however, see *Banking and Monetary Statistics 1941-1970*, chapter 4, for a discussion of changes in items reported). For other banks, semiannual and quarterly call report data were available since before 1959.

For MSBs, month-end time deposits beginning in December 1971 were obtained from NAMSB. For prior periods, time deposits were estimated

[5]Conversations with former FHLBB staff during the course of this research suggest that these data never, in fact, covered all operating S&Ls. Some data for non-FSLIC institutions were apparently estimated rather than obtained directly. Other sources report that federally insured S&Ls likely held as much as 95 percent or more of total S&L deposits. Recall that state-insured thrifts in Massachusetts and New York were chartered as MSBs.

[6]It isn't clear whether these data covered all credit unions or only federally insured institutions. Our guess is the latter. If so, other credit union deposits would be excluded from the aggregates, perhaps one-half of total credit union deposits.

[7]Smaller credit unions often hold, as a significant part of their assets, shares in large "corporate central" credit unions. Although the latter have some retail business, they primarily act as an investor of excess funds deposited with them by other credit unions.

[8]As in some other cases, this is a somewhat more specific statement of what we believe was done than we have, in fact, been able to locate.

by Board staff from data on total deposits at MSBs (available at least from 1959) and from time deposit data collected on quarterly FDIC surveys (available at least since 1966). We have no description of what was done for 1959-65, but it is likely that the 1966 ratio of time deposits to total deposits was simply maintained over this period. (Precisely what was done may be of little importance, since time deposits at MSBs were only 1 percent of total deposits in 1966.)

Time deposits of S&Ls at banks are netted from M2 in consolidation. Beginning in September 1973, time deposits of S&Ls at commercial banks were taken from a semiannual FHLBB publication, referred to in unpublished Board memoranda as the FHLBB March-September reporting system. For all dates prior to September 1973, it was assumed that S&Ls kept the same proportion of their cash assets in bank time deposits as they had in September 1973. In other words, S&L time deposits at banks from 1959-72 were assumed to be a constant fraction of the amount of "cash on hand and in banks" reported by S&Ls in annual condition statements to the FHLBB. The value of that fraction was the ratio of bank time deposits to cash assets shown in the September 1973 report in the FHLBB March-September reporting system.

Time deposits of credit unions at banks and S&Ls also are netted from M2. Deposits of credit unions at S&Ls (assumed to be time deposits) were reported at year-end by federal credit unions, and were available from the NCUA *Annual Report* since before 1959. The ratio of these assets to total assets was used to estimate these items for state-chartered credit unions. Annual reports issued by the NCUA and its predecessor were available since before 1959. Time deposits of credit unions at commercial banks were estimated at year-end; until 1974, they were treated as a residual, the difference between "cash" reported in the annual reports and estimated demand deposits. After 1974, the cash item excluded time deposits, which were then estimated by applying the ratio of time deposits to total assets in 1974 to total assets in later years. Year-end cash figures were available since before 1959 for federal credit unions, and since December 1964 for state-chartered credit unions from the annual reports.

Large Time Deposits in M3

The large time deposit component of the monetary aggregate M3 consists of time deposits over $100,000 at all depositories less domestic interbank time deposits and time deposits due to other depositories, foreign commercial banks and foreign governments. The distinction between large and small time deposits essentially begins in 1961. Construction of large time deposit data beginning in 1961 is discussed by both Friedman and Schwartz (1970) and Beck (1978).

Kenneth Kavajecz

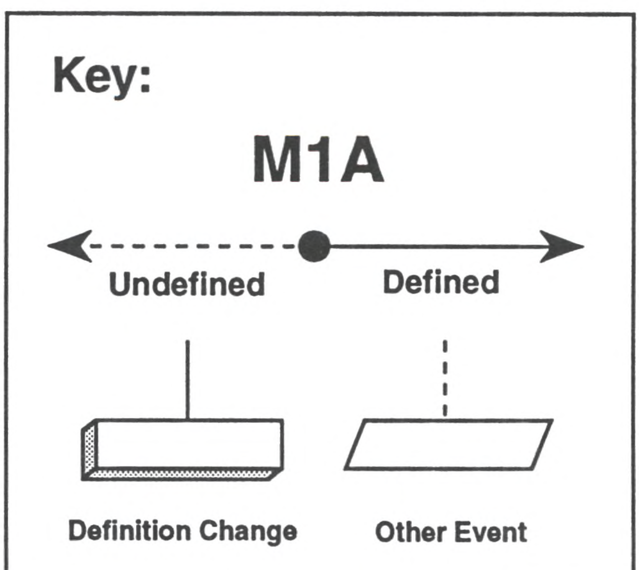
The Evolution of the Federal Reserve's Monetary Aggregates: A Timeline

This timeline follows the history of the monetary aggregates published by the staff of the Federal Reserve's Board of Governors. The chronology is based on the Board's J.3 and H.6 statistical releases as well as material from the *Federal Reserve Bulletin, Money Stock Revisions,* and other publications.

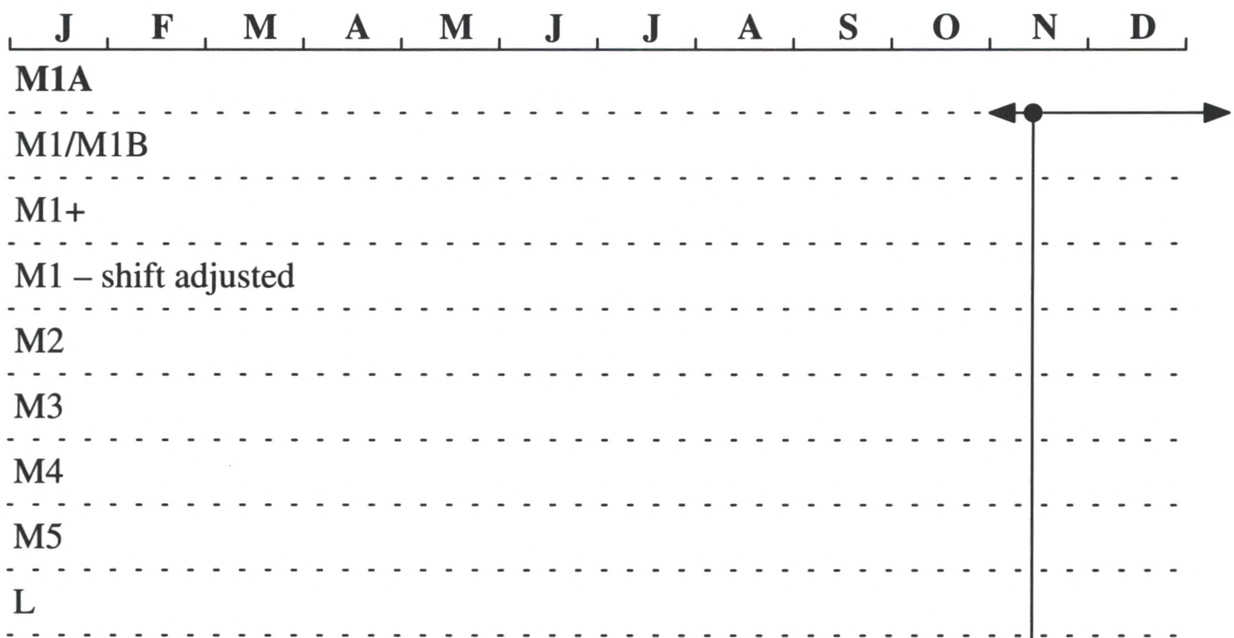
The timeline includes descriptions of all definition changes and benchmark revisions, the basis on which data were published (monthly, bimonthly, weekly), and the day of the week and time of day that the money stock data were released to the public. The last are of particular importance for financial researchers using high frequency data. Additional miscellaneous items related to the monetary aggregates are included, selected by the author on the basis of their likely importance to the evolution of the monetary aggregates and/or the role of monetary aggregates in monetary policy.

Note the following in the timeline:

- Each page gives information on events that occurred during a single year.
- The lines at the top of the pages trace the life of every official monetary aggregate published by the Board staff between 1959 and 1993 (experimental aggregates are excluded). The names of monetary aggregates that were defined and being published during a year are shown in bold face on that page, and the period over which they were being published is shown as a solid line.
- Each event of interest is shown as a vertical line with a parallelogram attached. Each event is also dated in the upper left corner of the parallelogram.
- Definitional changes are distinguished from other events by having a solid vertical line with a three-dimensional rectangle attached.



1960



November 14, 1960

The first Federal Reserve statistical release on the money supply was published. The J.3 release entitled *Demand Deposits, Currency, and Related Items* was thereafter published twice a month. The reported figures were averages of daily figures rather than the one–day figures reported in the *Federal Reserve Bulletin*. The money stock was called "the money supply." It measured a concept that would later be called M1A, namely currency plus demand deposits adjusted. The currency component included currency held outside the Treasury, the Federal Reserve, and the vaults of all commercial banks. The demand deposit component consisted of demand deposits other than those due to commercial banks and the U.S. Government, less cash items in process of collection (CIPC) and Federal Reserve float. CIPC items at member and nonmember banks were deducted separately from demand deposits at member and nonmember banks, respectively. Since Federal Reserve float was not divisible on the basis of a member–nonmember attribution, it was deducted in whole from the member bank demand deposit component.
(See footnote on J.3 release).

Day of the week released and release time.

Thursday Release
Immediate Release
Bi–monthly basis

1961

J F M A M J J A S O N D

M1A

M1/M1B

M1+

M1 – shift adjusted

M2

M3

M4

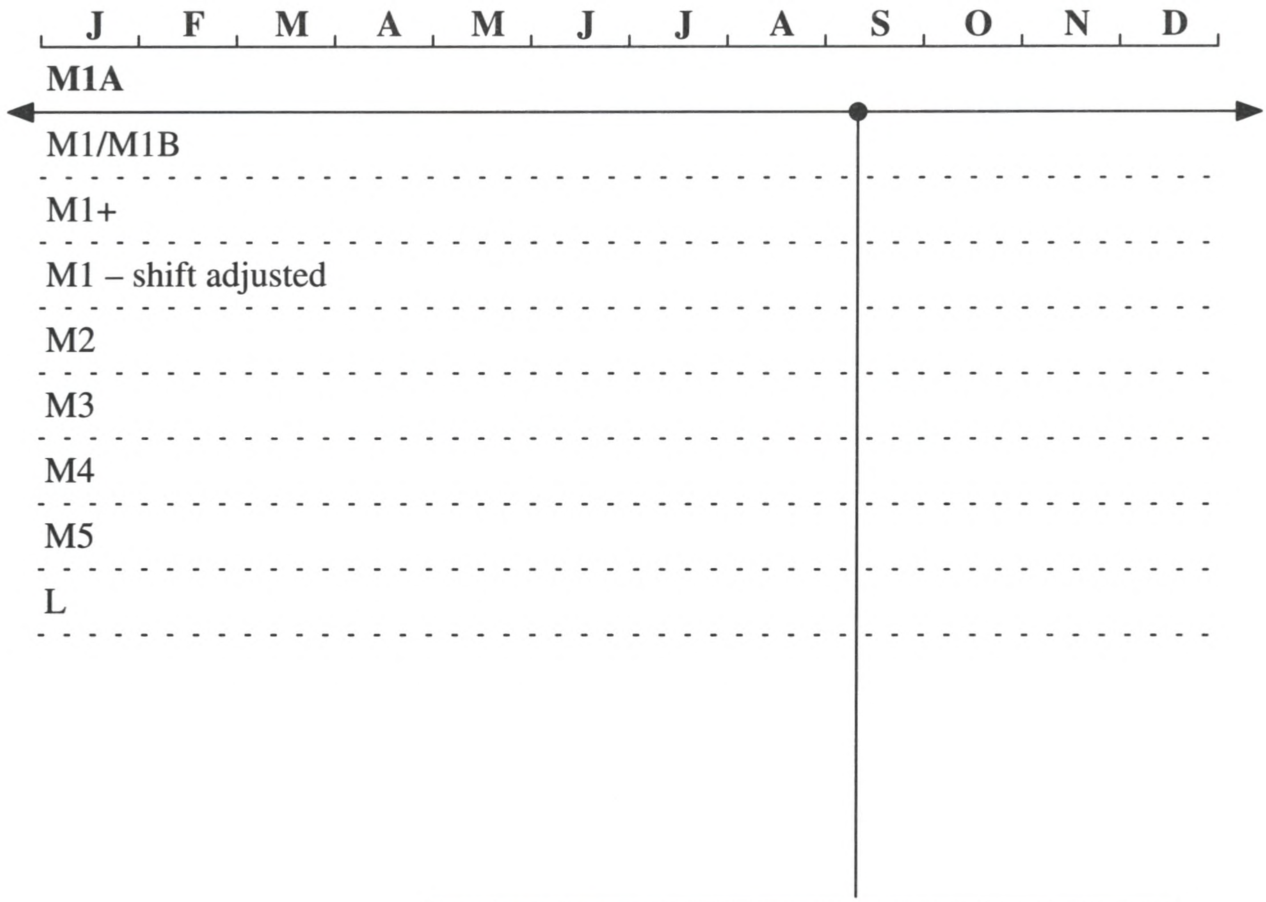
M5

L

Thursday Release
Immediate Release

Bi–monthly basis

1962



September 11, 1962
Annual benchmark and seasonal review.
Benchmarked to call reports available for 1961.
The definition of M1A was expanded to include demand deposits held by banks located in U.S. territories and possessions at U.S. commercial banks plus foreign demand balances at Federal Reserve banks. Foreign demand balances included demand deposits due to foreign governments, central banks and international institutions.
(See *Federal Reserve Bulletin (FRB)*, August 1962).

Thursday Release
Immediate Release

Bi–monthly basis

1963

J F M A M J J A S O N D

M1A

M1/M1B

M1+

M1 – shift adjusted

M2

M3

M4

M5

L

Thursday Release
Immediate Release

Bi–monthly basis

1964

J F M A M J J A S O N D

M1A

M1/M1B

M1+

M1 – shift adjusted

M2

M3

M4

M5

L

June 29, 1964
Annual benchmark and seasonal review.
Benchmarked to call reports available for 1962 and 1963.
(See *FRB*, June 1964).

Thursday Release
Immediate Release

Bi–monthly basis

1965

J F M A M J J A S O N D

M1A

M1/M1B

M1+

M1 – shift adjusted

M2

M3

M4

M5

L

July 30, 1965
Annual benchmark and seasonal review. Benchmarked to the June and December 1964 call reports. The J.3 release was replaced by the H.6 release, published weekly on Thursday.
The H.6 release showed week averages of daily data on a week ending Wednesday basis.
(See *FRB*, July 1965).

Thursday Release Immediate Release	Thursday Release Immediate Release
Bi–monthly basis	Week ending Wednesday basis

1966

J F M A M J J A S O N D

M1A

M1/M1B

M1+

M1 – shift adjusted

M2

M3

M4

M5

L

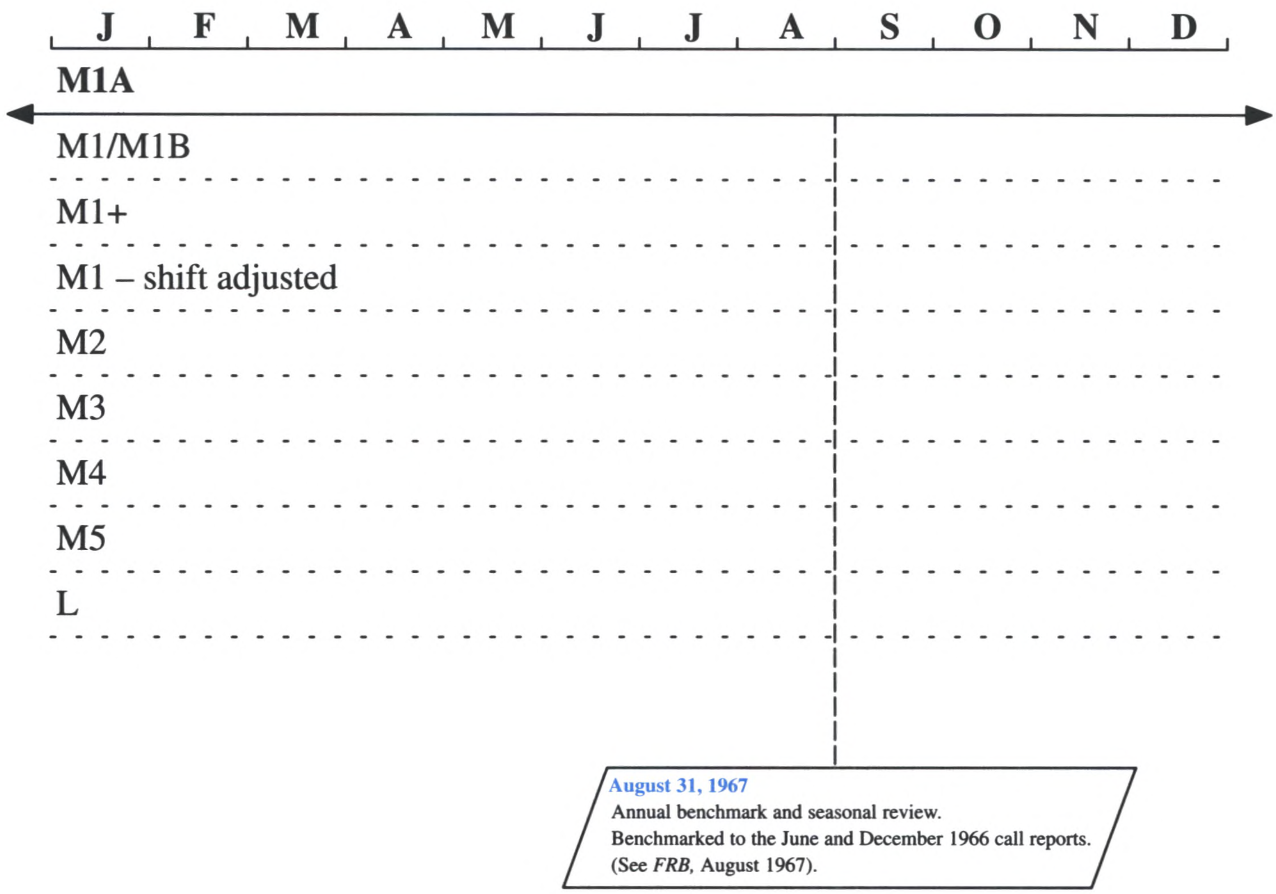
June 23, 1966
Effective June 9, 1966, balances accumulated for payment of personal loans were reclassified for reserve purposes and were excluded from time deposits reported by member banks. Although this did not affect the reported money supply at the time, it did affect the time deposit series reported separately on the H.6. The estimated amount of such deposits at all commercial banks ($1,140 million) was excluded from time deposits adjusted thereafter.
(See H.6 release).

Setember 29, 1966
Annual benchmark and seasonal review.
Benchmarked to the June and December 1965 call reports.
(See *FRB*, September 1966).

Thursday Release
Immediate Release

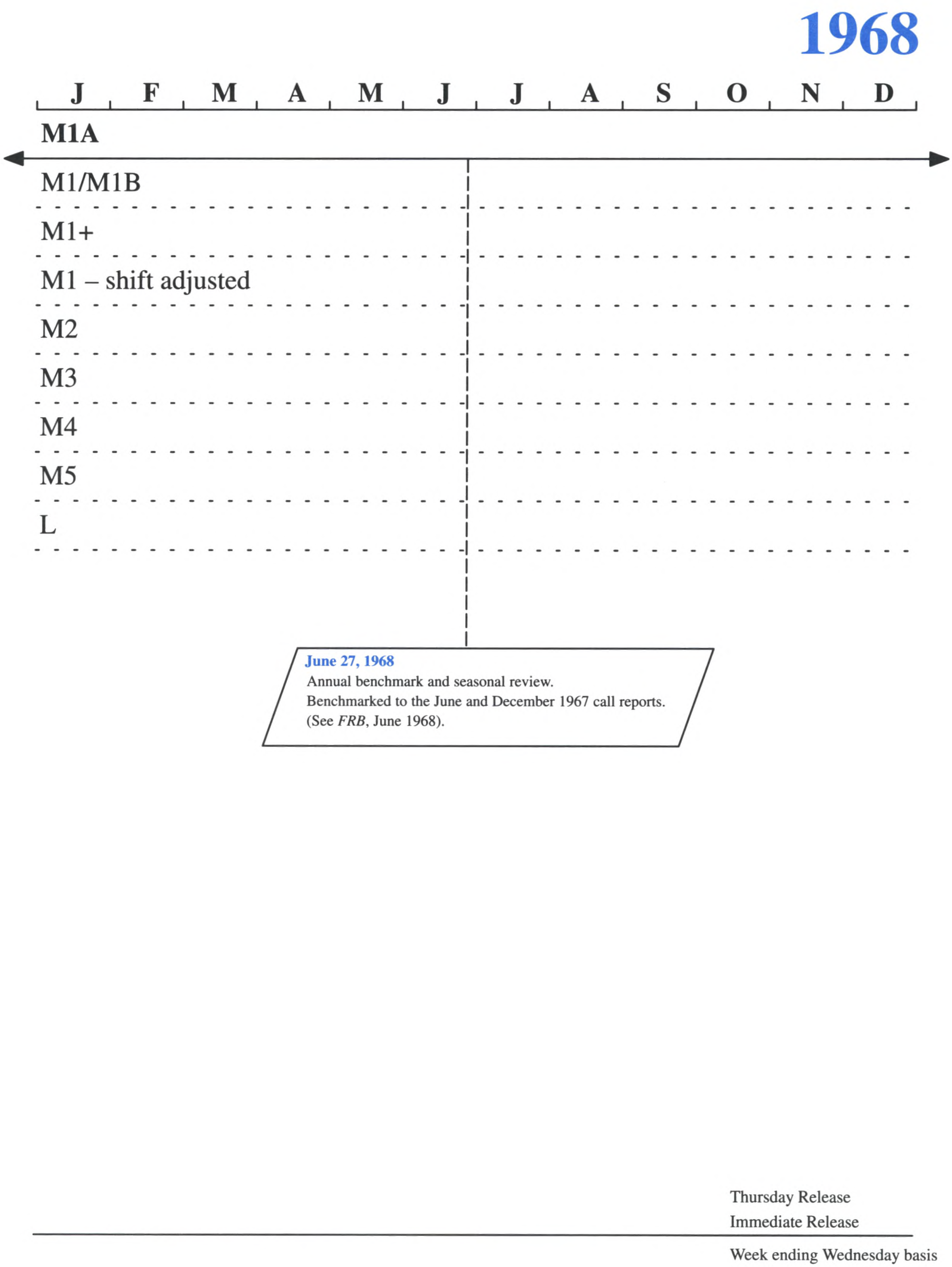
Week ending Wednesday basis

1967

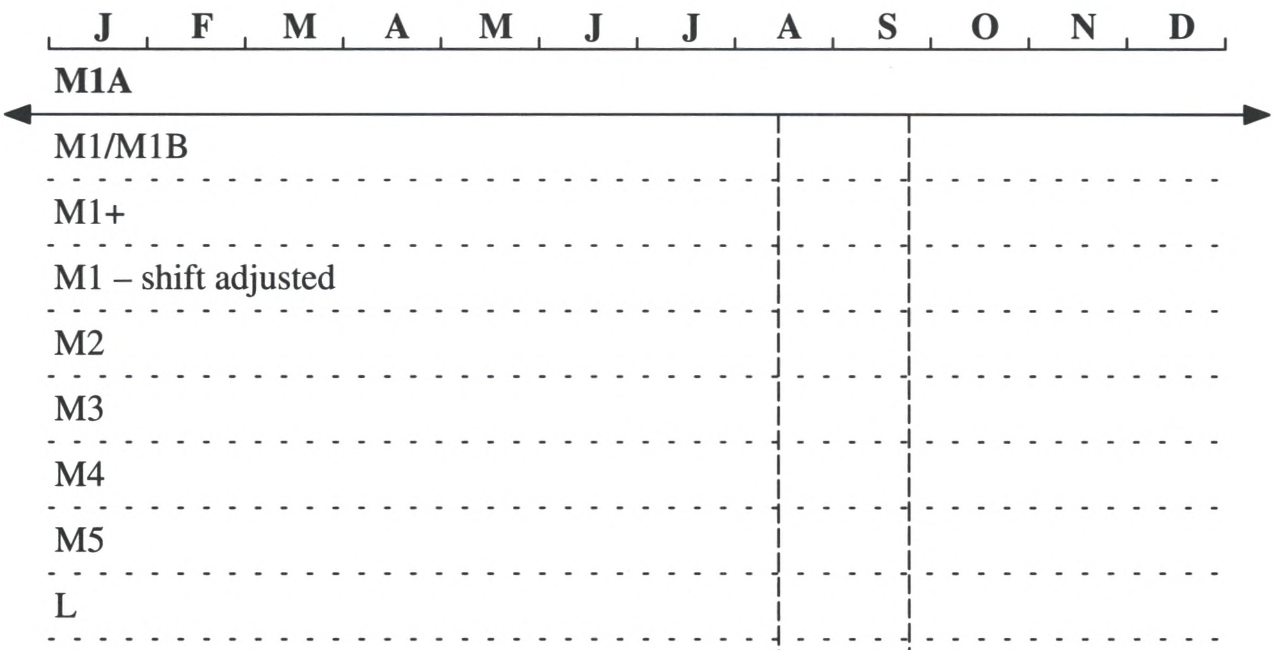


Thursday Release
Immediate Release

Week ending Wednesday basis


1968
J F M A M J J A S O N D
M1A
M1/M1B
M1+
M1 – shift adjusted
M2
M3
M4
M5
L
June 27, 1968
Annual benchmark and seasonal review.
Benchmarked to the June and December 1967 call reports.
(See FRB, June 1968).
Thursday Release
Immediate Release
Week ending Wednesday basis

1969

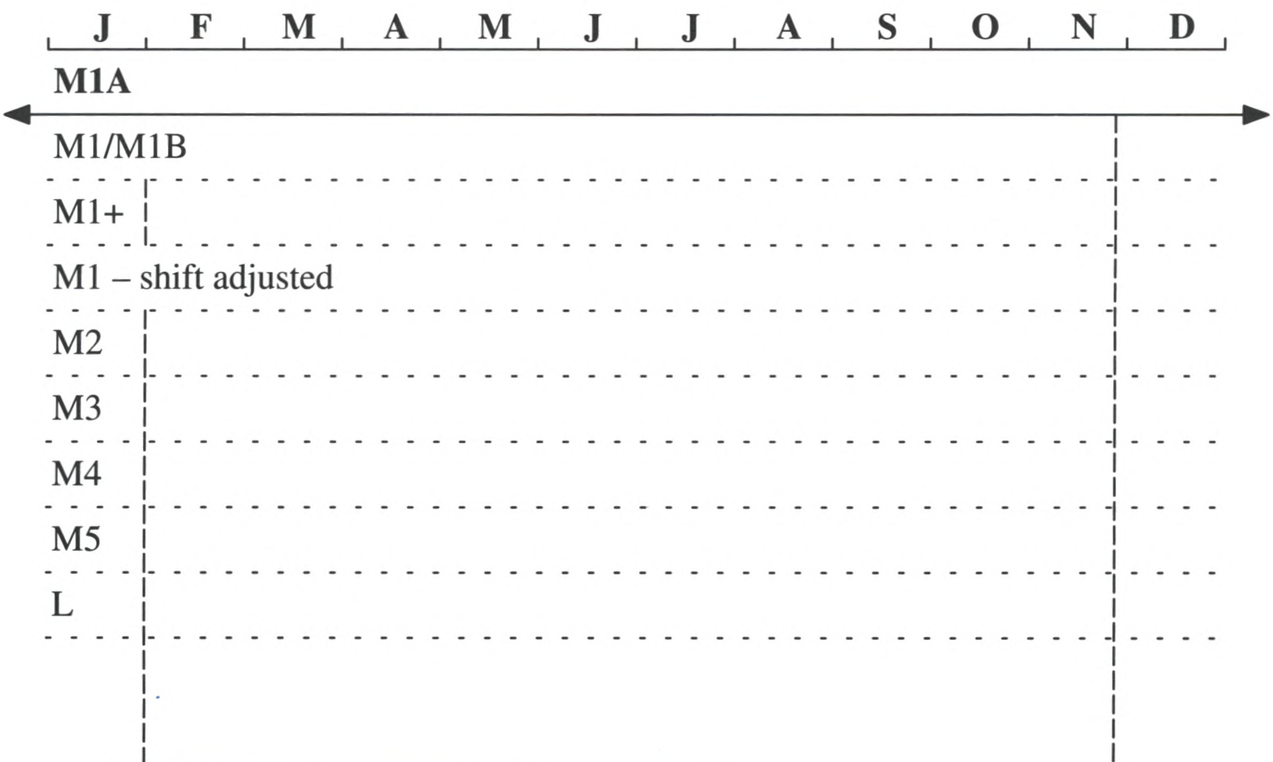


August 14, 1969
Effective August 6, 1969, the demand deposit component of the money supply was increased substantially due to a change in accounting procedures associated with bank clearing of Eurodollar transactions. Previously, an increasing volume of such transactions had increased CIPC without increasing demand deposits. Since CIPC was deducted from gross demand deposits in computing the money supply, the net demand deposit concept measured in the money supply had been understated by an increasing amount in recent years. A tentative revision was made to correct the downward bias from June 1967 to July 1969.

September 25, 1969
Annual benchmark and seasonal review. Benchmarked to the June and December 1968 and June 1969 call reports. (See *FRB*, October 1969).

Thursday Release
Immediate Release
Week ending Wednesday basis

1970

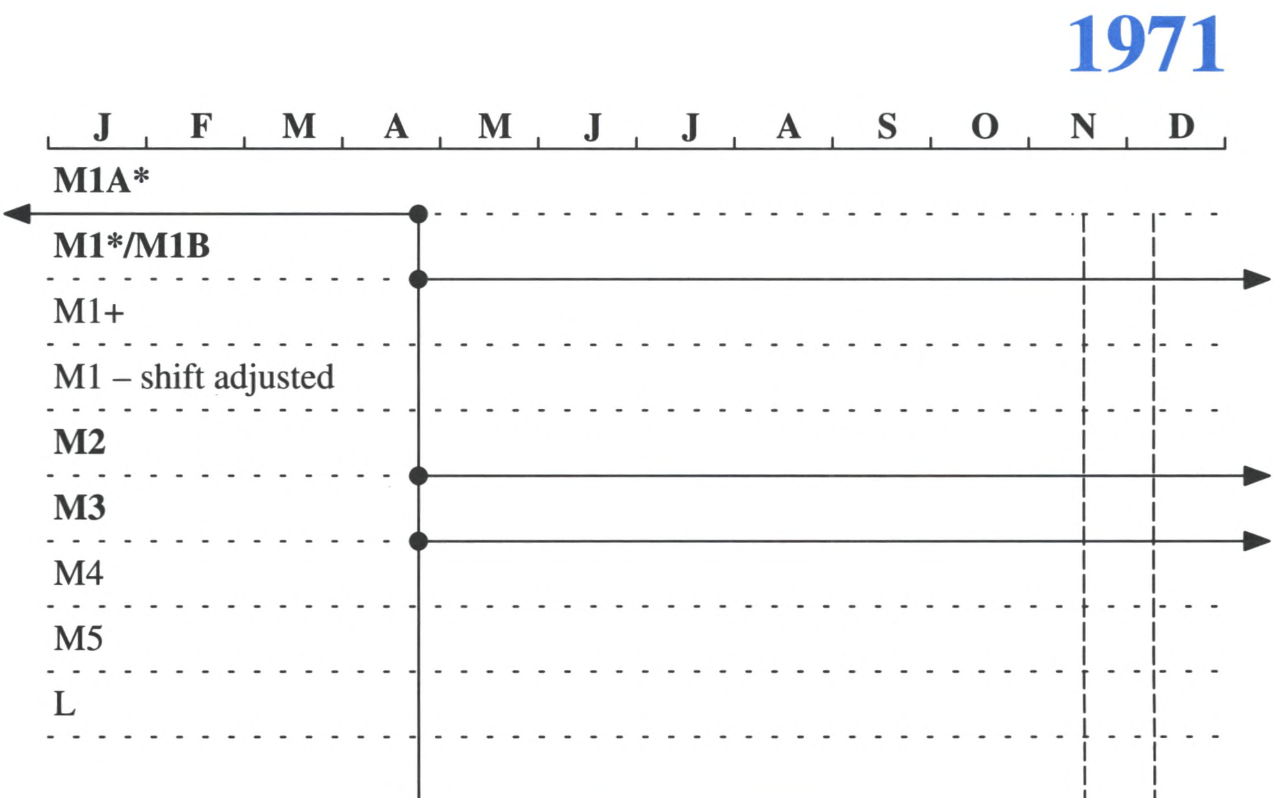


February 1, 1970
Mr. Arthur F. Burns replaced Mr. William McChesney Martin, Jr. as Chairman of the Federal Reserve Board. Chairman Martin had served since April 2, 1951.

November 27, 1970
Annual benchmark and seasonal review.
Benchmarked to the December 1969 and June 1970 call reports.
The revision this year encompassed for the first time certain new data, mainly from agencies and branches in the U.S. of foreign banks and from subsidiaries of U.S. banks organized under the Edge act to engage in international banking business. These new data served to correct a downward bias in the money supply series caused by the generation of CIPC on the books of U.S. domestic banks as a result of clearing a large daily volume of international transactions.
(See *FRB*, December 1970).

Thursday Release
Immediate Release

Week ending Wednesday basis



April 22, 1971

The Federal Reserve started to publish 3 monetary aggregates, M1, M2, M3. M1 and M2 were reported on a weekly and monthly basis while M3 was reported only on a monthly basis due to a lack of data sources at the time.

*M1 was the same as the previously published money stock, listed above as M1A, only the name had changed.

M2 was a broader aggregate that included M1 plus commercial banks' savings deposits, time deposits open account, and time certificates of deposit other than negotiable CDs issued in denominations of $100,000 or more by large weekly reporting commercial banks.

M3 was M2 plus deposits at mutual savings banks and savings and loan associations.

November 18, 1971

Annual benchmark and seasonal review. Benchmarked to the December 1970 and June 1971 call reports.

(See *FRB*, November 1971).

December 9, 1971

Money stock measures have been revised, beginning in September 1971 to reflect the formation of new banking institutions doing primarily international business. The vague description listed above was taken from a footnote on the H.6 release.

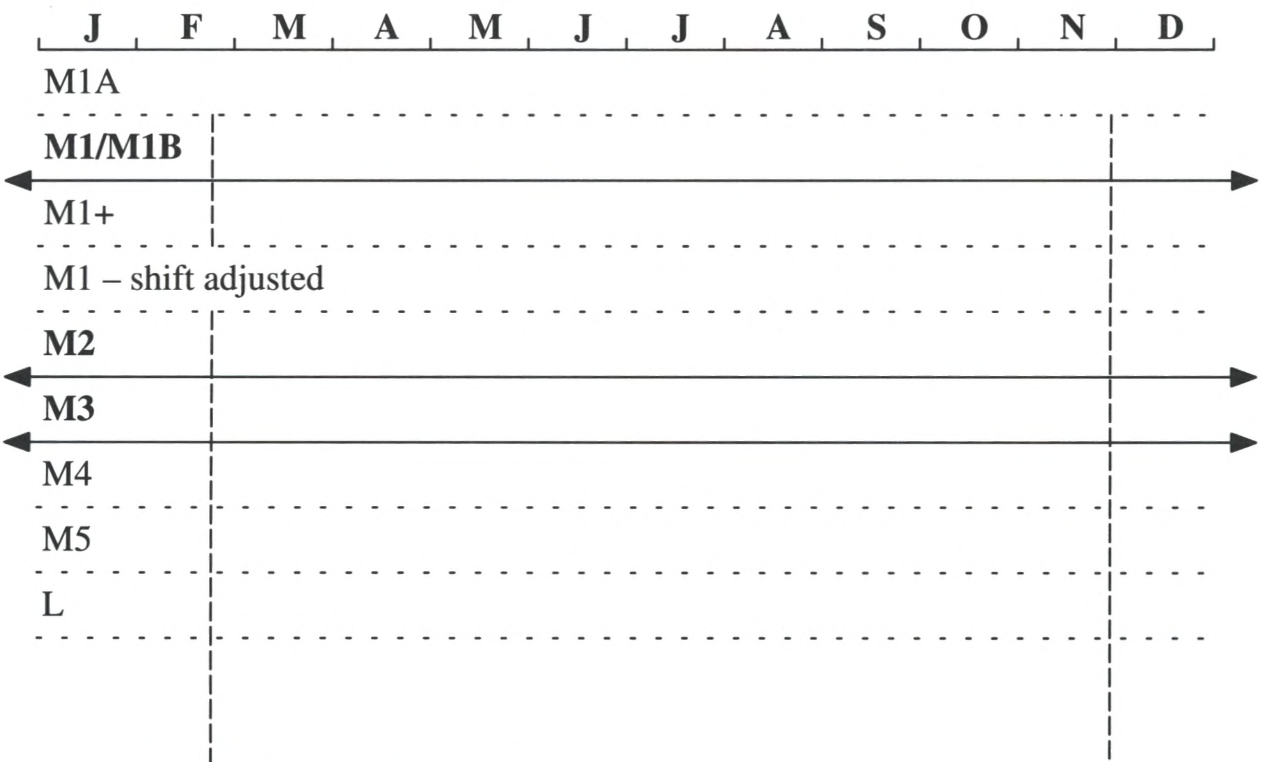
To what this refers is subject to some debate.

Thursday Release

Immediate Release

Week ending Wednesday basis

1972

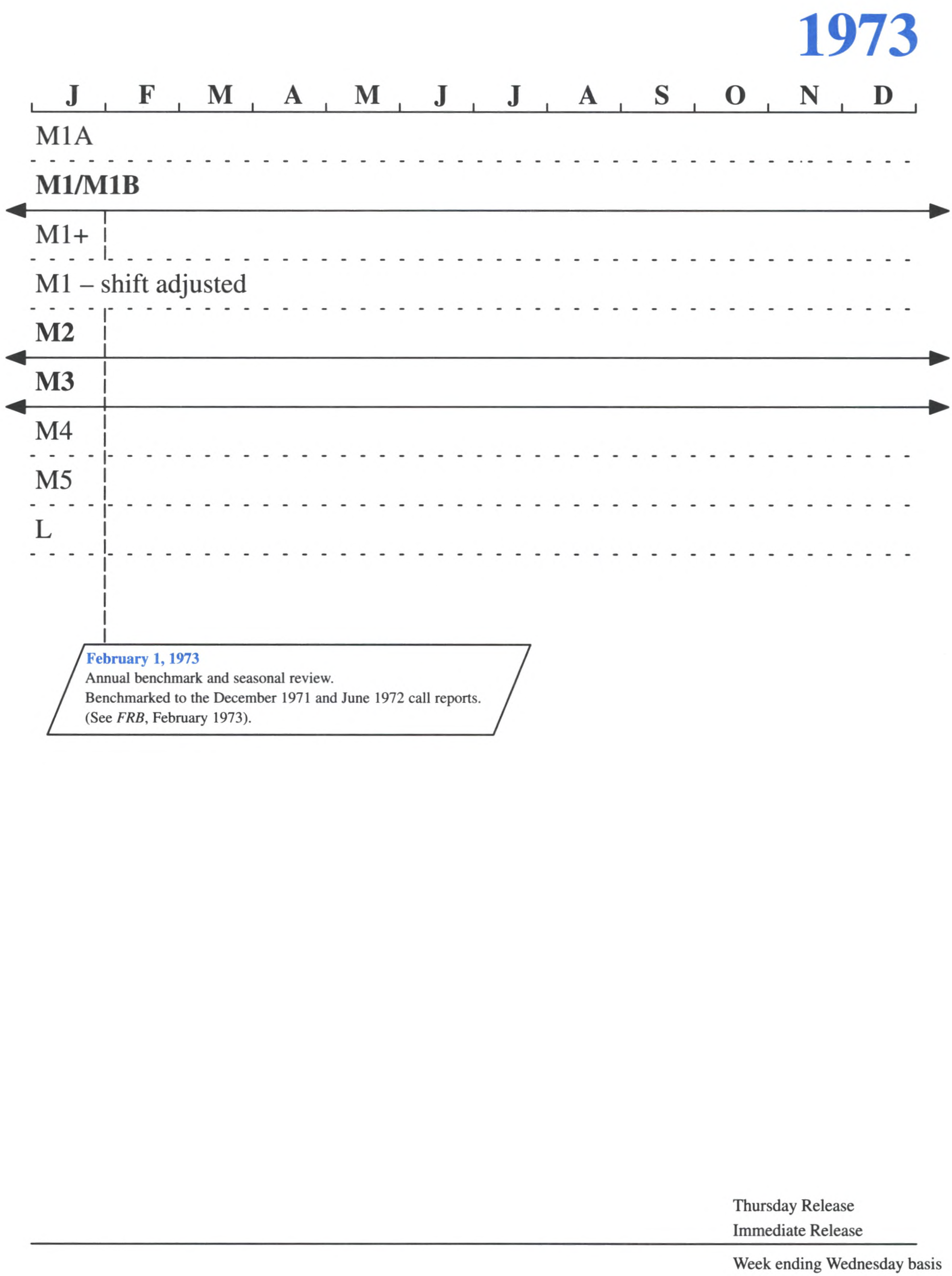


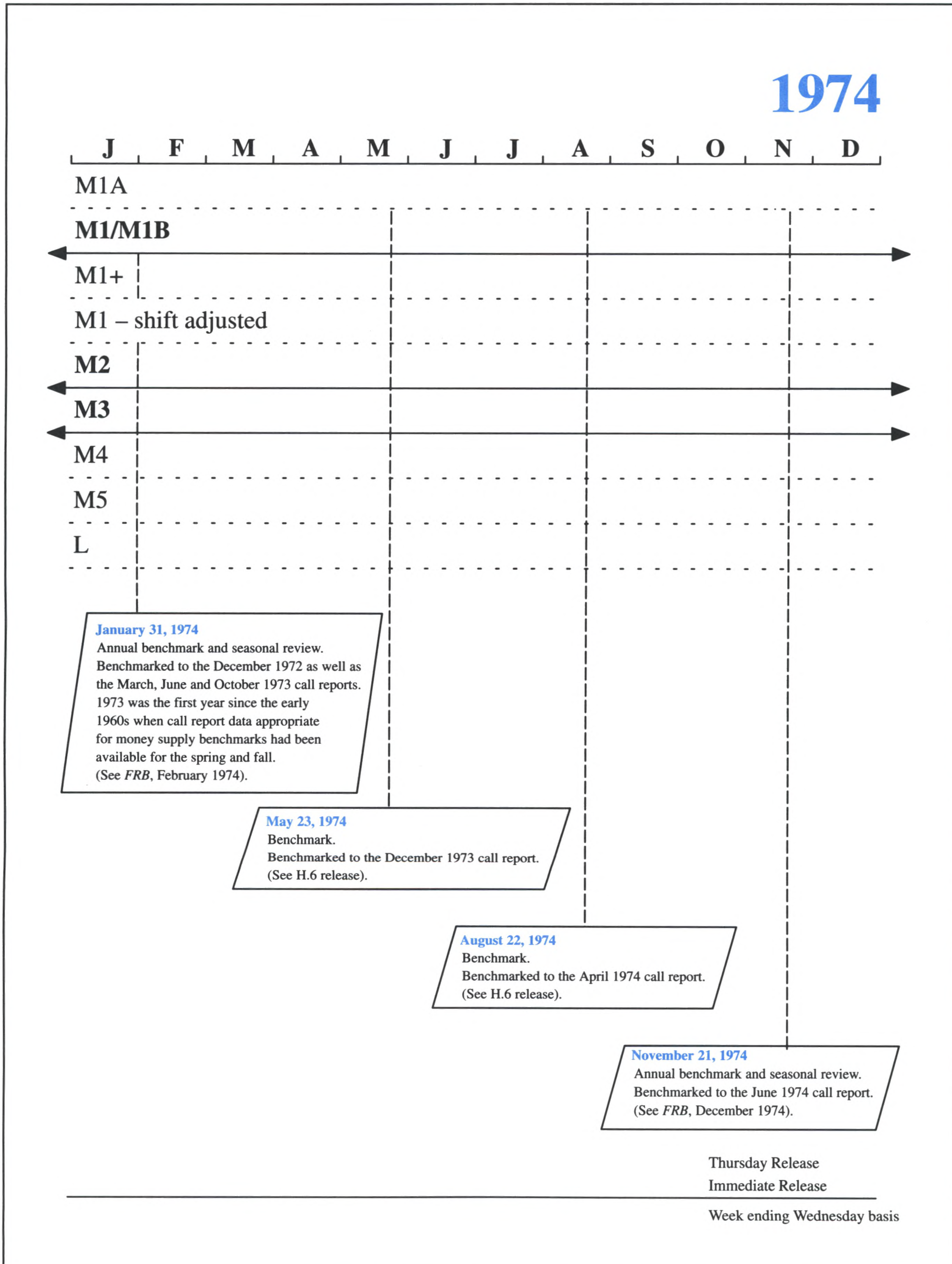
February 24, 1972
Benchmark and seasonal review of M3 data. Benchmarked to reflect new data for deposits at mutual savings banks and savings and loan shares.

November 24, 1972
A change in Regulation J, governing check collection procedures, was implemented on November 9, 1972. Because of its effects on clearing accounts on bank balance sheets, it had the effect of raising demand deposits as calculated for inclusion in the money supply. However, to avoid any discontinuities in the series, the resulting increase had been eliminated from the current series until the annual benchmark and seasonal review.

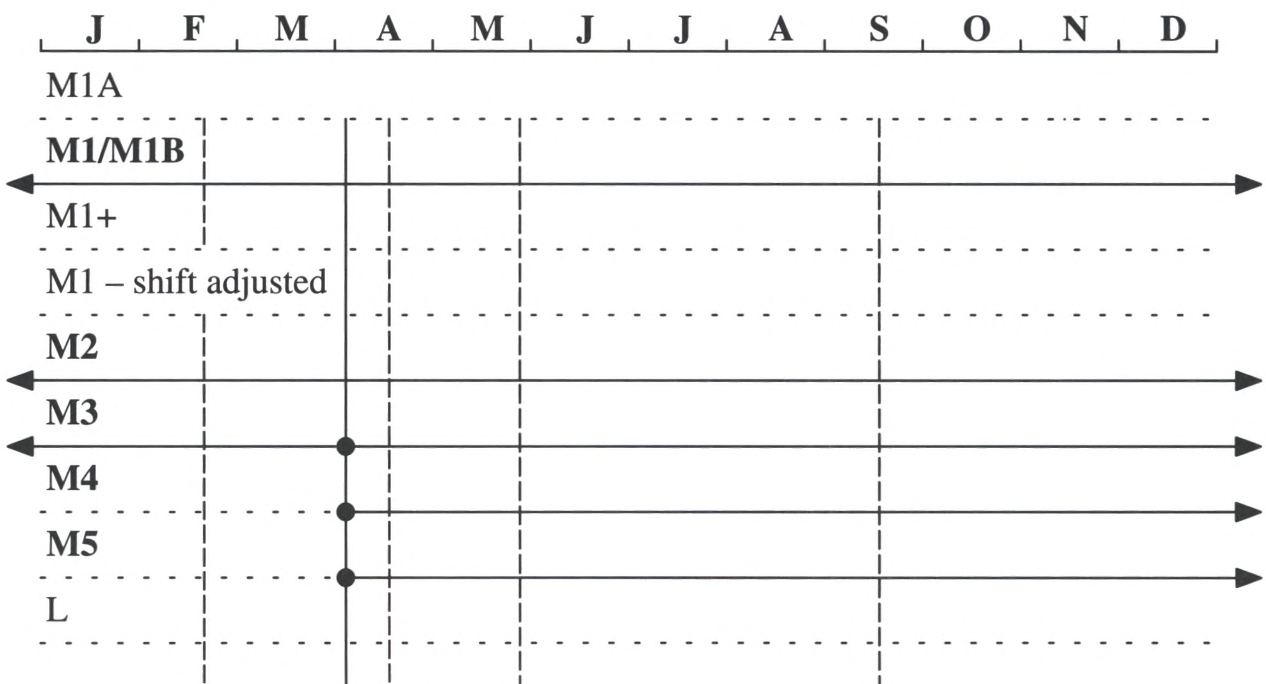
Thursday Release
Immediate Release

Week ending Wednesday basis


1973
J F M A M J J A S O N D
M1A
M1/M1B
M1+
M1 – shift adjusted
M2
M3
M4
M5
L
February 1, 1973
Annual benchmark and seasonal review.
Benchmarked to the December 1971 and June 1972 call reports.
(See FRB, February 1973).
Thursday Release
Immediate Release
Week ending Wednesday basis


1974
J F M A M J J A S O N D
M1A
M1/M1B
M1+
M1 – shift adjusted
M2
M3
M4
M5
L
January 31, 1974
Annual benchmark and seasonal review. Benchmarked to the December 1972 as well as the March, June and October 1973 call reports. 1973 was the first year since the early 1960s when call report data appropriate for money supply benchmarks had been available for the spring and fall. (See *FRB*, February 1974).
May 23, 1974
Benchmark.
Benchmarked to the December 1973 call report. (See H.6 release).
August 22, 1974
Benchmark.
Benchmarked to the April 1974 call report. (See H.6 release).
November 21, 1974
Annual benchmark and seasonal review.
Benchmarked to the June 1974 call report. (See *FRB*, December 1974).
Thursday Release
Immediate Release
Week ending Wednesday basis

1975



February 20, 1975
Benchmark and seasonal review.
Benchmarked to the October 1974 call report.
(See H.6 release).

April 3, 1975
On April 3, 1975, the Federal Reserve published two additional monetary aggregates, M4 and M5.
M1 and M2 remained unchanged from their inception in 1971.
The definition of M3 was revised to include credit union shares.
M4 was defined as M2 plus large negotiable time certificates of deposits issued by large weekly reporting commercial banks.
M5 was defined as M3 plus the same large time deposits added to M4.

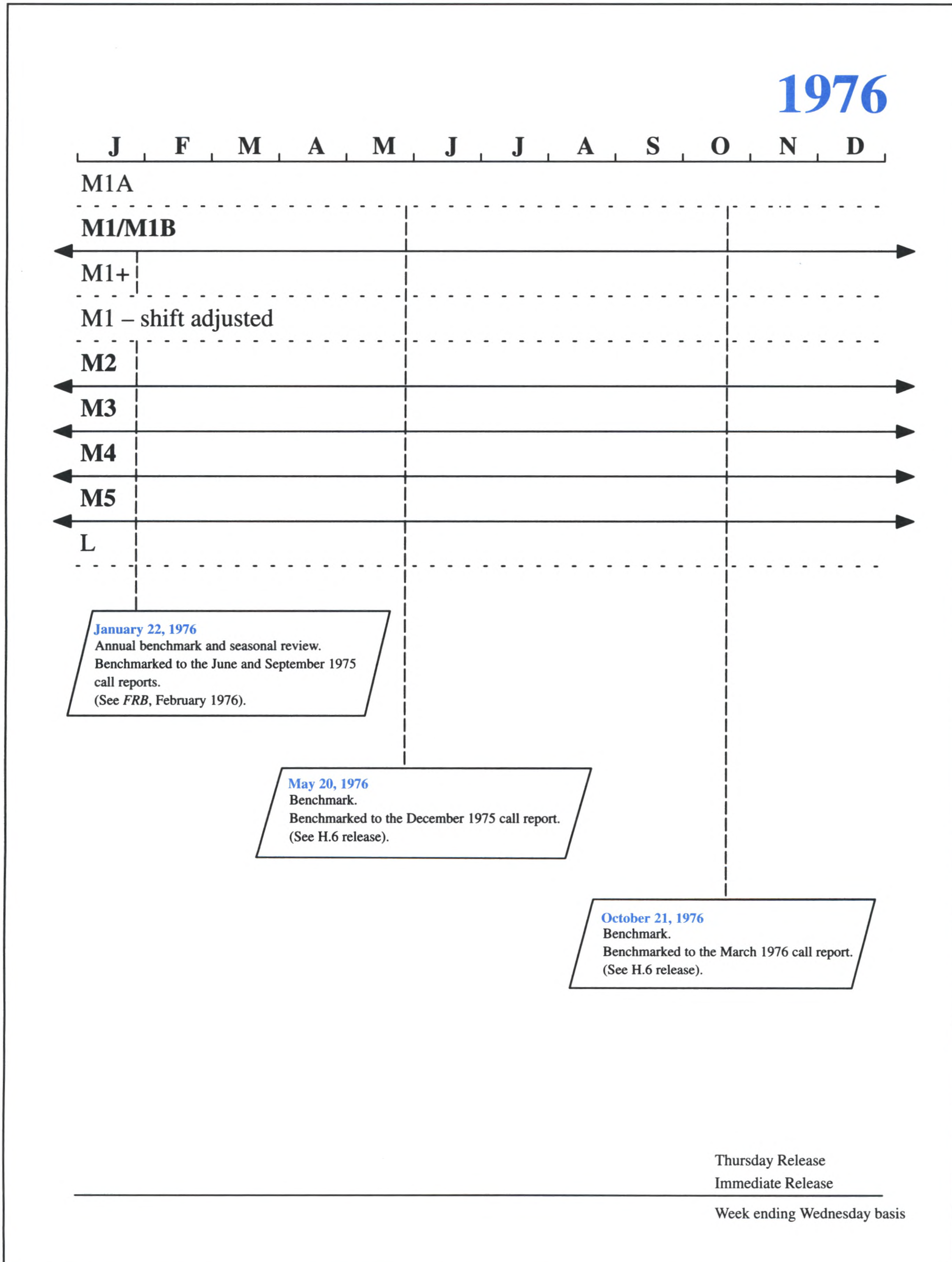
FOMC Meeting, April 14–15, 1975
First target growth cones announced for the monetary aggregates.
(See Anderson and Kavajecz, 1994, Table 4).

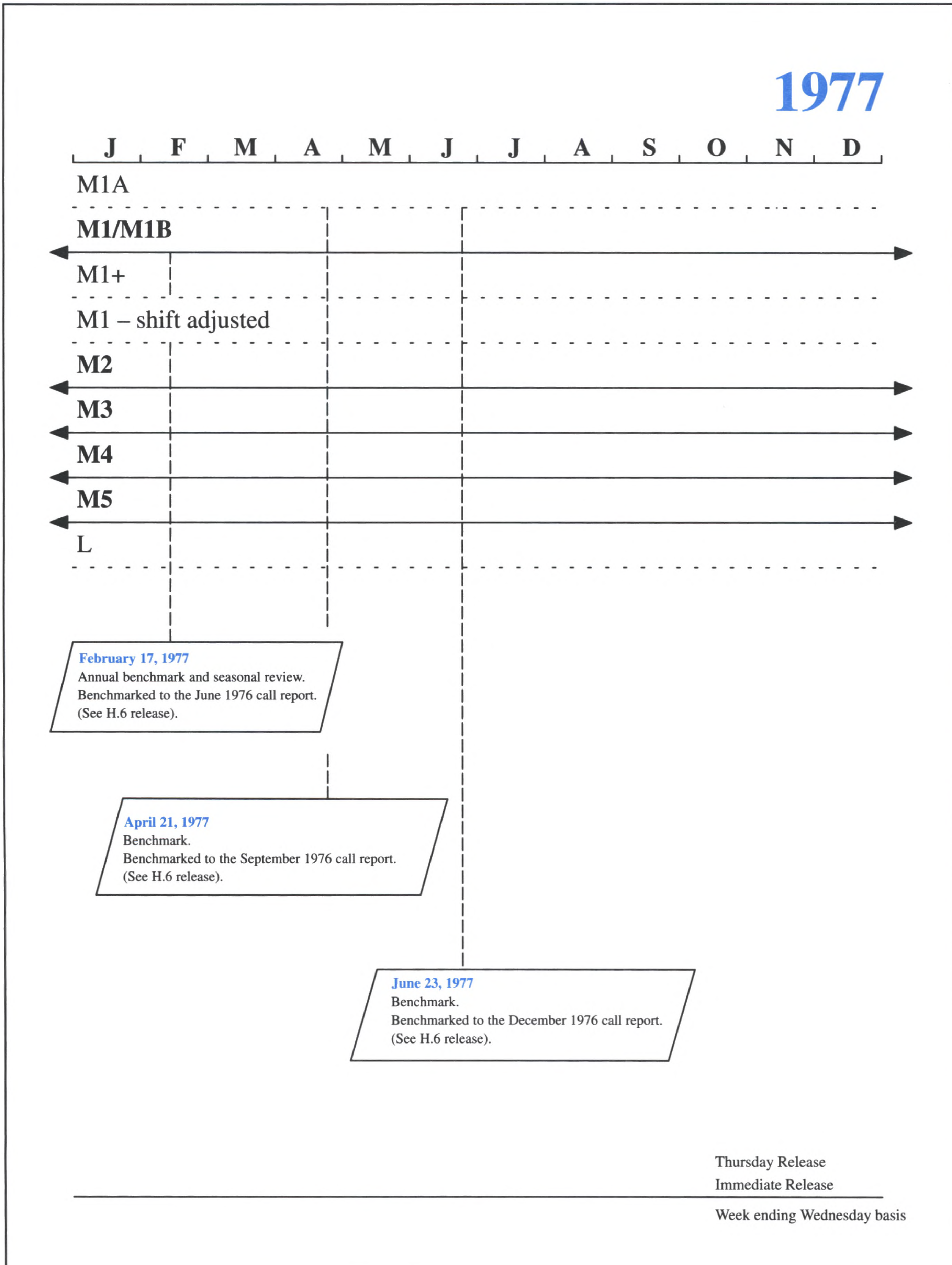
September 18, 1975
Benchmark.
Benchmarked to the April 1975 call report.
(See H.6 release).

May 22, 1975
Benchmark.
Benchmarked to the December 1974 call report.
(See H.6 release).

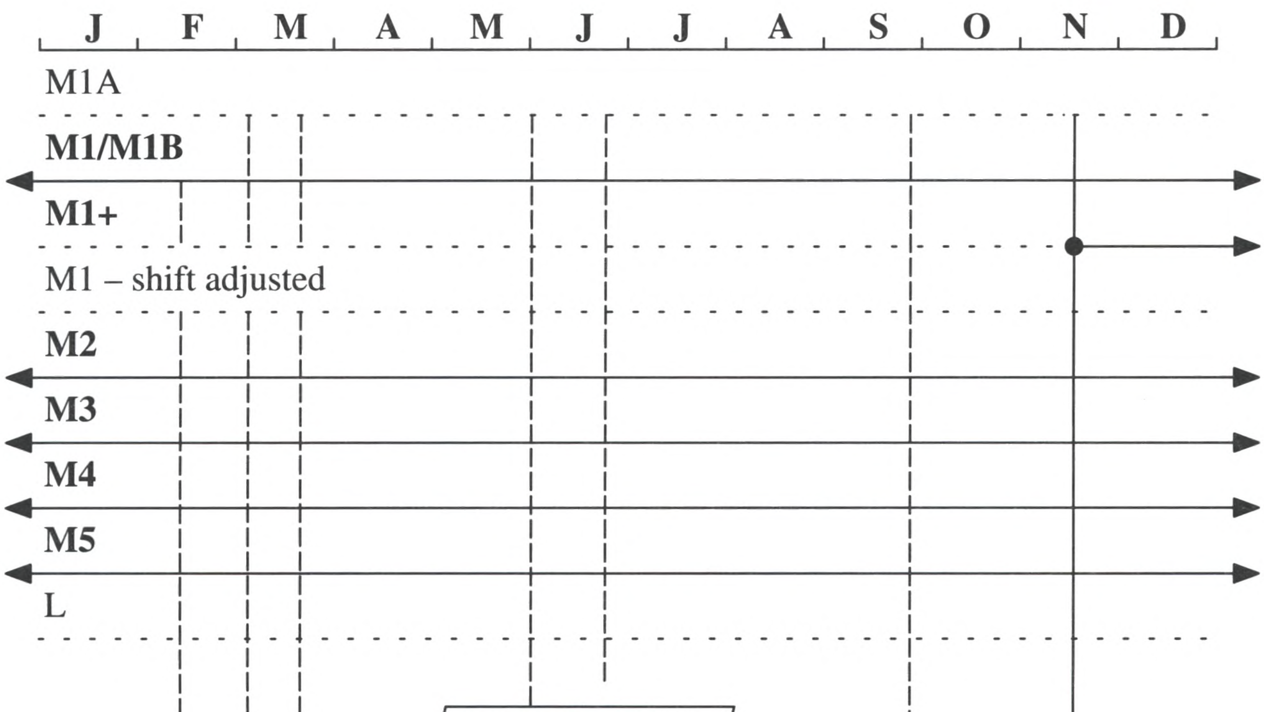
Thursday Release
Immediate Release

Week ending Wednesday basis


1976
J F M A M J J A S O N D
M1A
M1/M1B
M1+
M1 – shift adjusted
M2
M3
M4
M5
L
January 22, 1976
Annual benchmark and seasonal review.
Benchmarked to the June and September 1975 call reports.
(See FRB, February 1976).
May 20, 1976
Benchmark.
Benchmarked to the December 1975 call report.
(See H.6 release).
October 21, 1976
Benchmark.
Benchmarked to the March 1976 call report.
(See H.6 release).
Thursday Release
Immediate Release
Week ending Wednesday basis


1977
J F M A M J J A S O N D
M1A
M1/M1B
M1+
M1 – shift adjusted
M2
M3
M4
M5
L
February 17, 1977
Annual benchmark and seasonal review.
Benchmarked to the June 1976 call report.
(See H.6 release).
April 21, 1977
Benchmark.
Benchmarked to the September 1976 call report.
(See H.6 release).
June 23, 1977
Benchmark.
Benchmarked to the December 1976 call report.
(See H.6 release).
Thursday Release
Immediate Release
Week ending Wednesday basis

1978



February 10, 1978
Data from the Boston District estimated. Money stock measures for the week of February 1, 1978 subject to larger than normal revisions.

March 8, 1978
Mr. G. William Miller replaced Mr. Arthur F. Burns as Chairman of the Federal Reserve Board. Chairman Burns resigned on January 31, 1978.

March 23, 1978
Annual benchmark and seasonal review. Benchmarked to the December 1976 as well as March, June, and September 1977 call reports. (See H.6 release).

June 1, 1978
Money Market Time Deposits were authorized by Congress.

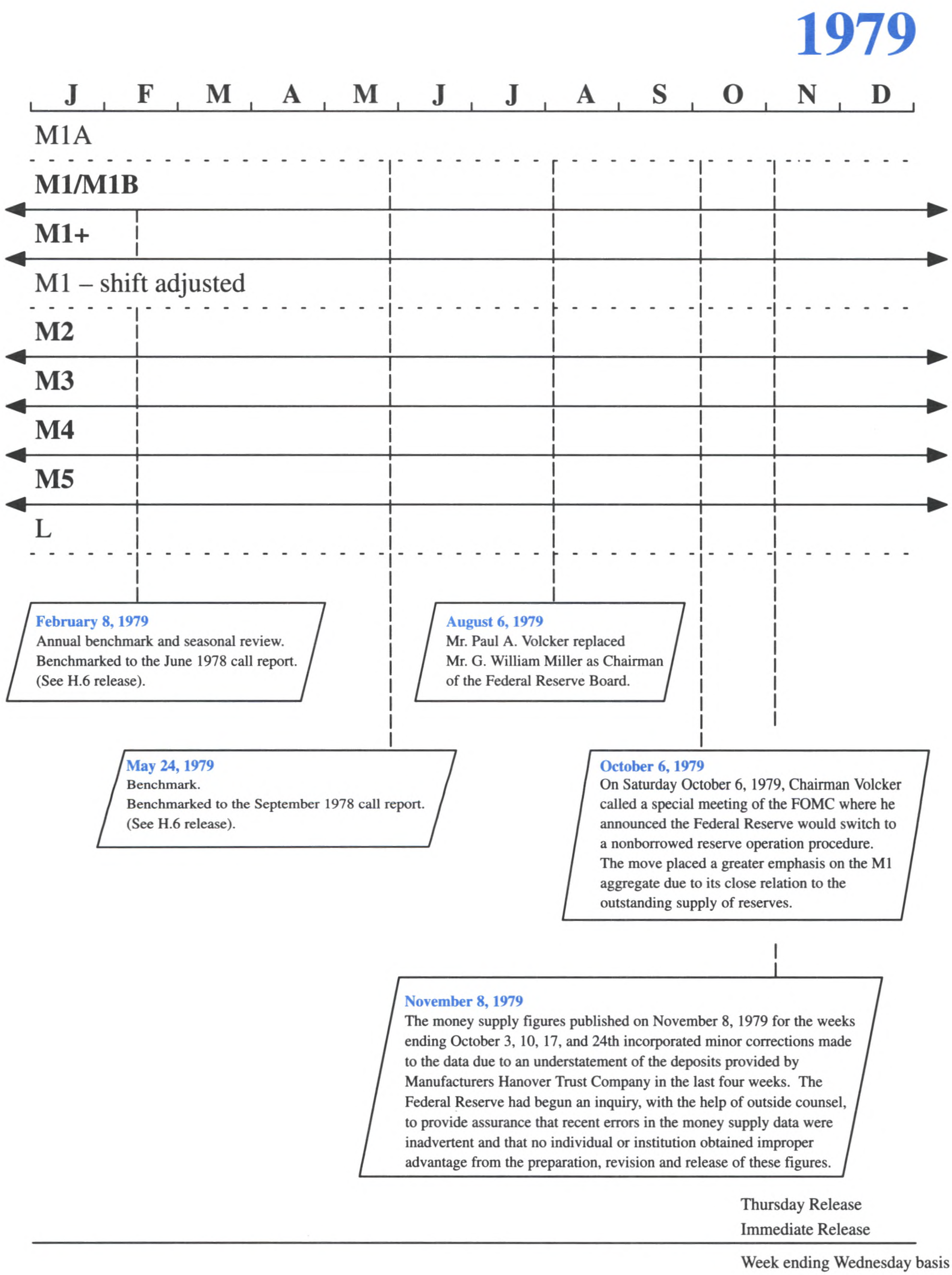
June 22, 1978
Benchmark.
Benchmarked to the December 1977 call report. (See H.6 release).

September 21, 1978
Annual benchmark and seasonal review. Benchmarked to the March 1978 call report. Corrected a recently discovered downward cash items bias over the period mid–1975 through September 1978. The bias was created by foreign related institutions transferring funds for their parent or subsidiaries. (See H.6 release).

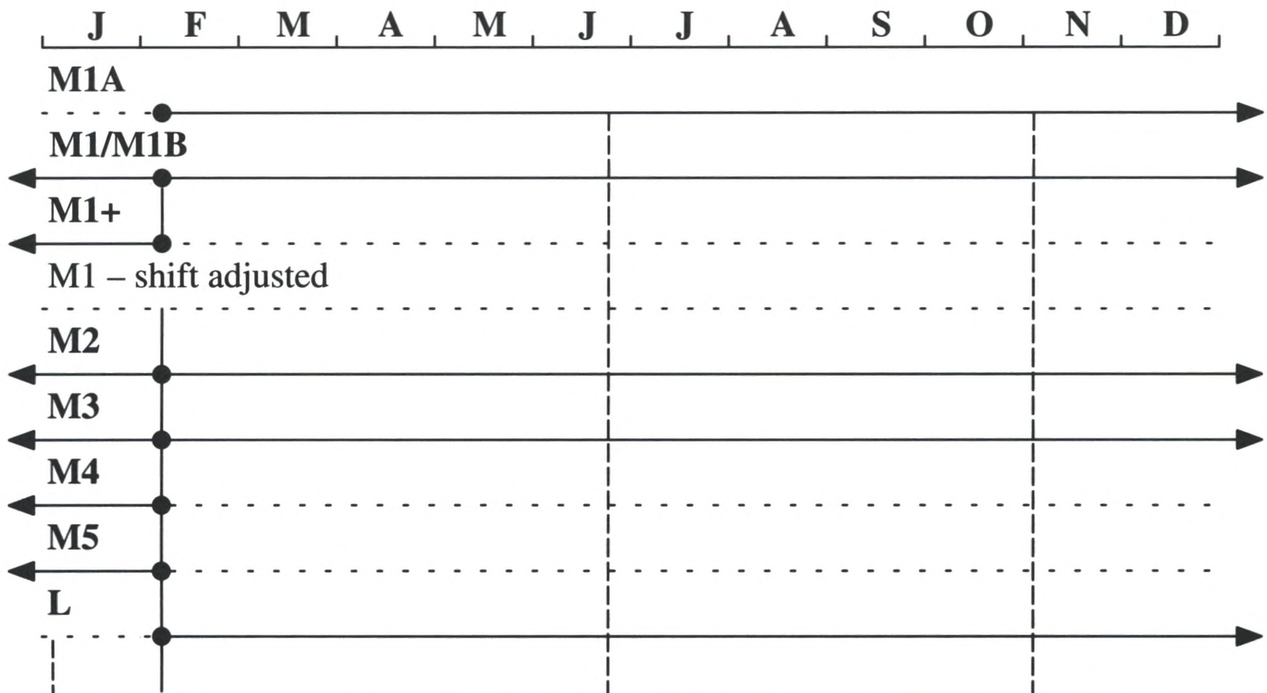
November 16, 1978
On November 16, 1978, the Federal Reserve published yet another money stock measure, M1+.
M1, M2, M3, M4 and M5 remained unchanged from the definitions outlined in 1975. M1+ was defined as the narrow money stock measure, M1, plus savings deposits at commercial banks, NOW accounts at banks and thrift institutions, credit union share drafts, and demand deposits at mutual savings banks.

Thursday Release
Immediate Release

Week ending Wednesday basis


1979
J F M A M J J A S O N D
M1A
M1/M1B
M1+
M1 – shift adjusted
M2
M3
M4
M5
L
February 8, 1979
Annual benchmark and seasonal review.
Benchmarked to the June 1978 call report.
(See H.6 release).
August 6, 1979
Mr. Paul A. Volcker replaced
Mr. G. William Miller as Chairman
of the Federal Reserve Board.
May 24, 1979
Benchmark.
Benchmarked to the September 1978 call report.
(See H.6 release).
October 6, 1979
On Saturday October 6, 1979, Chairman Volcker called a special meeting of the FOMC where he announced the Federal Reserve would switch to a nonborrowed reserve operation procedure. The move placed a greater emphasis on the M1 aggregate due to its close relation to the outstanding supply of reserves.
November 8, 1979
The money supply figures published on November 8, 1979 for the weeks ending October 3, 10, 17, and 24th incorporated minor corrections made to the data due to an understatement of the deposits provided by Manufacturers Hanover Trust Company in the last four weeks. The Federal Reserve had begun an inquiry, with the help of outside counsel, to provide assurance that recent errors in the money supply data were inadvertent and that no individual or institution obtained improper advantage from the preparation, revision and release of these figures.
Thursday Release
Immediate Release
Week ending Wednesday basis

1980



January 10, 1980
Benchmark.
Benchmarked to the December 1978 and March 1979 call reports.
(See H.6 release).

June 20, 1980
Benchmark.
Benchmarked to the June and September 1979 call reports.
(See H.6 release).

November 7, 1980
The money supply figures that would normally be published on November 14, 1980 may be delayed for a time in view of changes in the flows of data required by the Monetary Control Act of 1980.
The next H.6 release went out on November 18th.

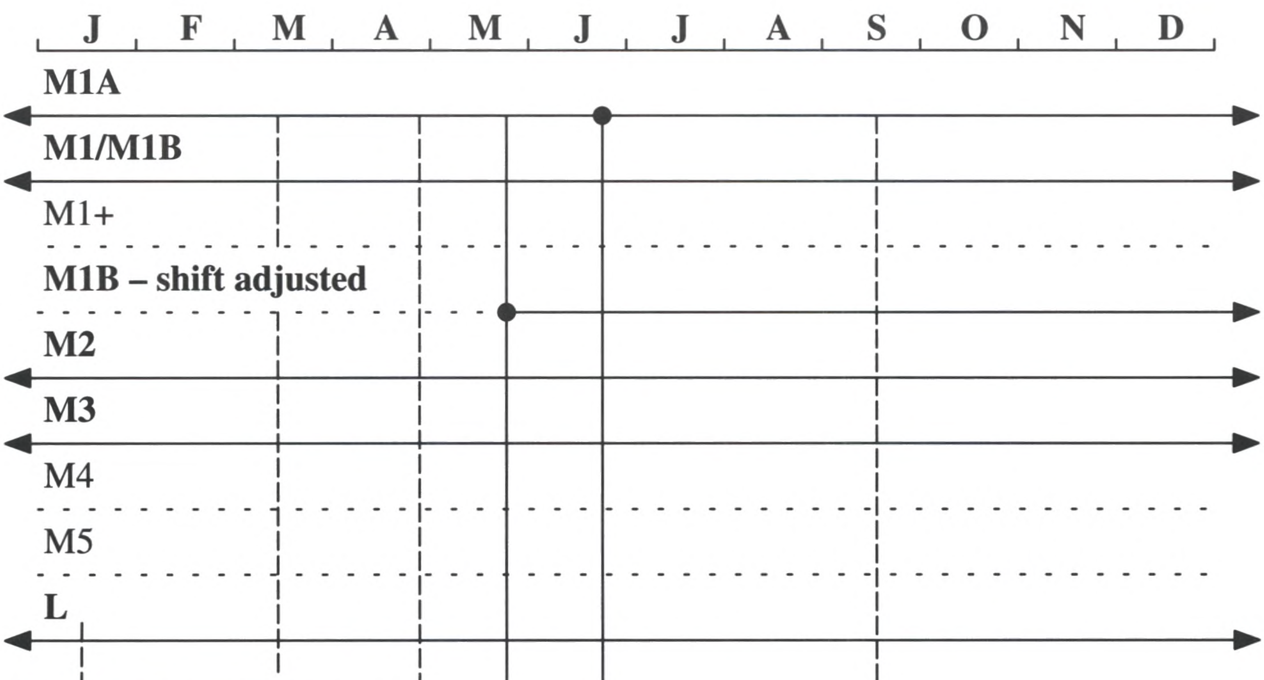
February 8, 1980
On February 8, 1980, the Federal Reserve radically reorganized how the monetary aggregates were defined.
M1 was renamed M1A without changing its definition.
M1B was defined to be M1A plus NOW and automatic transfer service (ATS) accounts at banks and thrift institutions, credit union share draft accounts and demand deposits at mutual savings banks.
M2 was redefined to be M1B plus overnight (and continuing contract) repurchase agreements (RP) that are issued by commercial banks to the non–bank public, overnight Eurodollars issued by Caribbean branches of member banks to U.S. non–bank customers, money market mutual fund shares, savings deposits and small time accounts (those issued in denominations less than $100,000) at commercial banks and thrift institutions. Note that M2 will differ from the sum of its components by a consolidation adjustment made to avoid double–counting the public's monetary assets, namely, the amount of demand deposits held by thrift institutions at commercial banks.
M3 was defined to be M2 plus large time deposits (those issued in denominations of $100,000 or more, net of the holdings of domestic banks, thrift institutions, the U.S. government, money market mutual funds, and foreign banks and official institutions), and term RPs at commercial banks and thrift institutions, net of term RPs held by money market mutual funds.
A new aggregate, L, was created and defined to be M3 plus the non–bank public's holdings of U.S. savings bonds, short–term Treasury securities, commercial paper and bankers acceptances (which excludes money market mutual fund holdings of these assets).
In addition, two addenda were included on the H.6 release, overnight RPs at commercial banks plus overnight Eurodollars and money market mutual fund shares.

February 15, 1980
Seasonal factors for the newly defined aggregates were released on the H.6.

(See *FRB*, February 1980).

Friday Release
Immediate Release
Week ending Wednesday basis

1981



January 16 and 23, 1981
The H.6 emphasized caution when interpreting the monetary aggregates because of the introduction of NOW accounts on a nationwide basis with heavy promotional efforts.

January 23, 1981
Benchmark.
Benchmarked to the December 1979 and March 1980 call reports.
This incorporated all the changes due to the implementation of the Monetary Control Act.
(See H.6 release).

May 22, 1981
Another monetary aggregate, called M1B–shift adjusted, was introduced. It was defined to be M1B less shifts to OCD from non–demand deposit sources.
All the definitions of the other monetary aggregates remained unchanged.

June 26, 1981
Benchmark.
Benchmarked to the September and December 1980 call reports.
The definition of the narrowest measure of the money stock, M1, was revised to include non–bank travelers checks.
All the definitions of the other monetary aggregates remained unchanged.

