

1-1-1993

Nominal Income Targeting with the Monetary Base as Instrument: An Evaluation of McCallum's Rule

Gregory Hess
Claremont McKenna College

David H. Small

Flint Brayton

Recommended Citation

Hess, Gregory, Small, David, and Flynt Brayton. "Nominal Income Targeting with the Monetary Base as Instrument: An Evaluation of McCallum's Rule," in *Operating Procedures and the Conduct of Monetary Policy: Conference Proceedings*, edited by Marvin Goodfriend and David Small, Finance and Economics Discussion Series Working Study 1, Volume 2, Federal Reserve Board, Washington, DC, 1993

This Conference Proceeding is brought to you for free and open access by the CMC Faculty Scholarship at Scholarship @ Claremont. It has been accepted for inclusion in CMC Faculty Publications and Research by an authorized administrator of Scholarship @ Claremont. For more information, please contact scholarship@cuc.claremont.edu.

NOMINAL INCOME TARGETING WITH THE MONETARY BASE AS INSTRUMENT:
AN EVALUATION OF MCCALLUM'S RULE¹

Gregory D. Hess, David H. Small and Flint Brayton ²

Traditional long-run objectives for monetary policy are low inflation and stable growth of real output at full employment. Nominal income targeting has been proposed as a policy that would strike a reasonable balance between these two goals. Long-run inflation would be restrained by low, stable nominal income growth, and real growth on average would not be affected by the conduct of monetary policy. In the short-run, such a policy would split temporary supply shocks into price and output effects, and pursuing a nominal income target would prevent these shocks from having any long-term effect on inflation. Shocks to the aggregate demand side of the economy, from any source, would be offset by such a policy.

Indeed, Bennett McCallum has set forth an operational proposal for nominal income targeting.³ Seeking to base his policy rule on a variable that the Federal Reserve can "control directly and/or accurately," McCallum selects the monetary base as the policy instrument.⁴ His rule adjusts base growth for

1. With "Estimates of Foreign Holdings of U.S. Currency--An Approach Based on Relative Cross-Country Seasonal Variations" by Richard D. Porter.

2. The authors are, respectively: Economist, Monetary Studies; Section Chief, Monetary Studies; and Section Chief, Macroeconomic and Quantitative Studies, at the Board of Governors of the Federal Reserve System. We would like to thank Richard Porter, Brian Madigan, and George Moore for their comments and Ellen Dykes for editorial assistance. We also gratefully acknowledge the research assistance of Allen Sebrell, Ron Goettler, and Chris Geczy.

3. "Monetarist Rules in Light of Recent Experience," American Economic Review Proceedings, vol. 74 (1984), pp. 388-91; "Robustness Properties of a Rule for Monetary Policy," Carnegie-Rochester Conference Series on Public Policy, vol. 29, (Autumn 1988) pp. 173-204; and "Targets, Indicators, and Instruments of Monetary Policy," Monetary Policy for a Changing Financial Environment, (Washington, D.C.: American Enterprise Institute, 1990), pp. 44-70.

4. McCallum adopts the following terminology. An instrument variable is one that can be directly controlled, a goal variable is the ultimate argument of the monetary authority's preferences, a target is an operational guideline for proceeding from one's instruments to one's goals, and indicators are variables that provide information to the Federal Reserve but are not instruments, targets, nor goals.

changes in trend velocity and for deviations of nominal GNP from its targeted path.

In this paper, we explore McCallum's monetary base instrument rule in the context of several models. The first section uses two models, previously utilized by McCallum, to demonstrate the general properties of his rule and to update through 1992 the empirical support for the rule. The second section uses models that allow a significant role for interest rates in transmitting the effects of changes in the monetary base to aggregate demand. The analysis in these two sections makes two main points: (1) Shifts, or instabilities, in the structural relationship between the base and nominal GNP in the 1980s and 1990s raise questions about the efficacy of the proposed rule; and (2) The ability of McCallum's base instrument rule to control nominal output depends on the response pattern of the target variable, nominal output, to changes in the base. In the sequence of models presented, we lay out these dynamic linkages in successively more detail and examine their implications for nominal income targeting.

RE-EXAMINING MCCALLUM'S RESULTS⁵

McCallum's rule for using the monetary base as an instrument to target nominal GNP is

$$(1) \quad \Delta b_t = \alpha - (1/N) \sum_{j=1}^N \Delta v_{t-j} + \lambda [x_{t-1}^* - x_{t-1}] ,$$

where: b \equiv log of the St. Louis monetary base

x \equiv log of nominal GNP

v \equiv log of the GNP velocity of the monetary base, $x - b$.

x^* \equiv target value of x (grows at 3 percent per year)

Δ \equiv first difference operator.

The coefficient α is chosen such that, absent influences from the other terms, the base grows at 3 percent per year (the assumed growth rate of potential real output). The second term in the rule adjusts base growth for recent trends in the GNP velocity of the

5. To make results in this section directly comparable to those presented by McCallum, we use the measure of the monetary base constructed by the Federal Reserve Bank of St. Louis and use GNP as a measure of aggregate output. In the second section we switch to GDP.

monetary base. In computing trend velocity, McCallum sets the length of averaging to sixteen quarters ($N = 16$). For example, if base velocity had been growing on average by 2 percent over the previous four years, growth of the base would be reduced by this amount to keep nominal GNP growing at 3 percent on average. Historical trends in base velocity that this "velocity adjustment" term would be expected to offset are shown in the upper and middle panels of chart 1. The final term of the rule adjusts base growth in response to deviations of nominal GNP from its targeted level; McCallum typically gives λ a value of 0.25.

In his evaluation of this policy rule, McCallum maintains the hypothesis that the economics profession lacks agreement on the appropriate theoretical and statistical paradigms with which to explain macroeconomic fluctuations. Consequently, he analyzes the base-instrument rule within a range of models. He simulates each model--with the base rule incorporated--subject to estimated historical shocks. The simulations are performed as "counterfactuals"-- that is, given the estimated empirical relationships among the variables of interest, what would have been the paths for these variables had the Federal Reserve followed McCallum's base instrument rule.

A Single-Equation Model of the Economy

To display its general properties, we first examine McCallum's rule in conjunction with a single-equation model of nominal income that relates contemporaneous nominal GNP growth to its lagged value and the growth of the monetary base. McCallum used this model, and we have attempted to replicate his results over the period 1954:Q1 to 1985:Q4 (see column i of table 1). Estimates for the extended time period 1954:Q1 to 1992:Q1 are reported in equation 2 and in column ii of table 1:

$$(2) \quad \Delta x_t = .008 + .341 \Delta x_{t-1} + .306 \Delta b_t + \mu_t,$$

(3.93) (4.70) (2.55)

$$\bar{R}^2 = .188 \quad \text{Durbin-h} = -1.45 \quad \text{SEE} = .0098$$

Sample period = 1954:Q1 to 1992:Q1

where SEE is the standard error of the estimate and (as throughout the paper) heteroskedasticity-robust t-statistics are reported in parentheses.⁶ This model, in conjunction with the base rule, produces a root-mean-squared deviation (RMSD) of simulated nominal GNP from the targeted values of 0.0243 for the period from 1954:Q1 to 1992:Q1. This RMSD represents an increase from the value of 0.0197 reported by McCallum when the model is estimated and simulated through 1985:Q4.⁷ The top panel of chart 2 displays the targeted and simulated values of nominal GNP.

More detailed observations on the model performance are evident in the middle panel of chart 2 which shows growth rates of the simulated values of nominal GNP and the monetary base, while the bottom panel shows the nominal GNP shocks that are fed into the simulation. Three observations are noteworthy. First, the short-run swings in simulated nominal GNP (dotted line, middle panel) closely follow the historical GNP shocks fed into the model (dotted line, lower panel). Accordingly, the quarterly standard deviations of simulated and actual nominal GNP growth are fairly close at 4.24 percent and 4.42 percent respectively.⁸ Second, medium-term swings in nominal GNP growth are damped. For example, the standard deviation of the fourth-quarter to fourth-quarter growth of nominal GNP for the years 1955-91 was 3.55 historically and is reduced to 2.38 in the simulations. And third, the mean growth of simulated nominal GNP over the full sample is 2.91 percent per annum when using McCallum's rule, compared with 7.30 percent growth of nominal GNP observed since 1954.

The particular episodes in which the base rule smooths nominal GNP can be seen by looking first at the two-year moving average of the errors in the bottom panel of chart 2 (solid line). At first, the moving average crosses zero frequently. Subsequently, however, it tends to be positive from 1975 to 1982 and negative on balance from 1982 to 1992. Over the first period, the growth in

6. In this paper we use NIPA data from the Bureau of Economic Analysis' recent 1987-base benchmark. To date, these series go back to 1959:Q1. We extrapolate prior to this date using growth rates from the Bureau's 1982-base benchmark.

7. Using currently published data, we obtain an RMSD of 0.0196 when we attempt to duplicate McCallum's results (see column i of table 1).

8. This lack of quarter-to-quarter improvement results from the monetary base responding to deviations of nominal GNP from target with a one-quarter lag.

simulated base tends to slow (middle panel) and, as a result, the growth of simulated nominal GNP tends to stay centered around 3 percent despite the positive shocks on average. During the later period, however, nominal GNP growth is kept around 3 percent as the negative shocks to nominal GNP are offset by an increase in simulated base growth.

To show how the monetary base would have moved under the rule as compared with actual base supply, in chart 3 we compare the simulated growth of the monetary base with its historical pattern (the mean has been subtracted from each series). McCallum's rule keeps the growth of the base roughly constant through the early 1970s, in contrast to the historical experience of accelerating base growth. Then, from the early 1970s to the early 1980s, simulated base growth falls as the economy is subject to positive aggregate demand shocks. In the early 1980's simulated base growth increases as the trend in velocity growth slows. Of particular interest is 1990-91, when actual base growth spiked during the recession. A rule that simply targeted the base would have led to a tightening of policy to keep base growth on target, but McCallum's rule calls for an acceleration in the growth of the monetary base; an acceleration which tends on average to be greater than which was actually observed.

Chart 4 further illustrates this aspect of McCallum's rule which calls for sharp responses of the monetary base to changes in economic performance. Here we decompose the growth in the base called for by McCallum's rule into the sum of the contributions from the constant 3 percent (not shown), the component due to GNP targeting, and the component due to shifts in long-run velocity. The component due to GNP targeting (the solid line) fluctuates around zero, reflecting the divergences of simulated from targeted nominal GNP. As can be seen, the divergence from zero has been more pronounced in the past ten years than it was in earlier years--reflecting less success by the rule in attaining the GNP target. Furthermore, the short-run swings in base growth (dot/dash line) are driven largely by GNP targeting, whereas the broad swings in the base are driven by changes in velocity growth. In particular, the velocity effect has been relatively stable over the past two years,

but the response to the movement of nominal GNP below target has caused nearly all of the acceleration in the simulated base.

A Model of Aggregate Demand and Supply

McCallum also evaluates his rule in the context of a small macro model with an aggregate demand equation and a supply side that incorporates sluggish wage and price behavior similar to that of the MPS model.⁹ We present this aggregate demand/aggregate supply model (ADAS) to show that (1) as in the analysis with the single-equation model, performance of the rule deteriorates after 1985 and (2) the main source of deterioration lies in the demand side of the model--where instabilities in base demand, if they exist, would show up.

The aggregate demand curve is similar to the nominal income model above (equation 2) except that GNP and the monetary base are specified in real terms and real government expenditures are added as an explanatory variable. This real aggregate demand equation (see also column ii of the aggregate demand panel of table 2) estimated through 1992:Q1, is

$$(3) \quad \Delta y_t = .004 + .320 \Delta y_{t-1} + .025 (\Delta b_t - \Delta p_t) \\ (3.51) \quad (3.75) \quad (0.20) \\ + .294 (\Delta b_{t-1} - \Delta p_{t-1}) + .175 \Delta g_t - .151 \Delta g_{t-1} + e_{yt} \\ (2.73) \quad (3.52) \quad (-2.98)$$

$$\bar{R}^2 = .208 \quad \text{Durbin-h} = -1.03 \quad \text{SEE} = .0086$$

Sample period = 1954:Q1 to 1992:Q1

where

- g ≡ the log of aggregate real government expenditures.
- y ≡ the log of real GNP
- p ≡ the log of the implicit GNP deflator.

9. For a description of the Federal Reserve's MPS model see Eileen Mauskopf and Flint Brayton, "Structure and Uses of the MPS Quarterly Econometric Model of the United States," Federal Reserve Bulletin, vol. 73 (1987), pp. 93-109; and Flint Brayton and Eileen Mauskopf "The Federal Reserve Board MPS Quarterly Econometric Model of the U.S. Economy," Economic Modelling (July 1985), pp. 170-292.

The aggregate supply side of the model has equations for nominal wages and prices. The wage equation relates the growth in nominal wages to changes in expected inflation and deviations of real GNP from potential. Our specification of this equation estimated through 1992:Q1 is

$$(4) \quad \Delta w_t = .001 + .230 (y_t - y_t^f) - .150 (y_{t-1} - y_{t-1}^f) + 1.0 \Delta p_t^e + e_{wt}$$

(2.91) (5.16) (-3.30)

$$\bar{R}^2 = .551 \quad \text{Durbin-Watson} = 1.59 \quad \text{SEE} = .0047$$

Sample period = 1954:1 to 1992:1

where

w_t \equiv the log of the nominal wage rate

y_t^f \equiv the log of full-employment real GNP

Δp_t^e \equiv the expected rate of inflation calculated as the lagged eight-quarter moving-average of inflation.

Our specification of the inflation equation relates inflation to lagged inflation and the lagged growth in wages estimated through 1992:Q1 is:

$$(5) \quad \Delta p_t = -.001 + .408 \Delta w_t + .222 \Delta p_{t-1} + .371 \Delta p_{t-2} + e_{pt}$$

(-1.31) (7.70) (3.01) (6.71)

$$\bar{R}^2 = .720 \quad \text{Durbin-h} = -1.70 \quad \text{SEE} = .0034$$

Sample period = 1954:Q1 to 1992:Q1

The results for equations 4 and 5 are also reported in column iv of the wage and price panels of table 2.¹⁰ These equations are

10. Column i presents the results for a non-neutral form of the model as presented by McCallum when estimated over the sample period 1954:Q1 to 1985:Q4, and these results are extended to 1992:Q1 in column ii. Column iii presents the results for the neutral model for the sample period 1954:Q1 to 1985:Q4, and these results are extended to 1992:Q1 in column iv.

similar to ones used by McCallum, except that we constrain them to yield a long-run aggregate supply function that is neutral with respect to inflation; those used by McCallum produce a positively sloped long-run aggregate supply curve.¹¹ To the price equation used by McCallum, we have added the second lag of Δp . With this change in specification, neutrality cannot be statistically rejected.¹² The unrestricted sum of the coefficients on wage growth and lagged inflation is 0.928. The F-test for the restriction that the sum of the price and wage coefficients is unity has a statistic of 2.3. The restriction cannot be rejected at the 5 percent level of significance. A similar test for neutrality in the wage equation tests the hypothesis that the coefficient on the expected inflation term is unity. That coefficient is freely estimated to be 0.876, and an F-test for the restriction of the coefficient being unity has an F-statistic of 3.26. Again, the restriction cannot be rejected at the 5 percent level of statistical significance. In sum, we cannot reject neutrality, and we proceed with the above specification that embodies it.

In the top panel of chart 5, we plot targeted and simulated nominal GNP for this model when estimated and simulated over the period 1954:Q1-92:Q1. The RMSD of 0.0497 for this period is 155 percent higher than the value of 0.0195 when the estimation and simulation period is 1954:Q1-1985:Q4.¹³ The bottom panel of

11. This observation should not be taken as a criticism of McCallum's specification. To reiterate, McCallum's approach was essentially agnostic. He was interested in testing the robustness of his rule in context of several models. The fact that he used a non-neutral specification does not imply that he endorsed the specification.

12. If the second lag of inflation were not included in equation 5, the Durbin-h statistic would be equal to -4.27.

13. In his comments on this paper, McCallum questions this result by trying to replicate it and showing a more limited increase in the RMSD than we show when the sample period is extended thorough 1991:Q4 -- he shows an increase from .0191 to .0277. He derives this result from a modified version of his aggregate demand and supply model in which the aggregate supply curve is constrained to be vertical in the long run as it is in our model. Based on the following, we believe our results to be valid. In the aggregate demand equation, McCallum estimates a value of .1549 on the contemporaneous real base, while our estimate of .025 indicates a weaker link between the base and real output. We first replicated McCallum's estimate using his data base.

chart 5 shows the growth of simulated nominal income and the simulated base. The standard deviations of the fourth-quarter to fourth-quarter annual growth rate of actual and simulated nominal GNP are nearly the same at the values of 3.55 and 3.75 respectively.

Evidence, presented in table 3, suggests that the underlying cause for the deterioration in the model's performance as the sample is extended is a weakening of the relation between real GNP and the real base--that is, an underlying instability in the aggregate demand side of the model. Each column of the table reports, for a given estimation range and value of λ , a decomposition of the RMSD into the effects due to aggregate demand shocks (e_{yt}), aggregate supply shocks (e_{wt} and e_{pt}), and the model's stability under the rule.¹⁴ The latter is merely the RMSD that would obtain, starting from the particular disequilibrium conditions of 1954:Q4, when the model is not subjected to shocks but is allowed to converge to the steady state using McCallum's rule for base growth.

In column i of table 3 we present the results for 1954:Q1 - 1985:Q4 when $\lambda = .25$. The aggregate demand shocks alone generate an

(Footnote continued from previous page)

but then substituted the 1987-based NIPA measures of real GNP as discussed in footnote 6 for his 1982-based GNP figures. This substitution causes the estimated coefficient on the contemporaneous base to fall from .1549 to .0488. To measure the empirical importance of this difference in the estimates, we increased the coefficient on the real base in our model to .1549, while leaving all other parameters unchanged. In simulating this version of our model thorough 1991:Q4, the RMSD fell to .024, which is in line with the value of .0277 reported by McCallum in his comments. It appears, therefore, that differences between the 1982-based and 1987-based GNP figures, and in the resulting estimates of the coefficient on the real base in the aggregate demand equation, explains most of the difference between McCallum's and our simulation results.

For our non-neutral specification, the RMSD is 0.0193 for 1954:Q1 to 1985:Q4 and increases to 0.0321 for the estimation and simulation range 1954:Q1 - 1992:Q1. However, there are two peculiar features about this system. First, the level of simulated real GNP lies uniformly below actual real GNP through the simulation period 1954:Q1 - 1992:Q1. Second, the divergence between actual and simulated real wages widens because of the non-neutrality of the wage equation.

14. Since the RMSD is the mean of squared terms, and is therefore nonlinear, the decomposition will not necessarily sum to its total. Also, the various shocks may be correlated with one another. The decomposition was achieved by alternatively zeroing out demand and supply shocks.

RMSD of 0.0200 compared with one of only 0.0058 for the aggregate supply shocks. This difference is, in part, due to the errors that are being fed into the aggregate demand equation having a standard error of 0.0089, whereas those for the wage and price equations are considerably smaller--0.0048 and 0.0036, respectively. But still, the sum of the coefficients on the real base in the aggregate demand equation is relatively high (0.5587), and thereby the rule-induced changes in the base can stabilize aggregate demand and the model converges to its steady state rather quickly, as indicated by the no-shock RMSD of 0.0046.

Column ii of table 3 extends the estimation and simulation ranges to 1992:Q1, but keeps $\lambda = .25$. As noted above, the RMSD for all shocks becomes larger in this case. In part, this increase results from the weaker relationship between the real base and real GNP: Coefficients relating the real base to real GNP sum to 0.3182 (the contemporaneous coefficient is near zero). This is also reflected in the rise of the RMSD to 0.0158 when the economy is not subjected to shocks. The value of $\lambda = .25$ is not as effective in restoring the model quickly to equilibrium even in the absence of shocks.¹⁵ Again, the model has a much higher RMSD when it is confronted with only aggregate demand shocks than when it is confronted with only aggregate supply shocks.

The Changing Relation Between the Monetary Base and GNP

In measuring the performance of the economy, we have followed McCallum in using the RMSD of simulated from targeted nominal GNP. But this statistic measures only the average performance over the entire sample period. If the performance over more recent years has deteriorated relative to that of earlier years, then the case for using this rule currently or in the future is correspondingly weakened.

To address this issue, for the estimation and simulation results reported in charts 6 and 7 we use a "rolling horizon" period fixed at fifteen years and we extend the analysis through 1992:Q1. As can be seen in chart 6 for the nominal income model, the RMSDs are

15. This instability may result from McCallum's selection of 1954:Q1 as the starting date for his estimation and simulation ranges or from the inclusion of the most recent time period, which weakens the relationships between real base growth and real GNP growth (as documented below). However, each of these possible explanations would fundamentally affect McCallum's methodology for evaluating his rule.

relatively low and stable until the early 1980s. Also, the coefficient linking the monetary base to nominal GNP is stable and significant. But this coefficient weakens, and the RMSD grows noticeably as the 1960s are discarded and the 1980s are added to the estimation and simulation ranges. Chart 7 presents a similar story for the ADAS model. Once more, the coefficient on the contemporaneous real base is significant only during the period from the mid-1970s until the early 1980s, at which point the coefficient on the lagged real base becomes significant.

