

Monetary Control and an Objective of Price Stability:
Evidence from a Neural Network

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ABSTRACT: “Inflation targeting” appears frequently in discussions of central bank objectives but the mechanics of how such a goal might be pursued remain elusive. This paper identifies two conditions – a policy instrument under direct control of the central bank and a predictable relationship between it or an intermediate target and the inflation rate – that must exist operationally and then evaluates which monetary variable(s) appear to be viable candidates for the practical implementation of an inflation targeting strategy.

KEY WORDS: Monetary policy, inflation, inflation targeting, Divisia monetary aggregates

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INTRODUCTION

The number of independent objectives policymakers can achieve is less than or equal to the number of independent policy levers at their disposal. Possessing only one policy lever - the quantity of reserves it supplies to the banking system - a central bank is thereby constrained to the pursuit of a single, independent objective at any given time. Because both economic theory and abundant empirical evidence suggest that the price level (or its rate of change) is the aggregate variable influenced most in the long run by central bank actions and their effects on the nominal quantity of money, a goal of price stability has been the basis of much recent work on issues such as the design of rules for the conduct of monetary policy or constraints on the amount of discretion that policymakers are free to exercise. The P-star model of Hallman, et al. (1991), which projected paths for inflation based on the growth rate of M2, subsequent work by Feldstein and Stock (1994), and McCallum's (1988) rule for growth rates of the monetary base represent three exercises in this vein; although the latter two focus on an objective path for nominal income, both still imply a fundamental long-run relationship between central bank actions and the aggregate price level.

A rule such as McCallum's, however, draws specific attention to an issue that often is overlooked in discussions of objectives for central bank policies: Its *instrument* of control - the monetary base - is controlled directly by the central bank's open market operations. In contrast, the P-star model, the work of Feldstein and Stock and other empirical studies of this type only offer evidence on the *leading indicator* properties of monetary variables: Because their behavior is not controlled directly by actions of the central bank, identifying a stable long-run relationship between a monetary aggregate and the price level or nominal spending establishes only a necessary, but not sufficient, condition for including any particular measure of money in discussions of monetary policy strategies.¹ Thus, McCallum aside, most discussions of which monetary aggregate (if any) might best suit a central bank's goals and

procedures have bypassed the question of whether a central bank can use its *instrument* to *control* the behavior of the monetary aggregate specified as an *intermediate target*.²

Another issue largely absent in work on monetary targeting is the influence of simple sum monetary index numbers on empirical results. These series, which still serve as the data reported and monitored by the Fed and other central banks, cannot internalize pure substitution effects as consumers shift, say, between other checkables and savings deposits within M2. As such, traditional measures of money allow the measured value of monetary service flows to change even if the value of the monetary sub-utility function is unaffected by substitutions induced by changes in relative prices. And, although the many deficiencies of simple sum aggregation were noted by Fisher (1922) seventy-five years ago and are not new to the discussion of measuring aggregated money, use of these measures persists in current empirical work.³

This persistence is puzzling because, since the late 1970s, economists have had access to alternative index number formulations grounded rigorously in the microeconomics of consumer optimization; these are the index numbers derived by Diewert (1976, 1978) and characterized as being in the “superlative” class. Of these, the Fisher-Ideal (level) and Divisia (growth rate) indexes have received the most attention in monetary work. For example, applications of Diewert's results to the specific question of monetary aggregation have been available since the early work of Barnett (1980, 1982). Moreover, results from the very beginning have revealed substantial differences between inferences drawn from these alternative indexes of money relative to those implied by work using simple sum measures.⁴ Finally, because no one has mounted a theoretical argument in defense of simple sum indexes or found a deficiency in the foundations of superlative indexes, this paper contributes additional evidence on how alternative measurements of money can affect the inferences drawn from empirical work.⁵

With these two broad issues as backdrop, this paper attempts to identify a “best” intermediate target variable for the Federal Reserve by dealing explicitly with the joint problem of which aggregate both can be controlled with some degree of precision by the central bank

and still share a close enough relationship with aggregate price movements to make it useful in pursuing a goal of price stability. Our results indicate that the problem of controlling an intermediate target's behavior is sufficiently important to raise serious questions about the viability of broad aggregates, whereas the unstable velocities of narrow simple sum measures greatly diminish the quality of their signals about future inflation. In contrast, the results suggest that narrow Divisia monetary aggregates can be controlled with accuracy by central bank actions and have stable velocities that permit close associations between their growth rates and inflation. ⁶ As such, it appears as if these indexes have the potential to be part of a strategy that uses monetary aggregates to achieve price stability.