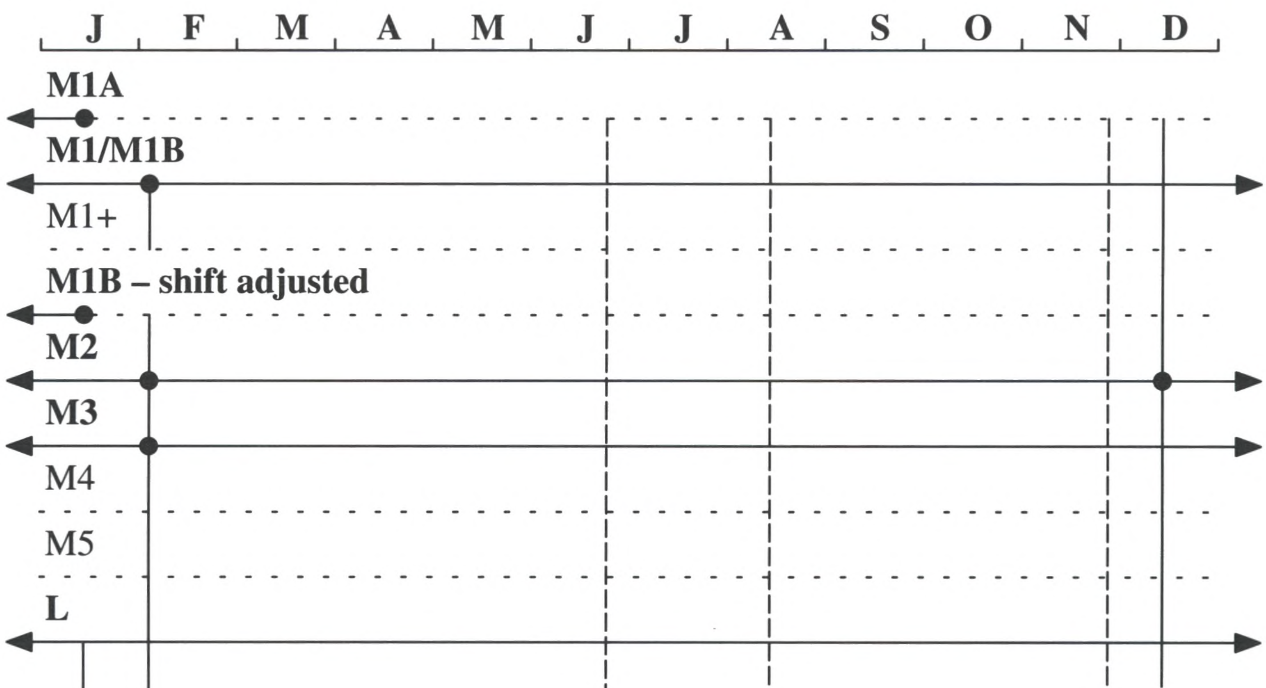
May 1, 1981
Annual seasonal review.
Adjustment of the monetary aggregates to include the effects of NOW accounts.
(See H.6 release).

March 13, 1981
The H.6 cautioned the interprepation of the aggregate measures due to the shifting of demand deposits and savings deposits into other checkable deposits (OCD) accounts. Estimates of the shifts obtained from various depository institution samples suggested that in January and February, 75 to 80% of the increase in excess of "trend" came from demand deposits and the other 20 to 25% came from savings deposits and other sources.
(See H.6 release).

September 18, 1981
The term RP component of M3 was revised and benchmarked to a survey of "retail RPs" conducted on August 31, 1981. The current methods of estimation did not pick up the increase which was attributed to recent active promotion.
(See H.6 release).

Friday Release
Immediate Release
Week ending Wednesday basis

1982



January 15, 1982
The H.6 was revised to only show 4 monetary aggregates, M1, M2, M3 and L. M1A and M1B–shift adjusted were dropped from the release. M1B was renamed M1 and the other aggregates remained unchanged.
(See H.6 release).

June 18, 1982
Revisions to the data reported on the H.6 were due to the inclusion of historical data on 3 general purpose/broker dealer (GP/BD) money market mutual funds that began reporting in May 1982, though their operations had begun earlier.

August 13, 1982
The Federal Reserve began publishing experimental seasonal factors once each month.

February 5, 1982
Annual benchmark and seasonal review.
Benchmarked to the March, June, and September 1981 call reports.
M1 analogous to the old M1B was redefined to exclude the estimated amount of vault cash held by thrift institutions to service their OCD liabilities in addition to the amount of thrift demand deposits already excluded from M1 for that reason. CIPC of thrift institutions was netted against the transactions deposits at the M1 level. Owing to unavailability of data, thrift CIPC previously had not been deducted.
M2 was redefined to include retail RPs (those issued in denominations of less than $100,000) as well as exclude institution–only money market mutual funds.
M3 had institution–only money market mutual fund shares added to it plus a consolidation component which is the amount of overnight RPs held by I/O money market mutual funds.
(See H.6 release).

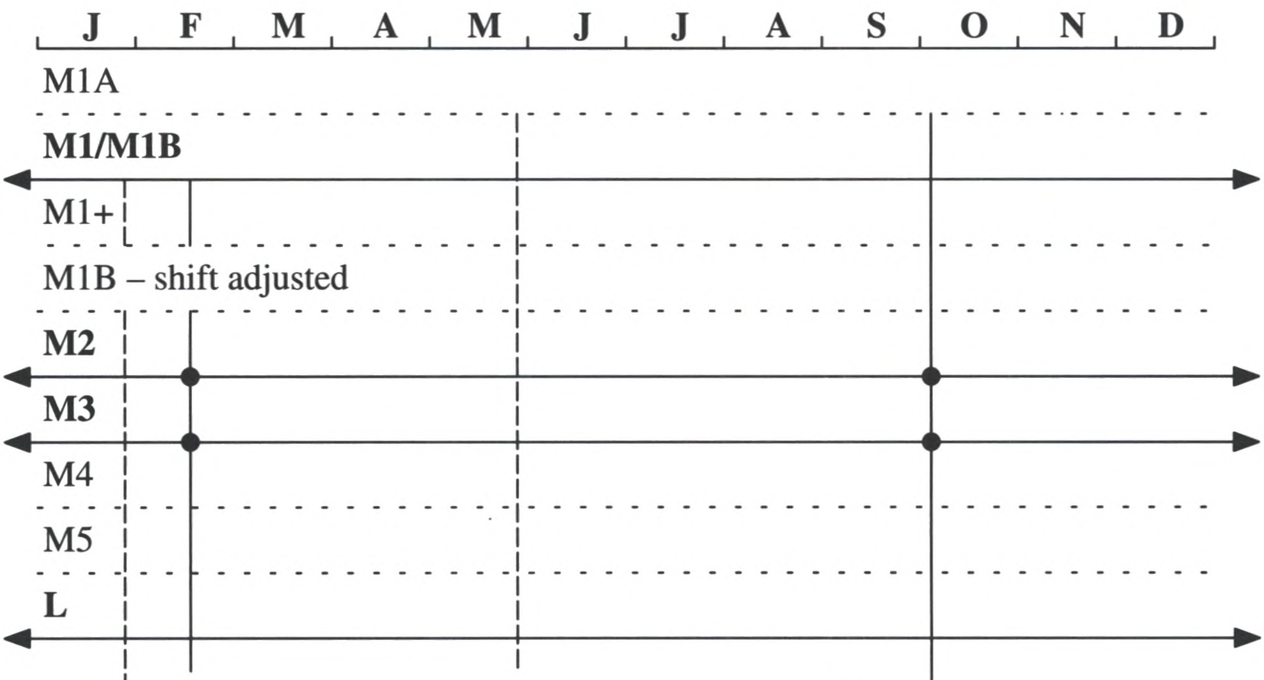
November 29, 1982
The H.6 was revised to exclude the addenda items from the first page and only showed the aggregates: M1, M2, M3, and L.

December 14, 1982
The Depository Institution Deregulation Committee (DIDC) revised Regulation Q to eliminate interest rate ceilings on money market deposit accounts (MMDA) with a required minimum balance of $2,500.
(See *FRB*, January 1983, Table 1.16).

Friday Release
@ 4:10 PM EDT
Week ending Wednesday basis (W.E.W.)

Friday Release
4:15 PM EDT
(W.E.W.)

1983



January 28, 1983
The Garn–St. Germain Act of 1982 had recently authorized money market deposit accounts. Beginning on January 28, 1983, MMDAs were reported separately as a component of the broader monetary aggregates. Due to the lack of historical data, they were reported on a not seasonally adjusted basis. Note that this did NOT revise the monetary aggregates because the deposits had previously been included in the savings component of M2.

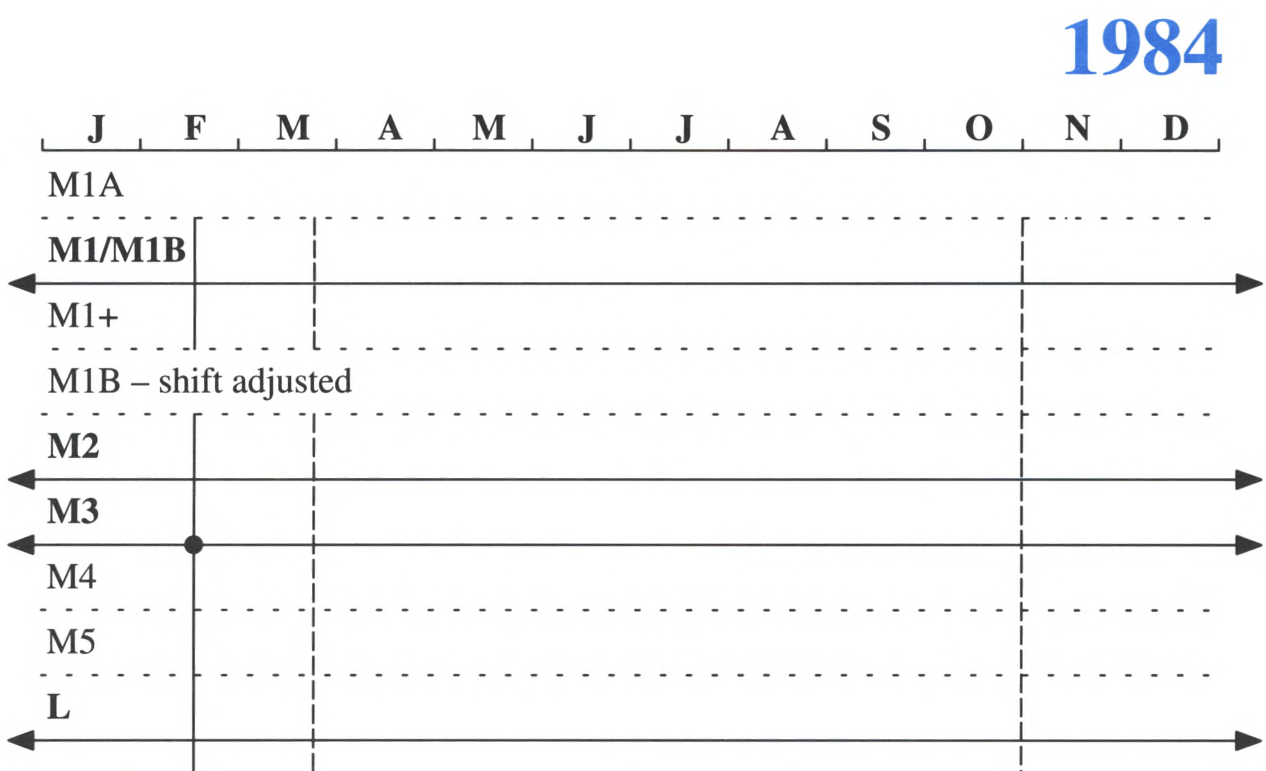
February 14, 1983
Annual benchmark and seasonal review.
Benchmarked to the December 1981 and March, June, and September 1982 call reports.
Two definitional changes have been implemented.
M2 was revised to include general purpose/broker dealer (GP/BD) tax–exempt money market mutual funds and exclude all IRA/Keogh balances at depository institutions and money market mutual funds.
M3 was revised to include institution–only (I/O) tax–exempt money market mutual funds.
(See H.6 release).

October 1, 1983
The DIDC moved to amend Regulation Q by eliminating interest rate ceilings on time deposits with maturities greater than 31 days and principal greater than $2,500.
(See FRB, November 1983, Table 1.16).

May 20th through June 10th 1983
Weekly data on savings deposits and small time deposits were not reported due to reporting difficulties associated with MMDAs. In addition, historical data were revised to reflect corrections of reporting errors beginning in December 1982.
(See H.6 release dated June 10, 1983).

Friday Release
@ 4:15 PM EDT

Week ending Wednesday basis



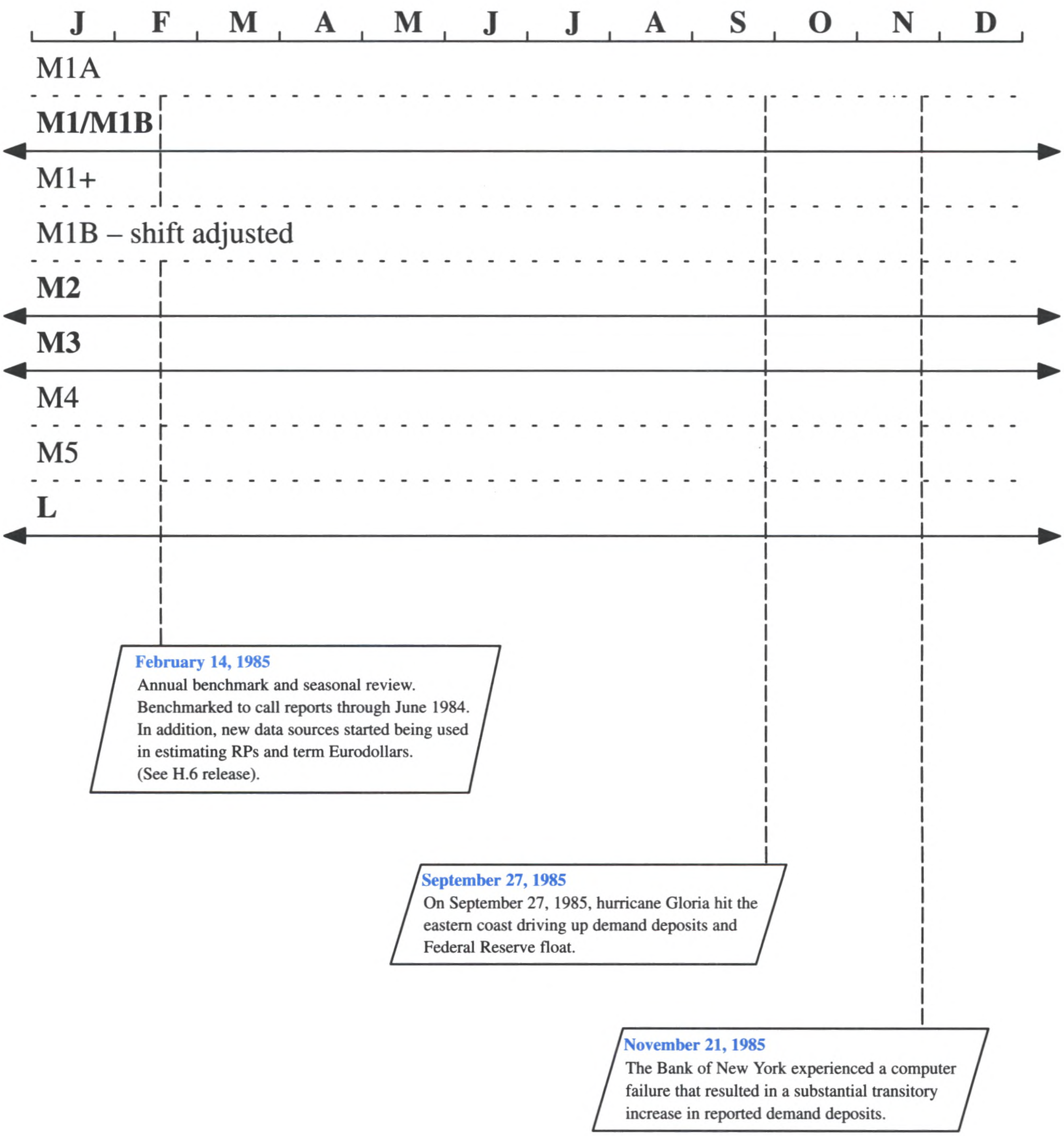
February 16, 1984
Annual benchmark and seasonal review.
Benchmarked to recent call reports.
The H.6 published on February 10, 1984 was the last one that presents deposits data on a week–ending Wednesday basis.
All data shown on the H.6 dated February 16, 1984, was shown on a week–ending Monday basis to correspond with the new reporting cycle under contemporaneous reserve requirements (CRR).
In addition, M3 was redefined to include term Eurodollars in Canada and the United Kingdom that are held by U.S. residents.
The rest of the aggregates remained unchanged definitionally.
(See H.6 release).

March 22, 1984
The H.6 began being released at 4:30 PM EDT on Thursdays.

November 1, 1984
Benchmark.
Benchmark due to revised data received in conjunction with annual shifts among weekly, quarterly and annual reporting panels. Similar benchmarks were not needed in later years because of improvements in the procedure used to handle the panel shifts at the Federal Reserve. In addition, institution–only money market mutual fund shares were revised back to November 1980 to reflect new data.

Friday Release @ 4:15 PM EDT	Thursday 4:15 PM	Thursday Release @ 4:30 PM EDT
W.E.W.	W.E.M.	Week ending Monday (W.E.M.)

1985



Thursday Release
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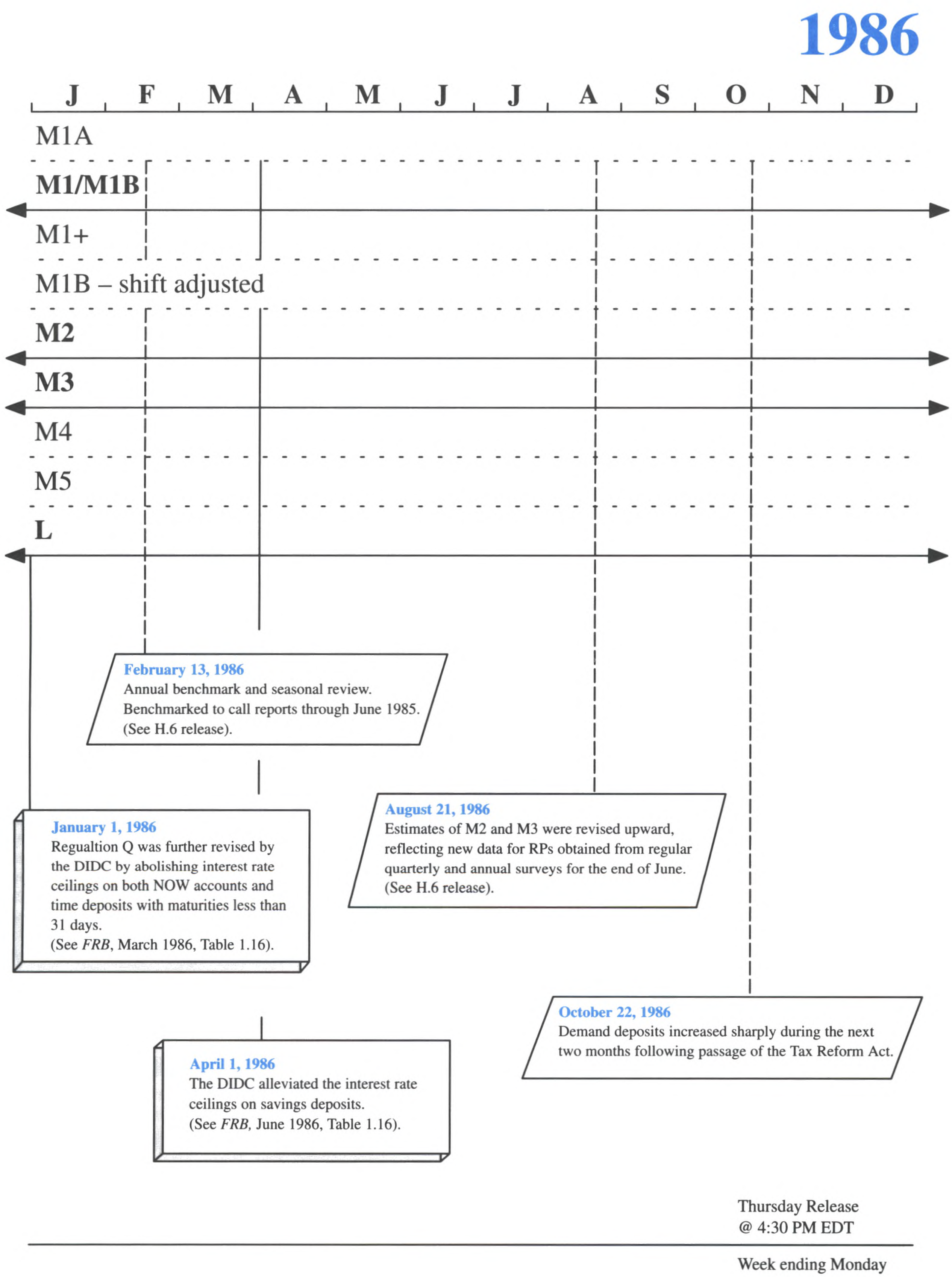
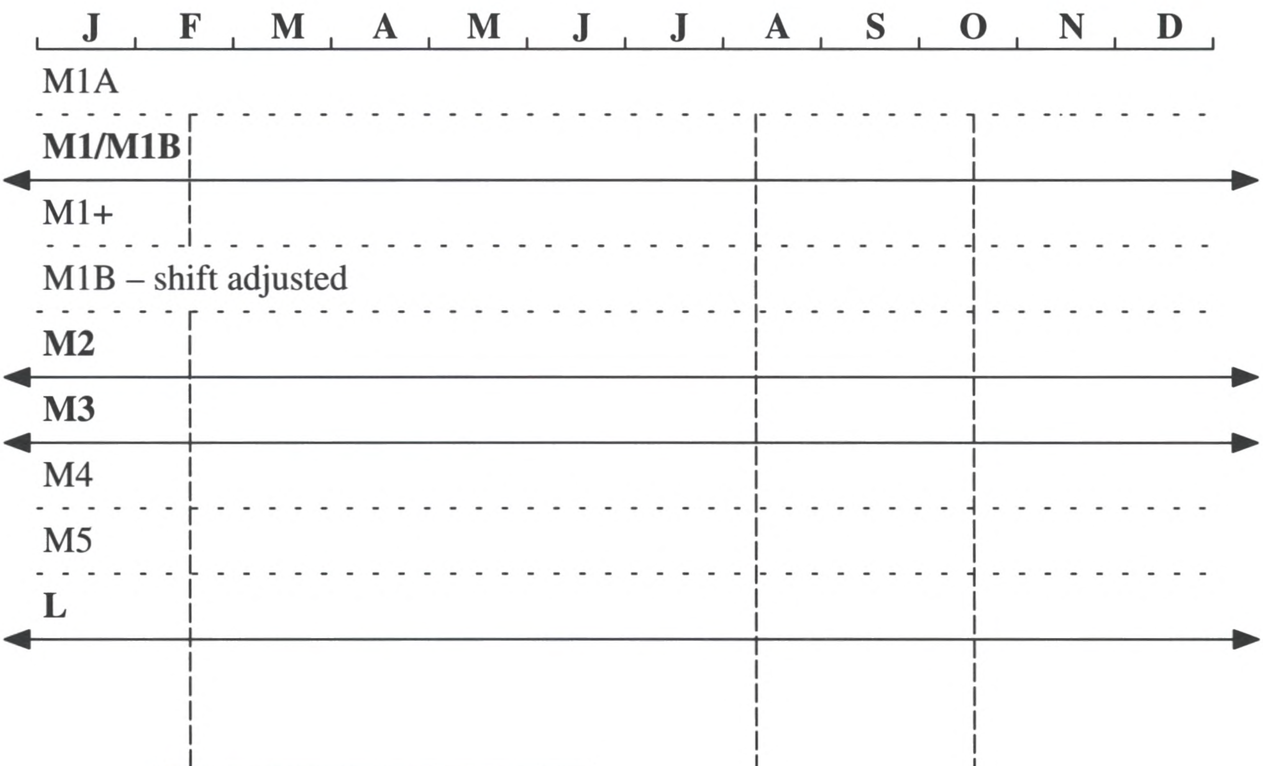
Week ending Monday


1986
J F M A M J J A S O N D
M1A
M1/M1B
M1+
M1B – shift adjusted
M2
M3
M4
M5
L
February 13, 1986
Annual benchmark and seasonal review. Benchmarked to call reports through June 1985. (See H.6 release).
January 1, 1986
Regualtion Q was further revised by the DIDC by abolishing interest rate ceilings on both NOW accounts and time deposits with maturities less than 31 days. (See FRB, March 1986, Table 1.16).
August 21, 1986
Estimates of M2 and M3 were revised upward, reflecting new data for RPs obtained from regular quarterly and annual surveys for the end of June. (See H.6 release).
April 1, 1986
The DIDC alleviated the interest rate ceilings on savings deposits. (See FRB, June 1986, Table 1.16).
October 22, 1986
Demand deposits increased sharply during the next two months following passage of the Tax Reform Act.
Thursday Release
@ 4:30 PM EDT
Week ending Monday

1987



February 12, 1987
Annual benchmark and seasonal review. Benchmarked to call reports through June 1986. (See H.6 release).

August 11, 1987
Mr. Alan Greenspan replaced Mr. Paul A. Volcker as Chairman of the Federal Reserve Board. (See *FRB*, September 1987).

October 19, 1987
The Dow Jones Industrial Average plummeted 500 points sending other major stock exchanges into a significant decline as well. The effect on the monetary aggregates was to boost liquid components due to the increased volume of transactions.

Thursday Release
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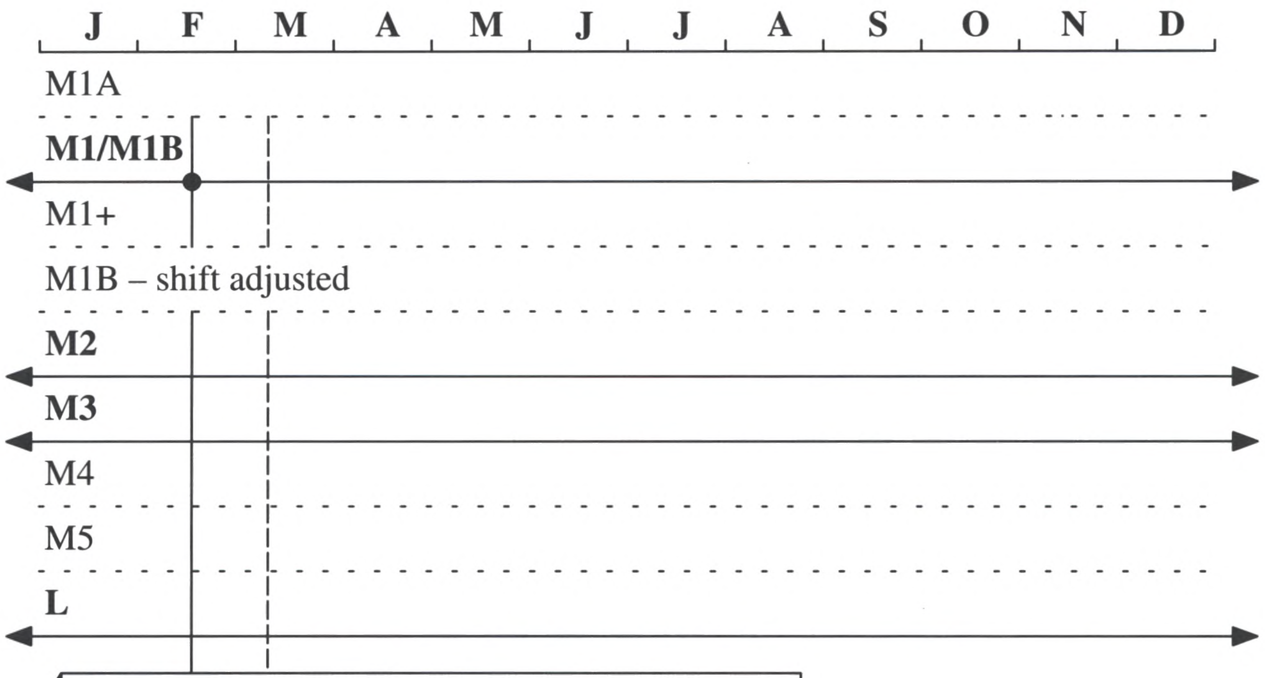
Week ending Monday

1988



February 18, 1988

Annual benchmark and seasonal review.

Benchmarked to call reports through June 1987.

Beginning on February 18, 1988, the H.6 included weekly estimates of M2 and M3 seasonally adjusted and seasonally unadjusted on the same publication schedule as M1.

M1 was redefined to make the treatment of thrift institutions identical with that of commercial banks in the construction of the monetary aggregates. Under the new definitions, all vault cash held by thrift institutions was excluded from the currency component of M1, and all demand deposits and OCDs held by thrifts were excluded from the demand deposit and OCD components, respectively. Previously, only a portion of the vault cash and transactions deposits held by thrifts were excluded at the M1 level—representing the estimated amount held to service their OCD liabilities—while the remainder was subtracted at the M2 level.

In addition to the redefinitions noted above, ATS accounts at credit unions—like those at commercial banks and all other thrift institutions—were now included in the OCD component of M1, rather than in the savings deposit component of M2.

The monetary aggregates M2 , M3 and L had no change in their definitions.

(See H.6 release).

March 10, 1988

Weekly seasonal factors for the nontransactions component of M2 beginning with the week of March 28, 1988 were revised to incorporate further analysis of certain holiday–related effects.

(See H.6 release).

Thursday Release
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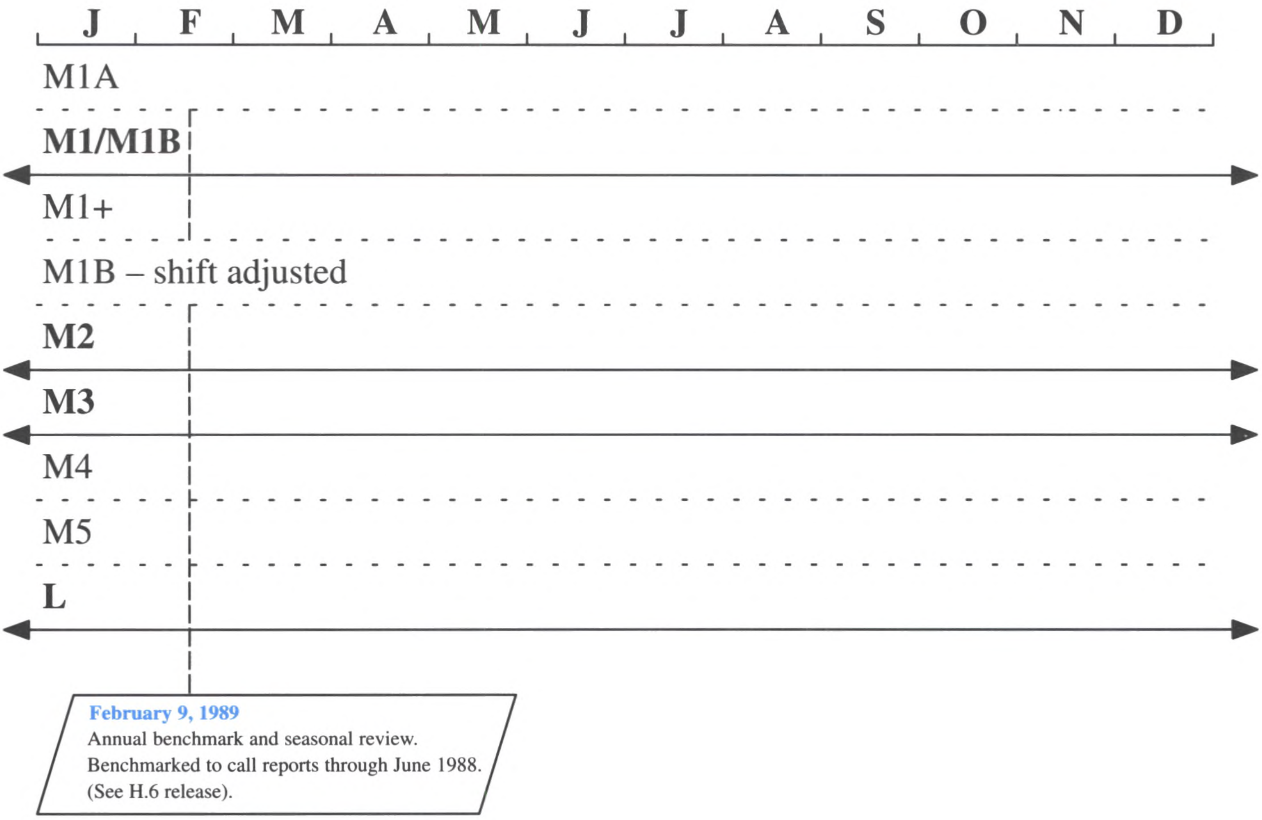
Week ending Monday

1989



Thursday Release
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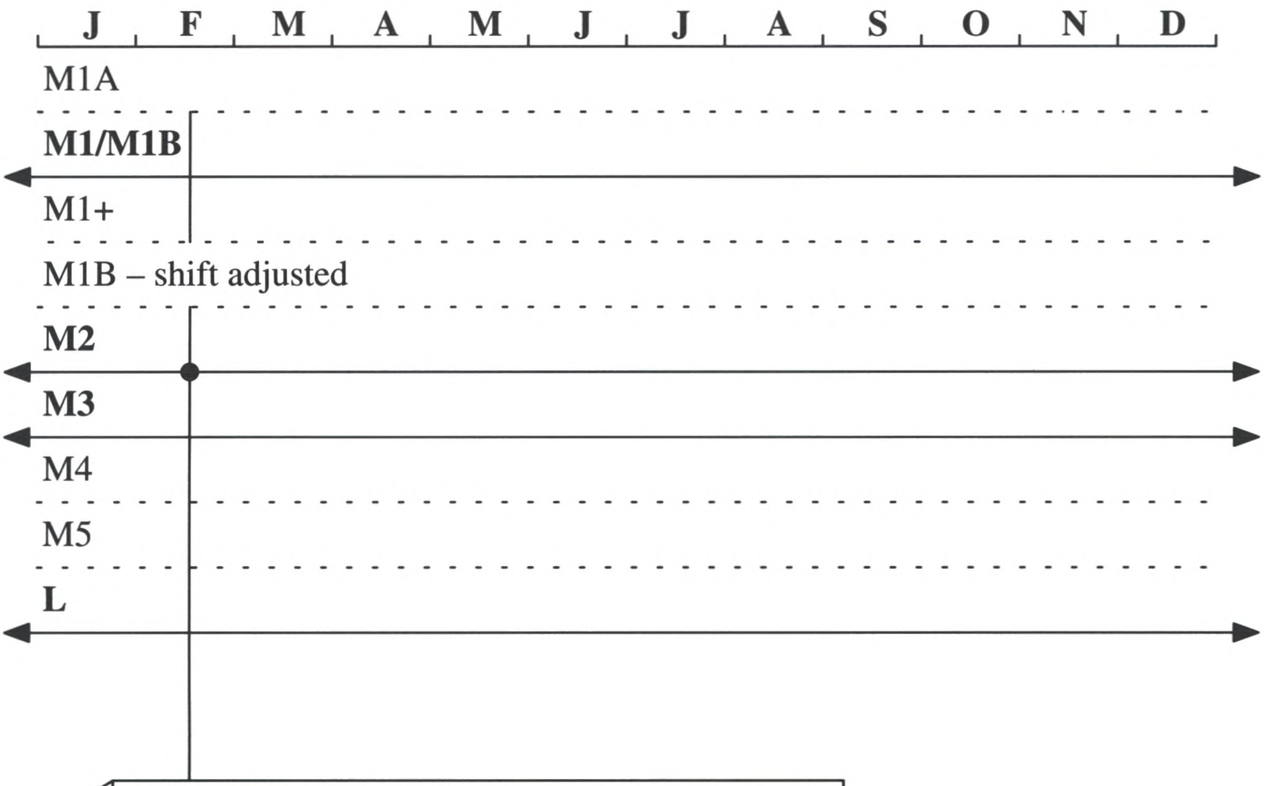
Week ending Monday

1990



February 15, 1990
Annual benchmark and seasonal review.
Benchmarked to call reports through June 1989.
M2 was revised to include overnight RPs issued by thrift institutions, formerly included with term RPs in the non–M2 component of M3.
This redefinition had no effect on the levels of M1 , M3 or L.
(See H.6 release).

Thursday Release
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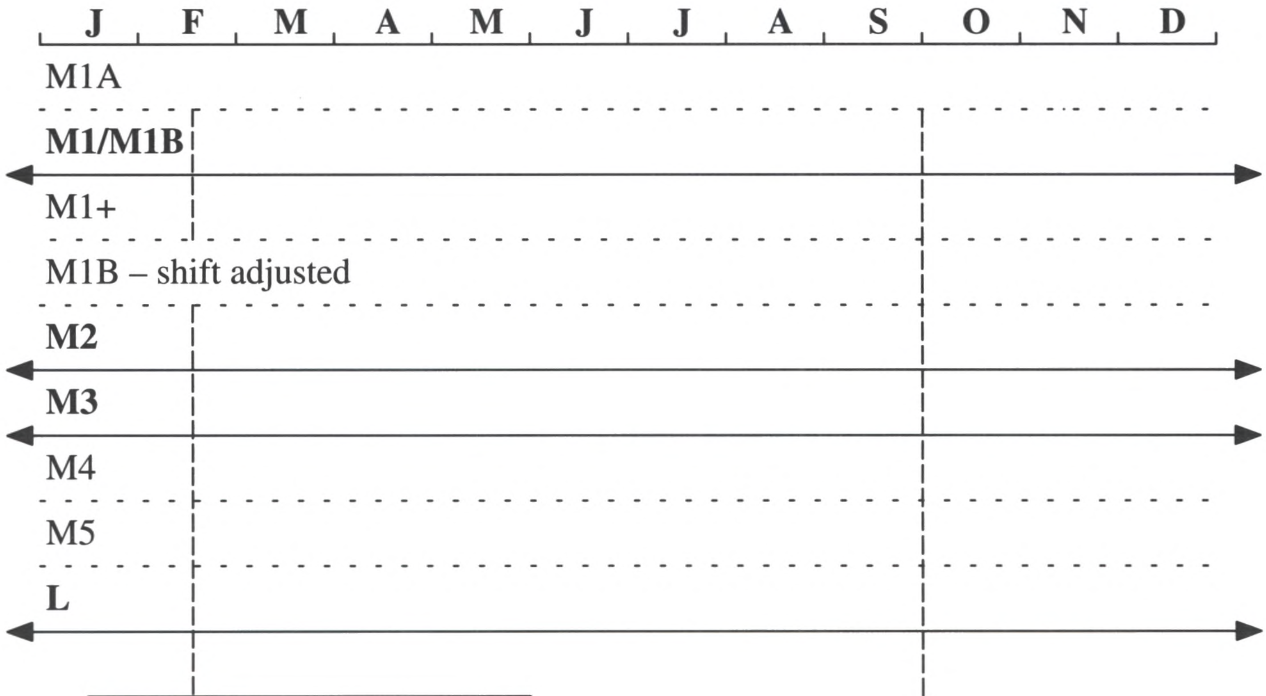
Week ending Monday

1991



February 7, 1991
Annual benchmark and seasonal review. Benchmarked to call reports through June 1990. (See H.6 release).

October 3, 1991
There was a change in the format of the H.6 release. The change is necessary because, on September 17, 1991, depository institutions began reporting to the Federal Reserve only their combined savings deposits and MMDAs, rather than reporting them separately, owing to changes in the deposits reports (FR2900). In order to calculate consistent seasonally adjusted data, the new seasonal factors are equal to the inverse of the weighted average of the inverses of the seasonal factors for savings deposits and MMDAs, where the weights are defined as the ratio of each component to the sum of the components during the month of August. In other words, the total of savings and MMDAs was split into its two components, 'savings' and 'MMDAs' for both commercial banks and thrifts. Then its old seasonal factors (published in February 1991) continued to be used, namely, the seasonal factors for bank savings, bank MMDAs, thrift savings, and thrift MMDAs. (See H.6 release).

Thursday Release
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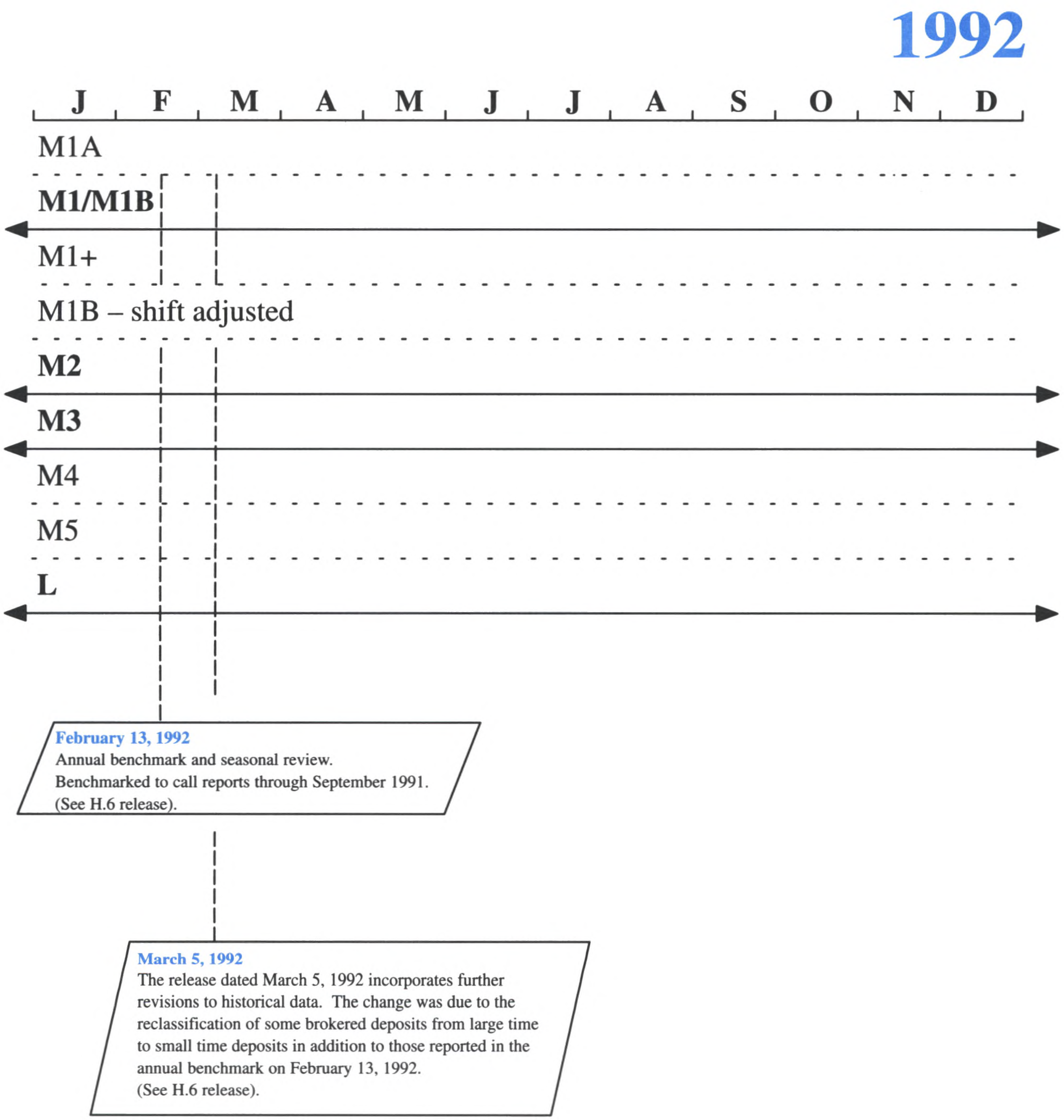
Week ending Monday



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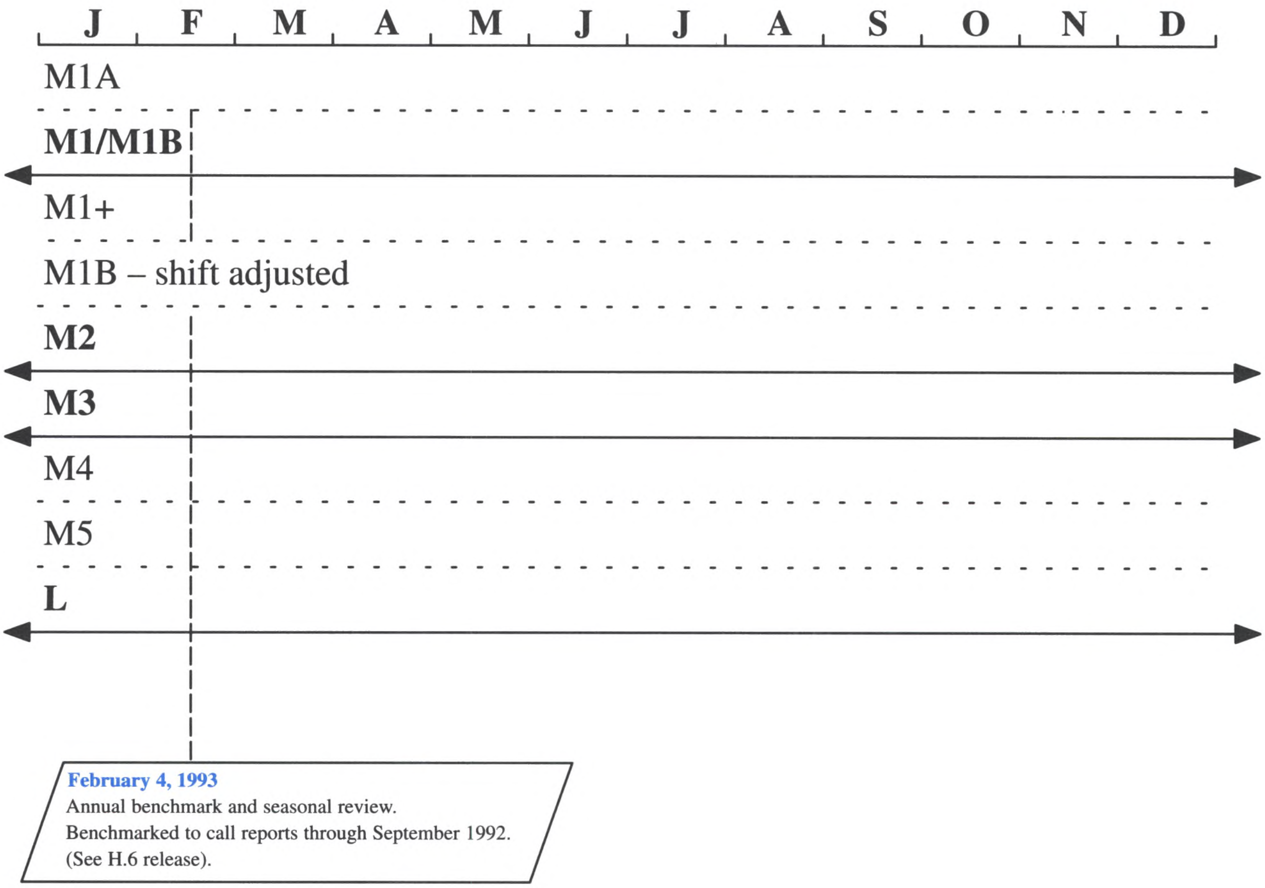
Week ending Monday

1993



Thursday Release
@ 4:30 PM EDT

Week ending Monday

FEDERAL RESERVE BANK OF ST. LOUIS

Charles W. Calomiris

Charles W. Calomiris is an associate professor at the University of Illinois, Urbana-Champaign, and is a co-director for the university's Office for Banking Research. He is also a faculty research fellow, National Bureau of Economic Research, and a visiting scholar at the Federal Reserve Bank of St. Louis.

Commentary

IN THEIR PAPER, Anderson and Kavajecz provide the rare public service of a careful examination of the construction of monetary data. The paper is important because the data on monetary aggregates are central to academic and policy research in macroeconomics. I expect that by the metric of the percentage of monetary economists who will have this paper in their file cabinets 10 years from now, this will be one of the most successful works in monetary economics. Data are forever. Like the Federal Reserve Board's *Banking and Monetary Statistics* and *All Bank Statistics*, Friedman and Schwartz's *Monetary Statistics of the United States*, Capie and Wood's *Monetary Statistics of the United Kingdom*, and Eisner's *How Real is the Federal Deficit?*, Anderson and Kavajecz pose and answer descriptive questions of lasting interest to macroeconomists. Judging from the paucity of this kind of work, its importance seems to be underestimated.

I found little to quibble with in the way the authors organized their description. In my discussion I will focus on the question of why researchers doing empirical monetary economics should care about the details of how monetary aggregates are measured and how those measurements have changed over time.

Five sets of issues seem central in motivating the potential usefulness of this exercise. First, and most obviously, any attempt to construct monetary aggregates for long stretches of time must do its best to ensure comparability of measures. This means coming to grips not only with financial innovations that affect the range of definitions of money, but also with changes in sampling procedures, seasonal adjustment, and other choices made by the data constructors.

Second, the Fed's procedure of revising data retrospectively to maintain consistent definitions and seasonal adjustment factors—which sometimes have produced large retrospective revisions of the aggregates—makes it difficult to compare empirical research of different vintages. For example, two studies of M1 money demand over the same period, performed at different dates, may differ not only because of specification, but because of the vintage of data used in each. It would be worthwhile to ask how much of the differences across studies of money demand can be attributed to retrospective revision of data, as opposed to the incorporation of additional periods of data, or differences in specification.

Third, there should be an objective outside evaluation of the Federal Reserve Board's choices of definitions of money and methods of seasonal and benchmark adjustment. Prior to this study, this was not feasible because relatively little was known about the Fed's procedures. Anderson and Kavajecz suggest that the Fed's decisions regarding what to include in the monetary aggregates are often influenced by whether adding a new component helps to stabilize the relationship between money and economic activity. While this procedure may make sense, in general, given the Fed's desire to use monetary aggregates as targets, it would be interesting to describe clearly how the Fed decides (and how it should decide) that the improvement in stability will persist (that is, it reflects a lasting behavioral change rather than a temporary statistical coincidence). How long should the Fed wait before incorporating new (apparently stabilizing) elements of money into its definitions of aggregates? Would an increased emphasis on Divisia indices be warranted in light of the difficulties posed by having to make an all-or-nothing decision about whether to include financial assets in one or more of the aggregates? Regarding seasonal adjustment, it would be interesting to consider how the Fed should determine when a change in seasonal factors has occurred—and how far back retrospective changes in seasonality should be made. What is the optimal choice of the period over which deterministic seasonals should be estimated? How much less relevant is distant information for estimating seasonal compared to recent information? Anderson and Kavajecz have provided researchers interested in these questions with a wealth of detail that will allow them to construct counterfactual rules for defining monetary aggregates, and to compare these with those adopted by the Fed.

Fourth, if the Fed attempts to keep monetary aggregates "on track" relative to economic activity (by altering definitions and adjustment factors), then this makes the reported aggregates unsuitable for performing hypothesis tests about the stability of money demand. Researchers interested in whether money demand is stable, therefore, should perform sensitivity analysis to examine whether reasonable counterfactual definitions of the aggregates lead to different conclusions about the stability of money demand.

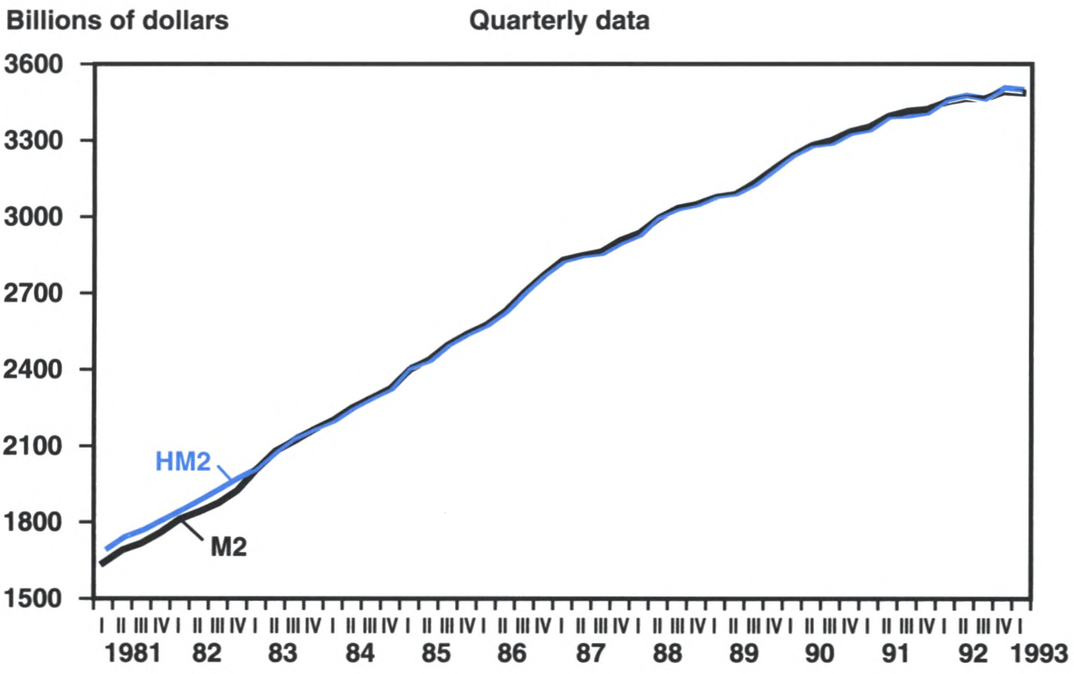
Finally, there is a problem I will label the "expectations error effect." The essence of this problem is that (unforecastable) errors in measurement, which affect expectations of agents in "real time," may weaken the apparent connection between money and output using ex post (corrected) monetary data. Assume for the sake of argument (unrealistically) that the current retrospective data on the monetary aggregates are "correct." That is, assume that all definitions, seasonal adjustments and revisions that have been made so far are perfectly accurate, and that no further revisions will be made in the series. Furthermore, assume that we can agree upon an econometric procedure for measuring the closeness of the relationship between money and output (using, for example, a "structural VAR" model of money, output and other variables).

Even under these ideal circumstances, the measured relationship between "true" money (measured ex post) and economic activity will be biased toward zero if money is initially measured with error. The reason is that "true" money, as well as errors in measuring aggregate money, will elicit responses that affect economic activity and money subsequently. Money and output are linked through "fundamental" structural links and through "expectational" effects. For example, an increase in an individual's holdings of money may lead him to rebalance his portfolio (putting pressure on interest rates to fall and output to rise in the standard IS-LM model). Second, estimates of monetary aggregates (which include initial measurement error) will also be taken into account by the public in economic activity if aggregates are used as economic indicators.

In the absence of measurement error, the individual agent can observe without error not only his own money, but also the aggregate. In the presence of measurement error, the aggregate is observed with error, and these errors will elicit real responses from agents. So, both announced and true money will be linked to output. Neither will be as strongly linked to output as true money in the absence of measurement error, and empirical analysis using ex post data (after removing errors) may underestimate the link between money and output.

Thus, temporary inaccuracies in monetary aggregate estimation (which elicit real responses) might explain weak correlations between money and output using ex post (accurate) data. How can one come to grips with this problem empirically to decide whether bias arising from "expectations error effects" is important for conclusions about the role of money in the economy? One simple first step is to compare various measures of monetary aggregates (and monetary growth rates) for a given period reported at different dates. If the differences among these measures are small, then the problem of potential bias is of little practical importance. If the differences

Figure 1
M2 Against HM2



are large, then one would have to take on the much harder job of measuring the extent of the bias by gauging the reaction of the public to measurement errors.

As Anderson and Kavajecz point out, there are several types of potential error, and each involves a different correction horizon. First-published numbers (which appear one or two weeks after the fact) are updated within a month or so because of the arrival of new data. They are changed (roughly) annually to adjust for changes in benchmarks and seasonals, and change with new definitions of the aggregates as well.

As an illustrative exercise, I chose the easiest case—M2 from January 1981 to January 1993. I chose this period because, as Anderson and Kavajecz show, there was no important change in the definition of M2 during this period, so that one can focus on the role of revisions from new data, benchmark changes, and changes in seasonal factors as sources of error. I constructed measures for this period using three different timings of measurement. I used the first date of publication of monthly M2 in the *H.6* statistical release as my definition of the initial measure of M2. This was released roughly two weeks after the end of the month. My second date of measurement is the M2 figure reported in the *Federal Reserve Bulletin*, which appears with a two-month lag. My third measure is the retrospective series as of January 1993.[1]

Using seasonally adjusted data from these sources for January, April, July and October, I constructed measures of the level of M2 and of

[1]Table 3 in Anderson and Kavajecz decomposes revisions in money into three different adjustments and expresses them in absolute terms. This is interesting for some purposes, but not for my purpose. I am interested in whether errors coming from all sources are potentially large relative to the actual number.

Figure 2
DM2 Against DHM2

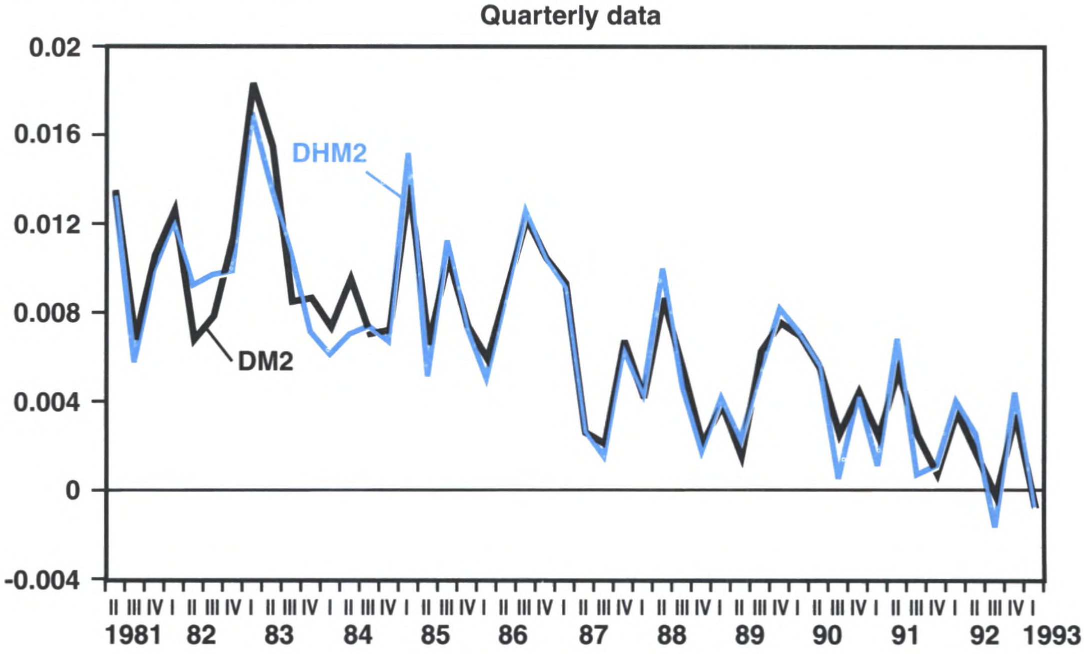
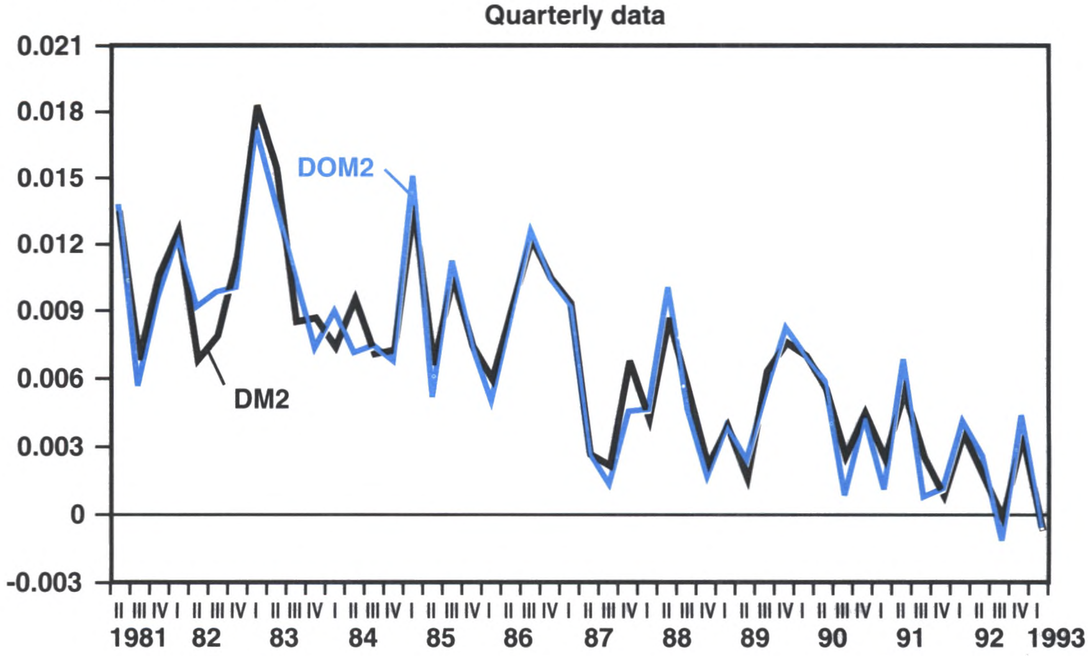


Figure 3
DM2 Against DOM2



that quarter's growth in M2 measured *at the time* the M2 number was reported. For example, M2 growth for the first quarter of 1982 according to the *H.6* release is the log difference between the first *H.6* number for M2 in April and the January 1982 number reported in that same release. Figures 1-3 compare these definitions of money and money growth using these three measurement horizons. The level and growth data from the 1993 series are labeled M2 and DM2; the data from *H.6* are labeled HM2 and DHM2; and the data from the *Bulletin* are labeled OM2 and DOM2.

These figures indicate that revision of M2 has been trivial in the 1980s, and so I conclude that for these series over this period, "expectations error effects" were not important. To the extent revisions did matter, long-term retrospective changes (the difference between M2 and O2, or DM2 and DOM2) are more important than those occurring within two months of initial publication.

One conclusion to draw from these findings is that, if there has been a breakdown in the relationship between M2 and output during the past decade, it cannot be attributed to temporary mismeasurement of money. Whether similar conclusions would be reached for M1 in the 1980s, or for these and other aggregates during other periods, remains an open question. As Anderson and Kavajecz note, Depository Institution Deregulation and Monetary Control Act (DIDMCA) improved the accuracy of monetary statistics in the 1980s, and M2 tends to be a smoother series than M1. Thus, my results may understate the importance of measurement error for other aggregates and earlier periods.

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K. Alec Chrystal and Ronald MacDonald

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Empirical Evidence on the Recent Behavior and Usefulness of Simple-Sum and Weighted Measures of the Money Stock

"We must have a good definition of Money, For if we do not, then what have we got, But a Quantity Theory of no-one-knows-what..."

Boulding (1969, p. 555)

THE FEDERAL RESERVE BANK of St. Louis has been, for the last three decades or so, at the center of an approach to macroeconomic policy which became universally known as "Monetarism." Indeed, the very term entered the public domain through an article in the Federal Reserve Bank of St. Louis' *Review* by Karl Brunner in 1968. The central tenet of monetarism was that there is a stable demand function for something called "money." Policy advice came down to recommending that the monetary authorities should deliver a steady rate of the growth of money within some target range.

The 1970s were a good time for monetarists. Velocity in the United States appeared to be on a stable trend, and the adoption of floating exchange rates generated a need for independent measures of monetary stance in most of the industrial countries. Monetary targeting was widely adopted and monetarism became a worldwide credo. Since the end of the 1970s, however, life has been much harder for monetarists. The stability of empirical monetary relationships became much more difficult to maintain, and government after government has given up even the notional attempt to target monetary aggregates. The allegedly monetarist government of Margaret Thatcher abandoned monetary targets in the United Kingdom in 1985. The Chairman of the Federal Reserve Board has recently announced that the Fed has ceased to monitor M2 and, instead, will be using the real interest rate as an indicator of monetary stance. Only the Bundesbank appears to be retaining any faith in the significance of monetary aggregates, though they have been widely criticized for so doing. (Norbert Walter, the chief economist of Deutsche Bank, has, for example, been quoted as saying that "...M3, the broad money supply indicator targeted by the central bank, was obviously distorted and devalued as an indicator." *Financial Times*, August 10, 1993, p. 2).

The standard explanation for why previously stable monetary relationships have broken down is financial innovation. In particular, liberalization and competition in banking have generated shifts in demand between components of money which have undermined earlier empirical regularities. Interest payments on transaction deposits have made it more difficult to distinguish money held for transaction from money held for savings.

Robert Rasche (1993) in his paper to the St. Louis Fed conference 12 months ago identified the beginning of the 1980s as a time of a critical regime change. This structural change, he claimed, had destroyed the validity of the traditional St. Louis reduced-form methodology as a means for explaining and forecasting the course of GNP. Policy makers around the world have clearly also been convinced that monetary aggregates provide little useful information to guide macro policy.

Presumably, nobody would argue that no guide to monetary policy was necessary. However, the advocates of a simplistic policy based upon any traditional measure of money as the sole guide are disappearing rapidly.

At the theoretical level, the significance of exogenous monetary shocks as a cause of business cycles has been under threat from the so-called Real Business Cycle school. For them, monetary disturbances are not the trigger to cycles but, rather, are an endogenous response to shocks emanating in the real economy. While this approach does not necessarily eliminate the validity of countercyclical monetary policy, it certainly reduces the significance of the traditional monetarist line that monetary shocks are the primary trigger to the cycle. Several recent empirical studies have apparently produced evidence to support the contention that money does not have any explanatory power—at least for real economic activity. (De Long and Summers, 1988; Friedman and Kuttner, 1992, 1993.)

The consensus view emerging from all of this appears to be that trying to target and control money is no longer a very sensible thing for policy makers to do. Monetary policy is now mainly about setting short-term interest rates, despite all the well-known difficulties that choosing the "correct" interest rate entails (Friedman, 1959).

This paper follows an alternative line of reasoning, for which there is an overwhelming theoretical case. There has been a major measurement error in virtually all of the previous literature on money. Instability in empirical relationships has been primarily due to the fact that simple-sum measures of money are not admissible aggregates on index-theoretic grounds. This error has been especially important in a period when characteristics of components which are added together have been changing.

We do not claim that correction of this measurement error salvages entirely the role of money as a macroeconomic indicator (though such may still be the case). Rather, our primary focus is to see whether acceptable indexes of money outperform traditional money measures in conventional tests. As is often the case in applied studies, the evidence turns out to be mixed but leaning in favor of the superiority of weighted over simple-sum aggregates.

Before presenting our own empirical evidence, we shall first review briefly the evolution of the concept of money and then the case for an appropriately constructed index.

What Is Money?

The definition of money has not been static over time. The first identifiable measure of money was undoubtedly the stock of the physical commodity which served as currency—typically precious metal. At some point, certainly by the 18th century in England, it was clear that bank notes had become a major element of the money stock so that a monetarist at that time would have had to extend the definition of money to include notes plus specie in the hands of the public. By the 19th century, financial innovation had moved things a stage further and the relevant concept of money had expanded yet again to include bank deposits, which could be used on demand and could be transferred by writing a check.

In recent times, the issue has been: Which of the other highly liquid assets held by the public should be included? The Radcliffe view in the United Kingdom and the view of Gurley and Shaw in the United States was that the boundary between money and other liquid assets was impossible to draw because so many close substitutes were available. This contention was countered successfully for a while by the evidence that elasticities of substitution were relatively small (Chetty 1969) and also by the evidence that predictions of monetarist approaches were fairly robust to minor definitional changes. In other words, the general message of the evidence was not so different if one used M1 or M2, or even M3.

Such a defense would be much harder to maintain today than it was 15 years ago. The introduction of interest payments on checking accounts in the United States led to a major reversal of the velocity trend—at least for M1 in about 1980. In the United Kingdom, abolition of quantitative ceilings on bank intermediation, also in 1980, led to a period of rapidly rising broad money coinciding with very slow narrow money growth. The innovations which followed were clearly associated with big movements of deposits from non-interest bearing to interest-bearing accounts. In such circumstance, neither narrow nor broad money proved to be reliable indicators—at least in the short term.

It would be a mistake to believe that the composition changes of the 1980s were a new phenomenon. In Volume I of *A Treatise on Money*, Keynes argued that an unchanged quantity of money could conceal important changes in circulation as holders transferred money between cash and savings deposits, and between income and business accounts. In Volume II, he reported the statistical finding that the proportion of deposit (savings) accounts to total accounts had risen in Britain from 38 percent to 46 percent between 1920 and 1926. According to Keynes, "... The continual transference from current to deposit accounts ... [acted as] a concealed measure of deflation..." (Keynes, 1930b, p. 10) sufficient to explain a drop in the price level of 20 percent over the period.

There is nothing remarkable about the fact that these composition changes have been noticed before. What is remarkable is that so many economists were happy to ignore them for so long in the post-World War II period. Partly, this was because the regulatory regime in most countries (interest ceilings and/or quantitative controls on intermediation) limited for some time the significance of the interface between checking and savings accounts, as well as the significance of nonbank competitors.

Money Measurement

A substantial amount of literature discusses the concept of money and its measurement (see Fisher, 1989, Chapter 1, for a survey). At the risk of oversimplifying, it is sufficient for present purposes to note that the traditional reason for regarding money as critically different from other assets is that it has a direct role in transactions and, hence, has a direct role in the trading activity of a market economy. According to the Quantity Theory, the money stock will determine the general level of prices (at least in the long term) and, according to monetarists, it will influence real activity in the short run.

For this reason, empirical measures of the money stock have tried to identify as components of money those instruments which can be used directly in transactions. The problem of our time is that a whole range of types of deposits which can be spent, more or less, directly also yield an interest rate and could, thus, be chosen as a form of savings as well.

From a micro-demand perspective, it is hard to justify adding together assets which have different and varying yields (Barnett, Fisher and Serletis, 1992). It has long been known that only things that are perfect substitutes can be combined as one commodity. There is ample evidence that the assets which are commonly combined in money measures are not in fact perfect substitutes.

From a micro-foundations perspective this leaves only two alternatives. The first is to restrict attention to a very narrow definition of money, which only needed non-interest bearing components. The alternative is to construct an index number of "monetary services" which could, in principle, capture the transactions services yielded by a wide range of financial assets in a superlative way (Diewert 1976, 1978). Two potential index numbers are the Divisia index proposed by Barnett (1980) and the Currency Equivalent (CE) index proposed by Rotemberg (1991) at the St. Louis conference in 1989.

The attraction of both of these monetary services indicators is that they internalize the substitution effects between components of a potential aggregate and, thus, solve the problem of composition changes which was discussed above. They do not in themselves guarantee the weak separability of any chosen aggregate, but they do approximate optimal aggregator functions for those collections of aggregates which have been found "admissible" on separability grounds (Belongia and Chalfant, 1989).

The theoretical case for weighted monetary aggregates is overwhelming—at least to anyone with a training in microeconomics and/or index number theory. The only objection could be on the grounds that it does not make an improvement over flawed simple-sum aggregates in practice. There has been a significant accumulation of evidence, however, to suggest that Divisia aggregates outperform their simple-sum equivalents. For example, Barnett (1980) showed that some apparent shifts in money demand in the United States were removed when Divisia measures replaced simple sum. Barnett and Spindt (1979) showed the informational superiority of Divisia over simple-sum measures. Belongia and Chalfant (1989) find Divisia M1A to have superior informational content to other admissible aggregates. Barnett, Offenbacher and Spindt (1984) also find evidence for the superiority of Divisia. Further support is provided by Serletis (1988). Lindsey and Spindt (1986) is one of the few papers which have looked at this comparison to come out against Divisia, though Fisher and Serletis (1989) is inconclusive.

Belongia (1993) has recently discovered that using weighted, as opposed to simple-sum, monetary aggregates alters significantly the conclusions that should have been reached by several recent influential studies. These studies have, on the whole, adduced evidence that money is not a "cause" of cycles in real activity. Hence, this suggests that the problems with tests of money in the economy in recent years may be more due to bad measurement theory rather than to an instability in the link between the true money and the economy. Rather than a problem associated with the Lucas Critique, it could instead be a problem stemming from the "Barnett Critique."

The idea of weighted monetary aggregates has spread outside the United States. Studies include Horne and Martin (1989) for Australia; Cockerline and Murray (1981) and Hostland, Poloz and Storer (1987) for Canada; Ishida (1984) for Japan; Yue and Fluri (1991) for Switzerland; and Belongia and Chrystal (1991) and Drake and Chrystal (forthcoming) for the United Kingdom. A recent Bank of England study in the United Kingdom context concludes: "A Divisia measure of money appears to have some leading indicator properties for predicting both nominal output and inflation...a case can clearly be made for including Divisia in the range of indicators analyzed by the authorities when forming their judgments on monetary conditions." (Fisher, Hudson and Pradhan, 1993, p. 63).

A variation on the traditional "closed economy" tests is provided by Chrystal and MacDonald (1993). They point out that exchange rate models have been just as dependent upon money measures as have demand for money studies or reduced form tests of monetary policy. It is no coincidence that exchange rate equations started to misbehave at the same time as velocity trends appeared to shift (in the early 1980s). By replacing simple-sum aggregates in an exchange rate model by Divisia aggregates, for the dollar-pound rate, they show that a simple, flexible, price monetary model can be salvaged as a long-run proposition. They also find that, when Divisia measures are used, the short-run forecasting performance is far superior on out-of-sample tests.

We now turn to some empirical results of our own. The results we shall present fall into two distinct sections. In the first section, we report comparisons of simple-sum and weighted measures of the money supply in the context of St. Louis Equations. The dependent variable is accordingly nominal GNP. We are aware of the problems encountered in the past with such methods (Rasche, 1993). However, it is a simple, familiar and well-known context within which to compare money measures. We are not concerned with the absolute validity of the results but only with the relative performance of different measures. Non-nested testing techniques were used to distinguish between various indicators of money.

In the second section, we use the more sophisticated modern time-series methodology to test for the existence of short-run and long-run causal links between money and real activity. It is this latter question which has dominated the recent literature. We add to this literature both by including alternative money measures and by providing international comparisons.

EMPIRICAL RESULTS WITH ST. LOUIS EQUATIONS

In this section, we report results of comparisons between traditional simple-sum aggregates, Divisia measures and the Rotemberg Currency Equivalent (CE) measure. We use the environment of a modified St. Louis Equation as a vehicle for these comparisons, and we use non-nested testing methods to identify superior informational content. We are well aware with all the difficulties associated with the St. Louis Equation methodology. If we cannot use this structure at a St. Louis Fed conference, however, where else can we? More seriously, this method offers simplicity and transparency. It does at least give us a feel for the properties of the data we are dealing with. A methodology more acceptable to the econometric purist will be reported in the following section.

None of the data we used was original to this study. The bulk of it was made available to us by Michael Belongia at the Federal Reserve Bank of St. Louis, though the U.K. Divisia series (post-1977) was constructed by the Bank of England (Fisher, Hudson and Pradhan, 1993). It should be noted that the time period of the study differs for each country, depending upon data availability. Data definitions also vary from country to country, but space does not permit an extensive discussion of such differences. Seasonally adjusted data were used in all cases.

The dependent variable is taken as the first difference of the log of nominal GDP or GNP. The first difference of the log of nominal government spending (federal in the United States case) on goods and services is used as a fiscal variable in all cases. A world trade variable was tested as an external demand variable but was not found to add explanatory power in the countries tested. Also tested was an interest rate variable. This was found to be important in this context only for the United States. Hence, the U.S. Equation includes the first difference of the Treasury bill rate.

The original St. Louis Equation contained lags of order 0-3. On quarterly data, most economists would expect to use at least 0-4, so, given the short data series for some countries, this is the standard lag length we adopted.

In parallel to the simple St. Louis Equation format, we also report tests in a version of the equation which includes the lagged dependent variable, lagged 1-4 periods. Additionally in this latter context we report an F test on the exclusion of money from the equation entirely. This provides useful information, not only about the relative informational content of different money measures but also about whether money matters at all. In some cases Divisia money matters but simple-sum money does not. The reverse is never true.

The basic test is to use the same equation in one case with simple-sum money and in another case Divisia or CE money. Three test statistics are reported for comparisons between the two formulations—the Davidson and MacKinnon J-test, the Fisher and McAleer JA-test and the Akaike Information Criterion (AIC). Other tests have been monitored, including the NT test of Pesaran and Godfrey and the Wald-type test. These other tests differ in detail but they do not alter the overall picture produced. Accordingly, they are not reported here. We refer to the J-test and the JA-test as being inconclusive when both formulations reject each other and indeterminate if neither rejects the other.