Formal tests for a shift in the coefficient on the base are reported in column iii of table 1 for the nominal income model and in column v of the aggregate demand panel of table 2 for the ADAS model. We test whether a permanent shift in the relation between base growth and GNP growth (nominal or real) has occurred since 1982:Q1. This date is used because, as Robert Rasche has found, it marks a significant break in the growth rate of velocity in estimates of demand equations for narrow money measures.¹⁶ For both models, a shift seems to have occurred because we can reject at the 1 percent level of statistical significance the hypothesis of excluding both an intercept shift and a slope coefficient shift for the base in 1982:Q1. Furthermore, for neither model can we reject the hypothesis that the sum of the coefficients on the base (real or nominal) in the aggregate demand equations (real or nominal) are zero after 1982:Q1. Using Chow tests for instability in all the coefficients, however, we cannot reject the hypothesis that the nominal and real aggregate demand functions are structurally unchanged after 1982:Q1. These results together suggest that, although a Chow test cannot reject that all the coefficients of the aggregate demand equations have changed, a more specific test focused on the relation between base growth and income growth (both real and nominal) finds that a substantial break has

16. Robert Rasche, "Demand Functions for Measures of U.S. Money and Debt," in Peter Hooper and others, eds., Financial Sectors in Open Economies: Empirical Analysis and Policy Issues, (Board of Governors of the Federal Reserve System, 1990). In his comments on Rasche's piece, McCallum cites work that explains the level of velocity as a function of long swings in interest rates rather than of permanent shocks to its growth rate. However, because McCallum considers aggregate demand and supply models where interest rates have been substituted out, these velocity dynamics should already be incorporated into the analysis if the model being used is the correct one.

occurred since 1982. In fact, the relation is not insignificantly different from zero.

Implications for Policymakers of the Shifting Relation Between the Base and GNP

The Monetary authority's response to economic developments is governed in McCallum's rule by two parameters; (1) the speed of response to deviations of nominal GNP from target and (2) the length of the lag used in measuring trend velocity. As we now discuss, the appropriate choice of these parameters may change as the relation between the base and nominal GDP shifts. With such shifts documented above for the last ten years, the best way to implement McCallum's general approach is less certain.

The Choice of the Monetary Authority's Response to Deviations of Nominal GNP from its Target. In general, the appropriate choice for the value of λ depends on the strength of the relation between the base and GNP, and the policymaker may need to change λ as estimates of this relation change. For example, if the relation between GNP and the base weakens, as suggested above, then to achieve a given performance of the economy, as measured by the RMSD, the policy response to deviations from target (λ) must increase.¹⁷

Indeed, moving the end of the estimation period for the ADAS model from 1985 to 1992 reduces the sum of the estimated base coefficients from 0.56 to 0.32, as shown in columns i and ii of table 3. To at least partially offset this decline in the link between the base and GNP, in column iii we increase the value of λ to 0.50. The value for the RMSD when the model is subjected to all shocks then drops to 0.0260--a value much smaller than the result for $\lambda = .25$ over the full sample (reported in column ii), but still 33 percent larger than the result for the original sample considered by McCallum (reported in column i). Also, when the model is subjected to no shocks, the rate at which the initial disequilibrium disappears is in line with McCallum's original results.

The Choice of Measuring Trend Velocity Shifts. Also implicit in implementing this rule is the choice of lag length in the measurement

17. An analogy is that, if the medicine is half as strong, the economy will need twice as much of it.

of velocity shifts. At one extreme, if all shifts in velocity growth are white noise, then the length of averaging changes in velocity (N) should be quite large to average out the errors and obtain a better estimate of long-run velocity growth. At the other extreme, if all changes to velocity growth are permanent, for example if velocity follows a random walk, then N should be equal to one since the most recent observation of velocity is the best predictor of its long-run value.

In chart 8, we plot the RMSD calculated over the 3-year intervals ending in the indicated year when the lag length is sixteen quarters as suggested by McCallum and when the lag length is four quarters. The two panels are for the nominal income and ADAS models when estimated over 1954:Q1 - 1992:Q1. This rolling horizon RMSD is meant to capture the marginal effect of the rule over specific time intervals. As can be seen in both panels, the choice of lag length makes a modest net difference from the early 1960s to the late 1970s.

In both panels of the chart, the sharpest increase and highest level of the RMSD when $N=16$, however, are realized in the years immediately following the break in the trend of velocity around 1982:Q1 that is evident in chart 1. As we have shown in chart 4 with respect to the nominal income model, during this period the velocity adjustment in the McCallum rule apparently was not quick enough to offset the shift in velocity. This is evident in that a major proportion of the increase in simulated base growth is due to GNP falling below target. In fact, the adjustment to the new trend of velocity is not completed until 1988 (see chart 4).

ANALYZING MCCALLUM'S RULE WHEN POLICY IS TRANSMITTED THROUGH INTEREST RATES

We now turn to models not utilized by McCallum and in which the transmission of monetary policy to the demand for real goods and services works solely through interest rates. We thereby test McCallum's rule for robustness across alternative demand sides much as he tested it against alternative supply-side specifications.¹⁸

The analysis is conducted with two models, and the examination with each serves distinct purposes. The first model is small-scale

18. Although in this paper we have used only the MPS-style supply side used by McCallum, he also evaluated his rule using real business cycle and monetary misperception supply sides.

and adds IS and LM equations to wage and price equations similar to those presented above. The model is kept fairly small so that the robustness of its performance with respect to key structural features can be examined. Of particular importance are those parameters that affect the response of short rates to the monetary base and the response of long rates to short rates. Alternative specifications of these two relations are examined.

The second model is the large-scale MPS model maintained by the Board's staff. In this model, McCallum's base instrument rule with $\lambda = .25$ leads to instrument instability. After looking at this, we examine using interest rates as the instrument to target nominal GNP in the MPS model.

A Small Macro-Model with Interest Rates

This model consists of a supply side which has wages and prices that are sticky in the short run but which is neutral with respect to inflation in the long run. On the demand side, the IS curve depends, among other variables, on the long real interest rate. These equations are presented in appendix 1 because we do not consider alternative specifications of them.

The demand side also contains the estimated base demand curve given below in equation 6 where a unitary coefficient is imposed on the log of nominal GDP, and a velocity trend that shifts in 1982:Q1 is incorporated. Therefore, the equation, in effect, models the detrended log of base velocity as a function of the Box-Cox transformation of the federal funds rate. (The Box-Cox transformation is explained below.) This shift in trend velocity, evident in chart 1, was previously documented by Rasche.¹⁹ The estimated velocity trend before 1982 is 2 percent per year and thereafter is -0.4 percent. At a funds rate of 4 percent, the interest elasticity of base demand is 0.029.

19. Rasche, "Demand Functions for Measures of U.S. Money and Debt."

$$(6) \quad \log(\text{Base}) = -2.18 + \log(\text{GDPN}) - .027 \text{ BoxCox}(\text{RFFE})$$

(459) (6.25)

$$- .005 \text{ TIME} + .006 \text{ D82T},$$

(47.9) (21.4)

$$R^2 = .999$$

$$\text{D-W} = .306$$

$$\text{Std. Error} = .0171$$

Estimation period = 1960:Q1 - 1992:Q1

where:

Base \equiv St. Louis Reserve Bank monetary base

GDPN \equiv nominal GDP

RFFE \equiv federal funds rate (effective yield)

D82T \equiv Shift in time trend, equals zero before 1982 and equal to one in 1982:Q1 and increasing by one per quarter thereafter.

Three aspects of this equation of special note are (1) its specification in terms of the levels of variables and the absence of lags of variables, (2) the shift in trend, and (3) the use of the Box-Cox transformation. First, by modeling the level of velocity as depending on only contemporaneous variables, we assume that the long-run response of base demand to a change in income or interest rates is completed in one period. This specification is advantageous to McCallum's rule in that the large contemporaneous interest elasticity helps to stabilize the model in the presence of base demand shocks-- that is, smaller changes in interest rates are needed to re-equilibrate the supply and demand for the base.

An adverse effect of this specification for the simulated performance of McCallum's rule is that the estimated shocks to base demand fed into the simulation may be larger than if a more explicit dynamic specification were chosen. When such specifications were examined, the general results were that over the past ten years, when our base demand equation had its largest and most systematic errors, the errors from the alternatives were not much different from those of

the chosen specification.²⁰ In particular, the errors from equation 6 and those from a base demand equation estimated by Rasche are compared in appendix 2, where we also present changes in U.S. currency held abroad as a possible contribution to recent base demand errors.

Second, by including a shift in the trend of velocity, the estimation errors fed into the simulation are reduced. Nonetheless, in the simulations, this shift in trend growth of base demand will be unexpected and McCallum's rule will try to accommodate it through the 16-quarter moving average of past changes in velocity.

The third aspect of the base demand equation concerns the functional form for interest rates. Two common choices are linear and logarithmic forms. Choosing the linear form has the disadvantage of allowing nominal interest rates to be negative--an outcome that can easily occur in the zero-inflation paths in these simulations. As a major focus in simulating this model is the behavior of interest rates, this outcome seems unsatisfactory. A logarithmic specification avoids the problem. But the log specification can also lead to very high nominal rates because that specification calls for proportional changes in interest rates as shocks are fed into the simulation.

In the base demand equation 6, our chosen specification for the federal funds rate employs the Box-Cox transformation.²¹ This functional form ensures that the interest rate remains positive, as would the logarithmic specification, but tempers increases in the funds rate when it is at a high level. The Box-Cox parameter is set at 0.2.²²

With this base demand equation and with base supply set by McCallum's rule, short-term interest rates are determined. Changes in short-term interest rates are transmitted to long rates by way of equation 7. Short and long rates move together one for one in the long run, with an equilibrium spread of the long rate over the short

20. These dynamic models led to general problems of convergence of the simulations.

21. The Box-Cox transformation of the variable x is $BC(x) = (x^\lambda - 1)/\lambda$, for $0 < \lambda \leq 1$. As λ approaches zero the Box-Cox transformation approaches the logarithm. For λ equal to one, it is a linear transformation.

22. Iterating over values of the Box-Cox parameter yields a value of 0.34 that minimizes the sum of squared errors in the base demand equation. The value of .2 was as close as we could get to this and still achieve convergence in the simulations.

rate of 100 basis points.²³ To examine the sensitivity of model simulations to the way long-rate dynamics are modeled, two alternative response patterns are entertained for short-run behavior. In the "quick" response case the full effect of the funds rate on the bond rate is contemporaneous. In the "slow" response case, a change of 100 basis points in the short rate produces current and subsequent quarterly changes in the long rate of 30, 30, 20, and 20 basis points respectively. (After analyzing this model, we make it linear in interest rates and let the bond rate depend on the one-quarter-ahead federal funds rate. The model is then solved assuming perfect foresight.)

$$(7) \quad RTB10Y_t = 1.0 + \sum_{i=0}^3 \alpha_i RFFE_{t-i},$$

$$\text{subject to: } \sum \alpha_i = 1$$

A. Quick Response

$$\begin{aligned} \alpha_0 &= 1 \\ \alpha_1 &= 0 \\ \alpha_2 &= 0 \\ \alpha_3 &= 0 \end{aligned}$$

B. Slow Response

$$\begin{aligned} \alpha_0 &= .3 \\ \alpha_1 &= .3 \\ \alpha_2 &= .2 \\ \alpha_3 &= .2 \end{aligned}$$

where

RFFE \equiv federal funds rate (effective yield)

RTB10Y \equiv 10-year Treasury bond rate

In moving from the nominal bond rate to the real rate that affects spending decisions, the expected inflation rate used to construct the real long-rate is set to zero in the simulations. This is consistent with McCallum's rule which achieves zero long-run inflation, even though there are short-run fluctuations in inflation associated with the shocks being fed in. This way of handling expected inflation in financial markets may be thought of as being consistent with a high degree of credibility that the McCallum rule will continue to be followed.

23. The quick adjustment specification given below and estimated over 1983:Q1 - 1992:Q1 yields a long-run intercept of 100.004 basis points. Extending the sample period back through the early 1980s would incorporate a period of oil shocks and an inverted yield curve-- which presumably is not indicative of steady-state behavior.

We examine the robustness of McCallum's policy rule in the context of this model by analyzing the economy's performance under variations in two key structural components--the speed of responses of base demand and of the long rate to changes in the funds rate. In all cases, we conduct simulations by first allowing the model to settle into a steady state and then feeding in the historical shocks.²⁴ The behavior of the endogenous variables therefore abstracts from all problems associated with a transition to zero inflation associated with implementing the rule.

First we examine effects of the short-run dynamic response of base demand to changes in interest rates by shifting progressively more of the long-run response of base demand to interest rates from the contemporaneous response to a one-period lagged response that was added to the model. The long-run interest rate response is left unchanged--as are all other parameters and the estimated shocks that are fed into the equation. Also, to provide favorable stability conditions, we use the "quick" response of the long rate to the short rate.

When the contemporaneous response of base demand to interest rates reaches as low as 60 percent of the long-run response, swings in simulated interest rates become highly magnified relative to the case of a full contemporaneous response to interest rates. In particular, with only base demand shocks being fed into the simulation, the funds rate frequently (nine times) exceeds 20 percent in the 1960s, and peaks at 27 percent over the 1970s and 1980s and again in the 1990s. In contrast, when the long-run effect of changes in interest rates is realized contemporaneously in the base demand equation, the funds rate fluctuates between 1 percent and 7 percent during the 1960s and peaks at 10 percent in the 1970s and 1980s and at 17 percent in the 1990s.

A second check for robustness is to compare the simulation performance under quick and slow adjustments of the bond rate to the federal funds rate.²⁵ The results of the simulations are presented in charts 9.A - 9.G. Each chart except the last shows the behavior of

24. Because the model has long lags, its dynamics are affected by the historical values of variables just before the simulation. These dynamics, which are specific to that period, are purged from the results by putting the model into a steady state before subjecting it to shocks.

25. The base demand equation has its full interest response contemporaneously as in equation (6).

the economy when it is subjected to a particular type of shock; in the last chart, all shocks enter the simulations. Each panel of a chart shows the behavior of a given variable when the model has either the quick (solid line) or the slow (dotted line) adjustment of the bond rate to the funds rate.

From these charts one can see that the ability of the base rule to control nominal GDP growth is affected by the response speeds of long rates to short rates. If the long rate responds slowly to short rates, the resulting interest rate variability will be well in excess of historical experience--for example, the funds rate approaches 60 percent at one point in the 1990s. While the lags in the slow response were chosen to accentuate the control problem, what is of interest is the sensitivity of model performance to the way the long rate is modeled. The effect on economic performance is most pronounced for base shocks, but it is also present for IS and wage and price shocks. That volatility feeds through to, and is augmented by volatility in other variables, in particular nominal GDP growth.

The RMSDs from these simulations are not directly comparable to those of the models presented earlier because in these simulations the errors for the IS curve exist only since 1980:Q4 and the simulations start in 1960:Q1 rather than in 1954:Q1. But to give a sense of the way in which the simulations compare, the RMSD with the quick adjustment is 0.025, which is similar to the RMSDs of the earlier models in which the base directly affects aggregate demand. The RMSD increases to .043 with the slow adjusting bond rate.

We carry this analysis one step further by allowing the long rate to depend on future short rates.²⁶ The model is respecified to be linear in interest rates and then is reestimated. Three specifications of the long-rate equation are examined: (1) weights of 0.5 on both the contemporaneous and first lagged values of the funds rate; (2) a weight of unity on the contemporaneous funds rate; and (3) weights of 0.5 on both the contemporaneous rate and a one-quarter lead

26. To solve the model we use the methodology developed by Gary Anderson and George Moore in "A Linear Algebraic Procedure for Solving Linear Perfect Foresight Models," Economics Letters, vol. 17 (pp. 247-52.) For a brief overview of this methodology see the appendix to "Inflation Persistence" by Jeff Fuhrer and George Moore, which was prepared for this conference.

of the funds rate.²⁷ An IS curve shock is used to illustrate the implications of a forward-looking long rate for the ability of the model and McCallum's rule to stabilize the economy.²⁸ The behavior of interest rates and nominal and real GDP (deviations from steady-state values) are presented in charts 10.A and 10.B respectively. In both charts, the left-hand panels compare responses when the long rate reacts with a lag and when it reacts fully contemporaneously. The right-hand panels again show the case of a full contemporaneous response but compare it with the specification incorporating the forward-looking long rate.

The general conclusion from charts 10.A and 10.B is that the forward-looking rate provides a little additional smoothing of economic performance.²⁹ The response of that long rate to the IS shock is sharpest in the case of a full contemporaneous link between the long and short rates (chart 10.A, lower panels). With a lag in the bond rate equation, the response is delayed. The peak response of the forward-looking long rate occurs contemporaneous with the shock; but by incorporating the future decline in the funds rate, the response is not so large as in the case of the full contemporaneous response of the long rate. The paths of nominal and real GDP growth in the alternative cases generally reflect the movements of the long rate: Both are smoothed the most with forward-looking rates because of less-pronounced overshooting of GDP growth.

The dependence of economic performance--shown in Charts 9 and 10--on the manner in which long rates are modeled can be seen as either strengthening or weakening the case for the McCallum rule. The adverse implication is that if in practice rates behave in a sluggish manner then excessive variability, if not instrument instability, may

27. Because the slow response of the long rate to changes in the short rate--as specified in equation 7--is just barely stable, we do not use it.

28. The IS curve is given a one-period shock of 1 percent at an annual rate to the growth of real aggregate demand. Because that equation--A-1 in appendix 1--is an error-correction specification, there is no long-run effect on the level of demand stemming from this growth rate shock.

29. Additional smoothing owing to a forward-looking component in the long rate would be apparent if shocks in the model were positively autocorrelated. In response to a shock, the perfect-foresight solution technique used here would extrapolate the shock into the future and cause the long rate to rise in anticipation of policy's continuing to offset the shock.

well emerge. Furthermore, such sluggish behavior of long rates can be interpreted as indirectly incorporating into the model long lags in the response of spending to changes in interest rates.

A positive interpretation of these results for implementing the McCallum rule also applies to any specific rule for conducting monetary policy. The rule gives the markets a firmer basis on which to interpret changes in the federal funds and with which to form expectations of future Federal Reserve moves. Long rates could be expected to move quickly in response to those shocks that call for persistent moves by the Federal Reserve and such responses would augment these policy moves. While these results suggest that the range of interest rate fluctuations would be moderated by this response of long rates, the potential for volatility induced by the rule would still depend importantly on the strength and patterns of the intertemporal responses of base and spending demands to changes in interest rates.

Analysis Based on the MPS Model.

Although differing considerably in size, the MPS model and the model analyzed in the previous section are similar in one critical respect: The transmission of monetary actions to the rest of the economy occurs through interest rates rather than through direct effects of monetary quantities. An issue addressed in this section is the choice of the policy instrument--the monetary base or the federal funds rate--and how this choice is influenced by the nature of the monetary transmission mechanism. In general terms, the degree of control over a target variable achieved by an instrument depends on the types and magnitudes of shocks that may intervene to affect the realization of the target variable, given the instrument's selected value. ³⁰ As discussed in the previous section, if the base is the policy instrument and monetary transmission is through interest rates, shocks to base demand affect the realized value of nominal output. Nominal output is insulated from this type of shock, however, if the

30. We assume that, even in the case of one target and one instrument, the instrument cannot be varied to offset the influence of all shocks on the target.

policy instrument is the federal funds rate.³¹

The first subsection below briefly describes the structure of the MPS model. The second subsection presents a test of two alternative views of the ways in which monetary actions are transmitted to real output. One view is labeled IR (interest rate) and is represented by the spending block of the MPS model; the other is the DM (direct money) view as specified in equation 3. The latter expresses real GNP growth as a function of lagged GNP growth, and current and lagged values of growth of the real base and real government purchases. Evidence providing some support for the IR view is reported. The final subsections present simulations of the MPS model under alternative policy rules. Compared with McCallum's proposal, the results favor the use of the funds rate as the policy instrument, rather than the base, while considerable support is found for nominal output as a policy target.

The MPS model. The MPS model, which contains roughly 125 estimated equations, 200 identities, and 200 exogenous variables, has been used at the Federal Reserve Board over the past twenty years for forecasting and analyzing alternative economic scenarios. The structure of the model is such that, in the long run, when markets clear and expectations are fulfilled, money is neutral and output is determined by aggregate supply. Short-run properties, however, are quite different: Aggregate demand largely determines the level of output, and the utilization rates of labor and capital may be either below or above their long-run equilibrium values; wages and prices adjust slowly; fiscal policy affects real output directly through the contribution of government spending to aggregate demand and less directly through the effect of tax policy on disposable income and investment incentives; changes in the supply of money affect nominal interest rates and, because inflation expectations are autoregressive, real interest rates, too. There are no direct effects of monetary

31. However, a base-instrument policy may be more effective at tempering the effects of aggregate demand shocks in the short run, because of the response of interest rates necessary to equilibrate base demand and supply. Another issue relevant to the choice of policy instrument is the temporal response of the target to a change in the instrument. Excessive instrument variability may arise if the response pattern grows in magnitude for a period of time, unless the policy rule is carefully designed.

quantities on real spending or prices.³² Rather, changes in money move interest rates, which in turn affect spending directly as well as indirectly through the value of wealth and the exchange rate.³³

Also important to the analysis presented below is the specification of the demand for the monetary base in the MPS model, especially the time profile of the interest elasticity of the demand for the base. For these exercises, the base is assumed to equal the currency component of M1 plus a required reserve ratio times deposits currently subject to reserve requirements--demand and other checkable deposits.³⁴ The structural equations for currency, demand deposits, and other checkable deposits each have estimated contemporaneous interest rate elasticities that are quite low, both in absolute size and in relation to the estimated long-run interest elasticities.³⁵ As illustrated earlier, the magnitude of the contemporaneous interest rate elasticity of base demand greatly affects how well a policy rule that uses the base as an instrument (or as a target, for that matter) performs if the transmission channel is through interest rates.