THE EMPIRICAL PROBLEM

An intermediate target for monetary policy, as discussed above, must embody two features: It must share a close and predictable relationship with the central bank's policy objective and its behavior must be controllable by central bank actions. As such, the relevant criterion for choosing a policy variable is not simply that a variable is the central bank's policy instrument or can be controlled closely by manipulations of it. Nor is the criterion of a close and reliable relationship with the final objective of policy because movements of a variable that performs well in this role may be largely unrelated to central bank actions. ⁷ Instead, as noted in Andersen and Karnosky (1977), the choice of a variable for the implementation of monetary policy should be determined by the policy strategy's overall error - control error plus projection error - rather than an evaluation of the two criteria independently or sequentially.

For our purposes, the instrument of monetary policy is taken to be the adjusted monetary base, which consists of currency in circulation and commercial bank reserves adjusted for changes in reserve requirements. ⁸ The control relationship can be written in growth rates as:

$$(1) \quad \Delta \ln M_t = \Delta \ln m_t + \Delta \ln B_t$$

where M = a monetary aggregate, m = the money multiplier for the corresponding monetary aggregate and B = the adjusted monetary base. Subsequent *actual* movements in the

multiplier, however, will be a combination of a forecast value for its growth rate (m_t') and a forecast error (e_t); this relationship can be expressed as:

$$(2) \quad \Delta \ln m_t = m_t' + e_t$$

Inserting equation (2) into equation (1) gives a revised monetary control equation of:

$$(3) \quad \Delta \ln M_t = \Delta \ln B_t + m_t' + e_t$$

where e_t is the error in monetary control.

"Projection" errors in this type of strategy occur at its second stage and arise from differences between the actual and predicted paths for the policy's goal variable (the inflation rate or nominal spending growth). For our chosen goal of controlling the rate of inflation, we can write a projection equation of the form:

$$(4) \quad \Delta \ln P_t = \alpha + \sum_{i=1}^k \beta_i \Delta \ln M_{t-k} + u_t$$

where P is the aggregate price level, M is the fitted valued from equation (3) and u is the projection error.

Within this general framework, it is possible to evaluate the relative usefulness of two different monetary aggregates (say, M1 and M2) in the conduct of policy by conducting the following test. After choosing different measures of money to serve as the dependent variable in the control equation (3), the fitted values from these estimations can be inserted into the projection equation (4) to yield (ignoring lags for expositional ease):

$$(4a) \quad \Delta \ln P_t = \alpha_0 + \alpha_1 m_{1t}' + \Delta \ln B_t + (\alpha_{12} + u_{1t})$$

$$(4b) \quad \Delta \ln P_t = \beta_0 + \beta_1 m_{2t}' + \Delta \ln B_t + (\beta_{12} + u_{2t})$$

where m_{1t}' and m_{2t}' are, respectively, the predicted values of the growth rates of the M1 and M2 multipliers and the terms $(\alpha_{12} + u_{1t})$ and $(\beta_{12} + u_{2t})$ are the total (control plus projection) errors associated with using those aggregates to pursue this particular policy objective. The aggregate with the smaller error will be preferred to the alternative.

Although this two-step procedure is best seen as an addition to work that evaluates controllability or in-sample associations between money and some goal variable individually, it also reveals one possible way in which a McCallum-type rule could neglect useful information.

Specifically, if the central bank uses the monetary base as both its instrument and its target in pursuing a path for prices or spending, the control error will be zero. A monetary aggregate controlled *with error* still may be preferred to the base, however, if the control and projection errors have significantly negative covariances. In this case, a control error that seems to be undesirable when viewed in isolation actually can improve forecasts for the final outcomes of policy actions and reduce the magnitude of the model's total error if its movements in the opposite direction of the projection errors are sufficiently large.⁹ Indeed, the existence of significant marginal information in the multipliers of (4a) and (4b) is the only reason for advocating use of a monetary aggregate rather than the monetary base in policy strategies.¹⁰ Thus, in evaluating the monetary base against monetary aggregates within the framework of equations (4a) and (4b), the test is essentially one on the significance and sign of any such covariation between e_t and u_t .

SELECTING AMONG ALTERNATIVE MONETARY VARIABLES

Eight variables are examined here for their potential usefulness in the policy format described above. These variables are the adjusted monetary base (AMB) and seven monetary aggregates that cover varying portions of the liability side of bank balance sheets; the latter include simple sum and Divisia measures of M1, M2, and the "MZM" ("money-zero maturity," see Poole (1991)) liabilities grouping suggested by Motley (1988), and a Divisia index of the "M1 plus" savings deposit grouping identified by tests of weak separability in Swofford and Whitney (1987).¹¹ The specific categories of bank liabilities used to construct each measure are shown in table 1. Details on construction of the Divisia indexes can be found in Anderson, et al. (1997).