The results are reported in Tables 1 to 7 for the United States, the United Kingdom, Australia, Germany, Switzerland, Canada and Japan, respectively. Let us consider each.

United States

The U.S. results are summarized in Table 1. Simple-sum aggregates M1 and M1A in general dominate their Divisia equivalents. From M2 onwards to broader aggregates, however, the domination is reversed. This is clear for M2 and M3, though the difference between Divisia L and simple-sum L is probably not significant. This general picture is not altered by the inclusion or exclusion of the lagged dependent variable.

From the F-tests it is clear that simple-sum M1A, Divisia M1A and Divisia M1 do not add significant explanatory power to the equation at normal significance levels. However, Divisia M2 has the greatest informational content of all the aggregates tested, though it is only marginally more significant than simple-sum M2.

The CE aggregate holds its own against M1 and M1A, though never establishing statistically significant domination in either direction. It loses out to the broader simple-sum aggregates, however, and also to the broader-based Divisia measures (the latter result is implied but not shown).

Overall, the M2 level of money aggregation seems superior, though the Divisia aggregate at this level does not dominate its simple-sum equivalent sufficiently to make an overwhelming case for preferring one to the other.

United Kingdom

The U.K. results appear in Table 2. There are far fewer aggregates to choose from in the U.K. case. The Bank of England even stopped report-

Table 1

St. Louis Equations for the United States: Simple-Sum vs. Weighted Money

Dependent variable: first difference of the natural log of nominal GNP.
Independent control variables: first difference of the natural log of federal spending on goods and services; first difference of the T-bill rate; the current period value and four lags of each variable are included as regessors.

Part 1: no lagged dependent variable in regression

M1 vs. Divisia M1		
Akaike Information Criterion (AIC)	favors M1	(4.42)
J-test	favors M1	(−.1; 3.06)
JA-test	favors M1	(−.72; 2.26)
M1 vs. Rotemberg Currency Equivalent (CE)		
AIC	favors CE	(−.24)
J-test	inconclusive	(2.74; 2.64)
JA-test	indeterminate	(1.56; 1.39)
M1A vs. Divisia M1A		
AIC	favors M1A	(3.78)
J-test	favors M1A	(−.59; 2.7)
JA-test	favors M1A	(−.67; 2.6)
M1A vs. CE		
AIC	favors CE	(−.55)
J-test	inconclusive	(2.7; 2.4)
JA-test	indeterminate	(1.66; 1.16)
M2 vs. Divisia M2		
AIC	favors Divisia M2	(−1.1)
J-test	favors Divisia M2	(2.42;1.8)
JA-test	favors Divisia M2	(2.04;1.4)
M2 vs. CE		
AIC	favors M2	(8.75)
J-test	inconclusive	(2.4; 4.9)
JA-test	favors M2	(.92; 3.6)
M3 vs. Divisia M3		
AIC	favors Divisia M3	(−1.76)
J-test	favors Divisia M3	(2.4; 1.5)
JA-test	favors Divisia M3	(1.9; 1.2)
M3 vs. CE		
AIC	favors M3	(6.45)
J-test	inconclusive	(3.07; 4.7)
JA-test	inconclusive	(2.05; 2.72)
L vs. Divisia L		
AIC	favors Divisia L	(−.31)
J-test	inconclusive	(2.35; 2.18)
JA-test	inconclusive	(1.6; 1.34)
L vs. CE		
AIC	favors L	(7.27)
J-test	inconclusive	(2.9; 4.8)
JA-test	inconclusive	(2.2; 3.98)

Note: The Akaike Information Criterion is an adjusted difference between two values of the likelihood function. It indicates the direction of informational advantage but has no critical bounds. The J and JA tests are *t*-statistics for the rejection of one model over the other and then the reverse. *"Inconclusive" = both significant; "Indeterminate" = neither significant.* Data period is 60:1–92:4.

Table 1 (continued)

Part 2: four lags of the dependent variable included

M1 vs. Divisia M1		
AIC	favors M1	(3.74)
J-test	favors M1	(.27; 2.8)
JA-test	indeterminate	(−.45; 1.78)
M1 vs. CE		
AIC	favors M1	(.46)
J-test	inconclusive	(2.49; 2.59)
JA-test	indeterminate	(1.6; 1.15)
M1A vs. Divisia M1A		
AIC	favors M1A	(3.2)
J-test	favors M1A	(−.42; 2.44)
JA-test	favors M1A	(−.55; 2.3)
M1A vs. CE		
AIC	favors CE	(−.84)
J-test	inconclusive	(2.7; 2.3)
JA-test	indeterminate	(1.4;.62)
M2 vs. Divisia M2		
AIC	favors Divisia M2	(−.74)
J-test	inconclusive	(2.4; 2.1)
JA-test	indeterminate	(1.87; 1.56)
M2 vs. CE		
AIC	favors M2	(5.76)
J-test	inconclusive	(2.4; 4.3)
JA-test	favors M2	(.62; 3.4)
M3 vs. Divisia M3		
AIC	favors Divisia M3	(−1.5)
J-test	favors Divisia M3	(2.24; 1.5)
JA-test	indeterminate	(1.63; 1.14)
M3 vs. CE		
AIC	favors M3	(3.4)
J-test	inconclusive	(3.05; 3.99)
JA-test	favors M3	(1.32; 2.26)
L vs. Divisia L		
AIC	favors Divisia L	(−.42)
J-test	inconclusive	(2.38; 2.21)
JA-test	indeterminate	(1.42; 1.29)
L vs. CE		
AIC	favors L	(3.93)
J-test	inconclusive	(2.9; 4.0)
JA-test	favors L	(1.85; 3.4)

Table 1 (continued)

Part 3: F-tests on exclusion of money from St. Louis Equation

		probability
M1	F(5,107)	= 2.36 [0.045]
M1A	"	= 1.88 [0.103]
M2	"	= 4.43 [0.001]
M3	"	= 3.49 [0.006]
L	"	= 3.69 [0.004]
Divisia M1	"	= 1.01 [0.418]
Divisia M1A	"	= 0.73 [0.600]
Divisia M2	"	= 4.73 [0.001]
Divisia M3	"	= 4.09 [0.002]
Divisia L	"	= 3.86 [0.003]
CE	"	= 2.19 [0.060]

Note: Exclusion test conducted in equation including lagged dependent variable shown in Part 2 of the table. This is equivalent to the concept of Granger causality tests, but includes contemporaneous observations on independent variables.

ing M1 and M3 in 1989 because it considered the data too distorted by financial innovation. Hence, the only choice using official statistics is between M0 (the monetary base) and M4. The results show a clear domination of Divisia M4 over simple-sum M4 both with and without the presence of lagged GDP. The non-nested tests, however, make it impossible to choose between Divisia M4 and M0. Also, while the Akaike Information Criterion favors M0 over simple-sum M4, the J-test and the JA-test are inconclusive and indeterminate, respectively. On the other hand, the F-test gives informational advantage to M0, with Divisia M4 running second. Simple-sum M4 has no significant explanatory power at normal probability levels. This suggests that Divisia M4 should replace simple-sum M4 as an indicator of the course of broad money in the United Kingdom.

Australia

Results for Australia appear in Table 3. They show comparisons between M2, M3 and their Divisia equivalents. The information criterion is always in favor of Divisia, and the significant J-tests favor Divisia. More dramatic perhaps are the F-tests which show that neither simple-sum aggregate matters at anything close to normal probability levels, while both Divisia aggregates do have significant informational content. This is probably the clearest case available which illustrates the domination of Divisia over simple-sum aggregates—especially for broad money measures.

Germany

Table 4 contains the results for Germany. The information criterion generally favors Divisia measures over their simple sum counterparts, with the exception of M3 in the absence of the lagged dependent variable. All the J- and JA-tests are indeterminate with the exception of the J-test which shows dominance of Divisia M2 over M2 (in the presence of the lagged dependent variable). The same test for M3 is very close to accepting Divisia M3 as dominating M3.

The overwhelming impression of the German results, however, is that conveyed by the F-tests, which show the very low informational content of all money measures. In this respect, only Divisia M3 is significant at even the 10 percent level and the simple-sum aggregates do not obviously matter at all. This is a surprising result for a country which has a reputation for sound monetary policy and adheres to a simple-sum M3 target. It is possible that the very success of monetary policy is responsible for a low variation of nominal income growth, which makes it hard to establish statistical relationships. However, it is also possible that Divisia money measures do a better job in tracking nominal GDP than their simple-sum equivalents.

Table 2

St. Louis Equations for the United Kingdom: Simple-Sum vs. Weighted Money

Dependent variable: first difference of the natural log of nominal GDP.
Independent control variables: first difference of the natual log of government spending on goods and services.

Part 1: no lagged dependent variable included in regression		
Divisia M4 vs. M4		
AIC	favors Divisia M4	(3.136)
J-test	favors Divisia M4	(1.05; 3.1)
JA-test	favors Divisia M4	(−.45; 2.2)
Divisia M4 vs. M0		
AIC	favors Divisia M4	(.168)
J-test	inconclusive	(2.77; 2.72)
JA-test	indeterminate	(1.52; .96)
M4 vs. M0		
AIC	favors M0	(−3.2)
J-test	inconclusive	(3.5; 2.5)
JA-test	indeterminate	(.49; .77)
Part 2: four lags of dependent variable included		
Divisia M4 vs. M4		
AIC	favors Divisia M4	(2.32)
J-test	favors Divisia M4	(1.3; 2.7)
JA-test	indeterminate	(−.16; 1.82)
Divisia M4 vs. M0		
AIC	favors M0	(−.78)
J-test	inconclusive	(3.17; 2.8)
JA-test	indeterminate	(1.5; .73)
M4 vs. M0		
AIC	favors M0	(−3.69)
J-test	inconclusive	(3.8; 2.7)
JA-test	indeterminate	(−.18; −.36)

Part 3: F-tests on exclusion of money from St. Louis Equation

		probability
M4	F(5, 78)	= 1.45 [0.215]
Divisia M4	"	= 2.33 [0.050]
M0	"	= 2.83 [0.021]

Note: Test is done in equation from Part 2 including lagged dependent variable. Data period is 1968:3–1992:4.

Switzerland

In Switzerland, (Table 5) Divisia aggregates dominate on information grounds, though the JA-test is always indeterminate and the J-test only gives clear dominance to Divisia on one occasion (Divisia M2 beats M2 in the presence of lagged GDP). The F-tests suggest that M1 and Divisia M1 are very similar in informational content (with a tiny advantage to Divisia). Simple-sum M2, by contrast, is overwhelmingly dominated by its Divisia counterpart. This confirms the simple (and obvious) conclusion from other countries that Divisia clearly dominates when it comes to broad money measures, but at the narrow money level it does not make much difference. This is clearly almost a tautology when narrow aggregates have minimal interest-bearing components.

Table 3

St. Louis Equations for Australia: Simple-Sum vs. Weighted Money

Dependent variable: first difference of the natural log of nominal GDP.
Independent control variable: first difference of the natural log of government spending.

Part 1: no lagged dependent variable included in regression		
M2 vs. Divisia M2		
AIC	favors Divisia M2	(−3.74)
J-test	inconclusive	(3.63; 2.67)
JA-test	indeterminate	(−.7; −.19)
M3 vs. Divisia M3		
AIC	favors Divisia M3	(−3.9)
J-test	favors Divisia M3	(3.2; .9)
JA-test	indeterminate	(1.1; −.82)
Part 2: four lags of dependent variable included		
M2 vs. Divisia M2		
AIC	favors Divisia M2	(−6.6)
J-test	inconclusive	(4.4; 3.3)
JA-test	indeterminate	(−1.5; −.07)
M3 vs. Divisia M3		
AIC	favors	(−5.6)
J-test	Divisia M3	(3.5; 1.1)
JA-test	indeterminate	(.94; −.53)

Part 3: F-tests on exclusion of money from St. Louis Equation

		probability
M2	F(5,43)	= 0.99 [0.430]
M3	"	= 0.82 [0.540]
Divisia M2	"	= 3.46 [0.010]
Divisia M3	"	= 2.84 [0.027]

Note: Data period is 1974:2–1989:4.

Canada

The Canadian results (Table 6) confirm the general pattern established above. M1 has a marginal edge over Divisia M1 (in the presence of lagged GNP, but not otherwise) but for broader aggregates the Divisia measure dominates where any discrimination is possible. Divisia L sweeps the board with its simple-sum equivalent and both Divisia M2 and Divisia M3 exhibit obvious domination. The F-tests confirm this general story. Simple-sum M1 has the greatest informational content, but it is closely followed by Divisia M1. Simple-sum M2, M3 and L do not have significant informational content at the 5 percent level, though all of their Divisia equivalents do so.

Japan

Japan does not fit in at all with the pattern of all the other countries in the sample (Table 7). On the basis of the Akaike Information Criterion, all of the simple-sum aggregates marginally dominate their Divisia counterparts. However, none of the J- or JA-tests are able to discriminate and the F-tests make it clear than none of the money measures has any explanatory power at all. In this context it makes no sense to try to distinguish between sets of numbers, none of which matter.

Japan's monetary aggregates differ from many others at the M2 and M3 level, because they include negotiable CDs. However, this would not

Table 4

St. Louis Equations for Germany: Simple-Sum vs. Weighted Money

Dependent variable: first difference of the natural log of nominal GDP.
Independent control variable: first difference of the natural log of government spending.

Part 1: no lagged dependent variable included in regression

M2 vs. Divisia M2		
AIC	favors Divisia M2	(–.85)
J–test	indeterminate	(1.84; 1.54)
JA–test	indeterminate	(.25; .93)
M3 vs. Divisia M3		
AIC	favors M3	(1.3)
J–test	indeterminate	(.57; 1.73)
JA–test	indeterminate	(–.06; .92)

Part 2: four lags of dependent variable included

M2 vs. Divisia M2		
AIC	favors Divisia M2	(–1.8)
J–test	favors Divisia M2	(2.9; 1.89)
JA–test	indeterminate	(–.36; –.014)
M3 vs. Divisia M3		
AIC	favors Divisia M3	(–1.17)
J–test	indeterminate	(1.88; 1.12)
JA–test	indeterminate	(.91; .24)

Part 3: F-tests on exclusion of money from St. Louis Equation

		probability
M2	F(5,41)	= 0.71 [0.620]
M3	"	= 1.66 [0.167]
Divisia M2	"	= 1.77 [0.140]
Divisia M3	"	= 2.08 [0.087]

Note: Data period is 1975:1–1990:1.

explain the poor performance of M1. Also, this should give an advantage to Divisia M2 and Divisia M3 which is not supported by the data. Either the Japanese economy behaves very differently from the others studied or there are serious data errors underlying this evidence.

We now turn to tests of the causal links between money and real activity using modern time-series methods.

TIME SERIES TESTS OF MONEY/ REAL ACTIVITY CAUSALITY

In this part of the paper, we consider Granger causality tests for a selection of Divisia and simple-sum money aggregates for each of the countries referred to in our St. Louis tests. The causality tests are based on vectors consisting of real GDP, the GDP deflator, a Treasury bill rate and the relevant measure of the money supply. Defining our causality vectors in this way facilitates separate modelling of the effect that different monetary impulses may have (particularly in the short run) on the real and price components of GDP. The Treasury bill rate is also included in the vector because of the well-known spurious effect money can have on output if an interest rate effect is excluded (Sims, 1980). Our causality tests have a number of other features, some of which are novel to this paper.

First, for reasons which are now widely accepted, it is extremely important that the variables entering the causality vector should be stationary and that any indication of cointegratability should be determined (see, Engle and Granger, 1987; MacDonald and Kearney, 1987). The latter aspect of the time-series properties of

Table 5

St. Louis Equations for Switzerland: Simple-Sum vs. Weighted Money

Dependent variable: first difference of the natural log of nominal GDP.
Independent control variable: first difference of the natural log of government spending.

Part 1: no lagged dependent variable included in regression		
M1 vs. Divisia M1		
AIC	favors Divisia M1	(−.064)
J-test	indeterminate	(1.37; −1.31)
JA-test	indeterminate	(1.35; −1.33)
M2 vs. Divisia M2		
AIC	favors Divisia M2	(−1.84)
J-test	inconclusive	(2.99; 2.76)
JA-test	indeterminate	(−.6; .76)
Part 2: four lags of dependent variable included		
M1 vs. Divisia M1		
AIC	favors Divisia M1	(−.05)
J-test	indeterminate	(.93; −.87)
JA-test	indeterminate	(.91; −.88)
M2 vs. Divisia M2		
AIC	favors Divisia M2	(−4.026)
J-test	favors Divisia M2	(3.1; 1.5)
JA-test	indeterminate	(.35; −.27)

Part 3: F-tests on exclusion of money From St. Louis Equation

		probability
M1	F(5,39)	= 2.9 [0.026]
M2	"	= 0.41 [0.840]
Divisia M1	"	= 2.92 [0.025]
Divisia M2	"	= 2.11 [0.085]

Note: Data period is 1975:2–1989:4.

the vector is important, since if there is one (or more) cointegrating relationships among the vector, then it is inappropriate to test for causality among a vector of first-differenced variables, because the Granger representation theorem asserts that such a vector will be misspecified; it will exclude important "long-run" information contained in the levels of the variables. (This was a point recognized by Friedman and Kuttner, 1992, in their causality tests on U.S. data [see their footnote 19], but they did not include such long-run elements in their testing framework.) A second important aspect of any causality test is that it should be robust to non-normal errors. Holmes and Hutton (1992) suggest handling this issue using a non-parametric rank F-test (instead of the standard F-test used in conventional causality studies). In this paper, we argue that since most departures from normality arise from heteroskedasticity, this issue may be dealt with using the Hansen-White non-parametric correction for heteroskedasticity.

The general class of causality tests employed in this section of the paper have come in for some criticism in the literature (see: Zellner, 1979, 1988; Basmann, 1963; and Cooley and LeRoy, 1985). In particular, it is argued that to be interpreted as indicating causality from, say, money to output, Granger-type causality tests have to be embedded in a structural setting and appropriate identifying restrictions imposed (see Holmes and Hutton, 1992, for a partial rebuttal). However, given our purpose is not to examine causality for a single measure of money, but rather to determine which measures from a range of simple-sum and Divisia money magnitudes have the greatest informational content,

Table 6

St. Louis Equations for Canada: Simple-Sum vs. Weighted Money

Dependent variable: first difference of the natural log of nominal GNP.
Independent control variable: first difference of the natural log of government spending.

Part 1: no lagged dependent variable included in regression

Divisia M1 vs. M1		
AIC	favors Divisia M1	(.34)
J-test	indeterminate	(.45; .78)
JA-test	indeterminate	(.09; .46)
Divisia M2 vs. M2		
AIC	favors Divisia M2	(6.0)
J-test	favors Divisia M2	(1.7; 4.8)
JA-test	favors Divisia M2	(−.84; 2.5)
Divisia M3 vs. M3		
AIC	favors Divisia M3	(3.67)
J-test	favors Divisia M3	(1.29; 3.5)
JA-test	favors Divisia M3	(−.39; 2.4)
Divisia L vs. L		
AIC	favors Divisia L	(8.43)
J-test	favors Divisia L	(−.43; 4.3)
JA-test	favors Divisia L	(−.99; 3.72)

Part 2: four lags of dependent variable included

Divisia M1 vs. M1		
AIC	favors M1	(−.19)
J-test	indeterminate	(.81; .56)
JA-test	indeterminate	(.44; .25)
Divisia M2 vs. M2		
AIC	favors Divisia M2	(3.34)
J-test	favors Divisia M2	(1.26; 3.3)
JA-test	indeterminate	(−.8; 1.04)
Divisia M3 vs. M3		
AIC	favors Divisia M3	(2.87)
J-test	favors Divisia M3	(.55; 2.71)
JA-test	indeterminate	(−.74; 1.53)
Divisia L vs. L		
AIC	favors Divisia L	(3.49)
J-test	favors Divisia L	(.49; 2.8)
JA-test	favors Divisia L	(−.49; 2.17)

Part 3: F-tests on exclusion of money from St. Louis Equation

		probability
M1	F(5,55)	= 7.05 [0.000]
M2	"	= 2.03 [0.088]
M3	"	= 1.37 [0.250]
L	"	= 1.25 [0.299]
Divisia M1	"	= 6.95 [0.000]
Divisia M2	"	= 3.34 [0.010]
Divisia M3	"	= 2.43 [0.047]
Divisia L	"	= 2.53 [0.039]

Note: Data period is 1968:3–1987:1.

Table 7

St. Louis Equations for Japan: Simple-Sum vs. Weighted Money

Dependent variable: first difference of the natural log of nominal GNP.
Independent control variable: first difference of the natural log of nominal government spending.

Part 1: no lagged dependent variable included in regression		
M1 vs. Divisia M1		
AIC	favors M1	(.32)
J-test	indeterminate	(−1.57; 1.86)
JA-test	indeterminate	(−1.7; 1.72)
M2 vs. Divisia M2		
AIC	favors M2	(.5)
J-test	indeterminate	(−.7; 1.45)
JA-test	indeterminate	(−1.09; 1.05)
M3 vs. Divisia M3		
AIC	favors M3	(.72)
J-test	indeterminate	(−.62; 1.53)
JA-test	indeterminate	(−1.01; 1.17)
Part 2: four lags of dependent variable included		
M1 vs. Divisia M1		
AIC	favors M1	(.503)
J-test	inconclusive	(−1.96; 2.23)
JA-test	inconclusive	(−2.03; 2.16)
M2 vs. Divisia M2		
AIC	favors M2	(.44)
J-test	indeterminate	(−.45; 1.49)
JA-test	indeterminate	(−1.19; .72)
M3 vs. Divisia M3		
AIC	favors M3	(.77)
J-test	indeterminate	(−.64; 1.56)
JA-test	indeterminate	(−1.08; 1.15)

Part 3: F-tests for exclusion of money from St. Louis Equation

		probability
M1	F(5,42)	= .79 [0.559]
M2	"	= .24 [0.942]
M3	"	= .38 [0.861]
Divisia M1	"	= .63 [0.675]
Divisia M2	"	= .11 [0.990]
Divisia M3	"	= .14 [0.981]

Note: Data period is 1976:1–1991:2.

we do not believe that the standard criticisms of our framework have as much import as they may have for more conventional studies. We also take encouragement from the fact that even in recent papers which only address the causality properties of a single money measure (see, for example, Friedman and Kuttner, 1993), Granger-type tests have still been employed (although, we would argue, incorrectly since such tests only involve a vector of differenced variables).

Unit Root And Multivarite Cointegrtion Results

We begin the empirical analyses of this section by testing for unit roots in the variables entering our causality vector. Although the cointegration method we employ below is due to Johansen and is, therefore, a multivariate test for the number of unit roots in a given vector, we nevertheless thought it worthwhile to examine some simple univariate unit root rests for motivational purposes, and also to guide us in the appropriate order of differencing for the variables entering the cointegrating tests.

There have been, in fact, a variety of proposed methods for implementing univariate unit roots tests (for example, Dickey and Fuller, 1979; Phillips and Perron, 1988; Stock, 1990; and Park and Choi, 1988) and each has been used in the applied macroeconomics literature. Since, however, there is now a growing consensus that the earliest, unit root test—due to Dickey and Fuller (1979)—has superior small sample properties compared to its competitors (see Campbell and Perron, 1991, for a discussion), we employ it. In particular, we estimate the following regression equation for the series entering our causality vector:

$$(1)\ \Delta x_t = \mu + \beta\tau + \pi x_{t-1} + \sum_{i=1}^{q} \gamma_i \Delta x_{t-i} + u_t,$$

where x is the variable of interest, μ and τ denote deterministic regressors (a constant and a time trend, respectively). Equation 1 represents a reparameterization of an autoregression of x_t in levels, where the length of the autoregression is set to ensure that u_t is serially uncorrelated. In this context, a test for a unit root in the series x_t amounts to a t-test of $\pi = 0$ (that is, the sum of the autoregressive parameters in the levels autoregression is unity). The alternative hypothesis of stationarity requires that π be significantly negative. Since under the null hypothesis of non-stationarity the calculated t-ratio will not have a student's t-distribution, critical values calculated by Fuller (1976) must be used instead.

In estimating equation 1 for so many country/variable combinations, we initially used a common lag length, q, of 4 for all variables. However, given the sensitivity of Augmented Dickey-Fuller (ADF) tests to the chosen lag length we also experimented with shorter lag lengths in instances where the estimated t-ratio on π was close to its critical value, this being particularly so when a variable appeared to be I(2). (In particular, and following the recommendation of Hall, forthcoming, and Campbell and Perron, 1991, we sequentially deleted insignificant lags of the dependent variable until we arrived at a parsimonious relationship which satisfied the non-autocorrelation criterion.) In the reported tables that follow, a shorter lag length than 4 is denoted by the number in parenthesis after the variable mnemonic. Where the default value of 4 is reported for the ADF statistic, it means that either all four lags are significant or, in instances where some lags are insignificant, reducing the lag length from 4 would not have made a qualitative difference to the interpretation.

In Tables 8 through 14, we present our estimates of the t-ratio for the estimated coefficient π in equation 1 for the levels and first and second differences of each series in question. This procedure facilitates a test for one and two unit roots, respectively. The t-ratio has been calculated with the time trend included in the regression equation, as in equation 1 (referred to as t_τ), and the trend excluded (referred to as t_μ). This follows the sequential testing strategy recommended by, for example, Perron (1988): If a deterministic component is excluded from a unit root test but such a component features in the data generation process (DGP) of the series, the resulting test will have low power. However, if the deterministic component is absent from the DGP, greater power may be obtained by estimating p without the trend component. In our unit root tests, all variables, apart from the interest rate series, have been transformed into natural logarithms. In order to capture any remaining seasonality in the variables, three seasonal dummies have been incorporated into our estimated version of equation 1.

A number of findings emerge from Tables 8 to 14. First, there are only two variables which appear to be stationary around a deterministic trend, namely the Australian Treasury bill rate and the Rotemberg Currency Equivalent measure —all the other variables appear to contain stochastic trends. As is common in many other studies of the time series properties of macroeconomic series, the level of the price deflator for a number of countries appears to be an I(2) process; that is, inflation in these countries is an I(1) process. Interestingly, it is also the case that some of our monetary series appear to be I(2) processes. In general we found that this result (but not the result for the deflator) was particularly sensitive to the lag length specified in the estimated equation.

For example, in the case of the United States, all of the simple-sum money measures appeared to be I(2) when q was set equal to 4 (DM1A and DM1 also appeared I(2) with four lags). However, in these instances it appeared that this lag length resulted in an overparameterized regression equation and the deletion of a single lag

Table 8

Unit Root Tests for the United States

	L		Δ		Δ^2	
	t_μ	t_τ	t_μ	t_τ	t_μ	t_τ
SSM1	−1.61	−2.08	−3.80	−4.35	−9.18	−9.16
DM1	−1.97	−2.16	−3.61	−4.34	−8.38	−8.35
SSM1A	0.03	−2.70	−3.61	−3.61	−9.29	−9.29
DM1A	0.77	−2.05	−4.13	−4.21	−9.52	−9.49
SSM2	1.40	−0.23	−3.20	−3.47	−8.37	−8.37
DM2	0.80	−1.78	−4.19	−4.22	−8.21	−8.19
SSM3 (1)	1.66	0.44	−2.93	−3.36	−9.14	−9.14
DM3	1.17	−1.27	−3.93	−4.06	−7.79	−7.79
SSL	1.40	−0.61	−1.73	−2.01	−7.05	−7.12
DL	0.95	−1.66	−3.68	−3.74	−7.81	−7.80
GDP	−1.73	−2.73	−4.51	−4.71	−7.69	−7.66
DEF	−1.01	−1.94	−1.74	−1.59	−6.52	−6.10
TB	−2.31	−2.03	−5.49	−5.64	−11.84	−11.78
RCE	−1.31	−3.70	−4.73	−4.76	−5.16	−5.14
BCE	0.67	−2.59	−3.58	−3.68	−6.38	−6.36

Note: Unless otherwise noted, each ADF statistic was computed with a lag of 3. SS denotes a simple-sum monetary aggregate; D denotes a Divisia aggregate; M denotes money; L denotes liquidity; GDP denotes real Gross Domestic Product; DEF denotes the GDP deflator; and TB denotes a Treasury bill rate. L, Δ and Δ^2 denote, respectively, the level and first and second difference of a variable. t_μ and t_τ are augmented Dickey Fuller statistics with allowance for a constant mean and for a trend in mean, respectively. The 5 percent critical values for t_μ and t_τ are −2.89 and −3.43, respectively (Fuller, 1976).

Table 9

Unit Root Tests for the United Kingdom

	L		Δ		Δ^2	
	t_μ	t_τ	t_μ	t_τ	t_μ	t_τ
SSM4 (2)	−0.44	−1.60	−3.07	−3.06	−7.39	−7.35
DM4 (1)	−0.72	−1.22	−3.64	−3.64	−10.42	−10.36
GDP	−1.06	−1.92	−3.81	−3.85	−8.22	−8.18
DEF	−2.07	−0.66	−2.71	−3.35	−5.02	−5.07
TB	−2.78	−3.12	−5.26	−5.25	−8.07	−8.03

Note: See Table 8.

Table 10

Unit Root Tests for Australia

	L		Δ		Δ^2	
	t_μ	t_τ	t_μ	t_τ	t_μ	t_τ
SSM2	0.97	−2.44	−3.21	−3.30	−4.76	−4.73
DM2	0.28	−1.73	−3.02	−3.02	−5.45	−5.40
SSM3 (2)	2.55	−0.26	−3.18	−4.24	−4.56	−4.49
DM3 (2)	2.39	−0.43	−3.01	−3.88	−5.17	−5.15
GDP	−0.22	−2.48	−3.68	−3.64	−5.07	−4.97
DEF	−1.15	−1.19	−3.34	−3.46	−4.24	−4.41
TB	−1.73	3.46	−3.33	−3.31	−5.17	−5.12

Note: See Table 8.

Table 11

Unit Root Tests for Germany

	L		Δ		Δ^2	
	t_μ	t_τ	t_μ	t_τ	t_μ	t_τ
SSM2 (1)	−0.75	−1.72	−3.11	−2.97	−9.38	−9.43
DM2 (1)	−0.45	−1.97	−3.74	−3.69	−8.27	−8.20
SSM3 (2)	−2.02	−2.72	−2.96	−3.23	−6.81	−6.75
DM3 (1)	−1.01	−2.62	−3.78	−3.84	−7.65	−7.57
GDP (1)	0.24	−1.08	−6.23	−6.21	−11.18	−11.08
DEF (2)	−1.99	−0.92	−2.76	−3.21	−7.24	−7.17
TB (2)	−1.99	−1.97	−3.63	−3.58	−6.98	−6.93

Note: See Table 8.

Table 12

Unit Root Tests for Switzerland

	L		Δ		Δ^2	
	t_μ	t_τ	t_μ	t_τ	t_μ	t_τ
SSM1	−1.17	−2.32	−3.43	−3.40	−5.11	−5.07
DM1	−1.18	−2.35	−3.44	−3.40	−5.10	−5.06
SSM2 (1)	0.15	−1.44	−3.30	−3.31	−7.16	−7.07
DM2 (1)	−1.19	−1.91	−3.19	−3.18	−7.25	−7.22
GDP	0.95	−1.57	−2.10	−2.78	−4.81	−4.75
DEF	−1.06	−0.94	−2.22	−2.03	−4.76	−4.87
TB	−1.76	−1.99	−3.03	−2.99	−5.84	−5.81

Note: See Table 8.

Table 13

Unit Root Tests for Canada

	L		Δ		Δ^2	
	t_μ	t_τ	t_μ	t_τ	t_μ	t_τ
SSM1	−2.64	−1.21	−3.02	−3.73	−5.77	−5.72
SSM2	−1.65	−1.15	−2.21	−2.61	−4.85	−4.86
SSM3	−2.04	−0.70	−1.72	−2.37	−5.67	−5.66
SSL	−1.80	1.48	0.32	−0.36	−1.99	−2.38
DM1	−2.72	−1.18	−2.93	−3.66	−5.23	−5.18
DM2	−2.06	−0.74	−2.68	−3.21	−5.44	−5.45
DM3	−2.63	−1.40	−2.25	−3.20	−5.47	−5.52
DL	−2.27	−0.79	−2.53	−3.26	−5.06	−5.12
GDP	−1.28	−1.87	−2.99	−3.11	−5.72	−5.66
DEF	−1.23	−2.21	−1.79	−1.94	−4.13	−4.18
TB	−1.44	−1.36	−3.24	−3.26	−5.86	−5.81

Note: See Table 8.

Table 14

Unit Root Tests for Japan

	L		Δ		Δ^2	
	t_μ	t_τ	t_μ	t_τ	t_μ	t_τ
SSM1	−1.18	−2.78	−3.08	−3.19	−4.72	−4.67
DM1	−1.19	−2.74	−3.01	−3.13	−4.64	−4.60
SSM2	−1.14	−2.31	−2.55	−2.65	−3.26	−3.19
DM2	−0.85	−2.31	−2.08	−1.96	−3.52	−3.53
SSM3	−2.11	−2.22	−2.44	−2.41	−2.69	−2.59
DM3	−1.34	−2.58	−1.70	−1.92	−3.28	−3.28
GNP (1)	0.38	−1.16	−5.15	−5.12	−9.41	−9.29
DEF	−2.07	−2.47	−2.45	−2.35	−4.87	−5.10
TB	−2.23	−3.36	−3.90	−3.64	−2.83	−2.71

Note: See Table 8.

made a dramatic difference to the estimated t-ratio on π (without significantly affecting the non-autocorrelatedness properties of the residuals). Indeed, with three lags all of the money measures with the exception of simple-sum M3 (SSM3) and simple-sum L (SSL) appear to be I(1); the former variable appears I(1) when $q=1$, while SSL appears I(2) at all lag lengths (again, the residuals in each of these cases were non-autocorrelated).

The country with the greatest preponderence of monetary aggregates being I(2) is Canada, in which six out of the eight chosen monetary aggregates appear to have two unit roots. The finding that the level of a country's price series is an I(2) process finds confirmation in a number of other empirical studies (see, for example, Johansen and Juselius, 1990). Furthermore, the finding that monetary aggregates are I(2) has also been reported by other researchers (Rasche, 1993), although this finding does not appear to be as robust as that for price deflators.

We now turn to an analysis of the cointegration properties of a vector of variables for each of our chosen countries. In particular, for each country we use the methods of Johansen (1988, 1991) to estimate the number of cointegrating vectors in $y' = [\chi m, gdp, def, tb]$, where m denotes the money supply, χ is either ss (for simple-sum) or d (for Divisia), gdp is real output, def is the deflator corresponding to output, and tb denotes the relevant interest rate (usually a Treasury bill rate). The fact that the variables entering y' may for any one country be a mix of I(1) and I(2) processes has to be taken into account in our implementation of the Johansen procedure, since the latter is only appropriate for I(1) variables and driftless I(0) variables. We therefore use the information from our unit root tests to reduce the order of integration of any I(2) variables to I(1), by entering the first difference of the level of such a variable. Thus, if a country's price level is I(1), we enter the change in the price level (equivalent to the inflation rate, since the price level is transformed logarithmically) and/or if the money measure is also I(2), it is also entered in differences.

In the context of estimating a conventional money demand function (which has the same set of variables as are contained in our y vector), Johansen (1991) has suggested dealing with the two unit roots in m and p by respecifying the y vector to consist of $(m\text{-}p)$, y, i and Δp. However, given the nature of the current exercise, and also since, in many instances it is only p that appears to be I(2), we do not believe that such a specification is as attractive as the one adopted here. To determine the number of unit roots in y' we use the following method, due to Johansen (1988, 1991). This method may be thought of as the multivariate equivalent of (1). It is assumed that y_t has the following autoregressive representation with Gaussian errors ε_t:

$$(2)\quad y_t = \Pi_1 y_{t-1} + \Pi_2 y_{t-2} + \ldots + \Pi_k y_{t-k} + \varepsilon_t, \quad t = 1,2,\ldots,T.$$

Equation 2 may be reparameterized as

$$(2')\quad \Delta y_t = \mu + \Pi y_{t-k} + \sum_{i=1}^{q} \Gamma_i \Delta y_{t-i} + u_t,$$

where $q = k-1$, $\Pi = \sum_{j=1}^{k} B_i - I$, B_j is an (n x n) matrix from the lag polynomial in the (levels) VAR and $\Gamma_i = -\sum_{j=i+1}^{k} B_j$ for $i=1,\ldots q$. The key difference between 1 and 2 is that in 2 there is no allowance for a deterministic trend (or that the series are driftless). The long-run static equilibrium corresponding to 2 is[1]

$$(3)\quad \Pi\chi = 0.$$

The matrix Π is the multivariate analogue of π in equation 1. Assuming that the variables entering the y vector do not have an order of integration greater than 1, then the right-hand side of equation 2 can only be stationary if the components of Πy_{t-k} are stationary. This, in turn, may be determined by the rank, r, of the matrix Π, and, in particular, whether $0 \leq r \leq n$, where n denotes the number of variables in y. If $r=n$ (that is, Π has full rank) then Πy_{t-k} can only be stationary if all n linearly independent combinations of y_{t-k} formed using Π are stationary: A standard VAR analysis in levels is appropriate here. If, at the other extreme, $r=0$ (and $\Pi=0$) then there are no linear combinations in y_t which are stationary, and (2) therefore becomes a VAR in first differences (this is the kind of VAR specification used in the

[1]Dynamic steady-state equilibrium simply involves the addition of a term in the constant vector of steady-state growth rates to equation 2, which we omit here for expositional purposes; this does not affect the subsequent discussion.

majority of traditional Granger causality tests). If, however $0<r<n$, Π will be of reduced rank and there must exist $(n \times r)$ matrices α and β such that $\Pi = \alpha\beta'$, and for Πy_{t-k} to be stationary $\beta' y_{t-k}$ must be stationary. The β matrix therefore contains the cointegrating vectors and α represents the matrix of adjustment vectors. For example, if β'_i is the ith row of β' then:

(4) $\beta'_i y_t \sim I(0)$.

Johansen (1988, 1991) has proposed a maximum likelihood method of estimating all of the cointegrating vectors contained in Π and significance tests to determine how many of the vectors are statistically significant. Since the Johansen technique is now well-known, we do not present it here. Instead, we simply note the two test statistics used to determine the number of significant cointegrating vectors.

In our application the likelihood ratio, or trace, test statistic (LR1), for the hypothesis that there are at most r distinct cointegrating vectors, is

(5) $$LR1 = T \sum_{i=r+1}^{n} ln(1-\lambda_i),$$

where $\lambda_{r+1},...,\lambda_n$ are the $n - r$ smallest squared canonical correlations between the y_{t-k} and Δy, corrected for the effect of the lagged differences of the y_t process (for details of how to extract the λ_i's, see Johansen 1988). Additionally, the likelihood ratio statistic for testing at most r cointegrating vectors against the alternative of $r+1$ cointegrating vectors is given by equation 4

(6) $$LR2 = Tln(1-\lambda_{r+1}).$$

Johansen (1988) shows that equations 5 and 6 have a non-standard distribution under the null hypothesis. He does, however, provide approximate critical values for the statistic, generated by Monte Carlo methods. (The critical values recorded in Johansen's 1988 paper are for a VAR without an intercept term or seasonal dummies. Since these were included in our empirical analysis, we used the critical values for 5 and 6 reported in Johansen and Juselius, 1990.)

In Table 15, our estimated values of LR1 and LR2 are presented, and the critical values and relevant null hypothesis are reported at the bottom of the table. Consider first the results for the United States. Interestingly, there is no evidence of cointegration for any of the narrow monetary measures (i.e. M1 and M1A). However, with the exception of SSM3, there is clear evidence of one unique cointegrating vector for all monetary measures which are broader than M1. It follows from this that it is the introduction of these broader monetary measures that produces a cointegrating set (and not the income, interest rate or inflation rate). Since the Rotemberg currency equivalent measure appears to be stationary around a deterministic trend, it would appear not to be an ideal candidate for the Johansen methodology. However, for completeness, and also since it is often difficult to discriminate between a variable which is stationary around a trend and one which has a stochastic unit root, we also test for the numbers of cointegrating vectors in a y vector defined for RCE. Interestingly, this also gives strong evidence of one cointegrating vector, as does the BCE measure. (BCE is a variety of currency equivalence which uses Divisia weights.) The evidence for other (non-U.S.) countries in Table 15 is also suggestive of there being long-run relationships contained in different specifications of the y' vectors: The vast majority of monetary measures produce at least one cointegrating vector and many produce two. Again, there does not appear to be any split between Divisia and simple-sum monetary measures in terms of the production of cointegrating relationships.

The broad picture to emerge from Table 15 is that there is strong evidence of at least one cointegrating vector for most country/money combinations. It also seems that, at least in this long-run modelling context, there is no sharp distinction between Divisia and simple-sum money. It may be, however, that one or other monetary measures produce more "sensible" estimates of the cointegrating vector and we return to this point in a later section (where we also examine sample specific issues which may be important for the United States). However, for the implementation of our causality tests, the main implication to be drawn from Table 15 is that a causality relationship specified simply in differences will be misspecified for the vast majority of country/money combinations. We therefore propose estimating the vector error correction models implied by our cointegration results and subjecting them to exclusion tests on the lags of each of the differenced (either first or second differenced, depending on the outcome of the results reported in Tables 8 to 14) and also on the lagged cointegrating terms. Since we correct the coefficient variance-covariance matrix for heteroskedasticity (using the methods of Hansen, 1980; and White, 1978), the exclusion tests are performed using linear Wald statistics,

Table 15

Estimated Trace and λMax Statistics

United States

Trace (LR1)

SSM1	DM1	SSM1A	DM1A	SSM2	DM2	SSM3	DM3	SSL	DL
0.02	0.10	0.07	0.14	3.80	5.13	3.45	5.08	2.31	4.77
5.19	0.07	7.66	7.73	10.38	12.80	8.14	11.59	8.05	10.99
18.55	18.05	17.83	18.69	23.34	23.34	20.54	21.91	20.65	21.53
40.17	38.13	33.73	40.25	57.92	58.85	47.67	52.35	54.99	53.27

United States

λMAX (LR2)

SSM1	DM1	SSM1A	DM1A	SSM2	DM2	SSM3	DM3	SSL	DL
0.02	0.01	0.07	0.14	3.80	5.13	3.45	5.08	2.31	4.77
5.18	5.06	7.59	7.58	6.58	7.66	4.66	6.51	5.73	6.22
13.35	12.88	10.16	10.97	12.94	10.63	12.39	10.32	12.60	10.53
21.61	20.08	15.90	21.56	34.58	35.41	27.13	30.44	34.34	31.74

United Kingdom

Trace (LR1)		λMax (LR2)	
SSM4	DM4	SSM4	DM4
1.89	3.85	1.89	3.85
10.20	12.17	8.31	8.32
38.34	37.53	28.13	25.36
88.45	64.20	50.12	26.67

Table 15 (continued)

Estimated Trace and λMax Statistics

Australia

Trace (LR1)				λMax (LR2)			
SSM2	DM2	SSM3	DM3	SSM2	DM2	SSM3	DM3
0.01	0.75	0.61	0.12	0.01	0.74	0.06	0.12
10.51	5.74	10.77	6.23	10.50	4.99	10.71	6.12
21.89	26.93	31.97	23.12	11.38	21.18	21.19	16.88
53.96	55.67	67.61	56.41	32.07	28.74	35.64	33.79

Germany

Trace (LR1)				λMax (LR2)			
SSM2	DM2	SSM3	DM3	SSM2	DM2	SSM3	DM3
0.02	0.28	0.81	0.68	0.01	0.03	0.81	0.68
11.11	12.62	17.08	18.44	11.10	12.34	16.26	17.76
29.62	39.21	40.02	43.56	18.51	26.58	22.94	25.11
63.38	77.27	70.38	81.55	33.75	38.06	30.37	37.98

Switzerland

Trace (LR1)				λMax (LR2)			
SSM1	DM1	SSM2	DM2	SSM1	DM1	SSM2	DM2
0.59	0.60	0.49	1.53	0.59	0.60	0.49	1.53
15.54	15.50	12.41	13.29	14.93	14.89	11.91	11.76
35.55	35.57	33.91	33.71	20.01	20.07	21.49	20.41
56.74	57.08	64.82	60.78	21.18	21.51	35.91	27.08

Table 15 (continued)
Estimated Trace and λMax Statistics

Canada

Trace (LR1)				λMax (LR2)			
SSM1	**DM1**	**SSM2**	**DM2**	**SSM1**	**DM1**	**SSM2**	**DM2**
2.35	2.67	0.77	0.16	2.35	2.67	0.77	0.16
15.06	15.00	8.28	6.66	12.71	12.33	7.51	6.50
41.85	43.42	21.36	17.74	26.79	28.41	13.07	11.08
79.71	81.55	53.38	55.68	37.86	38.13	32.03	37.95

Japan

Trace (LR1)						λMax (LR2)					
SSM1	**DM1**	**SSM2**	**DM2**	**SSM3**	**DM3**	**SSM1**	**DM1**	**SSM2**	**DM2**	**SSM3**	**DM3**
3.09	30.08	2.42	0.62	3.46	3.03	3.04	3.08	2.42	2.62	3.46	3.03
12.74	12.97	16.28	15.03	16.91	15.41	9.64	9.89	13.85	12.41	13.45	12.37
32.26	32.19	38.76	34.97	39.39	35.25	19.51	19.21	22.47	19.95	22.48	19.83
65.14	67.00	71.17	69.63	67.29	64.82	32.88	34.81	32.41	34.65	27.90	29.56

Null hypotheses and 5 percent critical values for Trace and λMax statistics.

Trace		λMax	
Null Hypothesis	5% Critical Value	Null Hypothesis	5% Critical Value
r<3	8.18	r=3 | r=4	8.18
r<2	17.95	r=2 | r=3	14.90
r<1	31.53	r=1 | r=2	21.07
r=0	48.28	r=0 | r=1	27.14

Note: Variables are defined in Table 8. The Trace and λMax statistics are defined in the text.

which have a central chi-squared distribution.

Causality Tests

The exclusion tests for each country are reported in Tables 16 through 22. Consider first the results for the United States, reported in Table 16. Since there is some ambiguity regarding the stochastic properties of the Rotemberg currency equivalent measure (see discussion above), we present two systems for this variable: one in which the variable enters as a level and a deterministic time trend is included in each equation of the system (the system with RCE1), and one in which it enters as a first difference and the ECM term from the Johansen estimates reported in Table 15 is also included in each equation of the system (the system with RCE2).

In terms of the U.S.' real output relationship, there is a very clear, significant, short-run influence of the Treasury bill rate. This influence is repeated in all of the other equations as well, (apart from the deflator equation when SSM1 and DM1 are used). This confirms the findings of much other research on the importance of including an interest rate in the causality specification (see: Sims, 1980; and Friedman and Kuttner, 1993). In equations in which an ECM term appears, the majority of significant impacts tend to occur in equations which feature the deflator or money (Divisia or simple sum) as the dependent variable. What then of the potential short-run differential impact of simple-sum and Divisia money? Interestingly, and in contrast to our initial discussion of the long-run impact,

Table 16

Causality Tests for the United States

	SSM1	GDP	DEF	TB
SSM1	87.21 (0.00)	4.19 (0.38)	4.22 (0.38)	17.43 (0.00)
GDP	1.22 (0.87)	28.67 (0.00)	4.63 (0.33)	10.61 (0.03)
DEF	2.85 (0.58)	5.55 (0.23)	56.56 (0.00)	13.44 (0.00)
TB	4.00 (0.00)	27.45 (0.00)	6.28 (0.18)	19.59 (0.00)
	DM1	**GDP**	**DEF**	**TB**
DM1	37.88 (0.00)	5.38 (0.25)	5.04 (0.28)	5.66 (0.23)
GDP	0.17 (0.99)	28.08 (0.00)	4.53 (0.34)	10.85 (0.03)
DEF	1.39 (0.84)	5.86 (0.21)	52.46 (0.00)	11.85 (0.02)
TB	17.32 (0.00)	28.33 (0.00)	6.81 (0.15)	10.01 (0.04)
	SSM1A	**GDP**	**DEF**	**TB**
SSM1A	68.74 (0.00)	1.07 (0.89)	12.78 (0.01)	40.14 (0.00)
GDP	2.73 (0.60)	22.40 (0.00)	2.37 (0.00)	11.39 (0.02)
DEF	4.90 (0.29)	5.16 (0.27)	64.57 (0.00)	10.51 (0.03)
TB	21.86 (0.00)	21.22 (0.00)	9.45 (0.05)	24.78 (0.00)
	DM1A	**GDP**	**DEF**	**TB**
DM1A	57.30 (0.00)	1.12 (0.89)	12.54 (0.01)	17.12 (0.00)
GDP	3.45 (0.48)	26.46 (0.00)	3.30 (0.51)	13.79 (0.00)
DEF	3.77 (0.44)	5.59 (0.23)	61.65 (0.00)	12.39 (0.01)
TB	16.81 (0.00)	21.17 (0.00)	9.29 (0.05)	23.56 (0.00)
	SSM2	**GDP**	**DEF**	**TB**
SSM2	48.63 (0.00)	7.34 (0.12)	4.82 (0.31)	6.75 (0.15)
GDP	13.67 (0.00)	9.73 (0.04)	1.50 (0.83)	7.53 (0.11)
DEF	20.93 (0.00)	8.51 (0.07)	23.76 (0.00)	14.57 (0.00)
TB	27.36 (0.00)	13.97 (0.00)	14.23 (0.00)	12.42 (0.01)
ECM	17.23 (0.00)	2.25 (0.13)	8.29 (0.00)	0.60 (0.44)
	DM2	**GDP**	**DEF**	**TB**
DM2	23.71 (0.00)	9.97 (0.04)	10.74 (0.03)	9.23 (0.05)
GDP	10.09 (0.04)	7.78 (0.09)	2.45 (0.65)	18.64 (0.00)
DEF	6.72 (0.15)	6.95 (0.14)	26.71 (0.00)	6.73 (0.15)
TB	95.24 (0.00)	18.35 (0.00)	18.51 (0.00)	14.47 (0.00)
ECM	18.39 (0.00)	4.52 (0.03)	12.19 (0.00)	4.74 (0.03)
	SSM3	**GDP**	**DEF**	**TB**
SSM3	89.12 (0.00)	5.04 (0.28)	8.74 (0.07)	1.04 (0.90)
GDP	11.88 (0.02)	15.23 (0.00)	2.61 (0.63)	9.80 (0.04)
DEF	12.32 (0.02)	6.84 (0.14)	25.13 (0.00)	10.49 (0.03)
TB	10.52 (0.03)	22.28 (0.00)	13.14 (0.01)	9.91 (0.04)
ECM	8.50 (0.00)	0.68 (0.41)	13.25 (0.00)	2.67 (0.10)

Table 16 (continued)

Causality Tests for the United States

	DM3	GDP	DEF	TB
DM3	38.22 (0.00)	8.64 (0.07)	10.82 (0.03)	7.16 (0.13)
GDP	9.20 (0.05)	9.37 (0.05)	3.21 (0.52)	18.27 (0.00)
DEF	6.45 (0.17)	6.58 (0.16)	29.61 (0.00)	6.61 (0.16)
TB	78.27 (0.00)	18.73 (0.00)	18.79 (0.00)	15.62 (0.00)
ECM	14.58 (0.00)	3.02 (0.08)	13.77 (0.00)	5.66 (0.02)
	SSL	**GDP**	**DEF**	**TB**
SSL	92.18 (0.00)	7.16 (0.13)	7.96 (0.09)	2.54 (0.64)
GDP	24.22 (0.00)	15.34 (0.00)	3.17 (0.53)	10.07 (0.04)
DEF	13.82 (0.00)	6.94 (0.14)	16.05 (0.00)	10.64 (0.03)
TB	20.53 (0.00)	27.57 (0.00)	13.11 (0.01)	11.04 (0.03)
ECM	17.05 (0.00)	0.75 (0.38)	13.69 (0.00)	1.17 (0.27)
	DL	**GDP**	**DEF**	**TB**
DL	33.11 (0.00)	12.01 (0.02)	7.79 (0.09)	7.39 (0.12)
GDP	12.87 (0.01)	10.37 (0.03)	2.91 (0.57)	14.26 (0.00)
DEF	6.47 (0.16)	7.07 (0.13)	26.05 (0.00)	7.05 (0.13)
TB	68.23 (0.00)	23.47 (0.00)	16.64 (0.00)	15.57 (0.00)
ECM	14.45 (0.00)	2.76 (0.09)	11.96 (0.00)	3.94 (0.04)
	RCE1	**GDP**	**DEF**	**TB**
RCE1	37.52 (0.00)	11.78 (0.02)	5.27 (0.26)	32.10 (0.00)
GDP	17.22 (0.00)	9.47 (0.05)	0.87 (0.93)	11.08 (0.02)
DEF	3.55 (0.47)	7.18 (0.13)	53.72 (0.00)	6.94 (0.14)
TB	17.83 (0.00)	15.47 (0.00)	4.92 (0.79)	10.16 (0.04)
	RCE2	**GDP**	**DEF**	**TB**
RCE2	26.14 (0.00)	8.57 (0.07)	10.33 (0.04)	28.56 (0.00)
GDP	16.07 (0.00)	13.65 (0.00)	1.69 (0.79)	13.13 (0.01)
DEF	2.86 (0.58)	7.11 (0.13)	42.38 (0.00)	7.11 (0.13)
TB	16.66 (0.00)	16.36 (0.00)	8.02 (0.09)	10.04 (0.04)
ECM	7.64 (0.00)	1.72 (0.18)	4.34 (0.04)	4.74 (0.03)
	BCE	**GDP**	**DEF**	**TB**
BCE	12.78 (0.01)	5.66 (0.23)	5.61 (0.23)	7.02 (0.11)
GDP	7.41 (0.12)	9.83 (0.04)	1.46 (0.83)	20.56 (0.00)
DEF	4.09 (0.39)	6.05 (0.19)	30.72 (0.00)	8.51 (0.07)
TB	62.27 (0.00)	17.52 (0.00)	12.19 (0.02)	12.95 (0.01)
ECM	0.27 (0.60)	4.46 (0.03)	5.79 (0.02)	6.44 (0.01)

Note: The variables are as defined in Table 8. The variable at the column head is the dependent variable. The numbers not in parentheses are linear Wald statistics, while the numbers in parentheses are marginal significance levels.

Table 17

Causality Tests for the United Kingdom

	SSM4	GNP	DEF	TB
SSM4	39.89 (0.00)	0.26 (0.99)	1.90 (0.75)	17.59 (0.00)
GNP	11.20 (0.02)	2.39 (0.66)	9.08 (0.06)	10.22 (0.04)
DEF	28.74 (0.00)	2.79 (0.59)	5.28 (0.26)	3.97 (0.41)
TB	4.44 (0.35)	3.97 (0.41)	11.99 (0.02)	8.66 (0.07)
ECM	4.26 (0.12)	8.46 (0.01)	24.38 (0.00)	10.71 (0.00)
	DM4	**GNP**	**DEF**	**TB**
DM4	15.58 (0.00)	4.88 (0.30)	14.59 (0.00)	13.52 (0.00)
GNP	1.43 (0.84)	1.91 (0.75)	6.18 (0.19)	7.60 (0.11)
DEF	16.30 (0.00)	2.17 (0.70)	12.23 (0.02)	8.15 (0.08)
TB	6.58 (0.16)	3.58 (0.46)	5.74 (0.22)	2.11 (0.72)
ECM	4.54 (0.10)	0.92 (0.63)	27.67 (0.00)	2.03 (0.36)

Note: See Table 16.

there is a clear differential impact. For example, in terms of the output equation, the Divisia monetary measure is significant at the 5 percent level in three cases (namely, DM2, DL and RCE1) and at the 7 percent level in two instances (that of DM3 and RCE1), but none of the simple-sum money terms enters significantly even at the 10 percent level. It is also interesting to note that among the two currency equivalent measures, it is only the RCE measure which features significantly in the real output equation (confirming the significant influence for this monetary measure noted by Belongia, 1993). The significance of these Divisia measures is repeated in the deflator equations (apart from RCE1, although, additionally, DM1A is also significant), although in these equations one of the simple-sum measures is also significant (for SSM1A). With respect to monetary causality in the United States, TB equations, both simple sum and Divisia seem to do equally well in that each measure has significant strikes.

The U.K. evidence, reported in Table 17, contrasts sharply with that for Switzerland. Neither M4 nor Divisia M4 affects real GNP. However, Divisia M4 does influence the inflation rate. Both money measures influence interest rates. Thus, the superiority of Divisia M4 over M4 is confirmed (at least so far as inflation is concerned), but the lack of causality from money to real activity is noteworthy.

The Australian results, recorded in Table 18, differ from the U.S. results in that the TB rate does not have a significant short-run influence in any of the real output equations or in the price equations. However, in common with the U.S. results, Divisia money is significant—both M2 and M3—in the real output equation, whereas the simple-sum measures are not. In contrast, however, it is the simple-sum measures which have a significant short-run impact in the TB equations rather than the Divisia measures. There are also significant long-run influences in all of the equations, although these do not seem to be confined to any particular measure of money.

For Germany, none of the monetary impulses —neither Divisia nor simple-sum—appears with a significant influence in the real output equations, although there would appear to be an interest rate effect in this equation for the two sum measures of money. Real GDP has a significant influence in all of the money equations, apart from SSM2. The joint effect of the TB rate is significant in all of the money equations and inflation, in turn, has a significant impact on interest rates.

Both simple-sum and Divisia monetary measures have also a significant influence on inflation and the TB rate in the Swiss case (Table 20), although in contrast to the German case

Table 18

Causality Tests for Australia

	SSM2	GDP	DEF	TB
SSM2	18.76 (0.00)	9.05 (0.06)	7.06 (0.13)	18.18 (0.00)
GDP	3.21 (0.52)	16.06 (0.00)	30.92 (0.00)	3.45 (0.48)
DEF	5.40 (0.25)	17.95 (0.00)	19.35 (0.00)	5.33 (0.25)
TB	21.29 (0.00)	2.51 (0.64)	6.18 (0.18)	13.15 (0.01)
ECM	0.68 (0.41)	2.32 (0.12)	0.07 (0.79)	8.68 (0.00)
	DM2	**GDP**	**DEF**	**TB**
DM2	19.24 (0.00)	9.15 (0.00)	4.24 (0.37)	3.87 (0.42)
GDP	4.07 (0.39)	15.68 (0.00)	22.32 (0.00)	4.91 (0.79)
DEF	6.08 (0.19)	16.68 (0.00)	19.61 (0.00)	4.01 (0.40)
TB	4.49 (0.34)	4.24 (0.37)	4.75 (0.31)	11.81 (0.02)
ECM	4.07 (0.04)	8.07 (0.00)	3.59 (0.06)	0.70 (0.40)
	SSM3	**GDP**	**DEF**	**TB**
SSM3	17.40 (0.00)	7.27 (0.12)	2.91 (0.57)	9.72 (0.04)
GDP	15.78 (0.00)	11.46 (0.02)	38.99 (0.00)	4.66 (0.32)
DEF	10.38 (0.03)	12.67 (0.01)	18.73 (0.20)	5.74 (0.22)
TB	12.91 (0.01)	2.67 (0.61)	6.21 (0.18)	19.21 (0.00)
ECM	18.76 (0.00)	10.14 (0.00)	7.54 (0.02)	6.52 (0.04)
	DM3	**GDP**	**DEF**	**TB**
DM3	27.15 (0.00)	14.94 (0.00)	2.53 (0.64)	1.47 (0.83)
GDP	4.24 (0.37)	24.13 (0.00)	30.65 (0.00)	5.45 (0.24)
DEF	7.99 (0.09)	24.23 (0.00)	15.79 (0.00)	6.71 (0.15)
TB	5.05 (0.28)	4.99 (0.28)	4.88 (0.29)	11.33 (0.02)
ECM	0.13 (0.72)	5.41 (0.02)	0.02 (0.88)	6.78 (0.00)

Note: See Table 16.

Table 19

Causality Tests for Germany

	SSM2	GDP	DEF	TB
SSM2	6.92 (0.14)	3.17 (0.53)	9.08 (0.00)	0.81 (0.74)
GDP	1.49 (0.83)	31.97 (0.00)	9.39 (0.06)	3.90 (0.42)
DEF	3.99 (0.41)	1.62 (0.81)	24.15 (0.00)	9.33 (0.05)
TB	10.56 (0.03)	16.55 (0.00)	7.68 (0.10)	14.35 (0.00)
ECM	3.91 (0.05)	6.41 (0.01)	11.79 (0.00)	0.85 (0.36)
	DM2	**GDP**	**DEF**	**TB**
DM2	8.92 (0.06)	1.54 (0.82)	9.88 (0.04)	6.93 (0.14)
GDP	18.82 (0.00)	9.08 (0.05)	6.52 (0.16)	6.87 (0.14)
DEF	5.15 (0.27)	3.28 (0.51)	33.66 (0.00)	10.16 (0.04)
TB	24.47 (0.00)	5.05 (0.78)	12.75 (0.01)	5.02 (0.78)
ECM	50.64 (0.00)	5.54 (0.06)	21.10 (0.00)	1.82 (0.40)
	SSM3	**GDP**	**DEF**	**TB**
SSM3	4.71 (0.32)	3.79 (0.43)	0.04 (0.99)	6.32 (0.18)
GDP	17.41 (0.00)	24.94 (0.00)	1.58 (0.81)	3.22 (0.52)
DEF	37.78 (0.00)	1.52 (0.82)	9.92 (0.04)	3.37 (0.49)
TB	21.18 (0.00)	10.68 (0.03)	12.55 (0.01)	9.99 (0.04)
ECM	38.10 (0.00)	6.46 (0.04)	3.79 (0.19)	25.81 (0.00)
	DM3	**GDP**	**DEF**	**TB**
DM3	16.73 (0.00)	2.37 (0.66)	14.54 (0.00)	7.16 (0.13)
GDP	30.32 (0.00)	19.03 (0.00)	4.63 (0.33)	4.64 (0.33)
DEF	50.59 (0.00)	1.08 (0.89)	7.29 (0.12)	11.17 (0.02)
TB	41.28 (0.00)	1.68 (0.79)	7.14 (0.13)	9.15 (0.06)
ECM	55.30 (0.00)	1.22 (0.54)	30.37 (0.00)	0.53 (0.76)

Note: See Table 16.

Table 20

Causality Tests for Switzerland

	SSM1	GNP	DEF	TB
SSM1	7.47 (0.11)	18.96 (0.00)	24.09 (0.00)	6.56 (0.16)
GNP	22.21 (0.00)	50.69 (0.00)	18.80 (0.00)	25.46 (0.00)
DEF	14.71 (0.00)	13.43 (0.00)	21.44 (0.00)	10.05 (0.04)
TB	10.35 (0.03)	26.68 (0.00)	7.15 (0.13)	12.74 (0.01)
ECM	25.22 (0.00)	10.65 (0.00)	13.21 (0.00)	2.54 (0.28)
	DM1	**GNP**	**DEF**	**TB**
DM1	7.26 (0.12)	18.83 (0.00)	24.75 (0.00)	6.59 (0.16)
GNP	20.11 (0.00)	50.48 (0.00)	19.68 (0.00)	24.96 (0.00)
DEF	15.04 (0.00)	12.91 (0.02)	21.76 (0.00)	10.18 (0.04)
TB	9.75 (0.04)	26.38 (0.00)	7.59 (0.11)	12.75 (0.01)
ECM	24.11 (0.00)	10.66 (0.00)	13.95 (0.00)	2.67 (0.26)
	SSM2	**GNP**	**DEF**	**TB**
SSM2	7.69 (0.10)	5.59 (0.23)	13.10 (0.01)	29.64 (0.00)
GNP	5.70 (0.22)	46.40 (0.00)	12.01 (0.02)	13.26 (0.01)
DEF	11.74 (0.02)	17.95 (0.00)	35.34 (0.00)	14.81 (0.01)
TB	30.06 (0.00)	49.45 (0.00)	15.47 (0.00)	23.78 (0.00)
ECM	14.15 (0.00)	32.73 (0.00)	10.53 (0.00)	11.94 (0.00)
	DM2	**GNP**	**DEF**	**TB**
DM2	10.17 (0.04)	10.64 (0.03)	30.98 (0.00)	18.57 (0.00)
GNP	4.54 (0.33)	76.37 (0.00)	23.46 (0.00)	26.24 (0.00)
DEF	5.07 (0.28)	8.85 (0.06)	44.67 (0.00)	19.76 (0.00)
TB	5.86 (0.21)	25.41 (0.00)	12.71 (0.01)	15.15 (0.00)
ECM	3.66 (0.16)	19.53 (0.00)	50.06 (0.00)	19.04 (0.00)

Note: See Table 16.

Table 21
Causality Tests for Canada

	SSM1	GNP	DEF	TB
SSM1	3.48 (0.48)	10.22 (0.03)	4.79 (0.31)	2.77 (0.54)
GNP	6.32 (0.18)	7.11 (0.13)	3.27 (0.51)	11.55 (0.02)
DEF	2.09 (0.72)	15.89 (0.00)	10.53 (0.03)	5.54 (0.23)
TB	8.94 (0.06)	1.91 (0.75)	3.98 (0.41)	16.95 (0.00)
ECM	15.08 (0.00)	11.46 (0.00)	1.80 (0.40)	9.02 (0.01)
	DM1	**GNP**	**DEF**	**TB**
DM1	5.39 (0.25)	8.89 (0.06)	5.16 (0.27)	3.82 (0.43)
GNP	11.20 (0.02)	7.09 (0.13)	5.95 (0.20)	9.65 (0.04)
DEF	2.34 (0.67)	34.00 (0.00)	16.58 (0.00)	7.17 (0.12)
TB	7.88 (0.09)	9.18 (0.05)	1.39 (0.84)	16.68 (0.00)
ECM	16.96 (0.00)	46.18 (0.00)	0.68 (0.71)	5.01 (0.08)
	SSM2	**GNP**	**DEF**	**TB**
SSM2	22.25 (0.00)	6.65 (0.16)	12.36 (0.01)	4.62 (0.33)
GNP	5.24 (0.76)	2.75 (0.60)	4.74 (0.31)	15.11 (0.00)
DEF	10.13 (0.04)	7.57 (0.11)	29.68 (0.00)	19.07 (0.00)
TB	49.24 (0.00)	5.11 (0.28)	6.06 (0.19)	11.16 (0.02)
ECM	0.04 (0.83)	9.85 (0.00)	0.68 (0.41)	0.78 (0.38)
	DM2	**GNP**	**DEF**	**TB**
DM2	30.89 (0.00)	1.24 (0.84)	5.46 (0.24)	6.97 (0.14)
GNP	8.97 (0.06)	2.02 (0.73)	2.89 (0.68)	12.25 (0.01)
DEF	8.61 (0.07)	11.33 (0.02)	19.24 (0.00)	19.59 (0.00)
TB	25.85 (0.00)	2.41 (0.66)	3.54 (0.47)	9.88 (0.04)
ECM	2.81 (0.09)	7.53 (0.00)	0.60 (0.44)	0.11 (0.74)

both Divisia measures appear significant in the output equation, as does SSM1. In common with a number of other countries, the TB rate has a statistical influence in all of the output equations and in three of the money equations. It is noteworthy that the joint effect of inflation is statistically significant in three out of four of the output equations.

The Canadian results (Table 21) portray little significant impact of money on any variable (the exceptions being SSM3 and DM3 in the TB equation). Interest rates also do not have the same significant role to play as they did in the U.S. case for real output, although they do feature in the majority of money equations. The effects of price (or, more correctly, inflation) feature prominently in almost all of the TB equations.

The Japanese causality pattern (reported in Table 22) is in many ways similar to that for Germany. Thus, neither simple-sum nor Divisia money enters significantly into the output equation, although there is a significant impact of both types of money in the inflation and TB equations. The TB rate also features significantly in all of the Japanese real output equations but, in contrast to the German case, only enters significantly into one other equation (apart from its own lags)—that for DM3.

Table 21 (continued)

Causality Tests for Canada

	SSM3	GNP	DEF	TB
SSM3	64.96 (0.00)	6.30 (0.17)	7.25 (0.12)	13.12 (0.01)
GNP	8.25 (0.08)	4.25 (0.37)	7.24 (0.12)	15.93 (0.00)
DEF	7.34 (0.12)	8.13 (0.08)	20.25 (0.00)	27.09 (0.00)
TB	16.58 (0.00)	7.00 (0.14)	9.04 (0.06)	10.08 (0.04)
ECM	0.00 (0.95)	13.33 (0.00)	0.34 (0.56)	1.02 (0.31)
	DM3	**GNP**	**DEF**	**TB**
DM3	22.32 (0.00)	1.27 (0.86)	5.27 (0.26)	10.69 (0.03)
GNP	12.82 (0.01)	4.67 (0.32)	4.01 (0.40)	13.26 (0.01)
DEF	26.96 (0.00)	6.08 (0.19)	18.74 (0.00)	21.38 (0.00)
TB	13.52 (0.00)	1.88 (0.76)	3.00 (0.56)	7.74 (0.10)
ECM	2.96 (0.23)	12.18 (0.00)	1.20 (0.55)	0.52 (0.77)
	SSL	**GNP**	**DEF**	**TB**
SSL	15.36 (0.00)	1.63 (0.80)	0.97 (0.91)	6.39 (0.17)
GNP	3.51 (0.48)	1.67 (0.79)	4.97 (0.29)	11.61 (0.02)
DEF	3.98 (0.41)	11.92 (0.02)	20.64 (0.00)	20.11 (0.00)
TB	7.50 (0.11)	1.78 (0.86)	3.87 (0.42)	14.04 (0.00)
ECM	1.15 (0.78)	11.48 (0.00)	0.51 (0.48)	0.57 (0.45)
	DL	**GNP**	**DEF**	**TB**
DL	59.15 (0.00)	1.38 (0.84)	1.38 (0.84)	4.19 (0.38
GNP	14.29 (0.00)	2.25 (0.68)	3.98 (0.41)	9.38 (0.05)
DEF	15.84 (0.00)	9.52 (0.04)	21.27 (0.00)	16.82 (0.00)
TB	9.34 (0.05)	2.04 (0.73)	3.78 (0.44)	10.11 (0.04)
ECM	1.97 (0.16)	8.55 (0.00)	0.58 (0.44)	0.09 (0.76)

Note: See Table 16.

We may summarize the results reported in this section in the following way. First, there appear to be countries in which Divisia money has greater informational content than simple-sum money and this is most clear in the U.S. and Australian cases. This is possibly because the pace of financial innovation has varied across countries. Such differential impacts across countries also holds true for other variables. In particular, the widely cited effect that the interest rate has in U.S. causality tests does not seem to carry over to other countries. Also, although Divisia money does not have a significant impact in all countries, the evidence for the United Kingdom suggests that this, at least in part, may be attributable to the sophistication with which the Divisia measure is constructed. Thus, although none of the U.K. Divisia measures has a significant effect on real output, the Bank of England Divisia measure (BOED) does have significant informational content for inflation. This measure is widely regarded as being superior to the other measures, perhaps because the Bank economists had access to detailed data on asset compositions which are not publicly available.

Table 22

Causality Tests for Japan

	SSM1	GNP	DEF	TB
SSM1	6.82 (0.15)	1.69 (0.79)	4.30 (0.37)	8.37 (0.07)
GNP	4.81 (0.31)	25.08 (0.00)	3.82 (0.43)	3.47 (0.48)
DEF	2.56 (0.63)	7.61 (0.11)	32.52 (0.00)	7.85 (0.09)
TB	3.84 (0.43)	9.83 (0.04)	7.39 (0.12)	10.65 (0.00)
ECM	10.66 (0.00)	12.33 (0.00)	6.55 (0.04)	10.94 (0.00)
	DM1	**GNP**	**DEF**	**TB**
DM1	11.93 (0.02)	1.46 (0.83)	3.97 (0.41)	8.89 (0.06)
GNP	5.25 (0.26)	24.64 (0.00)	3.75 (0.44)	3.39 (0.49)
DEF	2.21 (0.69)	8.04 (0.08)	34.01 (0.00)	7.92 (0.09)
TB	4.57 (0.33)	9.17 (0.06)	7.17 (0.13)	19.25 (0.00)
ECM	11.36 (0.00)	12.17 (0.00)	6.54 (0.04)	11.16 (0.00)
	SSM2	**GNP**	**DEF**	**TB**
SSM2	39.02 (0.00)	1.10 (0.89)	10.41 (0.03)	14.06 (0.00)
GNP	6.02 (0.19)	21.36 (0.00)	4.33 (0.36)	6.16 (0.18)
DEF	7.75 (0.10)	6.37 (0.17)	35.58 (0.00)	5.18 (0.27)
TB	7.13 (0.13)	12.22 (0.02)	7.10 (0.13)	17.47 (0.00)
ECM	9.15 (0.01)	14.14 (0.00)	3.61 (0.16)	10.97 (0.00)
	DM2	**GNP**	**DEF**	**TB**
DM2	57.64 (0.00)	1.04 (0.90)	11.72 (0.02)	11.08 (0.03)
GNP	4.36 (0.36)	22.02 (0.00)	3.92 (0.42)	4.48 (0.34)
DEF	9.19 (0.05)	8.15 (0.08)	34.41 (0.00)	8.04 (0.09)
TB	8.84 (0.06)	14.81 (0.00)	6.40 (0.17)	21.34 (0.00)
ECM	6.83 (0.03)	13.31 (0.01)	3.78 (0.15)	15.57 (0.00)
	SSM3	**GNP**	**DEF**	**TB**
SSM3	47.24 (0.00)	0.74 (0.94)	8.53 (0.07)	13.92 (0.01)
GNP	4.06 (0.39)	19.25 (0.00)	3.44 (0.48)	7.37 (0.11)
DEF	6.97 (0.14)	6.39 (0.17)	34.03 (0.00)	6.49 (0.16)
TB	7.03 (0.13)	10.49 (0.03)	6.97 (0.14)	17.58 (0.00)
ECM	7.74 (0.02)	12.69 (0.00)	3.57 (0.16)	10.03 (0.00)
	DM3	**GNP**	**DEF**	**TB**
DM3	66.52 (0.00)	0.73 (0.94)	12.16 (0.02)	10.93 (0.02)
GNP	3.19 (0.53)	20.91 (0.00)	3.23 (0.52)	4.59 (0.33)
DEF	9.70 (0.04)	8.13 (0.08)	33.71 (0.00)	8.20 (0.08)
TB	9.41 (0.05)	13.93 (0.00)	6.40 (0.17)	21.08 (0.00)
ECM	6.07 (0.05)	13.05 (0.00)	3.87 (0.14)	14.56 (0.00)

Note: See Table 16.

Table 23

Estimated Trace and λMax Statistics: United States Sub-Samples

TRACE (LR1)

SSM1	DM1	SSM1A	DM1A	SSM2	DM2	SSM3	DM3	SSL	DL	RCE	BCE
1.02	0.86	0.02	0.57	3.25	0.02	0.83	0.01	1.44	0.06	6.07	0.16
11.23	12.42	12.96	13.50	18.55	10.29	12.11	11.13	14.31	1.44	20.99	9.01
29.31	30.18	30.33	29.34	36.89	27.23	27.47	27.33	34.77	28.69	41.70	30.04
53.90	53.92	52.67	51.00	62.29	49.45	54.19	50.09	63.07	50.37	67.90	56.69

λMAX (LR2)

SSM1	DM1	SSM1A	DM1A	SSM2	DM2	SSM3	DM3	SSL	DL	RCE	BCE
1.02	0.86	0.02	0.57	3.25	0.02	0.83	0.01	1.44	0.06	6.08	0.16
10.22	11.56	12.93	13.44	15.30	10.28	11.29	11.12	12.86	9.38	9.38	8.84
18.07	17.76	17.37	15.84	17.34	16.94	15.35	16.19	20.46	20.46	20.46	21.03
24.60	23.74	22.34	21.66	26.40	22.21	26.72	22.76	28.91	28.91	26.28	26.66

Sub-Sample Results for the United States: the Post-1979 Regime Change

The causality results reported in the previous section are for the longest span of data for which consistent simple-sum and Divisia data are available for each country. Within each country-specific data sample, there may be one or two changes in the way monetary policy has been implemented. Thus, some countries have switched from targeting one particular aggregate to another or have switched from monetary targeting to interest rate targeting, or vice versa. Therefore, it is of interest to inquire if the results reported in the previous section carry through for sub-samples corresponding to specific monetary regimes. One of the possible examples of a regime change arises in the United States around 1980, when a combination of reforms (including a change in Fed operating procedure and a liberalization of deposit markets) produced an apparent shift in previously stable monetary relationships (Rasche 1993). Given this, and also since the U.S. data sample is one of the longest, we concentrate our sub-sample tests on our U.S. data set. In particular, we have re-estimated our U.S. causality tests for the first quarter of 1960 to the third quarter of 1979 (lags being generated within this sample).