Finally, the temporal dynamic structure of the MPS model is much more complex than that of any of the other models examined here or by McCallum. Thus, analysis with the MPS model also provides a test of the robustness of McCallum's rule to the degree of dynamic complexity in economic models. In the models that McCallum examines, variables are expressed as growth rates and, as is typical for these types of models, the dynamic structure is rather simple. The MPS model, however, is specified in levels. This approach tends to find

32. Although wealth is a determinant of spending in the model, its influence cannot be interpreted as a real balance effect. A change in the monetary base, absent any accompanying fiscal action that alters the stock of government debt, affects the composition of wealth but not its magnitude.

33. See note 9 for references to the MPS model. In addition, the model's monetary transmission mechanism is examined in Eileen Mausekopf, "The Transmission Channels of Monetary Policy: How Have They Changed?" Federal Reserve Bulletin, vol. 76 (December, 1990), pp. 985-1008.

34. For simplicity, we exclude vault cash and excess reserves from the measure of the base used.

35. The three equations are revised versions of those reported in Moore, Porter, and Small, "Modelling the Disaggregated Demands for M2 and M1: The U.S. Experience in the 1980s," in Peter Hooper and others, editors, Financial Sectors in Open Economies: Empirical Analysis and Policy Issues (Board of Governors of the Federal Reserve System, 1990), pp. 21-105.

significant dynamic adjustments and interactions at medium and low frequencies, besides those at high frequencies.

A Test of the Monetary Transmission Channel. Because of the importance of the nature of the monetary transmission mechanism to the choice of policy instrument, regression tests using the non-nested J test are conducted to compare the IR and DM specifications.³⁶ The test regression employed has the form

$$\Delta y = \beta X_{dm} + \alpha \hat{\Delta y}_{mps}$$

where Δy is real GNP growth, X_{dm} is the set of regressors from the DM equation 3, and $\hat{\Delta y}_{mps}$ is predicted real GNP growth from the demand block of the MPS model.³⁷ β (a vector) and α (a scalar) are coefficients to be estimated. In this form, the equation is a specification test of the DM model against the IR alternative. An estimate of α that is not significantly different from zero would be evidence that the particular representation of DM is not misspecified; an estimate significantly different from zero would indicate misspecification. Although carrying out the corresponding specification test with the IR view as the null hypothesis would be desirable, it would be quite involved, because the demand block of the MPS model is a large set of equations.

Estimates of the test regression are shown in table 4 for the period 1970:Q1-1989:Q4, the longest in-sample span over which the full

36. Davidson and MacKinnon, "Several Tests for Model Specification in the Presence of Alternative Hypotheses," *Econometrica*, vol. 49 (1981), pp. 781-94.

37. The latter is a time series of one-step-ahead forecasts of real GNP growth from the demand block of the MPS model. The demand block includes spending sectors (such as consumption and investment); income, employment and tax equations; and the financial sector (term structure and asset valuation equations). It excludes wage, price, and monetary sectors. Exogenous variables (aside from seasonal factors and fiscal parameters, whose values change only infrequently) are treated as stochastic with values projected using simple time series equations. The one-step-ahead simulations take the value of the federal funds rate as known. This assumption could reduce the variance of the forecasting errors if, historically, the funds rate were adjusted to offset contemporaneous shocks. Given small estimated values of contemporaneous interest elasticities in the model's spending equations, however, problems associated with endogeneity of interest rates cannot be substantial in one-step-ahead forecasts.

set of MPS equations can be simulated. The first column shows the estimates of the DM equation (that is, $\alpha = 0$). Coefficient values are similar to those estimated over other sample periods, shown above in table 2. The J test regression, column ii, estimates α to be significantly greater than zero--the point estimate is 0.60 and the t-statistic is 5.5. Moreover, the base growth coefficients in the regression are jointly insignificant. At a minimum, these results suggest that the IR demand specification in the MPS model provides an alternative to the simple DM equation that cannot be rejected.³⁸

The Federal Funds Rate Versus the Base as Policy Instruments: An Illustrative Simulation. To illustrate the properties of the MPS model under alternative policy instruments, while keeping nominal output as the policy target, we conduct two simulations involving a transitory downward shock of \$25 billion to real federal government purchases. One simulation incorporates McCallum's proposed base-instrument rule, but omits the velocity adjustment term because the design of the simulation precludes any permanent shifts to velocity. The other uses the federal funds rate as the policy instrument. In each case, the MPS model is adjusted so that it tracks historical values in the absence of shocks, and thus the target for nominal GDP is set equal to its historical path.³⁹

In the case of McCallum's rule, instability is quickly apparent, and the model solves for only five quarters. The path for the federal funds rate is (deviations from historical values, in percentage points): -0.53, -1.06, 4.24, -6.71, and 126.40. This instability, we believe, stems from the temporal pattern of the interest elasticity of base demand in the MPS model, described above.

38. Problems with bias and serial correlation of errors are found in the one-step-ahead forecasts of the MPS demand block, however. Although not directly relevant to the present analysis, earlier work indicated that there might be a small omitted direct channel from money (M2) to wages and prices in the MPS model. See Albert Ando, Flint Brayton, and Arthur Kennickell, "Reappraisal of the Phillips Curve and Direct Effects of Money Supply on Inflation," in Lawrence R. Klein, ed., Comparative Performance of U.S. Econometric Models (Oxford University Press, 1991), pp. 201-26.

39. The simulation runs from 1985:Q1 to 1991:Q4. The magnitude of the government purchases shock is equal to 0.6 percent of the baseline value of real GDP in the quarter in which the shock is introduced (1985:Q2).

We conjecture that altering the adjustment parameter (λ) in the policy rule would be unlikely to alter significantly the simulation results. We have not attempted to see if modifications to either the rule or the model would achieve a stable result.

The same shock to government spending is well controlled by a policy that targets the level and growth rate of nominal GDP but uses the federal funds rate as the instrument. (The next section describes the specific form of the rule.) The time profiles of the funds rate, nominal GDP, and its real and price components are plotted in chart 11. The funds rate falls initially as both the level and growth of nominal GDP are below baseline. Subsequently, the growth component of the target turns positive, and pushes the funds rate above baseline for a short period. All significant deviations of the instrument and target are completed within a year or so, although small oscillations in each persist for several years.

Alternative Policy Targets. Although his research has focused on nominal GDP as the target of policy, McCallum has also reported some tests of price level targeting.⁴⁰ In this final section, we use stochastic simulations of the MPS model to evaluate the two targets he has examined--nominal output and the price level--as well as M2.⁴¹ Because of the evidence of instability of base-instrument policies in the MPS model, the simulations take the federal funds rate as the policy instrument.

The stochastic simulation procedure used involves the repeated simulation of the model with randomly drawn additive shocks applied in each quarter to all estimated equations and more than 100 exogenous variables. Each policy analyzed is subjected to a sample of 180 twenty-quarter simulations, each differing by only the particular values of the random quarterly shocks that are applied. The shocks

40. McCallum, "Targets, Indicators, and Instruments of Monetary Policy."

41. In this analysis, nominal output, the price level and the M2 money stock are intermediate policy targets. As discussed below, the ultimate objectives, or goals, of policy are assumed to be stabilization of the price level and real output. Metrics employed to compare different policies are measures of variability of the price level and real output.

are based on actual historical errors.⁴²

For each policy, the federal funds rate, r , is adjusted in response to movements of the level and the four-quarter growth rate of the target, t_i :⁴³

$$r_t = \alpha_1 \hat{t}_{i,t} + \alpha_2 (\hat{t}_{i,t} - t_{i,t-4}).$$

Values of the instrument and targets are measured as deviations from a deterministic baseline simulation. The '^' denotes that current-quarter values of targets may be estimates, depending on the information lag assumed for each target. For nominal GDP and the GDP deflator, the information lag is assumed to be one-half quarter and, in these instances, $\hat{t}_{i,t}$ is measured as the average of values in the current and immediately preceding quarters. M2 is assumed to be known contemporaneously. For each target, we use a coarse grid search to find the values of the feedback coefficients that minimize a simple policy loss function, constructed as the unweighted average of the variances of the levels of real GDP and the GDP deflator (relative to values in the deterministic baseline).⁴⁴

Table 5 presents a summary of stochastic simulation results. To compare the ways alternative targets would perform over an extended period, we take the reported standard deviations from the fifth, and last, year of the stochastic simulations. Irrespective of whether targets are compared on the basis of standard deviations of real GDP,

42. The simulation procedure used by McCallum, and employed elsewhere in this paper, can be interpreted as one long stochastic simulation in which errors are drawn in their historical sequence. Other analyses of monetary policy rules using the MPS model and the stochastic simulation procedures described in this section are reported in Flint Brayton, William Kan, Peter Tinsley and, Peter von zur Muehlen, "Modeling and Policy Use of Auction Price Expectations," in Ralph Bryant and others, Evaluating Policy Regimes: New Research in Empirical Macroeconomics (The Brookings Institution, forthcoming), and in Flint Brayton and Peter Tinsley, "Interest Rate Feedback Rules of Price Level Targeting," unpublished manuscript, Board of Governors of the Federal Reserve System, Division of Research and Statistics, October, 3, 1991. The material in this section draws heavily on the latter reference.

43. The addition of the growth rate term was found to significantly improve the performance of the policies studied.

44. For the M2 and price level policies, however, the grid search yielded a sort of corner solution: If the policy feedback coefficients were increased beyond those reported, a substantial number of simulations failed to converge.

the GDP deflator or nominal GDP, the ranking of targets places nominal GDP first, M2 second, and price level last.⁴⁵ For the nominal GDP and M2 policies, the policy rule appears to be stable: The profile across the simulation interval of standard deviations (not shown) appears to level off in the fifth year. For the price target policy, standard deviations over the simulation horizon tend to increase by ever larger amounts, indicating that the policy is probably unstable.

The dominant performance of the nominal GDP target is relatively straightforward to explain. Nominal GDP has two advantages over an M2 target: First, it is more closely related to the assumed ultimate goals of policy--stability of the price level and of real output; And second, with an interest rate instrument, it is unaffected by shocks to money demand. It performs better than a price level because it requires the policy instrument to respond to deviations of both real output and price from their desired values. If the goal of policy is to control both types of deviations, a target that incorporates elements of each goal is likely to work better than one that does not. Moreover, direct policy responses to offset demand shocks help control prices, because output deviations are an important determinant of subsequent price movements in the MPS model and demand shocks are estimated to be quantitatively more significant than price shocks. Thus, the nominal GDP target provides better control over the price level than does a policy that targets prices directly.⁴⁶

Besides comparing results of alternative policies with each other, we can see how well the policies work in relation to measures of historical volatility. As table 5 shows, only the policy based on the nominal GDP target has a standard deviation of the unemployment rate that is similar in magnitude to the historical variation in this series. This finding seems to imply that stationarity of the price level could be achieved with no more variability of real activity than that observed historically. However, the volatility of quarterly changes in the funds rate, under the reported nominal GDP target policy, is somewhat higher than the historical standard deviation.

45. The policy ranking also is unaffected if the policy feedback parameters are varied over a wide range.

46. This statement holds only for relatively simple policy rules, such as the one examined here. A price target policy with a much more complex dynamic structure should be able to overcome the instability found for the price target rule examined here.

CONCLUSION AND SUMMARY

This paper has examined McCallum's proposed base-instrument rule for targeting nominal output in the context of two classes of economic models. The first class specifies a direct link between the monetary base and spending. In the second, the monetary transmission mechanism operates through interest rates. Within each class, several different models are examined. The paper reaches three main conclusions:

1 The relationship between the monetary base and nominal output seems to have weakened significantly in the past decade. This weakening brings into question the ability of a policy using the monetary base as the instrument to control nominal output effectively. In the sequence of models examined, the deterioration of the link between the base and output is shown to lie mainly within the aggregate demand side of the economy, with the base demand equation exhibiting a shift in the growth rate of velocity and large errors over the past decade.

2 In models in which the transmission mechanism of monetary policy is through interest rates, the ability of McCallum's' base-instrument policy to control nominal output is found to be very sensitive to the lag structure of (a) the interest rate sensitivity of base demand and (b) the speed with which changes in short-term interest rates are transmitted to spending through long rates. In an analysis with a small model, the degree of control over nominal output that McCallum's rule achieves is comparable to that found in the models with a direct link between the base and output only if the interest responsiveness of base demand is nearly contemporaneous and if the lag between the long-term interest rate and the short-term rate is very short. Additional tests in which a forward-looking term structure is introduced show some further improvement in control.

3 In experiments with the MPS model, results favor the use of the federal funds rate as the policy instrument; the lagged responses in the model's structure are such to make McCallum's base-instrument policy unstable. With the funds rate instrument, however, considerable support is found for using nominal income as a policy target, compared with using either M2 or the price level.

Finally, we note that in his comments appearing next in this volume, McCallum indicates that he was unsuccessful in attempting to replicate some of our results. With a version of his original ADAS model that approximates our ADAS model and with his base-instrument rule, McCallum found a less severe deterioration in economic performance as the sample period is extended over the last decade. We believe our results to be correct, and in footnote 13 have discussed them in light of McCallum's comments.

1. McCallum's Nominal Aggregate Demand Function

$$\Delta x_t = \alpha_0 + \alpha_1 \cdot \Delta x_{t-1} + \alpha_2 \cdot \Delta b_t + \alpha_3 \cdot \text{DUMM} + \alpha_4 \cdot \text{DUMM} \cdot \Delta b_t + e_{xt}$$

	(i)	(ii)	(iii)
α_0	.008 (.002) ***	.008 (.002) ***	.007 (.002) ***
α_1	.265 (.082) ***	.341 (.074) ***	.260 (.074) ***
α_2	.476 (.135) ***	.306 (.120) ***	.540 (.150) ***
α_3			.003 (.003)
α_4			-.496 (.231) **
Adj-Rsq.	.219	.188	.237
SEE	.010	.010	.009
RMSD	.020	.024	.057
Durbin's h	-1.43	-1.45	-1.54 ***
F(α :3,4)			11.72
F(α :2,4)			0.03
Chow	.74	.67	
Est. Range	1954:1-85:4	1954:1-92:1	1954:1-92:1

Adj-Rsq.: Adjusted R-squared.

*, **, ***: Significant at or below the 10 percent, 5 percent and 1 percent level, respectively.

RMSD : Root Mean Squared Deviation.

Durbin's h: Test for serial correlation with lagged dependent variables.

SEE: Standard error of the estimate.

Standard errors are heteroskedasticity consistent.

DUMM = 1 from 1982:Q1 to the end of the sample period, = 0 otherwise.

CHOW: Tests for a structural break for all coefficients in 1982:1.

F(α :3,4) is the F-test statistic for the hypothesis that $\alpha_3 = \alpha_4 = 0$.

F(α :2,4) is the F-test statistic for the hypothesis that $\alpha_2 + \alpha_4 = 0$.

2. McCallum's ADAS Model (continued on next page)

$$\text{Aggregate Demand: } \Delta y_t = \delta_0 + \delta_1 \Delta y_{t-1} + \delta_2 \Delta(b-p)_t + \delta_3 \Delta(b-p)_{t-1} + \delta_4 \Delta g_t + \delta_5 \Delta g_{t-1} + \delta_6 \text{DUMM} + \delta_7 \text{DUMM} \cdot \Delta(b-p)_t + \delta_8 \text{DUMM} \cdot \Delta(b-p)_{t-1} + e_{yt}$$

	With Non-neutral supply side		With neutral supply side		
	(i)	(ii)	(iii)	(iv)	(v)
δ_0	*** .004 (.001)	*** .004 (.001)	Same as Column (i) ^{a/}	Same as Column (ii) ^{a/}	.005 (.001)
δ_1	*** .263 (.088)	*** .320 (.085)			.268 (.083)
δ_2	*** .160 (.132)	** .025 (.125)			.223 (.146)
δ_3	*** .398 (.120)	** .294 (.107)			.408 (.135)
δ_4	*** .190 (.055)	*** .175 (.050)			.184 (.049)
δ_5	*** -.180 (.054)	*** -.151 (.051)			-.154 (.048)
δ_6					-.001 (.001)
δ_7					-.564 (.218)
δ_8					-.067 (.213)
Adj-Rsq.	.259	.208			.250
SEE	.009	.009			.010
Durbin's h	-1.02	-1.03			-1.11***
F($\delta:6,7,8$)					3.76
F($\delta:2,3,7,8$)					.50
CHOW	.54	.60			.60
RMSD	.019	.032	.019	.050	.056
Est. Range	1954:1-85:4	1954:1-92:1	1954:1-85:4	1954:1-92:1	1954:1-92:1

a/ The models of columns iii and iv differ from those of columns i and ii respectively in terms of their wage and price equations.

*, **, ***: Significant at or below the 10%, 5% and 1% level, respectively.

RMSD: Root Mean Squared Deviation for the full model.

Standard errors are heteroskedasticity consistent.

DUMM = 1 from 1982:1 to the end of the sample period, = 0 otherwise.

CHOW: Tests for a structural break for all coefficients in 1982:1.

F($\delta:6,7,8$): F-test statistic for $H_0: \delta_6 = \delta_7 = \delta_8 = 0$.

F($\delta:2,3,7,8$): F-test statistic for $H_0: \delta_2 + \delta_3 + \delta_7 + \delta_8 = 0$.

2. McCallum's ADAS Model (continued)

$$\text{WAGES: } \Delta w_t = \beta_0 + \beta_1 (y_t - y_t^f) + \beta_2 (y_{t-1} - y_{t-1}^f) + \beta_3 \Delta p_t^e + e_{wt}$$

	With Non-neutral supply side		With neutral supply side		(v) Same as Column (i)
	(i)	(ii)	(iii)	(iv)	
β_0	.004 (.001)	.002 (.001)	.002 (.001)	.001 (.001)	
β_1	.212 (.047)	.217 (.044)	.231 (.046)	.230 (.041)	
β_2	-.141 (.047)	-.140 (.045)	-.155 (.046)	-.150 (.058)	
β_3	.827 (.067)	.876 (.067)	1.0	1.0	
Adj-Rsq.	.542	.549	.544	.551	
SEE	.005	.005	.005	.005	
D-W	1.81	1.62	1.72	1.59	

$$\text{PRICES: } \Delta p_t = \gamma_0 + \gamma_1 \Delta w_t + \gamma_2 \Delta p_{t-1} + \gamma_3 \Delta p_{t-2} + e_{pt}$$

					(v) Same as Column (i)
	(i)	(ii)	(iii)	(iv)	
γ_0	-.001 (.001)	.001 (.001)	-.001 (.001)	-.001 (.001)	
γ_1	.428 (.055)	.384 (.050)	.446 (.058)	.408 (.052)	
γ_2	.180 (.081)	.202 (.077)	.189 (.078)	.222 (.074)	
γ_3	.350 (.060)	.342 (.058)	.365 (.058)	.371 (.055)	
Adj-Rsq.	.728	.718	.731	.720	
SEE	.004	.003	.004	.003	
Durbin's h	-1.70	-1.24	-2.01	-1.70	

Est. Range	1954:1-1985:4	1954:1-1992:1	1954:1-1985:4	1954:1-1992:1	1954:1-1992:1

a/ The model of column v differs from that of column iv in terms of the aggregate demand function.

Small, Hess and Brayton

3. Decomposition of RMSD for the ADAS Model^{a/}

	(i)	(ii)	(iii)
<u>RMSD</u>			
<u>Shocks</u>			
All	.0195	.0497	.0260
Agg. Demand	.0200	.0333	.0251
Agg. Supply	.0058	.0168	.0099
None	.0046	.0158	.0061
Value for λ	.25	.25	.50
Sum of the est. base coefficients (t-statistic)	.5587 (4.294)	.3182 (3.063)	.3182 (3.063)
Estimation Range	1954:1-1985:4	1954:1-1992:1	1954:1-1992:1

^{a/} Column i uses the model of column iii of table 2; columns ii and iii use the model from column iv of table 2.

4. Tests of the Monetary Transmission Channel

$$\Delta y_t = \beta_0 + \beta_1 \Delta y_{t-1} + \beta_2 \Delta(b-p)_t + \beta_3 \Delta(b-p)_{t-1} + \beta_4 \Delta g_t + \beta_5 \Delta g_{t-1} + \alpha \hat{\Delta y}_{mps,t}$$

	(i)	(ii)
β_0	.004 ^{***} (.001)	.007 ^{***} (.001)
β_1	.209 ^{**} (.104)	.009 (.095)
β_2	.162 (.150)	-.069 (.134)
β_3	.400 ^{***} (.155)	.185 (.137)
β_4	.147 (.115)	.244 ^{***} (.099)
β_5	-.278 ^{***} (.116)	-.174 [*] (.100)
α	-	.596 ^{***} (.108)
Adj.-Rsq.	.235	.452
SEE	.0089	.0075
Durbin Watson	2.05	1.91
Durbin's h	-.56 ^{***}	.73
F($\beta:2.3$)	7.40	.92

Est. Range: 1970:Q1 - 1989:Q4

Standard errors in parentheses

Adj.-Rsq: Adjusted R-squared

F($\beta:2.3$): F-test statistic for H0: $\beta_2 = \beta_3 = 0$.

*,**,***: Significant at or below the 10%, 5% and 1% level, respectively.