Among the available choices, the narrow aggregates are easier to control because they are composed primarily of demand deposits subject to reserve requirements and the Fed's policy lever is the monetary base. At the same time, the widened scope of substitution possibilities between deposits in M1 and those in broader aggregates, such as M2, have produced highly unstable behavior for the velocity of narrow aggregates and, hence, large errors in forecasts of future inflation. Conversely, many economists have argued in favor of

using broad aggregates because their observed velocities have been stable.¹² However, as reserve requirements have been eliminated on the non-M1 portion of M2 (including such things as savings and small time deposits), the behavior of the broad aggregates has borne essentially no relationship to that of the monetary base in recent years. Thus, with an expanded tension between monetary control and closeness of fit with the final goal variable, the propriety of one aggregate over another has become even more of an empirical, rather than a conceptual, issue. It also is important to note at this point that, with only a few exceptions (e.g., Stein (1994)), these joint issues have not been investigated for superlative indexes of money.

The Empirical Framework

The empirical implementation of equations (3) and (4) assumes that the adjusted monetary base can be controlled directly and without error by central bank open market operations, at least over the quarterly data interval adopted. For the ten monetary aggregates, whose behavior is influenced (rather than directly controlled) by open market operations, an equation was estimated to represent the link between money growth and the growth rate of the monetary base. This equation is the empirical counterpart of equation (3) and takes the form of:

$$(5) \quad \Delta \ln M_t = \alpha + \sum_{i=1}^p \beta_i \Delta \ln AMB_{t-i} + \sum_{k=1}^q \delta_k \Delta TB_{t-k} + u_t$$

where M_t is the candidate intermediate target, AMB is the adjusted monetary base and TB is the three-month Treasury bill rate. The intercept coefficient is an estimate of the average growth rate of the money multiplier and β_i and δ_j are distributed lag coefficients estimated over some lag lengths, p and q. Equation 5, therefore, represents a standard money multiplier model augmented by changes in the Treasury bill rate; this variable was added in light of evidence provided by Garfinkel and Thornton (1991) on the effect of changes in the T-bill rate on the money multiplier. The residuals from estimates of this equation are the control errors for the respective monetary aggregates.

The fitted values from equation 5 then were used as estimated values of money growth to be used on the right-hand-side of the inflation regression:

$$(6) \quad \Delta \ln P_t = \eta + \sum_{i=1}^r \lambda_i \Delta \ln P_{t-i} + \sum_{j=0}^s \theta_j M_{t-j}' + \omega$$

This expression for the inflation process relates the growth rate of the GDP Deflator (P_t) to its own past behavior and estimated current and past growth rates of some monetary variable. The errors from estimates of equation 6, which embody the control errors of equation 5 and the projection errors of equation 6, are the basis for the evaluation of alternative monetary variables below; the orders of the distributed lags for each equation were chosen on the basis of Akaike's final prediction error (FPE) criterion. As noted earlier, the actual growth rates of the adjusted monetary base are inserted as values for M' in equation 6 under the assumption that its behavior can be controlled without error.¹³ For the simple sum and Divisia measures of M1, M2, MZM and M1-plus, however, their estimated values from equation 5 were used when estimating equation 6. The period of estimation spans a sample of quarterly data over I/1965-IV/2000.

Neural Network Estimation

The relative performance of alternative measures of money was examined by estimating the two-equation system with an artificial neural network (ANN). This method, rather than standard econometric techniques, was chosen because attempts to develop models that forecast inflation accurately must confront all of the institutional *cum* structural shifts alluded to earlier as well as future, unknown adjustments that may appear in the underlying relationship between money and prices. As such, this type of problem requires a model of completely flexible form that not only can "learn" the properties of the historical data but, through this learning, also predict structural shifts such as the (yet unsolved) velocity puzzle of the 1980s. And although a flexible form of this type will not yield an explanation for *why* structural changes occurred, it is sufficient for forecasting only to identify an actual shift or to incorporate probabilities that a new structural shift lies somewhere in the forecast's horizon. The extent to which model flexibility contributes to forecast accuracy can be assessed by examining the relative sizes of each model's error band around the mean forecast and/or their degree of bias.

Artificial neural networks were developed as highly simplified models of the brain.⁹ Kolmogorov's theorem and recent improvements and extensions by Irie and Miyake (1988), Funahashi (1989), and Hornik, Stinchcombe and White (1989) have shown that the ANN can approximate any Borel measurable function to any degree of desired accuracy given a sufficient number of hidden nodes. In other words, an artificial neural network provides a completely flexible mapping that can approximate highly non-linear functions to any degree of desired accuracy as long as a sufficient number of hidden nodes are included in the ANN. This ability to approximate any unknown mapping provides researchers with a powerful tool that may enable them to understand better the interrelationships of explanatory variables.¹⁴

Recalling that the primary focus of this paper is *not* about the *theory* behind money-inflation causality but, rather, about the influence of measuring money on the model's outcomes, a specific structure for the ANN was chosen for its degree of flexibility. Specifically, the empirical problem is one where the same basic model and method are used for all of the estimates. Therefore, using an ANN with a greater flexibility of the functional form will highlight variations in the choice of explanatory variables as the primary cause of any improvement in forecast accuracy. Results from Dorsey, Johnson and Mayer (1994) are instructive on this point as they have shown that an ANN with four input nodes and five hidden layer nodes is able to approximate a Mackey-Glass AR(5) chaotic series function to a high degree of accuracy. Figure 1 shows a diagram of a neural network of this form, consisting of either four (model 1) or five (model 2) input nodes, six hidden nodes and one output node.