In Table 23, the estimated Trace and λmax statistics are reported for our chosen U.S. sub-sample. In contrast to the full sample results, it is noteworthy that all of the monetary measures produce at least one cointegrating vector (for the full sample, none of the M1 monetary measures produced any cointegrating vectors). We therefore use the information concerning the number of cointegrating vectors to set up appropriate VECMs for each monetary measure. The sub-sample exclusion tests based upon these VECMs are reported in Table 24. The broad conclusion to emerge from this table is, perhaps not surprisingly, that the sub-sample produces a very different picture with respect to the relative merits of simple-sum and Divisia money. More specifically, we note that the significant impact of money in the real output equations occurs for the narrow M1 measures of money and not for the broader measures (and, in terms of the M1 measures, simple sum seems to outperform Divisia since two of the sum measures are significant at the 5 percent level against one Divisia measure at this significance level). Of the two currency equivalent measures, RCE is insignificant in the GDP equation, while BCE is significant (albeit at the 6 percent level of significance) the reverse of our findings for the full sample. Other notable features of the sub-sample results, which are dis-

Table 24
Sub-Sample Causality Tests for the United States

	SSM1	GDP	DEF	TB
SSM1	57.23 (0.00)	11.28 (0.02)	13.04 (0.01)	32.78 (0.00)
GDP	5.87 (0.21)	2.44 (0.65)	1.98 (0.74)	6.99 (0.14)
DEF	8.87 (0.06)	5.34 (0.25)	39.38 (0.00)	1.11 (0.89)
TB	15.20 (0.00)	5.94 (0.20)	6.52 (0.16)	41.57 (0.00)
ECM	5.55 (0.02)	9.99 (0.00)	0.42 (0.52)	0.49 (0.48)
	DM1	**GDP**	**DEF**	**TB**
DM1	27.14 (0.00)	10.69 (0.03)	15.16 (0.00)	18.57 (0.00)
GDP	0.62 (0.96)	4.29 (0.37)	3.53 (0.47)	8.27 (0.08)
DEF	3.80 (0.43)	7.31 (0.12)	11.99 (0.02)	1.04 (0.90)
TB	22.95 (0.00)	5.28 (0.26)	8.33 (0.08)	22.31 (0.00)
ECM	1.20 (0.27)	10.22 (0.00)	3.29 (0.07)	0.03 (0.87)
	SSM1A	**GDP**	**DEF**	**TB**
SSM1A	40.06 (0.00)	10.76 (0.03)	16.73 (0.00)	30.93 (0.00)
GDP	7.13 (0.13)	3.64 (0.46)	4.18 (0.38)	5.72 (0.22)
DEF	4.79 (0.31)	6.82 (0.14)	20.98 (0.00)	0.41 (0.98)
TB	15.13 (0.00)	5.14 (0.27)	8.94 (0.06)	42.39 (0.00)
ECM	1.81 (0.18)	10.80 (0.00)	2.96 (0.08)	0.04 (0.83)
	DM1A	**GDP**	**DEF**	**TB**
DM1A	26.63 (0.00)	8.14 (0.08)	19.14 (0.00)	17.75 (0.00)
GDP	0.85 (0.93)	4.69 (0.32)	7.34 (0.12)	7.02 (0.13)
DEF	3.74 (0.44)	8.36 (0.08)	4.94 (0.29)	0.22 (0.99)
TB	25.91 (0.00)	5.31 (0.26)	11.08 (0.03)	23.14 (0.00)
ECM	0.00 (0.97)	9.33 (0.00)	7.17 (0.00)	0.12 (0.73)

tinct from the full sample results, include the finding of a strongly significant effect of money on the deflator for all measures of money (except RCE) and a much less important role for the interest rate in the output equation. (The TB rate is only significant in two instances, whereas it was significant in all cases for the full sample.)

CONCLUSION

The evidence from the St. Louis equations is fairly straightforward: Divisia weighted aggregates appear to offer advantages over broad simple-sum monetary aggregates. The credibility of narrow simple-sum aggregates has universally been undermined by the spread of financial innovation. Although results of our real income causality tests are less persuasive. However, they still give a clear edge to Divisia aggregates over simple sum. The results are not so strong that we can conclude that Divisia money matters while simple sum does not. Nonetheless, it is clear from the U.S. evidence that the advantages of Divisia are particularly strong after 1980, the period in which financial innovation is greatest. Pre-1980 data do not show any support for Divisia. It may well be that if we could base our tests on post-1980 data alone, we would find much stronger support for Divisia. Also, the existence of reverse causality (from real income to money) is not particularly surprising given the fact that most authorities are pegging short-term interest rates or exchange rates. Superficially, this would support the "real business cycle" view or even the "money doesn't

Table 24 (continued)

Sub-Sample Causality Tests for the United States

	SSM2	GDP	DEF	TB
SSM2	45.44 (0.00)	6.54 (0.16)	11.22 (0.02)	17.30 (0.00)
GDP	3.53 (0.47)	7.48 (0.11)	2.93 (0.57)	7.22 (0.12)
DEF	5.73 (0.22)	9.99 (0.04)	1.14 (0.88)	4.03 (0.40)
TB	46.46 (0.00)	2.02 (0.73)	6.48 (0.17)	35.07 (0.00)
ECM	8.08 (0.01)	15.69 (0.00)	9.66 (0.00)	1.38 (0.50)

	DM2	GDP	DEF	TB
DM2	45.70 (0.00)	6.06 (0.19)	17.51 (0.00)	8.73 (0.07)
GDP	5.31 (0.26)	9.10 (0.06)	4.16 (0.39)	10.08 (0.04)
DEF	4.53 (0.34)	5.14 (0.27)	20.15 (0.00)	5.75 (0.22)
TB	76.87 (0.00)	2.69 (0.61)	8.02 (0.09)	26.04 (0.00)
ECM	3.63 (0.05)	0.16 (0.69)	3.26 (0.07)	2.13 (0.14)

	SSM3	GDP	DEF	TB
SSM3	74.22 (0.00)	1.01 (0.91)	20.52 (0.00)	4.88 (0.29)
GDP	5.00 (0.29)	5.27 (0.26)	7.44 (0.11)	7.26 (0.12)
DEF	4.35 (0.36)	9.62 (0.05)	2.72 (0.61)	1.99 (0.74)
TB	15.43 (0.00)	10.61 (0.03)	11.13 (0.03)	25.20 (0.00)
ECM	4.23 (0.04)	10.22 (0.00)	14.81 (0.00)	0.79 (0.37)

	DM3	GDP	DEF	TB
DM3	98.38 (0.00)	2.89 (0.57)	18.94 (0.00)	9.85 (0.04)
GDP	8.00 (0.09)	5.71 (0.22)	9.10 (0.06)	4.34 (0.36)
DEF	9.88 (0.04)	8.99 (0.06)	2.68 (0.61)	0.94 (0.92)
TB	38.56 (0.00)	3.23 (0.52)	18.72 (0.00)	25.78 (0.00)
ECM	6.14 (0.01)	10.94 (0.00)	9.25 (0.00)	0.18 (0.67)

matter" view. However, it may instead be the old problem of observational equivalence.

The policy significance of these results may be limited. Monetary authorities can no more control Divisia aggregates than they can broad money. However, Divisia aggregates undoubtedly offer potential information to monetary authorities about the relative ease or tightness of monetary stance—much more so than do broad simple-sum aggregates. However, the body of research supporting Divisia is not yet sufficiently large or robust that we would wish to recommend direct targeting at this stage. What is important, however, is that official credible Divisia index numbers should be produced so that researchers can test exhaustively the performance of these indicators. Only when a clear consensus emerges should policy be directly linked to such indicators. Just because an indicator does well in the 1980s does not mean it will do well in the 1990s. Divisia aggregates did particularly well at handling the introduction of interest on checking accounts. They may be less useful in a period of, say, the widespread adoption of "smart" cards.

In short, while our results are encouraging enough to suggest that monetary authorities should commission further work on Divisia, the picture which emerges is not sufficiently clear-cut to lead to immediate policy recommendations. However, the message for the economics profession is much clearer. All those who do applied research using money should take on board the fact that simple-sum measures are substantially distorted and a better measure is likely to be provided by a monetary services index constructed along something like Divisia lines. Rejections of the role of money based upon flawed money measures are themselves easy to reject.

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Commentary

WE ARE INDEBTED TO K. Alec Chrystal and Ronald MacDonald (1994) for assembling a valuable body of evidence on the relative explanatory power of simple-sum and Divisia versions of the money supply aggregates across a range of countries. This contribution comes at a time when the usefulness of money supply measures is called into question by economists across the policy spectrum. I am dismayed at the wide agreement among macroeconomists ranging from Alan Blinder to Robert Rasche that the money to income relationship is broken and that our conventional understanding of money demand is at a loss to explain the decline in velocity that has occurred during the past decade. Has the quickening pace of financial innovation rendered old relationships obsolete, as many are suggesting? Somehow this all sounds too familiar. Those of you who were around in the 1970s may recall "The Case of the Missing Money." Then it was a puzzling rise in velocity, and one explanation put forward was the quickening pace of financial innovation (see: Enzler, and others, 1976; Goldfeld, 1976; and Hamburger, 1977). Economists, nevertheless, continued to think that monetary aggregates were important, enough so that they were disappointed again a decade later when their models seemed to go off track.

Even the "monetarists" are in disarray among themselves on the issue of which aggregate to watch. At a Federal Reserve Bank of San Francisco conference last spring, the Bank's president, Robert Parry, quipped that Milton Friedman had told him that M2 was growing much too slowly while Allan Meltzer had told him that M1 was growing much too fast, so he figured that monetary policy must be just about right. In the face of that kind of disagreement, it becomes difficult at best to explain to skeptical colleagues or the public why they should take any monetary aggregate seriously as an indicator of monetary policy. But as one of the few teachers of introductory macroeconomics (perhaps the only one) who bases their course on the Quantity Theory of Money rather than the Keynesian Expenditure Model, I can't afford to take such a pessimistic view.

The first and perhaps primary set of results presented in this paper uses regressions of the growth rate of nominal income on the growth rate of a money aggregate, the growth rate of federal spending on goods and services, and, in the case of the United States, the change in the yield on Treasury bills. Lags of zero to four quarters are included. A second set of results adds four lags of the dependent variable to the regression. Test statistics compare each simple-sum (*SS*) aggregate with its Divisia (*D*) counterpart. The Akaike Information Criterion (AIC) statistic compares the likelihoods of the two regressions, and two other tests each produce a pair of *t*-statistics, one that can reject *SS* in favor of *D* and another that can reject *D* in favor of *SS*. Finally, *F*-statistics for the exclusion of all the money terms in each regression address the question, "Does money matter at all?"

In thinking about these regressions, I found it useful to keep in mind the distinction between a money demand equation and a reduced form equation by Leonall C. Andersen and Jerry L. Jordan (1968) and Leonall C. Andersen and Keith M. Carlson (1970) in their landmark papers. A simple money demand equation might be of the form:

(1) $M = K(i)\ Y\ e^{\varepsilon}$,

where Y is nominal income and $K(i)$ a function of the nominal interest rate i. Taking logs, denoted by lower case letters, and rearranging we have:

(2) $y = m - k(i) - \varepsilon$.

This is a structural equation and to get to the reduced form we need a model for the interest rate, something like:

(3) $i = p^e + r(gov,\ real\ shocks)$,

where p^e is expected inflation and $r(gov,\ real\ shocks)$ is the real rate as a function of government fiscal variables denoted gov, say the deficit as a fraction of GDP, and real shocks which may not be directly observed. In forming p^e, economic agents will presumably use information in the past history of m and gov. Substituting for p^e and then i, we have the reduced form equation:

(4) $y = y(m\ with\ lags,\ gov\ with\ lags) + E(\varepsilon,\ real\ shocks)$,

which is akin to the equation estimated by Andersen and Carlson. The U.S. regressions run by Chrystal and MacDonald, which include an interest rate, are structural and therefore have no obvious role for government spending, while regressions without the interest rate for other countries are in reduced form. In the latter case, I would expect the deficit rather than spending on goods and services to be the more appropriate government fiscal variable.

I want to mention in passing that there is nothing here that says that velocity must be constant, or deterministically trended, or stationary, or even cointegrated with the interest rate for there to be a useful and predictable relationship between money and income. The error processes ε and E may be integrated processes like random walks and indeed coefficients may also be stochastic processes without destroying our ability to estimate models and make predictions, although the kinds of processes involved will affect the accuracy of predictions and the deterioration of accuracy with forecast horizon. Certainly the fact that velocity did not continue to move along its upward trend of the 1970s does not in itself imply that money-income models are invalid, as some people seem to be saying. Twenty years ago, John P. Gould and I (1974) noted that velocity has experienced trend reversals in the past, behaving much like a random walk. Neither the characterization of velocity as a random walk, nor its link to nominal interest rates should have lead us to expect the velocity trend of the 1970s to continue indefinitely.

Turning to the results of the U.S. regressions, I am struck by how weak the evidence is for using Divisia in comparisons with the simple-sum aggregates. I expected that the superiority of the D versions would increase with aggregation since the idea is to extract the transactions part of the aggregate. Indeed, according to the Akaike Information Criterion which looks at the difference in log likelihoods, SSM1 is favored over DM1; DM2 has a slight edge over SSM2; and DM3 is strongly favored over SSM3, although the progression fails with L. One reason that I am surprised how small the AIC statistics are for D aggregates is that in a sense they are already fitted to the data. It would be interesting to see a comparison between SSM1 and DM2 to see whether most of the benefits of purging SSM2 are captured by SSM1, which is more readily available to most of us in real time. Similarly, it would be interesting to see direct comparisons between the relatively simple Currency Equivalent (CE) aggregate proposed at this conference last year by Rotemberg (1993) and the D aggregates. It would be helpful to the reader to have goodness-of-fit measures and log likelihoods reported for all the regressions so that other comparisons could be made easily. The t-tests give very puzzling results, frequently giving inconclusive results in which each version is rejected, in turn, in favor of the other. The character of the results does not change when lags of the dependent variable are included.

Does money matter? Does it matter if money matters? Perhaps less than I might have thought in the context of structural regressions which include an interest rate. Certainly, variation in velocity, proxied by the interest rate, may account for a considerable variation in nominal income, so money is not the only monetary variable in the model. Indeed, it is not surprising then that in the results for the U.S. reported in Table 1 SSM2 matters, in the sense of the F-test for inclusion of that variable, much more than SSM1, since the velocity of SSM1 varies much more than the velocity of SSM2. What puzzles me is that DM1 matters so much less than SSM1, in fact not at all, and results are even worse for DM1A.

Has the money-to-income relationship broken down since the early 1980s? It might be interesting to see if the regressions using the D aggregates are more stable than those for SS aggregates.

For the remaining countries, the regression does not include the interest rate, so for the non-U.S. countries, we are looking at a reduced form. As explained above, however, I might have expected the fiscal variable to be the budget deficit rather than spending on goods and services. The message I get from these countries overall is that DM2 works better than SSM2, but it is not important to use the D version of M1. Japan, of course, is a special case. I say "of course" because Japan seems to be different in many economic studies, a fact often pointed out with pride in my experience by Japanese economists. In the case of money aggregates, not only does Divisia not matter, but nothing about the aggregates matters. It would be interesting to see how the time series for Japan differs from the other countries to see what accounts for this result. I suspect it reflects lack of variation rather than lack of a relationship.

The unit root tests are of particular interest to me because we have a chance here to compare across countries. It warmed my heart to see only one variable that is apparently stationary in levels less than expected by chance out of the 54 variables if these series were all unrelated. And that one variable is a T-bill rate (for Australia), which is already first differenced because it is a growth rate. What is perhaps more surprising is how few other variables are stationary in growth rates. For Australia, stationary inflation and growth rates for GDP and SSM3 go along with stationarity in the level of the T-bill rate. But only 13 of the 54 series are stationary in first differences at the .05 level. Indeed, countries as seemingly regular as Switzerland have non-stationary growth rates, and for Japan it is only the T-bill rate that is stationary in first differences. Evidently, we live in an I(2) world.

Chrystal and MacDonald draw on the technology of cointegration to try to detect long-run relationships among the variables. Since the variables are generally I(2) while the VAR model used for detecting cointegrating vectors is to be estimated in first differences of I(1) variables, it is growth rates which become the relevant "levels" for this analysis. The authors report finding one or two cointegrating vectors for all the countries, implying that there is a long-run relationship among growth rates of the variables. The M1 aggregates for the United States are an important exception. In general, though, we would be missing some long-run information if we looked only at relationships among the stationary second differences of these variables. It would be interesting to see what those cointegrating relationships look like, whether they resemble a money-demand function or are something quite unexpected.

The VAR is then combined with the error correction term implied by cointegration (where applicable) so that each variable (in turn, the change in the growth rates of money, real GDP, the deflator and the T-bill rate) is predicted by four lagged values of itself and each of the other variables, as well as by the error correction mechanism (ECM). As in so many VAR studies, it turns out that the strongest predictor is simply the lagged value of the variable being predicted. For the United States, lags of other variables are generally not useful in predicting GDP or the inflation rate, except that the T-bill rate helps to predict—and, in turn, is predicted by—GDP inflation and M. The ECM also helps to predict inflation in the case of the broader aggregates. As we look across countries, the most striking regularity is the power of awkward, unclear lags in predicting each variable. Otherwise there is little regularity in the pattern of results which range from Switzerland, where almost every variable helps to predict every other variable, to the United Kingdom, where only the ECM seems to matter for GNP. Why the great differences?

If there is one variable that money should be able to predict, it is inflation. If the Divisia aggregates are superior measures of money, then one might expect them to be superior predictors of inflation. There is, however, very little difference in the significance of lags of Divisia aggregates verses simple sum, and no clear margin in favor of the former. However, the ECM also presumably includes the money aggregate, so differences in the contribution of the ECM must be attributed to the distinction between the aggregates. In the case of Australia, for example, lags of SSM2 are more significant in explaining inflation than are lags of DM2, but the error correction term that appears in the DM2 equation is more significant. Since the two equations differ only in the choice of the money aggregate, one must credit DM2 with the greater predictive power of the ECM in that equation.

In fact, lags of the aggregate may not matter at all given the ECM, and yet the aggregate may be playing an essential role in the ECM. There are many examples in the tables where the money aggregate itself is not significant but the ECM is. We cannot conclude in these cases that money does not matter, and for that reason I would not call these causality tests.

Another reason to be cautious in concluding that money does not matter if the lags of it are not significant is that the VAR is a restrictive framework in which to detect dynamic relationships. A few lags of a noisy variable will contain little information if the variable operates with a long lag. The interest rate is a powerful leading indicator probably because it smoothes much of the information contained in the very noisy money-growth series. I think that this limitation of VARs is one of the main reasons why we have learned so little from the large volume of work based on them. Perhaps it is time to take seriously again distributed-lag modelling, which allows for differing lag structures on different variables.

I would like to conclude with a plea for visual presentation of data. Economists are traditionally afraid to look at their data—it is considered cheating. I find, on the contrary, that plotting the data is an invaluable tool for understanding models, why they work or do not work, and how specification might be improved. I am uncomfortable with a statistical result that I cannot see in the data. Often, plotting the data reveals why a relationship we expected to find does not show up in formal tests and where it has gone off track. In this spirit, I have prepared a few charts that may be very familiar to many, but which I found helpful in putting in perspective the notion of a long-run relationship between money and income.

In Figure 1, I have plotted the velocities of M1 and M2 along with the T-bill rate. I did not have ready access to the Divisia counterparts. It makes clear the huge difference between the stability of the M2 velocity and the great variation in M1 velocity. Clearly, in a model of the money-income relationship, it will be very important to be able to explain the latter but relatively unimportant to explain the former. It also makes clear the fact that M1 velocity reflects long-term variation in the short-term interest rate but not short-term variation, as Rotemberg (1993) and others have noted. It is by no means obvious to me that the decline in M1 velocity since the early 1980s is in any way inconsistent with the decline in interest rates. M1 velocity and the interest rate are plausibly cointegrated; that is, they appear to track over a long time period, although they move apart over shorter periods.

These dynamics are evident in Figure 2, which is a scatter plot with the log of the velocity of M1 on the vertical axis and the log of the T-bill rate on the horizontal. There is a clear difference between the small, short-run response of velocity to a change in the T-bill rate and the large, long-run response. The last several points represent the period since the recession when the sharp decline in short-term interest rates has been accompanied by only a modest decline in M1 velocity. But it is not clear that this sluggish short-term response is out of line with experience.

Since the velocity of M1 evidently responds to the T-bill rate with a lag, I have smoothed the T-bill rate by replacing it in Figure 3 with the T-bond yield. While the long-term bond market may not provide the optimal smoother for this purpose, it is free and was not contrived. Now the scatter follows a smooth curve and recent experience is indistinguishable from past experience, a fact noted by Poole (1988) and others. I fail to see why we should abandon the idea that there is a stable, long-run relationship in levels between money, interest rates and nominal income. I wonder whether the substantial changes in parameters associated in this paper with the 1979 change of monetary regime would hold if the bond rate replaced the bill rate.

I do want to call your attention to the scatter plot for M2 velocity and the T-bond yield in Figure 4, because this presents more of a puzzle in its recent behavior. Keep in mind that we are looking at relatively little variation in the velocity, but certainly the bond yield accounts for little of it. Indeed, the recent rise in the velocity of M2 runs counter to the decline in both short- and long-term interest rates. What gives? Perhaps it is the beginning of the end for M2 as Higgins

Figure 1

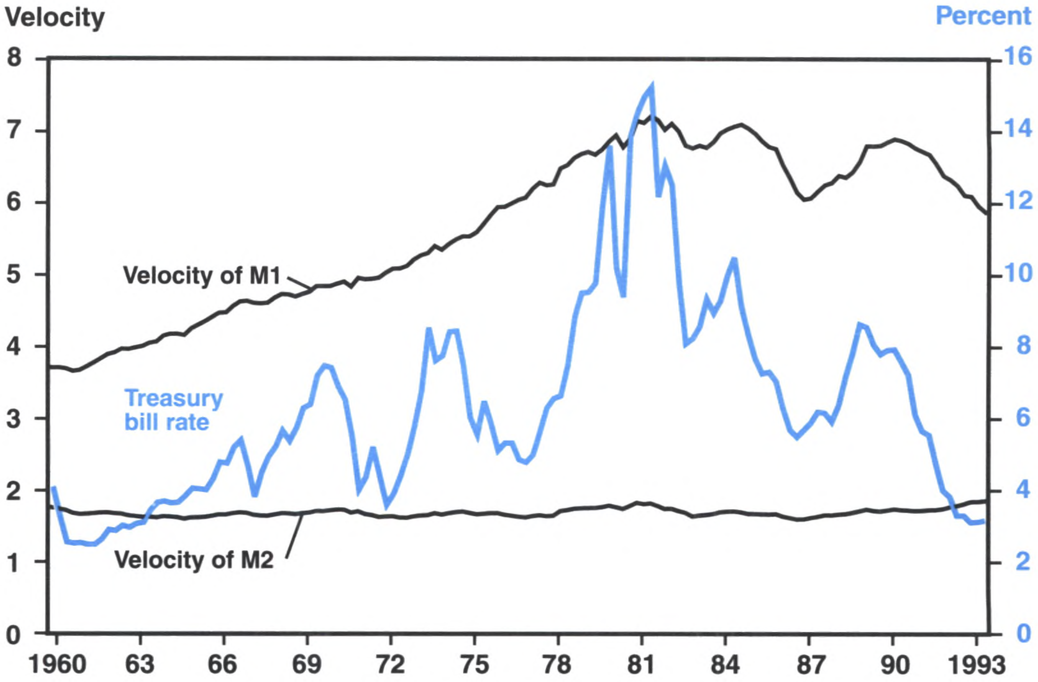


Figure 2

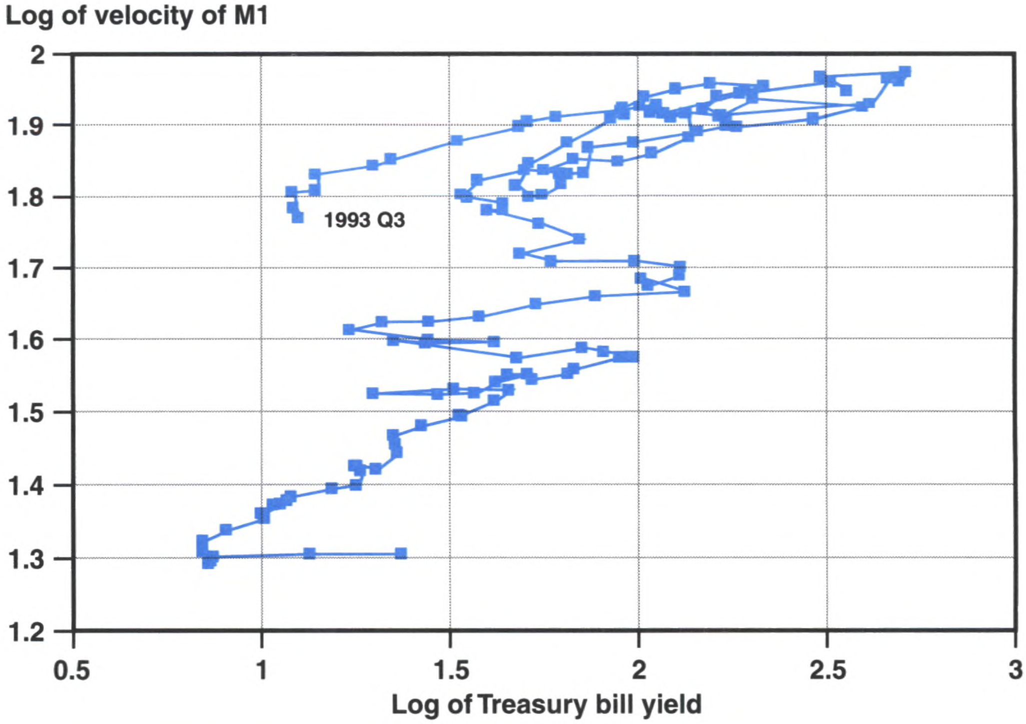


Figure 3

Log of velocity of M1

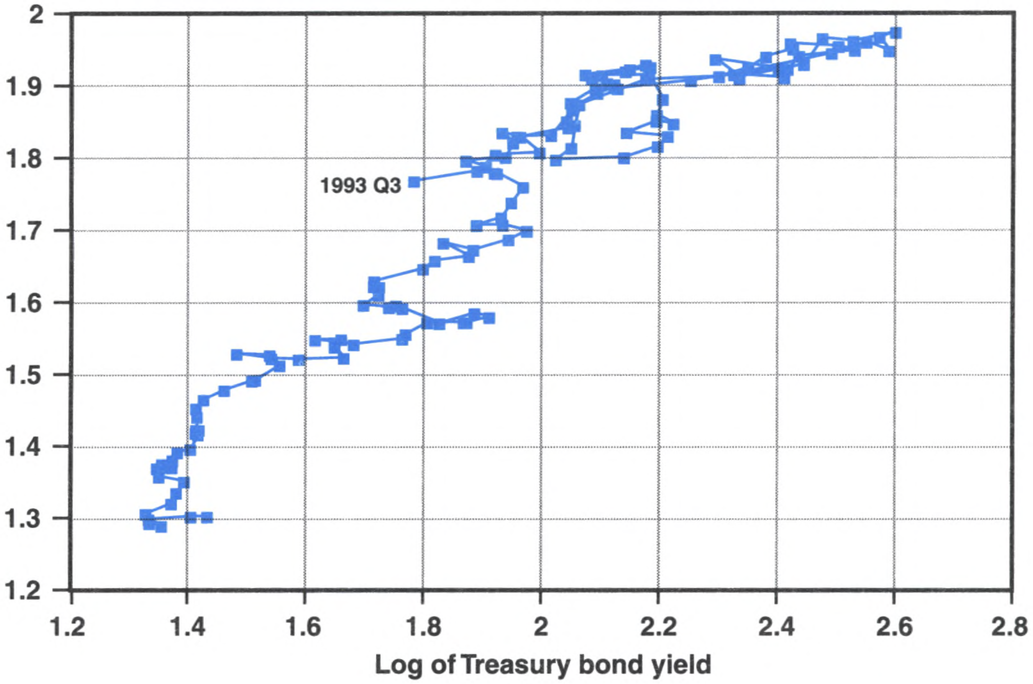
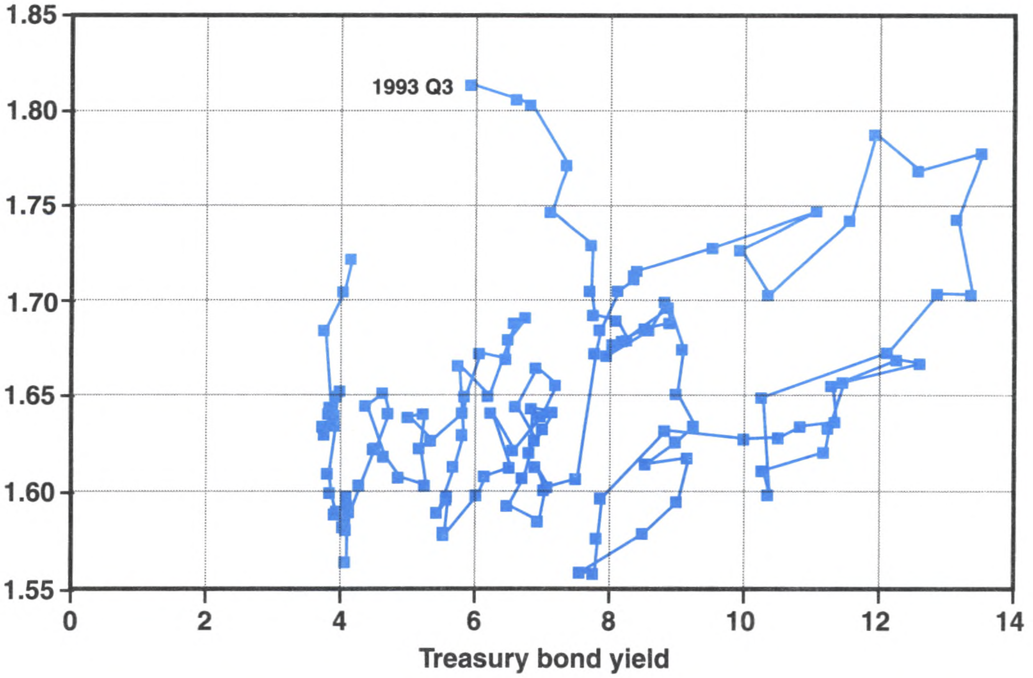


Figure 4

Velocity of M2



(1992) and others have suggested. My own view is that this is a temporary phenomenon related to the discovery of equity mutual funds by traditional holders of CDs. Even relatively sophisticated individuals have been explaining to me recently how mutual funds pay 15 percent compared to only 3 percent at the bank. There is an expected opportunity cost to holding M2 that we do not measure. My expectation is that M2 velocity will again fall into line after the public is awakened, perhaps rudely, to the fact that mutual fund shares are not CDs.

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Money Demand in a Flexible Dynamic Fourier Expenditure System

IN WELL-KNOWN SURVEYS of the growing literature on expenditure systems, Deaton and Muellbauer (1980) and Pollak and Wales (1992) describe many of the shortcomings of the existing work in this genre. Among the problems they list that inhibit the acceptance of these methods, the ones that seem most critical to us are (1) the failure to link theory to application, (2) improper aggregation techniques, (3) imprecise estimation of partial derivatives, (4) the failure of locally integrable models at some data points and (5) the misspecification of the dynamics. We can address several of these problems by extending the Fourier Flexible Form of Gallant (1981). Most notably, his technique provides global flexibility and arbitrarily accurate estimates of partial derivatives. In fact, the technique is capable of approximating the unknown function (an aggregator function, for example) to any desired degree of accuracy. The version of the Fourier model in current use, however, is static in nature, which inhibits its application to time-series data; in particular, studies by Gallant (1981), Ewis and Fisher (1985), and Fisher (1989, 1992), all employ the static model and all produce residuals that are not white noise for each share; see also Barnett, Fisher, and Serletis (1992). This may be due to inadequately modeled dynamics; in fact, there are no examples of a dynamic Fourier in the literature. The task of this paper is to produce and evaluate two dynamic alternatives in the context of the Fourier model.

In the traditional literature on consumer choice, the indirect utility function is approximated by a specific functional form in order to obtain expenditure shares and estimates of the important own- and cross-elasticities. One might attempt to estimate a parametric model, of course, but the results of such exercises have not been satisfactory. The chief problem has been model failure, partly related to the choice of specific (nonflexible) functional forms. To finesse this problem, a flexible functional form can be employed in order to estimate the unknown indirect utility function. Diewert (1974) defines a flexible functional form as a second-order approximation to an arbitrary twice continuously differentiable function $f(x)$ at any given point x^*; the popular translog is an example. The difficulty, however, is that this definition, and the resulting approximation, fails to impose precision on the partial derivatives of the function. Indeed, it is well-known that away from the point of approximation, the translog can perform quite poorly in its task of tracking the unknown function. The result is imprecise estimation of the expenditure shares.

Gallant (1981) developed the Fourier flexible form in order to approximate the unknown indirect utility function and its first derivatives arbitrarily accurately within a Sobolov norm. The first derivatives are important since the expenditure shares are derived by differentiation. The Fourier model, with its global properties, can then provide integrability over a finite region for the estimated model, assuming convergence. In particular, since integrability normally implies a convex closure over a finite region, one can presume desirable separability properties for data examined under the Sobolov norm. This contrasts, as noted, with the possible lack of closure on procedures that provide an approximation only at a single point in the data space; in particular, it contrasts with locally integrable models (such as the Translog).

In this paper, we produce two versions of the dynamic Fourier expenditure system; these are then compared with the static model in various ways. In section two we briefly discuss the static model before going into considerable detail over what we will be calling the "time-series approach" to making the Fourier model dynamic. This basically follows the lead of Anderson and Blundell (1982, 1983), whose results are both well-known and have been applied in the literature on flexible functional forms (see Serletis, 1991). In section three, we continue with a second version of the dynamics, this time involving the construction of the dynamic Fourier utility function. We term this the "dynamic utility function approach." In section four, we present examples of the two dynamic models in order to clarify the ideas and explain the notation. It is here possible to establish clear distinctions between the models in the context of the Fourier. In section five, we go over the procedures used to prepare the data, and in section six, finally, we discuss estimates of the two dynamic models that utilize the U.S. data previously described. We also discuss how the two models perform in comparison with their static equivalents. Our conclusions follow.

THE TIME SERIES APPROACH

Following Gallant (1981), the static Fourier flexible form approximation of an indirect utility function h(**v**) may be written as

$$(1)\ h_k(v,\theta) = a_0 + b'v + \tfrac{1}{2}v'Cv + \sum_{\alpha=1}^{A}\sum_{j=-J}^{J} a_{j\alpha}e^{ijk'_\alpha v},$$

where

$$C = -\sum_{\alpha=1}^{A} a_{o\alpha}k_\alpha k'_\alpha \text{ and } a_{j\alpha} = \bar{a}_{-j\alpha},$$

a_o, $a_{o\alpha}$ and b are real-valued, and **v** is a vector of the expenditure-normalized user costs of the particular assets involved in the exercise (Gallant, 1981). In this expression the overbar denotes complex conjugation and i is the imaginary number. A multi-index k_α, is an n-vector with integer components and is used to denote partial differentiation of the utility function (see the example in section four). The elements of a multi-index can be considered to be the weights (when multiplied by v) of the normalized price indexes.

In an empirical investigation, it is actually more convenient to work with a sine/cosine formulation rather than the exponential just written and so the following form is generally employed:

$$(2)\ h_k(v,\theta) = u_o + b'v + \tfrac{1}{2}v'Cv + \sum_{\alpha=1}^{A}\left(u_{o\alpha} + 2\sum_{j=1}^{J}[u_{j\alpha}\cos(jk'_\alpha v) - w_{j\alpha}\sin(jk'_\alpha v)]\right),$$

in which

$$C = -\sum_{\alpha=1}^{A} u_{o\alpha}k_\alpha k'_\alpha.$$

After differentiating equation 2 and applying Roy's identity, Gallant arrives at the following set of equations:

$$(3)\ y_i(v,\theta) = \frac{v_i b_i - \sum_{\alpha=1}^{A}\left(u_{o\alpha}v'k_\alpha + 2\sum_{j=1}^{J} j[u_{j\alpha}\sin(jk'_\alpha v) + w_{j\alpha}\cos(jk'_\alpha v)]\right)k_{i\alpha}v_i}{b'v - \sum_{\alpha=1}^{A}\left(u_{o\alpha}v'k_\alpha + 2\sum_{j=1}^{J} j[u_{j\alpha}\sin(jk'_\alpha v) + w_{j\alpha}\cos(jk'_\alpha v)]\right)k'_\alpha v},$$

for $i = 1, ..., n$ expenditure shares. This system is what is estimated with a vector of error terms appended. Equation (3) can be more compactly expressed as:

(4) $y_{it} = f(v_t, \theta)$.

Note that we have attached a time subscript in order to emphasize the static nature of the equations. This completes the discussion of the static Fourier Flexible model.

Consumption, monetary and production theories use past variables—in the utility function, in the constraints, or by time-series methods—to model habit persistence, adjustment costs and/or expectations. In a demand systems approach, incorporating dynamics in any of these ways complicates the calculation of the restrictions, which still must hold. In the following exercises we present results for the time-series function and, in section three, for the utility function. We present the models first, including with each a discussion of the restrictions, before presenting examples of both.

For the time series model, applying an ARMA (p,q) directly to equation (4) is one approach toward modeling the dynamic behavior of the consumer. This approach is taken by Anderson (1980) for the special case when $f(v_t, \theta)$ is linear in the expenditure-normalized prices v_t and the parameters θ. He shows that adding up, as the direct result of adopting the ARMA approach, implies four additional restrictions. Anderson and Blundell (1982, 1983) extend the results for the case in which $f(v_t, \theta)$ may be nonlinear in the parameters but linear in the normalized prices V, i.e., $f(v_t, \theta) = \pi(\theta)v_t$. When applying an ARMA$(p,q)$ to equation (4), they can extract a term, $y_{t-p} - \pi(\theta)v_{t-q}$, the gap between the shares lagged p periods and normalized prices lagged q periods, representing the long-run structure for a system of simultaneous equations. This approach is not applicable when the matrix $\pi(\theta)$ cannot be extracted, as is the case with the Fourier flexible functional form; as a consequence, we use an alternative approach for analyzing the long-run structure. First, an ARMA(p,q) is applied to equation (4). The result is:

(5) $A(L)y_t = B(L)f(v_t, \theta)$.

Here, where L is the lag operator, the terms $A(L)$ and $B(L)$ represent the following distributed lags

$$A(L) = I + A_1L + A_2L^2 + ... + A_pL^p$$

$$B(L) = I + B_1L + B_2L^2 + ... + B_qL^q.$$

Consider the following ARMA(1,1):

(6) $y_t = A_1^* y_{t-1} + f(v_t, \theta) + B_1^* f(v_{t-1}, \theta) + e_t$.

As in Anderson and Blundell (1982, 1983), the addingup restrictions require a transformation A_1^* of A_1 where the columns of A_1^* must sum to zero, and $a_{ij}^* = a_{ij} - a_{in}$ for $i=1,...,n$ and $j=1,...,n-1$. Similar restrictions for the matrix B_1^* apply. In sum, then, the dynamics appear as lagged shares y_{t-1} and lagged normalized prices v_{t-1}.

THE DYNAMIC UTILITY FUNCTION APPROACH

Individuals are unlikely, generally, to be able to adjust their consumption plans instantaneously. Rather than apply an arbitrary lag to the shares derived from a static optimization exercise, an attractive alternative is to allow past behavior to affect current decisions directly through the utility function. We can define the set of past decisions on a commodity to be an $nx1$ vector of shares (**s**) that are functions of all past values of v:

(7) $s = f(v_{t-r})$ for $r=1,...,n-1$.

Here, each share depends on its own lagged normalized price and the lagged normalized prices of the remaining n-1 shares. In this case, the representative consumer's dynamic indirect utility function can be expressed as

(8) $U = U(v,s)$,

where $v = P/M$ and s represents the dynamics. M is total "expenditures" on this class of assets. This is, in effect, a structural approach for obtaining dynamic shares since the dynamics are embedded in the decision process rather than appearing as dynamic extensions of the static shares (as in the time-series model). It produces a new version of the Fourier model, accordingly. To begin with, we will let $s = \chi_{t-1}$, so that each share depends on its own lagged value as well as on lags from the remaining n-1 shares.

The dynamic Fourier Flexible Form is defined as

$$(9)\quad g_k^d(z,\theta) = u_o + b'z + \tfrac{1}{2}z'Cz + \sum_{\alpha=1}^{A}\sum_{j=-J}^{J} a_{j\alpha}e^{ijk'_\alpha z}$$

and

$$C = -\sum_{\alpha=1}^{A} u_{o\alpha}K_\alpha K'_\alpha \qquad z = \begin{pmatrix} v'_t \\ v'_{t-1} \end{pmatrix}.$$

Parallel to equation 2, we may express the model as

$$(10)\quad g_k^d(z,\theta) = u_o + b'z + \tfrac{1}{2}z'Cz$$
$$+ \sum_{\alpha=1}^{A}\left(u_{o\alpha} + 2\sum_{j=1}^{J}[u_{j\alpha}cos(jk'_\alpha z) - w_{j\alpha}sin(jk'_\alpha z)]\right),$$

in which

$$C = -\sum_{\alpha=1}^{A} u_{o\alpha}K_\alpha K'_\alpha$$

In this formulation, a multi-index is now a 1 by $(r+1)(n)$ vector with integer components; in the static case, it was 1 by (n). Here, r is the number of lags. The dynamic shares for this problem are obtained by applying Roy's identity to equation 10:

$$(11)\quad y_i = \frac{v_{it}b_i - \sum_{\alpha=1}^{A}(u_{o\alpha}z'k_\alpha + 2\sum_{j=1}^{J} j[u_{j\alpha}\sin(jk'_\alpha z) + w_{j\alpha}\cos(jk'_\alpha z)])k_{i\alpha}z_i}{\sum_{i=1}^{n} b_i v_{it} - \sum_{\alpha=1}^{A}(u_{o\alpha}z'k_\alpha + 2\sum_{j=1}^{J} j[u_{j\alpha}\sin(jk'_\alpha z) + w_{j\alpha}\cos(jk'_\alpha z)])k'_\alpha z},$$

where $i = 1,\ldots,n$. This can be more compactly expressed as

$$(12)\quad y_t = f(v_t, v_{t-1}, \theta).$$

In this model, adding up is guaranteed, and no additional restrictions need to be applied at the estimation stage.

EXAMPLES OF THE TWO MODELS

In the two models just presented, the dynamics are captured in quite different ways. For the time-series approach, the dynamics enter in the form of lagged shares and lagged expenditure-normalized prices. In the dynamic utility function model, the dynamics enter only as lagged normalized prices in each of the share equations. The dynamic models can be more clearly compared with an example, which is what we now present. Note that we use what are termed "multi-indices" in the process of estimating the Fourier model. This is a notational convenience, as we have explained, for expressing the partial differentiation of the indirect utility function and can be considered as weights (linear combinations $k\alpha'v$) of normalized prices.

In this example we will be looking at four share equations, with $A=4$ and $J=1$ in the Fourier model. The multi-indices used for the time-series approach, assuming an ARMA(1,0), are:

$$k_\alpha = \begin{pmatrix} k_{1\alpha} \\ k_{2\alpha} \\ k_{3\alpha} \\ k_{4\alpha} \end{pmatrix} \text{ where } k_1 = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 1 \end{pmatrix}, k_2 = \begin{pmatrix} 1 \\ 0 \\ 1 \\ 0 \end{pmatrix},$$

$$k_3 = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 1 \end{pmatrix}, k_4 = \begin{pmatrix} 1 \\ 1 \\ 1 \\ 0 \end{pmatrix} \text{ with } V = \begin{pmatrix} V_{1t} \\ V_{2t} \\ V_{3t} \\ V_{4t} \end{pmatrix}.$$

Note that V defines the four expenditure-normalized prices. The multi-indices are set up in the same way as in Gallant (1981) and one must be careful, when taking partial derivatives, to ensure that the corresponding $k_{i\alpha}$ is used. In this example, the first element of each of the multi-indices, zero or one, corresponds to the first element in V; this is the normalized price, V_{1t}. Since the dynamics are modeled by adding lagged expenditure shares, the dimension of the multi-indices, which only appears in $f(v_t,\theta)$ in equation 5, stays the same when one moves from the static to the dynamic time series model.

On the other hand, in the dynamic utility approach, the inclusion of lagged normalized prices increases the length of each multi-index [see $f(v_t, v_{t-1}, \theta)$ in equation 12]; we use the following eight indices, accordingly:

$$k_1 = \left(\begin{array}{c} 1\\0\\1\\0\\ \hline 0\\0\\0\\0 \end{array}\right),\; k_2 = \left(\begin{array}{c} 0\\1\\1\\0\\ \hline 0\\0\\0\\0 \end{array}\right),\; k_3 = \left(\begin{array}{c} 1\\0\\1\\1\\ \hline 0\\0\\0\\0 \end{array}\right),\; k_4 = \left(\begin{array}{c} 0\\0\\0\\1\\ \hline 0\\0\\0\\0 \end{array}\right),$$

$$k_5 = \left(\begin{array}{c} 0\\0\\0\\0\\ \hline 1\\0\\0\\1 \end{array}\right),\; k_6 = \left(\begin{array}{c} 0\\0\\0\\0\\ \hline 0\\1\\1\\0 \end{array}\right),\; k_7 = \left(\begin{array}{c} 0\\0\\0\\0\\ \hline 0\\0\\1\\1 \end{array}\right),\; k_8 = \left(\begin{array}{c} 0\\0\\0\\0\\ \hline 0\\1\\1\\1 \end{array}\right).$$

In this case the vector of normalized prices is

$$z' = [v_{1t}, v_{2t}, v_{3t}, v_{4t}, v_{1,t-1}, v_{2,t-1}, v_{3,t-1}, v_{4,t-1}].$$

The first four elements of each k_α correspond to the static part of the vector z and the last four elements of each k_α to the dynamic elements of z. This separation of multi-indices enables one to test the static against the dynamic utility function because each multi-index has an associated parameter.

THE CONSTRUCTION OF DIVISIA MONETARY AGGREGATES

Most of the studies of money demand in the literature employ monetary aggregates that are simple sums of their components (for example, *M1 = Currency plus deposits*) and are constructed essentially without benefit of index-number theory. While simple-sum aggregation might serve policy makers well when interest rate fluctuations are relatively mild, it is at a disadvantage when the relative interest rates on the monetary components fluctuate significantly. A Divisia index is an alternative approach for aggregating data that is based directly on economic theory. The Divisia index, indeed, is designed to internalize the substitution effects (at constant utility) that arise from relative price changes. In fact, the simple-sum index cannot produce this result unless the components of the proposed aggregation are perfect substitutes. We have reason to believe this is not the case for the monetary aggregates in common use.

Having a satisfactory procedure such as the Divisia does not, however, tell us exactly what set of assets to consider or how to group the subsets of the data for efficient estimation. A procedure that is available is the linear NONPAR program of Varian (1982, 1983), which is based directly on the Generalized Axiom of Revealed Preference (GARP). Satisfaction of GARP on a set of data implies that there exists a non-satiated, concave, monotonic utility function across that particular set. Such a set of data, if it exists, can be examined for logical groupings, again using the program NONPAR. If such groupings can be established—that is, if weak separability holds—then, according to the Leontief-Sono definition of separability, the marginal rates of substitution between any two commodities in the monetary index are independent of changes in relative prices outside the monetary group. This group is then available for (Divisia) aggregation.

On the quarterly U.S. data from 1970:1 to 1985:2, Swofford and Whitney (1987) have constructed a set of real per capita measures of monetary quantities and a set of related nominal user costs to represent the prices of these quantities. With M1 denoting narrow money (excluding the deposits of businesses); OCD, other checkable deposits; SD, savings deposits in financial institutions; and STD, small time deposits in financial institutions, they find that the following arrangement passes the necessary and sufficient conditions for the General Axiom of Revealed Preference:

U[V(DUR, NONDUR, SERV, LEIS), M1, OCD, SD, STD].

Here, the first three items in the equation refer to components of total consumption, while LEIS refers to leisure (evaluated at the wage rate). Note that SD and STD describe vectors of the liabilities of the various financial institutions *(for example, SD = small time deposits in com-*

mercial banks, S&Ls, and so on).[1] Also, notice that in the arrangement just listed, the consumption and leisure activities are separable from the financial assets but not the converse. This implies the existence of an aggregate utility function defined across these monetary entities (for this time and place).

Because of the failure to establish a subgrouping of the monetary assets, it proves necessary to work with the following four aggregate commodities:

M1, OCD	*A1*
SDCB, SDSL, SDSB, SDCU	*A2*
STDCB, STDTH, STDCU	*A3*
DUR, NONDUR, SERV, LEIS.	*A4*

Here, *SDCB* and so on are savings deposits at commercial banks, S&Ls, mutual savings banks and credit unions, while STDCB and so on are small time deposits at commercial banks, thrifts and credit unions. To attempt to preserve the economic characteristics of this set of data up to a third-order remainder term, Divisia index numbers are constructed from the individual quantities and their associated user costs; these are designated as A1, ..., A4. Note that M1 and OCD are summed for convenience; this can be justified by further noting that the correlation coefficient between the user costs of these two items is .994.

Putting all the pieces together, then, we have monetary data (and user costs) that satisfy an empirical test for revealed preference, we have aggregated the data in a way that is designed to preserve their economic characteristics in the face of changes in relative prices and, finally, we propose to estimate the elasticities using a model which can come arbitrarily close to the elasticities implied by the true (but unknown) aggregate indirect utility function known to be defined (by the GARP test) over these entities. Note, especially, that satisfaction of GARP implies that there is a firm link between the indirect utility that is actually estimated and the underlying utility function that actually generates these data.

EMPIRICAL RESULTS

In our empirical work, we compare the results of the estimation of the three systems: the static, the time series dynamic and the utility function dynamic. Because the static theory is nested in each of the two dynamic theories, we present the results in that form. The comparisons are in terms of the significance of the coefficients, the characteristics of the residuals and the relevance of the dynamic formulations using the results of the Gallant-Jorgenson (1979) chi-square test. Unfortunately, the two dynamic approaches are not nested, so that we cannot compute a Gallant-Jorgenson test statistic. We do, however, offer a comparison utilizing the other statistics just mentioned. As it turns out, neither model has a clear advantage, although we do prefer the dynamic utility model in view of its economic properties and adequate performance. We also offer some comparisons with earlier work that utilized the static Fourier model over the same data space (Fisher, 1992). Here, there are dramatic differences in the estimated elasticities of substitution; we believe the dynamic results (utilizing the estimates from the dynamic utility approach) are considerably more reasonable than the earlier static results.

The share equations, with the across-equations restrictions, were estimated in the SAS system using PROC MODEL with nonlinear seemingly unrelated regression. The results for the dynamic time-series model appear in Table 1.

In this table, the *Bs* correspond to the quadratic terms in the Fourier Flexible Form, the *Us* and *Vs* to the Fourier series expansion, and the *As* to the lagged shares y_{t-1}.

These results describe reasonable fits, with 10 of the 12 adjustment parameters (A_{ij}) having *t*-

[1] The original variables were supplied by the Federal Reserve and appear in several publications by Farr and Johnson (1985a, 1985b). In this study, the monetary data are employed in per capita real form (where the latter is achieved by deflation with the CPI). SD represents savings deposits in commercial banks, S&Ls, mutual savings banks and credit unions, while STD represents the small time deposits of the same institutions. OCD is other checkable deposits and includes NOW accounts. See Swofford and Whitney's two papers for more details on the construction of the data.

As discussed in Swofford and Whitney (1987, 1988), the data were prepared as follows. Each monetary asset is deflated by the consumer price index for urban areas. OCD includes super NOW accounts. The user cost is the concept defined by Barnett (1978). For leisure, the quantity is 98 hours less average weekly hours worked during the quarter (times 52). The wage rate measures the opportunity cost of time. The consumption figures are taken from Department of Commerce data that also provides the implicit deflator for each category. A 10 percent depreciation rate is used in calculating the one-period holding cost of a durable good.

Table 1

Time Series Model: Dynamic Fourier Flexible Functional Form

Nonlinear SUR summary of residual errors

Eqn.	DF model	DF error	SSE	MSE	Root MSE	*R*-square	Adjust *R*-square
SM1	9	53	0.00438	0.0000827	0.00909	0.915	0.902
SM2	9	53	0.01650	0.0003113	0.01764	0.848	0.825
SM3	9	53	0.02445	0.0004613	0.02148	0.923	0.912

Nonlinear SUR parameter estimates

Parameter	Estimate	Approximate standard error	"T" Ratio	Approximate prob>|T|
B1	0.175462	0.08184	2.14	0.0367
B2	0.007578	0.25542	0.03	0.9764
B3	−0.448512	0.15285	2.93	0.0049
U01	−0.007955	0.02828	0.28	0.7796
U11	−0.009762	0.00710	1.37	0.1752
W11	0.023864	0.02545	0.94	0.3526
A11	0.419255	0.07229	5.80	0.0001
A12	0.259118	0.03873	6.69	0.0001
A13	0.197632	0.02071	9.54	0.0001
A14	0.190888	0.04239	4.50	0.0001
U02	−0.014187	0.01355	1.05	0.3000
U12	0.011554	0.01015	1.14	0.2599
W12	−0.019444	0.00809	2.40	0.0197
A21	−1.000371	0.13602	7.35	0.0001
A22	0.958742	0.06774	14.15	0.0001
A23	−0.034480	0.03080	1.12	0.2680
A24	0.766254	0.08967	8.55	0.0001
U03	0.020581	0.00692	2.97	0.0044
U13	−0.002235	0.00216	1.03	0.3062
W13	0.002259	0.00146	1.55	0.1272
A31	0.572904	0.11232	5.10	0.0001
A32	−0.381781	0.07622	5.01	0.0001
A33	0.276142	0.04249	6.50	0.0001
A34	−0.119175	0.08974	1.33	0.1899
U04	−0.009973	0.00554	1.80	0.0778
U14	−0.000714	0.00236	0.30	0.7638
W14	0.000171	0.00287	0.06	0.9527

N = 62
Objective = 2.0164
Objective*N = 125.0495
The Aij represent the dynamics.

values in excess of 2. Note that it is the surfaces of $(\partial/\partial x)g^*(x)$ and $(\partial^2/\partial x \partial x')\, g^*(x)$ that one aims to estimate accurately; it is not required that all parameters be significant. The coefficients capturing the dynamics tend to be the most significant parameters. We also calculated the autocorrelation and partial autocorrelations for each of the three share equations; the residuals here were white noise. In order to compare the dynamic and static results, we apply the Gallant-Jorgenson chi-square test to provide a comparison with the static equivalent of the time series model. The test statistic uses the value "objective*N" in the table. For the static model (the estimates are not shown here), the value of this statistic is 527.9597; for the dynamic it is 125.0495 as shown in the table. The value of the Gallant-Jorgenson statistic is then 527.9597-125.0495 = 402.9102 with degrees of freedom equal to the difference in the number of parameters, of 27-15 = 12. This calculation decisively rejects the static model.

Table 2

Utility Function Model: Dynamic Fourier Flexible Functional Form

Nonlinear SUR summary of residual errors

Eqn.	DF Model	DF Error	SSE	MSE	Root MSE	*R*-Square	Adjust *R*-square
SM1	9	53	0.01057	0.0001995	0.01412	0.796	0.765
SM2	9	53	0.01885	0.0003556	0.01886	0.826	0.800
SM3	9	53	0.03803	0.0007175	0.02679	0.880	0.862

Nonlinear SUR parameter estimates

Parameter	Estimate	Approximate standard error	"T" ratio	Approximate prob>|T|
B1	−0.163039	0.38557	0.42	0.6741
B2	−1.187580	0.32865	3.61	0.0007
B3	−1.028066	0.35163	2.92	0.0051
U01	0.016757	0.03275	0.51	0.6110
U11	−0.002319	0.01498	0.15	0.8776
W11	0.027816	0.02235	1.24	0.2187
U05	0.002500	0.02955	0.08	0.9329
U15	0.009921	0.01450	0.68	0.4968
W15	−0.064331	0.03009	2.14	0.0372
U02	−0.111290	0.03773	2.95	0.0047
U12	0.061322	0.01864	3.29	0.0018
W12	0.022699	0.01756	1.29	0.2023
U06	−0.008559	0.01160	0.74	0.4637
U16	0.006524	0.00869	0.75	0.4561
W16	0.001616	0.00993	0.16	0.8713
U03	−0.006461	0.01692	0.38	0.7041
U13	0.006416	0.01338	0.48	0.6335
W13	−0.113939	0.00800	1.42	0.1604
U07	−0.013340	0.01127	1.18	0.2419
U17	0.000898	0.00873	0.10	0.9185
W17	−0.016214	0.01118	1.45	0.1530
U04	−0.070695	0.01156	6.12	0.0001
U14	−0.010984	0.01223	0.90	0.3730
W14	−0.070924	0.00896	7.91	0.0001
U08	0.123303	0.00850	1.45	0.1530
U18	0.024230	0.01013	2.39	0.0204
W18	0.020177	0.01199	1.68	0.0982

N = 62
Objective = 2.3732
Objective*N = 147.1362

The dynamic utility model features interaction among the asset choices over time. This characteristic distinguishes the dynamic utility system from the time series approach. For this model the results are not quite as satisfactory as those just given. They follow in Table 2. Here, the R-squares are slightly lower, the objective*N statistic is higher, and there are fewer significant parameters. The static Fourier is nested within the dynamic utility function in terms of the multi-indexes (see section four). Consequently, we analyze the reduction in the residuals due to the dynamic specification (see Gallant, 1981). The residual sum of squares from the dynamic model is less than half the size of those obtained from the static model.

Quite often, the methods discussed to this point would be applied to systems of demand equations, as they are here. While the estimated structural equations themselves might be of interest, and for the dynamic versions presented here they could be used to generate forecasts, a typical concern is the elasticity of substitution among the assets. What the Fourier provides in this connection is precise estimates of a set of own- and cross-elasticities of substitution (and income) at each data point. This can reveal the nature of the substitutability or complementarity among the assets and the time-series behavior of this concept.

While we do not wish to explore the fine points of the data set just examined, a further illustration, because it reveals an important characteristic of the dynamic models, is in order. For the more interactive dynamic utility function model, Table 3 presents the estimates of the Allen partial elasticities of substitution among the four commodity bundles studied here. In the table, *Eij* is the elasticity of substitution between *Ai* and *Aj*. The Fourier Flexible Form provides a global approximation and hence we can calculate the asymptotic standard errors for each elasticity *(Eij)* at each point in time and then evaluate the significance of the estimate. The *Tij* in the table are the corresponding *t*-statistics for *Eij*.

Here, we show a complete set of substitution elasticities along with their associated *t*-values. Note that a positive value for the elasticity indicates substitution, while a negative indicates a complementary relation.

Several things stand out in Table 3. Most importantly, the elasticity of substitution between cash and savings assets (*E12* in the table) and between cash and time deposits (*E13*) are very precisely estimated at all data points. This was not the case for static estimates published elsewhere (Fisher, 1992). While we cannot say a priori what value of the elasticity of substitution is high, an elasticity over unity, as most are in the first column of the table, could be termed "elastic." Note that the result here is that cash and savings accounts are substitutes, as many would expect on the basis of intuition.

More provocatively, however, cash and time deposits appear to be "elastic" complements. This spells trouble for a simple-sum M3 definition of money, if these results are correct, since the simple-sum approach to aggregation treats all components as (perfect) substitutes. Clearly, we are not in a position to doubt our results. We have adopted a rigorous aggregation-theoretic approach and tied the empirical work to that as closely as our data would permit. In fact, the very theory we are using can be invoked in our defense: Economic theory does not say whether commodities will be substitutes or complements *in practice*. That is, in practice, economic agents decide what assets are substitutes and what are complements. Our results indicate that they use cash and time deposits as if they are complements, at least over this data sample. We also should point out that this is not an unusual finding in this literature (see the survey in Barnett, Fisher and Serletis, 1992).

Another interesting finding, and one that demonstrates the power of the dynamic approach, is that the elasticities shown in Table 3 are much more stable than those obtained from the static model. For this comparison, we refer to the elasticities produced in the static Fourier from the same data set, as published in Fisher (1992). In Figure 1 we show the results for the substitution relation between cash and savings deposits. Note especially that the two series are scaled differently, an adjustment necessary because the static estimates fluctuate so wildly. While both series are generally positive (indicating that they are substitutes), the static estimates are occasionally negative (although they were not significantly less than zero). This sort of result is not ruled out by economic theory, but is still hard to explain in terms of the known characteristics of these assets.

In Figure 2 we present a comparison between the results for the static Fourier and the dynamic utility model where the former results are, again, drawn from the earlier study. In this case we compare cash *(A1)* and small time deposits *(A3)*, a relation that is consistently that of complementarity in Table 3.

Once again the dynamic elasticities are relatively constant. In addition, the static elasticities are sometimes positive and sometimes negative (and statistically so, in both cases, at some dates). Clearly, then, the complementary relationship between cash and small time deposits is clearly established in the dynamic utility function results. We note that such results are quite common in this literature (see Barnett, Fisher and Serletis, 1992).

CONCLUSIONS

In the introduction to this paper, we listed five areas in which existing studies of expenditure systems frequently fall short, in Diewert's opinion. Obviously, the innovation of this paper is to convert a static system into a dynamic one; this deals with one of his concerns. Diewert is also concerned that existing studies do not link the theory to the application firmly enough. This we have attempted to address both by setting out

Table 3
Substitution Elasticities: Dynamic Utility Model

	E12	T12	E13	T13	E14	T14	E23	T23	E24	T24	E34	T34
70:2	1.291	2.983	−0.250	2.367	0.509	1.394	−0.614	1.106	0.146	1.153	−1.286	14.957
70:3	1.276	3.163	−0.259	2.532	0.445	1.329	−0.601	1.164	0.102	0.857	−1.291	14.973
70:4	1.255	3.389	−0.270	2.751	0.371	1.218	−0.592	1.241	0.049	0.438	−1.301	14.906
71:1	1.167	3.669	−0.272	3.026	0.290	1.107	−0.610	1.462	−0.047	0.491	−1.269	14.076
71:2	1.163	3.744	−0.270	3.071	0.273	1.057	−0.610	1.490	−0.068	0.718	−1.280	14.219
71:3	1.166	3.896	−0.278	3.216	0.233	0.932	−0.595	1.491	−0.084	0.890	−1.307	14.273
71:4	1.115	4.050	−0.279	3.368	0.195	0.832	−0.602	1.609	−0.129	1.480	−1.292	13.771
72:1	1.101	3.896	−0.265	3.202	0.236	0.987	−0.625	1.643	−0.124	1.436	−1.256	13.693
72:2	1.077	4.083	−0.266	3.382	0.188	0.825	−0.619	1.712	−0.165	1.979	−1.271	13.523
72:3	1.052	4.269	−0.273	3.596	0.134	0.623	−0.605	1.763	−0.198	2.450	−1.282	13.165
72:4	1.010	4.451	−0.282	3.873	0.065	0.328	−0.582	1.820	−0.236	3.052	−1.282	12.547
73:1	1.033	4.524	−0.297	4.058	0.046	0.230	−0.568	1.755	−0.226	2.766	−1.314	12.436
73:2	0.995	4.672	−0.335	4.543	−0.047	0.261	−0.527	1.738	−0.238	3.071	−1.320	11.475
73:3	1.041	4.739	−0.446	5.808	−0.150	0.875	−0.421	1.359	−0.125	1.304	−1.383	9.225
73:4	1.008	4.726	−0.465	5.944	−0.194	1.167	−0.412	1.383	−0.141	1.538	−1.375	8.904
74:1	0.920	4.791	−0.507	5.954	−0.302	2.083	−0.381	1.464	−0.176	2.098	−1.323	8.123
74:2	1.152	4.725	−0.426	5.233	−0.074	0.386	−0.419	1.228	−0.067	0.666	−1.434	10.784
74:3	1.284	4.358	−0.364	4.063	0.090	0.375	−0.444	1.091	0.010	0.083	−1.460	13.096
74:4	1.184	4.615	−0.392	4.663	−0.010	0.049	−0.460	1.292	−0.079	0.811	−1.438	12.212
75:1	1.231	4.094	−0.306	3.543	0.169	0.669	−0.548	1.353	−0.074	0.702	−1.397	14.327
75:2	1.216	3.977	−0.281	3.352	0.204	0.790	−0.579	1.416	−0.094	0.898	−1.374	14.565
75:3	1.199	4.134	−0.294	3.577	0.162	0.659	−0.567	1.442	−0.111	1.085	−1.381	14.093
75:4	1.190	4.117	−0.287	3.539	0.168	0.685	−0.576	1.471	−0.121	1.195	−1.373	14.101
76:1	1.169	4.137	−0.282	3.551	0.165	0.683	−0.587	1.526	−0.139	1.413	−1.361	13.984
76:2	1.137	4.249	−0.286	3.713	0.136	0.588	−0.588	1.596	−0.166	1.761	−1.352	13.559
76:3	1.107	4.347	−0.291	3.880	0.107	0.482	−0.586	1.654	−0.189	2.083	−1.346	13.145
76:4	1.055	4.499	−0.303	4.207	0.049	0.240	−0.576	1.738	−0.224	2.632	−1.333	12.371
77:1	1.041	4.487	−0.291	4.157	0.056	0.273	−0.586	1.785	−0.239	2.827	−1.321	12.366
77:2	1.030	4.515	−0.295	4.235	0.041	0.206	−0.581	1.797	−0.245	2.935	−1.319	12.199
77:3	0.997	4.611	−0.318	4.586	−0.020	0.109	−0.555	1.805	−0.257	3.201	−1.316	11.491
77:4	0.977	4.651	−0.330	4.813	−0.054	0.299	−0.539	1.801	−0.262	3.253	−1.313	10.997
78:1	1.003	4.625	−0.323	4.654	−0.022	0.118	−0.549	1.772	−0.248	2.987	−1.322	11.359
78:2	1.031	4.612	−0.328	4.605	−0.008	0.044	−0.546	1.715	−0.227	2.663	−1.338	11.573
78:3	0.982	4.718	−0.420	5.550	−0.159	0.944	−0.463	1.578	−0.202	2.430	−1.349	9.671
78:4	0.994	4.692	−0.527	6.350	−0.274	1.722	−0.357	1.232	−0.104	1.061	−1.388	7.894
79:1	0.992	4.653	−0.569	6.378	−0.329	2.097	−0.319	1.119	−0.079	0.788	−1.401	7.546
79:2	1.000	4.632	−0.576	6.336	−0.335	2.119	−0.313	1.090	−0.071	0.716	−1.407	7.581
79:3	1.067	4.658	−0.545	6.507	−0.260	1.529	−0.335	1.083	−0.051	0.492	−1.437	8.127
79:4	1.139	4.448	−0.618	6.911	−0.319	1.806	−0.237	0.718	−0.062	0.464	−1.528	7.332
80:1	1.194	4.103	−0.634	6.714	−0.289	1.456	−0.212	0.569	0.113	0.782	−1.596	7.133
80:2	1.299	4.479	−0.503	5.621	−0.074	0.332	−0.301	0.751	0.128	0.907	−1.545	9.679
80:3	1.267	4.593	−0.472	5.429	−0.067	0.313	−0.353	0.927	0.052	0.427	−1.510	10.522
80:4	1.265	3.983	−0.590	6.200	−0.164	0.707	−0.224	0.524	0.202	1.035	−1.626	7.546
81:1	1.296	3.675	−0.586	5.700	−0.110	0.409	−0.208	0.427	0.268	1.128	−1.679	7.396
81:2	1.323	3.688	−0.552	5.332	−0.040	0.140	−0.223	0.440	0.289	1.212	−1.677	7.778
81:3	1.382	3.333	−0.581	4.869	−0.024	0.071	−0.135	0.223	0.422	1.295	−1.783	7.238
81:4	1.329	3.513	−0.573	5.281	−0.052	0.172	−0.193	0.364	0.328	1.244	−1.707	7.567
82:1	1.319	3.653	−0.562	5.401	−0.054	0.191	−0.215	0.427	0.292	1.221	−1.680	7.760
82:2	1.338	3.774	−0.532	5.211	−0.011	0.038	−0.238	0.478	0.283	1.286	−1.659	8.378
82:3	1.395	4.130	−0.435	4.379	0.102	0.362	−0.330	0.688	0.207	1.252	−1.577	11.357
82:4	1.349	4.221	−0.380	4.034	0.117	0.443	−0.416	0.940	0.081	0.599	−1.505	13.092
83:1	1.460	3.505	−0.323	2.887	0.358	0.951	−0.444	0.772	0.237	1.454	−1.558	15.850
83:2	1.479	3.353	−0.328	2.730	0.410	0.996	−0.414	0.671	0.324	1.823	−1.593	15.791
83:3	1.485	3.344	−0.341	2.768	0.401	0.953	−0.383	0.610	0.359	1.881	−1.632	15.192
83:4	1.483	3.396	−0.342	2.826	0.385	0.940	−0.388	0.629	0.340	1.832	−1.622	15.251
84:1	1.483	3.421	−0.347	2.874	0.373	0.917	−0.382	0.622	0.339	1.814	−1.628	15.054
84:2	1.493	3.241	−0.326	2.581	0.438	0.978	−0.381	0.580	0.382	1.855	−1.654	15.085
84:3	1.465	3.392	−0.388	3.119	0.318	0.775	−0.317	0.507	0.388	1.744	−1.695	12.801
84:4	1.470	3.640	−0.376	3.254	0.287	0.782	−0.367	0.643	0.296	1.676	−1.623	14.393
85:1	1.471	3.447	−0.329	2.814	0.379	0.971	−0.413	0.696	0.294	1.714	−1.579	15.821
85:2	1.463	3.319	−0.306	2.615	0.429	1.067	−0.444	0.733	0.291	1.733	−1.547	16.458

Figure 1
Substitution Elasticities Between Cash (A1) and Savings Deposits (A2), 1970-1985

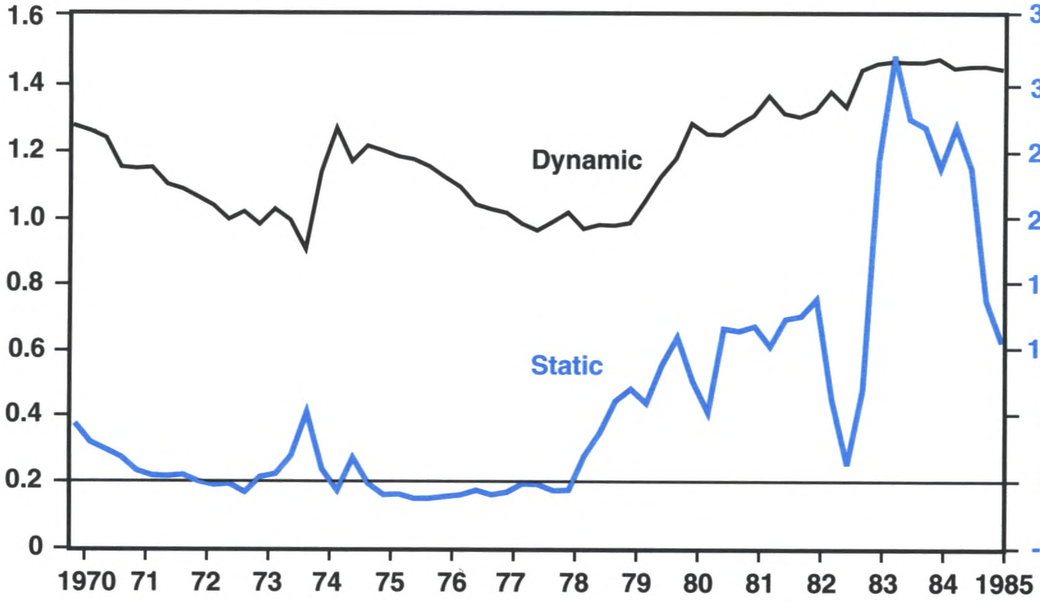
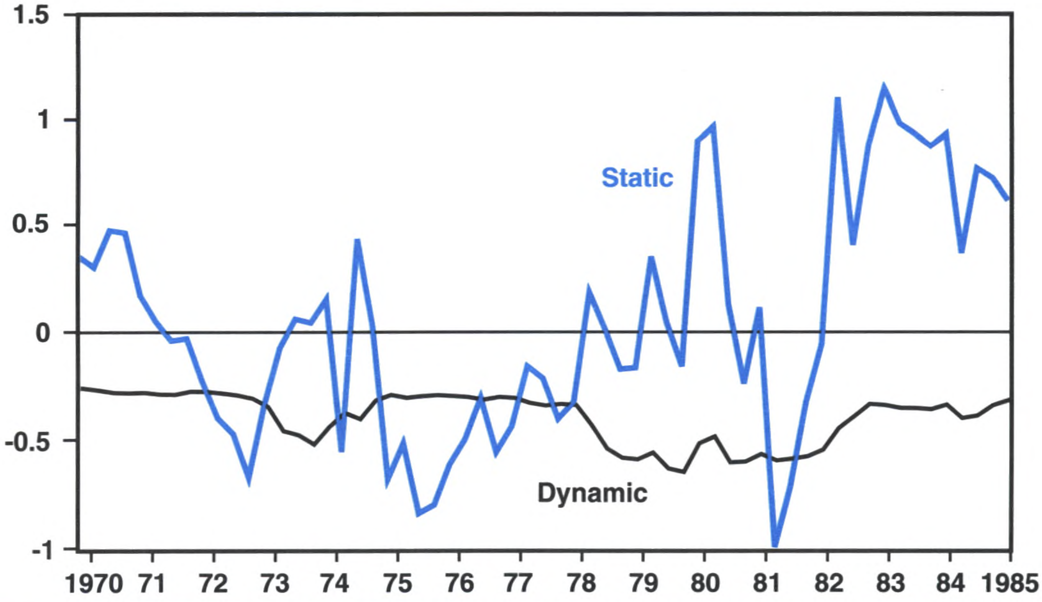


Figure 2
Substitution Elasticities Between Cash (A1) and Time Deposits (A3), 1970-1985



the theory and by dealing with two of his further concerns: aggregating in a consistent fashion and employing a system that provides arbitrarily accurate estimates of the partial derivatives of the system. What we did not do, which is in his list of concerns, is examine the model at every data point.

In our results, the dynamic models derived and estimated appear clearly superior to the (nested) static models. We are not able to compare the two dynamic formulations directly, because they are not nested, but we find the statistical performance of the time series approach to be superior, while the dynamic-utility approach seems better able to capture the economic interactions among the assets studied. Furthermore, most of the estimated share equations produced white noise residuals, and this is a characteristic that is not shared by the static estimates, whether of the nested form in this paper or in the earlier (static) Fourier results that we have been using as a benchmark.

For the dynamic utility model, we have produced a set of elasticities of substitution and charted those between cash (M1 + OCD) and savings deposits and between cash and small time deposits. The former are shown to be substitutes in the dynamic system, and, more important, to be much more stable than static estimates produced in an earlier study. The latter are actually complements, although the negative elasticity of substitution is generally less than minus one, a finding that is not without foundation theoretically. We anticipate that further study of the model and/or the U.S. data will provide further observations on this phenomenon.

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Commentary

DOUG FISHER AND ADRIAN FLEISSIG develop and estimate a Dynamic Fourier Expenditure System in an attempt to meet some criticisms that have been raised against the literature on expenditure systems. First, I will discuss Fisher and Fleissig's model in terms of their own criteria set forth in their introduction. Then I will discuss their specification in terms of some criteria for an ideal model that Carl F. Christ proposed in his paper at last year's Federal Reserve Bank of St. Louis Economic Policy Conference. Finally, I will make some general comments about research on money stock measurement.