5. Stochastic Simulation of Alternative Policy Targets^{a/}

	Policy target			Historical standard deviation ^{b/}
	Nominal GDP	M2	GDP deflator	
Policy feedback coeff's (α_1, α_2)	(25,100)	(150,300)	(5.50)	
Information delay (quarters)	0.5	0	0.5	
Standard deviations: ^{c/} (levels, except as noted)				
real GDP	3.91	5.08	7.11	-
GDP deflator	4.19	5.78	10.12	-
nominal GDP	3.03	5.85	12.25	-
federal funds rate				
quarterly change		2.34	1.44	0.42 1.69
level	4.06	3.18	2.49	-
unemployment rate	1.47	2.33	3.30	1.57
M2	4.11	2.09	9.38	-

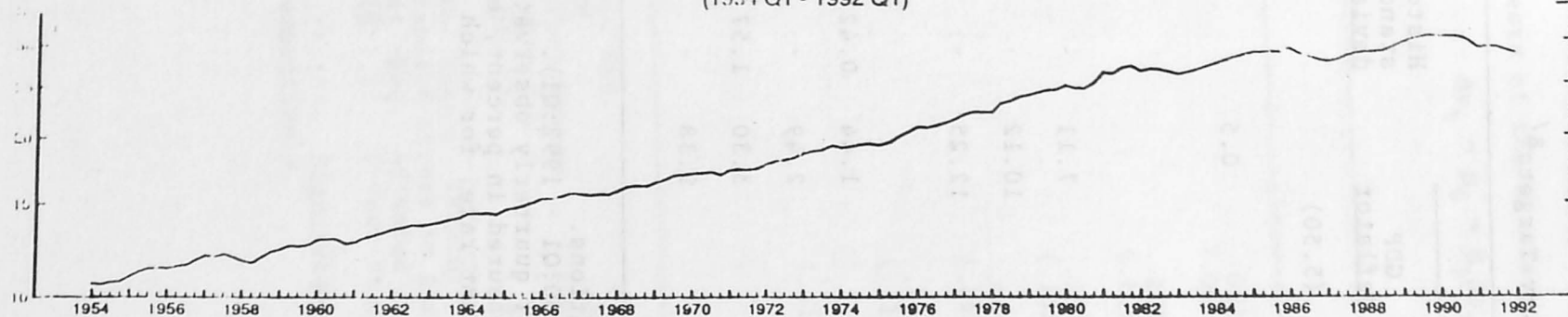
a/ Based on 180 20-quarter stochastic simulations.

b/ Calculated for stationary series only (1960:Q1 - 1992:Q1).

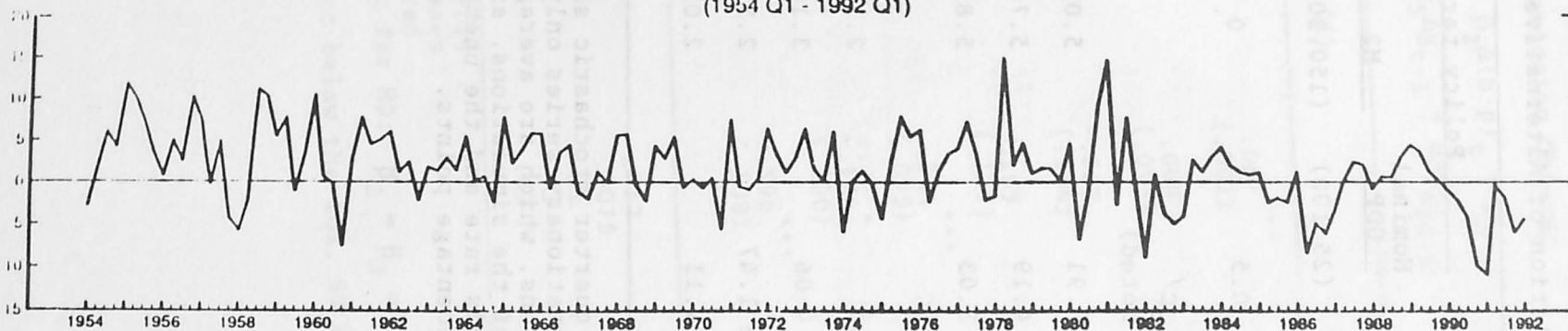
c/ Standard deviations, which are averages of quarterly observations in the fifth year of the simulations, are measured in percent, except for the federal funds rate and the unemployment rate, for which they are measured in percentage points.

Chart 1

Base Velocity
(1951 Q1 - 1992 Q1)



Growth of Base Velocity
(1954 Q1 - 1992 Q1)



Growth of Nominal Income and St. Louis Base
(1954 Q1 - 1992 Q1)

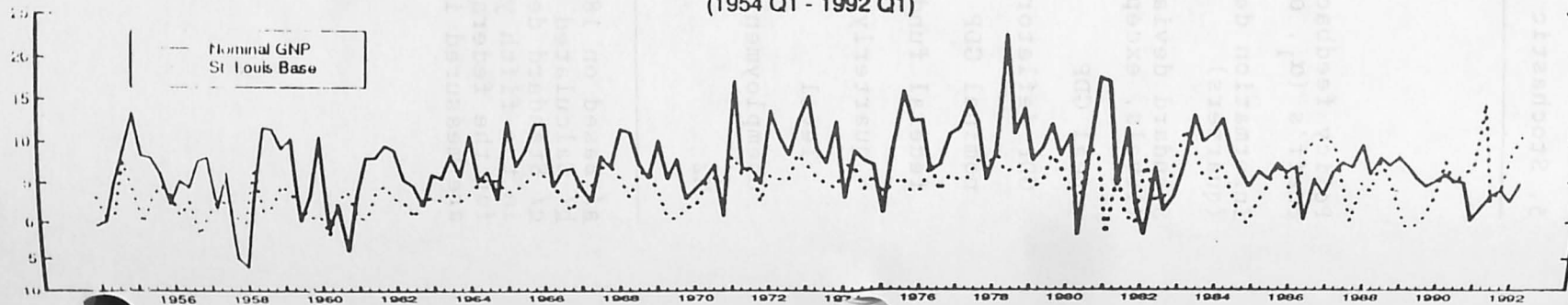
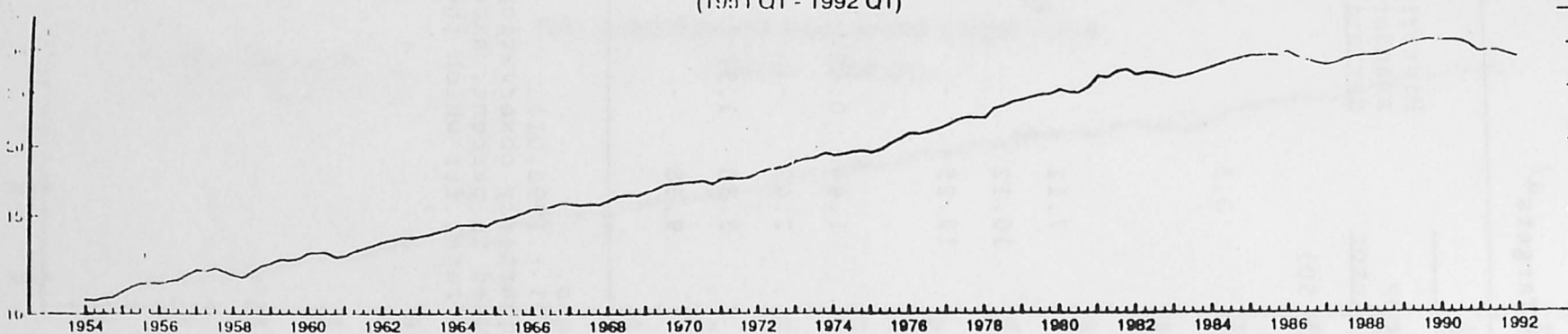


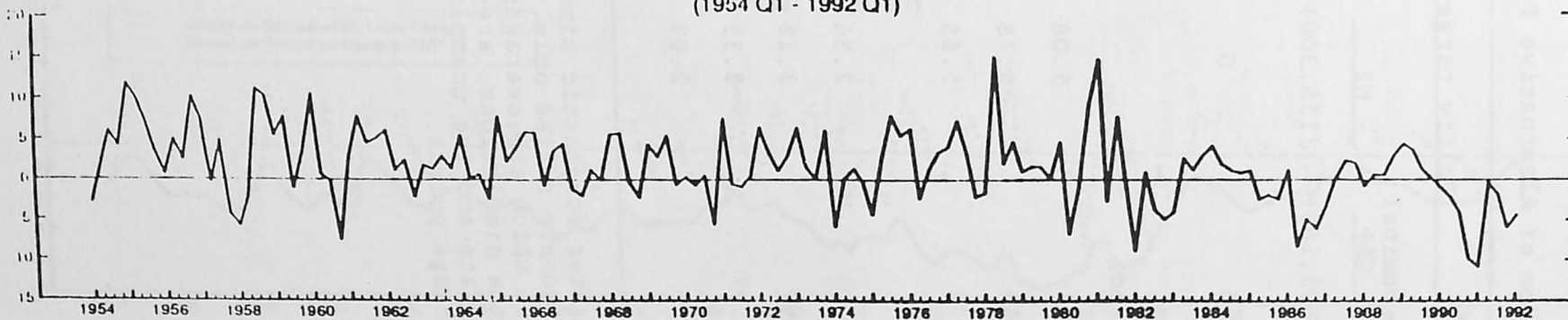
Chart 1

Chart 1

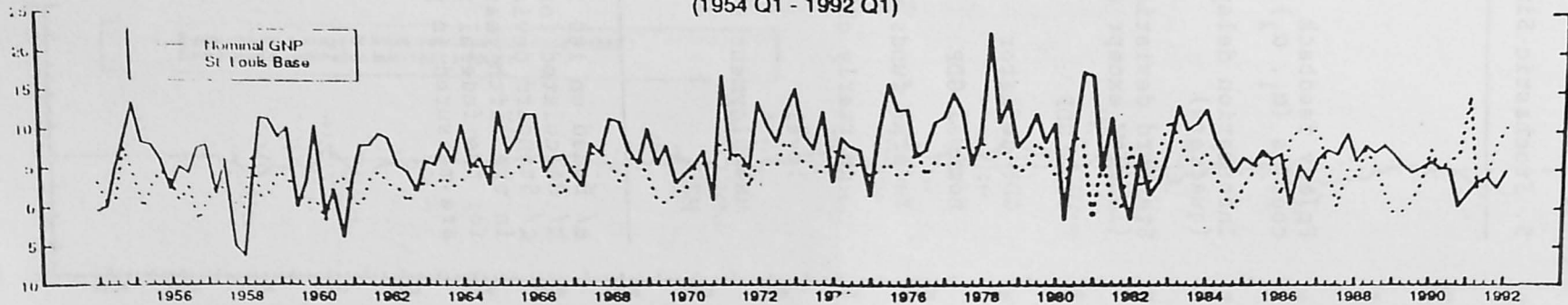
Base Velocity
(1951 Q1 - 1992 Q1)



Growth of Base Velocity
(1954 Q1 - 1992 Q1)



Growth of Nominal Income and St. Louis Base
(1954 Q1 - 1992 Q1)



5. Stochastic Simulation of Alternative Policy Targets^{a/}

	Policy target			Historical standard deviation ^{b/}
	Nominal GDP	M2	GDP deflator	
Policy feedback coeff's (α_1, α_2)	(25.100)	(150,300)	(5.50)	
Information delay (quarters)	0.5	0	0.5	
Standard deviations: ^{c/} (levels, except as noted)				
real GDP	3.91	5.08	7.11	-
GDP deflator	4.19	5.78	10.12	-
nominal GDP	3.03	5.85	12.25	-
federal funds rate				
quarterly change		2.34	1.44	0.42 1.69
level	4.06	3.18	2.49	-
unemployment rate	1.47	2.33	3.30	1.57
M2	4.11	2.09	9.38	-

a/ Based on 180 20-quarter stochastic simulations.

b/ Calculated for stationary series only (1960:Q1 - 1992:Q1).

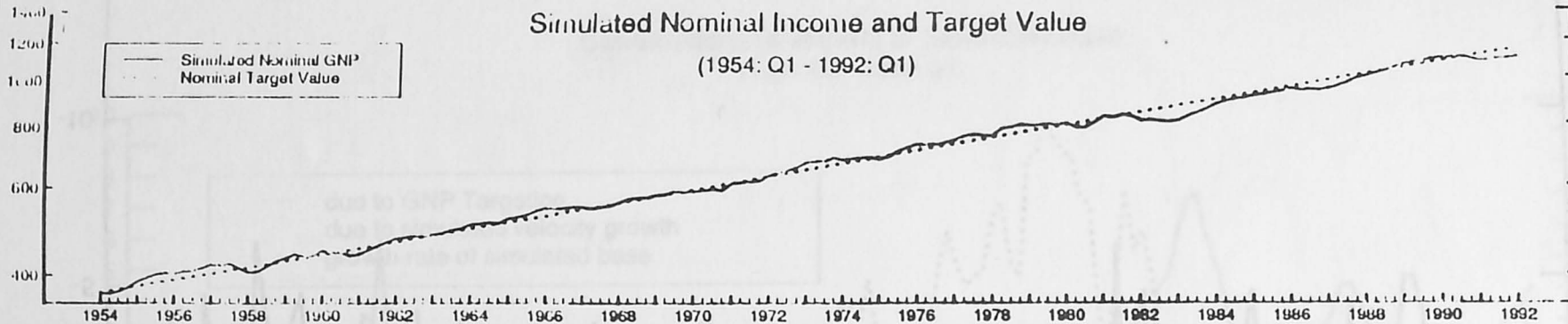
c/ Standard deviations, which are averages of quarterly observations in the fifth year of the simulations, are measured in percent, except for the federal funds rate and the unemployment rate, for which they are measured in percentage points.

Chart 2

Nominal Aggregate Demand Model

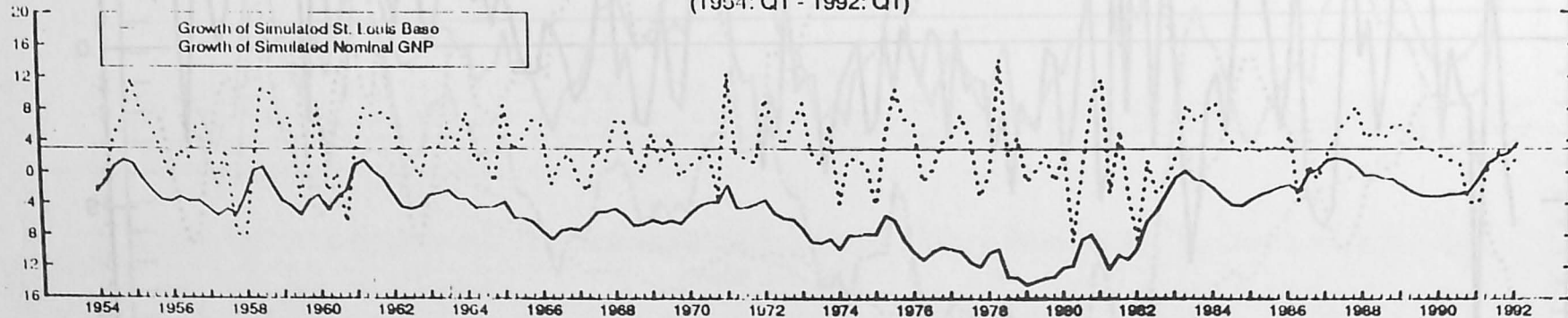
Simulated Nominal Income and Target Value

(1954: Q1 - 1992: Q1)



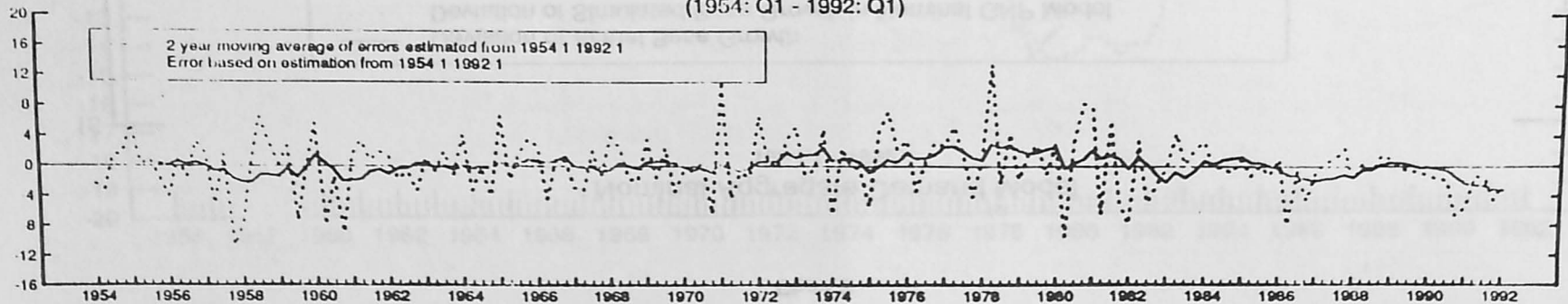
Growth of Simulated Nominal Income and Simulated St. Louis Base*

(1954: Q1 - 1992: Q1)



Errors and 2 Year Moving Average of Errors from Nominal Income Equation

(1954: Q1 - 1992: Q1)



Horizontal line at 3 percent indicates targeted long run value of Nominal GNP Growth.

Nominal Aggregate Demand Model

1954:1 - 1992:1

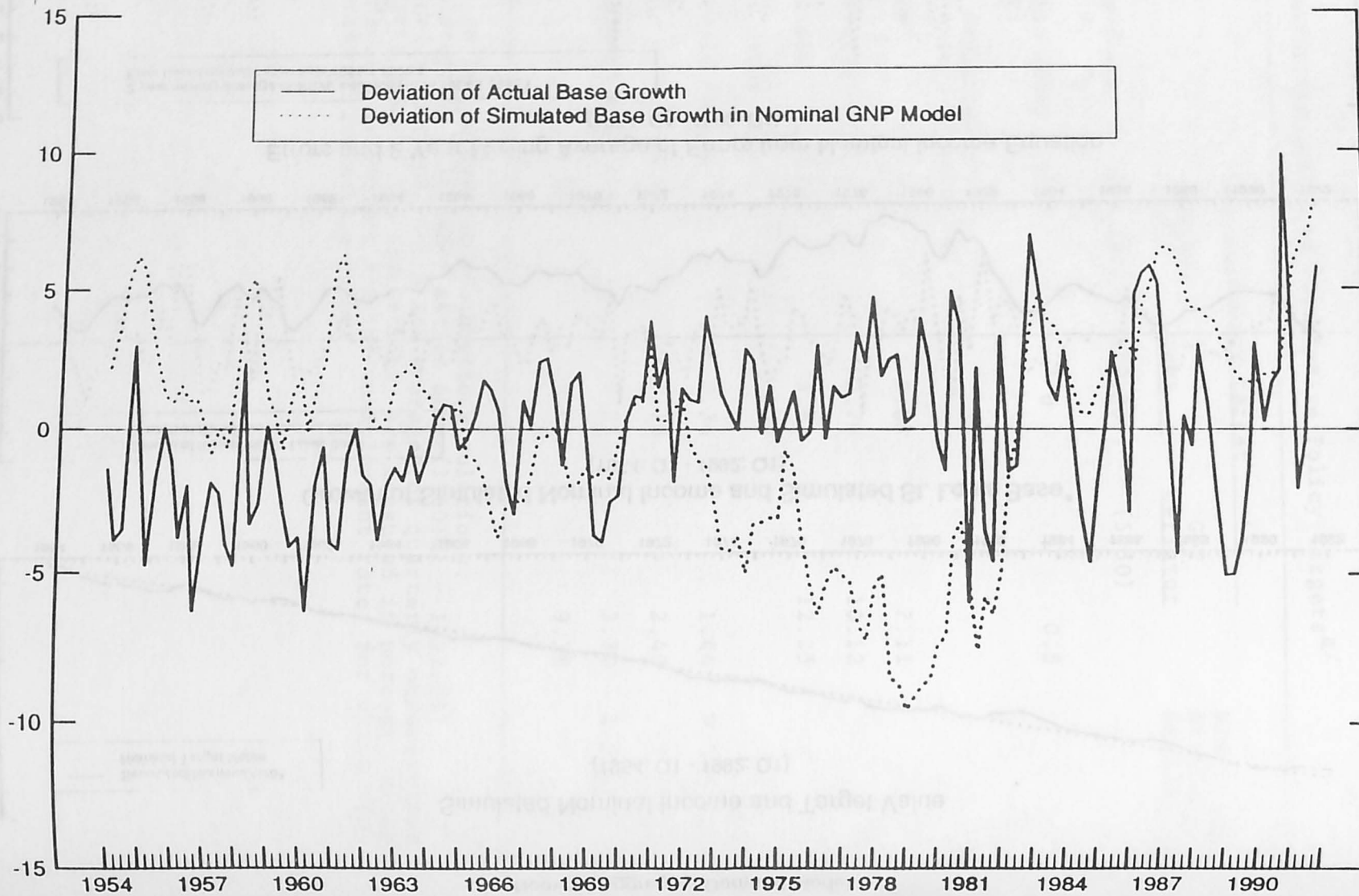


Chart 4

Nominal Aggregate Demand Model

Contributions to Growth of Simulated Base
(1956: Q2 - 1992: Q1)