Each observation is input to the ANN at the input layer. The values for the input variables are multiplied by weights corresponding to each of the connecting lines in the figure. Thus, the input to each of the hidden nodes is the weighted sum of the inputs:

$$h_{mi} = \sum_{j=1}^4 \omega_{mj} X_{ji} - \omega_{m5}$$

The weighted sum of the inputs then is passed through the nonlinear function (the hidden node)

$$H_{mi} = \frac{1}{1 - e^{-h_{mi}}}$$

and the weighted sum of the outputs from the hidden nodes is the output of the network for that observation.

$$O_i = \sum_{m=1}^6 \gamma_m H_{mi} - \gamma_7$$

The parameters of the model (ω 's and γ 's) are selected to minimize the sum of squared errors (as in most problems of this type).

The complexity of the error surface and the tendency of hill-climbing techniques to become trapped in local optima, motivated the use of a genetic algorithm adapted by Dorsey, Johnson and Mayer (1994) to optimize the ANN.¹⁵ The genetic algorithm search procedure, first proposed by Holland (1976), works in a manner similar to natural selection. Each potential solution to the problem (a vector of the ω s and γ s) is selected randomly from the parameter space. A population of these vectors, or "strings" as they are commonly called, represents a generation. In this analysis, a generation consists of 20 vectors. Each vector of randomly-chosen values then is used with the data to compute the model's sum of squared errors. A "fitness value" then is computed for each string where the fitness value is inversely related to the sum of squared errors and thereby gives higher probabilities of replication to those solutions associated with better fits.

The next iteration of the procedure selects a new generation, with replacement, from the current generation and gives, as noted higher probabilities for any string being selected for the new generation as its fitness value rises. Once a new generation is selected, the strings are paired randomly. A corresponding point along each pair of vectors then is selected randomly, the vectors are broken at that point and the residual fragments are swapped. This is referred to as the "crossover" operation. Finally, each component of each new vector has a small probability of being selected for mutation. Should a component be mutated, then that element is replaced with a new value randomly drawn from the parameter space. Each of the new strings then is used with the data to compute the sum of squared errors and the process repeats. This process continues for a

large number of generations until the solution converges. Dorsey and Mayer (1994) compared the¹¹ genetic algorithm to a number of other global search algorithms on a wide variety of optimization problems and found that it consistently dominated all the other algorithms in its ability to obtain the global solution.

The Test Statistic

Whatever the merits of applying a flexible form estimation to the current problem, the individual results for all of the eleven, two-equation systems estimated still do not permit direct distinctions to be drawn among the competing models (measures of money). The reason is that the framework embodied in equations 5 and 6 does not nest any version of equation 6 within any of the other specifications. As such, comparisons between competing measures of money were conducted using a method for testing non-nested hypotheses, the J-test developed by Davidson and MacKinnon (1981). This procedure establishes one specification of equation 6 as the null hypothesis and then tests whether an alternative specification using another intermediate target variable adds to the explanatory power of the specification under the null hypothesis.

In particular, assume that we want to test the specification under the null (H_0)

$$\mathbf{H_0}: y = f(x, z, \beta_1) + e_t$$

against the alternative,

$$\mathbf{H_1}: y = g(w, z, \beta_2) + e_2$$

The J-test is conducted simply by estimating

$$y = (1 - \phi)f(x, z, \beta_1) + \phi g + \mu$$

where g is the vector of fitted values for y under the alternative hypothesis. The test is then whether ϕ is significantly different from zero using a conventional t-test. If the data are better fit to a model of the form $f(x, z, \beta_1)$, then ϕ should not be different from zero. Alternatively, if ϕ is different from zero, then the information from the model specified as $g(w, z, \beta_2)$ adds to the explanatory power of $f(x, z, \beta_1)$. The process is repeated by reversing the null and alternative hypotheses and repeating the same testing procedure. Such a procedure offers one of four possible outcomes: variable x contains more information than variable y ; variable y

contains more information than variable x ; each variable adds to the explanatory power of the other; or neither variable adds significantly to the information embodied in the other.¹²

RESULTS

The qualitative results of the J-tests are shown in table 2; more detailed results for the two equations of the model are shown in tables 3 and 4. The matrix cells indicate, of any-two variable comparison, which of the two performed better in equation 6; the two possible indeterminate cases are denoted "B" (both variables added explanatory power) or "N" (neither had significant explanatory power). Beginning in section A of the table, the rows and columns present results only for the adjusted monetary base and the three simple sum measures. Limiting the discussion only to these data, the matrix entries show that M1 appears to dominate all alternatives. In the specific comparison against the monetary base, reasoning discussed earlier would suggest that, despite the erratic behavior of M1 velocity in the post-innovations era, information contained in its multiplier and a sufficiently large covariance between M1's control and projection errors produce an overall policy error smaller than that produced by use of the base alone. Similar reasoning also would explain why M1 produces smaller overall errors relative to the other two simple sum aggregates. Thus, although aberrant behavior of M1's velocity (one criterion) led the Fed to abandon target ranges for it in 1987, the joint consideration of both control and projection errors shows it to be preferred to other simple sum aggregates still considered in policy discussion.