FISHER AND FLEISSIG'S CRITERIA

In their introduction, Fisher and Fleissig mention five of what they feel are the most telling shortcomings of the expenditure system literature. The first they mention is a failure to link theory and application. On one level they have met this criticism admirably. They chose to use the Fourier form as a flexible form specification that is able to approximate any unknown indirect utility function. They have also modeled the dynamics in a way that makes economic sense with their dynamic utility function specification. On another level they have not linked theory and application. Their discussion of the elasticities of substitution that they have estimated is fairly terse. While they show that the elasticity of substitution between two assets is more stable with one dynamic specification, they do not discuss the sign, magnitude or economic interpretation of their estimated elasticities more than in passing. They say that their elasticities are typical for this literature, but is that good or bad? They do not cite specific previous studies nor do they mention the size or sign of elasticities from other studies. Are we surprised that old consumer M1 and other checkable deposits (OCD) and savings accounts are substitutes but old consumer M1 and OCD and small time deposits are complements? These results make sense to me but their implications should be explained in the paper. What about the size of these elasticities? What is their meaning? My view is that other economists may miss the importance of the expenditure system literature, if those of us doing research using such systems continue to omit a thorough discussion of the elasticities that these systems produce and a comparison of these elasticities with those produced by previous research.

The second shortcoming of the expenditure system literature that Fisher and Fleissig address is improper aggregation over goods. In my view they have handled this problem in a very nice way. Expenditure systems like the Fourier system are very parameter-intensive, and aggregation over goods is required to make them tractable. Fisher and Fleissig have used both revealed preference results and good judgment about which goods to aggregate. I feel that in estimating systems such as these both are needed. However, I feel I must point out that Fisher and Fleissig have used a revealed preference test for a direct utility function to back up the specification of an indirect utility function. Direct utility function results may be suggestive of the structure of the indirect utility function, but they are not necessarily more than suggestive.

Fisher and Fleissig's third and fourth problems with the expenditure system literature are imprecise estimations of partial derivatives and use of locally integrable models, for which the first- and second-order conditions do not obtain at some data points. The Fourier System was developed to handle these criticisms of other specifications, such as the translog, so Fisher and Fleissig have admirably handled these criticisms as they set out to do.

The last problem Fisher and Fleissig set before themselves to solve is misspecification, often nonspecification, of dynamics in expenditure systems. They model the dynamics with two very general specifications. One, the time series model, is statistical in nature. Another, the dynamic utility function model, is consistent with economic theory. My view is that they are correct to model the dynamics in very general ways. Gerald Whitney and I (1994) have found that data in similar categories to those that Fisher and Fleissig have used can only be rationalized by a well-behaved direct utility function with some incomplete category adjustment within some quarters. But since Fisher and Fleissig are unable to choose between their two dynamic specifications, we cannot yet say that they have correctly specified the dynamics. They have, however, certainly done a better job modeling the dynamics than other researchers in this area. In a sense they have begun the debate on how to correctly model the dynamics within flexible consumer expenditure systems.

In summary, with a couple of reservations, Fisher and Fleissig have done a good job in meeting the criteria they set forth for their model. Next, I turn to the question of how their models compare with someone else's criteria for an ideal econometric specification.

CARL CHRISTS CRITERIA FOR AN ECONOMETRIC MODEL

At last year's St. Louis Fed conference, Carl F. Christ suggested seven characteristics of an ideal econometric model. I will next examine Fisher and Fleissig's paper in light of this ideal.

Christ's first criterion is that the estimated model should provide a good description of some interesting set of past data. Certainly, Fisher and Fleissig's model has been used to investigate an interesting issue—money holdings. There are also a reasonable number of coefficients that are statistically different from zero, and they test and find the residuals of their model are white noise.

The second criterion that Christ sets out (and one that he stressed) is that the model should be testable against data that were not used to estimate it and were not available when it was specified. Fisher and Fleissig have not done this. Since their sample ends in 1985, and Fisher and Fleissig have presumably formulated their model in recent years, this would be a tough challenge. A model estimated on data that ends eight years ago could not be expected to predict today's data very accurately. The new data set collected by the research staff of the St. Louis Fed could be used to estimate a dynamic flexible model, which then could be put to this test over the next few years.

Christ's third criterion, related to his second, is that the estimated model should describe events for at least a few quarters after it was formulated and estimated. As with Christ's second criterion, Fisher and Fleissig's specification cannot be reasonably put to this test. But a specification estimated with the St. Louis Fed's updated data could be.

The fourth criterion is that the model should make sense in the light of our knowledge of economics. Of course, the dynamic Fourier specification is flexible with respect to arbitrary elasticities, and it also does not generate negative shares. But Fisher and Fleissig's specification does generate asset pairs that switch from substitutes to complements over their sample. This is a puzzling result that they do not explain.

Christ's fifth criteria is that a simple model is superior to a complex model. Fisher and Fleissig's model is not simple, leaving open the possibility that an otherwise equal but simpler model will be found. Of course, this could be said of any specification. This does suggest that someone might want to test Barnett's Asymptotically Ideal Model with this type of data since it has similar characteristics to the Fourier model and may be simpler, depending on the formulation used.

The sixth criteria for judging a model is that, other things being equal, a model that explains a wide variety of data is better. Fisher and Fleissig's model does explain a wide variety of data, but some of it has been aggregated. An argument could be made to estimate this model before aggregating the data. But Fisher and Fleissig have used the soundest aggregation techniques in the literature, the model they necessarily used is very parameter-intensive, and the disaggregate data series is of a relatively short duration.

Christ's seventh and final criterion is that models that nest special cases are preferable. Fisher and Fleissig's dynamic Fourier models nest the static Fourier and, in that respect, meet Christ's ideal. Unfortunately, these models do not nest other Flexible Functional forms nor do the dynamic specifications nest each other.

Of course, Fisher and Fleissig's dynamic Fourier flexible functional form does not meet all of Christ's ideals. Fisher and Fleissig did not, nor would they, claim that it does, and I do not mean to give the impression that they would make such a bold claim for their model. Their model seems to meet the first and the fourth through the seventh criteria fairly well. Criteria two and three concern the ability of flexible expenditure systems to predict future behavior, which seems a worthwhile area of investigation to pursue with such specifications.

For the most part, Fisher and Fleissig's specifications meet their own criteria that they set out to meet, and Christ's criteria for an ideal specification that they were probably only generally trying to meet. Their paper is an important contribution to a growing literature on economic monetary aggregates. I want to close with a few comments on this literature.

THE ECONOMIC MONETARY AGGREGATES LITERATURE

I feel that Fisher and Fleissig's paper is an important contribution to the question of what is money. Much of my work in this area has involved nonstochastic revealed preference tests. Not much is known about the power of such tests, and there are doubts about the validity of these tests, so work such as Fisher and Fleissig's showing that per capita behavior is consistent with stochastic models is very important.

The literature on economic monetary aggregates suggests that the aggregates on which the central bank focuses may not be the ones that people use. If people are using one aggregate and the central bank is controlling another, then stable "policy" may lead to an unstable price level. Policy in such a situation might be destabilizing, because the public and the central bank are engaged in a two-sided game, with each side having a different objective—the monetary aggregate each uses. This implies that it is important for central banks to attempt to identify what the public in their country is using as money.

Also, there may not be an economic monetary aggregate in an area. When looking for an economic monetary aggregate, the question we are really asking is, "Is there a common currency for a particular area?" This area may or may not be a nation state. If there is no economic monetary aggregate in an area, then, again, "monetary" policy would not likely lead to predictable results.

Finally, there may be multiple economic monetary aggregates in use. Consumers may be using one aggregate and business another. Controlling both aggregates may be mutually exclusive. In such a case, optimal monetary policy may require minimizing some loss function over the aggregates, with each one weighted by how closely related each aggregate is to the price level.

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Financial Firms' Production and Supply-Side Monetary Aggregation Under Dynamic Uncertainty

THIS PAPER IS FOCUSED ON the production theory of the financial firm and supply-side monetary aggregation in the framework of dynamics and risk. On the demand side, there has been much progress in applying consumer demand theory to the generation of exact monetary aggregates and integrating them into consumer demand system modeling.[1] However, on the supply-side, monetary services are produced by financial firms through financial intermediation, and, hence, exact supply-side monetary aggregation must be based upon financial firm output aggregation. Most of the literature on exact aggregation theory is based upon perfect certainty, which often is a reasonable assumption regarding contemporaneous consumer goods allocation decisions. Risk, however, is an important consideration in modeling the decisions of financial intermediaries. Furthermore, that risk not only applies to future prices and interest rates, but also to contemporaneous interest rates and thereby to the contemporaneous user costs of produced monetary services. In this paper we derive a model of financial firm behavior under dynamic risk, and we find the exact monetary services output aggregate. We estimate the Euler equations that comprise the first-order conditions for optimal behavior by financial firms.

Barnett (1978,1980) introduced economic aggregation and index number theory to demand-side monetary aggregation by applying Diewert's (1976) results on superlative index numbers. The proposed Divisia index in Barnett's work is an element of Diewert's superlative index number class. Analogous to demand-side monetary aggregation, Hancock (1985, 1987), Barnett (1987), and Barnett, Hinich and Weber (1986) have provided results on supply-side monetary aggregation.[2] They use neoclassical economic theory to model

[1]See Barnett, Fisher and Serletis (1992).

[2]"Demand-side" and "supply-side" imply respectively the demand for monetary services by consumers and manufacturing firms, and the production of monetary services by financial intermediaries. Barnett (1987) has shown that consumer's demand for money and manufacturing firm's demand for money result in the identical aggregation problem, at least in the perfect certainty case. However, supply-side aggregation of produced monetary services creates uniquely different aggregation problems resulting from the existence of required reserves, which alter the user cost of produced monetary services. For further results regarding demand for monetary services by manufacturing firms, see Robles (1993) and Barnett and Yue (1991).

financial firms' production, so the existing economic aggregation and index number theory are directly applicable. In fact, throughout the literature on applying economic aggregation and index number theory to monetary aggregation, researchers usually assume perfect certainty. Exceptions are Barnett and Yue (1991) and Poterba and Rotemberg (1987), who generalize to demand-side exact monetary aggregation under risk. Supply-side monetary aggregation under risk has not previously been the subject of research.

Introduction of dynamics and uncertainty into supply-side monetary aggregation requires extensions of earlier research in this area. A financial firm's portfolio is generally diversified across different investment instruments, and the portfolio's rate of return is unknown at the time that the investment decision is made. Hence, the assumption of perfect-certainty and single-period modeling is not appropriate. Furthermore, superlative index numbers, such as the discrete time Divisia index, have known tracking ability only under the assumption of perfect certainty. In this paper, we develop a dynamic approach to supply-side monetary aggregation under uncertainty.

Historically, the literature on financial intermediation has produced many diverse models, often linked only weakly with neoclassical economic theory and having various objectives. The early view of the creation of money by financial firms, primarily viewed to be banks, was the deposit multiplier approach. By this theory in its original form, the process of creating money is simply determined by the reserve requirement ratio. Another approach is based upon the Miller-Modigliani theorem, which asserts the irrelevance of financial firms to the real economy in a setting of a perfect capital market. In recent years, many economists have questioned the appropriateness of either of those two very different propositions and attempts have been made to extend those theories by weakening the underlying assumptions.

Another approach is based upon the capital-asset pricing model (CAPM). Under the assumptions of that model, either the financial firm's portfolio rate of return is normally distributed or investors have a quadratic utility function defined over end-of-period wealth. Under either of those assumptions, the financial firm's optimal portfolio behavior can be represented by maximizing utility over the portfolio's expected rate of return and variance. This approach has been useful in modeling the optimal portfolio allocation decision conditionally upon the real resource inputs, which are not explained endogenously. Another important approach is represented by Diamond and Dybvig (1983). They apply traditional consumption-production theory and use an intertemporal model subject to privately observed preference shocks to examine the equilibrium between banks and depositors. The studies in this tradition have been successful in explaining bank runs. However, banks, serving solely as a production technology to depositors, play only a passive role in that approach.

Another approach is represented by Hancock (1985, 1987), Barnett (1987), and Barnett, Hinich and Weber (1986). They treat the financial intermediary in the same manner as a conventional production unit and use neoclassical firm theory to model a financial intermediary's production of output services and employment of inputs subject to the firm's technological feasibility constraint.[3] This approach fully models the role played by financial firms as producers of monetary services. Moreover, it provides the needed tools to apply existing economic aggregation theory to aggregation over financial firms' output monetary services, which comprise the economy's inside money. However, those studies have not developed a dynamic model of financial firms' production under uncertainty. This paper provides that difficult extension of financial firm modeling and output aggregation under neoclassical assumptions with dynamic risk.

With the theoretical model of a financial firm's monetary services production and the derived exact theoretical output aggregate, we estimate the model's parameters and test for weak separability of output services from factor inputs. We then substitute the parameter estimates into the weakly separable output aggregator function to generate the estimated exact supply-side monetary aggregate.[4] To this end, we develop a procedure for testing weak separability and for estimating the parameters of a flexible functional form specification of bank technology. The estimation is accomplished

[3]The papers of Tobin (1961) and Brainard and Tobin (1963, 1968) were the first to argue forcefully for the use of microeconomics and equilibrium theory in modeling the financial firm.

[4]Diewert and Wales (1987) and Blackorby, Schworm and Fisher (1986) have illustrated the difficulty of maintaining flexibility, regularity and weak separability simultaneously.

through Hansen and Singleton's (1982) generalized method of moments approach to estimating Euler equations.

Our empirical results are based upon commercial banking data. Our evidence indicates that banks' outputs are weakly separable from factor inputs in the transformation function. Moreover, even under uncertainty, the Divisia index provides a better approximation to the estimated theoretical aggregate than does the simple-sum or CE index.[5] These findings support the existence of a supply-side monetary aggregate and the potential usefulness of the Divisia index to aggregate over the weakly separable monetary assets on the supply side of money markets. The result is a measure of inside money, in the sense of monetary services produced by private financial firms.

The paper proceeds as follows. In the next section, we construct our theoretical model of monetary service production by financial firms under dynamic uncertainty. The model reduces to a dynamic stochastic choice problem, for which we derive the Euler equations. In the third section, we present our approach to flexible parametric specification, weak separability testing and parameter estimation using Hansen and Singleton's (1982) generalized method of moments estimation. The fourth section formulates the empirical application using banking industry data. The fifth section contains the empirical results, including parameter estimates, weak separability test results, the estimated theoretical aggregate, and the comparison among index number approximations to the estimated exact aggregate, where the index numbers considered include the Divisia, simple-sum and CE indexes. Section 6 brings together the demand side with the supply side to investigate the implications of our model in general equilibrium. Section 7 provides a graphical illustration of the errors-in-the-variables problem produced by the use of the simple-sum index as a measure of the monetary service flow. The final section presents a few concluding remarks.

THEORETICAL MODEL

In this section, we derive our theoretical model of monetary services production by financial firms under dynamic uncertainty. Consider a financial firm which issues its own liabilities and reinvests the borrowed funds in primary financial markets. In this process, real resources such as labor, materials and capital are used as factors of production in creating the services of the produced liabilities. Those produced liabilities are deposit accounts providing monetary service combinations that would not have existed in the economy without the financial firm. The liabilities of the financial firms include, for example, demand deposits and passbook accounts, and are assets to the depositors. The value added through the creation of those assets by a financial intermediary is that firm's contribution to the economy's inside money services. Without the existence of financial firms and the accounts that they create, investors in money markets would be limited to the use of primary money-market securities as the short maturity assets in their portfolios. While the produced liabilities of financial firms may not appear to be "outputs" to an accountant looking at the firm's balance sheet, the produced liabilities of financial firms are the outputs of the firms' production technologies.[6]

The financial firm's profits are made from the interest rate spread between the financial firm's financial assets (loans) and the firm's produced liabilities. That spread must exceed the real resource costs, in order for the firm to profit from its operation. Let Y_t be the real balances of the financial firm's asset (loan) portfolio during period t.[7] Let R_t be the portfolio rate of return, which is unknown at the beginning of each period. Financial firms also hold excess reserves in the form of cash, which has a nominal return of zero. The real balance of cash holding is C_t. Let y_{it} be real balances in the firm's ith produced account type and h_{it} be holding cost per dollar for that liability, where $i=1,\dots,I$.[8] The amount of the jth real resource used is z_{jt}, and

[5]The formula for computing the Divisia index is in Barnett (1980). Further details regarding the data sources used with the index are in Thornton and Yue (1992), who also provide instructions on downloading the data from the Federal Reserve Bank of St. Louis' public electronic bulletin board, called FRED. The formula for computing the CE ("currency equivalent") index is in Rotemberg, Driscoll and Poterba (1991).

[6]See Barnett (1987).

[7]As used in this paper, portfolio is the sum of all investments.

[8]The holding cost h_{it} is defined as $h_{it}=r_{it}+R_t k_{it}$. In this formula, r_{it} is the account's net interest rate, which is defined such that all the benefits (for example, service charges) and costs (for example, deposit insurance) generated by the borrowed funds have been factored into the interest rate, and $R_t k_{it}$ is the implicit tax rate on the financial firm from the existence of a reserve requirement on that account type. Required reserves are assumed to yield no interest and hence, produce an opportunity cost to the financial firm, since the firm otherwise could have invested the required reserves at a positive rate of return.

its price is w_{jt}, *where* $j=1,\ldots,J$. Let P_t be the general price index, which is used to deflate nominal to real units. All financial transactions are contracted at the beginning of each period, but interest is paid or received at the end of the period. The cost of employing resource z_{jt} is paid at the start of the period.

The firm's variable profit at the beginning of period t in accordance with Hancock's (1991, equation 3.1) formula, is

$$(1)\quad \pi_t = (1+R_{t-1})\, Y_{t-1}P_{t-1} - Y_tP_t + C_{t-1}P_{t-1} - C_tP_t + \sum_{i=1}^{I} [y_{it}P_t - (1+h_{i,\,t-1})y_{i,\,t-1}P_{t-1}] - \sum_{j=1}^{J} w_{jt}z_{jt}.$$

The first two terms in equation 1 represent the net cash flow generated from rolling over the loan portfolio during period t. The third and fourth terms represent the change in the nominal value of excess reserves. The fifth term is the net cash flow from issuing produced financial liabilities. The last term is total payments for real resource inputs.

Portfolio Y_t investment, however, is constrained by total available funds, under the assumption that all earnings are paid out as dividends. The relationship is

$$(2)\quad Y_tP_t = \sum_{i=1}^{I} (1-k_{it})\, y_{it}P_t - C_tP_t - \sum_{j=1}^{J} w_{jt}z_{jt},$$

where k_{it} is the reserve requirement ratio for the ith produced account type, with $0 \leq k_{it} \leq 1$. Rearranging, equation 2 can be seen to state that total deposits $\sum_{i=1}^{I} y_{it}P_{it}$ are allocated to required reserves, excess reserves, investment in loans, and payments for all real resource inputs. Substituting 2 into 1 to eliminate Y_t, we obtain the firm's profit function subject to its balance sheet constraint:

$$(3)\quad \pi_t = \sum_{i=1}^{I} \{[(1+R_{t-1})\,(1-k_{i,\,t-1}) - (1+h_{i,\,t-1})]y_{i,\,t-1}P_{t-1} + k_{it}y_{it}P_t\} - R_{t-1}C_{t-1}P_{t-1} - \sum_{j=1}^{J} (1+R_{t-1})\, w_{j,\,t-1}z_{j,\,t-1}.$$

We assume the financial firm chooses the level of borrowed funds, excess reserves, and real resource inputs to maximize its expected discounted intertemporal utility of variable profits, subject to the firm's technology. We further assume the financial firm's intertemporal utility function is additively separable. Then, the firm's maximization problem can be expressed by the following dynamic choice problem:

$$(4)\quad Max\; E_t\Big[\sum_{s=t}^{\infty} \Big(\frac{1}{1+\mu}\Big)^{s-t} U(\pi_s)\Big]$$
$$s.t.\quad \Omega(y_{1s},\ldots, y_{Is}, C_s, z_{1s},\ldots, z_{Js}) = 0 \quad \forall\; s \geq t,$$

where E_t denotes expectation conditional on the information known at time t, μ is the subjective rate of time preference and is assumed to be constant, U is the utility function, π_s is the variable profit at period s given by equation 3, and Ω is the firm's transformation function, defining the firm's efficient production technology from

$$(5)\quad \Omega(y_{1s},\ldots, y_{Is}, C_s, z_{1s},\ldots, z_{Js}) = 0 \quad \forall\; s \geq t.$$

In accordance with the usual properties of a neoclassical transformation function, Ω is convex in its arguments. In addition, the inputs are distinguished from the outputs by the inequality constraints:[9]

$$(6)\quad \frac{\partial \Omega}{\partial C_t} \leq 0, \quad \frac{\partial \Omega}{\partial z_{jt}} \leq 0 \quad \forall\; j=1,\ldots, J$$

and

$$(7)\quad \frac{\partial \Omega}{\partial y_{it}} \geq 0 \quad \forall\; i=1,\ldots, I.$$

We also assume that Ω is continuous and second-order differentiable.

Substituting equation 3 into 4, we have

$$(8)\quad Max\; E_t \Big\{\sum_{s=t}^{\infty} \Big(\frac{1}{1+\mu}\Big)^{s-t} U\Big(\sum_{i=1}^{I} \{[(1+R_{t-1})\,(1-k_{i,\,t-1}) - (1+h_{i,\,t-1})]y_{i,\,t-1}P_{t-1} + k_{it}y_{it}P_t\} - R_{t-1}C_{t-1}P_{t-1} - \sum_{j=1}^{J} (1+R_{t-1})\, w_{j,\,t-1}z_{j,\,t-1}\Big)\Big\}$$
$$s.t.\quad \Omega(y_{1s},\ldots, y_{Is}, C_s, z_{1s},\ldots, z_{Js}) = 0 \quad \forall\; s \geq t.$$

We now proceed to derive the Euler equations, comprising the first-order conditions, for this stochastic optimal control problem. We use Bellman's method. To do so, we must put the decision into Bellman's form, which requires identifying the state and control variables and determining that the decision, stated in terms of those variables, is in the form providing known Euler equation structure.

[9]See Barnett (1987), Hall (1973) and Diewert (1973).

We assume that the financial firm behaves competitively, so that the prices $h_{i,s-1}$ and $w_{j,s-1}$ are taken as given by the firm. In addition, $h_{i,s-1}$ and $w_{j,s-1}$ are nonstochastic, since they are lagged one period. From the same perfect competition assumption, it follows that R_s, k_{is}, and P_s are random processes that are not controllable by the firm. We select as state variables during period s: $y_{i,s-1}\ \forall\ i$, $z_{j,s-1}\ \forall\ j$, C_{s-1}, R_{s-1}, R_s, k_{is}, $h_{i,s-1}$ $\forall\ i$, $w_{j,s-1}\ \forall\ j$, P_{s-1}, and P_s. We choose $y_{is}\ \forall\ i$ and $z_{js}\ \forall\ j$ to be the control variables during period s.

Define $\boldsymbol{w}_s$ to be the vector of all of the state variables, and define $\boldsymbol{u}_s$ to be the vector of all control variables. Let Λ_s be the subset of state variables defined by $\Lambda_s = (R_s, k_{is}, h_{i,s-1}\ \forall\ i, w_{j,s-1}\ \forall\ j, P_s)$. We assume that Λ_s follows a first-order Markov process, with transitions governed by the conditional distribution function $F(\Lambda_{s+1}|\Lambda_s)$. Hence, the transition equation for state variables $(R_{s-1}, R_s, k_{is}, h_{i,s-1}\ \forall\ i, w_{j,s-1}\ \forall\ j, P_{s-1}, P_s)$ is implicitly defined by $F(\Lambda_{s+1}|\Lambda_s)$. The transition equations for $y_{i,s-1}\ \forall\ i$ and $z_{j,s-1}\ \forall\ j$ are the trivial identities

(9) $y_{is} = y_{is},\ \forall\ s$

and

(10) $z_{js} = z_{js},\ \forall\ s.$

The role played by these two equations in our application of Bellman's method follows from the fact that each of the variables in equations 9 and 10 are included both among the control and state variables, although with a time shift distinguishing them in each of their roles.[10] Hence, with the appropriate time shift in the subscript, equations 9 and 10 can be viewed as connecting together some of the control and state variables. This connection accounts for the function of those equations as transition equations. In particular, the left-hand sides can be identified as next-period state variables, while the right-hand sides can be identified as current-period control variables. Hence, each of those equations can be interpreted as defining the evolution of a state variable conditionally on a control variable. The transition equation for C_{s-1} is implicitly determined by the transformation function 5.

The objective function in equation 8 is an infinite summation of discounted utilities of variable profits, starting at period t. Recalling the time shifts appearing in our definition of the state and control variables during period s, we see that the discounted utility of variable profit at period s depends only on that period's state variables and control variables. By examining the transition equations, it is evident that each state variable is a function of only previous controls and not of previous values of the states. In particular, if we let $\boldsymbol{g}$ represent the vector of all transition functions, we can rewrite the dynamic decision problem as

$$Max\ E_t\ \{\sum_{s=t}^{\infty} (\frac{1}{1+\mu})^{s-t} U[\pi_s(\boldsymbol{w}_s, \boldsymbol{u}_s)]\}$$

$$s.t.\ \boldsymbol{w}_{s+1} = \boldsymbol{g}(\boldsymbol{u}_s),\ s \geq t.$$

This dynamic problem meets all of the conditions to be a recursive problem in the Bellman form. Using Bellman's principle, we can derive the first-order conditions for solving the dynamic problem 8. The Bellman recursive equation is

$$v(\boldsymbol{w}_t) = \max_{\boldsymbol{u}_t} E_t\{U[\pi_t(\boldsymbol{w}_t, \boldsymbol{u}_t)] + \frac{1}{1+\mu} v(\boldsymbol{w}_{t+1}) \mid \boldsymbol{w}_t,\ s.t.\ \boldsymbol{w}_{t+1} = \boldsymbol{g}(\boldsymbol{u}_t)\},$$

where $v(\boldsymbol{w}_t)$ is the optimized value of the objective function.

The first-order conditions for the Bellman equation are

$$(11)\quad E_t\Big[\frac{\partial U}{\partial \pi_t}(\pi_t)\frac{\partial \pi_t}{\partial \boldsymbol{u}_t}(\boldsymbol{w}_t, \boldsymbol{u}_t) + \frac{1}{1+\mu}\frac{\partial \boldsymbol{g}'}{\partial \boldsymbol{u}_t}(\boldsymbol{u}_t)\frac{\partial v}{\partial \boldsymbol{w}_t}(\boldsymbol{w}_{t+1}) \mid \boldsymbol{w}_t\Big] = \boldsymbol{0}.$$

The functional form of v is unknown. However, since $\frac{\partial \boldsymbol{g}'}{\partial \boldsymbol{w}_t} = \boldsymbol{0}$ we can use the Benveniste and

[10]The use of such trivial identities as transition equations (laws of motion) in optimal control and dynamic programming is not unusual. For example, it is common in optimal growth models to define current capital stock to be a state variable, while next period's capital stock is defined to be a control, with those state and control variables tied together by a trivial identity. The nontrivial dynamics is found in the objective function of such models. See, for example, Sargent (1987, p. 24).

Scheinkman equations to eliminate $\frac{\partial v}{\partial \boldsymbol{w}_t}(\boldsymbol{w}_{t+1})$.[11]

The general form of the Benveniste and Scheinkman equations is

$$\frac{\partial v}{\partial \boldsymbol{w}_t}(\boldsymbol{w}_t) = \frac{\partial U}{\partial \pi_t}(\pi_t)\frac{\partial \pi_t}{\partial \boldsymbol{w}_t}(\boldsymbol{w}_t, \boldsymbol{u}_t) + \frac{1}{1+\mu}E_t\Big[\frac{\partial \boldsymbol{g'}}{\partial \boldsymbol{w}_t}(\boldsymbol{w}_t, \boldsymbol{u}_t)\frac{\partial v}{\partial \boldsymbol{w}_t}(\boldsymbol{w}_{t+1})\Big].$$

Since $\frac{\partial \boldsymbol{g'}}{\partial \boldsymbol{w}_t} = \boldsymbol{0}$, the above equation implies

$$(12)\quad \frac{\partial v}{\partial \boldsymbol{w}_t}(\boldsymbol{w}_t) = \frac{\partial U}{\partial \pi_t}(\pi_t)\frac{\partial \pi_t}{\partial \boldsymbol{w}_t}(\boldsymbol{w}_t, \boldsymbol{u}_t).$$

Substituting 12 into 11, we get

$$(13)\quad E_t\Big[\frac{\partial U}{\partial \pi_t}(\pi_t)\frac{\partial \pi_t}{\partial \boldsymbol{u}_t}(\boldsymbol{w}_t, \boldsymbol{u}_t) + \frac{1}{1+\mu}\frac{\partial \boldsymbol{g'}}{\partial \boldsymbol{u}_t}(\boldsymbol{u}_t)\frac{\partial U}{\partial \pi_t}(\pi_{t+1})\frac{\partial \pi_t}{\partial \boldsymbol{w}_t}(\boldsymbol{w}_{t+1}, \boldsymbol{u}_{t+1}) \mid \boldsymbol{w}_t\Big] = \boldsymbol{0}.$$

A very general specification of utility to represent risk is the hyperbolic absolute risk aversion (HARA) class, defined by

$$(14)\quad U(\pi_t) = \frac{1-\rho}{\rho}\Big(\frac{h}{1-\rho}\pi_t + d\Big)^{\rho},$$

where ρ, h and d are three parameters to be estimated. The following useful utility functions are fully nested special cases of the HARA class:[12]

a. risk neutrality: $\rho=1$, $U(\pi_t)=h\pi_t$,

b. quadratic: $\rho=2$, $U(\pi_t) = -(1/2)(-h\pi_t + d)^2$,

c. negative exponential: $\rho=-\infty$ *and* $d=1$, $U(\pi_t)=-e^{-h\pi_t}$,

d. power: $d=0$ *and* $\rho<1$, $U(\pi_t) = (\pi_t^{\rho}/\rho)$,

e. logarithmic: $d=\rho=0$, $U(\pi_t) = \log \pi_t$.

The general HARA specification for $U(\pi_t)$ satisfies the relevent theoretical regularity conditions when the domain of $U(\pi_t)$ is constrained to $\{\pi_t\colon \frac{h}{1-\rho}\pi_t+d>0\}$ with h constrained to satisfy $h>0$. When $\rho>1$, absolute risk aversion (Arrow-Pratt) is decreasing, and when $\rho>1$, absolute risk aversion is increasing. The power utility function special case is very widely used. Since that functional form exhibits constant relative risk aversion (CRRA), the power utility function often is called the CRRA or isoelastic case.[13]

Differentiating (14) with π_t, we get

$$(15)\quad \frac{\partial U}{\partial \pi_t} = h\Big(\frac{h}{1-\rho}\pi_t + d\Big)^{\rho-1}.$$

Using equations 13 and 15 along with the defined state variables, control variables and transition equations, we obtain

$$(16)\quad E_t\Big\{P_t k_{it}\Big(\frac{h}{1-\rho}\pi_t+d\Big)^{\rho-1} + P_t\frac{1}{1+\mu}\Big[(1+R_t)(1-k_{it})-(1+h_{it}) + R_t\frac{\partial\Omega/\partial y_{it}}{\partial\Omega/\partial C_t}\Big]\Big(\frac{h}{1-\rho}\pi_{t+1}+d\Big)^{\rho-1}\Big\} = 0 \qquad \forall\, y_{it},\ i=1,\dots,I$$

and

$$(17)\quad E_t\Big[P_t R_t\frac{\partial\Omega/\partial z_{jt}}{\partial\Omega/\partial C_t}\Big(\frac{h}{1-\rho}\pi_{t+1}+d\Big)^{\rho-1} - (1+R_t)w_{jt}\Big(\frac{h}{1-\rho}\pi_{t+1}+d\Big)^{\rho-1}\Big] = 0 \qquad \forall\, z_{jt},\ j=1,\dots,J.$$

Equations 16 and 17 are a system of $I+J$ nonlinear equations. Theoretically, from 16 and 17 plus the transformation function 5, we could solve for $(Y_{1t},\dots,Y_{It}, C_t, Z_{1t},\dots,z_{Jt})$. However, in practice the solution could be produced only numerically, since a closed form algebraic solution rarely exists for such Euler equations.

[11]See Sargent (1987) for an excellent presentation of dynamic programming.

[12]See Ingersoll (1987, pp. 37-40). In case (d) below, imposing the restriction *d=0* alone on equation 14 will not produce the exact form provided for the power function. However, the form acquired subject to that sole restriction is a positive affine transformation of the power function. Hence both forms represent the same risk behavior.

[13]See, for example, Barnett and Yue (1991).

In the following discussion, we extend the dynamic decision 8 into the more general case incorporating learning by doing technological change. In the econometric literature on estimating returns to scale in manufacturing, increasing returns to scale usually are found, despite the fact that increasing returns to scale violates the second-order conditions for profit maximization. We believe that a likely source of this paradox is the potential to confound technological change with returns to scale, when learning by doing technological change exists but is not incorporated within one's model.

Let $\boldsymbol{y}_t$ be the vector of $\boldsymbol{y}_{it}$ for all i and $\boldsymbol{z}_t$ be the vector of $\boldsymbol{z}_{jt}$ for all j. We then write the maximization problem as

$$(18)\quad Max\ E_t\Big[\sum_{s=t}^{\infty}\Big(\frac{1}{1+\mu}\Big)^{s-t}U(\pi_s)\Big]$$

$$s.t.\ \Omega(\boldsymbol{y}_s, C_s, \boldsymbol{z}_s, \boldsymbol{y}_{s-1}) = 0 \qquad \forall\ s \geq t.$$

The appearance of $\boldsymbol{y}_{s-1}$ in the transformation function represents learning by doing. Firm technology improves through experience.

At the present stage of this research, we are not using the learning by doing extension of our model in our empirical work, so we only provide the Euler equations below, without supplying the details of the derivation. Those Euler equations under learning by doing are

$$(19)\quad E_t\Big\{\frac{\partial U}{\partial \pi_t}(\pi_t)\frac{\partial \pi_t}{\partial \boldsymbol{y}_t}(\boldsymbol{w}_t, \boldsymbol{u}_t)$$

$$+\frac{1}{1+\mu}\Big[\frac{\partial U}{\partial \pi_t}(\pi_{t+1})\frac{\partial \pi_t}{\partial \boldsymbol{y}_{t-1}}(\boldsymbol{w}_{t+1}, \boldsymbol{u}_{t+1})$$

$$-\frac{1}{1+\mu}\frac{\partial \Omega/\partial \boldsymbol{y}_{t-1}}{\partial \Omega/\partial C_t}(\boldsymbol{w}_{t+1}, \boldsymbol{u}_{t+1})$$

$$\frac{\partial U}{\partial \pi_t}(\pi_{t+2})\frac{\partial \pi_t}{\partial C_{t-1}}(\boldsymbol{w}_{t+2}, \boldsymbol{u}_{t+2})$$

$$-\frac{\partial \Omega/\partial \boldsymbol{y}_t}{\partial \Omega/\partial C_t}(\boldsymbol{w}_t, \boldsymbol{u}_t)\frac{\partial U}{\partial \pi_t}(\pi_{t+1})$$

$$\frac{\partial \pi_t}{\partial C_{t-1}}(\boldsymbol{w}_{t+1}, \boldsymbol{u}_{t+1})\Big]\Big\} = \boldsymbol{0} \qquad \forall \boldsymbol{y}_t$$

and

$$(20)\quad E_t\Big\{\frac{\partial U}{\partial \pi_t}(\pi_t)\frac{\partial \pi_t}{\partial \boldsymbol{z}_t}(\boldsymbol{w}_t, \boldsymbol{u}_t)$$

$$+\frac{1}{1+\mu}\Big[\frac{\partial U}{\partial \pi_t}(\pi_{t+1})\frac{\partial \pi_t}{\partial \boldsymbol{z}_{t-1}}(\boldsymbol{w}_{t+1}, \boldsymbol{u}_{t+1})$$

$$-\frac{\partial \Omega/\partial \boldsymbol{z}_t}{\partial \Omega/\partial C_t}(\boldsymbol{w}_t, \boldsymbol{u}_t)\frac{\partial U}{\partial \pi_t}(\pi_{t+1})$$

$$\frac{\partial \pi_t}{\partial C_{t-1}}(\boldsymbol{w}_{t+1}, \boldsymbol{u}_{t+1})\Big]\Big\} = \boldsymbol{0} \qquad \forall \boldsymbol{z}_t$$

Equations 19 and 20 are generalizations of (16) and (17). If learning by doing is excluded by imposing $\partial\Omega/\partial \boldsymbol{y}_{t-1} = \boldsymbol{0}$, then (19) and (20) reduce to (16) and (17), respectively. In the rest of the current paper, we return to the special case of no technological change.

A further nested special case is also interesting. We acquire risk neutrality by setting $\rho = 1$. As is conventional under risk neutrality, discounting is acquired objectively by replacing the subjective rate of time discount, μ, by R_t.[14] One reason for interest in that special case is that, in general equilibrium theory, the assumption of complete contingent claims markets combined with perfect competition can be shown, under certain additional assumptions, to produce the conclusion that firms will be risk neutral, even if their owners are risk-averse. The risk aversion of the owners then is captured within the contingent claims prices, which are taken as given by the firms' managers under perfect competition.[15]

While this theoretical issue is interesting, we do not consider it alone to be a convincing reason to impose risk neutrality on the management of an industry that behaves in a manner exhibiting clear risk aversion. However, we are interested in that fact that the Divisia index, along with virtually all of the literature on index number theory, is produced under the assumption of perfect certainty. This fact would suggest that the tracking ability of such index numbers may degrade as the level of risk aversion in-

[14] While the risk-neutral case is acquired directly by making those substitutions in the original decision problem, the resulting Euler equations are not acquired simply by making those substitutions in the risk-averse Euler equations, 16 and 17. The reason is that a cancellation within the Euler equations that is produced when the rate of discount is the constant, μ, does not apply when the rate of discount becomes the variable, R_t. In particular, after replacing ρ with 1.0, and μ with R_t, it also is necessary to multiply the two terms within equation 17 *by* $1/(1+R_t)$ to get the risk neutral case Euler equations. No such adjustment is needed within equation 16, since no relevant factors cancelled out in the derivation of equation 16. This observation also is relevant to the risk-neutral Euler equations 80 and 81 below.

[15] See, for example, Debreu (1959, ch. 7) and Duffie (1991, section 6.3). Regarding the complications produced by incomplete markets, see Magill and Shafer (1991, section 4).

creases. Hence, we produce results both with and without risk neutrality imposed, as a means of exploring the extent to which the tracking ability of index numbers is degraded in the risk averse case relative to the risk-neutral case.

Under risk neturality, our Euler equations reduce to[16]

$$(19') \quad E_t\left[P_t \frac{R_t(1-k_{it}) - r_{it}}{1+R_t} + P_t \frac{R_t}{1+R_t} \frac{\partial\Omega/\partial y_{it}}{\partial\Omega/\partial C_t}\right] = 0 \qquad \forall\, y_{it},\ i=1,\ldots,I$$

and

$$(20') \quad E_t\left[P_t \frac{R_t}{1+R_t} \frac{\partial\Omega/\partial z_{jt}}{\partial\Omega/\partial C_t} - w_{jt}\right] = 0 \qquad \forall\, z_{jt}, j=1,\ldots,J.$$

The assumption of perfect competition is itself sufficient for the existence of a representative firm. See Debreau 1959, p. 45, result 1. Hence, the theory acquired from our model can be applied with data aggregated over banks.[17]

SUPPLY-SIDE MONETARY AGGREGATION AND A WEAK SEPARABILITY TEST

Having formulated our dynamic model of financial firm production under uncertainty and having derived the Euler equations, we can proceed to investigate the exact supply-side monetary aggregates that are generated, if the firm's output monetary services are weakly separable from inputs.

Supply-Side Aggregation

Most money in modern economies is inside money, which is simultaneously an asset and a liability of the private sector. Inside money provides net positive services to the economy, as a result of the value added that is created by the financial intermediation that produces the inside money. In our model, the borrowed funds that are outputs produced by financial intermediaries are inside money. Inside money may take various forms such as demand deposits, interest-bearing checking accounts, small time deposits, and checkable money market deposit accounts. The sum of the dollar value in such accounts does not measure the services of inside money, any more than the sum of subway trains and roller skates measures transportation services, since the components of the aggregate are not perfect substitutes. The aggregation-theoretic exact quantity aggregate does, however, measure the service flow.[18]

The procedures involved in identifying and generating the exact quantity aggregates of microeconomic theory are described in detail by Barnett (1980). The approach necessarily involves two steps: identification of the components over which exact aggregation is admissible and determination of the aggregator function defined over those components. The first step determines whether or not an exact aggregate exists, and the second step creates the exact aggregate that is consistent with microeconomic theory. The second step cannot be applied unless the first step succeeds in identifying a component cluster that satisfies the existence condition. That existence condition, which is the basis for the first stage clustering of components, is blockwise weak separability. In accordance with the definition of weak separability, a blocking of components is admissible if and only if the goods in the block can be factored out of the structure of an economy through a subfunction. In other words, it must be possible to formulate the economic structure in the form of a composite function, with the goods in the cluster being the sole variables entering into the inner function of the structure. If that condition

[16]Observe that only one time subscript exists in the risk-neutral Euler equations, so that the solution becomes static. Once the nonlinear utility function has been removed from the objective function, the terms with common time subscripts can be grouped together. However, under risk aversion, even under our assumption of intertemporal strong separability, more than one time subscript exists within the utility function for each time period, since both current and lagged t appear as subscripts in equation 3 for each value of profit, π_t. Hence, the dynamics found within the objective function of equation 4 cannot be removed by regrouping terms.

[17]In fact, Debreu's theorem can be used to aggregate over all firms of all types in the economy to produce the aggregated technology of the country. The representative firm maximizes profits subject to that aggregated technology. However, we use the theorem only to aggregate over the firms in one industry. It should be observed that the ease of aggregation over firms under perfect competition is in marked contrast with the complexity of the theorems on aggregating over consumers.

[18]See, for example, Blackorby, Schworm and Fisher (1986) regarding the importance of using appropriately aggregated output data from firms.

is satisfied, an exact quantity aggregate exists over the goods in the cluster and the aggregator function that produces the exact aggregate over those goods is the inner function within the composite function.

Let $\boldsymbol{y}=(y_{1t},\ldots,y_{It})'$ and $\boldsymbol{x}=(C_t, z_{1t},\ldots,z_{Jt})'$ where $\boldsymbol{y}$ is the vector of the firm's outputs and $\boldsymbol{x}$ is the vector of the firm's inputs. The transformation function becomes

$$\Omega(\boldsymbol{y},\boldsymbol{x})=0.$$

An exact supply-side aggregator exists over all of the elements of $\boldsymbol{y}$ if and only if $\boldsymbol{y}$ is weakly separable from $\boldsymbol{x}$ within the structure of Ω. Mathematically, that statement is equivalent to the existence of two functions H and y_0 such that

$$\Omega(\boldsymbol{y},\boldsymbol{x})=H(y_0(\boldsymbol{y}),\boldsymbol{x}),$$

where $y_0(\boldsymbol{y})$ is a convex function of $\boldsymbol{y}$.[19] In aggregation theory, $y_0(\boldsymbol{y})$ is called the output aggregator function. Furthermore, suppose that $y_0(\boldsymbol{y})$ is linearly homogeneous in $\boldsymbol{y}$. Under this assumption, if each y_i grows at the same common rate, the theoretical aggregate $y_0(\boldsymbol{y})$ will grow at that rate. Clearly, without that condition, $y_0(\boldsymbol{y})$ could not serve as a reasonable aggregate.[20]

As shown by Leontief (1947a, 1947b), the weak separability condition is equivalent to

$$(21)\quad \frac{\partial}{\partial x_k}\left(\frac{\partial\,\Omega(\boldsymbol{y},\boldsymbol{x})/\partial y_i}{\partial\,\Omega(\boldsymbol{y},\boldsymbol{x})/\partial y_j}\right) = 0 \quad \textit{for all } k.$$

If a subset of the components of $\boldsymbol{y}$ were weakly separable from all of the other variables in Ω, then an exact output aggregate would exist only over the services of that subset of components and not over the services of all outputs. If we can test for the separability structure of the transformation function and acquire the functional form of $y_0(\boldsymbol{y})$, when $\boldsymbol{y}$ is weakly separable from $\boldsymbol{x}$, then we could estimate the parameters of $y_0(\boldsymbol{y})$ to acquire an econometric estimate of the exact output aggregate.

Although aggregation theory can provide us with the tools to estimate the exact aggregator function, the resulting aggregate is specification and estimator dependent. Alternatively, the literature on statistical index number theory provides nonparametric approximations to aggregator functions when the existence of the aggregator can be demonstrated through a weak separability test. Statistical index numbers provide only approximations to the theoretical aggregate, however, and when uncertainty exists, little is known about the tracking ability of statistical index numbers as approximations to the exact aggregates of microeconomic theory. In this paper we consider the Divisia, simple-sum and CE indexes to explore their abilities to track the econometrically estimated exact output aggregate.[21] We produce our econometric estimate of the exact theoretical aggregate, for comparison with the index numbers, by using generalized method of moments (GMM) estimation of the parameters of the Euler equations under rational expectations. We do the GMM estimation both under risk aversion and under the imposition of risk neutrality, to investigate sensitivity of our conclusions to risk aversion.

Flexibility, Regularity and Weak Separability

In empirical applications, there are two widely used approaches to testing for the weak separability condition that is necessary for economic aggregation: the nonparametric, nonstochastic approach based upon revealed preference and the statistical, parametric approach.[22] Since we are working from within a parametric specification, the conventional parametric approach to testing the hypothesis is to be preferred. In fact, we shall see that weak separability will be a strictly nested null hypothesis within our parametric specification, and, hence, conventional statistical testing is available immediately. In addition, the nonparametric approach, at its current state of development, is nonstochastic and, hence, has unknown power.

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[19]See Barnett (1987).

[20]Without linear homogeneity of y_0, the exact aggregate would become the distance function, rather than y_0, and would reduce to y_0, only under linear homogeneity of y_0. We do not pursue that generalization in this study, but see Barnett (1980) for details.

[21]The Divisia monetary aggregate index was introduced by Barnett (1978, 1980). The simple-sum index is the traditional monetary index acquired by simply adding up the component quantities without weights. The CE index is the currency equivalence aggregate, originated by Rotemberg (1991) and Rotemberg, Driscoll and Poterba (1991). For an alternative interpretation of the CE index as an economic monetary stock index connected with the Divisia service flow, see Barnett (1991).

[22]See Swofford and Whitney (1987).

Restrictive parametric specifications can bias inferences. As a result, flexible functional forms have been developed and are widely used in current studies. A flexible functional form, by definition, has enough free parameters to approximate locally to the second-order any arbitrary function.[23] However, using flexible functional forms creates a new problem. These models, unlike earlier, more restrictive models, may not globally satisfy the regularity conditions of economic theory, including the monotonicity and curvature conditions. It would be desirable to be able to impose global theoretical regularity on these models, but most of the models in the class of flexible functional forms lose their flexibility property, when regularity is imposed.[24] We use a model that permits imposition of regularity, without compromise of flexibility.

While flexibility and regularity are desirable in any neoclassical empirical study, weak separability in some blocking of the goods is also needed to permit aggregation over the goods in that block. We again are presented with the risk of losing flexibility by imposing a restriction, and in fact imposing weak separability on many flexible functional forms greatly damages the specifications' flexibility. For example, imposing weak separability on the translog function does great damage to its flexibility.[25] Because of the difficulties in imposing regularity and separability simultaneously without damage to flexibility, parametric tests of weak separability have been slow to appear and have been applied only to the static, perfect certainty case in which duality theory is available. In our case of dynamic uncertainty, very little duality theory is currently available.

In this section, we develop an approach that permits testing and imposing blockwise weak separability within a globally regular and locally flexible transformation function that is arising from a dynamic, stochastic choice problem. Our approach uses Diewert and Wales' (1991) symmetric generalized McFadden functional form to specify the technology of the firm.[26] In the discussion to follow, we first specify the model's form under the null hypothesis of weak separability in outputs. We then provide the more general form of the model that remains valid without the imposition of weak separability.

Using the notations defined previously, if $\boldsymbol{y}$ is weakly separable from $\boldsymbol{x}$, then

$$\Omega(\boldsymbol{y},\boldsymbol{x}) = H(y_0(\boldsymbol{y}),\boldsymbol{x}).$$

We further assume that the transformation function is linearly homogenous. Instead of specifying the form of the full transformation function Ω directly and thereafter imposing weak separability in $\boldsymbol{y}$, we impose weak separability directly by specifying $H(y_0,\boldsymbol{x})$ and $y_0(\boldsymbol{y})$ separately. We acquire our weakly separable form for Ω by substituting $y_0(\boldsymbol{y})$ into $H(y_0,\boldsymbol{x})$. Since our specifications of $y_0(\boldsymbol{y})$ and $H(y_0,\boldsymbol{x})$ are both flexible, it follows that our specification of Ω is flexible, subject to the separability restriction.

We specify H to be the symmetric generalized McFadden functional form

$$(22)\quad H(y_0,\boldsymbol{x}) = a_0 y_0 + \boldsymbol{a}'\boldsymbol{x} + \frac{1}{2}\,[\, y_0,\ \boldsymbol{x}' \,]\ \overline{\boldsymbol{A}} \begin{bmatrix} y_0 \\ \boldsymbol{x} \end{bmatrix} / \alpha'\boldsymbol{x},$$

with $\alpha'\boldsymbol{x}\neq 0$, where a_0, $\boldsymbol{a}'=(a_1,\dots,a_n)$, and $\overline{\boldsymbol{A}}$ consist of parameters to be estimated. The matrix $\overline{\boldsymbol{A}}$ is $(n+1)\times(n+1)$ and symmetric. The vector $\alpha'=(\alpha_1,\dots,\alpha_n)$ is a fixed vector of nonnegatvie constants.[27] The division by $\alpha'\boldsymbol{x}$ in 22 makes H linearly homogeneous in y_0 and $\boldsymbol{x}$.

To conform with the partitioning of the vector $(y_0,\boldsymbol{x}')$, we partition the matrix $\overline{\boldsymbol{A}}$ as

$$\overline{\boldsymbol{A}} = \begin{bmatrix} A_{11} & \boldsymbol{A}_{12} \\ \boldsymbol{A}_{21} & \boldsymbol{A} \end{bmatrix}$$

where A_{11} is a scalar, $\boldsymbol{A}_{12}$ is a $1\times n$ row vector,

[23] The flexibility here is sometimes called Diewert-flexible or second-order flexible. See Diewert (1971). The flexibility applies only locally. However, Gallant (1981, 1982) introduced the Fourier semi-nonparametric functional form, which can provide global flexibility asymptotically. Barnett, Geweke and Wolfe (1991) have developed the alternative seminonparametric asymptotically ideal model (AIM), which is globally flexible asymptotically and has advantages in terms of regularity.

[24] See Gallant and Golub (1984), Lau (1978) and Diewert and Wales (1987). However, if we can choose a model whose regularity region contains the data, then the regularity will be satisfied without imposing additional restrictions.

[25] See Blackorby, Primont and Russell (1977). Denny and Fuss (1977) propose a partial solution to avoid destroying flexibility. Their approach is to impose weak separability conditions at a point. However, local weak separability is not sufficient for the existence of a global aggregator function.

[26] Diewert and Wales (1987) alternatively also developed the generalized Barnett model. Although we have not used that model in this study, the generalized Barnett model has been applied to the analogous perfect-certainty case by Barnett and Hahm (1994). Regarding the merits of the generalized Barnett model in testing for weak separability, also see Blackorby, Schworm and Fisher (1986).

[27] We use the term "fixed constants" to designate constants that the researchers can select *a priori* and treat as constants during estimation.

$\boldsymbol{A}_{21}$ is an $n \times 1$ column vector, and $\bar{\boldsymbol{A}}$ an $n \times n$ symmetric matrix. Since $\bar{\boldsymbol{A}}$ is symmetric, it follows that $\boldsymbol{A}_{12} = \boldsymbol{A}'_{21}$.

Let $(y_0^*, \boldsymbol{x}^*) \neq 0$ be the point about which the functional form is locally flexible. That point is selected by the researcher in advance, in a manner analogous to the selection of the point about which a Taylor series is expanded. Since the transformation function is assumed to be linearly homogeneous, the specification in the above form is not parsimonious, and hence, we further can restrict the model without losing the local flexibility property.[28] We therefore impose

(23) $\alpha' \boldsymbol{x}^* = 1,$

(24) $A_{11} y_0^* + \boldsymbol{A}_{12} \boldsymbol{x}^* = 0,$

and

(25) $\boldsymbol{A}'_{12} y_0^* + \boldsymbol{A} \boldsymbol{x}^* = \boldsymbol{0}_n,$

where $\boldsymbol{0}_n$ is an n-dimensional vector of zeros. Under 23, 24 and 25, it can be verified that the number of free parameters in equation 22 equals the minimum number of free parameters needed to maintain flexibility.

Solving 24 and 25 for A_{11} and $\boldsymbol{A}_{12}$, we have

(26) $\boldsymbol{A}'_{12} = -\boldsymbol{A}\boldsymbol{x}^*/y_0^*$

and

(27) $A_{11} = \boldsymbol{x}^{*\prime}\boldsymbol{A}\boldsymbol{x}^*/y_0^{*2}.$

Substituting 26 and 27 into 22 yields

$$(28)\ H(y_0, \boldsymbol{x}) = a_0 y_0 + \boldsymbol{a}'\boldsymbol{x} + \frac{1}{2}(\alpha'\boldsymbol{x})^{-1}\boldsymbol{x}'\boldsymbol{A}\boldsymbol{x} - (\alpha'\boldsymbol{x})^{-1}\boldsymbol{x}^{*\prime}\boldsymbol{A}\boldsymbol{x}(y_0/y_0^*) + \frac{1}{2}(\alpha'\boldsymbol{x})^{-1}\boldsymbol{x}^{*\prime}\boldsymbol{A}\boldsymbol{x}^*(y_0/y_0^*)^2.$$

Diewert and Wales (1987) have proved that $H(y_0, \boldsymbol{x})$, defined by equation 28, is flexible at $(y_0^*, \boldsymbol{x}^*)$.

In a similar way, we define $y_0(\boldsymbol{y})$ to be

$$(29)\ y_0(\boldsymbol{y}) = \boldsymbol{b}'\boldsymbol{y} + \frac{1}{2}\boldsymbol{y}'\boldsymbol{B}\boldsymbol{y}/\beta'\boldsymbol{y},$$

with the parameters satisfying

(30) $\beta'\boldsymbol{y}^* = 1,$

(31) $y_0^* = \boldsymbol{b}'\boldsymbol{y}^*,$

and

(32) $\boldsymbol{B}\boldsymbol{y}^* = \boldsymbol{0}_m,$

where $\boldsymbol{b}' = (b_1, \ldots, b_m)$, and the $m \times m$ symmetric matrix $\boldsymbol{B}$ consists of parameters to be estimated, $\beta' = (\beta_1, \ldots, \beta_m)$ is a fixed vector of nonnegative constants, and $\boldsymbol{y}^* \neq 0$ is the point at which local flexibility of equation 29 is maintained.

Substituting 29 into 28, we get

$$\begin{aligned}(33)\ \Omega(\boldsymbol{y}, \boldsymbol{x}) &= H(y_0(\boldsymbol{y}), \boldsymbol{x}) \\ &= a_0\,(\boldsymbol{b}'\boldsymbol{y} + \frac{1}{2}(\beta'\boldsymbol{y})^{-1}\boldsymbol{y}'\boldsymbol{B}\boldsymbol{y}) + \boldsymbol{a}'\boldsymbol{x} \\ &\quad + \frac{1}{2}(\alpha'\boldsymbol{x})^{-1}\boldsymbol{x}'\boldsymbol{A}\boldsymbol{x} \\ &\quad - (y_0^*\alpha'\boldsymbol{x})^{-1}\boldsymbol{x}^{*\prime}\boldsymbol{A}\boldsymbol{x}(\boldsymbol{b}'\boldsymbol{y} + \frac{1}{2}(\beta'\boldsymbol{y})^{-1}\boldsymbol{y}'\boldsymbol{B}\boldsymbol{y}) \\ &\quad + \frac{1}{2}(y_0^{*2}\alpha'\boldsymbol{x})^{-1}\boldsymbol{x}^{*\prime}\boldsymbol{A}\boldsymbol{x}^*(\boldsymbol{b}'\boldsymbol{y}) \\ &\quad + \frac{1}{2}(\beta'\boldsymbol{y})^{-1}\boldsymbol{y}'\boldsymbol{B}\boldsymbol{y})^2,\end{aligned}$$

which is a flexible functional form for $\Omega(\boldsymbol{y}, \boldsymbol{x})$ and satisfies weak separability in outputs.

Neoclassical curvature conditions require $\Omega(\boldsymbol{y}, \boldsymbol{x})$ and $y_0(\boldsymbol{y})$ to be convex functions, and neoclassical monotonicity requires $\partial\Omega/\partial\boldsymbol{y} \geq 0$ and $\partial\Omega/\partial\boldsymbol{x} \leq 0$. Diewert and Wales (1987), theorem (10) have shown that $H(y_0, \boldsymbol{x})$, defined by 28, and $y_0(\boldsymbol{y})$, defined by 29, are globally convex if and only if $\boldsymbol{A}$ and $\boldsymbol{B}$ are positive semidefinite.

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[28] A flexible functional form is parsimonious if it has the minimum number of parameters needed to maintain flexibility. Diewert and Wales (1988) have acquired the minimum number of parameters needed to provide a second-order approximation to an arbitrary function. If a specification for an arbitrary function with n variables is flexible, it must have at least $1+n+n(n+1)/2$ independent parameters. In our case, the linear homogeneity imposes $1+n$ extra constraints on the first and second derivatives of H, so the minimum number of parameters needed to acquire flexibility is reduced by $1+n$.

For $\Omega(\boldsymbol{y},\boldsymbol{x})$ to be convex, we further need

$$(34)\quad \frac{\partial H(y_0,\boldsymbol{x})}{\partial y_0} \geq 0.$$

If 34 holds, then $\Omega(\boldsymbol{y},\boldsymbol{x})$ is globally convex in $(\boldsymbol{y},\boldsymbol{x})$, when $H(y_0,\boldsymbol{x})$ is convex in $(y_0,\boldsymbol{x})$ and $y_0(\boldsymbol{y})$ is convex in $\boldsymbol{y}$.[29]

If the unconstrained estimates of $\boldsymbol{A}$ and $\boldsymbol{B}$ are not positive semidefinite symmetric matrices, positive semidefiniteness can be imposed without destroying flexibility by the substitution

$$(35)\quad \boldsymbol{A} = \boldsymbol{qq'}$$

and

$$(36)\quad \boldsymbol{B} = \boldsymbol{uu'},$$

where $\boldsymbol{q}$ is a lower triangular $n\times n$ matrix and $\boldsymbol{u}$ is a lower triangular $m\times m$ matrix.[30] In estimation, we replace $\boldsymbol{A}$ and $\boldsymbol{B}$ by lower triangular matrixes $\boldsymbol{qq'}$ and $\boldsymbol{uu'}$, so that the function 33 is globally convex if 34 is true.

Monotonicity restrictions are difficult to impose globally. However, we can impose local monotonicity with simple restrictions. Differentiating 33 with respect to $(\boldsymbol{y},\boldsymbol{x})$, we get

$$(37)\quad \frac{\partial\Omega}{\partial\boldsymbol{y}} = a_0\,[\boldsymbol{b}+\frac{1}{2}\,(2(\beta'\boldsymbol{y})^{-1}\boldsymbol{By}-(\beta'\boldsymbol{y})^{-2}\beta\boldsymbol{y'By})] - (y_0^*\alpha'\boldsymbol{x})^{-1}\boldsymbol{x}^{*\prime}\boldsymbol{Ax}[\boldsymbol{b}+\frac{1}{2}\,(2(\beta'\boldsymbol{y})^{-1}\boldsymbol{By} -(\beta'\boldsymbol{y})^{-2}\beta\boldsymbol{y'By})] + (y_0^{*2}\alpha'\boldsymbol{x})^{-1}\boldsymbol{x}^{*\prime}\boldsymbol{Ax}^* [\boldsymbol{b}+\frac{1}{2}\,(2(\beta'\boldsymbol{y})^{-1}\boldsymbol{By}-(\beta'\boldsymbol{y})^{-2}\beta\boldsymbol{y'By})] (\boldsymbol{b'y}+\frac{1}{2}\,(\beta'\boldsymbol{y})^{-1}\boldsymbol{y'By})$$

and

$$(38)\quad \frac{\partial\Omega}{\partial\boldsymbol{x}} = \boldsymbol{a}+\frac{1}{2}\,[2(\alpha'\boldsymbol{x})^{-1}\boldsymbol{Ax}-(\alpha'\boldsymbol{x})^{-2}\alpha\boldsymbol{x'Ax}] - [(y_0^*\,\alpha'\boldsymbol{x})^{-1}\boldsymbol{Ax}^*-(y_0^*\,\alpha'\boldsymbol{x})^{-2}y_0^*\alpha\boldsymbol{x}^{*\prime}\boldsymbol{Ax}] (\boldsymbol{b'y}+\frac{1}{2}\,(\beta'\boldsymbol{y})^{-1}\boldsymbol{y'By}) -\frac{1}{2}\,(y_0^{*2}\alpha'\boldsymbol{x})^{-2}y_0^{*2}\,\alpha\boldsymbol{x}^{*\prime}\boldsymbol{Ax}^*(\boldsymbol{b'y} +\frac{1}{2}(\beta'\boldsymbol{y})^{-1}\boldsymbol{y'By})^2.$$

If we evaluate these derivatives at $(\boldsymbol{y}^*,\boldsymbol{x}^*)$, we have

$$(39)\quad \frac{\partial\Omega}{\partial\boldsymbol{y}}=a_0\boldsymbol{b}$$

and

$$(40)\quad \frac{\partial\Omega}{\partial\boldsymbol{x}}=\boldsymbol{a}.$$

Applying the method of squaring technique, we impose on 39 and 40 the monotonicity conditions[31]

$$(41)\quad \frac{\partial\Omega}{\partial\boldsymbol{y}}(\boldsymbol{y}^*,\boldsymbol{x}^*) = a_0\boldsymbol{b}\geq 0 \quad \text{and} \quad \frac{\partial\Omega}{\partial\boldsymbol{x}}(\boldsymbol{y}^*,\boldsymbol{x}^*) = \boldsymbol{a}\leq 0.$$

Equation 41 assures that the monotonicity conditions are satisfied locally at $(\boldsymbol{y}^*,\boldsymbol{x}^*)$.

We have shown that the functional form defined by equation 33 and restricted to satisfy equations 23, 30-32, 34-36 and 41 is flexible, locally monotone, and globally convex, provided that the assumed weakly separable structure is true. Although we do not impose global monotonicity, we do check and confirm that monotonicity is satisfied at each observation within our data. In the following discussion, we will define a more general flexible functional form that does not require weak separability.

The number of independent parameters in equation 33 is

$$(42)\quad 1+n+\frac{n(n+1)}{2}+m-1+\frac{m(m-1)}{2}.$$

We know that the minimum number of parameters required to maintain flexibility for a linearly homogeneous function with $n+m$ variables is

$$(43)\quad 1+n+m+\frac{(n+m)\ (n+m+1)}{2} - (1+n+m).$$

Subtracting 42 from 43, we get $n(m-1)$, which is the number of additional parameters that must be introduced into equation 33 to acquire

[29]See Diewert and Wales (1991) for the proof.

[30]See Lau (1978) and Diewert and Wales (1987).

[31]See Lau (1978).

a flexible functional form for a general transformation function. Let

(44) $\Omega(\boldsymbol{y},\boldsymbol{x}) = H(y_0(\boldsymbol{y}),\boldsymbol{x}) + \boldsymbol{c}'\boldsymbol{y} + \boldsymbol{y}'\boldsymbol{C}\boldsymbol{x} \,/\, (\gamma'\boldsymbol{y} + \lambda'\boldsymbol{x}),$

where γ and λ are vectors of nonnegative fixed constants, the vector $\boldsymbol{c}' = (c_1, \ldots, c_m)$ and the $m \times n$ matrix $\boldsymbol{C}$ are new parameters to be estimated, and the division by $\gamma'\boldsymbol{y} + \lambda'\boldsymbol{x}$ makes Ω linearly homogeneous. Because of the linear homogeneity property, we have more free parameters than needed for flexibility and, hence, we can impose the following additional restrictions without losing local flexibility:

(45) $\gamma'\boldsymbol{y}^* + \lambda'\boldsymbol{x}^* = 1,$

(46) $\boldsymbol{c}'\boldsymbol{y}^* = 0,$

(47) $\boldsymbol{y}^{*\prime}\boldsymbol{C} = \boldsymbol{0}'_n,$

and

(48) $\boldsymbol{C}\boldsymbol{x}^* = \boldsymbol{0}_m,$

where $(\boldsymbol{y}^*,\boldsymbol{x}^*)$ is the point at which local flexibility is maintained. Under equations 45-48, the number of new free parameters added into 44 is exactly equal to $n(m-1)$. Diewert and Wales (1991) have proved that the function 44 is a flexible functional form at $(\boldsymbol{y}^*,\boldsymbol{x}^*)$ for a general nonseparable transformation function.

Global convexity is difficult to impose in this case. However, we can derive the restrictions for local convexity at $(\boldsymbol{y}^*,\boldsymbol{x}^*)$. Deriving the Hessian matrix of 44 and evaluating at $(\boldsymbol{y}^*,\boldsymbol{x}^*)$, we have

(49) $\nabla^2\Omega(\boldsymbol{y}^*,\boldsymbol{x}^*) =$

$$\begin{bmatrix} a_0\boldsymbol{B} + \boldsymbol{b}\boldsymbol{b}'\boldsymbol{x}^{*\prime}\boldsymbol{A}\boldsymbol{x}^* / y_0^{*2} & \boldsymbol{C} - \boldsymbol{b}\boldsymbol{x}^{*\prime}\boldsymbol{A}/y_0^* \\ \boldsymbol{C}' - \boldsymbol{A}\boldsymbol{x}^*\boldsymbol{b}'/y_0^* & \boldsymbol{A} \end{bmatrix}.$$

If $\nabla^2\Omega(\boldsymbol{y}^*,\boldsymbol{x}^*)$ is positive semidefinite, then $\Omega(\boldsymbol{y}^*,\boldsymbol{x}^*)$ is convex at $(\boldsymbol{y}^*,\boldsymbol{x}^*)$. Let

(50) $\boldsymbol{A} = \boldsymbol{q}\boldsymbol{q}',$

(51) $\boldsymbol{C} = \boldsymbol{v}\boldsymbol{q}',$

and

(52) $\boldsymbol{B} = a_0^{-1}[\boldsymbol{v}\boldsymbol{v}' + \boldsymbol{u}\boldsymbol{u}'],$

where $\boldsymbol{q}$ and $\boldsymbol{u}$ are lower triangular matrices introduced for reasons described above, and $\boldsymbol{v}$ is an unrestricted $m \times n$ matrix. Then $\nabla^2\Omega(\boldsymbol{y}^*,\boldsymbol{x}^*)$ is a positive semidefinite symmetric matrix.[32]

Using 50-52, we rewrite 47, 48 and 32 as

(53) $\boldsymbol{y}^{*\prime}\boldsymbol{v} = \boldsymbol{0}'_n,$

(54) $\boldsymbol{v}(\boldsymbol{q}'\boldsymbol{x}^*) = \boldsymbol{0}_m,$

and

(55) $\boldsymbol{u}'\boldsymbol{y}^* = \boldsymbol{0}_m.$

The function defined by 44 and satisfying 23, 30-31, 45-46 and 50-55 is a flexible functional form for a general transformation function at $(\boldsymbol{y}^*,\boldsymbol{x}^*)$. In addition, local convexity is satisfied.

We now turn to imposing local monotonicity. Differentiating 44 with respect to $(\boldsymbol{y},\boldsymbol{x})$ and evaluating at $(\boldsymbol{y}^*,\boldsymbol{x}^*)$, we have

(56) $\dfrac{\partial\Omega}{\partial\boldsymbol{y}} = a_0\boldsymbol{b} + \boldsymbol{c}$

and

(57) $\dfrac{\partial\Omega}{\partial\boldsymbol{x}} = \boldsymbol{a}.$

As above, we use the method of squaring to impose nonnegativity on 56 and nonpositivity on 57. The estimated results then satisfy local monotonicity.

Comparing 33 with 44, we see that weak separability of outputs in 44 is equivalent to:

(58) $H_0\!: \boldsymbol{c} = \boldsymbol{0}_m$ *and* $\boldsymbol{v}_{m\times n} = \boldsymbol{0}_{m\times n}.$

Note that under the null hypothesis, H_0, equation 44 reduces to 33. Hence, $\boldsymbol{y}$ is weakly separable from $\boldsymbol{x}$ if and only if H_0 is true.

We have derived two flexible functional forms with appropriate regularity properties. One structure holds in the general case and the other under the null hypothesis of weak separability. We now are prepared to test weak separability and to estimate the parameters of the transformation function. The basic tool is Hansen and Singleton's generalized method of moments (GMM) estimator.

[32]See Lau (1978) and Diewert and Wales (1991).

Substituting the functional form given by either 33 or 44 into the Euler equations 16 and 17, we obtain our structural model, which consists of a system of integral equations. A closed form solution to such Euler equations rarely exists. However, GMM permits estimating nonlinear rational expectations models defined in terms of Euler equations. Hansen (1982) has proved that under very weak conditions, the GMM estimates are consistent and asymptotically normally distributed.[33]

In the GMM framework, there are two methods of testing hypotheses.[34] The first approach applies Hansen's asymptotic χ^2 statistic to test for no overidentifying restrictions. We impose the weak separability restrictions 58 on the flexible functional form 44, estimate the restricted system, and then run Hansen's test for no overidentifying restrictions. Since 44 reduces to 33 after imposing the weak separability restrictions, we can substitute equation 33 itself directly into the Euler equations to impose the null for testing. If the test of no overidentifying restrictions is rejected, then the restrictions imposed under the null hypothesis are rejected, where in our case the null is the weakly separable structure imposed on the transformation function.

The second approach to hypothesis testing with GMM is based on the asymptotically normal distribution of the GMM parameter estimators. Let θ be the vector of parameters to be estimated in equation 44. Then the GMM estimator $\hat{\theta}$ has an asymptotically normal distribution with mean θ and covariance matrix Σ.

Let τ be an $[n(m-1)]\times 1$ vector which contains all $n(m-1)$ independent parameters in the vector $\boldsymbol{c}$ and the matrix $\boldsymbol{v}$. The hypothesis of weak separability can be rewritten now as $\tau = \mathbf{0}$ or equivalently as a set of linear restrictions of the form

$$(59)\quad \boldsymbol{S}\theta = \tau = \mathbf{0},$$

where $\boldsymbol{S}$ is an $[n(m-1)]\times[(n+m+1)/2]$ matrix whose elements are all zeros and ones.

From the known asymptotic distribution of $\hat{\theta}$, we have

$$(60)\quad \sqrt{T}\,(\boldsymbol{S}\hat{\theta} - \boldsymbol{S}\theta) \overset{a}{\sim} N(\mathbf{0}, \boldsymbol{S}\Sigma\boldsymbol{S}'),$$

where T is the number of observations. Under the null hypothesis, H_0: $\boldsymbol{S}\theta = 0$, we have

$$\sqrt{T}\,\hat{\tau} \overset{a}{\sim} N(\mathbf{0}, \boldsymbol{S}\Sigma\boldsymbol{S}'),$$

where $\hat{\tau} = \boldsymbol{S}\hat{\theta}$. We obtain the following χ^2 statistic

$$(61)\quad \boldsymbol{\Phi} = (\sqrt{T}\,\hat{\tau})'[\boldsymbol{S}\Sigma\boldsymbol{S}']^{-1}(\sqrt{T}\,\hat{\tau}) = T\hat{\tau}'[\boldsymbol{S}\Sigma\boldsymbol{S}']^{-1}\hat{\tau} \overset{a}{\sim} \chi^2_{n(m-1)}.$$

Although Σ is unknown, we can replace it by a consistent estimate without changing the asymptotic results. The test is one sided, with the null of separability rejected if $\boldsymbol{\Phi}$ is large.

EMPIRICAL APPLICATION

Barnett and Hahm (1994), and Hancock (1985, 1987, 1991) have analyzed monetary service production by the banking industry in detail, under the assumptions of perfect certainty and neoclassical joint production. The balance sheet of a bank consists of fund-providing functions and fund-using functions. The fund-providing functions include demand deposits, time deposits and nondeposit funds.[35] The fund-using functions include investment, real estate mortgage loans, installment loans, credit card loans and industrial loans. In our theoretical model, the sources of funds are the firm's borrowed funds, and the uses of funds are the firm's portfolio. The total available funds on the balance sheet are total assets minus premises and other assets.

On the average, demand deposits and time deposits account for over 85 percent of total available funds. The equity capital included in the non-deposit funds can be treated as a fixed factor that does not enter the variable profit

[33] Hansen (1982), Hansen and Singleton (1982), and Newey and West (1987) provide a detailed discussion of GMM estimation.

[34] See Mackinlay and Richardson (1991).

[35] Demand deposits consist of checking accounts, official checks, money orders, treasury tax accounts and loan accounts. Time deposits consist of regular savings, money market deposit accounts, other time accounts, retirement accounts, and certificates of deposit under $100,000. Nondeposit funds consist of equity capital, federal funds purchased, borrowed money, capital notes and debentures, time deposits of $100,000 and over, other money market instruments, and other liabilities.

function.[36] For these reasons, we only choose demand deposits and time deposits as borrowed funds in our model. Turning to inputs, excess reserves are total cash balances minus required reserves. Other real resource inputs are labor, materials and capital.[37] Capital is treated as fixed, and we include only variable factors in the transformation function. An obvious direction for possible future extension of this research would be the incorporation of some or all capital as variable factors to produce inferences applicable to a longer run perspective than that implicit in our definition of variable and fixed factors.

Using equations 16 and 17, the Euler equations are

$$(62)\quad E_t\{P_t k_{1t}(\frac{h}{1-\rho}\pi_t+d)^{\rho-1} + P_t\frac{1}{1+\mu}[(1+R_t)(1-k_{1t}) - (1+h_{1t}) + R_t\frac{\partial\Omega/\partial D_t}{\partial\Omega/\partial C_t}](\frac{h}{1-\rho}\pi_{t+1}+d)^{\rho-1}\}=0,$$

$$(63)\quad E_t\{P_t k_{2t}(\frac{h}{1-\rho}\pi_t+d)^{\rho-1} + P_t\frac{1}{1+\mu}[(1+R_t)(1-k_{2t}) - (1+h_{2t}) + R_t\frac{\partial\Omega/\partial T_t}{\partial\Omega/\partial C_t}](\frac{h}{1-\rho}\pi_{t+1}+d)^{\rho-1}\}=0,$$

$$(64)\quad E_t\{[P_t R_t\frac{\partial\Omega/\partial L_t}{\partial\Omega/\partial C_t} - (1+R_t)w_{1t}](\frac{h}{1-\rho}\pi_{t+1}+d)^{\rho-1}\}=0,$$

and

$$(65)\quad E_t\{[P_t R_t\frac{\partial\Omega/\partial M_t}{\partial\Omega/\partial C_t} - (1+R_t)w_{2t}](\frac{h}{1-\rho}\pi_{t+1}+1)+d)^{\rho-1}\}=0,$$

where D_t is demand deposits, T_t is time deposits, L_t is labor input, M_t is materials input, and w_{1t} and w_{2t} are the prices of labor and materials respectively.

Using the notations in section three, we can write

$\boldsymbol{y}'=(D_t,T_t)$ and $\boldsymbol{x}'=(C_t,L_t,M_t)$.

If the weakly separable structure of the transformation function is true, then equation 33 is the transformation function. As discussed in section three, the weak separability hypothesis can be tested by applying Hansen's χ^2 statistic.

The derivatives of Ω with respect to its arguments are given by equations 37 and 38. The fixed constants and the center of the local approximation need to be selected before estimation. We choose

$y_0^*=1$, $\boldsymbol{y}^{*\prime}=(1,1)$, *and* $\boldsymbol{x}^{*\prime}=(1,1,1)$

as the center of approximation. To locate that center within the interior of the observations, we rescale the data about the midpoint observation

$$(66)\quad \tilde{x}_i^t = x_i^t / x_i^{t^*} \quad \forall\, i=1,2,3 \text{ and}$$

$$\tilde{y}_i^t = y_i^t / y_i^{t^*} \quad \forall\, i=1,2,$$

where t^* represents the midpoint observation.[38] We correspondingly rescale each price by multiplication by the midpoint observation. That rescaling of prices keeps dollar expenditures on each good unaffected by the rescaling of its quantity.