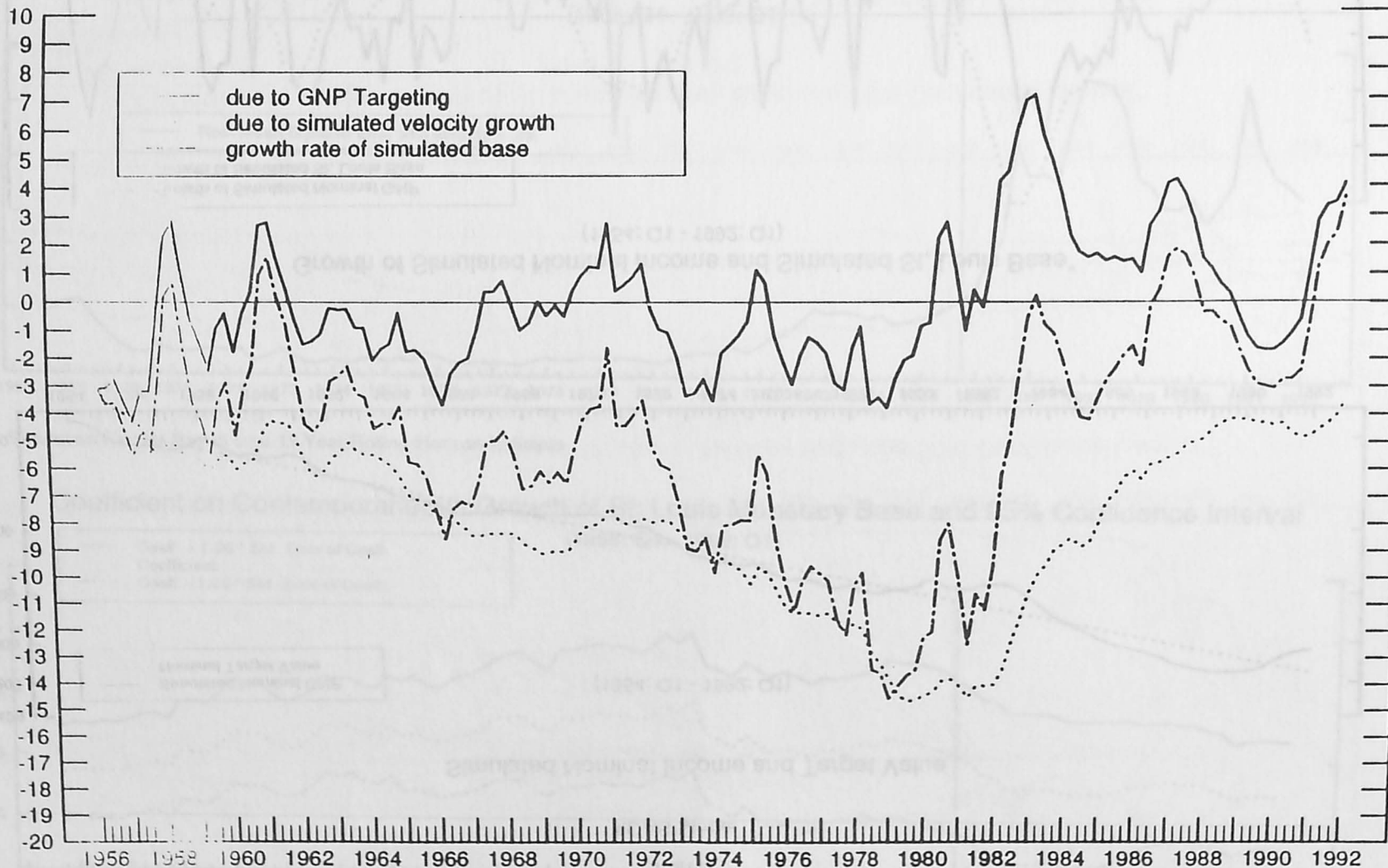
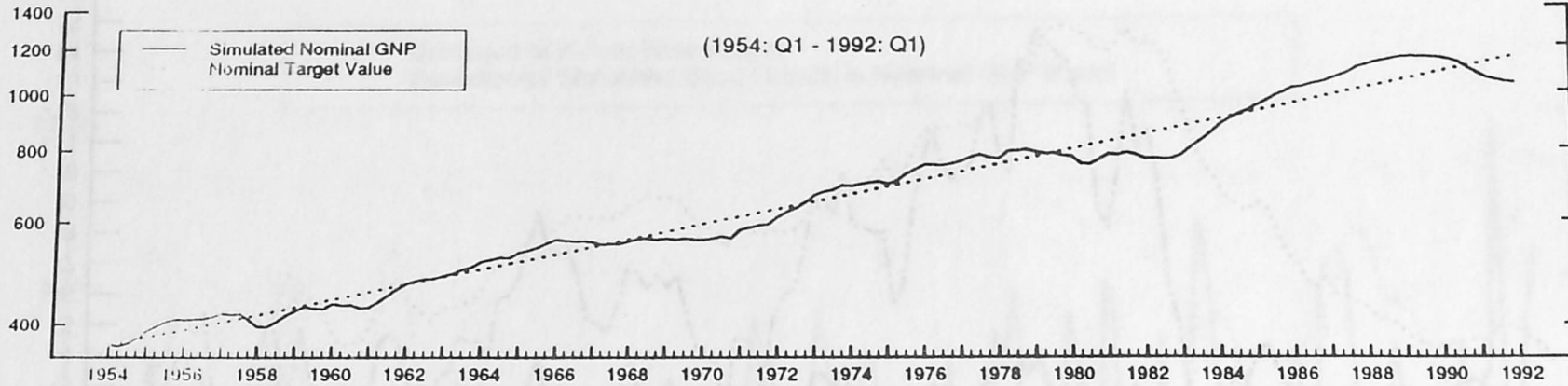


Chart 5

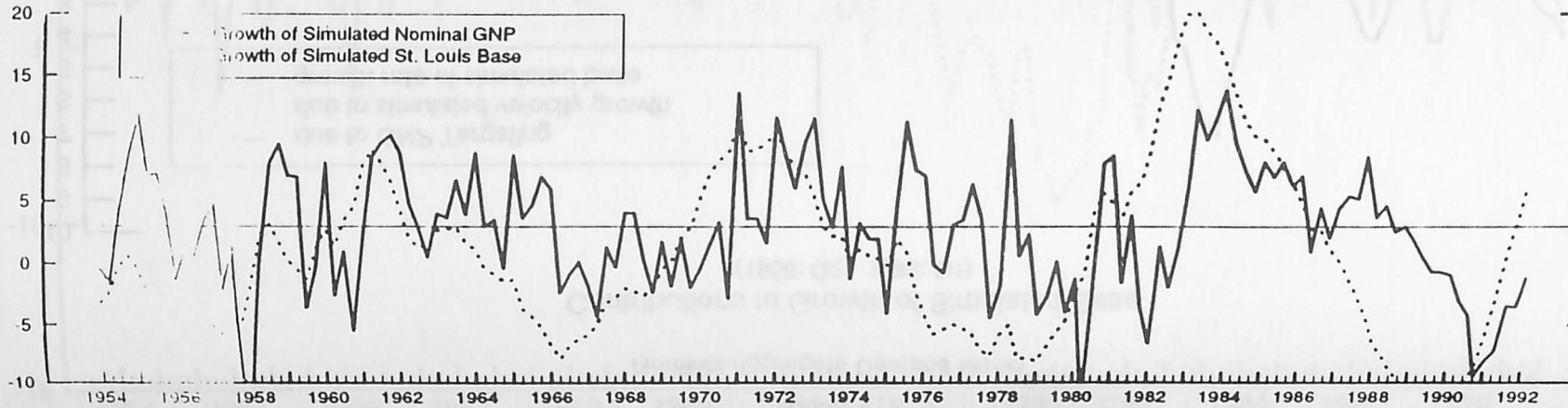
ADAS Model

Simulated Nominal Income and Target Value



Growth of Simulated Nominal Income and Simulated St. Louis Base*

(1954: Q1 - 1992: Q1)

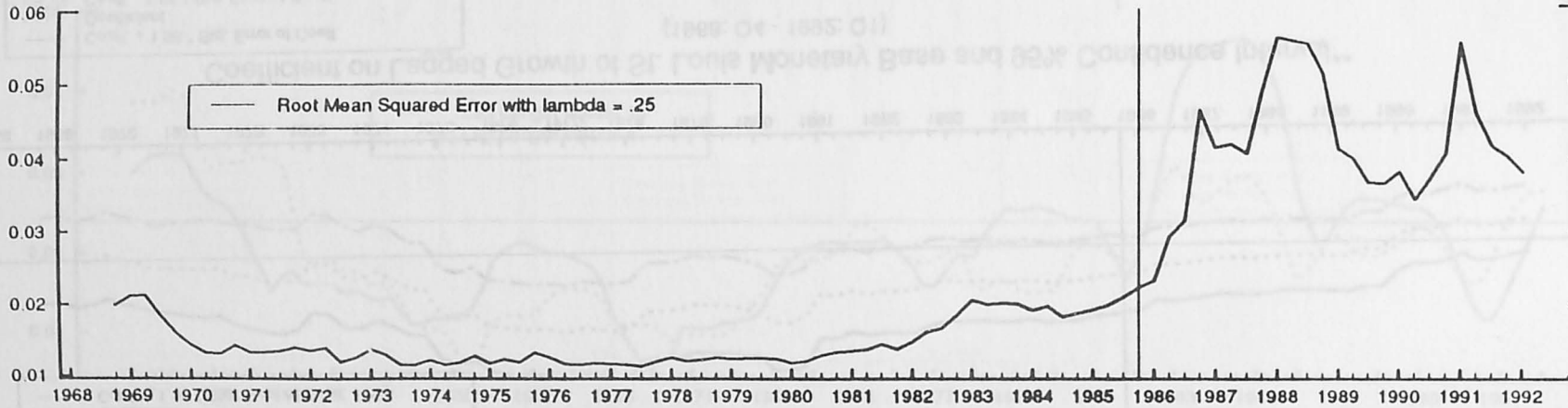


Horizontal line at 2 percent indicates targeted long-run value of Nominal GNP Growth.

Chart 6

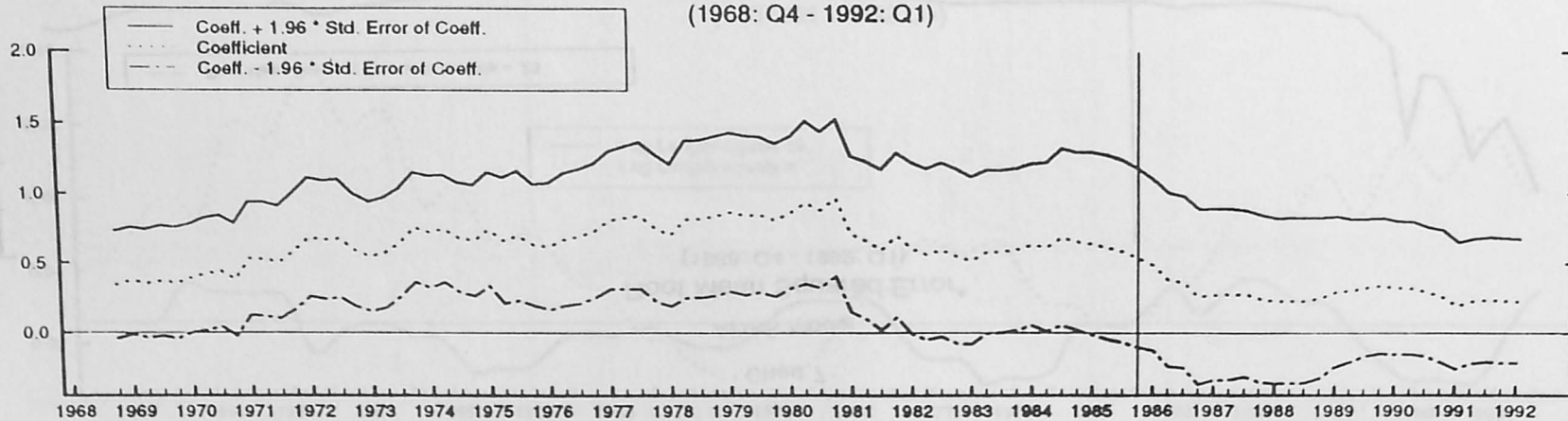
The Nominal Aggregate Demand Model

Root Mean Squared Error
(1968: Q4 - 1992: Q1)



Simulation Results Based on a 15 Year Rolling-Horizon Estimate

Coefficient on Contemporaneous Growth of St. Louis Monetary Base and 95% Confidence Interval
(1968: Q4 - 1992: Q1)

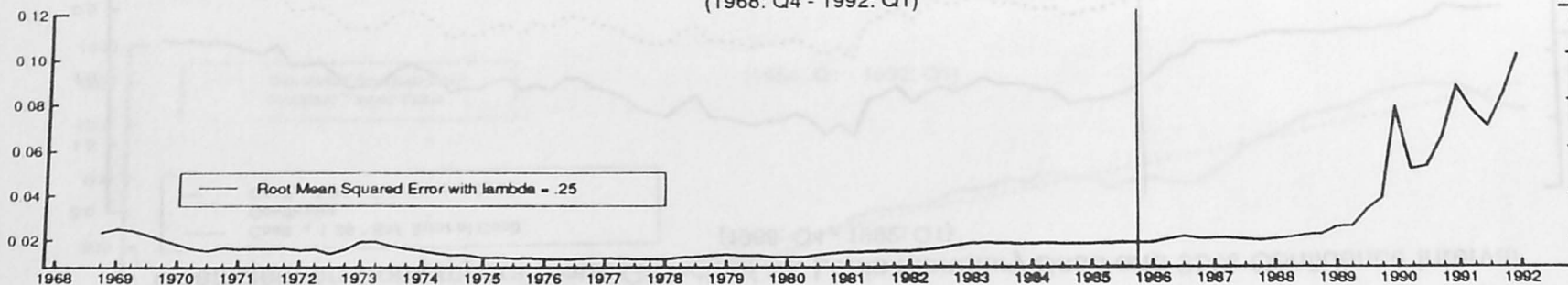


Regression Results Based on a 15 Year Rolling-Horizon Estimate

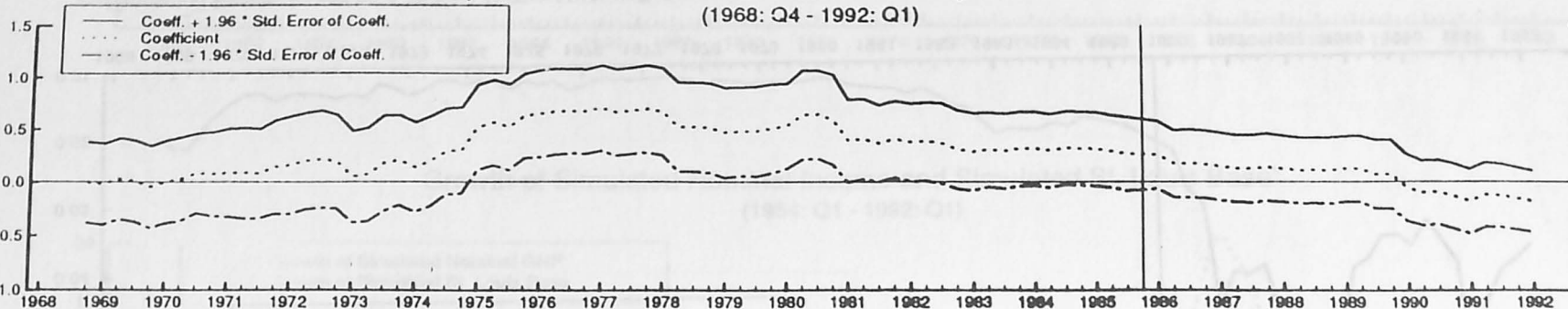
Chart 7

ADAS Model

Root Mean Squared Error*
(1968: Q4 - 1992: Q1)



Coefficient on Contemporaneous Growth of St. Louis Monetary Base and 95% Confidence Interval**
(1968: Q4 - 1992: Q1)



Coefficient on Lagged Growth of St. Louis Monetary Base and 95% Confidence Interval**
(1968: Q4 - 1992: Q1)

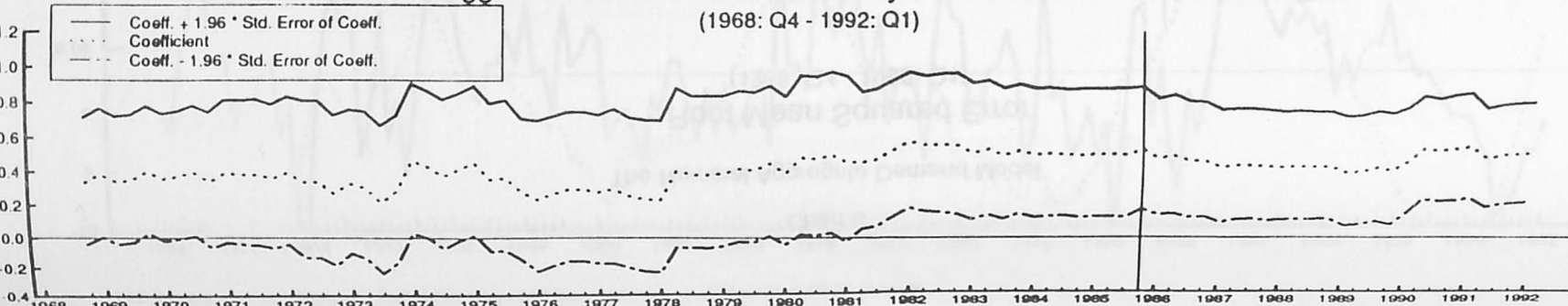
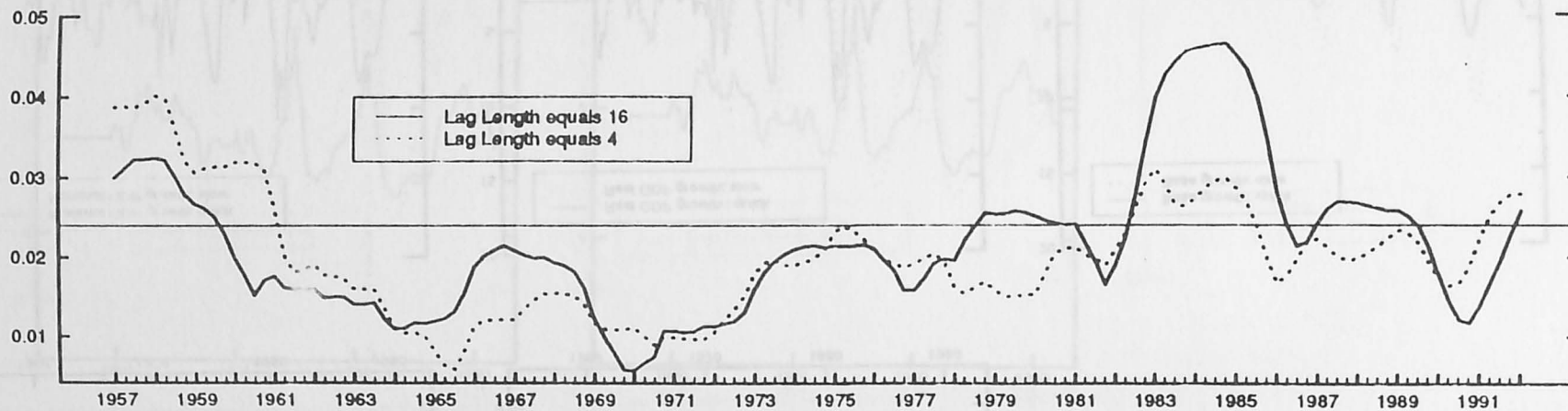


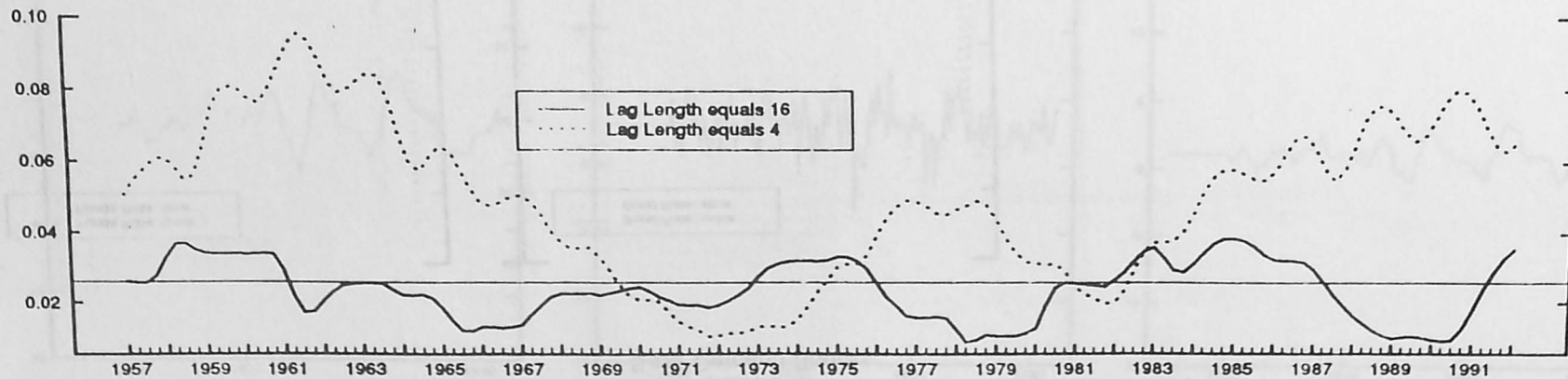
Chart 8

Root Mean Squared Error Calculated Over Three Year Time Span Ending at Indicated Date
(1957 Q1 - 1992 Q1)