Section B of table 2 shows results for Divisia aggregates in pairwise comparisons against simple sum aggregates. Here, the results show a clear preference for a Divisia measure of the M1-plus grouping over all measures except the sum M1. Moreover, because many discussions of monetary aggregation focus on differences in the composition of bank liabilities included in the measure **or** the weighting scheme of the aggregate in isolation, these results demonstrate the importance of both questions considered jointly. That is to say, if only weighting mattered, the table should reveal distinctions between two aggregates of the same liabilities but differing only in their weights. Similarly, if only composition mattered, the results should reveal an insensitivity to choice of weights for an aggregate. The clear difference between the performance of Divisia M1-plus and other measures, however, indicates that both

weighting and composition matter to the construction of a monetary aggregate. ¹³ Also noteworthy in this portion of the table is the consistent rejection of M2 as a candidate intermediate target even though it continues to occupy a central position in discussions of monetary policy.

Finally, section C of table 2 evaluates the relative information content of the base and the four Divisia aggregates considered. Here, the choice seems to be between the base and Divisia M1-plus as both dominate all other alternatives in pairwise comparisons and both add to the other when the base or Divisia M1-plus is posited as the null. As with the results of section B, the importance of an aggregate's composition as well as the index number formulation is buttressed by finding that Divisia M1-plus adds information to other specifications whereas the Divisia aggregates of other groupings do not.

The full table thus renders three possible approaches to the conduct of monetary policy in pursuit of price stability. One is the use of simple sum M1 as an intermediate target. Although tests results support this choice, it nonetheless must be rejected as a candidate because, like any simple sum index, it has no basis in economic or index number theory and has no valid statistical properties. As such, there is no reliable basis for concluding that its performance in a specific application over a specific period of time can be extrapolated to predictions about other applications and intervals. Choosing between the two remaining candidates - the base and Divisia M1-plus - in the absence of any additional empirical tests amounts to a choice between competing predispositions about the performance of a central bank and the monetary data generated over time by changes in institutional arrangements. With regard to the base, it is possible to advocate its candidacy on the merits of a zero control error. The competing candidacy of Divisia M1-plus can be defended on the possibility that information contained in its multiplier may be more important empirically over different intervals of time. But, with a list of eight candidates reduced to two, the most prudent direction for a central bank to take would be use of the base instrument to pursue price stability directly while monitoring the behavior of a Divisia M1-plus index of aggregated money for those occasions where it may provide additional information useful to the conduct of policy. In regard to the latter, changes in the behavior of the Divisia M1-Plus multiplier may signal

accelerations or decelerations of money growth and attendant changes in the drift of policy¹⁴
actions not revealed by the evolution of base growth alone.

SUMMARY AND CONCLUSION

One approach to the conduct of monetary policy suggests that a central bank influence the behavior of an intermediate target variable to achieve some ultimate policy objective. Within this framework, the critical and necessary attributes of an intermediate target are that it have a predictable relationship with the ultimate goal of policy - the behavior of the inflation rate in this study - and that it can be controlled by central bank actions. Thus, while a number of studies have made arguments in favor of a particular monetary aggregate (e.g., M2) based only on the criterion of its relationship with some final goal variable, most of these same studies have not addressed results indicating that the behavior of M2 cannot be controlled by the Fed under existing institutional arrangements in the U.S. Conversely, narrow aggregates such as M1, which can be controlled by the Fed's actions, have shown increasingly weak associations with the inflation rate and nominal magnitudes more generally. Finally, virtually all of the literature on both issues is based on the official, but invalid, simple sum index numbers still reported by the Fed. Irrespective of what political considerations are responsible for the continued publication of these data, results based on them must be suspect as a matter of science.

The general conclusion of the empirical results reported here is that M2 and other monetary aggregates included in current discussions of monetary policy are dominated by two alternatives: the monetary base and a Divisia index based on M1 liabilities plus savings deposits. Although simple sum M1 also is supported by the empirics, the problems inherent in this type of index number argue against its use. With philosophical differences representing the choice between policy strategies using the monetary base or Divisia M1-plus, the results also suggest further research to investigate other criteria that might present a more concrete reason for preferring one over the other. Or, in the absence of this evidence, the most prudent course for the Fed may be to use the base for implementing policy while monitoring the behavior of Divisia M1-plus for insights its behavior may offer.