We select the fixed nonnegative constants α_i and β_i such that

$$(67)\quad \alpha_i = |\bar{\tilde{x}}_i| / \sum_{j=1}^{3} |\bar{\tilde{x}}_j| \qquad \forall\, i=1,2,3$$

and

$$(68)\quad \beta_i = |\bar{\tilde{y}}_i| / \sum_{j=1}^{2} |\bar{\tilde{y}}_j| \qquad \forall\, i=1,2,$$

where $\bar{\tilde{x}}$ and $\bar{\tilde{y}}$ are the sample means of $\tilde{x}$ and $\tilde{y}$ respectively. Note that α_i and β_i satisfy equations 23 and 30, as is required. With our data sam-

[36]See Barnett (1987). Equity capital includes preferred and common stocks, surplus, undivided profits and reserves, and valuation reserves.

[37]Labor includes managerial labor and nonmanagerial labor. Materials include stationery, printing and supplies, telephone, telegraph, postage, freight and delivery.

[38]The data point at which all quantities are set to unity can be arbitrary.

ple, we find $\alpha_1=0.33$, $\alpha_2=0.35$, $\alpha_3=0.32$, $\beta_1=0.58$, and $\beta_2=0.42$.

Before estimating the independent parameters, we need only impose the inequality restrictions. Equation 31 implies $b_2=1-b_1$, and the monotonicity condition (41) requires $b_i\geq 0$. Hence, it also follows that $b_i\leq 1$. Combining these conditions, we can replace b_1 and b_2 by

$$(69)\quad b_1 = \sin^2(\xi) \text{ and } b_2 = \cos^2(\xi)$$

and estimate ξ. Since $\Omega(\boldsymbol{y},\boldsymbol{x})=0$, we also normalize $a_0=1$.

The monotonicity condition 41 requires $a_i\leq 0$, which we impose by replacing a_i by $-\tilde{a}_i^2\ \forall\ i=1,2,3$, where $\tilde{a}_i,\ \forall\ i=1,2,3$, are the new parameters to be estimated. The convexity conditions are imposed by replacing $\boldsymbol{A}$ and $\boldsymbol{B}$ by the lower triangular matrices $\boldsymbol{qq'}$ and $\boldsymbol{uu'}$ respectively, where $\boldsymbol{q}$ and $\boldsymbol{u}$ are

$$\boldsymbol{q} = \begin{bmatrix} q_{11} & 0 & 0 \\ q_{21} & q_{22} & 0 \\ q_{31} & q_{32} & q_{33} \end{bmatrix}$$

and

$$\boldsymbol{u} = \begin{bmatrix} u_{11} & 0 \\ u_{21} & u_{22} \end{bmatrix}.$$

Equation 32 implies

$$(70)\quad \begin{bmatrix} u_{11} & 0 \\ u_{21} & u_{22} \end{bmatrix} \begin{bmatrix} u_{11} & u_{21} \\ 0 & u_{22} \end{bmatrix} \begin{bmatrix} 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}.$$

Solving 70, we get $u_{21} = -u_{11}$ and $u_{22} = 0$. Substituting them into equation 36, we have

$$(71)\quad \boldsymbol{B} = u_{11}^2 \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}.$$

The above discussion identifies all the independent parameters to be estimated in the specification of the transformation function. They are ξ, u_{11}, the lower triangular matrix $\boldsymbol{q}$, and the vector $\tilde{\boldsymbol{a}}'=(\tilde{a}_1,\tilde{a}_2,\tilde{a}_3)$.

The primary data source is the Federal Reserve's Functional Cost Analysis (FCA).[39] We got our data from the Federal Reserve Bank of St. Louis. The data used are the National Average FCA Report, which contains annual data from 1966 to 1990. Hence, there are a total of 25 observations in our annual data. Monthly data is not available from the FCA. From the FCA, we acquired banks' portfolio rate of return, the net interest rates on demand deposits and time deposits, and the nominal quantity of demand deposits, time deposits and cash balances.[40] The prices and quantities of labor and materials are aggregate producer prices and quantity indexes from the data in the FCA Report and the *Survey of Current Business.*[41] The required reserve ratio is from the *Federal Reserve Bulletin.* The implicit price deflator is the implicit GNP deflator from the Citibank data base. We deflate the nominal dollar balances of all financial goods to convert them into real balances.

EMPIRICAL RESULTS

We use the GMM estimator in the TSP mainframe version (version 4.2) to estimate our model. In the disturbances we allow for conditional heteroskedasticity and second-order moving average serial correlation. Using the spectral density kernels in TSP, our estimated results are robust to heteroskedasticity, autocorrelation and positive semidefinite weighting matrix. To use the GMM method, instrumental variables must be selected. We choose as instruments the constant, the federal funds rate, the discount window rate, the composite bond rate (maturities over 10 years), the holding cost of demand deposits and time deposits, the lagged banks' portfolio rate of return, excess cash reserves, and capital. In estimation, we replace h by h^2 to impose nonnegativity of the resulting h^2. That nonnegativity is needed for regularity in the definition of the HARA class.

The GMM parameter estimates, subject to imposition of weak separability of outputs from inputs, are reported in Table 1. All three parameters in the utility function are statistically

[39] The Functional Cost Analysis program is a cooperative venture between the Federal Reserve Banks and the participating banks. This program is designed to assist a participating bank in increasing overall bank earnings as well as to improve the operational efficiency of each bank function.

[40] The net interest rate equals the interest paid minus service charges earned plus FDIC insurance premiums paid.

[41] See Barnett and Hahm (1994) for a detailed discussion about the aggregation of labor and material.

Table 1

GMM Estimates Using the HARA Utility Function with Weak Separability in Outputs Imposed

Parameter	Estimate	Standard error	t-Statistic
h^2	0.003	0.122	0.024
$\rho-1$	2.330	25.625	0.091
d	0.001	0.044	0.012
$\mu+1$	1.090	0.165	6.602
ξ	58.382	0.201	290.459
u_{11}	0.232	0.418	0.555
q_{11}	0.186	0.078	2.372
q_{21}	0.418	0.106	3.931
q_{31}	0.105	0.048	2.178
q_{22}	0.477	0.101	4.725
q_{32}	0.120	0.162	0.743
q_{33}	0.116	0.505	0.230
$\tilde{a}_1$	0.323	0.035	9.117
$\tilde{a}_2$	0.436	0.058	7.523
$\tilde{a}_3$	0.280	0.038	7.448

insignificant at the 5 percent level. As a result of the very low precision of those three parameter estimates, it is clear that we have introduced risk aversion in a manner incorporating too many parameters for the available sample size. Hence, we need to restrict HARA to one of its less deeply parameterized special cases. As observed in the second section, the HARA class reduces to the popular power (CRRA isoelastic) utility function. We now test whether that popular special case is accepted.

Equation (61) in the third section provides a statistic to test that a set of parameters is jointly equal to zeros. When the set of parameters includes only one element, the χ^2 test statistic Φ, given by equation (61), equals the number of observations multiplied by the square of the t-statistic of that parameter. We calculated that $\Phi=0.0033$, while the critical value is 6.635 at the one percent significance level. Hence, we cannot reject $d=0$, and the power utility function is accepted. We reestimate the model using that specification.

To impose the inequality restriction $0 < \rho < 1$, which is sufficient for regularity of the power utility function special case, we replace ρ by $\sin^2(\tilde{\rho})$ and estimate $\tilde{\rho}$. In addition, to prevent the implausible possibility of a negative subjective rate of time discount, we replace μ by $\tilde{\mu}^2$ and estimate $\tilde{\mu}$.[42] The estimated results, subject to imposition of weak separability of outputs from inputs, are reported in Table 2.[43] All parameters are significantly different from zero at the 5 percent level except for $\tilde{\mu}$, u_{11}, *and* q_{33}. Monotonicity is necessarily satisfied at $(\mathbf{y}^*, \mathbf{x}^*)$, since local monotonicity was imposed at that point. We use the estimated parameters to determine whether monotonicity is satisfied elsewhere in the sample. Substituting the estimated parameters into equations 37 and 38, we find that $\partial\Omega/\partial\mathbf{y}>0$ and $\partial\Omega/\partial\mathbf{x}<0$ everywhere in the sample. Hence, no violations of monotonicity occurred within the sample. Regarding curvature, we have imposed global convexity on $H(y_0,\mathbf{x})$ and $y_0(\mathbf{y})$. To verify global convexity of $\Omega(\mathbf{y},\mathbf{x})$, we must check equation 34 at each data point.

[42]Actually only the upper bound imposed on ρ is required by theory. Hence, if we had found that the lower bound implied by our substitution was binding, we would have switched to the more sophisticated substitution of $2-\cosh(\tilde{\rho})$ in place of ρ. But in practice our estimate of ρ was strictly positive, so we did not have to resort to the introduction of hyperbolic functions. Furthermore, our imposition of nonnegativity on μ was equally as harmless, since no corner solutions were acquired on that inequality restriction either. In fact, in the HARA case, we did not impose nonnegativity on μ at all, since we got nonnegativity from our estimates without the need to impose it, and in retrospect it is evident that we could have done the same in the power utility case.

[43]The instrumental variables are the constant, the federal funds rate, the discount window rate, the composite bond rate (over 10 years), the three-month T-bill rate, the yields on demand deposits and time deposits, the lagged bank's portfolio rate of return, and capital.

Table 2

GMM Estimates Using the Power Utility Function with Weak Separability in Outputs Imposed

Parameter	Estimate	Standard error	t-Statistic
$\tilde{\rho}$	−524.629	9.410	−55.754
$\tilde{\mu}$	0.351	0.187	1.877
ξ	60.692	0.019	3122.720
u_{11}	0.171	0.283	0.605
q_{11}	0.240	0.050	4.821
q_{21}	0.461	0.077	5.980
q_{31}	0.103	0.018	5.908
q_{22}	0.418	0.047	8.958
q_{32}	0.093	0.029	3.147
q_{33}	−0.025	0.412	−0.062
$\tilde{a}_1$	0.330	0.031	10.762
$\tilde{a}_2$	0.482	0.045	10.607
$\tilde{a}_3$	0.217	0.020	10.836

Differentiating $H(y_0,\boldsymbol{x})$ with respect to y_0, we get

$$(72)\ \frac{\partial H(y_0,\boldsymbol{x})}{\partial y_0} = a_0-(\alpha'\boldsymbol{x})^{-1}\boldsymbol{x}^{*\prime}\boldsymbol{A}\boldsymbol{x}/y_0^{*} + (\alpha'\boldsymbol{x})^{-1}\boldsymbol{x}^{*\prime}\boldsymbol{A}\boldsymbol{x}^{*}y_0/y_0^{*2},$$

where y_0 is given by equation 29. Substituting the estimated parameters into equation 72, we find that $\partial H(y_0,\boldsymbol{x})/\partial y_0>0$ at every data point. Convexity of Ω is satisfied throughout the sample.

The weak separability hypothesis is tested by using Hansen's χ^2 test for no overidentifying restrictions. His test statistic is

$$(73)\ \Phi = TQ\sim\chi^2_{e-f},$$

where T is the number of observations, Q is the value of the objective function, e is the number of orthogonal conditions, and f is the number of parameters estimated.[44] The calculated statistic is 27.6, while the critical value is 41.64 at the 1 percent significance level. We cannot reject the weak separability hypothesis. Hence, the existence of a theoretical monetary aggregate over the outputs produced by banks is accepted.

Substituting the parameter estimate of ξ from Table 2 into equation 69, we obtain $b_1 = 0.76$ and $b_2 = 0.24$. The estimated theoretical aggregate then is acquired by substituting the estimated parameters and fixed constants into equation 29 to get

$$(74)\ y_0(D_t,T_t)=0.76D_t+0.24T_t+\frac{1}{2}\left[\frac{.17^2(D_t-T_t)^2}{.58D_t+0.42T_t}\right].$$

It is important to recognize that this aggregator function should not be used for forecasting or simulation outside the region of the data, and hence its usefulness is limited to research within the sample. While we have confirmed monotonicity within the region of the data, this aggregator function is not globally regular for all possible nonnegative values of the variables outside that region.

Having our econometrically estimated theoretical supply-side monetary aggregate, we now proceed to investigate whether any of the well known nonparametric statistical index numbers can track the estimated exact aggregate adequately. By converting from $\tilde{\rho}$ back to ρ and then computing the degree of relative risk aversion, $1-\rho$, we find that the degree of relative risk aversion is $1-.07=.93$. Since risk neutrality occurs only for zero values of relative risk aversion, we do not have risk neutrality. But there is no currently available theory regarding the tracking ability of nonparametric statistical index numbers when risk aversion exists. Hence, our only method of investigating the tracking

[44] The value of the objective function is defined as $Q = g_N(\hat{\theta})'\hat{W}_N g_N(\hat{\theta})$, where $g_N(\hat{\theta})$ is the sample mean of the moment conditions and $\hat{W}_N$ is the weighting matrix that defines the metric in making $g_N(\hat{\theta})$ close to zero in the GMM estimation procedure.

ability of the more easily computed nonparametric statistical indexes is to estimate the exact index econometrically, as we just have done, and compare its behavior with that of the statistical index numbers.

In this paper, we compare the estimated theoretical aggregate with the Divisia, simple-sum and CE indexes. Rotemberg, Driscoll and Poterba (1991) have found that the growth rate of the CE index is very volatile with monthly data. Hence, they have proposed (see their footnote 11) a method of smoothing that index's growth rates by replacing the index's weights by 13-month, centered moving averages. Since we are using annual data, there already is a form of smoothing implicit in the data construction. Nevertheless, in addition to computing the annual contemporaneous CE index, we compute the smoothed index in accordance with the method selected by Rotemberg, Driscoll and Poterba.

To parallel the 13-month centered moving-average smoothing as closely as possible with annual data, we use a three-year centered moving average. In a sense, our results with unsmoothed annual data slightly undersmooths relative to Rotemberg, Driscoll and Poterba's method, while the three-year centered moving average oversmooths relative to Rotemberg, Driscoll and Poterba's method. Nevertheless, as we shall see, the CE index's growth rate remains too volatile. A centered moving average is not defined at the start and end of a sample. Hence, a special method is needed to phase in the centered moving average at the start of the sample and phase it out at the end of the period. For that purpose, we use the procedure advocated by Rotemberg, Driscoll and Poterba. Figure 1 contains plots of the levels of all those aggregates. Figure 2 contains plots of their growth rates. We also separately plot the growth rate of each of the four statistical index numbers (simple sum, Divisia, unsmoothed CE and smoothed CE), with the growth rate of the estimated theoretical path superimposed. These plots are given in Figures 3, 4, 5 and 6.

While no econometric estimation is needed to compute the Divisia index, it is important on the supply side to incorporate the required reserves implicit tax into the user cost formula, when computing the Divisia output index. The user-cost formula is needed to compute the prices of monetary services, since the Divisia quantity index is a function of prices as well as quantities. On that subject, also see Barnett and Hahm (1994), Barnett, Hinich and Weber (1986), Hancock (1985, 1987, 1991) and Barnett (1987), who derive and supply the user cost of supplied monetary services, when required reserves yield no interest. The resulting real user-cost price for account type i is

$$(75)\quad \Phi_{ift} = \frac{(1-k_{it})\,R_t - r_{it}}{1+R_t}$$

$$(76)\quad = \Phi_{ict} - \frac{k_{it}R_t}{1+R_t},$$

where r_{it} is the own rate of return defined in footnote 8, and where

$$(77)\quad \Phi_{ict} = \frac{R_t - r_{it}}{1+R_t}.$$

The nominal user cost is $P_t\,\Phi_{ift}$. The second term on the right-hand side of equation 76 is the discounted implicit tax on banks resulting from the nonpayment of interest on required reserves. Equation 77 is the same form as the user-cost price paid on the demand side by depositors, where R_t is the benchmark yield on a pure investment asset producing no services other than its own yield, so that equation 77 is the discounted foregone interest given up by the depositor in return for the services provided by asset type i.

Clearly the Divisia index tracks the theoretical aggregate more accurately than any of the other two indexes. The smoothed and unsmoothed CE index's level paths are almost identical to each other, as shown in Figure 1, despite the improvement in the performance of the CE index's growth rate plot after smoothing. Before 1972, the Divisia and estimated theoretical index are almost identical. After 1972, a small gap opens between them.

The CE index almost always underestimates the theoretical aggregate throughtout the sample period, with the gap growing to be larger after 1980. The simple-sum index always overestimates the theoretical aggregate, with the gap growing to be large and remaining large after only a few years. In terms of levels, the tracking error of the CE index is smaller than that of the simple-sum index, especially early in the same period. However, the CE index is much more volatile than the theoretical aggregate, especially from 1979 to 1983. Comparing Figures 5 and 6, we see that the CE index with smoothed weights is less volatile than the unsmoothed in-

Figure 1

Levels of Five Monetary Aggregates (parameters of theoretical monetary aggregate estimated with risk aversion permitted)

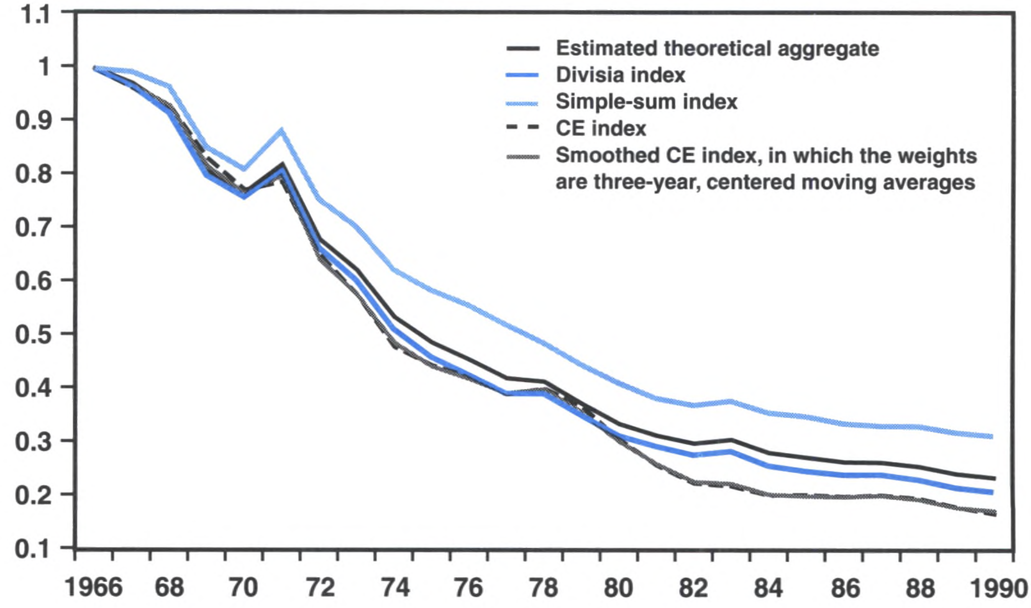


Figure 2

Growth Rates of Five Monetary Aggregates (parameters of theoretical monetary aggregate estimated with risk aversion permitted)

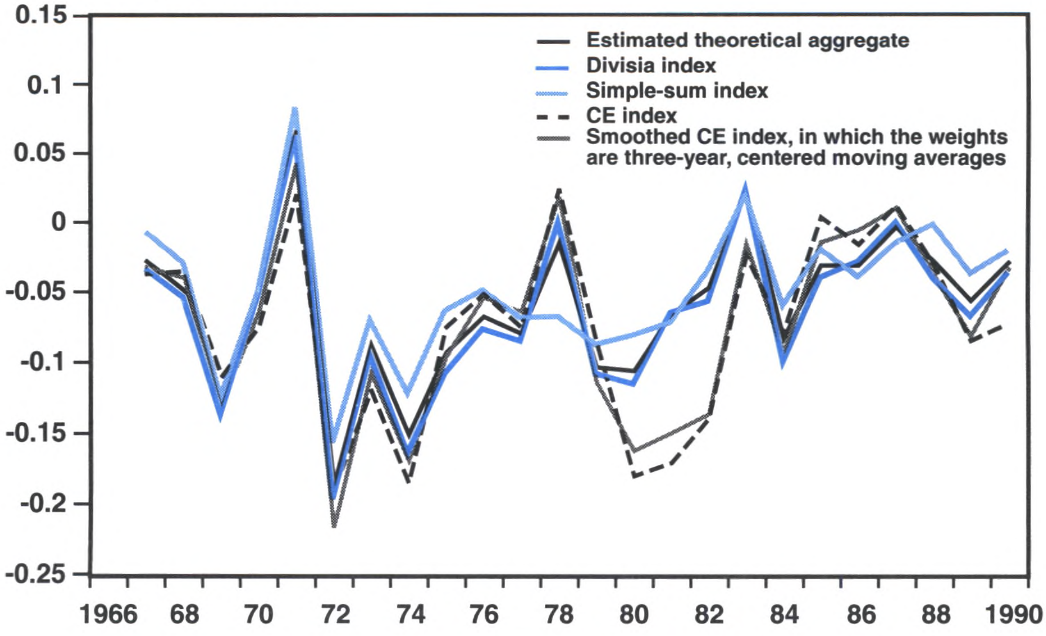


Figure 3

Growth Rates of Theoretical Monetary Aggregate and Divisia Index (with risk aversion permitted)

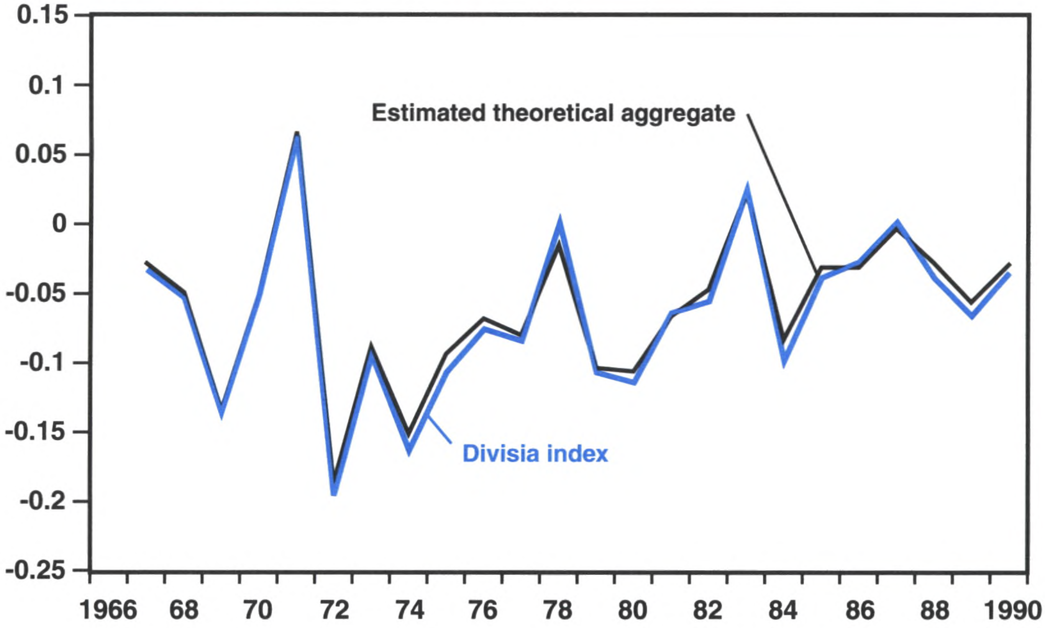


Figure 4

Growth Rates of Theoretical Monetary Aggregate and Simple-Sum Index (with risk aversion permitted)

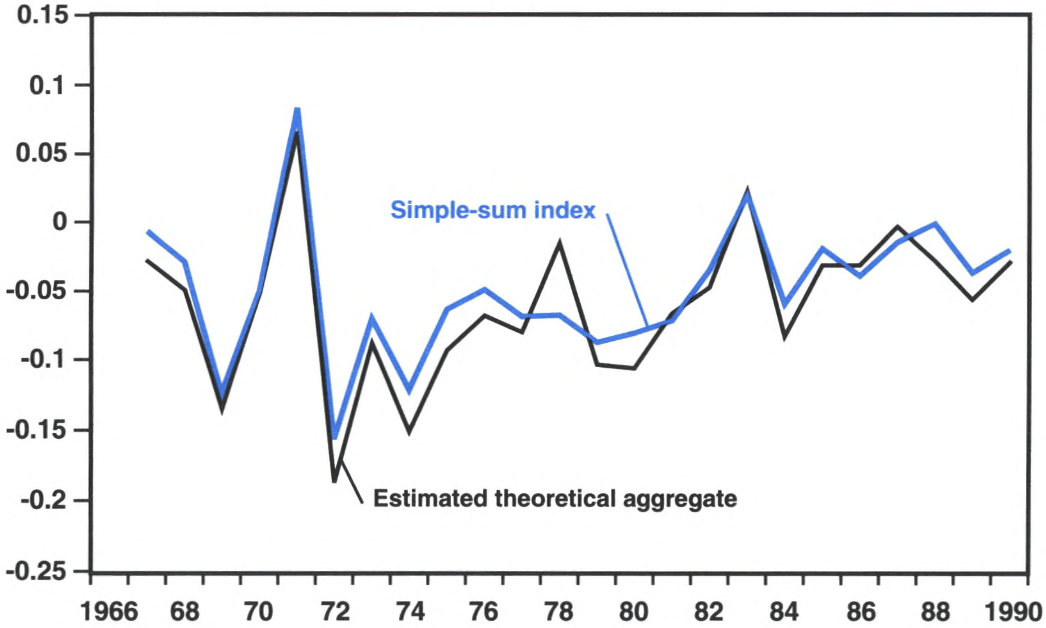


Figure 5

Growth Rates of Theoretical Monetary Aggregate and CE Index (with risk aversion permitted)

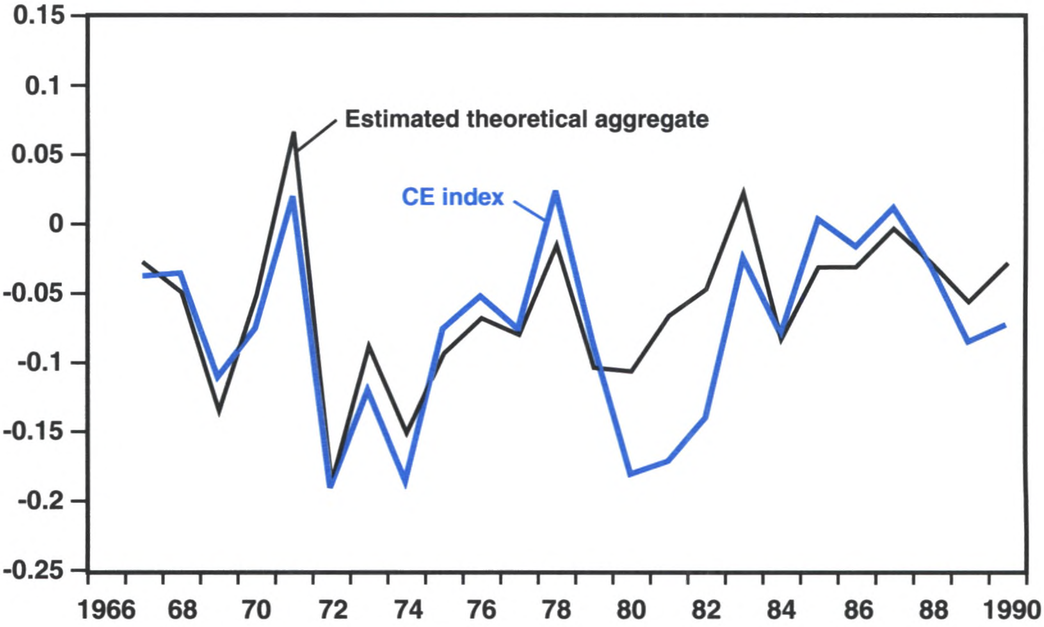


Figure 6

Growth Rates of Theoretical Monetary Aggregate and Smoothed CE Index (with risk aversion permitted)

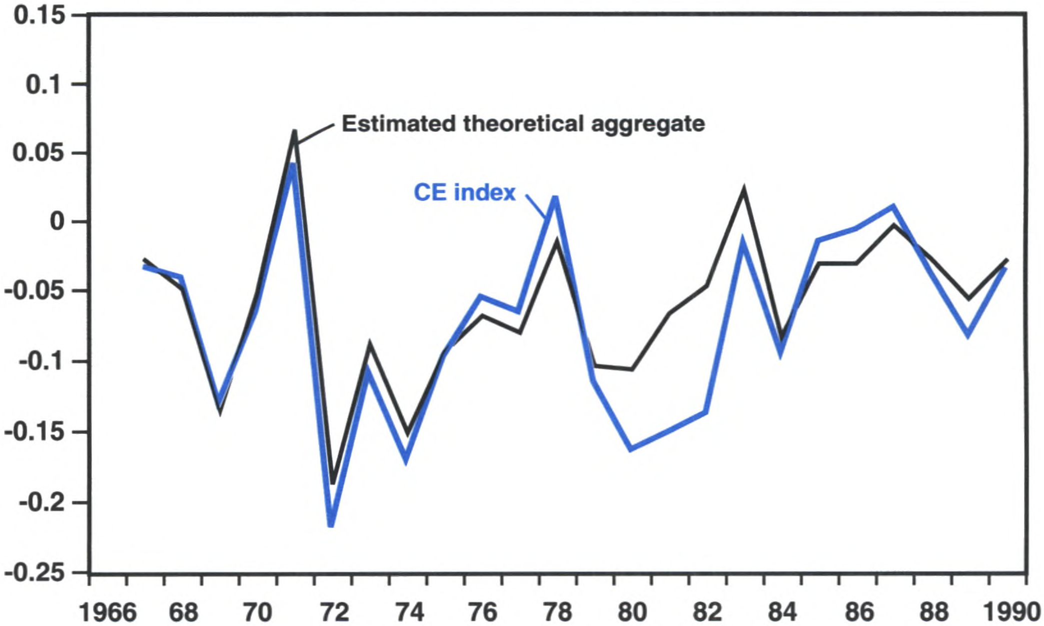


Table 3

GMM Estimates with Weak Separability in Outputs and Risk Neutrality Imposed

Parameter	Estimate	Standard error	*t*-Statistic
ξ	61.82	0.005	11968.80
u_{11}	0.27	0.019	14.31
q_{11}	0.18	0.005	32.78
q_{21}	0.38	0.022	17.01
q_{31}	0.07	0.007	10.14
q_{22}	0.44	0.023	19.09
q_{32}	0.11	0.063	1.68
q_{33}	0.16	0.132	1.25
$\tilde{a}_1$	0.33	0.002	162.74
$\tilde{a}_2$	0.50	0.003	164.39
$\tilde{a}_3$	0.23	0.006	36.50

dex, but the volatility still remains larger than that of the estimated theoretical index. We could experiment with even more smoothing of the CE index than is advocated by Rotemberg, Driscoll, and Poterba, but we feel that further experimentation in that direction would produce an index having dynamics determined more by the ad hoc method of smoothing than by the theory that produces the index. Furthermore, we suspect that smoothing adequate to fix the index between 1979 and 1983 would oversmooth elsewhere. Hence, it seems that there is no way that the CE index can track the growth rates adequately throughout the sample.

In short, as a measure of the level of the money stock, the simple-sum index performs most poorly, while in terms of growth rates, the CE index performs most poorly. In both cases, the Divisia index performs best. These results are in the accordance with index number theory, although most of that theory is available in rigorous form only under the assumption of perfect certainty. Our weak separability test supports the existence of an inside-money output aggregate in banking, and our plots support the use of the Divisia index as the best currently available statistical index for tracking that output aggregate.

For comparison purposes, we repeat the above estimation and testing in the special case of risk neutrality. The Euler equations, 62-65, under risk neutrality become[45]

$$(78)\quad E_t\{P_t\frac{R_t(1-k_{1t})-r_{1t}}{1+R_t}+P_t\frac{R_t}{1+R_t}\,\frac{\partial\Omega/\partial D_t}{\partial\Omega/\partial C_t}\} = 0,$$

$$(79)\quad E_t\{P_t\frac{R_t(1-k_{2t})-r_{2t}}{1+R_t}+P_t\frac{R_t}{1+R_t}\,\frac{\partial\Omega/\partial T_t}{\partial\Omega/\partial C_t}\} = 0,$$

$$(80)\quad E_t\{P_t\frac{R_t}{1+R_t}\,\frac{\partial\Omega/\partial L_t}{\partial\Omega/\partial C_t}-w_{1t}\} = 0,$$

and

$$(81)\quad E_t\{P_t\frac{R_t}{1+R_t}\,\frac{\partial\Omega/\partial M_t}{\partial\Omega/\partial C_t}-w_{2t}\} = 0.$$

The parameter estimates acquired from GMM estimation under risk neutrality, with weak separability in outputs imposed, are in table 3.[46] Substituting the parameter estimate of ξ in the risk-neutrality case into equations 69, we obtain $b_1=0.777$ and $b_2=0.223$. The estimated theoretical aggregate then is acquired by substituting the estimated parameters and fixed constants into equation 29 to get

$$(82)\quad y_0(D_t,T_t) = 0.777D_t+0.223T_t + \frac{1}{2}\left[\frac{.275^2(D_t-T_t)^2}{.58D_t+0.42T_t}\right].$$

The value of the weak separability test statistic, equation 73, is 9.25, while the critical value is 21.666 at the 1 percent significance level. We cannot reject the weak separability hypothesis and, hence, the existence of a theoretical mone-

[45]In producing equations 80 and 81 as special cases of the corresponding risk-averse Euler equations, recall footnote 14.

[46]The instrumental variables are the constant, the discount rate, the lagged banks' portfolio rate of return, excess cash reserves and capital.

tary aggregate over the outputs produced by banks again is accepted. Furthermore, monotonicity and convexity again are accepted throughout the region of the data.

Figures 7-12 provide the risk-neutral plots analogous to those in Figures 1-6 under risk aversion. Imposing risk neutrality produced negligible gain in tracking ability for any of the indexes. Hence, at least with this data, risk aversion does not seriously compromise index number theory.

THE REGULATORY WEDGE

Although the imposition of risk neutrality did not improve the tracking ability of any of our indexes, the risk-neutral special case does permit especially simple graphical illustration of equilibrium phenomena through the use of separating hyperplanes. In particular, with risk neutrality and complete contingent claims markets, each consumer maximizes utility and each firm maximizes profits conditionally upon any fixed, realized contingency (i.e., state). Hence, perfect certainty methods of graphical illustration are available in the risk neutral case, with the understanding that the illustration is conditional upon the realization of all contingencies.

If no regulatory wedge exists between the demand and supply side, a hyperplane separates tastes from technology. But in the case of commercial banks, a regulatory wedge does indeed exist. This conclusion follows from the observation in footnote 8 that an implicit tax is imposed upon banks through the existence of non-interest bearing required reserves. Hence, the user cost price received by banks for the production of monetary services differs from the user cost price paid by depositors for the consumption of those services. The difference is the implicit tax.

The formulas for the user cost prices on each side of the market for produced monetary services was derived by Barnett (1978, 1980, 1987) and computed by Barnett, Hinich and Weber (1986). The result is most easily illustrated in the case of an economy with one consumer, who consumes all of the economy's monetary services, one financial intermediary, which produces all of the economy's monetary services, and two monetary assets. Equilibrium in the monetary sector of the economy at a fixed contingent state is illustrated in Figure 13, when no reserve requirements exist. Money market equilibrium at a fixed contingent state, when one or both of the monetary assets is subject to reserve requirements, is illustrated in Figure 14.

In Figure 13, equilibrium is produced by the familiar separating hyperplane. The separating hyperplane simultaneously supports an indifference curve from below and a production possibility curve from above. The axes represent quantities of each of the two monetary assets demanded and supplied. Equilibrium in the two markets exists at the mutual tangency of the separating hyperplane, the indifference curve, and the production possibility curve at a given optimal level of factor use. In equilibrium, the quantities demanded of each asset are equal to the quantities supplied at the equilibrium point $\boldsymbol{y}^e=(y_1^e,y_2^e)$. In addition, the gradient vector to the separating hyperplane produces the equilibrium user-cost prices. The vector of user-cost prices paid by the consumer, $\boldsymbol{\phi}_c$, are equal, in equilibrium, to the vector of user-cost prices received by the financial intermediary, $\boldsymbol{\phi}_f$. The user cost price of asset type i is defined by equation 77 above.

With factor employment assumed to be set in advance at its optimum, $\boldsymbol{x}^*$, the optimum level of aggregate monetary service production, y^*, is defined to be the solution for y^* to the equation $H(y^*,\boldsymbol{x}) = 0$, where $y^*=y_0(\boldsymbol{y})$ and where $\Omega(\boldsymbol{y},\boldsymbol{x}) = H(y^*,\boldsymbol{x}) = H(y_0(\boldsymbol{y}),\boldsymbol{x})$, as explained in the subsection above. Hence, Figure 13 is drawn conditionally upon that fixed setting of y^*, so that the production possibility surface is the set $\{(y_1,y_2): y_0(y_1,y_2)=y^*\}$.

However, the situation is very different, when required reserves exist. In that case, two different supporting hyperplanes exist in equilibrium. One supporting hyperplane exists for the financial intermediary, and another exists for the consumer. In Figure 14, the line with gradient equal to the consumer's monetary-asset user-cost prices, $\boldsymbol{\phi}_c$, is the consumer's supporting hyperplane and it is his budget constraint in equilibrium. That line is tangent to the displayed indifference curve in equilibrium. The financial intermediary's supporting hyperplane has gradient equal to the financial intermediary's user-cost prices, $\boldsymbol{\phi}_f$. That hyperplane is the financial intermediary's iso-revenue line, which is tangent to the firm's production possibility curve at the equilibrium point. While the user-cost price paid by the consumer for the services of asset type i

Figure 7

Levels of Five Monetary Aggregates (parameters of theoretical monetary aggregate estimated with imposed risk neutrality)

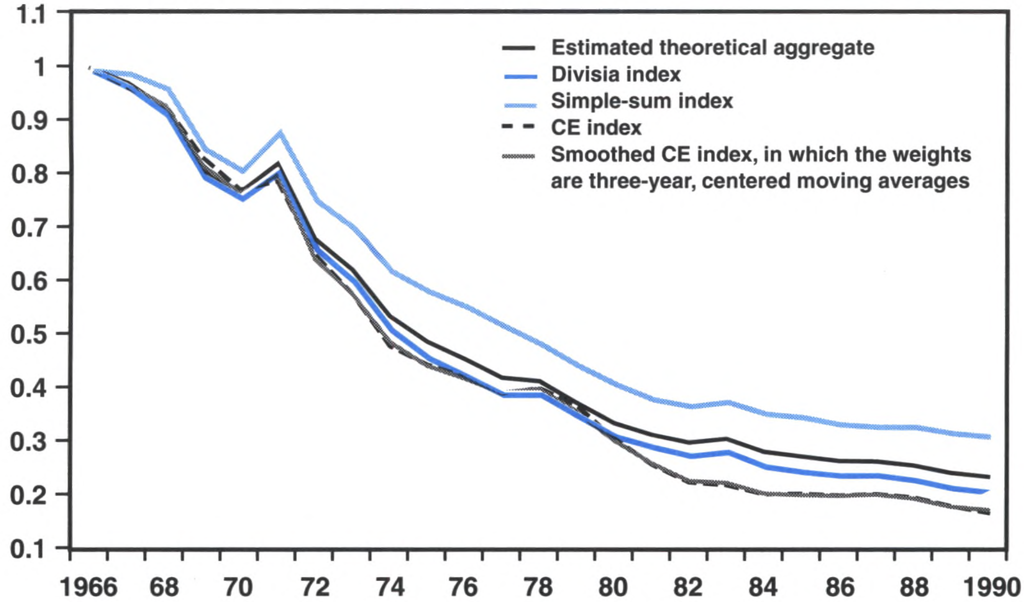


Figure 8

Growth Rates of Five Monetary Aggregates (parameters of theoretical monetary aggregate estimated subject to imposed risk neutrality)

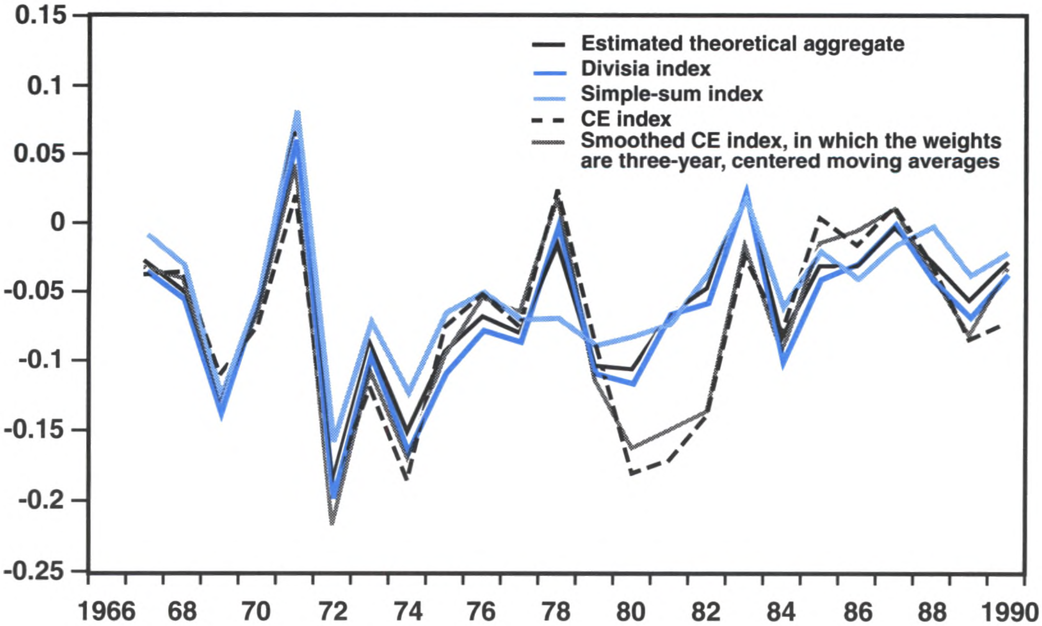


Figure 9

Growth Rates of Theoretical Monetary Aggregate and Divisia Index (with imposed risk neutrality)

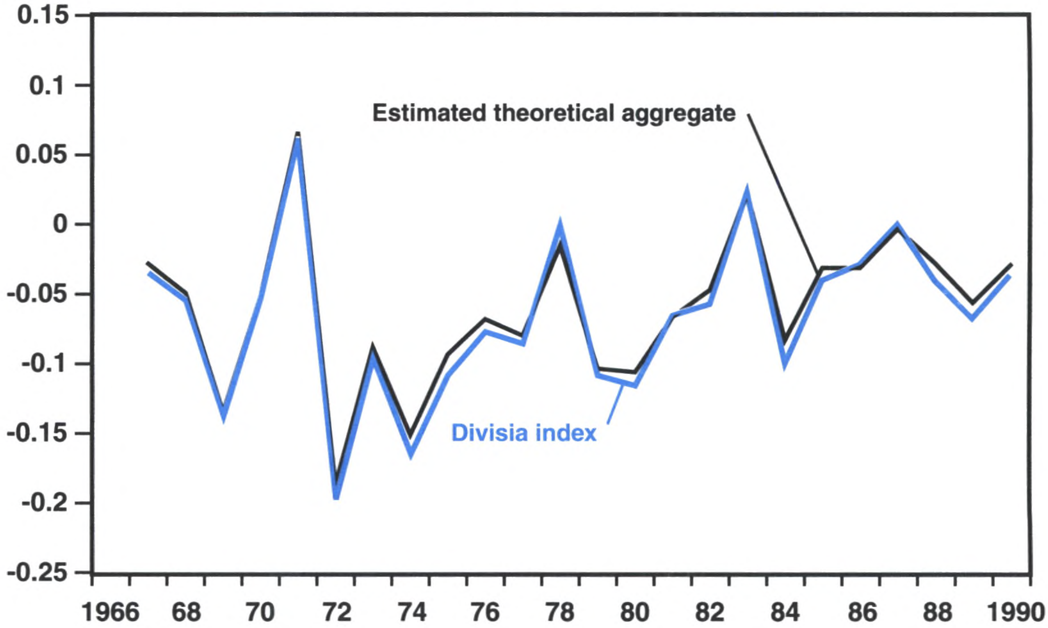


Figure 10

Growth Rates of Theoretical Monetary Aggregate and Simple-Sum Index (with imposed risk neutrality)

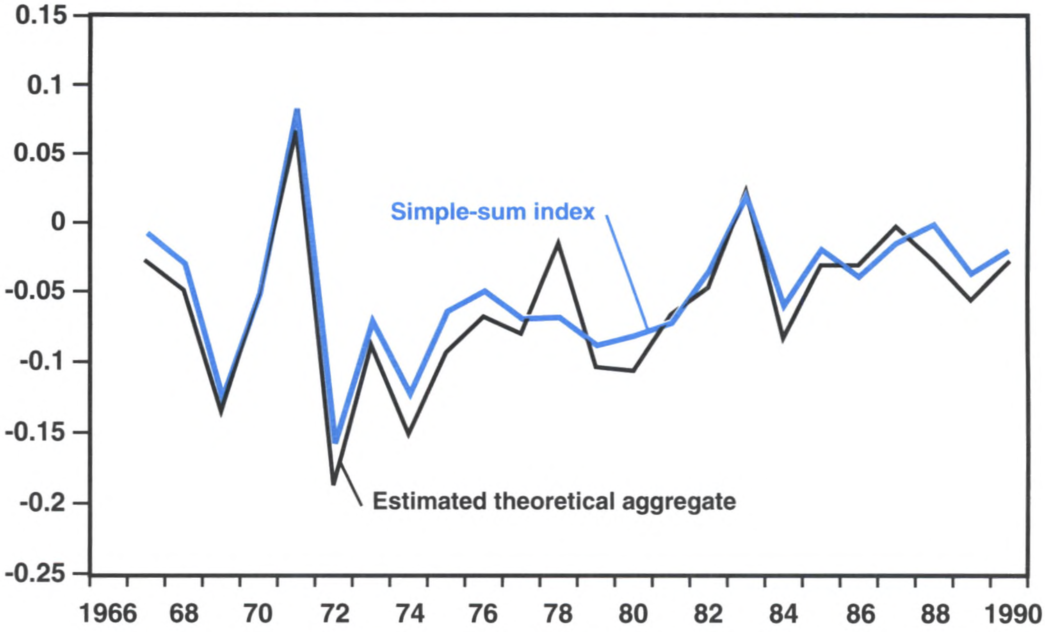


Figure 11

Growth Rates of Theoretical Monetary Aggregate and CE Index (with imposed risk neutrality)

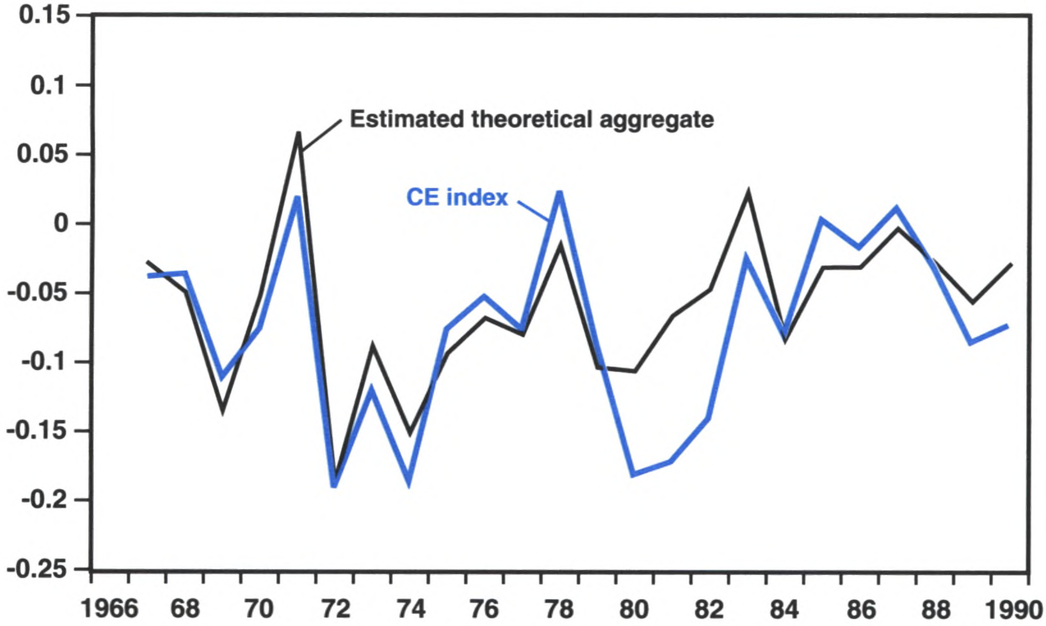


Figure 12

Growth Rates of Theoretical Monetary Aggregate and Smoothed CE Index (with imposed risk neutrality)

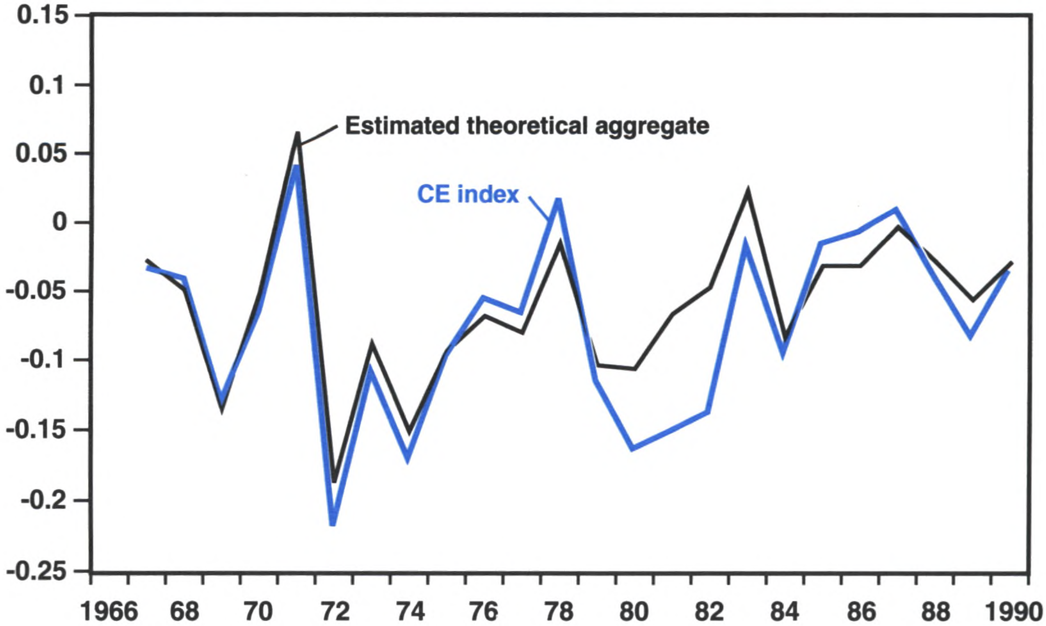


Figure 13
Equilibrium with No Required Reserves

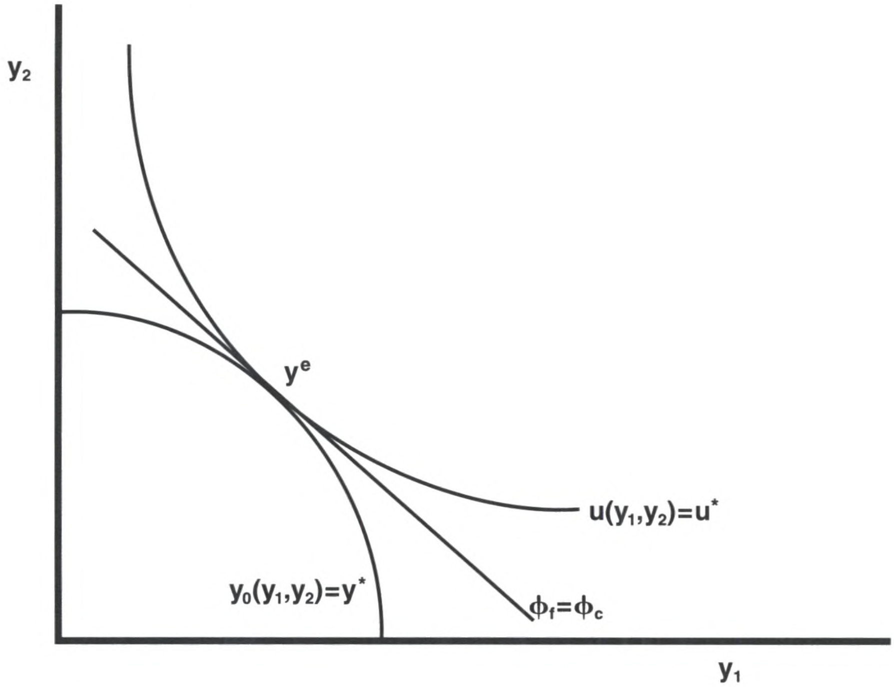
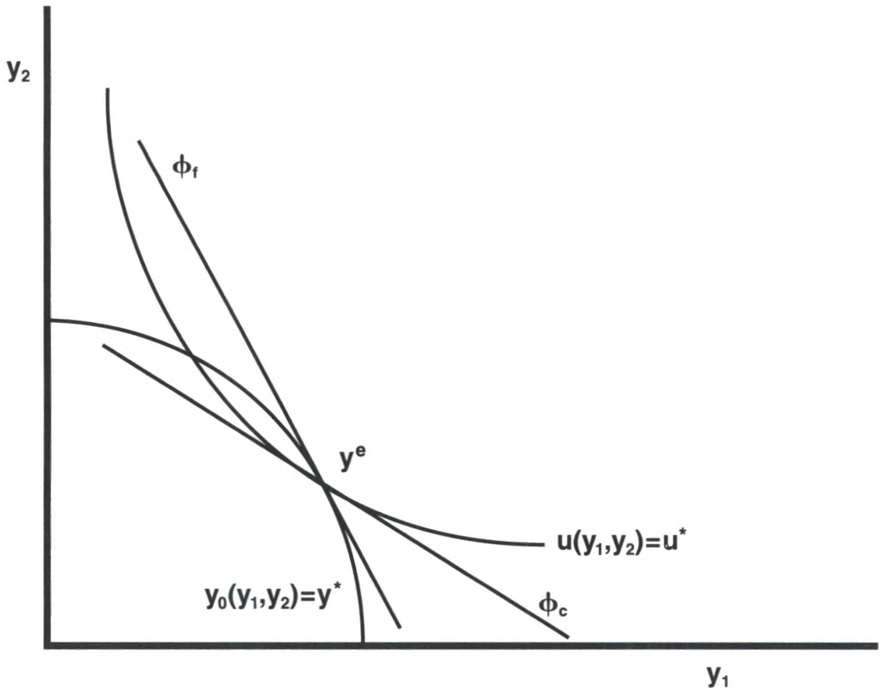


Figure 14
Equilibrium with Required Reserves



is still defined by equation 77, the user-cost price received by the bank for producing those services now is defined by equation 75, which does not equal equation 77 unless no required reserves exist.

The equilibrium point is the point $\boldsymbol{y}^e$ at which the two supporting hyperplanes intersect, and the angle between them is the regulatory wedge produced by the implicit reserve requirement tax paid by the financial intermediary in the form of foregone interest on required reserves. At the equilibrium point both markets are cleared, and the consumer is maximizing utility subject to the displayed budget constraint, while the financial intermediary is maximizing revenue subject to the displayed production possibility curve.

THE ERRORS-IN-THE-VARIABLES PROBLEM

This same figure also can be used to illustrate the magnitude of the errors-in-the-variables problem produced by the use of the simple-sum index as a measure of the flow of monetary services. Figure 15 illustrates the range of the error on the demand side, while Figure 16 does the same on the supply side. The same illustration could be produced on the supply side by replacing the two indifference curves that are convex to the origin with two production possibility curves, that are concave to the origin. The conclusion would be the same.

In both figures, the hyperplane represents the set

$$A = \{(y_1, y_2): \; y_1 + y_2 = M_{ss}\},$$

where M_{ss} is the measured level of the simple-sum index, while A is the set of possible values of the monetary asset component quantities (y_1, y_2) that are consistent with the measured level of the simple-sum index.

For any such measurement on the simple-sum index, the value of the demand-side monetary service flow received by asset holders could be anywhere within the set

(83) $\{u(y_1, y_2): \; (y_1, y_2) \in A\}$.

The range of that set is the gap between the utility levels at which the two indifference curves are drawn in Figure 15. Clearly, the upper indifference curve is the one which intersects the hyperplane A at the highest possible utility level, while the lower indifference curve is the one which intersects the hyperplane A at the lowest possible utility level. We see that magnitude of the errors-in-the-variables problem in that illustration, when measured by the range of the set (83), is $M_{max} - M_{min}$. The same conclusion is produced on the supply side from Figure 16, but with set 83 replaced by[47]

$$\{y_0(y_1, y_2): \; (y_1, y_2) \in A\}.$$

The simple-sum monetary aggregates produce a disturbingly large and entirely unnecessary errors-in-the-variables problem. Figures 15 and 16 illustrate the reason. Figures 1-12 illustrate the effect, under circumstances that are most favorable to the simple-sum aggregates: a low level of aggregation over assets having similar yields. With broader aggregation over assets having very different own rates of return, including currency with a zero rate of return, the continued use of simple-sum monetary aggregates by central banks becomes even more difficult to comprehend. The days when all monetary components had zero-own rates of return are long gone.

CONCLUSIONS

In this paper, we develop a theoretical model of monetary service production by financial firms. Earlier models either have permitted risk, but with minimal connection with neoclassical economic theory, or have made full use of neoclassical production theory, but under the assumption of perfect certainty. The latter case has been developed extensively by Barnett (1987), Barnett and Hahm (1994), and Hancock (1985, 1987, 1991). We extend that latter fully neoclassical production approach to the case of risk aversion, subject to Diewert and Wales's symmetric generalized McFadden technology. Our approach permits risk aversion without compromising second-order flexibility or neo-

[47]The magnitude of the gap, $M_{max} - M_{min}$, may differ, when a regulatory wedge is produced by required reserves, but the difference between the conclusions on the demand and supply side is not likely to be large. If the errors-in-the-variables problem is large on one side of the market it is likely to be approximately as large on the other side of the market. See Barnett, Hinich and Weber (1986) for relevant empirical evidence.

Figure 15
Demand Side Errors-in-Variables

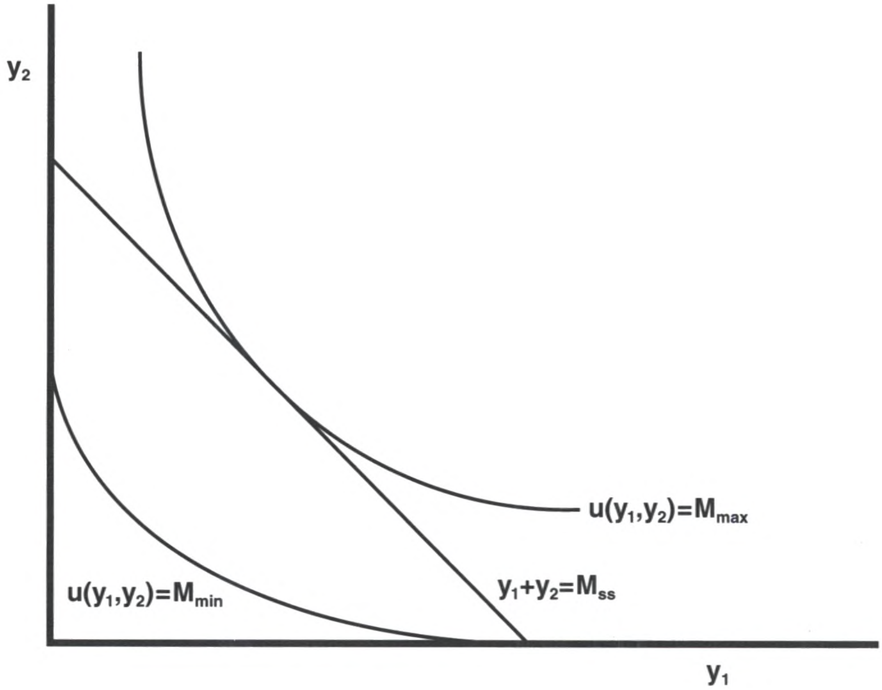
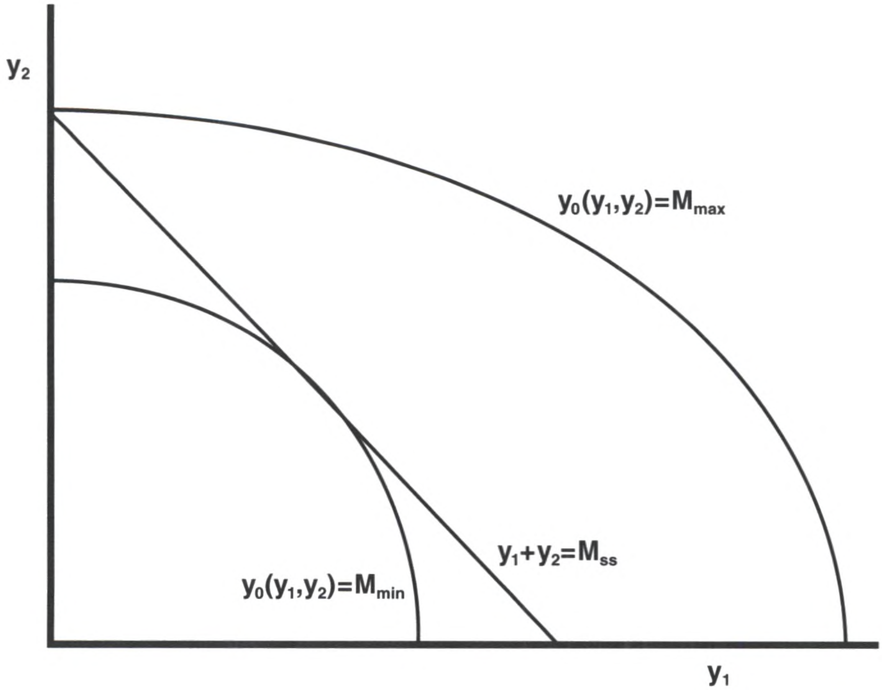


Figure 16
Supply Side Errors-in-Variables



classical regularity of the specification. This is true with or without the imposition of global blockwise weak separability, which we therefore are able to test and to impose, when accepted. Using the resulting Euler equations, we explore exact output aggregation in this paper.

Although applicable to all financial intermediaries, we apply our approach only to the banking industry. While it is possible to impose regularity in curvature conditions upon the generalized McFadden specification, monotonicity can be imposed only locally without damaging the models flexibility. Diewert and Wales's alternative specification, called the generalized Barnett model, is globally regular both in terms of curvature and monotonicity, and hence, that model was used by Barnett and Hahm (1994) in the perfect certainty case. However, in the current paper, using the generalized McFadden model, the estimated parameters satisfy the neoclassical monotonicity and convexity conditions for all observations, even though only convexity was imposed globally. Hence, we doubt that our conclusions would have been much different if we had used the generalized Barnett model in producing our estimated Euler equations. The hypothesis that bank's outputs are weakly separable from inputs is accepted. Hence, the existence of an exact supply-side theoretical monetary aggregate is accepted for banks. The resulting output aggregate is the banking industry's contribution to the economy's inside money services.

While our theory provides a means of econometrically estimating the exact supply-side monetary aggregate, no theory currently is available to support the use of a nonparametric statistical index number as an approximation to the parametrically estimated exact aggregate. Considering the complexities of the GMM estimation involved in producing the estimated exact aggregate, a nonparametric statistical index would, in practice, be much easier to compute and use. We compute the currently most popular of those indexes and find that at least for our sample, the Divisia index tracks the estimated theoretical index more accurately than the others. This conclusion holds regardless of whether or not we impose risk neutrality during estimation of the exact theoretical aggregate. Risk aversion does not appear to produce appreciable degradation of the tracking ability of the Divisia index with our data.

We believe that the approach developed in this paper could be used to investigate technological change in banking, economies of scale and scope in banking, value added in banking and its connection with inside money creation, and the transmission mechanism of monetary policy. We have in fact taken a first step in the direction of producing one of those extensions: We have derived and supplied the Euler equations with learning by doing technological change included in technology. A longer-run framework for the theory also could be productive. In particular, some of the factors excluded from the variable cost function as fixed factors could be incorporated among the variable factors. Bank capital is one such example. Incorporating capital among the variable factors could permit integration of the model with economic growth theory, in which capital evolves endogenously in accordance with a law of motion. In short, this is just a start in a direction that we expect will be very productive for researchers interested in the role of financial institutions in the economy.

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Commentary

IT IS A PLEASURE TO TAKE PART in a scholarly conference focusing on empirical and theoretical issues relevant to the conduct of monetary policy and the behavior of financial markets. Most of the discussion at this conference, and indeed most of the work on monetary aggregates, including a great deal by Bill Barnett, has been about the demand side. Demand elasticities and the degree of substitutability of various monetary assets and liabilities are not just of academic interest. They have direct and obvious relevance to the conduct of monetary policy.

While there has been a great deal of work on demand, there has been relatively little work on the supply side of the market. The scarcity of supply studies is perhaps inherited from simpler days when commercial banks, limited in their ability to compete for deposits and constrained in their portfolio choices, dominated the supply of monetary assets. In a world where currency and demand deposits are the primary monetary assets, with no close substitutes, monetary control was relatively simple; control of bank reserves provided a tight control on the supply of demand deposits and shifts between currency and demand deposits were relatively easily monitored and offset. In today's economy, with a rich menu of monies and near monies, the task is not so simple. The instruments of control—the supply of reserves, reserve requirements and the discount rate—have remained essentially the same while the menu of monetary assets has proliferated. Financial firms and markets can alter significantly the suppliers of their assets and liabilities without policy accommodation. In this environment not only is there a question of what to control, but control itself is less direct and the timing and magnitude of the response to policy less certain. In these circumstances, the Barnett-Zhou examination of the competitive supply of money and near monies by financial firms is a welcome and important enterprise.

The authors focus on the supply behavior of the most important of the financial intermediaries, commercial banks. They model the banking industry as a competitive profit maximizing firm, stressing the dynamic nature of bank's optimization problem and the presence of risk. The banking firm maximizes the present discounted value of expected utility, where the utility in each period is a function of that period's "cash flow" and displays risk aversion. The bank decides on its supply of liabilities, taken to be demand and time deposits in the empirical analysis, and its demand for excess reserves and "loans." Both assets and liabilities mature in one period, with the returns on loans being uncertain. A production function determines the real resource costs associated with these portfolio decisions; in the estimation this function is assumed to be weakly separable, so that the relative costs of demand and time deposits do not depend on excess reserves nor on inputs of labor and materials.

The authors develop general methods for estimating dynamic and stochastic models of bank behavior and demonstrate the feasibility of using these techniques in the context of a specific bank model. While the techniques could be applied in a wide range of settings, the model focused on in the paper incorporates two assumptions that severely limit the role for dynamics. In particular, both bank assets and liabilities are assumed to mature in "one" period and the net proceeds of the borrowing and lending decisions made by a bank in one period are entirely paid out when the assets and liabilities mature one period later. This is implied by equation 2: Liabilities issued in a period exactly cover required reserves, excess reserves, portfolio investment and the payments for real resources. Hence, equity is zero (as the author's indicate there would be no essential difference if it was non zero but constant); there is no room for retaining earnings. As a consequence, the only effect of a decision in period (t) on *net* cash flow occurs at the beginning of period (t+1). The net portfolio returns (the net cash flow consequence of decisions made in the previous period) are all paid out when they arrive. Hence, if dividends—the net cash generated and distributed to the owners of the firm—were entered in the utility function, the firm's optimization problem would be time separable and decisions could be made separately, period by period.

What, then, makes the firm's decision dynamic in Barnett-Zhou? The reason is that the "cash flow" entered in the utility function is not the cash actually generated and distributed, but a measure of profits developed by Diana Hancock (equation 1). This measure differs from actual cash flow by an amount reflecting changes in required reserves. In Hancock's profit function required reserves are not recorded as an asset requiring the use of funds. Yet, from the budget constraint in equation 2, liabilities exceed the sum of excess reserves, loans and resource cost by exactly the amount of required reserves. Hence, the Hancock profit function records as a positive cash flow an amount equal to required reserves in the period liabilities are incurred, and records a negative cash flow in the period they are repaid. These components of Hancock's profit function simply reflect the need to place a portion of the deposits in reserve. I have difficulty understanding how to motivate their inclusion in the utility function; they do not correspond to payments to the owners of the firm, nor do they constitute an increase in the net worth of the bank. Although counting these flows as profits has essentially no effect on the present value of the bank, it does serve to create a link between time periods, making the problem dynamic.

Several features could be added to the author's model of banks which would greatly increase the role for dynamics. Illiquidity and maturity mismatch may be less important today than earlier in the postwar period, but they remain significant reasons for treating the bank as a multiperiod firm. One extension would be to incorporate the fact that some of banks' investments are in assets with maturities substantially greater than the maturity of their liabilities. If held to maturity, investments made today have to be financed by future borrowing. Second, since some bank assets are relatively illiquid, it would be interesting to build into the specification some costs of rapid asset disposal. Similarly, as with physical investment, there are costs of adjustment on the rate of acquisition of assets. Another important extension would be to treat explicitly the dynamics of equity growth. As with any firm, growth in equity, either by new issue or by retention of earnings, plays an important role in the growth of the industry. Explicit treatment of capital accumulation seems particularly desirable given the capital requirements placed on bank portfolios, requirements which many thought were an important constraint on bank lending in recent years. Including these elements would not only substantially increase the importance of dynamics in the model, it would also add to the menu of risks by, for example, allowing for the risks reflecting the interaction of illiquidity and deposit uncertainty. Not only can the author's model be extended to analyze more complicated models of banks, but it will undoubtably be useful in the study of other financial intermediaries, institutions that share many of the features of banks and, like banks, should be analyzed within a dynamic and stochastic framework.

A number of the author's results are quite interesting. After restricting the utility function to the CRRA class, they find the degree of risk aversion significant and on the order of one. They test and find they cannot reject weak separability, hence their estimates are consistent with the existence of a theoretical monetary aggregate. The estimated aggregator function itself, evaluated at a point where demand and time deposits are of equal magnitudes, gives a marginal rate of transformation implying that one dollar of demand deposits is equivalent to approximately three dollars of time deposits. This sounds like a plausible magnitude in the current regulatory environment; it would be interesting to know how different estimates would be for an early subset of the data when reserve requirements, portfolio restrictions and capital requirements were so different.

In the author's specification, excess reserves are an important input, while required reserves are seen as a sterile asset entering the firms technology neither as an input nor as an output. There was a time when reserve requirements were quite high relative to estimates of bank's own transactions needs and this assumption would seem quite plausible. As reserve requirements have fallen, however, the distinction between required and excess reserves has become less sharp. Another interesting extension of the model, therefore, would be to include required reserves as an input and to test whether their importance has fallen over time.

As these comments suggest, I have found this an innovative and stimulating paper which opens up several new avenues for future research, and I look forward to watching the progress in this important enterprise.

William A. Barnett and Ge Zhou[1]

Response to Brainard's Commentary

WE HAVE GREATLY BENEFITED from Brainard's stimulating comments on our paper. We agree with his suggestions for extensions to this research, and in fact expect to have extended versions available in the near future. For example, Barnett, Kirova and Pasupathy (1994) are including an extended model in their paper being prepared for the Federal Reserve Bank of Cleveland conference in September 1994. That model contains dynamic capital growth through Tobin's *q*, both for financial intermediaries producing monetary services as outputs and for manufacturing firms demanding monetary services as inputs. In addition, that model contains an endogenous dividend payout decision, produced by entering loans into technology as an output, along with the deposits which currently are the sole outputs. Introducing loans into the technology as an output eliminates the need for Barnett and Zhou's (1994) equation 2, which determines loans as a function of deposits under the assumption that all earnings are paid out as dividends.

Some readers may find Brainard's comments difficult to interpret, however, since they reflect unpublished background material developed during correspondence. The following few theorems are relevant to understanding the nature of the model's dynamics and the merits of extending the model further to exhibit deeper dynamics.

Equation 2 in our paper is imposed to require the firm to pay out all earnings as dividends, since introduction of an endogenous dividend payout decision is beyond the scope of our paper. Equation 1 is in the general form of the profit function used by Hancock (1985, equation 3.1) in her book and in her papers on financial intermediation under certainty. Equation 1 holds, regardless of how the dividend payout decision is made. Our equation 3 is acquired by imposing equation 2 on equation 1 through direct substitution. Hence, equation 3 is Hancock's variable profit function under the restriction that all earnings are paid out as dividends.

Under exactly that same payout restriction, Barnett (1987, equation 3.7) derived a different variable profit function for the same financial intermediary, and Barnett and Hahm (1994) recently have used Barnett's formulation of the variable profit function in estimating the technology of commercial banks. In correspondence, we found that Brainard had a very strong preference for use of Barnett's, rather than Hancock's, variable profit function under the payout restriction. The discussion about dynamics in Brainard's comment, including his discussion of the accounting for required reserves,

[1]Barnett's research on this paper was partially supported by NSF grant number SES 9223557. We have benefited from many discussions with Richard Anderson on this subject, and a lengthy and highly informative exchange of faxes with William Brainard.

explains his reasons for preferring Barnett's function to Hancock's.

Obviously Barnett would not dispute the merits of Barnett's variable profit function, and he is not at all displeased that Brainard so strongly prefers his variable profit function to Hancock's. Nevertheless, it may seem paradoxical that two different variable profit function formulas exist for the same firm under the same assumptions, and that we chose to use Hancock's rather than Barnett's formula in our paper in this volume. As we shall observe below, the distinction between the two variable profit functions is actually much more subtle than may appear to be the case, and the choice between them in our paper is little more than an econometric trick—barring empirical evidence to the contrary.

We begin by verifying that equation 1 in our paper is indeed exactly Hancock's variable profit function, with only the notation changed.

Theorem 1: The variable profit function defined by equation 1 in Barnett and Zhou (1994) is identical to Hancock's (1991, equation 3.1) variable profit function.[2]

Proof: Hancock's (1991, equation 3.1) variable profit function, using her notation, is

$$\pi_{Ht} = -B_t - \sum_{i=1}^{N_1+N_2} b_i[(1+h_{i,t-1})y_{i,t-1}\, P_{t-1} - y_{it}P_t],$$

where B_t = expenditure on variable factors; P_t = the general price level; y_{it} = a financial asset quantity if $i=1,...,N_1$, or a financial liability quantity if $i=N_1+1,...N_1+N_2$; h_{it} = the holding period yield on y_{it} if y_{it} is an asset, or the holding cost on y_{it} if y_{it} is a liability; and we define the indicator function b_i such that $b_i = 1$ if y_{it} is a liability and $b_i = -1$ if y_{it} is an asset.

A more convenient notation would be to use the symbol A to denote assets instead of the notation N_1 and L to denote liabilities instead of the notation N_2. Making that change in notation and using the indicator function b_i as defined above, we acquire:

$$\pi_{Ht} = -B_t - \sum_{i=1}^{L} [(1+h_{i,t-1})y_{i,t-1}P_{t-1} - y_{it}P_t]$$
$$+ \sum_{i=L+1}^{A+L} [(1+h_{i,t-1})y_{i,t-1}P_{t-1} - y_{it}P_t].$$

Further changing to the notation in Barnett and Zhou (1994), let $B_t = \sum_{j=1}^{J} w_{jt}z_{jt}$, where z_{jt}, $J=1,...,J$, are the nonfinancial variable factors, and w_{jt}, $j=1,...,J$, are their prices. We then can rewrite the variable profit function as:

$$\pi_{Ht} = -\sum_{j=1}^{J} w_{jt}z_{jt} - \sum_{i=1}^{L} [(1+h_{i,t-1})y_{i,t-1}P_{t-1} - y_{it}P_t]$$
$$+ \sum_{i=L+1}^{A+L} [(1+h_{i,t-1})y_{i,t-1}P_{t-1} - y_{it}P_t].$$

As in Hancock (1991), the assets consist of loan investments and excess reserves, which in our notation are Y_t and C_t respectively. Furthermore, let R_t be the single period holding yield on Y_t and let the yield on C_t be zero, as in Hancock (1991). The variable profit function now becomes:

$$\pi_{Ht} = -\sum_{j=1}^{J} w_{jt}z_{jt} - \sum_{i=1}^{L} [(1+h_{i,t-1})y_{i,t-1}P_{t-1} - y_{it}P_t]$$
$$+ C_{t-1}P_{t-1} - C_tP_t + (1+R_{t-1})Y_{t-1}P_{t-1} - Y_tP_t,$$

which is exactly equation 1 in Barnett and Zhou (1994). Q.E.D.

In the next theorem, we prove that the difference between the discounted present value of the profit flow produced from Hancock's formula (that is, Barnett and Zhou's 1994 equation 1) and the discounted present value of the profit flow produced by Barnett's (1987, equation 3.7) formula is a function only of initial conditions. The proof is produced under imposition of Barnett and Zhou's equation 2, which requires all earnings to be paid out as dividends.

Let y_{it} be deposits in account type i and let r_{it} be the single period holding yield on that account. Let K_{it} be the required reserve ratio on that account. Before proving the equivalency theorem, we define the two formulations of the variable profit function as follows.