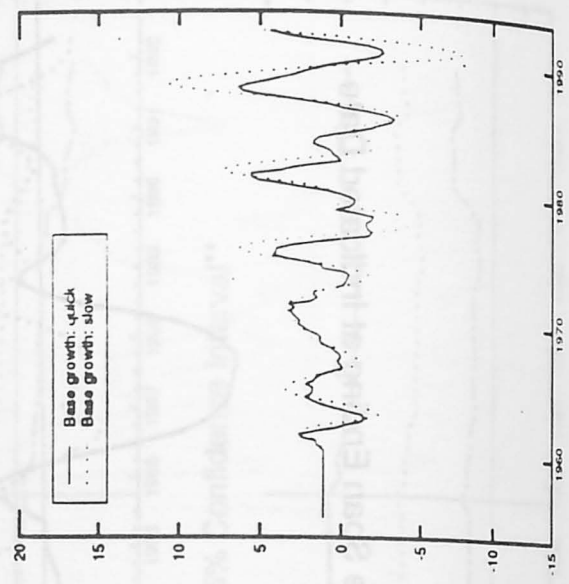
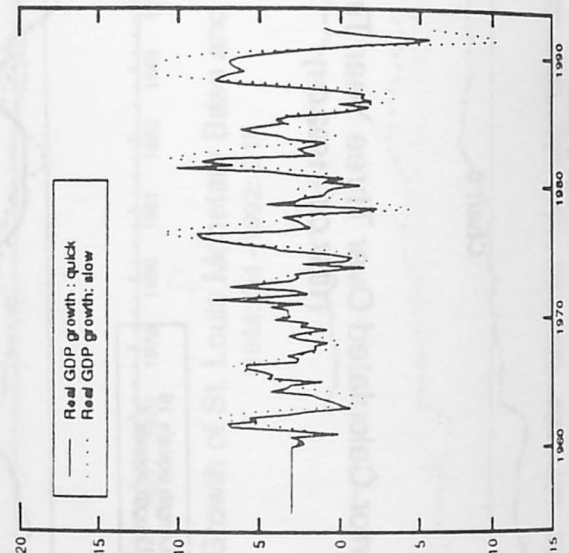
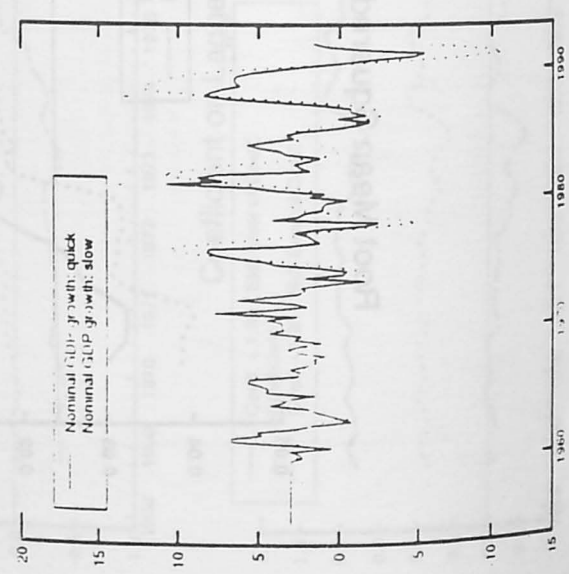
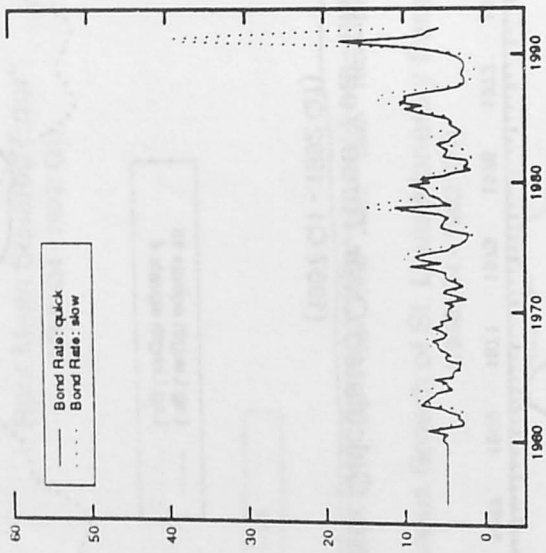
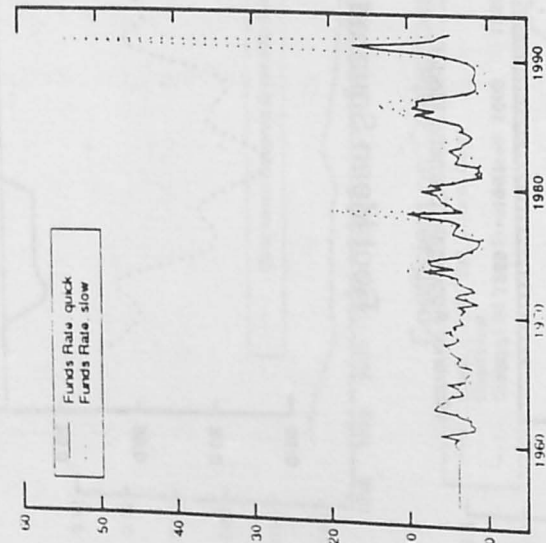
Nominal Aggregate Demand Model

Root Mean Squared Error Calculated Over Three Year Time Span Ending at Indicated Date
(1957 Q1 - 1992 Q1)



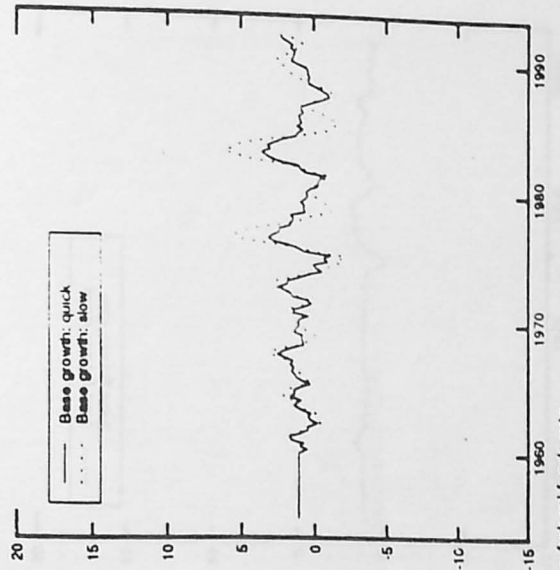
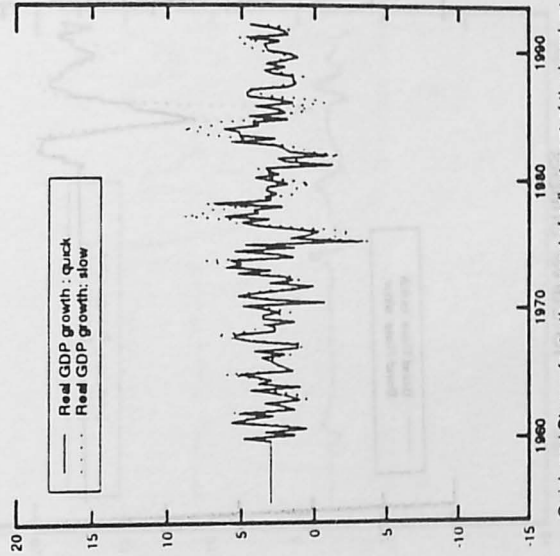
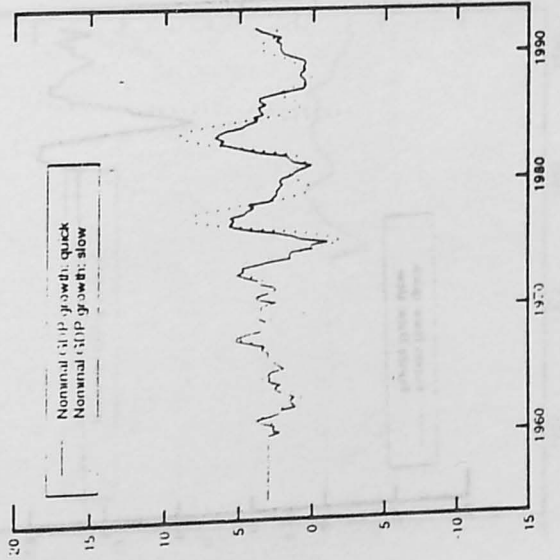
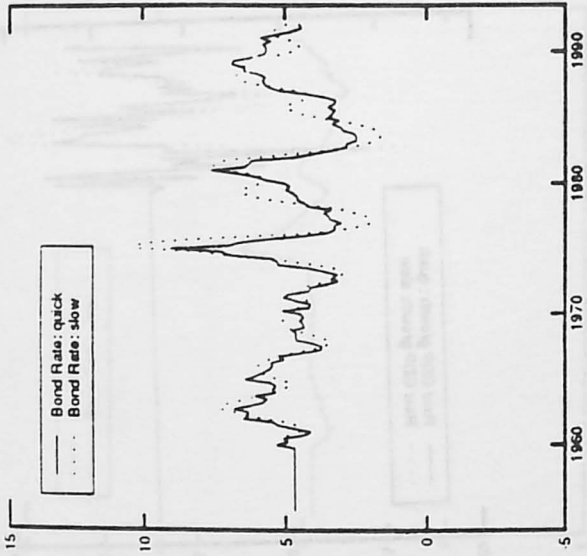
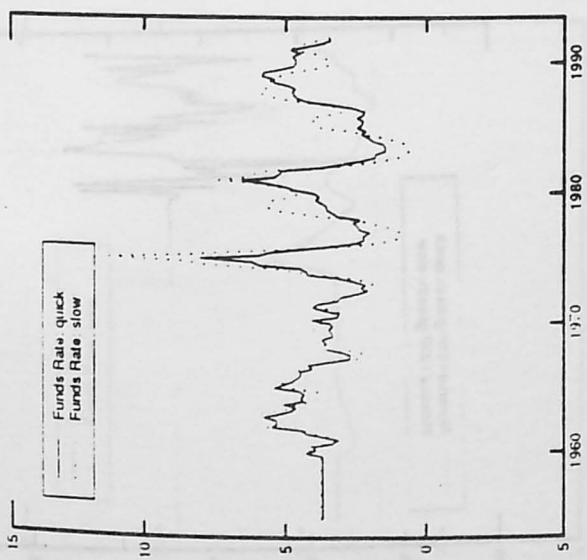
ADAS Model

Chart 9-A
Base Demand Shocks



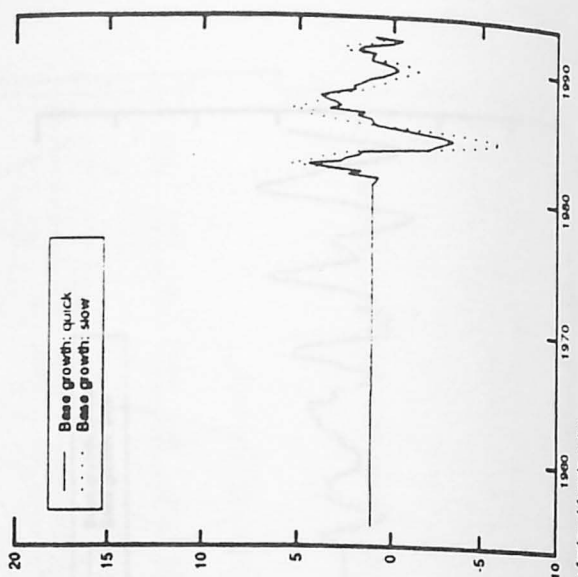
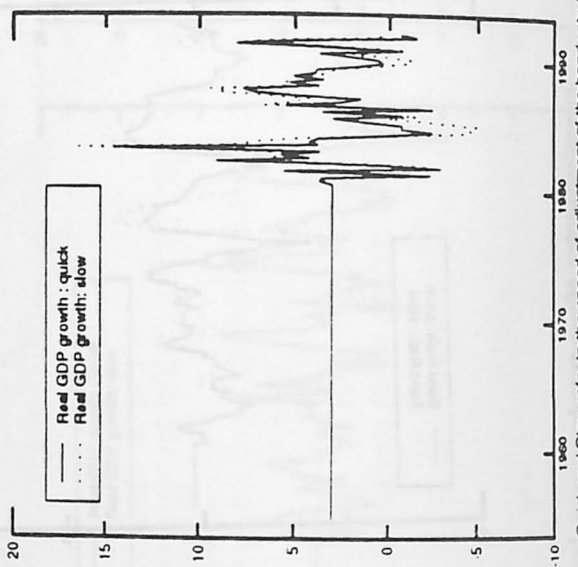
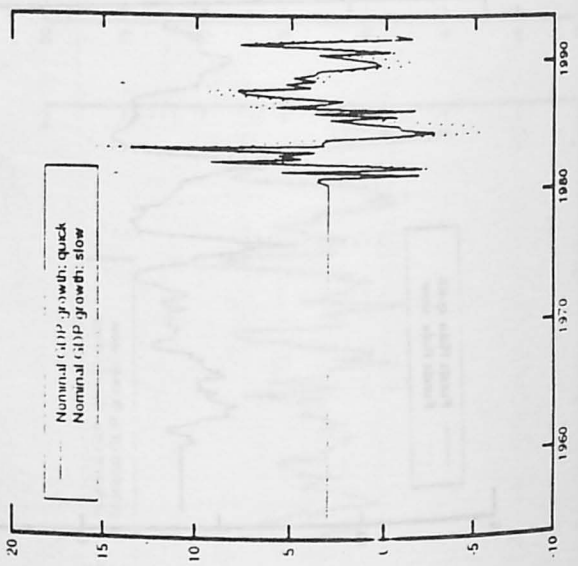
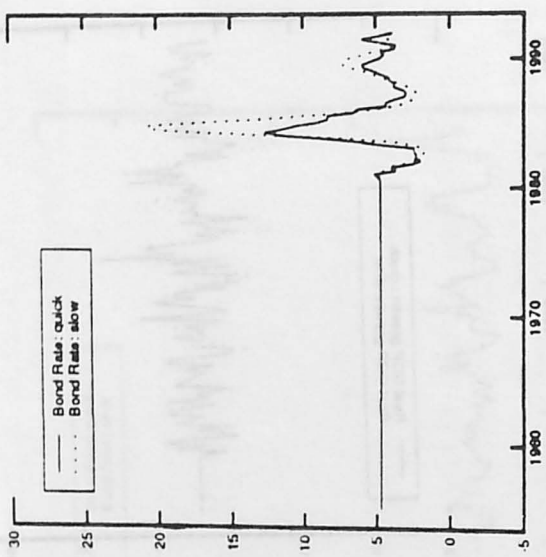
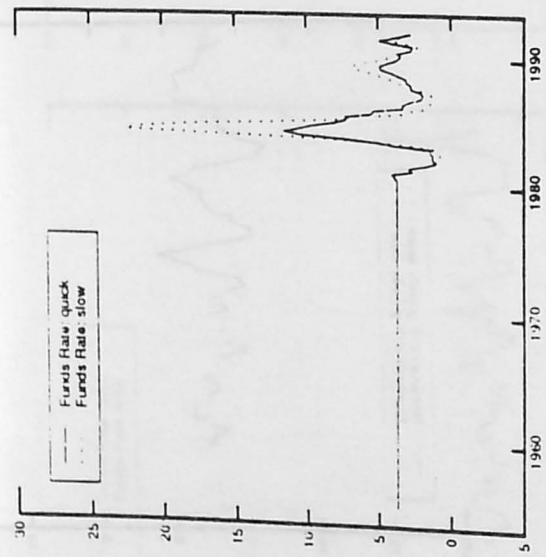
Quick and Slow refer to the speed of adjustment of the bond rate to the federal funds rate

Chart 9-B
Price and Wage Equation Shocks



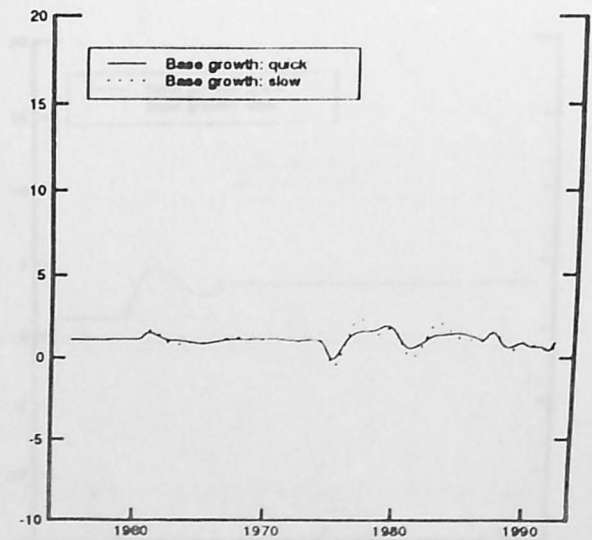
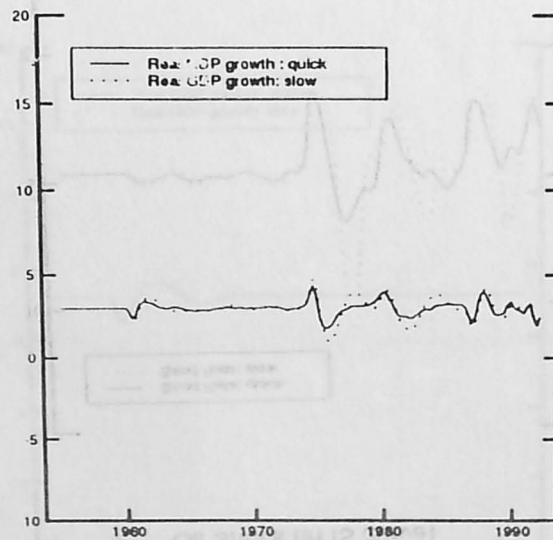
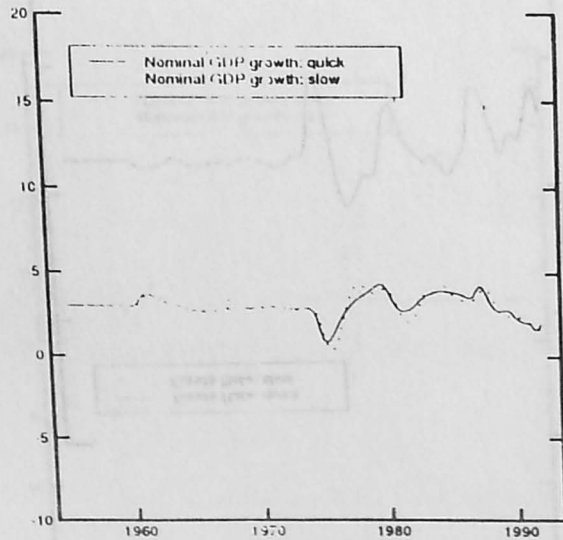
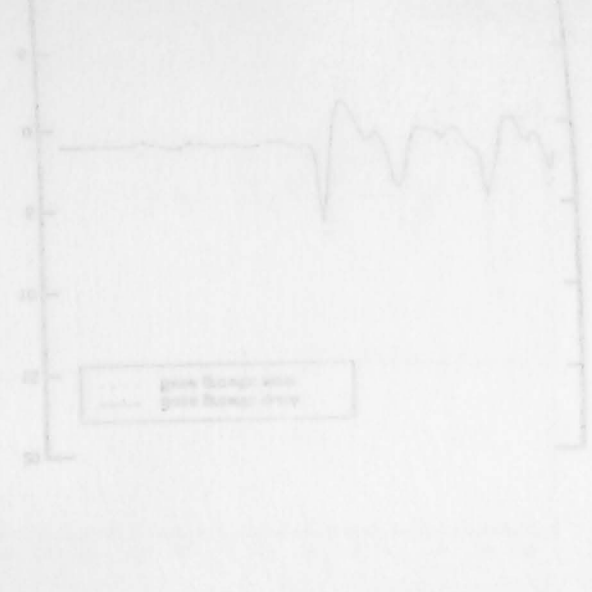
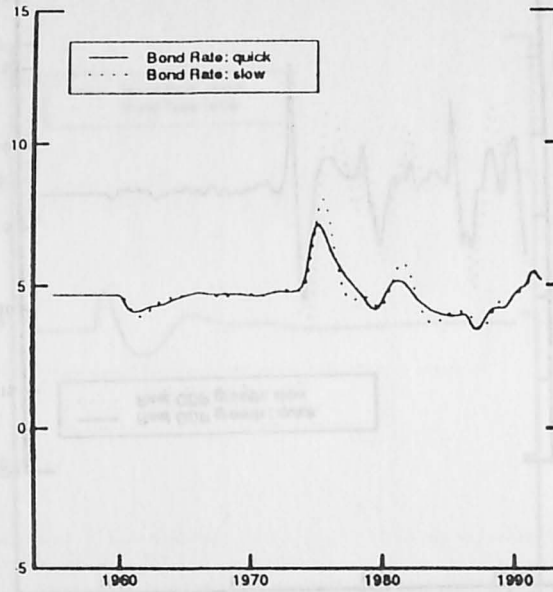
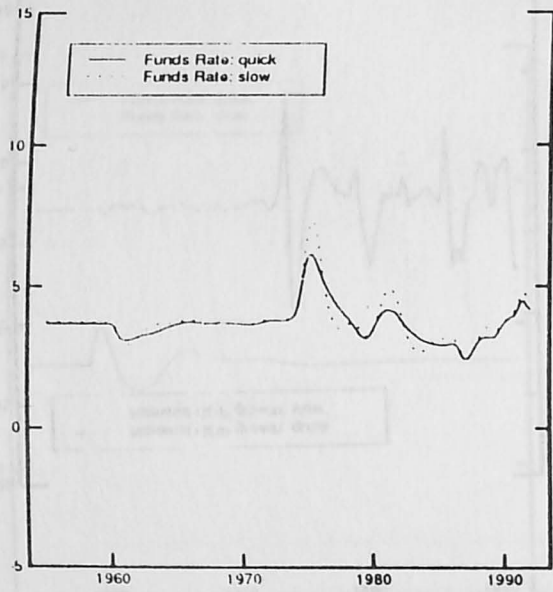
Quick and Slow refer to the speed of adjustment of the bond rate to the federal funds rate