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15

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Figure 1. Artificial Neural Network Used to Estimate Money-Inflation Relationships

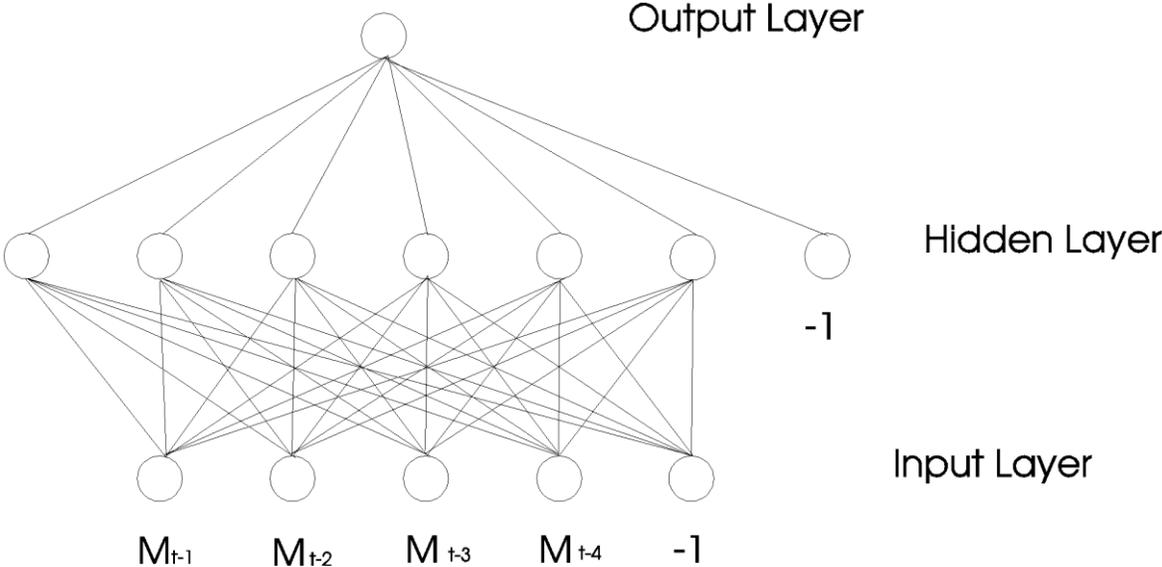


Table 1. Bank Liabilities Used to Compose Alternative Money Stock Measures

AGGREGATE LIABILITIES INCLUDED:

1) Adjusted Monetary Base = Reserve balances held with the Federal Reserve Banks, required reserves held by Edge corporations, currency in circulation, and an adjustment for reserve requirements.

2) M1 = CURR + TVCKS + DDCON + DDBUS + OCD + SNOWCB + SNOWTH

3) M2 = M1 + ONRP + ONED + MMMF + MMDACB + MMDATH +
SVGCB + SVGTH + STDCB + STDTH.

4) MZM = M2 - (STDCB + STDTH) + IOMMF

5) M1-plus = CURR + TVCKS + DDCON + DDBUS + OCD +
MMDACB + MMDATH + SVGCB + SVGTH.

(The OCD series used to construct M1-plus includes SNOWCB and SNOWTH).

where:

CURR = Currency held by the nonbank public.

TVCKS = Traveler's checks.

DDCON = Demand deposits of consumers.

DDBUS = Demand deposits of businesses.

OCD = Other Checkable Deposits.

SNOWCB = Super NOW accounts at commercial banks.

SNOWTH = Super NOW accounts at thrifts.

ONRP = Overnight repurchase agreements.

ONED = Overnight eurodollar deposits.

MMMF = Money Market Mutual Funds.

MMDACB = Money Market Demand Account Deposits at commercial banks

MMDATH = Money Market Demand Account Deposits at thrifts.

SVGCB - Savings deposits at commercial banks.

SVGTH - Savings deposits at thrifts.

STDCB = Small time deposits at commercial banks.

STDTH = Small time deposits at thrifts.

IOMMF = Institution-only Money Market Mutual Funds

Table 2. Qualitative Results of J-tests

A. The Base and Simple sum aggregates

	<u>AMB</u>	<u>M1</u>	<u>M2</u>
M1	M1		
M2	AMB	M1	
MZM	AMB	M1	N

B. Simple sum v. Divisia aggregates

	<u>M1</u>	<u>M2</u>	<u>MZM</u>
DM1	M1	N	N
DM2	M1	N	N
DMZM	M1	N	N
DM1plus	B	DM1plus	DM1plus

C. The Base and Divisia aggregates

	<u>AMB</u>	<u>DM1</u>	<u>DM2</u>	<u>DMZM</u>
DM1	AMB			
DM2	AMB	N		
DMZM	AMB	N	N	
DM1plus	B	DM1plus	DM1plus	DM1plus

Table 3. Results for Equation (5) relating the Monetary Base to Alternative Monetary Aggregates. Quarterly, 1965Q1 - 2000Q4 (coefficient sum, t-statistic, lag length)