Definition 1: Barnett's (1987, equation 3.7) variable profit function is

$$\pi_{Bt} = \sum_{i=1}^{L} \eta_{it}y_{it} - \sum_{j=1}^{J} w_{jt}z_t - \eta_{ct}c_t,$$

[2]Also, see equation (3) in Hancock (1985) for another statement of Hancock's formula.

where the user cost of account y_{it} is

$$\eta_{it} = P_t \frac{(1-k_{it})R_t - r_{it}}{1+R_t},$$

and the user cost of excess reserves c_t is

$$\eta_{ct} = P_t \frac{R_t}{1+R_t}.$$

Definition 2: Barnett and Zhou's (1994, equation 3) variable profit function is

$$\pi_{BZt} = \sum_{i=1}^{L} \{[(1+R_{t-1})\ (1-k_{i,t-1}) - (1+h_{i,t-1})]y_{i,t-1}P_{t-1} + k_{it}y_{it}P_t\} - R_{t-1}C_{t-1}P_{t-1} - \sum_{j=1}^{J} (1+R_{t-1})w_{j,t-1}z_{j,t-1},$$

where $h_{is} = r_{is} + k_{is}R_s$.

Note that by Theorem 1, Definition 2 also defines Hancock's (1991, equation 3.1) variable profit function under the restriction that all earnings are paid out as dividends (Barnett and Zhou's (1994), equation 2). After multiplying Barnett's variable profit function (defined by Definition 1 above) through by $1+R_t$, it is easily seen that the profit function preferred by Brainard in his comments (as further clarified by our private correspondence) is Barnett's profit function. The equivalency theorem, producing a connection between Definitions 1 and 2, follows.

Theorem 2: *The discounted present value of the firm,* C_B, produced from Barnett's profit function flow, π_B, differs from the discounted present value of the firm, C_H, produced from Barnett and Zhou's (in other words, Hancock's with no retained earnings) profit function flow, π_{BZt}, by a function, $K(I)$, containing only initial conditions, I. In other words, there exists $K(I)$, depending only upon initial conditions, such that $C_H = C_B + K(I)$.

Proof: Define the discount factor δ_s such that

$$\delta_s = \begin{cases} 1 \text{ when } s=t \\ \prod_{a=t}^{s-1} (1+R_a) \text{ when } s \geq t+1, \end{cases}$$

where R_a, $a=t,...,s-1$, are current and expected future values of the rate of return, R_t, defined above to be the single period holding yield on Y_t. The discounted capitalized value of the profit stream π_{BZt} at time t is

$$C_H = \sum_{s=t}^{\infty} \frac{1}{\delta_s} \pi_{BZs},$$

while the capitalized value of Barnett's profit stream π_B is

$$C_B = \sum_{s=t}^{\infty} \frac{1}{\delta_s} \pi_{Bs}.$$

Substituting the formulas for the profit streams into the two capitalized values and manipulating algebraically, we find

$$C_B = \sum_{s=t}^{\infty} \frac{1}{\delta_s} \pi_{Bs} = \sum_{s=t}^{\infty} \frac{1}{\delta_s} [\sum_{i=1}^{L} \eta_{is}y_{is} - \sum_{j=1}^{J} w_{js}z_{js} - \eta_{cs}c_s]$$

and

$$C_H = \sum_{s=t}^{\infty} \frac{1}{\delta_s} \pi_{BZs} = K + C_B,$$

where

$$K = \sum_{i=1}^{L} \{[(1+R_{t-1})\ (1-k_{i,t-1}) - (1+h_{i,t-1})]y_{i,t-1}P_{t-1}\} - R_{t-1}C_{t-1}P_{t-1} - \sum_{j=1}^{J} (1+R_{t-1})w_{j,t-1}z_{j,t-1}.$$

Observe that K depends only upon initial conditions, since the intertemporal decision is made at time t over periods t, $t+1$, $t+2$,..... Q.E.D.

Theorem 2 proves that under the restriction that all earnings are paid out as dividends and except for a function of initial conditions, Barnett's variable profit function and Hancock's variable profit function are simply different ways of spreading the capitalized value of the firm over time. Any flow of funds or transaction that appears in one formula necessarily also appears in the other, but potentially with a time shift between them. Those time shifts are all properly discounted, however, as demonstrated by the fact that the two profit streams produce the same capitalized value up to $K(I)$. In his comment, Brainard observes correctly that the choice between the two profit flow formulas "has essentially no effect on the present value of the bank." Theorem 2 above makes that point clear.

The discussion that follows will extract from Theorem 2 its precise implications for the model estimated by Barnett and Zhou in this volume. Our discussion will compare the solutions of the two decisions defined below.

Decision 1: For some utility function, U, the firm determines its factor demands and output supplies by maximizing, $EU(C_B)$, which is the expected utility of the capitalized value C_B.

Decision 2: For some utility function, *V*, the firm determines its factor demands and output supplies by maximizing, $EV(C_H)$, which is the expected utility of the capitalized value C_H.

Observe that all terms in each capitalized value are inside the respective utility function, which is not assumed to be intertemporally separable in either case. The marginal utility of anything varied within either capitalized value depends upon everything else in that capitalized value. In short, neither utility function is intertemporally separable and the solution of either decision is deeply dynamic. In fact, each solution is intertemporally simultaneous with all time subscripts appearing in all Euler equations.

To determine whether there are any substantial differences between Decisions 1 and 2, we now define the following concept.

Definition 3: Two decision problems are observationally equivalent if the solution functions (factor demand and output supply) functions produced by solving one problem are identical to the solution functions produced by solving the other at any fixed setting of the initial conditions.

The following theorem and corollary are now easily proved.

Theorem 3: For any given fixed value of the initial conditions function, $K(I)$, and any given utility function, *U*, there exists a utility function, *V*, such that $V(C_H)=U(C_B)$ for all possible settings of the firm's decision variables (the controls).

Proof: For given $K(I)$ and *U*, define *V* such that $V(x+K(I))=U(x)$ for all nonnegative values of the scalar x. Now let $x=C_B$, and let $C_H=x+K(I)$. By substitution, the result is immediate. Q.E.D.

Corollary 1 to Theorem 3: Decisions 1 and 2 are observationally equivalent.

Proof: The corollary follows immediately from Definition 3 and Theorem 3. Q.E.D.

The implications of the above results at this point are the following. To justify the introduction of risk aversion into the decision of the firm, we implicitly assume the existence of incomplete markets.[3] How to model the decisions of firms with incomplete contingent claims markets is controversial. One approach that has been proposed is to apply principle agent theory in a form that produces incentive compatibility, when the decision is delegated by the owners to a professional manager. The source of the risk averse, concave utility function is the utility function of the principle agent.

Having introduced expected utility maximization into the firm's decision in that controversial manner, we then see from the above corollary that it makes no difference whether we use Hancock's variable profit function or Barnett's in producing the Euler equations to be estimated. The Euler equations are identical and the decision is deeply dynamic, with all time subscripts appearing in each Euler equation. The choice between the two profit formulas is a choice between two different methods of spreading the same capitalized value over time. But since it is the capitalized value itself that enters as the sole argument of the utility function, the method of spreading over time is irrelevant. Corollary 1 is the result.

The problem at this point is that estimating a system of simultaneous Euler equations is beyond the state of art. We need a means of decreasing the depth of the model's dynamics. An obvious method would be to impose a separability restriction on the utility of capitalized value. We could use complete separability, blockwise separability, weak separability, or strong separability. Separability restrictions are testable structural restrictions, and behavior is not invariant to such structural restrictions.[4] In addition, nothing in principle agent theory helps us to choose between such restrictions, which in fact all may be wrong. The utility function may indeed be nonseparable, and the decision may be unavoidably deeply dynamic. Furthermore, we are aware of no empirical results that would help us to choose between the many simplifying separability restrictions, and the few results in that area in Barnett (1981) indicate that separability restrictions are strong restrictions that often are rejected in empirical tests.

[3]If contingent claims markets are complete, then the owner will instruct the manager to maximize profits conditionally upon the prices in contingent claims markets. Those prices contain the information about the risk aversion of the owner and, hence, the managers will be instructed to behave in a risk-neutral manner relative to those prices. See Duffie (1991) and Magill and Shafer (1991).

[4]This issue does not exist in the perfect-certainty or risk–neutral case, since in those cases there is no utility function to be structurally separable. The invariance theorem, then, is the end of the story.

Under such circumstances, applied researchers regularly choose simplifying assumptions on the basis of their usefulness in estimation. One possibility is intertemporal strong separability in Hancock's profit stream. Another possibility is intertemporal strong separability in Barnett's profit stream. More formally, those two possibilities are Assumptions 1 and 2 below, respectively.

Assumption 1: The utility function, V, is intertemporally strongly separable in $\{C_{H,t}:t=1,...,\infty\}$.

Assumption 2: The utility function, U, is intertemporally strongly separable in $\{C_{B,t}:t=1,...,\infty\}$.

There are many other such possibilities produced by grouping together terms in the capitalized value in different manners. Behavior is not invariant to choices between those possible separability restrictions. In terms of the degree of simplification of the Euler equations, complete intertemporal separability in Barnett's profit stream (Assumption 2), as assumed by Barnett and Hahm (1994), produces the most extreme simplification. The decision becomes completely static. Complete intertemporal separability in Hancock's profit stream (Assumption 1) produces a more modest decrease in the depth of the dynamics: The solution becomes recursive, with two time subscripts appearing in the Euler equations.

Barnett and Zhou (1994) selected and imposed the latter restriction, since the resulting recursive form of the solution assists in GMM estimation. Brainard (1994), in his commentary, argues forcefully for intertemporal strong separability in Barnett's profit stream. We have no reason to dispute his strong prior on this subject. His views are reasonable, and obviously Barnett (1987) and Barnett and Hahm (1994) must have had somewhat similar priors in mind when they published their work. Nevertheless, it is also possible that the opposite extreme may be true. The utility function may be completely nonseparable, so that both Assumptions 1 and 2, along with all other possible separability restrictions, may be wrong.[5] The Euler equations would thereby be intertemporally simultaneous, so that we cannot readily estimate the model with current methods because of the depth of the dynamics. Even worse, it may be the case that the use of a risk averse principle agent as a means of introducing risk aversion into the decision of the firm may be a defective approach. That question at present is unresolved in economic theory.[6]

Under these circumstances, we feel justified in choosing our separability restriction based upon the resulting estimation convenience. Producing interesting dynamics with long-run economic growth was not an objective of Barnett and Zhou (1994), which was an exploration in aggregation theory for firms under uncertainty. We agree with Brainard that far more interesting dynamics would be produced by introducing a law of motion for capital, which indeed will be included in Barnett, Kirova and Pasupathy (1994).

We wish to acknowledge that the above clarifying proofs resulted from our correspondence with Brainard, and we are indebted to him for motivating this exploration of the connection between Hancock's and Barnett's formulations. Many of his other suggestions will be used in future extensions of our research such as the estimation of the model with learning-by-doing technological change. Although we have not yet estimated that model, the Euler equations for that extended model are provided in Barnett and Zhou (1994) and the dynamics in that model are indeed dynamic in an interesting manner.

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[5]In fact, the assumption of intertemporal separability of preferences has become controversial in the real business cycle literature. See, for example, Kydland and Prescott (1982).

[6]See for example Magill and Shafer (1991).

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Can the Central Bank Achieve Price Stability?

THE FOMC'S STATED POLICY objectives are to "foster price stability and promote sustainable growth in output." Can these objectives be achieved with the tools available? We know that there is a long-run relationship between the ratio *M/y=Money/real GDP* and the *P=GDP deflator* of the form

(a) $P = V(M2/y)$,

where V is the velocity function, shown in Figure 1. The Federal Reserve would like to select ranges for monetary growth over the coming year consistent with price stability.[1] This is the policy of monetary targeting. The rationale for the policy of monetary targeting is the existence of a stable and reliable relationship between the rate of growth of monetary aggregate Mi [denoted $\mu_i(t)$] and the rate of inflation (denoted π) either during year t or possibly $t+1$ of the form

(b) $\pi(t) = c + c'\mu_i(t)$ or

(c) $\pi(t) = c + c'\mu_i(t-1)$.

Equation (a) is a long-run relation between the price level and the stock of money per unit of real GDP, and equations (b) and (c) are shorter-run relations between the rate of growth of prices and the rate of growth of money. They are quite different.

It has been amply demonstrated by monetarists that neither the growth of M1 nor of M2 produces a stable and reliable relationship of the form (b) or (c).[2] The targeting of M1 was abandoned when the velocity function changed drastically after 1980, and M2 targeting was then used. There was subsequent disappointment with targeting M2. Figure 2a-d shows why monetary targeting equations (b) and (c), either for M1 or M2, are not reliable. The source of the problem is the instability and unreliability of the velocity function (V1 for M1, and V2 for M2 in Figure 3a). This led Alan Greenspan (1993) to question the usefulness of M2 targeting [equation (b) or (c)]:[3]

"...the relationship between money [M2] and the economy may be undergoing a significant transformation....This is not to argue that money growth can be ignored in formulating monetary policy....Selecting ranges for monetary growth over the coming year consistent with desired

[1] By price stability, we mean a desired rate of change of prices, which need not be zero.

[2] See Belongia and Batten (1992), Thornton (1992), Garfinkel and Thornton (1989), and Ritter (1993).

[3] The article by Ritter (1993), "The FOMC in 1992: A Monetary Conundrum," conveys the serious problems that arose when the FOMC tried to implement the policy of monetary targeting.

Figure 1
GDP Deflator and the Ratio of M2/Real GDP

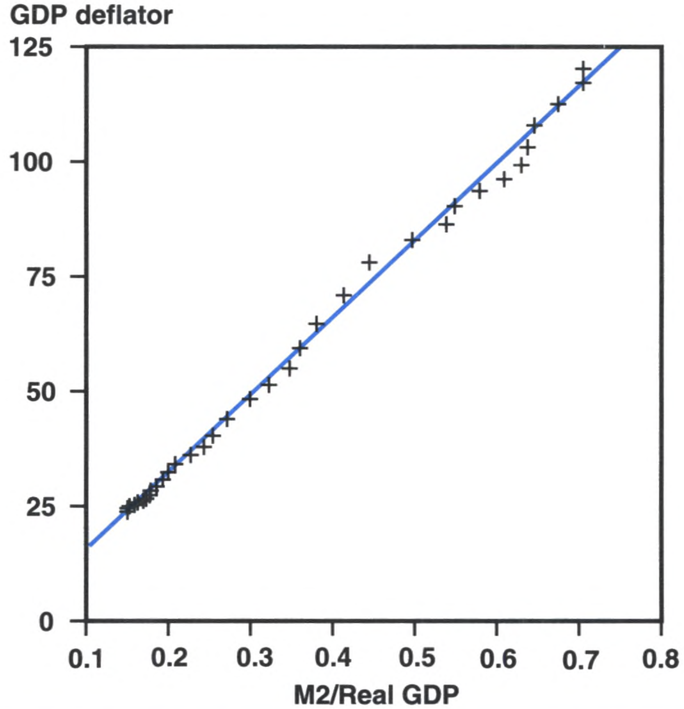


Figure 2a
Inflation and the Growth of M2

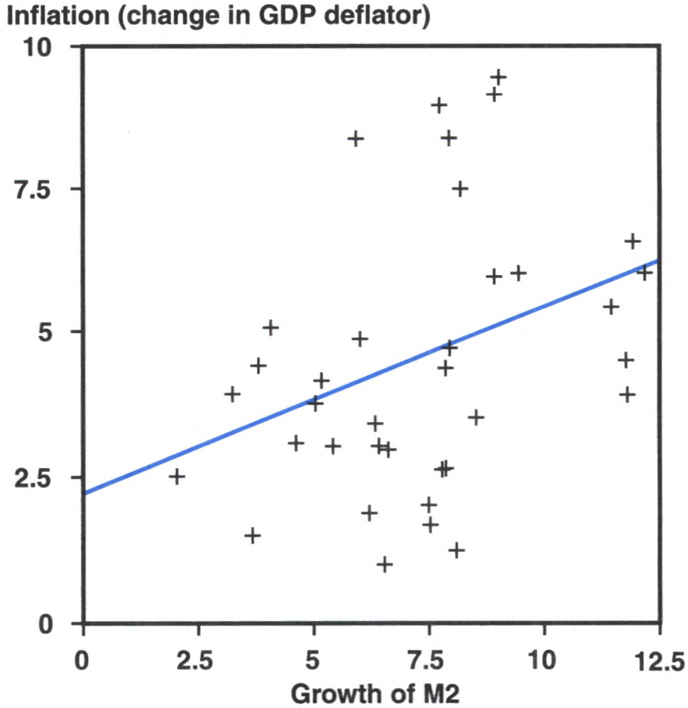


Figure 2b
Inflation and the Growth of M1

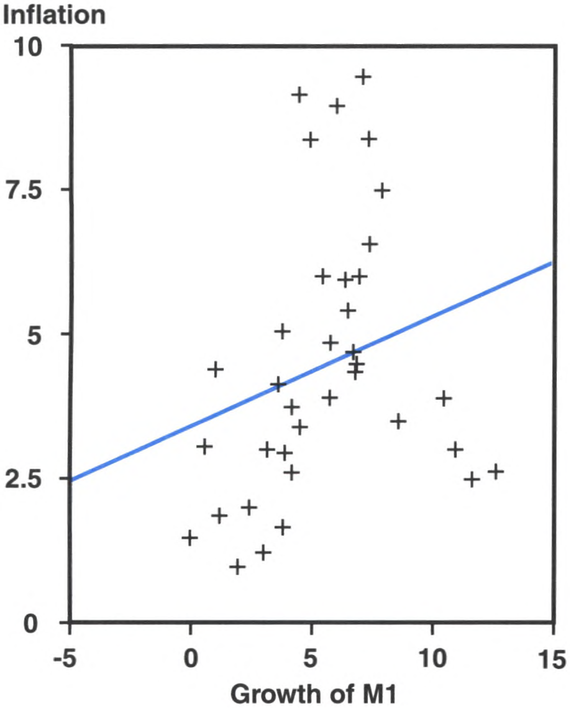


Figure 2c
Inflation and the Lagged Growth of M2

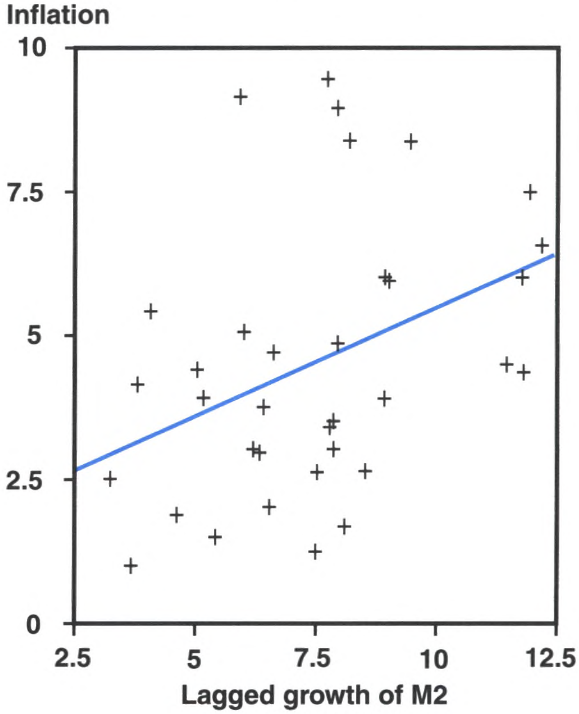


Figure 2d
Inflation and the Lagged Growth of M1

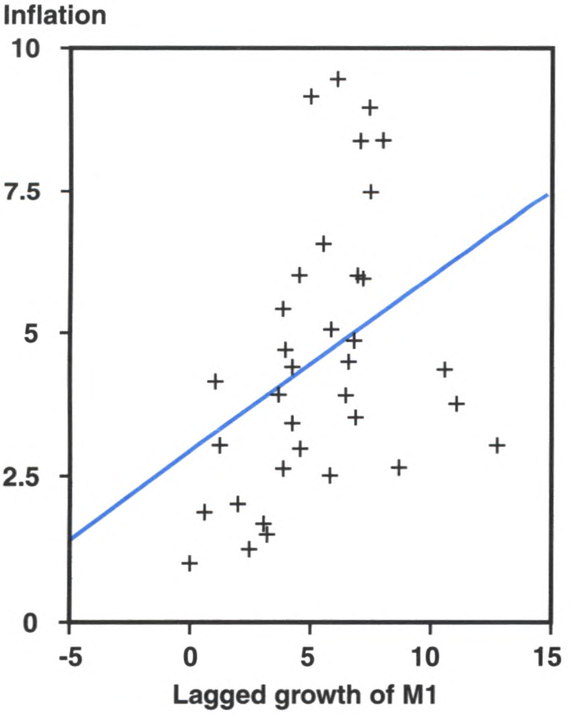


Figure 2e
Inflation and the Growth of Divisia M2

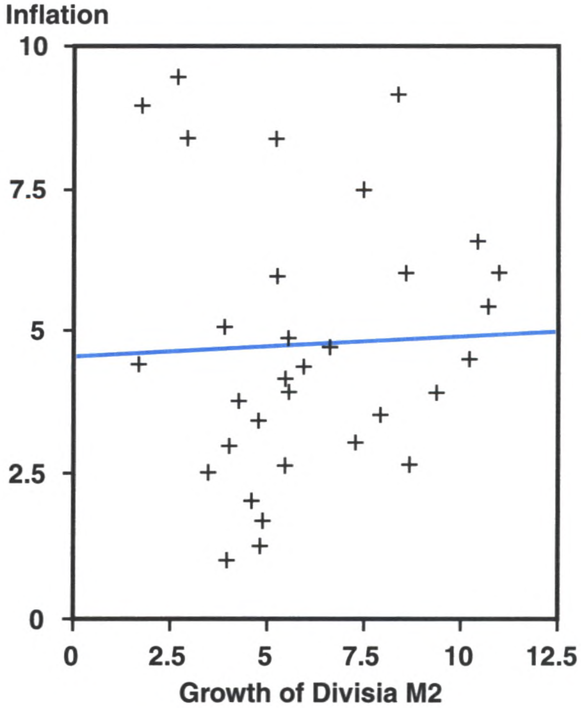


Figure 3a
Velocity of M1 and M2

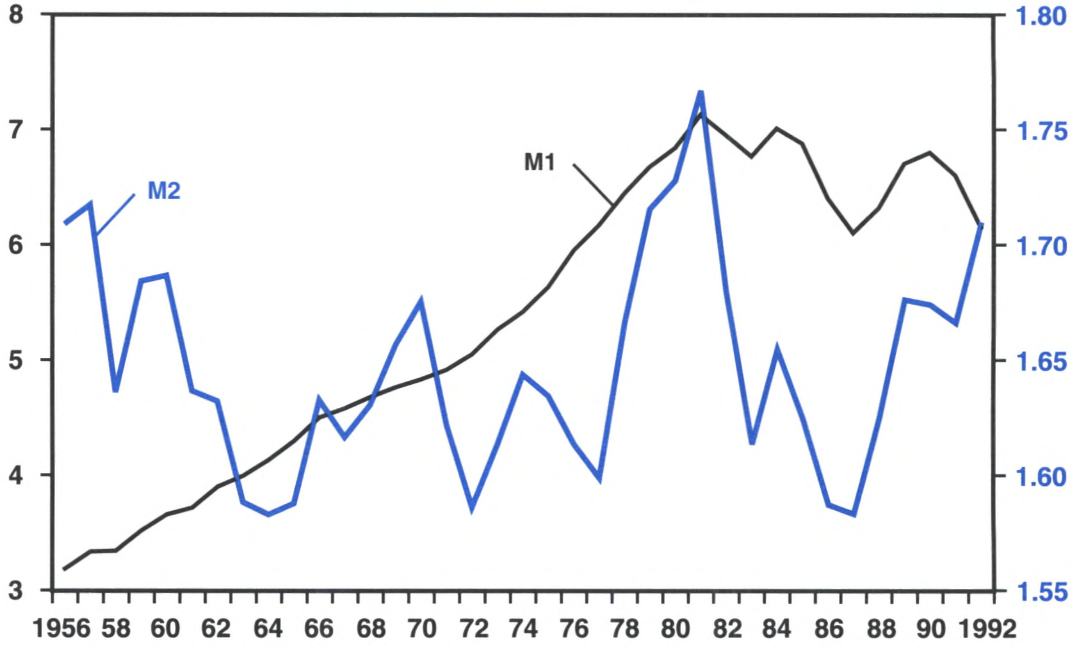
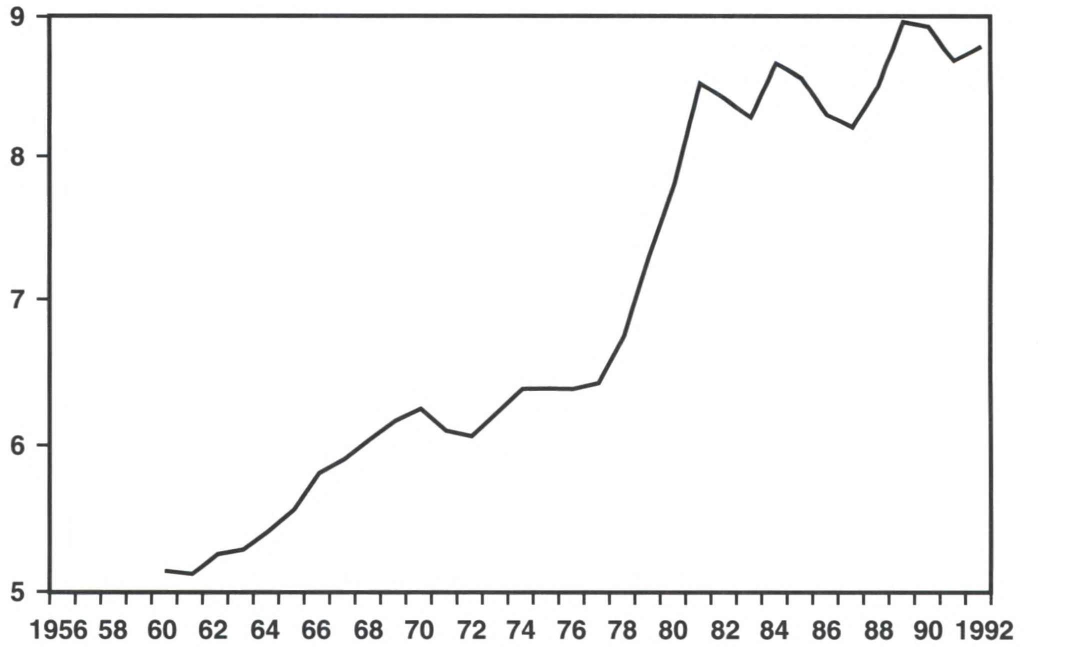


Figure 3b
Velocity of Divisia M2



economic performance, however, is especially difficult when the relationship [velocity] between money and income has become uncertain. Recent experience suggests that...measuring money against such ranges may lead to erroneous conclusions regarding the stance of monetary policy."

Greenspan's disappointment with the use of monetary targeting (M2) has led him to revive the concept of interest rate targeting.

The ultimate question is how the central bank should try to produce price stability and sustainable growth. Our paper addresses several important questions:

1. Is there an economically significant, structurally stable, policy-rule-invariant relationship between the rate of growth of a monetary aggregate and the rate of growth of the price level? If so, that monetary aggregate is referred to as an indicator. What monetary aggregates, if any, qualify as indicators?

2. Which monetary aggregate is an intermediate target? An intermediate target is defined as a variable *Z* which is an indicator and is also controllable over a range of policy regimes.

3. Under what conditions can Federal Reserve policy be used to speed the recovery and what will be the consequences for the rate of inflation?

4. Does the controllable Treasury bill rate qualify as an indicator or intermediate target?

Our major conclusions are:

A. The relation between the growth of the monetary aggregate and inflation is indirect. The change in the rate of inflation depends upon the unemployment rate and the growth of real balances which changes real aggregate demand. Neither the growth of M2 nor the growth of adjusted reserves per se conveys very much useful information about the course of inflation in the near future, because the inflation and unemployment rates interact in a dynamic manner. Within the context of the dynamic model, the growth of M2 is a good indicator of the rates of inflation and unemployment.

B. The growth of M2 has both an endogenous component and a directly controllable part. The link between the growth of M2 and reserve growth was tight from 1958-1975 and then became very weak from 1975-1992. Hence, the growth of M2 is primarily an indicator. The growth of adjusted bank reserves is an intermediate target for the rate of inflation, but less so for the unemployment rate, within the context of the dynamical system.

C. Weighted monetary aggregates are inferior to M2 as an indicator.

D. The nominal or "real" Treasury bill rate fails completely as an indicator, so it cannot be an intermediate target.[4]

The flow chart below describes the relation between the research design and the conclusions stated above. The Federal Reserve has been seeking a direct relation between the growth of monetary aggregate Mi, where *D(log Mi)* is denoted μ_i, in a given year and the rate of inflation $D(\log P) = \pi$ in the subsequent year.[5] We have seen that there is no direct relation between $\mu_i(t-1)$ and inflation $\pi(t)$. The reason is that the relation between inflation and money growth is indirect and works through a dynamic model. We first derive the structural equations of a dynamical system involving the state variables *X*, which are the inflation (π), the anticipated inflation (π^*) and unemployment rates (u).[6] The input is the rate of growth of a monetary aggregate $\mu = DM/M$. The resulting reduced form system (the SM dynamical system) is of the form $DX = AX + B\mu + e'$, described in Table 1 or the flow chart below.[7]

SM dynamical model			money growth	
$X \leftarrow DX = AX + B\mu + e'$	$\leftarrow \mu$	$\leftarrow$	$\mu = CX + bz + e''$	$\leftarrow z$
indicator				*control*

[4]An intermediate target is an indicator, but not necessarily the reverse.

[5]For economy of notation throughout the paper, the operator *D* represents either the discrete first difference operator $Dx = x(t) - x(t-1)$ or the continuous time derivative $Dx = dx/dt$ as appropriate in the context.

[6]The unemployment rate $u(t) = U(t) - Ue$ is the deviation between the measured unemployment rate $U(t)$ and the equilibrium level *Ue*.

[7]SM denotes the Stein Monetarist dynamical model as developed in Stein (1982).

Table 1

The Reduced-Form Equations for the Dynamics of Inflation and Unemployment, from the SM Model

(7) $Du = a_{11}u + a_{12}\pi + a_{13}\pi^* + e'; a_{11} < 0, a_{12} < 0, a_{13} > 0, a_{12} + a_{13} = 0$

(8) $D\pi = a_{21}u + a_{22}\pi + a_{23}\pi^* + b_{24}\mu + e''; a_{21} < 0, a_{22} < 0, a_{23} > 0, b_{24} > 0,$
$a_{22} + a_{23} + b_{24} = 0$

(9) $D\pi^* = -c\pi^* + c\,\mu; 1 > c > 0$

(9.1) $\pi^*(t) = (1-c)^n \pi^*(t-n) + c(1-c)\mu(t-1) + c\sum_{2}^{n} (1-c)^s \mu(t-s) = C(L)\mu$

Note: $u = U\text{-}Ue$ = unemployment rate U less the equilibrium rate Ue. π = inflation rate. μ = rate of monetary growth.

We estimate a surrogate of the SM dynamical model, in which the dependent variables X are the observable unemployment and inflation rates. The equations of the surrogate model are:

$$\pi(t)-\pi(t-1) = b'_0 - b'_1U(t-1) + b'_2 [\mu(t-1) - \mu(t-1)] + e_1;$$
$$U(t) - U(t-1) = a'_0 - a'_1 U(t-1) - a'_2[\mu(t-1)-\pi(t-1)] + e_2;$$
$$E(e_i) = 0.$$

The effect of the growth of the monetary input μ upon the rate of inflation is indirect: It operates through the dynamical system, which also involves the unemployment rate. The change in the rate of inflation depends upon the unemployment rate and the rate of change of real balances $(\mu-\pi)$. The change in the unemployment rate depends upon its level and the change in real balances. We have already seen that there is no direct relation between the rate of monetary expansion $\mu(t-1)$ and the subsequent rate of inflation $\pi(t)$. However, when we consider how the rate of M2 monetary expansion $\mu(t-1)$ operates upon the dynamical system, implied by the structural equations, the growth of M2 is a very good indicator of the subsequent rates of inflation and unemployment. The matrices A and B are structurally stable and policy-rule invariant; and the surrogate system is a good predictor. This is conclusion A above, that the growth of M2 is a good indicator. We show that the growth of M2 is better than alternative monetary aggregates (conclusion C).

We then consider the intermediate target issue: To what extent is the growth of M2 controllable? This is the next link in the flow chart: $\mu = CX + bz + e''$. The rate of monetary expansion μ has two components. One component is the growth of reserves z which is controllable. The other component is CX, the induced part of the growth of M2, which responds to the state of the economy. We estimate this relationship. From 1958–75, the growth of M2 was determined by the controllable growth in reserves. After 1975, and especially after 1984, the growth of reserves did not have that effect and the growth of M2 was endogenous. The reason is that the growth of the non-M1 component of M2 was not controllable by the growth of reserves (conclusion B). The growth of M2 was an intermediate target prior to 1975, and much less so afterwards.

Combining the two links, we ask whether the controllable growth of reserves z operates through the dynamical system, of the following form:

$$X \longleftarrow DX = (A+BC)X + (Bb)z + (Be''+e') \longleftarrow z$$

intermediate target *control variable*

The answer is that this system is acceptable for the inflation rate and less so for the unemployment rate in recent years. This is in conclusion B. Finally, we ask whether the controllable Treasury bill rate operating through the dynamical system can be considered to be an intermediate target. Conclusion D is that there is no informational content to the controllable Treasury bill rate. It is neither an indicator nor an intermediate target.

THE SM DYNAMIC MODEL[8]

The Structural Equations

There are five structural equations and one identity to the SM dynamic model. First: The rate of inflation $\pi = Dp/p$ depends upon the excess demand for goods, $J(t)$ = *aggregate real demand less current real GDP*, and the rate of growth of unit labor costs DW/W, where W is unit labor costs. This is equation 1, where $D = d/dt$, γ is a parameter:

$$(1)\ \pi = DW/W + \gamma J.$$

Second: The growth of unit labor costs depends upon the state of the labor market, reflected by the deviation between the unemployment rate $U(t)$ and its equilibrium rate Ue, and by the anticipated rate of inflation π^*. This is equation 2. That is, the anticipated rise in the real unit labor costs depends negatively upon the excess supply in the labor market, where the excess supply is reflected in the unemployment rate.

$$(2)\ DW/W = \pi^* - h[U(t) - Ue]$$

Equation 3 simply states that the observed unemployment rate is positively related to the unobserved excess supply of labor. The demand for labor depends negatively upon real unit labor costs, and the supply of labor has an algebraically greater relationship with the real unit labor costs than does the demand. Hence, the observable unemployment rate, which is positively related to the unobservable excess supply of labor, depends positively upon real unit labor costs W/P.

$$(3)\ U(t) = b_0 + b_1 \ln (W/P)$$

The real excess demand for goods $J(t)$ = *real aggregate demand less real GDP* is equation 4, when we have solved for the equation, which produces portfolio balance.[9] In terms of the usual Keynesian 45-degree diagram, J is the vertical distance between aggregate demand and current real GDP (the ordinate on the 45-degree line). The basic parameter of the aggregate demand curve is real balances per unit of capacity output. Hence, the excess demand for goods depends upon the unemployment rate (which is negatively related to the ratio of actual to capacity output), real balances $m(t) = M/PY^*$ per unit of capacity output Y^* and disturbances $\eta(t)$.

$$(4)\ \gamma J(t) = J(U, m; \eta) = J_1 U + J_2 \ln (m) + \eta,\ J_i > 0.$$

Substitute equations 2 and 4 into equation 1 to obtain 1.1. It is clear that the inflation equation is not the usual expectations augmented Phillips curve, since it contains the real balances as variables as well as the unemployment rate and rate of anticipated inflation.

$$(1.1)\ \pi = \pi^* - h[U\text{-}Ue] + \gamma\ J_1 U + J_2 \ln (m) + \eta$$

The anticipated rate of inflation slowly converges to the trend rate of monetary growth per unit of output, equation 5. Variable $\mu(t)$ is the rate of monetary growth and n is the trend rate of growth of output. There are two established facts:

(a) There is a long-run, positive relation between the price level and some monetary aggregate (Figure 1), and

(b) On a year-to-year basis, there is no reliable relationship $\pi = c + c'\mu$ between money growth and the subsequent rate of inflation (Figure 2). That is, there is very little informational content in the current rate of monetary expansion concerning the rate of inflation in the near future.[10]

In our Bayesian framework, there is a prior anticipated rate of inflation $\pi^*(t)$.[11] Then, there is

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[8]This is explicitly developed in Stein (1982), and Infante and Stein (1980). Here, we attempt to simplify and focus exclusively upon the basic characteristics. The SM refers to my version of a monetarist system. The techniques of analysis are different from conventional monetarists since the velocity function is not used and the SM model involves an interaction of unemployment and inflation. The conclusions, however, are quite close to those of Friedman, hence the term monetarist. In a sense, the SM dynamic model lies between the thinking of Friedman and Tobin.

[9]This is discussed in equation 19 in connection with the intermediate target.

[10]We have no need to use the subjective concept of anticipated or unanticipated money growth.

[11]We use the concept of Asymptotically Rational Expectations as developed in Stein (1992a,b). Our results are not sensitive to the specific form of the anticipated inflation equation. Any anticipations function that satisfies the following conditions will suffice. First, in the steady state, a change in the rate of monetary expansion changes actual and anticipated inflation by the same amounts. Second, a change in the rate of monetary expansion at time t does not change the current rate of anticipated inflation by as much.

Table 2

The Surrogate System: Estimated Inflation and Unemployment Equations

	Growth M2 = μ		Growth reserve = z	
Variable	Inflation π	Unemp U	Inflation π	Unemp U
constant	1.4 [0.1]	1.96 [0.00]	1.6 [0.06]	1.6 [0.01]
U(t−1)	−0.39 [0.01]	0.76 [0.00]	−0.34 [0.016]	0.69 [0.00]
π(t−1)	0.86 [0.00]	0.29 [0.00]	0.92 [0.00]	0.23 [0.00]
μ(t−1)	0.21 [0.03]	−0.23 [0.00]	——	——
z(t−1)	——	——	0.16 [0.02]	−0.13 [0.01]
ADJ.R-SQ	0.77	0.76	0.78	0.71
LM prob (F)	0.07	0.72	0.18	0.72

Notes: Sample period 1958-92, annual, N=35. Columns one and two refer to equations 10 and 11 for growth of M2; columns three and four refer to equations 12 and 13 for growth of reserves. The two-tail significance level is shown in brackets.

current information, which is the current rate of monetary expansion $[\mu(t) - n]$. Combining the two, the posterior anticipated inflation $\pi^*(t+1) = (1-c)\pi^*(t) + c[\mu(t)-n]$, is a linear combination of the prior and the current information. The coefficient c is the weight given to the current sample of information. Subtract the prior from both sides and derive:

$$(5)\ D\pi^* = \pi^*(t+1;t) - \pi^*(t) = c[\mu(t) - n - \pi^*(t)].$$

The "credibility" argument is contained in the value of coefficient c. If the public believes that the central bank is committed to an inflation target [the prior $\pi^*(t)$], then variations in the current rate of monetary expansion $[\mu(t) - n]$ will be given a low weight and coefficient c will be small. Coefficient c reflects the predictability that the current rate of monetary growth will continue for a long time and the tightness of the relation between money growth and inflation over the relevant horizon.

The rate of growth of real balances relative to the trend rate of growth of output n is equation (6), which closes the system.

$$(6)\ Dm/m = \mu - \pi - n.$$

These dynamic interactions between the inflation rate, unemployment rate and monetary policy must be explicitly considered if we are to answer the questions posed at the beginning of this paper: Specifically, what is an indicator and what is an intermediate target? Equations 1–6 are solved in the dynamic form described by Table 1. These differential equations imply the steady-state relations as well as the medium-run dynamics. The steady-state solution is that: The unemployment rate converges to the equilibrium rate. The latter is independent of monetary factors. The actual and anticipated rates of inflation converge to the growth of the money supply (or growth of the money supply less the long-term growth rate of the economy). Equation 5 or 9 may be solved to yield equation 9.1 in Table 1. The anticipated rate of inflation at any date t is a weighted sum of past rates of monetary expansion, with declining weights.

AN EMPIRICAL SURROGATE SYSTEM USING M2 AS INPUT

The system described in Table 1 involves the measured unemployment and inflation rates and the nonobservable anticipated rate of inflation. For empirical analysis, we convert the SM dynamic model in Table 1 into a surrogate system, involving measurable quantities only. These, in the form of equations 10 and 11 below, are used for empirical estimation in Table 2. The surrogate system mimics the dynamical system. First we explicitly derive, from equations 1–6 of the SM model, the reduced form equations in Table 1. Then we show how the surrogate system is derived from the SM model.

Differentiate equation 3 with respect to time and use 2 to obtain 7:

$$(7)\ Du = b(\pi^* - hu - \pi) + e' = a_{11}u + a_{12}\pi + a_{13}\pi^* + e'$$

Differentiate 1 with respect to time, using 4–7 to obtain equation 8. The constraints on the coefficients follow from definitions of a_{ij} and b_{ij}:

$$(8)\ D\pi = -hb(J_1-h)U - [(J_1-h)b + J_2]\pi + [(J_1-h)b-c]\,\pi^* + (J_2+c)\,(\mu-n) + e'' = a_{21}U + a_{22}\pi + a_{23}\pi^* + b_{24}\,(-n) + e''$$

Equation 9 is equation 5 above:

$$(9)\ D\pi^* = -c\pi^* + c\mu$$

The continuous time dynamical system 7–9 in Table 1 may be written as $DX = AX + B\mu + e$, where $X = (u,\pi,\pi^*)$. We use e as a generic representation of a random variable with a zero expectation.

In this paper, we use annual rather than quarterly data because we obtained clear-cut, significant results with annual data (Table 2), whereas nothing of economic significance emerged when we used the noisy quarterly data, as shown in the appendix. When the data are annual and one just uses the observable U, π and μ the surrogate empirical system is equations 10 and 11.

$$(10)\ \pi(t) = b_0 + b_1U(t-1) + b_2\pi(t-1) + b_3\mu\,(t-1) + e';$$

$$H_0\!: b_2 + b_3 = 1;\ b_1 < 0$$

$$(11)\ U(t) = a_0 + a_1U(t-1) + a_2\pi(t-1)\ a_3\mu\,(t-1) + e'';$$

$$H_0\!: a_2 + a_3 = 0;\ a_3 < 0$$

There are two important theoretical constraints concerning monetary neutrality. Equal rises in money growth and inflation do not change real balances and, hence, have no effect upon the unemployment rate. Similarly, in the steady state, the actual and anticipated rates of inflation will change by as much as the rate of monetary expansion. One is not free to construct any monetary aggregate as either an indicator or an intermediate target simply on the grounds that it seems work over the period considered. Instead, the monetary aggregate must be closely linked to the theory, such that the variable satisfies certain neutrality constraints. The neutrality constraints in the indicator system are as follows. In a comparative steady state, money and prices change by the same proportion, there is no effect upon the unemployment rate. The constraint in inflation equation 10 is that in the steady state a change in the rate of monetary expansion will change the actual and anticipated rates of inflation by the same amount: $b_2 + b_3 = 1$. The constraint in unemployment equation (11) is that, when money and prices change by the same amount, there is no effect upon real unit labor costs and no change in the unemployment rate: $a_2 + a_3 = 0$.

With these constraints, the surrogate system 10 and 11 mimics the SM dynamic system, Table 1.[12]

Regarding equations 7–9 or 10 and 11, a rise in the rate of monetary expansion relative to the initial rate of inflation has several effects. First, it raises real balances which raises aggregate demand. The rise in aggregate demand raises the rate of inflation. Second, the rise in the rate of monetary expansion raises the anticipated rate of inflation (by coefficient c in equation 5 or 9 above). The rate of growth of the nominal wage will rise, by the anticipations effect in equation 2 above. This effect will not be great because a

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[12]This can be seen as follows. The estimates (from Table 2) of the surrogate system 10 and 11 are 10.1 and 11.1. The SM model (Table 1) can be written as (A.1)-(A.3) when the following values are used. The half-life of the deviation of: (i) the inflation rate from its equilibrium value is two years, (ii) the unemployment rate from its equilbrium value is 3.5 years and (iii) anticipated inflation from its equilibrium is five years. This gives us the coefficients in the principal diagonal of matrix A. (ii) The effects of inflation and anticipated inflation upon the change in unemployment and the change in inflation are equal and opposite (see equations 7, 8). (iii) All variables are measured as deviations from their steady-state values. Then the SM dynamic system is:

(A.1)	$D\pi =$	$-.197\,\pi$	$-\ .1\,u$	$+\ .197\pi^*$
(A.2)	$Du =$	$-.1\pi$	$-\ .347u$	$+\ .1\pi^*$
(A.3)	$D\pi^* =$			$-\ .138\pi^*$

Surrogate system (estimates from Table 2, rounded)

(10.1)	$D\pi = -.2\,\pi - .4\,u$
(11.1)	$Du = .25\pi - .3\,u$

Let the initial conditions, corresponding to points *B* and *C* in phase-diagram Figure 8 be as follows for the two systems.

	SM		*Surrogate system*	
	B	C	B	C
$\pi(0)$	−2	0	−2	0
$u(0)$	2	−2	2	−2
$\pi^*(0)$	−2	0		

The trajectories of the inflation and unemployment variables are very similar.

rise in the current rate of monetary expansion will convey little information about the rate of inflation, as is seen in Figure 2. The net effect will be that the rate of inflation will rise, as a result of both the rise in aggregate demand due to the rise in real balances, and the rise in the growth of nominal unit labor costs. However, real unit labor costs will decline and unemployment will decline. These are the short-run effects. As time proceeds, the decline in unemployment and a rise in the rate of anticipated inflation will raise real unit labor costs and the unemployment rate will converge to its equilibrium rate.

Later, we shall consider the intermediate target system, equations 12 and 13, where the input is the growth of reserves z.

$$(12)\quad \pi(t) = b'_0 + b'_1 U(t-1) + b'_2 \pi(t-1) + b'_3 z(t-1) + e';$$

$$H_0: b'_2 + b'_3 = 1;\ b'_1 < 0$$

$$(13)\quad U(t) = a'_0 + a'_1 U(t-1) + a'_2 \pi(t-1) + a'_3 z(t-1) + e'';$$

$$H_0: a'_2 + a'_3 = 0;\ a'_3 < 0$$

We ask in the next section whether, within the context of the dynamical system, there are economically significant (the neutrality constraints are satisfied), structurally stable, policy-invariant relations equations 10 and 11. When the input $\mu(t-1)$ is the growth of M2, the answer to all of these questions is yes, and there is no change in the values of the coefficients even when policy changed drastically.

Empirical Estimates of the Surrogate System: The Input is the Growth of M2[13]

Table 2 summarizes the empirical results for both equations 10 and 11, where the input is μ the growth of M2. Column one refers to inflation equation 10, column two refers to unemployment equation 11.[14] In each cell is the value of the regression coefficient and, in brackets, the two-tail significance level. Summary and diagnostic statistics are at the end of the table and in the text.

The Inflation Equation

Table 2, column one, describing SM inflation equation 10 indicates that the growth of M2 is a good indicator, within the context of the second-order dynamical system. The coefficients have the hypothesized and statistically significant signs, satisfy the theoretical constraints, have remarkable structural stability despite changes in policy rules, and this equation has considerable predictive accuracy.

First, each coefficient in column one has the hypothesized sign and is significantly different from zero. The coefficient of the lagged unemployment rate $b_1 = -0.39$, with a two-tail significance level of 0.01; the coefficient of the lagged M2 growth $b_3 = 0.21$ with a significance level of 0.03. The coefficient of the lagged inflation $b_2 = 0.86$ with a significance level of 0.00.

Second, the neutrality requirement is satisfied. The Wald test concerns the neutrality hypothesis that $b_2 + b_3 = 1$: In the steady state a rise in the rate of monetary expansion raises the rate of inflation by the same amount. The sum of these coefficients is not significantly different from unity: the probability $[b_2 + b_3 = 1] = prob[.86 + .21 = 1] = 0.52$.

Third, there are some mixed results concerning equation evaluation tests. There is no strong evidence of serial correlation of the residuals. The LM/Breusch-Godfrey statistic tests whether the lagged residuals add to the explanatory power of the equation. The hypothesis that the coefficients of all of the lagged residuals are zero has a probability of 0.07. The Ramsey RESET test indicated that there seems to be no specification error in the formulation of the inflation equation. The ADF statistic for the stationarity of the residuals was −2.4, which is a bit low to maintain the stationarity hypothesis. The ARCH test statistic allows us to reject the hypothesis of heteroskedasticity.

Fourth, is the issue of structural stability and predictability, during a period when there were changes in the policy rule. There is no single, commonly accepted break point for the policy rule change. Structural stability is examined in two ways, displayed in Figures 4 and 5. We examine whether the coefficient b_3 of lagged money growth in inflation equation 10 (Table 2,

[13]All of our data are from the data bank of the Federal Reserve Bank of St Louis, and our software package is MicroTSP® 7.0.

[14]The last two columns refer to the intermediate target system (discussed later) where the input is the growth of reserves z. Column three refers to inflation equation 12, and column four refers to unemployment equation 13.

Figure 4

Recursive Estimate of the Coefficient of Lagged M2 Growth in Equation 10

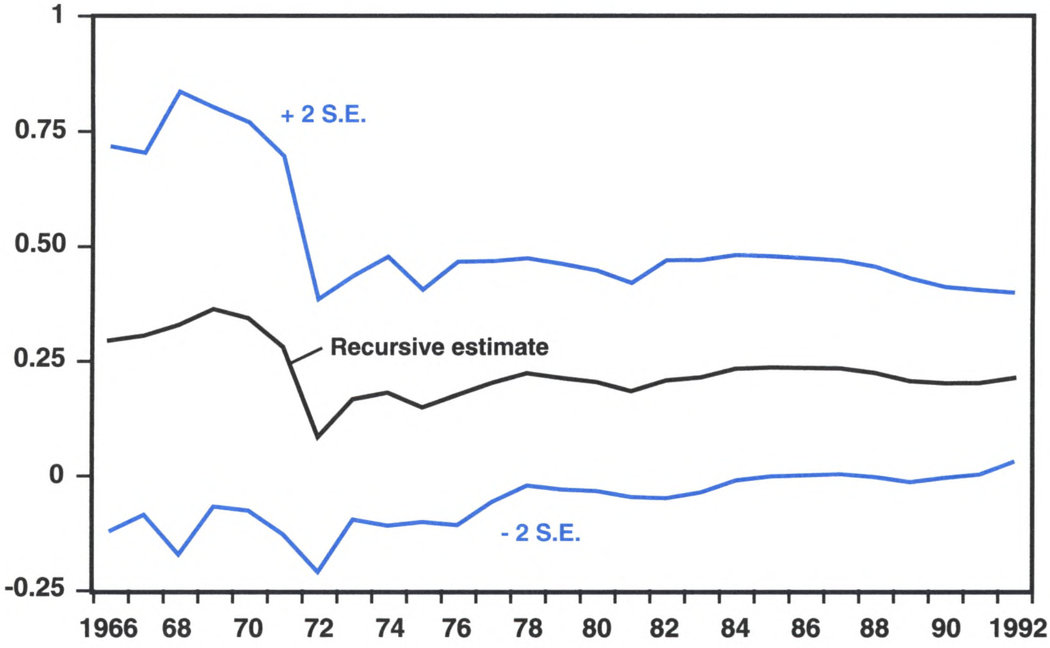
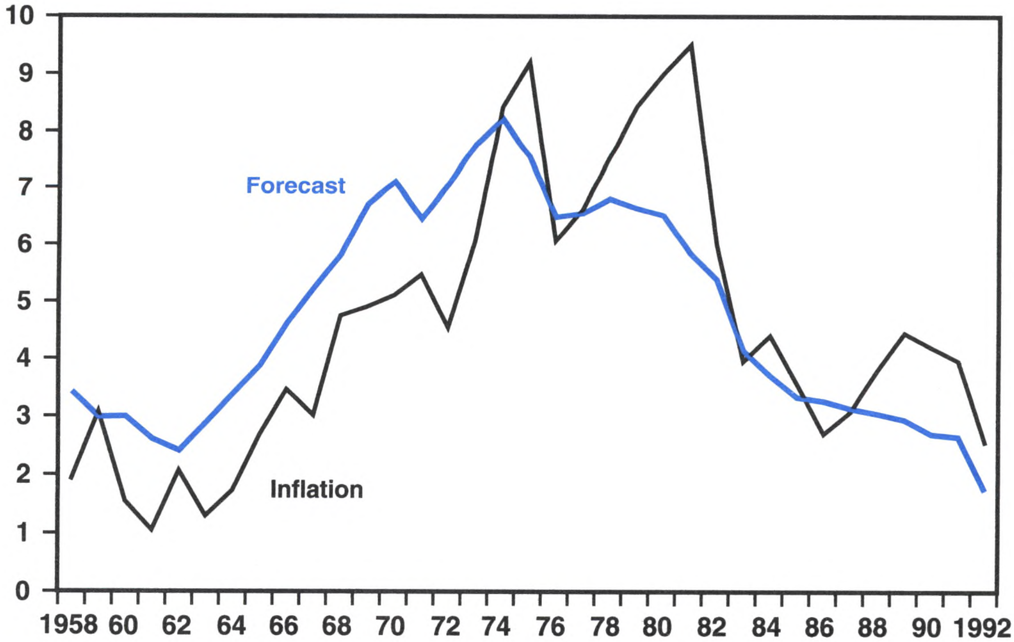


Figure 5

Dynamic Ex Ante Forecast of Inflation, Using Lagged M2 Growth as the Input



column one) is stationary or whether it evolves over time and responds to changes in the policy rule. Figure 4 is a recursive estimate of coefficient $b_3(t)$ using data through time t. If $b_3(t)$ displays significant variation as more data are added (as time increases), it is strong evidence of instability. If policy rule changes significantly affect the structure, the coefficient estimates will undergo dramatic changes. Figure 4 shows remarkable stability for coefficient $b_3(t)$, whereas the velocity series (Figure 3) show significant variation. The other coefficients in equation 10 (Table 2, column one) also are quite stable.

If the inflation equation using M2 is structurally stable, it should be useful for prediction: Otherwise, M2 is not an indicator. Figure 5 displays an N-period-ahead dynamic forecast. There is never any correction for previous forecast errors. The graph INFM2 uses previously predicted values of the rate of inflation as the lagged dependent variable in the next prediction, but uses actual values of the lagged unemployment rate and rate of monetary expansion.[15] It is necessary to know the state of the economy measured by $U(t-1)$ as well as the rate of monetary expansion $\mu(t-1)$ to predict the subsequent rate of inflation $\pi(t)$. A comparison of the actual rate of inflation with the dynamic ex ante forecast using the growth of M2 as the input indicates that the actual rate converges to the predicted rate. Hence, equation 10 is structurally stable, policy-invariant and useful for prediction. Compare Figure 5 with Figure 2 to see the importance of knowing the state of the economy to predict inflation.

A unit root test on the growth of real balances $(\mu - \pi)$ indicated that it is stationary at a level of 2.8 percent per annum. That is $E(\mu - \pi) = 2.8$ *per annum*. Since the steady state rate of inflation $\pi = \mu - n$, where n is the long term growth rate, the estimates are sensible. From Table 2 column one, and the above, the half-life of the convergence of inflation to its steady state value $\mu - 2.8$ is 3.47 years.[16]

For all of these reasons, we therefore conclude that, within the context of difference equation 10: (1) The growth of M2 is a good indicator of inflation, and (2) there is no evidence that policy rule changes had any effects upon the relation between money (M2) growth and inflation in equation 10.

The Unemployment Rate Equation and the Effect of M2 Growth

We have seen that, within the context of the SM model, the growth of M2 is a good indicator of inflation. In that equation, the change in the inflation rate depends positively upon the lagged growth of real balances which raises the excess demand for goods (aggregate demand less current GDP) and negatively upon the state of the labor market measured by the lagged unemployment rate, which reflects the cost-push effects. Even if one knew the path of the growth of M2, it would be insufficient to predict the course of inflation, unless one could also predict the path of the unemployment rate. The omission of the unemployment rate is the main reason for the poor relation between the rate of inflation and the growth of M2 in Figure 2. To understand how the FOMC can achieve price stability and "sustainable growth in output," and how M2 growth affects both inflation and unemployment, we must examine the interactions between M2 growth, inflation and unemployment.

Table 2, column two, examines the unemployment rate equation 11 during the same sample period used for the inflation rate. It shows how the rate of growth of M2 affects the unemployment rate and is perfectly consistent with the theory described above. The coefficients are subject to several constraints. The coefficient a_1 of the lagged unemployment rate must be less than unity for convergence to the equilibrium rate $Ue = a_0/(1-a_1)$.[17] The coefficient of the lagged growth of real balances should be negative, since it produces the rise in aggregate demand for goods. This means that the coefficient a_2 of lagged inflation should be positive (raise unem-

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[15] This is the FORCST command in MicroTSP®.

[16] Let the growth of real balances $\mu - \pi$ be denoted by x. The UROOT equation was $Dx = 2.1 - 0.75\, x + 0.4\, Dx(-1)$. The coefficient 0.75 is significant, $UROOT(C,1) = -4.3$ (MacKinnon 1 percent = −3.6). Hence, x is stationary and will converge to the steady-state value 2.1/0.75=2.8, used above. From Table 2, if the unemployment rate is at its equilibrium value, let p be the deviation between the inflation rate and its steady state value: $Dp = -.2\, p$ (rounding). This implies that the half life is $T = \log 0.5 / \log 0.2 = 3.47$ years.

[17] The mean unemployment rate 1957-92 is 6 percent. The estimate of $a_0 = 1.9$ with a standard error of 0.55. The estimate of $a_1 = 0.76$ with a standard error of 0.09. If $a_1 = 0.7$ and $a_0 = 1.8$, then Ue is 6 percent.

ployment) and coefficient a_3 of lagged monetary expansion should be negative (lower unemployment) and equal to $-a_2$. The neutrality constraint is $(a_2 + a_3 = 0)$: A rise in the steady state rate of monetary expansion will produce an equal rise in the rate of inflation, and no change in the equilibrium unemployment rate.

Each coefficient has the correct sign and is significant at the 1 percent level. The neutrality hypothesis is satisfied. The $prob[H_0: a_2 + a_3 = 0] = prob[.29 - .23 = 0] = 0.46$ means that monetary factors cannot affect the steady-state unemployment rate. However, changes in the lagged rate of monetary expansion produce short-run changes in the unemployment rate.[18]

The equation (column two) passes the diagnostic tests.[19] This equation is structurally stable over various policy regimes, and the equation has considerable predictive accuracy. Figures 6 and 7 indicate the predictive value and stability of the coefficients of the unemployment equation, despite the many changes in the policy regime. Figure 6 compares the actual unemployment rate with the rate forecasted from a dynamic ex ante simulation, where previously predicted values of the unemployment rate are used as the lagged dependent variable, but actual values are used for lagged inflation and growth of M2. The forecast refers to the equation in column two in which the input is the growth of M2. The actual rate of unemployment converges to the prediction. Figure 7 is a recursive estimate of the coefficient a_3 of the effect of the lagged rate of M2 growth. Despite the many changes in the policy rule used by the monetary authorities, this coefficient is remarkably stable. All of this evidence suggests that, if the policy variable is the rate of growth of M2, the policy ineffectiveness hypothesis is not in evidence. The structure of the model and values of parameters have been very stable despite changes in the policy rule used by the Federal Reserve, the deregulation of financial markets and the high mobility of international capital.

WHY THERE IS NO DIRECT RELATION BETWEEN MONEY GROWTH AND THE RATE OF INFLATION

On the basis of the theoretical and empirical analysis, we may explain why Figure 2 shows no relation between the current rate of inflation and the current or lagged rate of money growth. From equations 10 and 11, we derive a phase diagram, Figure 8. From these equations and the coefficient estimates in Table 2 (rounded) columns one and two, derive equations 10.1 and 11.1. The curve $d\pi = d(inflation) = 0$, which corresponds to equation (10.1), is the set of unemployment rates $u(t) = U(t) - Ue$ and inflation rates $\pi(t)$, such that inflation is not changing. The curve $du = d(unemp) = 0$ is the set of unemployment and inflation rates, such that the unemployment rate is not changing; and it corresponds to equation 11.1.

$$(10.1)\quad d(inflation) = \pi(t) - \pi(t-1) = -0.2[\pi(t-1) - \mu(t-1)] - 0.4u(t-1) = 0$$

$$(11.1)\quad d(unemp) = u(t) - u(t-1) = 0.25[\pi(t-1) - \mu(t-1)] - 0.3u(t-1) = 0$$

Let the rate of money growth (relative to capacity output) be m. Point $(m,0)$ in Figure 8 is the steady state: where the unemployment rate $u = U - Ue$ is zero, and where inflation is equal to money growth (relative to capacity growth). The curve $d(inflation) = 0$ is downward sloping for the following reason. When inflation is below m, there is a rise in real balances, which raises excess aggregate demand and hence the rate of inflation. To keep inflation from changing, there must be a rise in u which reduces the cost-push element. The $d(inflation) = 0$ is negatively sloped, and the directions of horizontal motion are towards the curve $d(inflation) = 0$.

The curve $d(unemp) = 0$ is positively sloped for the following reason. Suppose that the

[18]These results are inconsistent with the New Classical Economics, but are consistent with basic monetarist (Friedman) views. Notice that we only work with measurable variables and do not use arbitrary and subjective estimates of anticipated or nonanticipated money growth. Belongia points out that the measure of unanticipated money growth is very sensitive to the monetary aggregate considered (as well as to what are the regressors in the equation for anticipated money growth).

[19]There is no evidence of serial correlation. The probability of the F-statistic that all of the coefficients are zero is 0.00, the adjusted $R\text{-}square = 0.76$; $DW = 2.0$; ARCH (2 lags) $prob = 0.16$ indicates that there is no problem with heteroskedasticity and using the Ramsey RESET test, we do not find any evidence of misspecification.

Figure 6

Dynamic Ex Ante Forecast of the Unemployment Rate, Using Lagged M2 Growth as the Input (Equation 11)

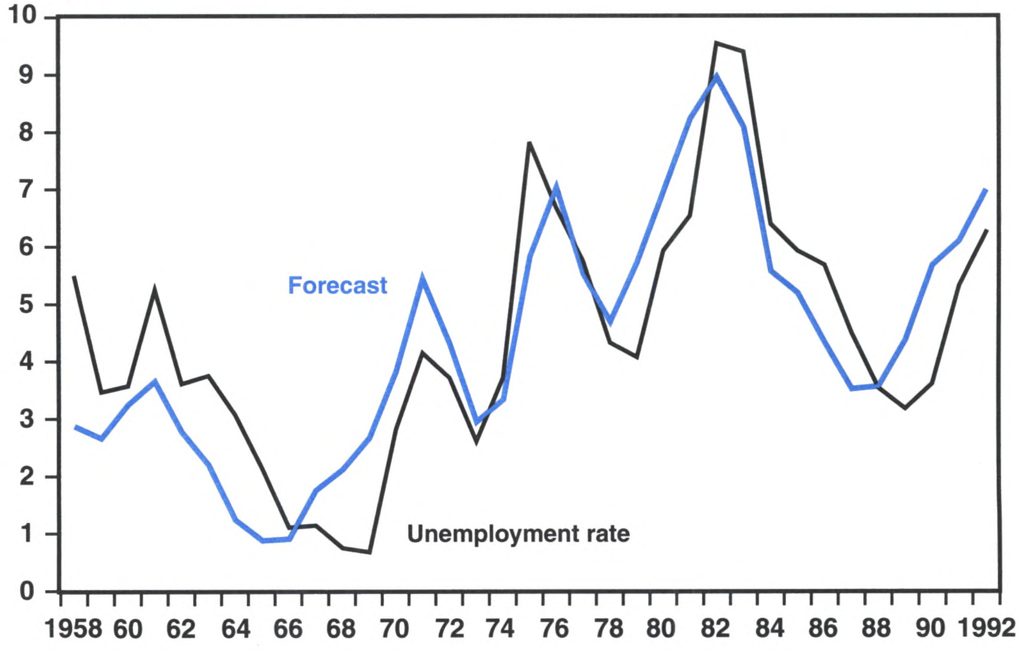


Figure 7

Recursive Estimate of the Coefficient of Lagged M2 Growth in Equation 11

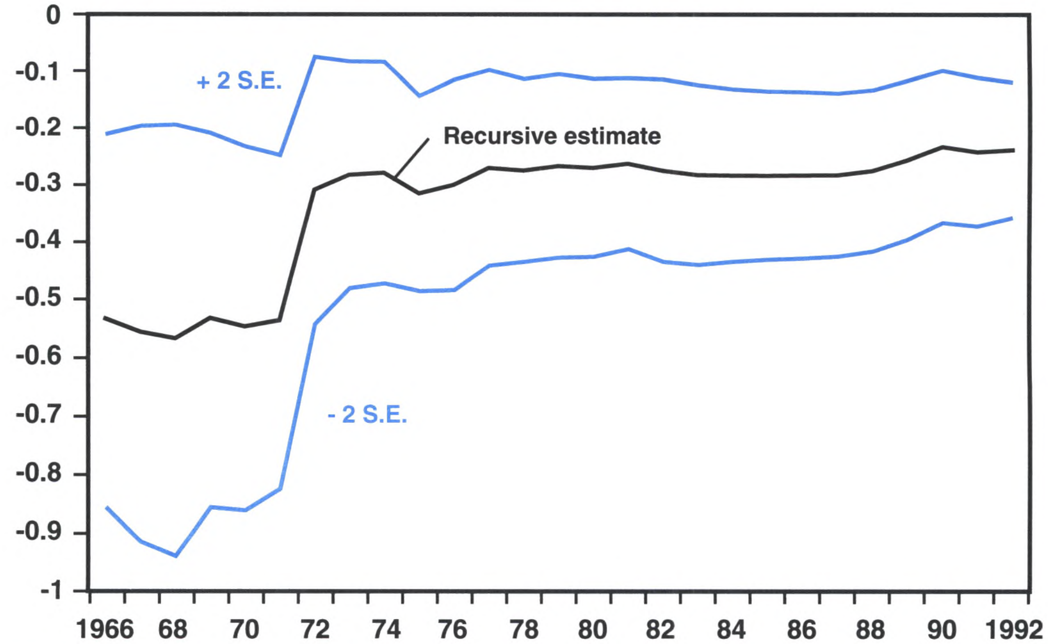
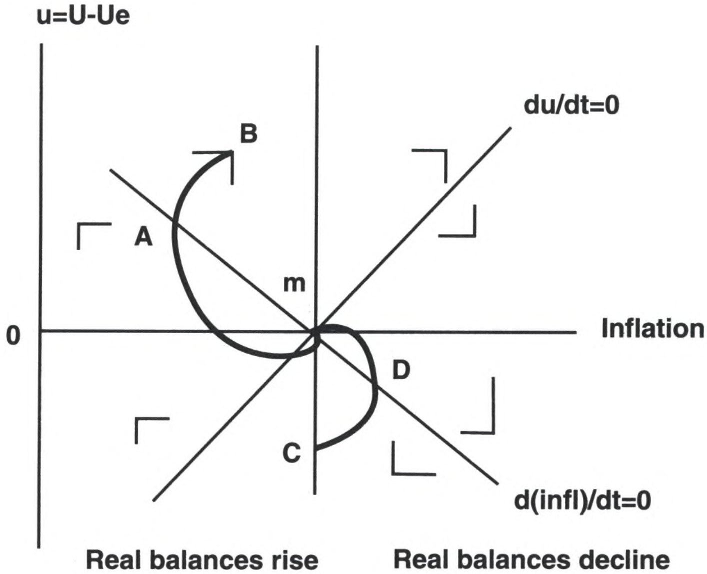


Figure 8
Phase Diagram



Note: Steady state is point (m,0), where m is growth of M2 less long-term growth of the economy.

economy were at point *m* and then the unemployment rate rose *(u > 0)*. The rise in unemployment reduces the growth of nominal labor costs and real unit labor costs tend to decline. This will cause unemployment to decline. To keep *u* from changing, aggregate demand must decline. A rise in inflation above *m* will reduce real balances which reduces aggregate demand. Therefore, the *d(unemployment) = 0* curve is positively sloped. The vertical movement will be towards this curve, because above (below) it wages are growing at a smaller (greater) rate than prices.

With the phase diagram, we may answer two questions:

(1) Why do we find, as in Figure 2, no relation between current or lagged money growth and current inflation?

(2) Will a rise in the rate of monetary expansion, designed to stimulate the economy, lead to higher inflation in the near future?

The answer to these questions depends upon where the economy is situated in Figure 8. There are two variables:

(1) What is the deviation between the rate of inflation and the rate of monetary expansion? Where is the economy along the abscissa?

(2) What is the deviation between the unemployment rate and its equilibrium value? Where is the economy along the ordinate?

From any point, the system will converge to point *m*, where the unemployment rate is at its equilibrium value, and the rate of inflation is equal to the rate of money growth (relative to the trend rate of growth of the economy). The trajectories vary with the initial conditions. Given the estimates of the coefficients in 10.1 and 11.1, the system will be damped cyclical.[20]

Consider two cases where money growth is *m*, but the initial conditions vary. We can explain why there is no relation between money growth and inflation in Figure 2. Suppose that, when the unemployment rate is above the equilibrium, an expansionary monetary policy is undertaken to accelerate the return to "full employment." The rate of monetary growth is raised above the inflation rate. The economy starts at point *B*.

[20]The characteristic equation implied by 10.1 and 11.1 is $\lambda^2 + .5\lambda + .16 = 0$. The roots are complex, but the system is stable.

The trajectory will be *BAm.* Initially, along *BA,* both the inflation rate and unemployment rate decline. The weakness in the labor market more than offsets the effect of a rise in real balances upon aggregate demand, and the inflation rate declines. Wages decline relative to prices, and unemployment declines. Along *BA,* a rise in the rate of monetary expansion does not lead to more inflation. When the economy reaches point *A,* the lower unemployment rate implies that the weakness in the labor market is insufficient to offset the effect of a rise in real balances upon aggregate demand, and the inflation rate rises. Prices continue to rise relative to wages, and unemployment continues to decline. Along *Am,* the inflation rate rises though the unemployment rate is above its equilibrium level.[21] Along trajectory *BAm,* the inflation rate declines and then rises for the same rate of money growth.

Similarly, suppose that the economy started at point *C,* where inflation is equal to money growth, but unemployment is below the equilibrium rate. Nominal wages will rise which will raise the rate of inflation. Wages will rise faster than prices, and the rise in real unit labor costs will increase unemployment. The economy moves along *CD.* At point *D,* the rate of decline of real balances lowers aggregate demand and offsets the wage-push effect. The rate of inflation declines, wages continue to grow faster than prices and the unemployment rate continues to rise. Along trajectory *CDm,* the inflation rate rises and then declines for the same rate of money growth.

We have explained why the rate of money growth is a good indicator of the rate of inflation only within the context of the dynamic system, equations 10 and 11, where inflation and unemployment interact. No useful information about the rate of inflation is conveyed just by looking at the rate of monetary expansion per se as in Figure 2. If the rate of monetary expansion is raised to speed a recovery, this need not imply more inflation in the near future. The exact trajectories for inflation and unemployment implied by equations 10 and 11, in Table 2, columns one and two, are easily calculated.

THE USE OF WEIGHTED MONETARY AGGREGATES[22]

Several economists have argued that we know that the standard measures of monetary aggregates violate the basic principles of the economic theory of index numbers, because simple-sum measures incorrectly assume that the components are perfect substitutes and, hence, cannot internalize pure substitution effects. Belongia stated that "The potential for this sort of [substitution] shift in measured money, of course, is exactly the type of thing that may be behind the break in velocity and instability of money demand functions." The contention of Belongia, Chrystal and MacDonald (this *Review*) is that ostensible changes in the relationships between money growth and inflation observed in the 1980s, which have been subjectively attributed to "financial innovations" are simply due to improper measurements of the monetary aggregate. Instead of using ad-hoc, arbitrary measures of the "true" monetary aggregate, WMA have been constructed to internalize shifts among monetary aggregates based upon substitution effects. These are basically Divisia indices, by which the components of the WMA are weighed by their share of total expenditure on monetary services.[23]

Their contention is not obvious. Figure 2e, graphs (along with the regression line) the rate of inflation against the growth of Divisia M2. There is no apparent relation between the two variables. Figure 3b plots the velocity of Divisia M2 (nominal GDP divided by Divisia M2). The relation does not demonstrate any more stability than the velocities of M1 or M2 (Figure 3a).

[21] This differs from the Keynesian NIRU view. See Modigliani and Papademos (1975, 1976). For a critique, see Carlson (1978) and Stein (1982, ch. 4). The analysis differs fundamentally from the New Classical propositions. Neither view is consistent with the results in Table 2.

[22] The importance of Divisia indices has been developed by Barnett. I am drawing upon Belongia (1993a,b) in the discussion of weighted monetary aggregates (WMA), who supplied me with the data to use as WMA in the SM dynamic model.

[23] A WMA is constructed as follows (See Belongia). Let $u_i(t)=[R(t)-r_i(t)] / [1 + R(t)]$, where R(t) is the return on a long term grade B corporate bond, $r_i(t)$ is the asset's own rate of return. Denote the vector of the u's by $u=(u_1,...,u_n)$, and the vector of the value of balances in the *i-th* asset category by $q=(q_1, ...,q_n)$. The weight $s_i(t)$ of the *i-th* asset is (b) $s_i(t) = u_i(t)q_i(t)/u(t).q(t)$, where the denominator is an inner product. The weighted monetary aggregate WMA is (c) WMA(t)=s(t).q(t). The period denotes the inner product operation.

We examine the hypothesis that the WMA are the correct empirical counterparts of what is meant by money in the theory in the second section[24]:

(1) The money should have the neutrality properties, noted alongside equations (10) and (11) above. A rise in the rate of monetary expansion should produce the same rise in the steady state rate of inflation. Equal changes in money growth and inflation should have no effect upon the unemployment rate.

(2) The WMA should satisfy the requirements for an indicator for both inflation and unemployment. It should be able to explain variations in the rate of inflation and how monetary policy exerts short-run changes upon the unemployment rate. Specifically: Given information in year $(t-1)$, to what extent can the WMA be used to predict inflation and unemployment in year t? The WMA have the desirable property that they are not arbitrary measures of "moneyness." They have the limitation that their weights, which are interest rate differentials, are endogenous variables. When a monetary component is changed, the interest rate differentials change. Since the weights in the index change with the endogenous interest rates, the WMA is not a control variable and cannot be considered as an intermediate target.

We already analyzed M2 as an indicator in Table 2 for the sample period 1958-92. Table 3 compares three weighted monetary aggregates with M2 during the same sample period 1961-92, in terms of equations 10 and 11. The three WMA are used: *DM2 = Divisia M2; CE = Rotemberg's currency equivalent; DCE = Divisia currency equivalent.* In each case $\mu_i(t)$ is the rate of growth (percent per annum) of the aggregate. Our object is to see how each responds to points 1 and 2 above. Our conclusions, to be discussed, are:

(1) The M2 aggregate is the best of the potential indicators.

(2) The Divisia currency equivalent DCE is acceptable.

(3) The Divisia M2 (DM2) and the Currency Equivalent (CE) are unsatisfactory.

The upper part of Table 3 is inflation equation 10, and the lower part is unemployment rate equation 11. The entries are the regression coefficients and the two-tail significance levels in brackets. We also note the adjusted R-square and the probability implied by the LM statistic that there is no serial correlation.

Consider the successes. First is M2 in column one. In the inflation equation, the sum of the coefficients of lagged inflation and lagged M2 growth (0.87 + 0.18) is not significiantly different from unity. Each coefficient is significant. In the unemployment equation, each coefficient is significant. The sum of the coefficients of lagged inflation and lagged M2 growth (0.28 – 0.22) is not significantly different from zero. Second is the Divisia Currency Equivalent (DCE), which also passes these tests. However, the coefficients in the M2 equation are closer to their theoretical values than those in the DCE. The coefficients of lagged inflation and money growth should be equal and opposite in sign.

Next are the failures. The Divisia M2 (DM2) fails in the inflation equation. The coefficient of its growth μ is not significant. The currency equivalent (CE) fails in the unemployment rate equation. The coefficient of its growth μ is not significant. My conclusion is that M2 is the best of the indicators when it is used in the dynamic SM model, in which both unemployment and inflation interact.