Chart 9.C



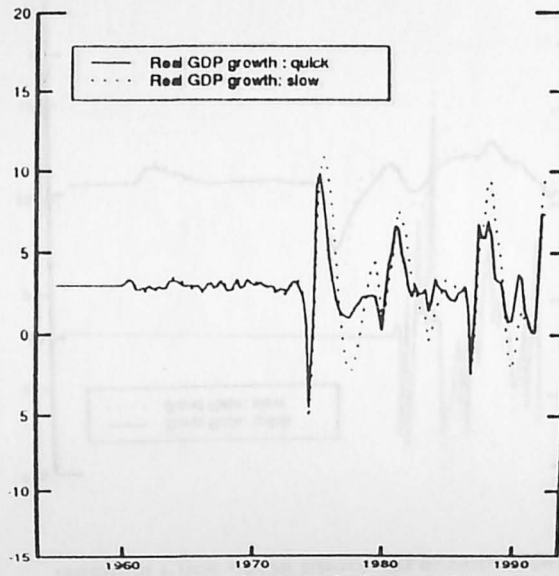
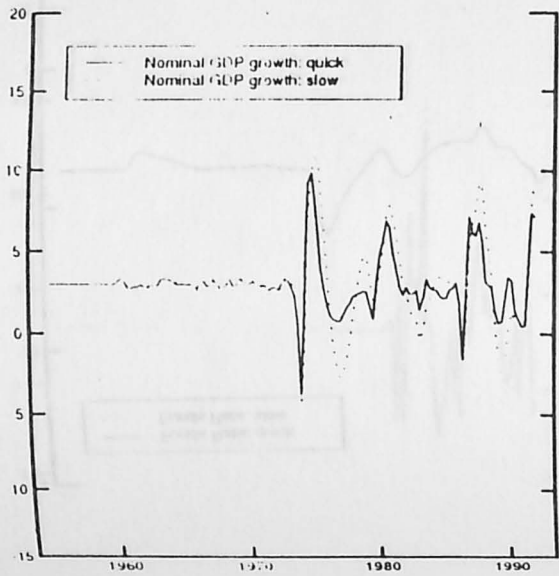
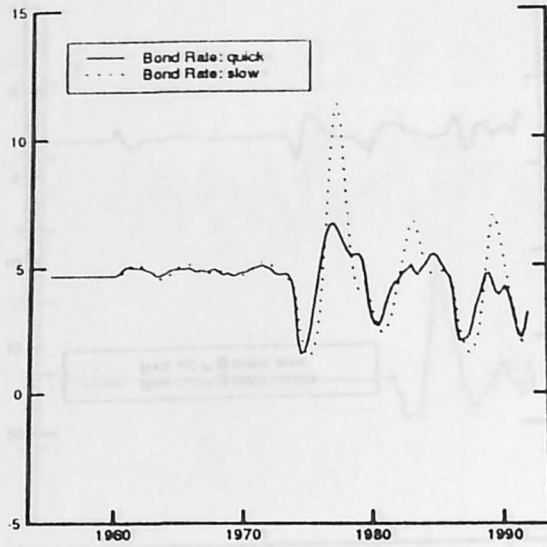
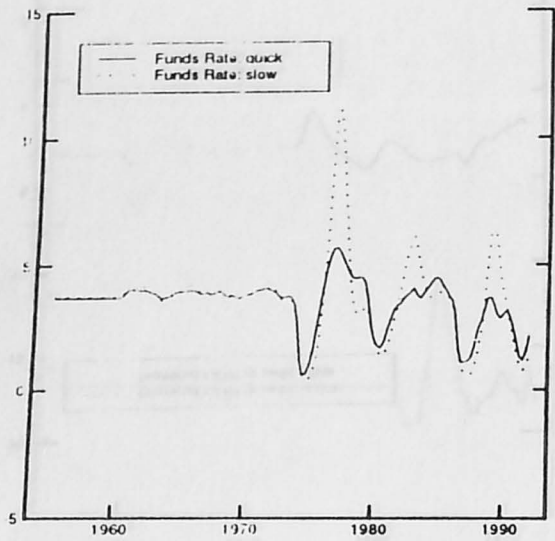
Quick and Slow refer to the speed of adjustment of the bond rate to the federal funds rate

Chart 9-D
Relative Price of Oil Shock (in supply side)



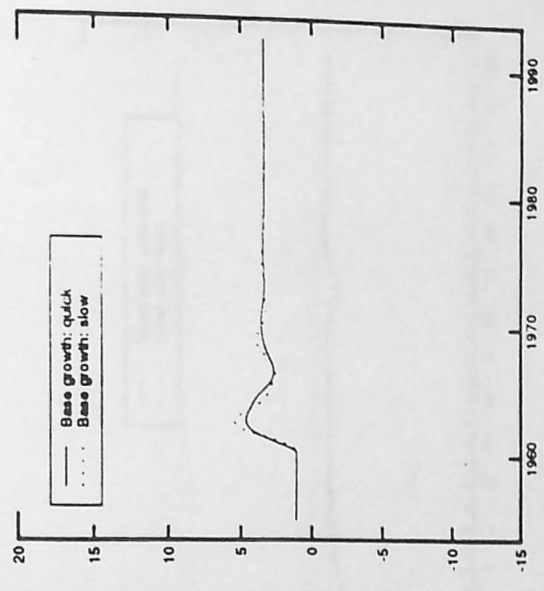
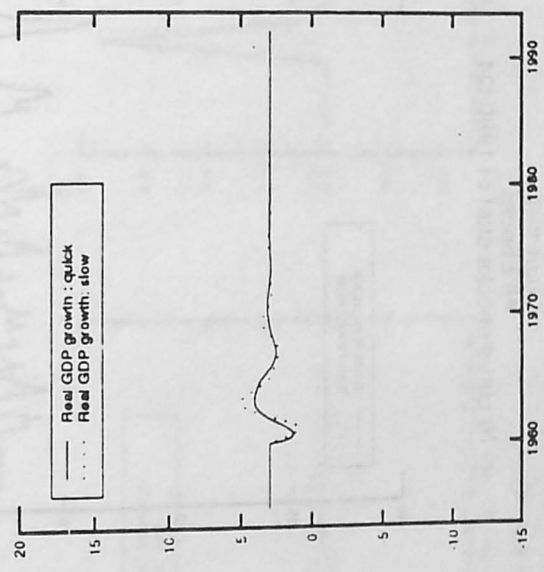
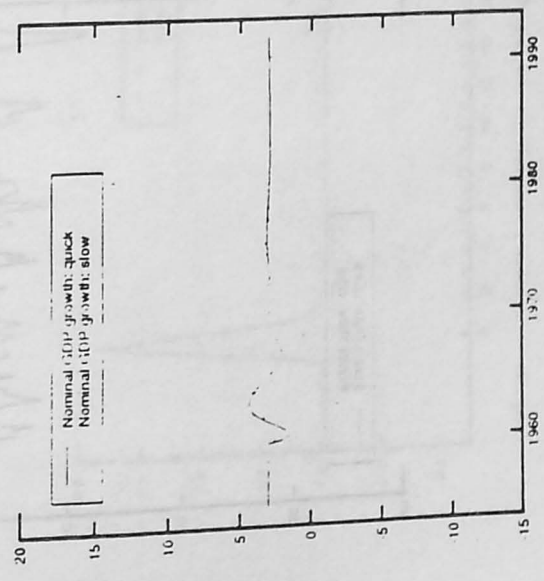
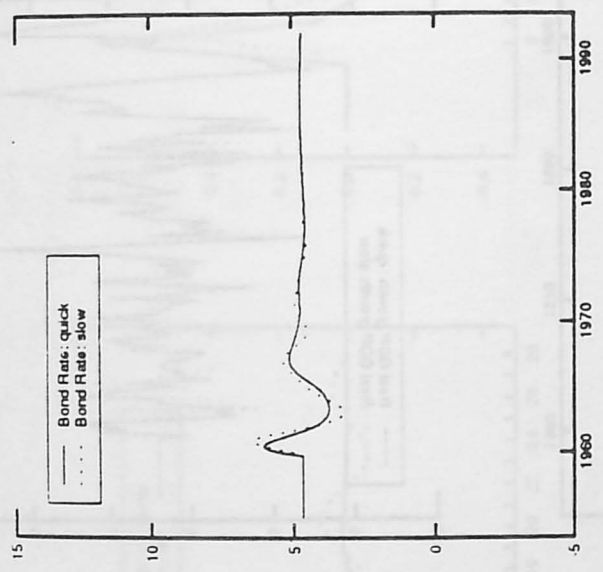
Quick and Slow refer to the speed of adjustment of the bond rate to the federal funds rate

Chart 9-E
Oil Shock (in IS curve)



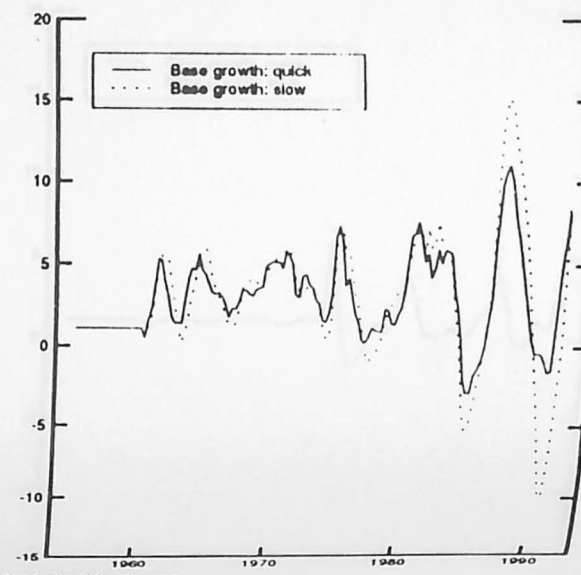
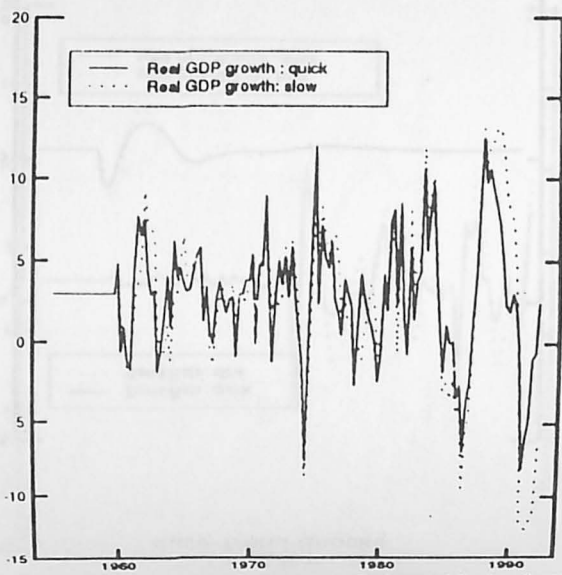
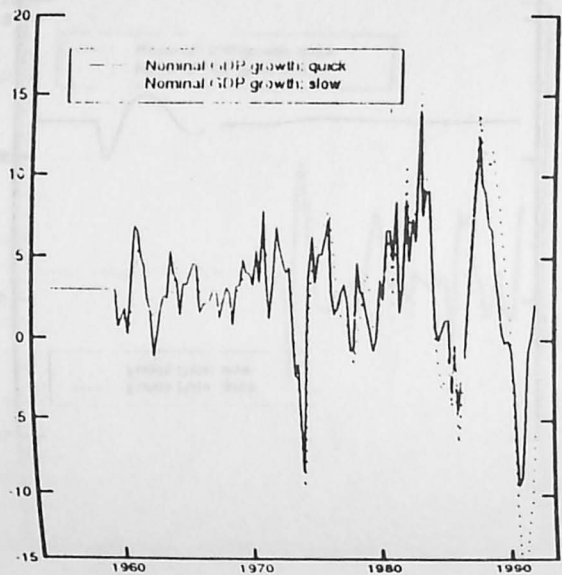
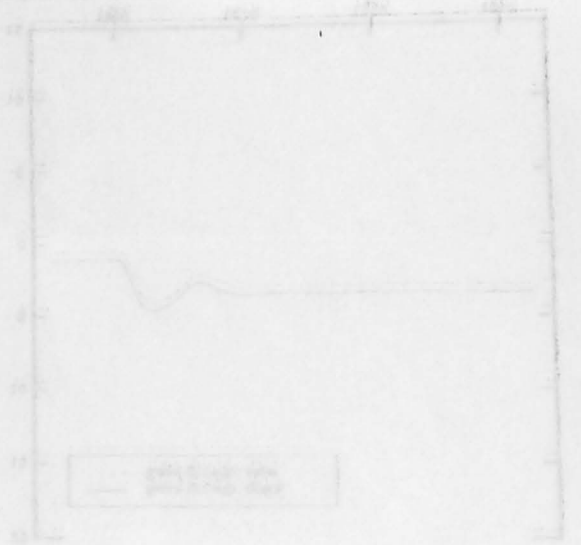
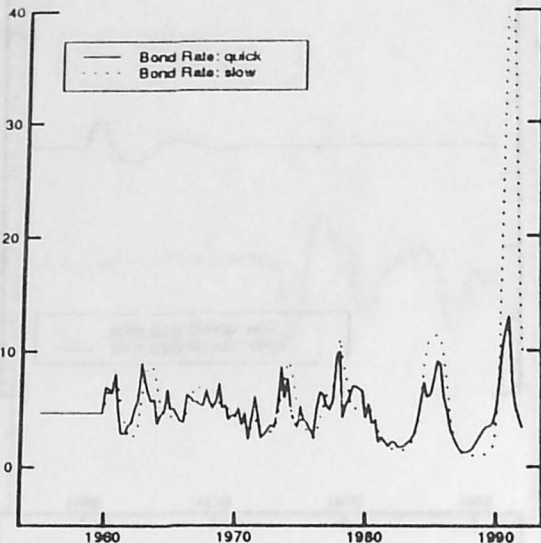
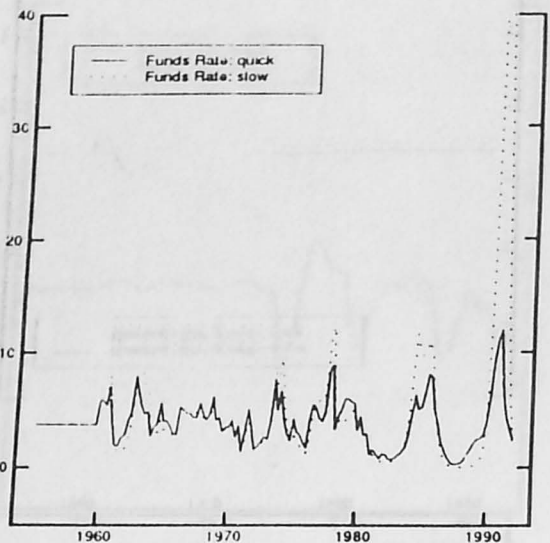
Quick and Slow refer to the speed of adjustment of the bond rate to the federal funds rate

Chart 9-F
Base Trend Shocks



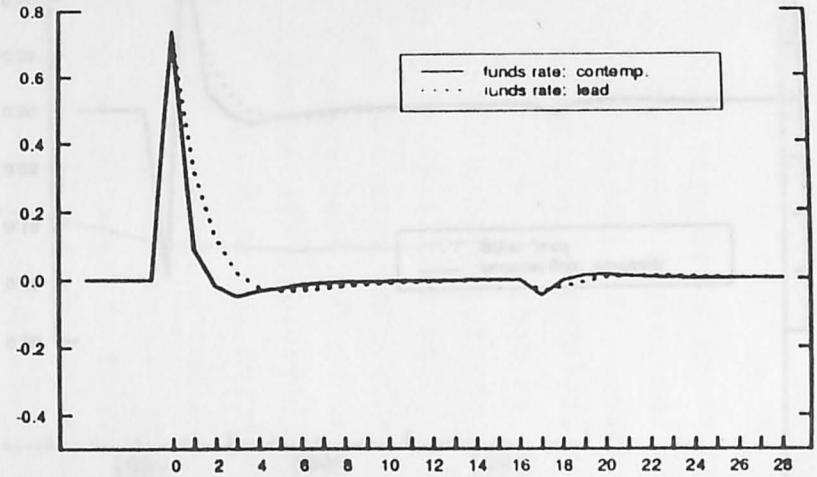
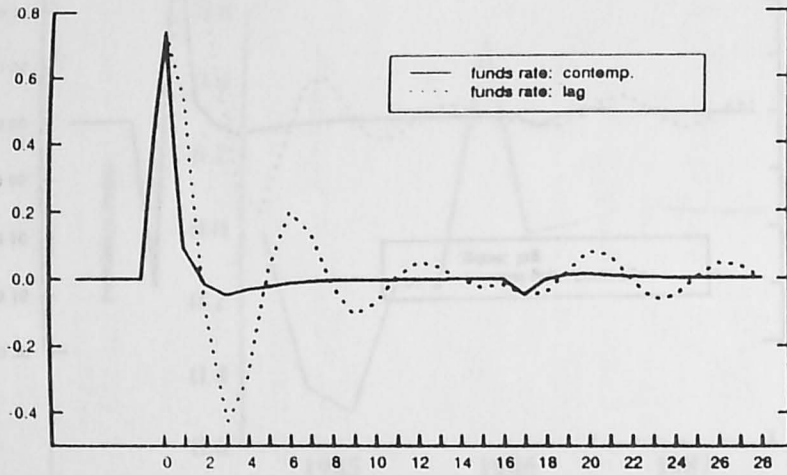
Quick and Slow refer to the speed of adjustment of the bond rate to the federal funds rate

Chart 9-G
All Shocks
IS curve shocks start in 1980:Q4

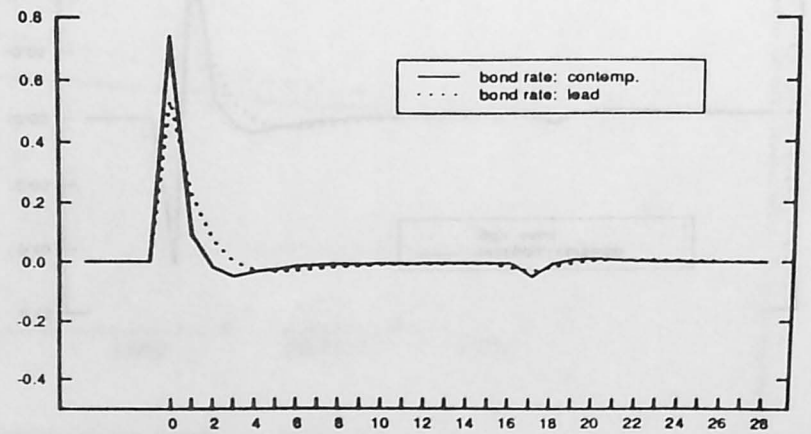
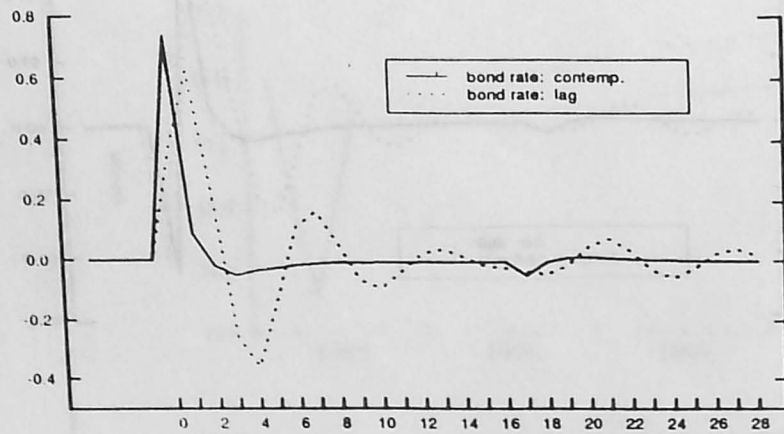


Quick and Slow refer to the speed of adjustment of the bond rate to the federal funds rate

Chart 10-A
Effects on Interest Rates of IS Curve Shock
(With Alternative Long-Rate Assumptions)