Monetary Aggregate	Constant	AMB	ΔTB3	R²
M1A	1.34 (0.83)	0.50 (2.26) (0-3)	-3.89 (3.94) (0-8)	.49
M1	-2.07 (1.48)	1.22 (6.32) (0-5)	-2.61 (4.05) (0-4)	.55
MZM	3.17 (1.33)	0.53 (1.63) (0-1)	-10.04 (7.30) (0-5)	.51
M2	5.60 (4.55)	0.26 (1.56) (0-1)	-0.85 (1.83)	.09
DM1A	-0.23 (0.21)	0.80 (5.54) (0-1)	-1.61 (3.94)	.45
DM11	.34 (1.31)	0.75 (5.41) (0-3)	-1.22 (2.12)	.39
DMZM	3.40 (1.43)	0.26 (0.79) (0-2)	-7.54 (5.58) (0-6)	.50
DM2	5.10 (2.47)	0.05 (0.18) (0-2)	-2.02 (2.11) (0-3)	.26
DM1+	-9.54 (1.72)	2.17 (2.91) (0-8)	8.46 (1.82)	.35

Notes: t-statistics are for $H_0: \Sigma \text{AMB}=0$ and $H_0: \Sigma \Delta \text{TB3}=0$. Fitted values from these equations were used in the estimation of the inflation relationship shown in Equation (6) in the text.

Table 4. Results for Inflation Equation in the System Estimation, Quarterly 1965Q1-2000Q4²⁴
 (coefficient sum, t-statistic, lag length)

Monetary Aggregate	Constant	M	M	R2
AMB	-0.16 (0.25)	0.88 (13.59) (1-3)	0.11 (1.55) (0-1)	0.63
MIA	0.44 (0.78)	0.89 (12.37) (1-3)	0.03 (0.52) (0-1)	.61
M1	0.50 (0.87)	0.88 (12.68) (1-7)	0.02 (0.26) (0-1)	.63
M2	2.08 (1.93)	0.86 (12.04) (1-3)	-0.18 (1.44)	.58
MZM	1.36 (2.85)	0.82 (11.91) (1-3)	-0.06 (2.41)	.62
DMIA	0.59 (1.05)-	0.88 (13.01) (1-3)	0.01 (0.14) (0-1)	.61
DM1	1.10 (1.85)	0.87 (12.97) (1-3)	-0.06 (0.98)	.61
DMZM	1.26 (2.67)	0.82 (11.59) (1-3)	-0.06 (2.21)	.61
DM2	1.27 (2.41)	0.85 (12.11) (1-3)	-0.09 (1.78)	.59
DM1+	0.52 (1.44)	0.87 (13.93) (1-3)	0.02 (1.85)	.64

FOOTNOTES

1 It should be noted that Feldstein and Stock (1994) recognize this point and admit that M2 cannot be controlled by the Fed under current institutional arrangements. They also devote several pages (pp. 51-54) to a discussion of institutional changes that could provide the central bank control of M2 necessary for its use as an intermediate target.

2 A new contribution in this area is by S. Thornton (2006) who examines the performance of Divisia – as well as simple sum - monetary indexes in a framework similar to that of McCallum. She finds evidence that indicates Divisia measures of money generally outperform simple sum aggregates and that Divisia M2 appears to perform best in an adaptive rule with a path for nominal GDP as an objective. Her work, however, does not include Divisia measures of either the MZM or M1-plus liabilities groupings. Also see Dorsey (2000), which employs a neural net method to address the single question of forecasting inflation out-of-sample for the U.S. and Germany (in isolation from the issue of monetary control) and finds strong evidence in favor of the information content of Divisia indexes of money.

3 See, for example, Keynes (1930, vol 2. p. 10) and Hawtrey (1930). For a concise and more recent discussion of choosing weights for an aggregate index of money, see Friedman and Schwartz (1970, p. 152): "The more general approach (using different weights for each component of an aggregate and allowing them to vary over time) has been suggested frequently but experimented with only occasionally. We conjecture that this approach deserves and will get much more attention than it has so far received. The chief problem with it is how to assign the weights and whether the weights assigned by a particular method will be relatively stable for different periods or places or highly erratic. So far there is only the barest beginning of an answer." Their footnote 5 lists references to empirical work from the 1960s using various approaches to weighting. Belongia (1995) presents a more recent survey of work on weighted measures of aggregated money.

4 See, for example, Barnett, et al. (1984) on the subject of the demand for money and Barnett (1984) on the velocity of money. Barnett, et al. (1997, 1992) and the papers in Belongia and Binner (2000) across ten countries provide more recent references on these empirical differences. Finally, Belongia

(1995) surveys work on weighted monetary aggregates that pre-dates the index number results of Diewert. Even these efforts, based on data long before the advent of financial innovations, illustrate the importance of weighting to the construction of a monetary aggregate; Elliot (1964) is perhaps most interesting for the question of M1 v. M2 and whether savings deposits should be treated differently from demand deposits. In contrast, a single, unpublished paper by Lindsey and Spindt (1986) evaluating Divisia aggregates in a single application has been the primary citation used by critics of their use.