A cogent analysis of the deficiency of Divisia indices of money has been given by Otmar Issing of the Deutsche Bundesbank (1992, p. 296). He wrote:

> "In phases with an interest rate pattern in which the yield on time deposits is almost that on the yield on public bonds outstanding, time deposits to all intents and purposes disappear from the definition of the money stock (CE aggregates) or hardly contribute at all to money stock growth (Divisia Aggregates). Should time deposit rates exceed the yield on bonds outstanding, then this leads to either negative growth of these aggregates or the changed maximum interest rate is taken into consideration so that monetary capital components possibly contribute to growth in the money stock. The reason here is that — based on a utility maximization approach — liquidity is measured in

[24] It is essential that one have a macroeconomic theory to evaluate whether an empirical measure of money corresponds to a theoretical concept. Barnett, Belongia and others correctly object to the ad hoc measures of "moneyness" that have been offered to replace M2. Many of these measures even fail to satisfy the neutrality requirement.

Table 3
Inflation and Unemployment Equations Using Alternative Measures of Money

Variable	Growth rate of the monetary aggregate i: i=M2		i=DM2		i=DCE		i=CE	
Inflation equation 13								
Constant	1.88	[0.03]	2.15	[0.02]	2.44	[0.00]	1.78	[0.05]
U(t−1)	−0.44	[0.00]	−0.39	[0.01]	−0.46	[0.00]	−0.19	[0.21]
π(t−1)	0.87	[0.00]	0.90	[0.00]	0.97	[0.00]	0.85	[0.00]
μ_i(t−1)	0.18	[0.045]	0.13	[0.12]	0.10	[0.07]	0.027	[0.06]
ADJ-RSQ	0.79		0.76		0.78		0.78	
LM-prob	0.14		0.07		0.17		0.12	
Unemployment equation 14								
Constant	1.60	[0.00]	1.19	[0.04]	0.92	[0.10]	0.84	[0.23]
U(t−1)	0.81	[0.00]	0.75	[0.00]	0.80	[0.00]	0.68	[0.00]
π(t−1)	0.28	[0.00]	0.26	[0.00]	0.18	[0.00]	0.24	[0.00]
μ_i(t−1)	−0.22	[0.00]	−0.15	[0.007]	−0.10	[0.008]	0.001	[0.92]
ADJ-RSQ	0.82		0.81		0.78		0.71	
LM-prob	0.80		0.76		0.75		0.65	

Notes: The sample covers 1961-92. N = 32. The two-tail significance level is shown in brackets. The data are from the Federal Reserve Bank of St. Louis. DM2 = Divisia M2; DCE = Divisia currency equivalent; CE = currency equivalent.

terms of forfeited yields, while the dimension of risk — contrary to the portfolio optimization approach — is not taken into account. The interest rate for a particular form of investment not only contains a premium for foregoing liquidity but also a risk premium owing to yield volatility. As empirical studies show, in particular the CE-M3 aggregate has in the past been subject to extreme fluctuations and the correlation with growth rates of GNP was in fact negative. Furthermore, the velocity of circulation of this aggregate was substantially more instable (sic) than that of M3."

The Divisia M2 is too much dependent upon endogenous weights, which are interest rate differentials, to be useful as an indicator of a theoretical concept of money. It misses the unique aspect of money that it is the safe asset used as the medium of exchange.

The Controllability of Money Growth

We have shown that growth of M2, denoted μ_2, is a good indicator. There are two distinct issues: To what extent is money growth endogenous? To what extent is money growth controllable? In equation 14, part CX is endogenous, X is a vector of the state of the economy and z is the growth of reserves.[25] Unless variations in μ are controllable, they are not responsible for variations in inflation and unemployment; and the central bank does not have the wherewithal to control inflation in the medium run.[26]

(14) $\mu_2 = CX + bz + e$

We can relate total reserves R to $M2$. There is a close relationship between reserves R and M1, through a system of reserve requirements. Call the reserve requirement ratio $R/M1 = a$. We can then write:

$$R/M2 = (R/M1)\ (M1/M2) = a\ (M1/M2)$$

and therefore,

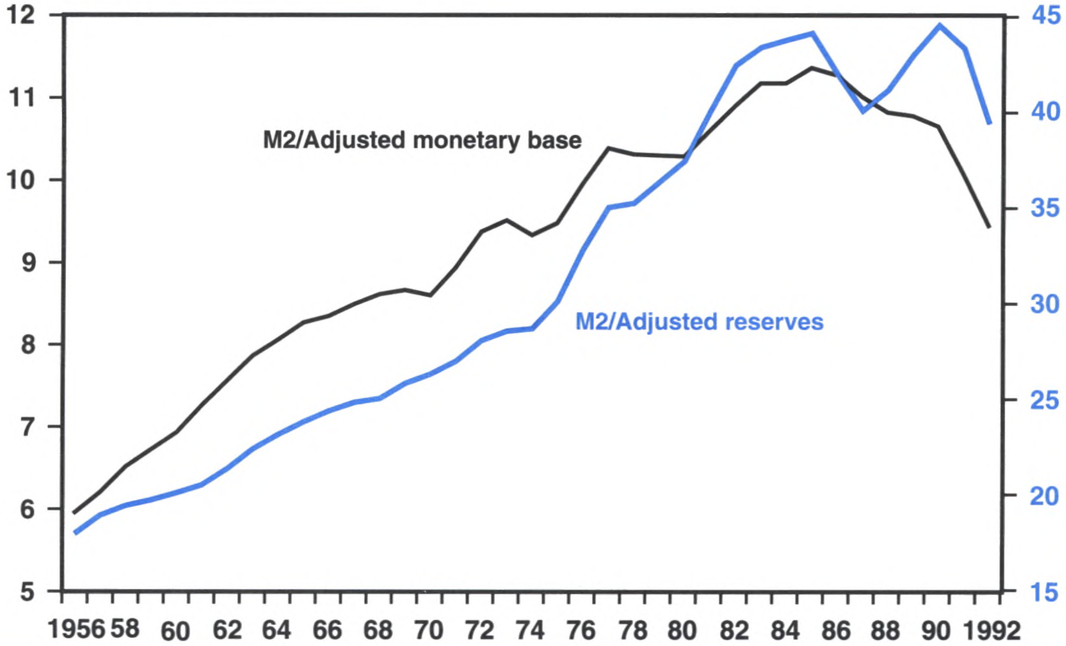
$$\log M2 = \log (M2/M1) + \log R - \log a.$$

[25]For notational simplicity, let *e* generically represent the random variable with a zero expectation.

[26]In the long run, as Figure 1 indicates, the price level is still closely tied to M2/real GDP.

Figure 9

Ratios of M2 to the Adjusted Monetary Base and Adjusted Reserves



The rate of change of *Mi* (i=1, 2) is denoted μ_i and the growth of reserves is denoted z. Thus, we have equation 15, which we relate to equation 14:

(15) $\mu_2 = (\mu_2 - \mu_1) + z + e$

(14) $\mu_2 = CX + bz + e$

The growth of M2 in equation 15 has three components: the growth in adjusted reserves z, which is controllable; the growth in the non-M1 component of M2, which is $(\mu_2 - \mu_1)$; and the e term, which reflects nonsystematic factors.[27] Thornton noted several points. First, the Fed has a tight control on $M1 = R/a$ via reserves. Second, the ratio of M1 to M2 declined from 0.5 in 1959 to 0.25 in 1977, and has then fluctuated around this level. Third, the policy variable, which is the growth of reserves, does not have a significant effect upon $(\mu_2 - \mu_1)$. The Fed can control only the M1 component of M2 but cannot control the other component $(\mu_2 - \mu_1)$ directly. For example, suppose that a rise in fiscal policy or private demand tends to raise the growth of nominal GDP, which induces a growth in the demand for money. The given growth of reserves controls the growth of M1. There will be a growth in M2 relative to M1 to accommodate the induced rise in the demand for money. This means that $CX=(\mu_2 - \mu_1)$ is endogenous; and it may well be the major source of variation of the rate of money growth in equation 15.

Figure 9 suggests that there has been a structural break in the controllability of the growth of M2. The graph is the ratio of M2 to adjusted reserves. It has a relatively constant positive trend until 1975. The trend rises drastically to about 1984. Then it falls to zero or becomes negative. A similar situation exists with the ratio of M2 to the adjusted monetary base. We shall now be more precise.

We consider two components of money growth in equation 16 which correspond to 14 and 15.

(16) $\mu_2 = c' \, DNGDP(-1) + bz + e$

The control part is the controllable growth of reserves. The induced part is related to the lagged growth of nominal GDP, denoted

[27]The controllability of M2 is the subject of the important paper by Thornton (1992), upon which we draw.

Table 4

The Rate of Growth of M2 as a Function of the Lagged Growth of Nominal GDP and the Growth of Adjusted Reserves (Equation 16)

Variable	1958-92	1958-75	1975-92
Constant	3.60 [0.02]	3.40 [0.01]	2.10 [0.45]
DNGDP(−1)	0.31 [0.05]	−0.04 [0.71]	0.56 [0.04]
z	0.27 [0.06]	0.90 [0.00]	0.17 [0.39]
DW	1.10	1.69	1.10
ADJ R-SQ	0.12	0.64	0.14

Note: The two-tail significance level is shown in brackets.

DNGDP (−1).[28] The induced part corresponds to *CX* in equation 14. That means that if the omitted fiscal variables and shocks to private demand induce a rise in the demand for money, the growth of M2 will respond, although the growth of M1 is tied to the growth of reserves.

There are several implications from Table 4, which are consistent with Thornton's findings.[29] First, consider column two, which concerns the early period 1958–75. The growth of reserves is the significant determinant of the growth of M2, with a coefficient 0.9, which is not significantly different from unity. The growth of lagged nominal GDP is not significant.[30] A regression of μ_2 on z and a constant gives almost the identical results, during the first period. Hence one could confidently claim that $\mu_2 = c + z + e$, where c is a trend which corresponds to the growth of M2/M1. The money supply was both controllable and the controllable part was the dominant component. Hence from 1958 to 1975, the growth of M2 was an intermediate target for both the inflation and unemployment rates. This is "Monetarism Triumphant."

Second, consider column one containing the entire period 1958-92. It would seem that both the growth of reserves and the growth of nominal GDP are significant. However, the equation evaluation tests tell a different story. The recursive residuals (not shown) keep moving outside the plus-or-minus-2 standard error bands, which implies that the structure is progressively changing. Figure 10 is a recursive estimate of the coefficient of the growth of reserves. This coefficient has a clear downward trend from unity towards zero, indicating that the control part is becoming less significant since the mid-1970s. The reason is shown in column three containing the period 1975-92. This column is a direct contrast to column two, the 1958-75 period. The growth of reserves is not significant. The lagged growth of nominal GDP is significant. However, the regressors only explain 14 percent of the variation in the growth of M2. During the period 1975-92, it is not apparent that the growth of M2 was an intermediate target.

THE INTERMEDIATE TARGET SYSTEM

It is quite possible that we have omitted significant variables from the induced part CX of money growth, so that it seems that money growth is no longer controllable by the growth

[28]The lag is used to avoid a simultaneous equation problem. We also used for the induced part the Treasury bill and Treasury bond rates, which could reflect changes in the structure of interest rates, which would ultimately induce substitutions between M1 and M2. However, they were not significant additions to the growth of reserves.

[29]Similar results were obtained when the regressors were the lagged unemployment and inflation rates.

[30]The equation for this period passes all of the equation evaluation tests: There is no serial correlation (LM test), heteroskedasticity (ARCH test).

Figure 10

Recursive Estimate of the Coefficient of the Reserves Growth in Equation 16

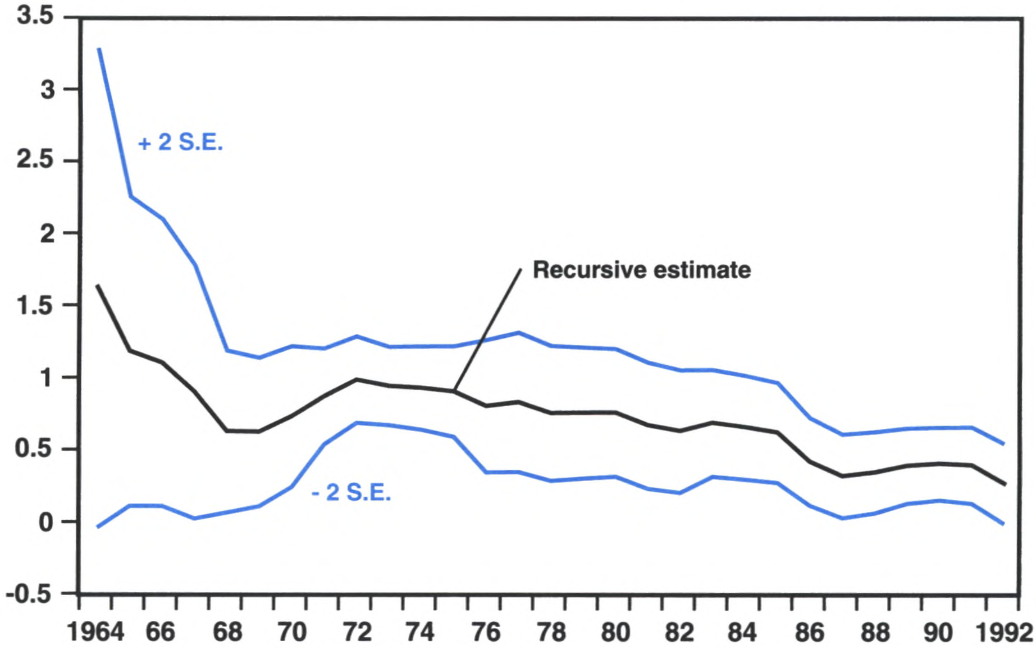


Figure 11

Dynamic Ex Ante Forecast of Inflation, Using Lagged Resources Growth as Input (Equation 12)

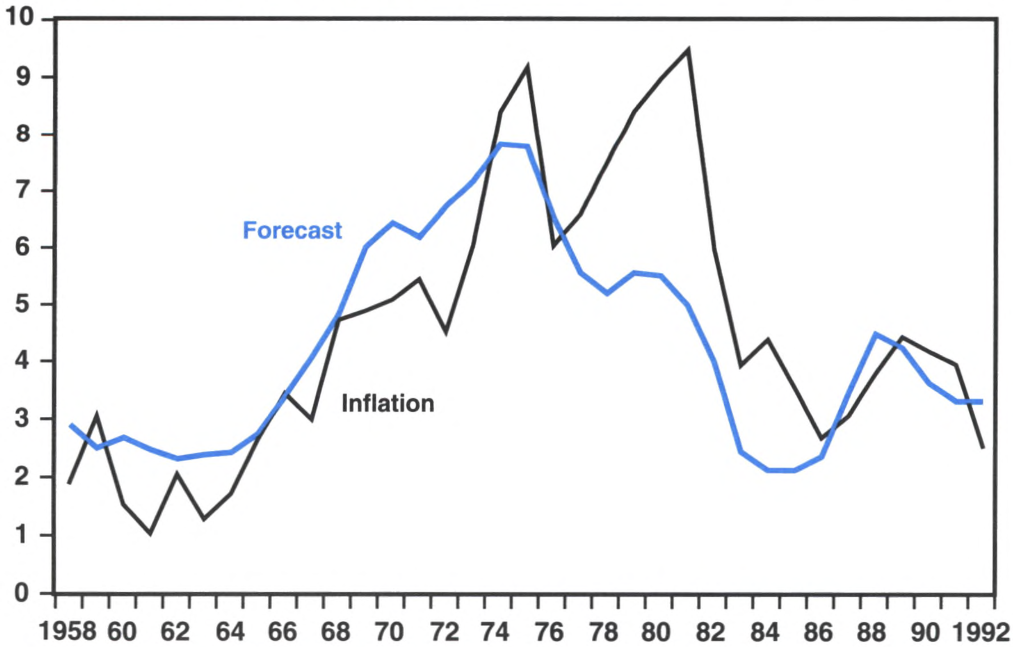
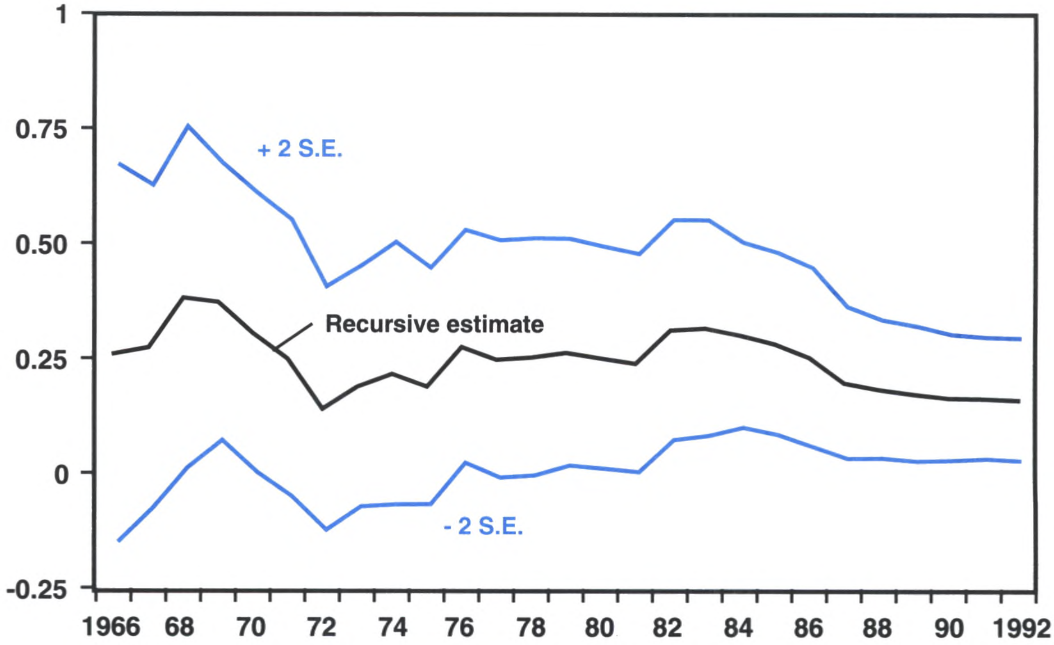


Figure 12

Recursive Estimate of the Coefficient of Lagged Reserves Growth in Equation 12



of reserves. The control equations involving the growth of reserves were described in the second flow chart, shown here again:

$$X <\text{---}\ DX = (A+BC)X + (Bb)z + (Be''+e^1) <\text{-----------}z$$

intermediate target *control variable*

A direct test of controllability is equations 12 and 13, in the surrogate system, estimated in Table 2, columns three and four:

$$(12)\ \pi(t) = b_0' + b_1'U(t-1) + b_2'p(t-1) + b_3'\,z(t-1)+e;$$
$$H_0\!: b_2' + b_3' = 1;\ b_1' < 0$$

$$(13)\ U(t) = a_0' + a_1'U(t-1) + a_2'\pi(t-1) + a_3'\,z(t-1)+e;$$
$$H_0\!: a_2' + a_3' = 0;\ a_3' < 0$$

Call this the control system. The next two sections show that the controllable growth of reserves may be a good intermediate target for the rate of inflation. The subsequent section shows that the short-term Treasury bill rate, which may be controllable, has no informational content; it is neither an indicator nor an intermediate target. Interest rate targeting, which has had disastrous results both in the Great Depression and the pre-1979 periods, is to be avoided at all costs.

The Growth of Adjusted Reserves Is An Intermediate Target[31]

In the control system, the control input is z the growth of adjusted reserves. This variable is

[31]We did not use the growth of the adjusted monetary base as the control variable for two reasons. First, it failed to satisfy the neutrality requirement. Second, it is not a reliable control over the growth of M1 due to the significant variations in the currency ratio. See Garfinkel and Thornton.

clearly controllable.[32] We evaluate whether the control system is structurally stable and policy-rule-invariant, when there have been changes in Federal Reserve operating procedures and policy, and financial market deregulation. Table 2, columns three and four, and the subsequent analysis show that the control system is quite significant for the inflation rate but less so for the unemployment rate.

The Inflation Equation in the SM Model with the Growth of Adjusted Reserves

The inflation equation is 12. The rate of inflation rises when (1) real reserves rise, the growth of reserves exceeds the current rate of inflation, or (2) when the labor market is tight, the unemployment rate is below its equilibrium rate. In the steady state, the rate of inflation will rise by the same amount as the rise in the growth of reserves. Real reserves converge to a constant. This is the neutrality hypothesis $b'_2 + b'_3 = 1$ in 12. The second factor states that the coefficient of the lagged unemployment rate is negative.

Table 2, column three, is consistent with these hypotheses. Each coefficient is significant and has the hypothesized sign.[33] The Adj. *R-SQ=0.78*. The neutrality hypothesis is confirmed. It is seen with a Wald test that the sum of the coefficients of the inflation and growth of reserves is not significantly different from unity: *prob* $[b'_2 + b'_3 = 1]$ = *prob* $[0.92 + 0.16 = 1] = 0.44$.

We show in several ways that this equation is structurally stable and policy-invariant. First, Figure 11 compares the actual rate of inflation with a dynamic ex ante forecast derived from Table 2, column three, denoted INFRES. The large deviations for the 1977-80 period are corrected by 1986; and the model is back on track. Second, Figure 12 displays the structural stability in a clear and dramatic way. It is a recursive estimate of coefficient b'_3 which relates the effect of a change in $z(t-1)$ the growth of reserves in year $t-1$ upon $\pi(t)$ the rate of inflation in year t, given the initial values of unemployment and inflation. This coefficient is fairly stable, despite the changes in policy regime over the period. The conclusion is that the growth of adjusted reserves is an intermediate target for achieving price stability, within the context of the dynamic equation.

The Unemployment Rate Equation with the Growth of Adjusted Reserves

The inflation equation is not sufficient to answer the question: How can the central bank achieve price stability and "promote sustainable growth?" The reason is that the inflation rate is affected by the state of the unemployment rate as well as by its past history and the growth of reserves. Attempts to reduce the rate of inflation by varying the growth of reserves will affect, in the medium run, the unemployment rate. In turn, the unemployment rate will affect the inflation rate. Another dimension to this problem concerns whether monetary policy can also affect, in the medium run, the unemployment rate, and what will be the consequences for the rate of inflation?

We turn to equation 13 in Table 2, column four, to see to what extent the growth of reserves affects the unemployment rate. Table 3, column four, is consistent with several hypotheses. First,

---

[32] We believe that the growth of reserves is controllable and has not been an endogenous variable, even in the 1979–82 period when there was fairly explicit interest rate targeting. If the growth of reserves were endogenous, then it should be responding to the growth of nominal GDP and the value of the Treasury bill rate. A rise in the growth of nominal GDP, given the Treasury bill rate, should increase the demand for reserves and induce a greater supply. Similarly, given the growth of nominal GDP, a decline in the Treasury bill rate should induce a decline in the growth of reserves to force the treasury bill rate up to a desired level. We examined the issue of whether the growth of reserves *(DRES=z)* has been an endogenous variable by regressing it upon the lagged growth of nominal GDP *[DNGDP(–1)]* and the lagged Treasury bill rate *[TB3(–1)]*, to avoid a simultaneous equation problem. The sample period is 1959–92. The dummy variable (DUM) was set at *DUM=1* during the 1979–82 period, and *DUM=0* otherwise. We constructed two variables, *DUM*DNGDP* and *DUM*TB3*, to highlight the short period of interest rate targeting. The regression equation was

(14) *DRES* = *5.13* –*0.257 DNGDP(–1)* + *0.40TB3(–1)*
(t-stat) *(2.7)* *(–1.09)* *(1.3)*

*-0.48*DUM*DNGDP(–1)* + *0.118DUM*TB3(–1)*
(–0.77) *(0.22)*

ADJ R-squared = *0.00.* No coefficient is significant and there is no evidence that the growth of reserves has been an endogenous variable in any significant way during the period 1959–92.

[33] There is no evidence of either serial correlation (LM test *prob=0.18*) or heteroskedasticity (ARCH test *prob=0.49*). The Ramsey RESET test of whether there are omitted variables, incorrect functional form or correlation between the regressors and the error term indicates that the probability that there is no specification error is 0.38.

Figure 13

Dynamic Ex Ante Forecast of the Unemployment Rate, Using Lagged Resources Growth as the Input (Equation 13)

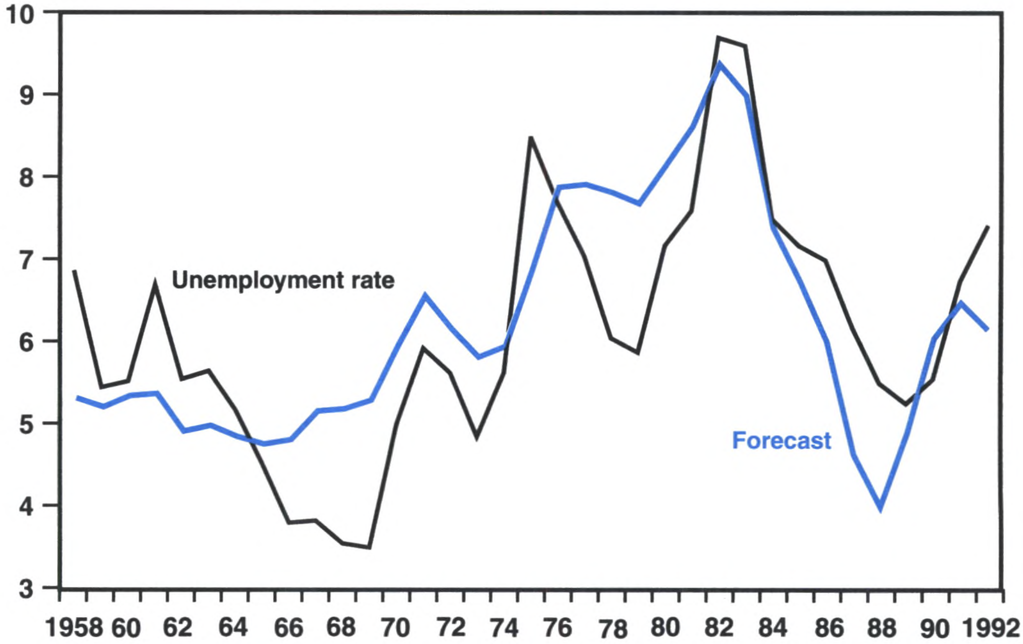
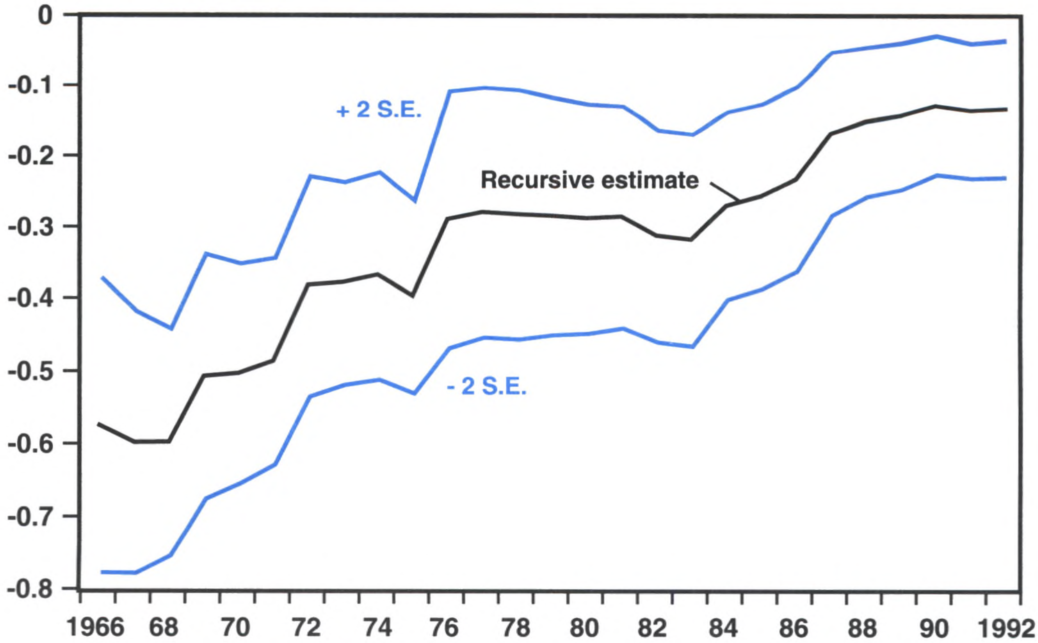


Figure 14

Recursive Estimate of the Coefficient of Lagged Reserves Growth in Equation 13



each coefficient has the correct sign and is significant at the 1 percent level; and the $R^2=0.71$.[34] Second, the neutrality hypothesis is confirmed. When reserves rise at the same rate as the rate of inflation, there is no effect upon the unemployment rate, which would then converge to its equilibrium rate. Hence, $a_2' + a_3' = 0$, that is, the coefficients of inflation and the growth of reserves sum to zero. Using a Wald test, the Prob $[a_2'+a_3'=0] = Prob[0.23 - 0.13=0] = 0.23$, thereby confirming the neutrality hypothesis.

Third, the explanatory power of this equation is much less satisfactory than the inflation equation where the input is the growth of M2. In Figure 13, the actual unemployment rate is compared with a dynamic ex ante simulation of the value implied by the coefficients in Table 2, column four, where the lagged dependent variable is the previously predicted value. The forecast predicts basic trends but gives misleading predictions of the level of the unemployment rate.

Fourth, Figure 14 plots the recursive estimate of the coefficient $a_3' < 0$ of the lagged growth of reserves. The absolute value of this coefficient has been diminishing over the sample period.[35] A possible reason for the decline in importance of the growth of reserves in the unemployment equation may be that the growth of reserves has become a less important determinant of money growth (Figure 13) in a period when the non-M1 component of M2 has become more important.

The Treasury Bill Rate is Not an Intermediate Target: It Adds No Useful Information

The Federal Reserve has revived the issue of interest rate targeting, where the Treasury bill rate is an intermediate target. Is there evidence to support interest rate targeting? The Treasury bill rate, denoted i_1, is controllable. Hence, it should be used to evaluate interest rate targeting. The surrogate dynamic SM model implied equations 12 and 13. If interest rate targeting makes any economic sense, the interest rate should be a significant input into the dynamic inflation and unemployment rate equations, either by itself $[\delta=0]$ or as additional information $[\delta=1]$ to the growth of M2, in equations (12.1) and (13.1).

$$(12.1)\ \pi(t) = c_1 + c_2U(t-1) + c_3\pi(t-1) + \delta c_4\mu(t-1) + c_5 i_1(t-1) + e$$

$$(13.1)\ U(t) = c_1' + c_2'U(t-1) + c_3'\pi(t-1) + \delta c_4'\mu(t-1) + c_5' i_1(t-1) + e'$$

Since the rate of inflation is a regressor, a rise in the nominal interest rate in the regression corresponds to a rise in the observed real rate.[36] Table 5 describes the results of such a test. Column one is the inflation equation, which just uses the Treasury bill rate as a control $[\delta = 0]$. It is seen that the coefficient of the Treasury bill rate is not significant. It contains no additional information about what will happen to inflation. Column two adds the growth of M2 as an input $[\delta = 1]$. The growth of M2 is highly significant (as it was in Table 2), and the Treasury bill rate remains insignificant. The conclusion here is that adding the Treasury bill rate adds no information about what will happen to inflation.

Columns three and four concern the unemployment rate. In column 3 $[\delta=0]$, the results are bizarre. The coefficient of the nominal interest rate is not significant at the 5 percent level, and the coefficient of inflation is not significant. Given the nominal interest rate, a rise in the rate of inflation corresponds to a decline in the real rate of interest. This should lower the unemployment rate, but it does not. Therefore, it would appear that real interest rate targeting is not promising. In column four, we add the rate of M2 growth $[\delta=1]$. The results turn sensible for everything but the Treasury bill rate, which continues to remain insignificant. The conclusion is that the Treasury bill rate at $(t-1)$ adds absolutely no information to what is obtained from the results in Table 2.

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[34]There is no evidence of serial correlation (LM test *prob=0.72*) nor of heteroskedasticity (ARCH test *prob=0.64*). According to the RESET test, there is no evidence of misspecification (RESET test *prob=0.12*).

[35]I do not have an explanation why the coefficient $a_3<0$ in Figure 9 is stable, but $a'_3<0$ is not in Figure 14.

[36]If there is real interest rate targeting, the only available information concerns observed, not anticipated, rates of inflation. It requires prescience for the monetary authority to use estimates of anticipated inflation that cannot be objectively justified. It is not clear whether the spread between the bond rate and Treasury bill rate is a more or less accurate measure of anticipated inflation than is the recent ex post inflation. In either case, the onus of finding the true ex ante real rate is upon the advocates of interest rate targeting.

Table 5

Inflation and Unemployment Rate Equations

	Equation 12.1		Equation 13.1	
Variable				
Constant	$\pi(t)$ $[\delta=0]$	$\pi(t)$ $[\delta=1]$	$U(t)$ $[\delta=0]$	$U(t)$ $[\delta=1]$
$U(t-1)$	1.99 [0.02]	1.39 [0.12]	1.27 [0.05]	1.89 [0.00]
$\pi(t-1)$	−0.24 [0.12]	−0.39 [0.018]	0.56 [0.00]	0.72 [0.00]
$i(t-1)$	0.95 [0.00]	0.858 [0.00]	0.12 [0.18]	0.226 [0.01]
$\mu(t-1)$	−0.059 [0.61]	−0.008 [0.94]	0.15 [0.07]	0.079 [0.27]
				−0.22 [0.00]

Note: Sample period is 1958-92. N=35. The two-tail significance is shown in brackets.

The Transmission Mechanism

There is a good reason why the Treasury bill rate is neither an indicator nor an intermediate target. This concerns the transmission mechanism. Aggregate investment demand depends upon the Keynes-Tobin q-ratio. Monetary policy exerts its effects upon the economy through this ratio. Keynes (1936, p. 151) explained the theory of the q-ratio: "...the daily revaluations of the stock exchange, though they are primarily made to facilitate transfers of old investments between one individual and another, inevitably exert a decisive influence on the rate of investment. For there is no sense in building up a new enterprise at a cost greater than that which a similar enterprise can be purchased; while there is an inducement to spend on a new project what may seem like an extravagent sum, if it can be floated off on the stock exchange at an immediate profit."[37]

Formally, let $q'.k$ be the market value of k the existing capital and let $p.k$ be the reproduction cost.[38] Their ratio is the q-ratio.

(17) $q = q'.k \,/\, p.k$

The portfolio balance equation 18 is that the ratio of money to the market value of capital $M/q'.k$ depends upon $L(i)$ where i is a vector of opportunity costs $i=(i_1,\ldots,i_n)$, and element i_i is the perhaps controllable Treasury bill rate. Solve equation (18) for $q=q'.k \,/\, p.k$, which is associated with portfolio balance and obtain 19. Denote $m=M/p.k$, the ratio of real balances per unit of capital.

(18) $M/q'.k \;=\; M \,/\, q\,pk \;=\; M/pk \,/\, q \;=\; L(i)$

(19) $q \;=\; [M/p.k] \,/\, L(i) \;=\; m \,/\, L(i)$

Monetary policy, which changes reserves, operates as follows in the context of equation 19. Let there be a rise in real bank reserves, which is a control variable. The higher ratio of reserves to deposits induces banks to purchase financial assets, equity or debt. The greater willingness to lend induces their customers to borrow to purchase equity and debt. The money stock rises. Given the vector of expected returns i on the n-assets, the prices of existing assets, real and financial, rise. This is a rise in the Keynes-Tobin q-ratio, the ratio of the prices of existing assets (stock prices, bond prices, physical plant), relative to their reproduction costs. This encourages the production of investment goods and raises the excess demand for goods relative to current GDP.[39] This is the logic of having m in equation 19 above: It reflects the q-ratio effect. The rise in $q=q'.k/p.k$ need not be reflected in the Treasury bill rate or in any particular interest rate. Changing the Treasury bill rate without changing the growth of M2 has a negligible effect upon the q-ratio, whereas changing the money stock has a large effect, assuming that both are controllable. Interest rate targeting of the Treasury bill rate provided a misleading indicator of what has been

[37] The role of financial markets in capital formation, along these lines, is the theme of Stein (1987, ch. 7; 1991, ch. 3).

[38] The period represents an inner product. Variables q', k and p are vectors of market prices, physical quantities and reproduction costs, respectively. Capital and bonds are in vector k and the weighted sum is $q'.k$. This is definitely in the spirit of Keynes and Tobin.

[39] This is not the textbook transmission mechanism, but it is the one stressed by Keynes, Tobin and Friedman.

happening to the *q*-ratio, or the stance of monetary policy, as was stressed by Friedman and Schwartz in their account of the Great Contraction.[40]

CONCLUSIONS

In the long run, the GDP deflator is closely related to the quantity of M2 per unit of real GDP.[41] The question examined in this paper concerns how the Federal Reserve should select ranges for monetary growth over the coming year to achieve a given rate of change in the price level in the near future. Our conclusions were stated as propositions A-D at the beginning of the paper. Friedman does not think that the inflation rate can be controlled finely:

"...we cannot predict at all accurately just what effect a particular monetary action will have on the price level and, equally important, just when it will have that effect. Attempting to control directly the price level is therefore likely to make monetary policy itself a source of economic disturbance because of false stops and starts ...Accordingly, I believe that a monetary total is the best currently available immediate guide or criterion for monetary policy—and I believe that it matters much less which particular total is chosen than that one be chosen (1969, p. 108-9)...there seems little doubt that a large change in the money supply within a relatively short period will force a change in the same direction in income and prices...But when the money changes are moderate, the other factors come into their own. If we knew enough about them and about the detailed effects of monetary changes, we might be able to counter these effects by monetary measures. But it is utopian given our present level of knowledge. There are thus definite limits to the possibility of any fine control of the general level of prices by a fine adjustment of monetary change." (p.181)

Friedman's argument should be qualified, in view of the analysis in this paper. First, the choice of the monetary aggregate does matter. No aggregate has the same quality of explanatory power as does M2, within the context of the dynamical system. Second, there is a serious question whether the growth of M2 is controllable. From 1958 to 1975, the growth of M2 was controllable. The equation for its growth was a constant (which is the trend) plus the growth of reserves plus an error. From 1975 to 1992, the link between the growth of M2 and the growth of reserves was no longer apparent.

What should be the Federal Reserve's control policy, since the link between M2 growth and reserve growth after 1975 is not apparent? We concluded that:

(1) The growth of M2 is a good indicator within the context of the dynamic model. However, it is doubtful that it is controllable in the medium run.

(2) The Federal Reserve should place greater weight upon its control of inflation, than upon the attempt to fine-tune the economy, because the inflation equation in the reduced form system has more stability and predictability than does the unemployment equation in that system.[42]

[40]One of the most vivid examples of the dangers of interest rate targeting, inspired by Friedman and Schwartz, is shown below, which compares 1929 with 1932. The data are from the U.S. Department of Commerce; the appropriate series are noted. The first row is the S&P index (B85), the second row is the implicit price deflator *P'* for fixed investment (B68), the ratio of the two is an index of the *q*-ratio. The fourth row is *i1*, the Treasury bill rate (B83). The variable *i2* is the basic yield of 30-year corporate bonds (B75). Variable *i3* is the Manhattan real estate mortgage rate (B78). The row labelled *P* is the implicit GNP deflator (B63) and *M* is the money supply (B110). The average annual rate of growth of *P* and *M* is in square brackets in the 1932 column.

The movement in the treasury bill rate was a misleading measure of the extent that the *q*-ratio changed.

The Great Depression Period

variable	1929	1932
S&P index	26.02	6.93
Price investment good	39.4	31.6
q-ratio index	0.66	0.22
treasury bill (i1)	4.42% pa	0.88% pa
30 yr corp (i2)	4.22	4.7
mortgage rate (i3)	5.92	5.75
GNP deflator P	50.6	0.2[−7.67% pa]
Money stock	26,419	20,689[−8.15% pa]

[41]See Figure 1. There is also a close long-run relation between M2 and the quantity of adjusted reserves, and, hence, a long-run relation between the GDP deflator and the ratio of adjusted reserves per unit of real GDP. These relationships look similar to Figure 14. However, none of these three relationships passes the usual cointegration tests.

[42]Hall (p. 278) wrote: "I conclude that established models are unhelpful in understanding this recession [1990–92] and probably most of its predecessors." Insofar as the growth of M2 was controllable prior to 1975, the SM dynamic model does explain the recessions. See Figure 6 above. However, after 1975 it is not clear that the growth of M2 is controllable. Hence, the good fit in Figure 6 after 1975 does not contradict Hall.

(3) Friedman's admonitions concerning fine tuning with respect to money, which is not obviously controllable, should apply to fine tuning of the reduced form system using the controllable growth of reserves. Mathematically, Friedman's argument is that given the uncertainty concerning the values of the parameters in Table 2 as reflected in their standard errors, the central bank should be most reluctant to vary its control variable in pursuing its objective of price stability lest growth be adversely affected. However, an optimal control policy in this context has not as yet been established.[43]

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[43]The reason is that the coefficients of the dynamical system — equations 11, 12 and Table 2 (columns three and four) — are stochastic, with significant standard errors which do not go to zero as the sample size increases. This problem is being studied at present by Wendell Fleming (Department of Applied Mathematics, Brown University) and the author.

Appendix
Use of Quarterly Data in Estimating the Dynamic SM Model

The results in the table below indicate why we used annual data in our empirical analysis. Inflation is measured relative to the previous quarter, but at an annual rate. The growth of M2 is measured in the same manner. The effects build up over time and quarterly movements per se have no significance.

Consider first columns one and two, which correspond to equations 10 and 11. In the inflation equation (column one) only the lagged dependent variable is significant at the 5 percent level. The lagged money growth is significant at the 8 percent level, but the equation fails to satisfy the neutrality constraint. Theoretically, in an equation such as 10, regardless of the time span, the sum of the coefficients of lagged inflation ($b_2=0.75$) and lagged money growth ($b_3=0.08$) should sum to unity. The null hypothesis that $b_2+b_3=1$ has a probability level of 0.014; hence, the neutrality (null) hypothesis is rejected. In addition, there is very serious serial correlation of the residuals. The LM statistic, using three lags, where the null is no serial correlation, has a probability of 0.00. The ARCH test rejects homoskedasticity at the 3 percent level.

Column two relates to equation 11. At first glance, the results are significant. However, there are difficulties. First, the coefficient of the lagged unemployment rate (0.98) is not significantly different from unity, and the constant is not significantly different from zero. Thus, if inflation equals money growth, the unemployment rate converges to zero. Second, there is serious serial correlation of the residuals. Using lags up to two quarters, the LM test of no serial correlation has a probability of 0.00. Third, the ARCH test of no heteroskedasticity has a probability of 0.00. So the unemployment equation in column two fails using these diagnostics. The conclusion is that we cannot have confidence in the results of columns one and two.

Columns three and four consider two lags of inflation and money growth, where time is measured in quarters. This means that a span of half a year is being considered. The main results are that nothing of significance, other than the effects of its own lagged variable, is apparent by focusing upon quarters rather than upon annual data. The only significant variables in the inflation equation (column three) are the lagged inflation rates one and two quarters. The one-quarter lagged money growth is not significant. The lagged two-quarter money growth is significant at the 8 percent level. So, nothing much shows up within two quarters. Second, in the unemployment rate equation (column four), the lagged dependent variable is significant. Inflation during the previous two quarters is not significant. The money growth in the previous quarter is not significant. However, the money growth two quarters earlier is significant. Compare Table 2 in the text with the table above. These are the reasons why we used annual data in the analysis in the paper.

Table A1
Inflation π and Unemployment U Equations (10-11)

	Equation 10	Equation 11	Equation 10	Equation 11
Variable	π	U	π	U
Constant	0.91 [0.12]	0.21 [0.12]	0.76 [0.16]	0.26 [0.04]
$U(t-1)$	−0.07 [0.50]	0.98 [0.00]	−0.15 [0.11]	0.99 [0.00]
$\pi(t-1)$	0.75 [0.00]	0.036 [0.00]	0.42 [0.00]	0.02 [0.21]
$\pi(t-2)$	——	——	0.44 [0.00]	0.03 [0.14]
$\mu(t-1)$	0.08 [0.083]	−0.032 [0.00]	0.01 [0.84]	−0.002 [0.86]
$\pi(t-2)$	——	——	0.09 [0.08]	−0.05 [0.00]

Notes: Quarterly data. M2 Growth is the input. The sample is 1956:4-1992:4 The two-tail significance is shown in brackets.

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Commentary

THE TITLE OF THE PAPER by Jerry Stein is somewhat misleading. A more accurate title would be "The Resurrection of M2 as a Monetary Indicator," or "M2 Lives; Long Live M2." The paper is really about how well the M2 aggregate functions as a monetary indicator to guide monetary policy. Because the paper provides support for M2 as a monetary indicator, Jerry concludes that the central bank can achieve price stability. I agree with Jerry that the central bank can achieve price stability, but this is not really the focus of the paper because, as I discuss later, the success of M2 as a monetary indicator is not required for a central bank to achieve the price stability objective.

THE BASIC IDEA

The basic idea behind the paper is a simple one: A monetary indicator may by itself convey little information about future inflation or unemployment—even though it is actually an excellent indicator for these variables—if the dynamic interaction between inflation and unemployment is ignored. This point may be a simple one, but it is important nonetheless because it has often been overlooked in the recent debates about whether the Federal Reserve should use M2 as a monetary indicator or target. What the model in Stein's paper shows is that dynamic interactions between inflation and unemployment imply that the effect of M2 growth on the economy depends very much on the current state of the economy. If the economy is slack with high unemployment and M2 growth rises, inflation is likely to fall at first, but then will rise in the long run. Similarly, if the economy is booming with unemployment low, a decline in M2 growth may be followed by rising inflation at first rather than falling inflation. The relationship between M2 growth and inflation may thus not be very apparent, even though there is a close relationship between M2 growth and inflation in the long run as the standard quantity theory of money predicts.

Recent research which finds that M2 is a poor monetary indicator has looked solely at the direct relationship between M2 growth and a particular economic variable such as inflation or real output. Stein's analysis indicates that this approach may be highly misleading and that, when the dynamic interactions between inflation and unemployment are taken into account, M2 comes out very well as an appropriate indicator for the monetary authorities. Stein's resurrection of M2 has advantages over other recent attempts to resurrect M2 as in Feldstein and Stock (1993). They find that M2 helps predict nominal output growth, but is not a good forecasting variable for either inflation or real output growth. It is not clear that the Feldstein-Stock finding is all that comforting to M2 advocates since we do not directly care about nominal output growth, but are more interested in its components—inflation and real output growth.

Indeed, Stein's paper may help explain why Feldstein and Stock find that M2 growth works well in forecasting nominal output growth, but does poorly in forecasting its components. When M2 growth rises, Stein's dynamic system indicates that real output rises at first but this rise does not continue, while inflation rises later. In both the short and the long run, nominal output growth is higher when M2 growth rises, and this may explain the link between M2 growth and nominal output growth that Feldstein and Stock find. On the other hand, the different response of real output growth and inflation in the short and long runs make it harder to find a link between M2 growth and real output growth and inflation.

SOME CRITICISMS

Stein's paper provides a useful perspective on how to interpret the evidence on monetary indicators and provides new evidence that M2 might have a useful role as a monetary indicator. This paper suggests that the abandonment of M2 by the Fed outlined in Alan Greenspan's recent testimony in Congress may be premature. Despite finding value in this paper, like any good discussant I have to poke some holes in its arguments and raise some criticisms.

One serious problem with the evidence in the paper is that the favorable findings for M2 growth as a monetary indicator only appear with annual data. Jerry deserves to be commended for being very forthright in indicating that M2 and his model do not fare well with the quarterly data in Appendix 2. Jerry attributes the problem with the quarterly data to the noisiness of this data. I continue to be quite disturbed, however, that the results with quarterly data are so poor. A key point of his analysis is that it focuses on dynamic interactions. When we are interested in dynamic interactions, we are particularly interested in looking at data observed at short intervals such as a quarter because data averaged over longer intervals such as a year may not reveal much about the dynamics. The disappointing results with quarterly data are thus very troubling, because this is the data that would seem to be more suited to tests of his model.

Another issue about the robustness of M2 as a monetary indicator arises when the paper uses the M2 divisia index instead of M2 in the estimated equations. In K. Alec Chrystal's paper in this volume, divisia M2 tends to outperform simple-sum M2 in the forecasting equations, and yet Stein's results with divisia M2 do not satisfy the theoretical restrictions of his model. Since there are some theoretical restrictions arguments for divisia indices over simple-sum aggregates, the lack of robustness of the results using divisia M2 is somewhat disturbing, particularly because other researchers such as Chrystal find that divisia M2 does pretty well.

I also have some problems with the paper's evidence on the poor forecasting performance of real interest rates in the dynamic model. The way the effect of real interest rates is tested is to add one lag of the nominal interest rate as an explanatory variable in the regressions, which also include one lag of the inflation rate. A rise in the lagged nominal interest rate is thus equivalent to a rise in the lagged ex-post real interest rate in these regressions. Although the coefficient on the lagged nominal interest rate therefore reflects the effect of the lagged ex-post real interest rate, it is the effect of the ex-ante real interest rate, a forward-looking variable, that is more relevant to the debate on whether real interest rates should be used as a monetary indicator. One variable that researchers have looked at that is meant to represent the effect of real interest rates is the spread between short- and long-term interest rates. The idea is that the long rate reflects expected inflation and so the short-long spread tells us something about the real short-term interest rate. The short-long spread does pretty well in forecasts of real economic activity [for example, see Hardouvelis (1991), Bernanke and Blinder (1992) and Bernanke and Mishkin (1992b)], and it might be worthwhile to look at how well it does in Stein's framework.

I also have some questions about the paper's evidence on the controllability of M2. The paper provides evidence that the coefficient on adjusted reserves in an M2 regression is not significant after 1975, thus casting doubt on the controllability of M2 in recent years. Although the conclusion that M2 is uncontrollable might be correct, I think the jury is still out on this one. Despite Stein's evidence, M2 might be more controllable than his evidence suggests because there are a lot of other factors that affect the relationship between M2 and adjusted reserves that are left out of his regression. If these factors are predictable by the monetary authorities, then the monetary authorities might be able to offset them and exercise far tighter control of M2 than Stein's regression equation suggests.

POLICY IMPLICATIONS

The paper indicates that since M2 growth works well in the dynamic model, it is a good long-run indicator for inflation. In addition, Jerry comes to the conclusion that since his inflation equation has more stability than the unemployment equation, the Federal Reserve should focus on price stability rather than unemployment as the goal of monetary policy. I strongly agree that the primary focus of central banks should be price stability rather than the business cycle. The uncertain effects of monetary policy on real output is one reason, as Jerry points out. Another important reason, however, relates to the expectations created by a particular strategy for monetary policy.

Stein's paper does not emphasize this second reason for focusing on the price stability objective because it does not make use of rational expectations. Whether you buy into it completely or not, the rational expectations revolution has taught us important lessons about the problems that face central banks who attempt to manipulate real output or unemployment. If a central bank tries to reduce business cycle fluctuations, models such as Barro and Gordon (1983) indicate that this strategy will lead to high inflation without necessarily achieving any reduction in the degree of business cycle fluctuations. The problem is that attempts to reduce business cycle fluctuations destroy the credibility of the central bank and so create expectations that high inflation will be accommodated, which results in a self-fulfilling prophecy.

This lesson from rational expectations models has had an important impact on the economics profession. Most macroeconomists take the issue of credibility very seriously when discussing monetary policy and, as a result, tend to support the view that monetary policy should focus almost exclusively on price stability. Thus, whether macroeconomists are monetarist or not, or whether they accept the evidence in Stein's paper resurrecting M2 as a monetary indicator, they tend to agree with Stein's view that price stability should be the primary goal of a central bank.

The importance of credibility and expectations about monetary policy suggests an important reason why monetary targeting might be useful for monetary policymakers. As Bernanke and Mishkin (1992a) point out, targets for growth rates of monetary aggregates might help signal the public about the long-run intentions of a central bank regarding inflation. Adherence to a monetary target may lower the public's inflation expectations, which helps keep inflation from getting out of hand. Stein's paper lends some support to the use of M2 targeting in the United States because it suggests that M2 growth is a good indicator for inflation in the long-run and, thus, can provide an appropriate signal to the public.

To finish my comments, I want to return to the issue of why I think the title of Stein's paper is misleading. Jerry's paper is not really about whether the central bank can achieve price stability. It is true that having M2 be an accurate monetary indicator makes it easier for a central bank to achieve price stability both because it provides a more accurate guide to monetary policy and because it enables the central bank to signal the public about its anti-inflationary stance. However, even if M2 or any other monetary aggregate is a poor monetary indicator, central banks can achieve price stability. Indeed, this is exactly what we have seen over the last 10 years in the United States.

The way I would characterize the Federal Reserve's strategy for the conduct of monetary policy in recent years is that it has not made much use of any specific monetary indicator. Instead, it has operated in the following manner: Whenever the economy has been getting close to full employment or inflation has risen, the Fed has stood ready to slam on the brakes by restricting reserves growth and raising interest rates until inflationary pressures subside. This strategy is not too different from nominal GDP targeting, although the weights on real output growth and inflation may not be equal as in nominal GDP targeting.

This strategy seems to work pretty well in the United States and in other countries as long as the central bank pursues the following rule-like behavior: It creates expectations that when inflationary pressures increase, it will pursue tighter monetary policy and then lives up to these expectations by actually carrying out this policy. The outcome of this policy in the United States has been a low inflation rate with very little variability. Since the success of this policy has not been based on the use of any monetary indicator, it should be clear that price stability can be achieved without it. Thus, even if we are unable to find a satisfactory monetary indicator, there is still a strong case for rule-like behavior on the part of the central bank to control inflation.

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A Conference Panel Discussion

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The Role of Rules in Monetary Policy

I WILL TRY TO ASSUME my comparative advantage on this panel and put a broader-brush perspective on monetary aggregates, intermediate targets, rules versus discretion, and the recent history of monetary policy-making. Many of my positions have been stated in various parts of several of the recent *Economic Reports of the President.*

Above all, monetary policy ought to be forward-looking. It should be rule-like, or rules-based, but not necessarily mechanical as in a Friedman or Shaw fixed money growth rule. Let me state a few propositions that support my position and which a fair reading of history would conclude are sensible even though there are persons at this conference who have argued contrary propositions over time.

The first is that high inflation, indeed even high and stable inflation, can carry substantial cost to the economy. It was not uncommon in the late 1970s and early 1980s for people to argue that if we could more or less stabilize inflation so that the variance was much smaller than it had been, a high mean of 10 or 12 percent might be far preferable to bearing the potential cost of disinflation. The cost of disinflation was viewed as inordinately high, and indeed we did have a high cost, as Rick Mishkin stated, in the recessions of 1980 and 1981-82. But that cost, according to any serious analysis, was far less than the simple models that many economists were using predicted, especially in terms of lost output. The costs were perhaps a third, and certainly less than half, in terms of lost real output than what had been predicted for the amount of disinflation engendered.

The cost of inflation stems from a variety of things but one of the most important is that the fiscal rules that determine our tax system are not invariant to the rate of inflation. While we eventually in the early '80s indexed tax brackets for inflation, we did not index the definition of income. We still have historic cost depreciation. We still have nominal capital gains tax, tax nominal interest, and allow deductions for nominal interest. It is complex, but when you are looking at investment decisions, those are important. This is part of the reason why monetary policy in the late 1970s, likely the worst episode in the post-World War II history of monetary policy, was so bad. Attention was being paid to nominal interest rates rather than, as difficult as they are to measure, expected long-run real *net-of-tax* interest rates.

The second point I would make, and will come back to, is that those who argue that indeed money does matter initially—and not just for prices but for real output—seem to have been correct. A tighter monetary policy than the Fed envisioned in the early '80s led to that costly (but not as costly as predicted) disinflation. I think that the simple monetarist propositions available at that time broke down with the collapse of M1 velocity in the early 1980s (and again with the collapse of M2 velocity in the early 1990s).

The simplistic notions of monetarists took a beating, even if the fundamental tenets were, and I think continue to be, more or less correct. Keynesian and neo-Keynesian arguments took a beating as well since writers in the econometric Keynesian tradition greatly overstated what the cost of the disinflation would be in terms of lost output. Those who focused on expectations and on credibility proved to be—and let me make sure I am careful about this—*partially* correct, in my opinion. I think they were no more fully correct than the monetarists were or than the simple Keynesians and neo-Keynesians were. All of these schools of thought contained elements of truth, but none was a sufficient descriptor of the economy or prescriber of economic policy. We have learned through the work of some people at this conference and others that some households and businesses indeed are liquidity-constrained and do respond to short-run cash flows. Hence, there is some scope for affecting the shorter term course of the economy, if and when that proves to be desirable, with discretionary policy.

Expectations certainly have been shown to matter. A large part of the reason that the last decade has been substantially better than the previous decade, in terms of macroeconomic performance and in a manner I will describe in a moment, stems from the fact the Fed has gradually built considerable credibility on reducing inflation and keeping inflation low and stable. The inflation expectations premium has been gradually abating.

The next point I would make is that the economics profession ought to be quite humble about both our ability to go from changes in monetary policy to short-run changes in nominal GDP, and from the change in nominal GDP to the changes in inflation and real output. Humility is called for in far greater magnitude than has been evidenced by most economists; that will lead me back in a moment to the proposition that I will make about nominal GDP rules.

The weight of the evidence accumulated during the recent relatively successful disinflation—first in the early '80s and later in the last few years, from double digits down to the 4 to 5 percent range and, later, from that range down to around 3 percent—suggests that after adjusting for the state of the economy the disinflation was achieved in the context of much lower unemployment and much less lost output than had been expected. Some people claim that the 1970s was just as good a decade and that despite the long expansion in the 1980s, the growth then was no higher. But the 1980s were a period when lots of inflation was taken out of the system and the previous decade was a situation in which lots of inflation was added to the system. Indeed, if you step back (and I know it is hard when you are doing technical research on a specific subject) and look at post-World War II history, we were in this horrible situation where at corresponding stages of each cycle—the midpoint, trough or peak—inflation at that point was getting higher and higher. And perhaps the most remarkable thing is that not only was inflation stabilized but that relationship was broken, hopefully for a considerable length of time, for the foreseeable future. There were many people who, circa 1980, thought we would have, as I mentioned, not only something close to a depression to get inflation down to low levels, but that inflation would then start to accelerate substantially once we got well into the next expansion.

Can we do better? My answer is yes. And I will get to that in a second. As I said earlier, the worst episode was the late 1970s and I believe that there were several fundamental mistakes. One was accommodation and, without getting into personalities, I'll just say that it seemed to me we had a Fed in the late 1970s that was really not responsible. Whatever modest impetus and modest cost-push supply-shock we had, whatever oil prices did, was a tiny fraction of the total impact on the acceleration of inflation. Some people attribute up to 3 percentage points in the 13 percent rate to the oil shock. But the inflation was basically a monetary phenomenon.

The Volcker disinflation of the late 1970s and early 1980s, if I can revert to a professor giving grades, gets a B+ or A−. It was achieved at much less cost than anticipated despite the severe recession, but also I think Rick Mishkin is right that the Fed really wasn't looking just at money as velocity was collapsing. I do believe that monetary policy, ex post, proved to be much tighter than the Fed had imagined and they did want a more gradual disinflation (that is one reason they don't get an A). Whether a more gradual disinflation could have been achieved at a lower cost is something we will never know. I give the Fed an A– for its policy in the late 1980s to try and proactively head off an incipient, building inflation. And this gets back to a point several people have made that monetary policy has to be forward-looking.

The Fed rarely gets credit when it prevents the inflation rate from going from, say, 4.5 percent to 6.5 percent, because people never see it get up to 6.5 percent and then go back down again. And so I think an A– because they probably went a little too far. While they couldn't have foreseen the oil shock or anticipate the size of the defense drawdowns and other things going on in the economy, they probably should have done better at understanding that the regulatory system of financial institutions was going to take some steam out of the economy. Whether that was desirable is another story, but I think that you can't understand monetary policy without also looking at the regulatory structure of the financial system. I would give the Fed lower marks for easing too slowly and too timidly but, to be intellectually honest, had they eased as I thought desirable—a bit more rapidly and a bit more aggressively —how much of that would have shown up in output and how much of that in slower reduction in inflation is certainly an open question.

I certainly give them much higher marks than most of the academic economics profession—Samuelson, Tobin, Solow, Feldstein, Friedman, McCracken and others. Yet, by the end of '91 or early '92, they got to about where they should be, and I think the Fed is pretty close to where it ought to be, although it probably will need to move to a less accomodative policy as 1994 progresses.

What have they been doing? At various times, the Fed has announced or listed in prime directives that they have been looking at interest rates, reserves, M1 and M2, commodity prices, exchange rates, and so on. I think it is very clear that on the Federal Open Market Committee (FOMC) people are looking at different things but that, in general, the primary concern is and has been reducing inflation. They have been somewhat opportunistic about doing that. They get concerned when it appears that inflation looks like it may accelerate or over bad news in contemporaneous data about inflation. It is an interesting issue how much information that it is conveying and its potential as a leading indicator of future inflation. They have tended to take advantage of opportunities to try to take another round out of inflation when that seems desirable. When the economy happens to be slack, they tend to try to help the economy somewhat in the short run. While there was not a lot of discussion in the last year or two about price stability, there was a lot of discussion of that as the primary goal a few years ago—they view their job as to try to keep inflation low and steady and try to avoid doing anything that leads to an unnecessarily large swing in output. I echo the lender-of-last-resort, avoid-a-financial-panic issue. They have operated under some big structural changes in the economy, including the declining fraction of credit extended by the banking system, the fact that far less of broad monetary aggregates is reserved against any more, changes in the international arena which leads to far more mobility of capital, and so on.

What I infer from all of this is that the Fed has to be a compass, not a weather vane, laying out a basic path that they are trying to achieve for their policy. I think they have done that, although at times less than clearly. In general, they have laid out a course of what they are trying to achieve that has generally been fairly reasonable, with a couple of exceptions in the last decade or so. It is a rules-based policy, not one that is a fixed rule, but one that basically lays out a policy path that is deviated from only rarely and temporarily, for contingencies that are generally well-understood by the public to be rare events. The basic rules-based framework is the proper one for monetary policy, and I think it is probably the way to understand what the Greenspan Fed has been trying to do, and perhaps the Volcker Fed up to a point as well.

A far more difficult question is what do you do about specific indicators. I personally do not believe that M2 is a sufficient intermediate indicator. I don't believe nominal GDP is either, since we still have the problem of separating out real growth and inflation. I believe the list of indicators must include more than one simple measure such as M2, or adjusted reserves, or M1. That is not necessarily a disingenuous intellectual exercise to throw the Congress off their backs, although that may be a valuable purpose. I think that there is information contained in a variety of indicators and the Fed is going to have to look at all of them.

Secondly, I believe that it is desirable for the Fed to lay out parameters, broadly speaking, despite Rick Mishkin's argument that the Bundesbank and the Swiss have often been way off in money growth targets. The Fed will continually face episodes such as we had in the early '80s and the early '90s when relationships between reserves and rates, between one or another monetary aggregate and nominal GDP, and among nominal GDP, real GDP and inflation, will be far less stable than they are at other times. Nevertheless, I do believe it is desirable for the Fed, in the context of the rules-based policy, to lay out what it is trying to achieve and how it is trying to achieve it in a world of incomplete information, rapid structural change and inaccurate data. That is not a simple task, but one the Fed has performed, by any fair evaluation, quite well for the past decade-and-a-half.

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What Is the Fed's Decision Problem?

WHAT IS THE BEST model of a piece of iron? If it is to be thrown, the best model might be a uniform mass of fixed density and shape. If it is to conduct electricity, thinking of the piece of iron as a hollow tube like a pipe that carries water, is illuminating. For purposes of studying its magnetic properties, it may be best to consider the piece of iron as a collection of rigidly located magnetic dipoles that can be aligned or not. In general, the best model depends on the use to which the model is put.

In an economic setting, the best economic model is one that helps us understand the choices made by economic agents. Unfortunately, the specific nature of the Fed's decision problem remains obscure in most discussions of Federal Reserve policy. In these remarks, I look at the Federal Reserve through the lens of decision theory. While I'm not necessarily suggesting that the Fed must or should specify an explicit objective function, I do think that decision theory is nonetheless a very useful framework for thinking about the economy, monetary aggregates and the Fed's policy role. This should be a comfortable notion for economists, virtually all of whose models are based on decision theory.

The Objective Function

Many purely political attacks on the Fed are posed in terms of the objective function. Nonetheless, its specification is a substantive issue. Focusing on the Fed's role in monetary policy, there seems to be some consensus within the Fed that there is a lexicographic preference to keep inflation down, and given low inflation, to stimulate economic growth. Separate criteria are applied to crisis management such as the injection of cash to help illiquid specialists during a crash. None of this is entirely satisfactory: Lexicographic preference for reducing inflation is certainly not the ultimate objective of the Fed, which might ultimately seek a good outcome for the economy given the complex interaction between the Fed, the Congress, the rest of government, and the rest of the economy.

In order to achieve a good outcome, part of the Fed's objective should be political survival with powers (including independence) intact. It seems that the lexicographic objective to keep inflation down is intended to do some good in the economy subject to political survival and given inherent limitations on what the government can do to help the economy. This narrow view of the Fed does not seem ideal, but is surely better than what would come under the political control that would result from any loss of the Fed's independence.

Control Variables

Although control variables include such things as reserve requirements and discount window policy, the most commonly used control variable is the open market operation. I continue to be puzzled as to why the Fed confines its open market operations to trading only once each day in a very limited set of securities, most often repurchase agreements in short-term Treasuries. At the same time, the Fed seems to be very interested in the behavior of long rates, apparently believing that movements in long rates signal changes in expectations of inflation. In other words, the Fed is trading short-term instruments while judging the success or failure of its actions, relative to maximizing its objective function, by watching long-term rates. This choice of control variable, given the objective function, seems puzzling. Since the Fed is not the only economic actor in the economy that looks to long rates to think about inflation, perhaps a better way to influence expectations of inflation is by trading long-term bonds themselves. Why doesn't the Fed trade long-term bonds? One reason often cited is, in truth, irrelevant: Operation Twist in the '60s was a bad idea imposed on the Fed from outside and it didn't work. A more serious suggestion is that the Fed may not be big enough to affect long rates or, in other words, that long-term bonds may not in fact be a feasible control variable.

The reasons why it may be infeasible for the Fed to trade enough to move long rates, however, aren't self-evident and usually are left unstated. In addition to long-term bonds, there are numerous other financial instruments such as futures and options on Treasuries that might be used as control variables. One reason for considering these instruments as control variables arises from the recent finance literature on how price pressure—the amount prices move in response to trading volume—varies across markets. Price pressure is a lot like walking down the demand curve as a monopolist: When your early trades have a big effect on price, you get a much less favorable price on subsequent trades. Most agents who take a position with respect to market interest rates want to minimize price pressure. The Fed actually may prefer the *opposite* perspective. If the Fed's motive for trading is an attempt to change expectations (say, of future inflation) without taking on too large a risky position, the Fed may want to *maximize* (not minimize) price pressure for a given level of exposure. Trading long-term instruments may be a feasible way to do so.

Constraints

What are the constraints faced by the Fed in maximizing its objective function? Almost every discussion of Fed policymaking hinges on some implicit constraint. If the Fed is, in fact, too small to move long rates, for example, then there must be some limitation to the Fed's ability to short T-bills and go long Treasury bonds or vice versa; otherwise, it seems that they surely could take positions that would move long-term rates. It should be interesting to specify explicitly such restrictions. Other constraints may arise from the Fed's charter. Does the Federal Reserve Act constrain the amount of risk the Fed is permitted to absorb? It might seem not. After all, what is interest rate risk to an agent who can always print money to satisfy a claim?

Several central banks have learned the hard way the limitations on their ability to influence foreign exchange markets. The possibility of large losses (or even profits) seems less likely in domestic markets, given the printing of money and possible deferral of paper losses. Nonetheless, given the 1993 magnitude of $16 billion returned to the Treasury by the Fed, it seems that trading gains or losses of $5 billion could cause severe political damage. If the Fed misjudges its capacity to bear risk, it can cause significant damage by being either too bold or too timid.

The Information Set

We have discussed the objective function, the controls, and the constraints. We cannot understand a decision problem without knowing the decision maker's information set. In finance, we routinely gather a great deal of information by monitoring more or less continuously the market prices of securities. Macroeconomists similarly often monitor high-frequency data such as market interest rates as indicators of expected inflation and the level of the stock market for expectations of economic activity. There are, however, many other variables that should be considered. Option prices, such as Standard & Poor's 100 index options and T-bond futures options, may be used to infer the types and amount of risk people perceive in the market. These data permit us to separate the degree of investors' *uncertainty* about the level of future inflation from investors' expectations of the *level* of inflation. This is important because it is the degree of uncertainty about inflation, not the level itself, that makes planning difficult for businesses using nominal contracts. Similarly, the stock index options measure investors' uncertainty about the overall level of future economic activity.

Other data, such as information on the money stock or unemployment, are available at an intermediate frequency. These intermediate frequency data provide some independent information beyond what is available in security prices, although how much is really an empirical question. And then there are the low-frequency time series, which are very important, such as inflation or industrial productivity.

This plethora of variables raises the difficult question: When we can't look at 16 things at once, how do we summarize the information in a way that is useful for policymaking? This is the type of question that is implicit in the choice of a monetary aggregate or any other policy indicator or target. In principle, we should not throw anything away. However, if we put too many variables in our statistical analysis, the loss of power will reduce the quality of fit, especially when some ultimate objectives such as production and inflation are available only at low frequencies. Although it seems sensible to focus on a subset of the available data, it is unclear what should be the criterion for combining data or for deciding which data to throw away and which data to retain.

This brief look at the Fed's decision problem suggests several interesting avenues for research. It would be useful to have a careful and apolitical analysis of the Fed's objectives. We should quantify the Fed's constraints on trading, base money creation, and risk-bearing. Empirically, we should have more work with high-frequency data (daily and intra-day) and more examination of the Fed's actual controls (trades) and their direct impact on markets. It would be interesting to understand better how to aggregate low- and high-frequency data. Keeping the Fed's decision problem in mind will help to guide our research toward the most important policy issues.

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Monetary Policy Without Monetary Aggregates

THE PAPERS PRESENTED at the conference represent a useful step in the ongoing search for improved ways of measuring monetary aggregates. Their basic idea, of weighting components of the aggregates by a measure of the extent to which they serve as media of exchange, should be rather appealing to anyone who views the medium-of-exchange function as the defining characteristic of money. And I don't know of any other potential defining characteristic (for example, the store-of-value function) that makes any sense. So, to repeat, I find quite promising the idea that some indices and weighted sums might do a better job than the simple-sum aggregates in measuring the quality of money.

But while this type of study seems potentially useful for the purpose of studying money demand behavior, building econometric models and judging the historical record, I am not enthusiastic about the development from the perspective of monetary targeting. The reason—as some of you will have heard me argue before—is that I believe that there is a good way of conducting monetary policy that does not rely on any targeted monetary aggregate. Instead, it uses as its target variable nominal GDP, or GNP, or domestic demand, or some such measure of aggregate nominal spending.

There are several ways of arguing that nominal GDP (or whatever) is a more appropriate target variable than any monetary aggregate. The simplest and most blatant is to just assert that it is obvious that a central bank's main job is to keep total nominal spending growing smoothly at a noninflationary rate. But one can proceed more circumspectly by arguing instead that from the perspective of hitting price level or inflation targets, on average over the next decade or so, we know with much greater accuracy what growth rate of nominal GDP will do the job than we do for M1 or M2. And even if the task of developing an improved index of money is successful, it will still be true that we will know with more accuracy what rate of growth is needed (to deliver a chosen inflation rate) for nominal GDP.

To the foregoing one might naturally respond, why not make inflation the target directly rather than indirectly? But to this there are two answers. One is that, because the price level usually responds more slowly to policy actions than does nominal GDP, a policy feedback rule is more likely to generate dynamic instability—so-called instrument instability—if it responds to target misses for the price level rather than nominal GDP. And the second argument is that generating a smoothed path for nominal GDP is likely to result in smaller fluctuations of real GDP— that is, reduced cyclical variability. (I am, of course, aware that we cannot be certain about the latter, given current knowledge, and also that it is not desirable to smooth out responses to all types of shocks. But I will stand by the statement nevertheless.)

To return to the issue concerning monetary aggregates, the only advantage that I can see for them (as targets), relative to nominal GDP, is that observations are available more often and more promptly. But we could certainly devise other measures of nominal aggregate spending that would be available more frequently and promptly. Furthermore, it is not clear that having measurements more frequently is terribly important. Over the last year or so, we have experienced quarter after quarter of rapid M1 and base growth at the same time as very slow M2 growth. These aggregates were suggesting either excessively loose or excessively tight monetary policy, depending on which one you utilized. But nominal GDP growth chugged along reasonably close to 5 percent (per annum) in almost every quarter, which is just about enough for 3 percent real growth and 2 percent inflation. So if 2 percent is the Fed's concept of "zero inflation," which seems defensible, then policy behavior has been just about right from a medium-term perspective. And the point, relative to the issue regarding the frequency and promptness of measurements, is that these various growth rates have differed in the manner described above for many months in succession.

One objection that is sometimes raised against nominal GDP targets is that they might make it appear to the public that the Fed is controlling real GDP—that it is attempting a role that is greater than is actually feasible. But I would not presume that these targets would be publicly announced. The role for targets that I have in mind is as significant inputs that the FOMC would use in making its decisions, as proposed by Taylor (1993). Announcements are much less important, I believe, than behavior.

Having appropriate targets is, of course, not the whole story; to conduct monetary policy successfully it is also necessary to have a policy feedback process—among friends I would call it a "rule"—that specifies instrument settings, that is, settings of a variable that the central bank can control directly or with great accuracy. In my own studies,[1] which have been designed to see if a simple rule would succeed in hitting nominal GNP targets with reasonable accuracy in a variety of (small) econometric models, I have usually used the St. Louis adjusted monetary base as the instrument variable. The reason for that choice is that the base's growth rate provides a nice measure of the pace at which open market purchases (or sales) are being conducted, and if the adjusted base is used the measure takes account of changes in reserve requirements as well. So it seems to be the most natural aggregate among those that are highly controllable —which the base is since it appears on the Fed's own balance sheet and so could be monitored daily (and thereby kept close to the specified values).

The other main contender for the role of the instrument variable is, of course, the federal funds rate (or some other short-term interest rate). But interest rates seem quite unattractive because a high interest rate suggests tight money from a short-term perspective but easy money from a long-term perspective. Or, as I say to my students, if a central bank wants interest rates to be lower, then it needs to raise interest rates. That strikes me as an extremely undesirable feature for an instrument variable. In addition, I have tried in my simulation work to design interest rate rules and have found that they perform much more poorly than ones with the base instrument.[2] These results, at the quarterly frequency, are not definitive but they are supportive of the belief that the base is the better instrument from a macroeconomic perspective.

Most actual central banks are, of course, extremely resistant to proposals for accurate base control, on a short-term basis, and have accordingly been rather unreceptive to such policy rule suggestions. One important reason for that resistance, I believe, is the belief that exerting short-term base control would generate more financial market instability and would also require the central bank to give up its role as the lender of last resort. But I would like now to argue against that belief.

There is a fairly well-known paper by Goodfriend and King (1988) that emphasizes that functioning as the lender of last resort does not necessarily require the provision of discount window loans; what is necessary is that the central bank makes available additional base money at times of financial crisis. And they argue that this response would come about automatically if interest rate smoothing were being practiced. Some critics have described the Goodfriend-King scheme as calling for a constant rate of base money growth during times of financial crisis,

[1]These include McCallum (1988, 1990, 1993a).

[2]See McCallum (1990, pp. 61-6; and 1993a, Section VII).

but that is an entirely incorrect description of what their argument or proposal actually is.

Consequently, in a paper that I have very recently written for a Bank of Japan conference (McCallum, 1993b), I have tried to follow up on the Goodfriend-King idea by exploring the possibility of using a nominal GNP targeting rule to generate implied quarterly settings of the monetary base, and then to combine that with a higher-frequency rule that calls for weekly adjustments of a federal funds rate instrument that are designed to achieve the specified quarterly base values. This weekly rule can be made to imply a lot of week-to-week smoothing of the funds rate and thereby automatically to provide lender-of-last-resort support to the financial system. But can it do that while simultaneously hitting the quarterly base settings with reasonable accuracy? That is clearly an empirical question whose answer depends upon the size of shocks that occur and the strength of weekly responses of the base to funds rate adjustments. But I have begun to study that question in this new paper, and the results obtained are quite encouraging.

I would like to conclude by expressing my appreciation to the St. Louis Fed's Research Department for continuing their long-running program of searching for ways to improve the conduct of monetary policy.

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