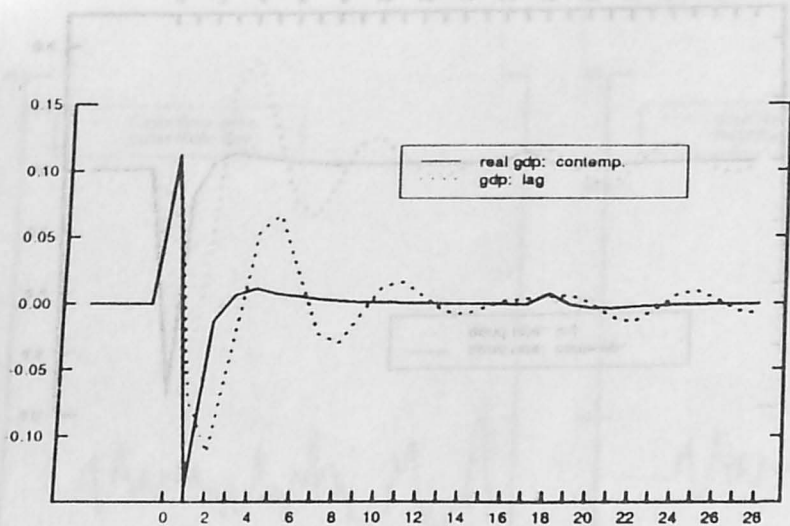


temporary shock is imposed in quarter 0

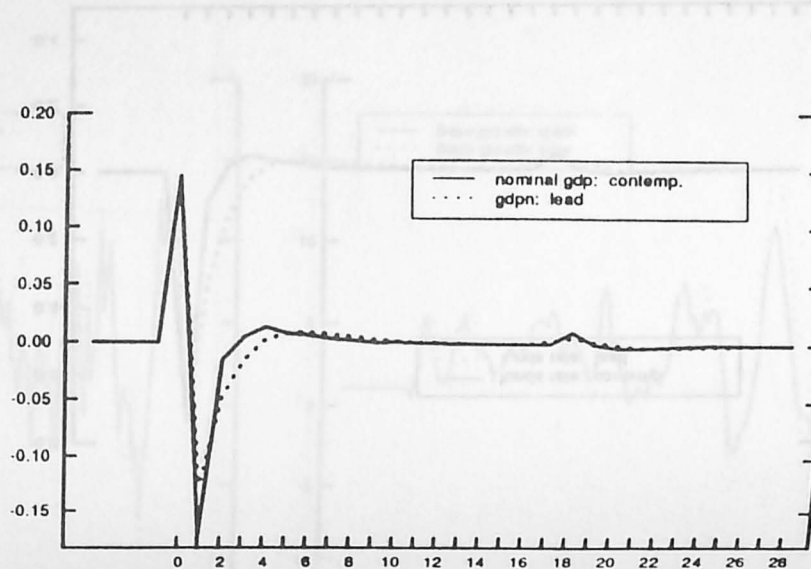
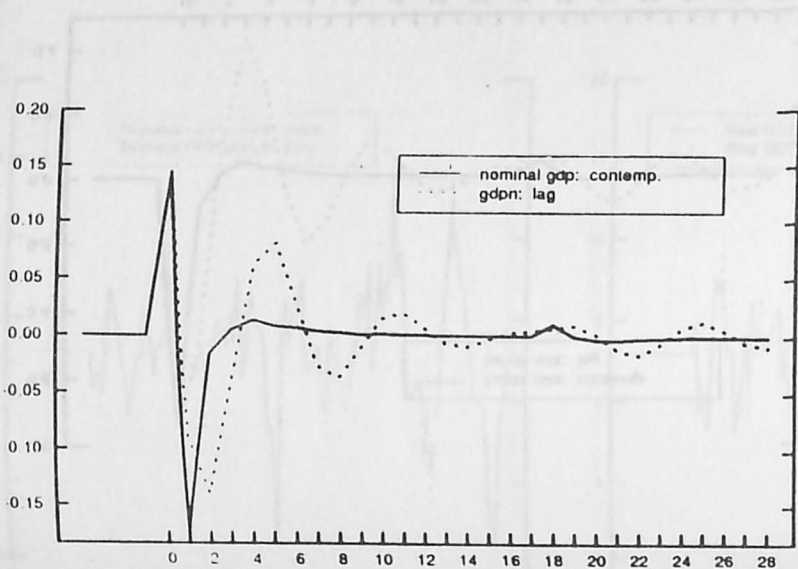
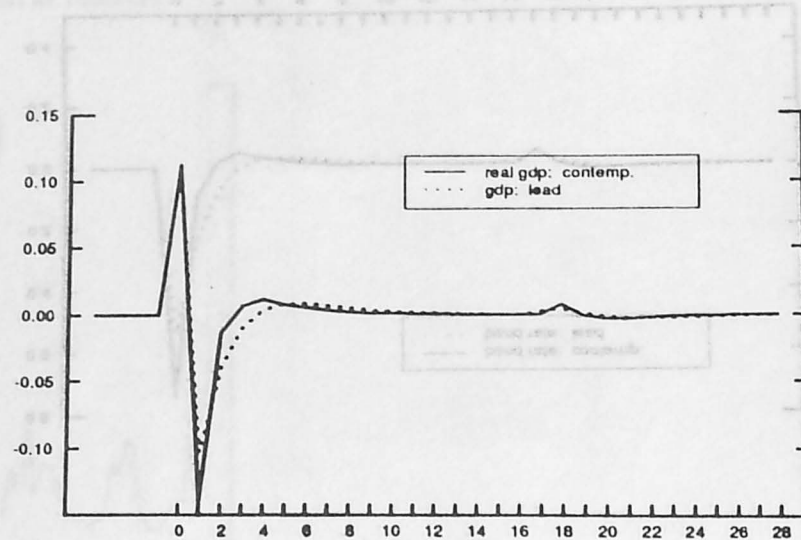


contemp. = contemporaneous response only of long to short rate
lag = one period lag and contemporaneous responses of long to short rate (with equal weights)
lead = one period lead and contemporaneous responses of long to short rate (with equal weights)

Chart 10-B
Effects on GDP Growth of IS Curve Shock
(With Alternative Long-Rate Assumptions)



temporary shock is imposed in quarter 0

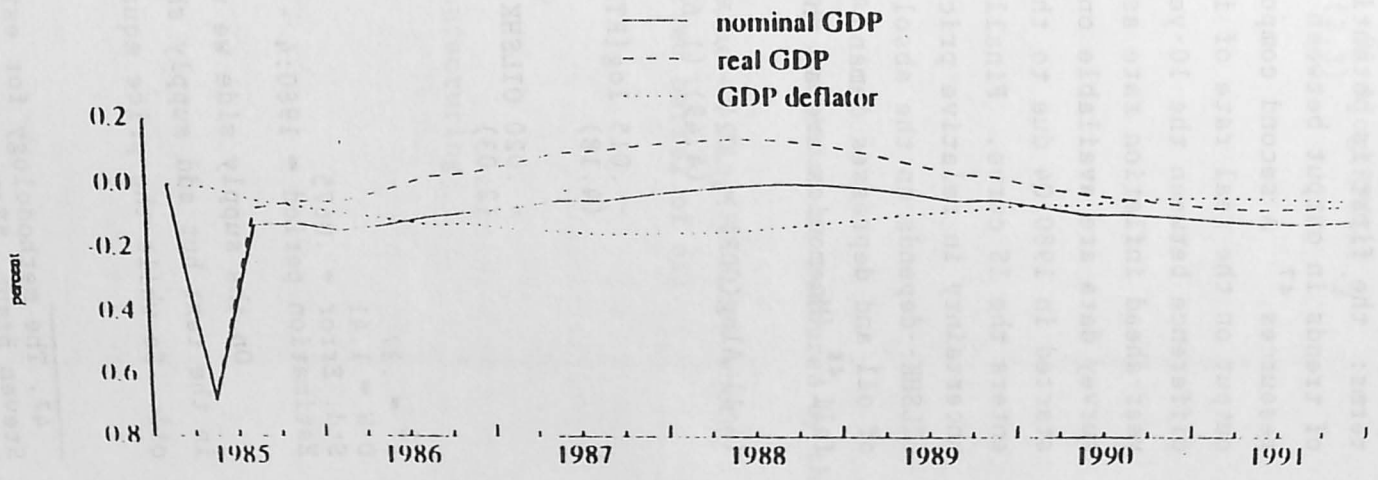
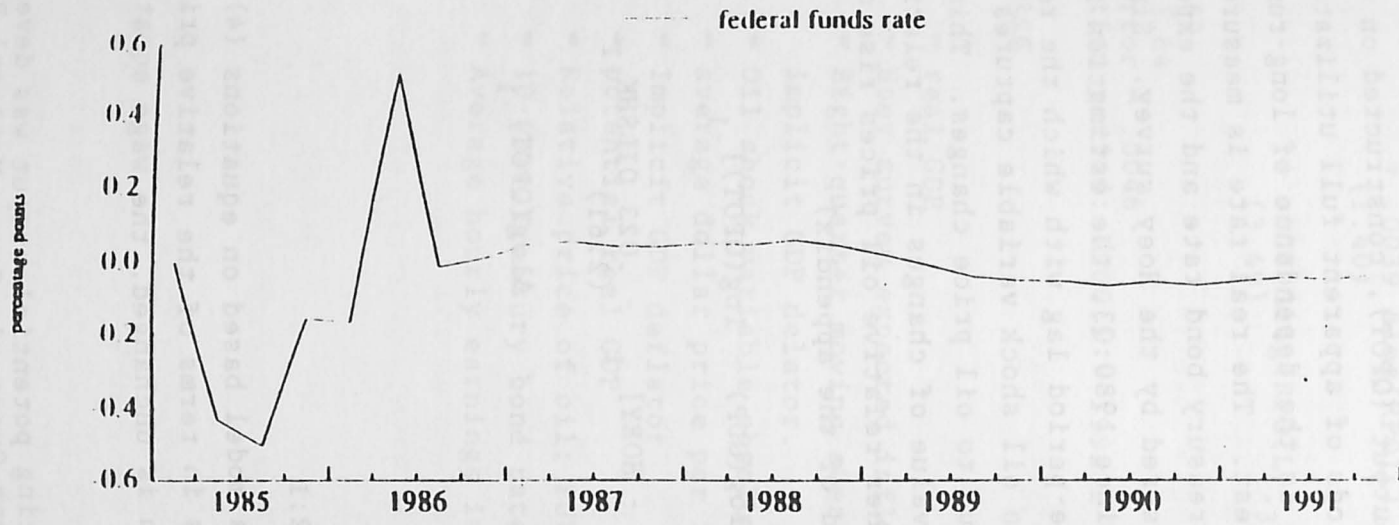


contemp = contemporaneous response only of long to short rate

lag = one period lag and contemporaneous responses of long to short rate (with equal weights)

lead = one period lead and contemporaneous responses of long to short rate (with equal weights)

Chart 11
POLICY RULE: FUNDS RATE INSTRUMENT; NOMINAL GDP TARGET
One-time negative government spending shock
 (deviations from baseline)



APPENDIX: I

In the IS curve in the small macro model with interest rates, the demand for real GDP adjusts to the lagged value of the gap between GDP and its long-run equilibrium value. The latter is composed of two terms: the first is potential output (QPOT), constructed on the basis of trends in output between periods of apparent full utilization of resources.⁴⁷ A second component is the dependence of long-run output on the real rate of interest. The real rate is measured as the difference between the 10-year Treasury bond rate and the expected 10-year-ahead inflation rate as measured by the Hoey survey. Since the survey data are available only since 1980:Q3, the estimation is started in 1980:Q4 due to the one-period lag with which the real rate enters the IS curve. Finally, an oil shock variable captures uncertainty in relative prices due to oil price changes. This term--OILSHK--depends on the absolute value of changes in the relative price of oil and depresses demand whether relative oil prices rise or fall.⁴⁸ (Mnemonics are at the end of the appendix)

$$\begin{aligned}
 (A-1) \Delta \log(\text{GDP}) = & .024 - .071 [(\log(\text{GDP}) - \log(\text{QPOT}))_{-1}] \\
 & (4.49) \quad (1.65) \\
 & - .015 \log[\text{RTB10Y} - \text{HOEY}]_{-1} - .023 \text{OILSHK}_{-1} \\
 & (4.18) \qquad \qquad \qquad (2.61) \\
 & - .020 \text{OILSHK}_{-2} - \Delta \log(\text{QPOT})_{-1} \\
 & (2.03)
 \end{aligned}$$

$$R^2 = .37$$

$$D-W = 1.41$$

$$\text{Std. Error} = .0675$$

Estimation period = 1980:4 - 1992:1

On the supply side we use a model based on equations (4) and (5) in the text but add supply shocks in terms of the relative price of oil. So while the price equation is unchanged, the wage equation is:

47. The methodology for estimating potential output was developed by Steven Braun. "Estimates of Current Quarterly Gross National Product by Pooling Preliminary Labor Market Data" Journal of Business and Economic Statistics, vol. 8, (July, 1990), pp.293-304.

48. The lagged change in the log of potential output--with the unitary coefficient--assures that output grows as the rate of potential output in steady-state equilibrium.

$$\begin{aligned}
 (A-2) \Delta \log(\text{WAGE}) = & .0014 + .25(\log(\text{GDP}) - \log(\text{QPOT})) \\
 & (3.60) \quad (4.98) \\
 & - .18(\log(\text{GDP} - \log(\text{QPOT}))_{-1} - \text{INFLAG} \\
 & (3.53) \\
 & + .0039 \Delta \log(\text{RPOIL})_{-1} + .01 \Delta \log(\text{RPOIL})_{-2} \\
 & (1.40) \quad (2.3) \\
 & + .008 \Delta \log(\text{RPOIL})_{-3} \\
 & (3.49)
 \end{aligned}$$

$$R^2 = .62$$

$$D-W = 1.64$$

$$\text{Std. Error} = .0046$$

Estimation period: 1960:1 - 1992:1

Mnemonics

- GDP = real GDP
- HOEY = Hoey survey expected inflation
- INFLAG = Eight-quarter moving average of inflation as measured by the implicit GDP delator.
- OILSHK = Oil shock variable absolute value of $\Delta \log(\text{PUVFL}/\text{P})$ where
- PUVFL = average dollar price per imported barrel of oil.
- P = Implicit GDP deflator
- QPOT = potential real GDP
- RPOIL = Relative price of oil: PUVFL/P
- RTB10Y = 10-year Treasury bond rate
- WAGE = Average hourly earnings in manufacturing

APPENDIX II: BASE DEMAND SHOCKS

In the model with a disaggregated aggregate demand side of the economy, we specified the following base demand function (heteroskedasticity robust t-statistics in parentheses):

$$(1). \quad b_t = -2.18 + 1.0 x_t - .022 r_t - .005 T + .006 D82T$$

(455.83) (-6.33) (-48.40) (21.30)

$$\text{Adj-R}^2 = .986 \quad \text{D-W} = .31 \quad \text{Std. Error} = .0171$$

Estimation period = 1960:1 - 1992:1

where:

b_t ≡ log of the St. Louis monetary base

x_t ≡ log of nominal GDP

r_t ≡ Box-Cox transformation of the federal funds rate

T ≡ Linear time trend

$D82T$ ≡ Linear time trend beginning in 1982:1

Since the estimated base demand shocks can contribute substantially to the fluctuations in simulated interest rates, the residuals from this model are compared with those from a base demand specification advocated by Robert Rasche.⁴⁹ Rasche considers two specifications for the demand for the monetary base--one unrestricted and one restricted. In the former, the growth rate of the monetary base is regressed on a constant, contemporaneous and lagged growth rates of real GNP and the contemporaneous and lagged growth rates of a short term interest rate. The estimated unrestricted version is :

$$\Delta b_t - \Delta x_t = -.002 - .008 \Delta R_t - .015 \Delta R_{t-1} - .010 \Delta R_{t-2} + .007 D82$$

(-3.25) (-1.89) (-3.15) (-3.08) (6.88)

$$-.848 \Delta y_t + .134 \Delta y_{t-1} + .245 \Delta y_{t-2} - .537 \text{DINFU}_t +$$

(-18.85) (2.41) (5.08) (-5.70)

$$R^2 = .764 \quad \text{D-W} = 1.10 \quad \text{Std. Error} = .0055$$

49. See "M1 - Velocity and Money Demand Functions: Do Stable Relationships Exist?" in Carnegie-Rochester Conference Series on Public Policy, 27, 1987, p. 9-88.

Estimation period = 1953:2 - 1992:1⁵⁰

where:

x_t \equiv log of nominal GNP

y_t \equiv log of real GNP

D82T \equiv Dummy variable equal to zero prior to 1982:1 and one thereafter.

DINFU \equiv A measure of unexpected inflation, constructed as the residuals from an ARIMA(0,1,1) model for the inflation rate.

R \equiv The log of the 3 month Treasury bill rate.

D82T \equiv Linear time trend beginning in 1982:1

The restricted specification imposes three constraints. First, all the interest rate coefficients are equal. Second, the coefficients on lagged real GNP are equal. And third, the sum of the coefficients on real GNP sum to zero. Rasche interprets this last restriction to mean that the velocity of the monetary base responds only to transitory changes in real income. Together these restrictions decrease the number of estimated coefficients from 9 to 5.

$$\Delta b_t - \Delta x_t = \begin{matrix} -.006 & -.018 & \sum_{j=0}^2 \Delta R_{t-j} & -.719 (\Delta y_t - .5 \sum_{j=1}^2 \Delta y_{t-j}) \\ (-9.86) & (-10.33) & & (-14.84) \end{matrix} \\ -.574 \text{ DINFU}_t + .007 \text{ DUM82}_t \\ (-4.94) \quad (6.13)$$

$$R^2 = .712 \quad D-W = 1.13 \quad \text{Std. Error} = .0061 \\ \text{Estimation period} = 1953:2 - 1992:1^{51}$$

The F-statistic for the test of the null hypothesis that the restrictions hold is 9.22. The restrictions can be rejected at the 5 percent level of statistical significance. Using these variables,

50. Excluding 1980:1 to 1980:3 due to the imposition of credit controls.

51. Excluding 1980:1 to 1980:3 due to the imposition of credit controls.

Rasche also found that for this specification the restrictions were rejected for the 1953:2-1985:4 and 1953:1-1981:4 estimation periods.

Chart A-1 plots the residuals from Rasche's restricted and unrestricted specifications, and the change in the residuals from the base demand function used in the simulations (equation 6). In Table A-1 we provide some descriptive statistics for these three estimates of historical shocks to base demand, both for the full overlap of the samples, 1960:1 to 1992:1 (excluding 1980:1-1980:3), and for the subsample 1982:1 to 1992:1.

The table and chart show that the errors from equation (6) have a significantly larger variance than those from either of Rasche's models. But starting in the early 1980's and continuing through the present, the errors from all three models track each other closely. During the 1990's there appears to be some association of these errors with estimates of changes in U.S. currency held abroad--see Chart A-2. The note by Richard Porter attached at the end of this paper briefly describes the construction of this series.

Table A-1

1960:1 - 1992:1

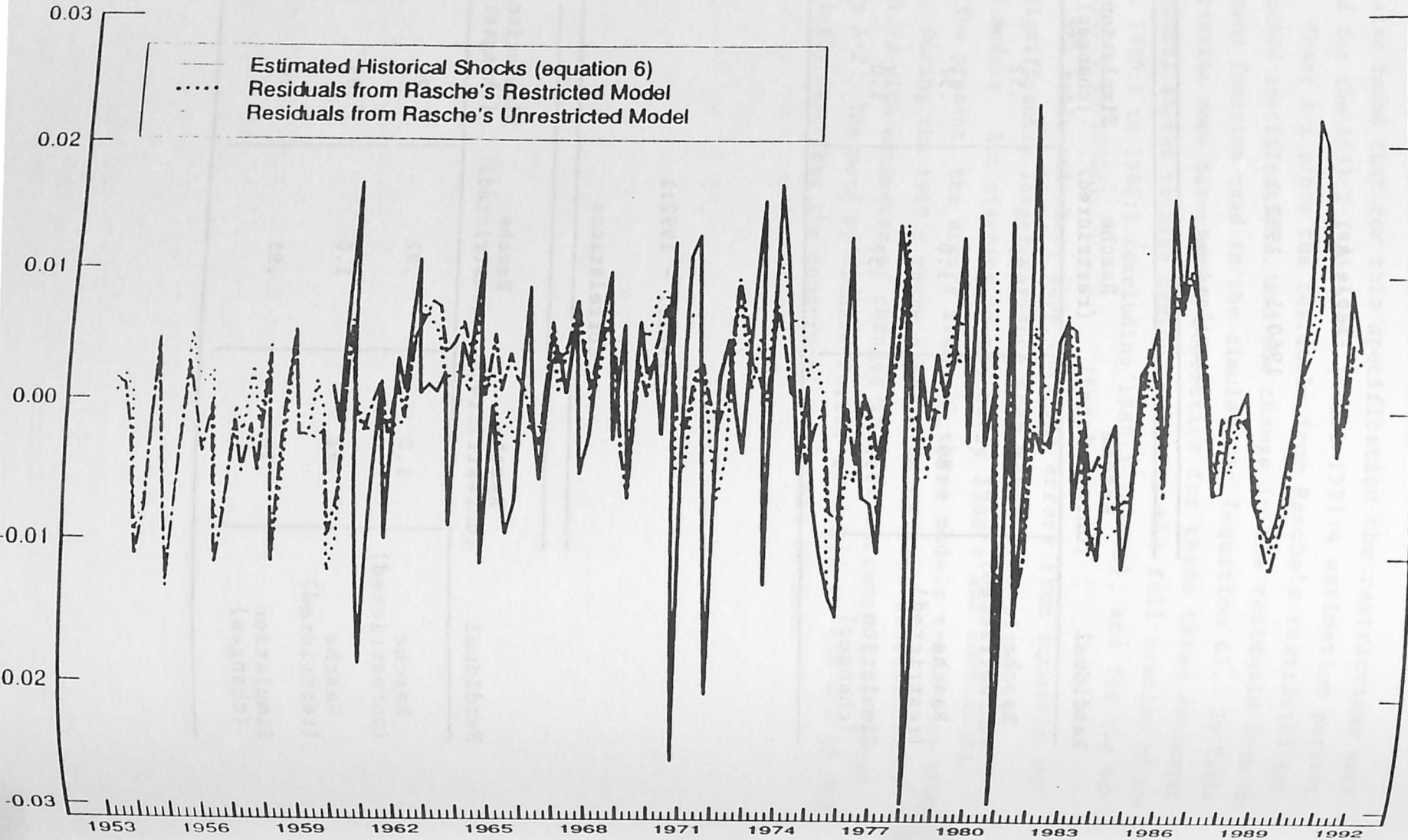
Residual	Correlations			Variance
	Rasche (unrestricted)	Rasche (restricted)	Simulation (changes)	
Rasche (unrestricted)	1.0	.89	.52	2.8•e-3
Rasche (restricted)	.89	1.0	.57	3.8•e-3
Simulation (changes)	.52	.57	1.0	8.8•e-3

1982:1 - 1992:1

Residual	Correlations			Variance
	Rasche (unrestricted)	Rasche (restricted)	Simulation (changes)	
Rasche (unrestricted)	1.0	.92	.76	3.5•e-3
Rasche (restricted)	.92	1.0	.85	4.4•e-3
Simulation (changes)	.76	.85	1.0	7.5•e-3

Chart A - 1

Residuals from Estimated Demand Functions for the Monetary Base
(1953 Q2 - 1992 Q1)



Preliminary Estimate of Dollar Change in U.S. Currency Held Abroad
(billions of dollars)