⁵ A variety of criticisms have been directed, however, to practical considerations in the construction of Divisia aggregates. For rebuttals of the most frequent of these, see the Appendix to Belongia (1995).

⁶ Belongia and Gilbert (2000) offer updated evidence on the time series behaviors of alternative measures of velocity. Whereas the growth rates of velocities associated with both simple sum and Divisia measures of money are best characterized by random walks, the drift components of the simple sum measures change in the 1980s while those for the Divisia measures do not. Related evidence is reported by Dorsey (2000), who found that a neural network using only lagged values of money growth as explanatory variables yielded out-of-sample forecast errors for inflation that were smaller when Divisia measures of money were used. He also noted that the forecasts based on Divisia indexes did not deteriorate significantly as the forecast horizon was extended.

⁷ A related criticism, due to Mason (1976), has to do with the widespread practice of defining "money" on the basis of in-sample fits between various aggregates and either the inflation rate or nominal spending in a particular model. Based on the "money is what money does" axiom attributed to Friedman and Schwartz (1970) and reflected in the modern work discussed in the introduction to this paper, Mason described this practice as one of circular reasoning: After choosing the criterion for performance sought from a measure of money, "money" then is defined as whatever measure produces the best result. It also should be noted that the empirical strategy suggested by Friedman and Schwartz and Mason's critique of it both pre-date Diewert's results on the foundation and construction of superlative index numbers.

⁸ Some recent work, such as that of Bernanke and Blinder (1992), has used the federal funds rate

in this capacity. To do so, however, risks drawing an incorrect inference about the nature of central bank actions. Specifically, the value on the *quantity* axis of a diagram for bank reserves can change only if the Fed uses open market operations to change the quantity of reserves available.

Conversely, the value on this diagram's *vertical* axis, the federal funds rate, can change from either a shift in the supply of bank reserves *or* a change in the demand for reserves associated with fluctuations in aggregate output and the aggregate demand for credit. Thus, the fed funds rate is endogenous and changes in it offer no clear signal that the Fed has done anything to act upon it.

⁹ For criticisms of this type of approach to policy implementation, see McCallum (1985).

¹⁰ A frequent, but unsubstantiated, criticism of using superlative indexes of money in policy decisions is that their behavior cannot be controlled, i.e., they would not move in close and predictable ways in response to a given change in the setting of the policy instrument (the base). While no empirical evidence exists to support this assertion, Spindt (1984) found that Divisia aggregates were no less controllable than the official, simple sum aggregates. Unfortunately, this study used a sample period that ended in December 1982, just prior to the widespread adoption and use of new deposits introduced by financial innovations. Belongia (2004), however, provides more background on reasons why the multiplier of a Divisia aggregate may be *less* volatile than that of a simple sum aggregate and reports results, based on several intervals of data, indicating that control errors for Divisia aggregates are no larger than those for simple sum measures.

¹¹ The last grouping also was proposed by Rotemberg, et al. (1995) in their work on a “currency equivalent” (CE) measure of money based on weights different from those of the Fisher-Ideal or Divisia indexes. Although Barnett (1991) showed that, under certain conditions, the weights used in a CE index produce a stock analog to the Divisia flow measure of monetary services, they produced extremely volatile series for money and led Rotemberg, et al. to use a centered-average smoothing procedure that has the unfortunate characteristic of not revealing the current growth rate of money until seven months after the fact. The M1-plus collection of bank liabilities also was used in Belongia (1996) to illustrate significant differences between inferences based on simple sum and Divisia measures of money.

¹² For one discussion of why this result is neither unexpected nor particularly useful for the broad simple sum aggregates, see Barnett and Zhou (1994). The general argument is that broadening the coverage of any aggregate will smooth its velocity by introducing expanded opportunities for increases in some components to be offset by declines in others. An implication of this result is that a central bank using a simple sum aggregate will have to broaden its definition of money continually as substitution effects, which *cannot* be internalized by a simple sum index, eventually will cause its velocity to become erratic.

¹³ Boschen and Talbot (1991) also provide some evidence on the direct relationship between base growth and inflation.

14. If the necessary variables to be used in a model are known and are appropriately measured, then the ANN should be useful in approximating the relationship among the variables. The ANN has the ability to approximate complex nonlinear interactions among variables to a high degree of accuracy and even as Caporaletti, et. al. (1994) have recently shown the ANN works well for approximating simultaneous equation systems.

¹⁵ See Dorsey and Mayer (1995) for a detailed discussion of the application of the genetic algorithm for optimization and a more focused discussion of the application of the genetic algorithm for optimizing the neural network can be found in Dorsey, Johnson and Mayer (1994).