Working Paper Series

Structure From Shocks

WP 99-06

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THE FEDERAL RESERVE BANK OF RICHMOND
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Federal Reserve Bank of Richmond Working Paper No. 99-6

August 1999

JEL Nos. E50 C52

Keywords: monetary policy, impulse response functions, correlations, dynamic behavior.

Abstract

Arguments in favor of Keynesian models as opposed to real business cycle models are often made on the grounds that the correlations and impulse response patterns found in the latter are inconsistent with the data. A recent and prominent example of this type of reasoning is Gali (1999). But such conclusions involve a joint hypothesis that implicitly assumes a certain characterization of monetary policy. This paper shows just how crucial the systematic portion of monetary policy is for interpreting many of the correlations and impulse response functions emphasized in the literature. Basically, the featured empirical facts are not useful for discerning the underlying price setting behavior of firms.

*I wish to thank Marvin Goodfriend, Andreas Hornstein, Robert King, and Pierre Sarte for a number of useful suggestions. I have also greatly benefitted from many helpful discussions with Alex Wolman. The views expressed herein are the author's and do not represent the views of the Federal Reserve Bank of Richmond or the Federal Reserve System.

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Arguments in favor of Keynesian models as opposed to real business cycle models are often made on the grounds that the correlations and impulse response patterns found in the latter are inconsistent with the data. Critics further assert that these correlations are consistent with models that include price rigidities. Gali (1999) constitutes a prominent example of this reasoning. He observes that conditional on a technology shock the contemporaneous correlation between labor effort and labor productivity is negative. He then makes the case that this observation implies that prices are sticky. Basu, Fernald, and Kimball (1998), using different identifying assumptions, also find this correlation in the data and make a similar assertion. Mankiw (1989) provides still another example of this type of reasoning. He points out that RBC models produce the counterfactual implication that inflation and real activity are negatively correlated and so are inconsistent with the existence of a Phillips curve, which would not be the case in a sticky price model.

But statements like those of Gali, Basu, Fernald, and Kimball, and Mankiw really involve a joint hypothesis that implicitly assumes a certain characterization of monetary policy. Gali (1999) uses intuition based on a money supply rule to defend identifying assumptions that yield a fall in employment in the presence of positive technology shocks. The fall in employment together with an increase in output produces the negative correlation between employment and labor productivity. However, under the interest rate rule estimated in Clarida, Gali, and Gertler (1997), positive technology shocks produce an increase in both employment and labor productivity. Given the correct estimation of the rule, one must question either the underlying theoretical model or the empirical identifying assumptions that produce the impulse responses estimated by Gali[1]. The same is true for the assertions of Basu and Kimball. Furthermore, work by Christiano and Todd (1996) is able to generate the labor-productivity correlation estimated by Gali within the confines of the RBC paradigm. Thus, to discriminate among classes of models based on a few correlations is a perilous enterprise, especially when those correlations are sensitive to the nature of monetary policy.

How important the specification of monetary policy is for the dynamic behavior of the economy is shown within the confines of a model similar to that used by Gali (1999). The model includes staggered price setting rather than one-period price rigidity, and capital accumulation. One can see the effects of the systematic portion of policy by examining how the model economy reacts to a shock under

[1] For a more detailed investigation concerning the robustness of results in the face of varying identifying assumptions see Sarte (1997).

different specifications of a monetary policy rule. The experiments show that, in the presence of significant linkages between real and nominal variables, the way shocks propagate through an economy is intimately linked to the systematic behavior of the monetary authority. In particular, the justification put forth by both Gali and Basu and Kimball for favoring a sticky price model over an RBC model no longer applies. Also, the correlations between real and nominal variables are sensitive to the specification of the central bank's feedback rule. Depending on the form of the monetary policy rule, the model is capable of producing either positive or negative correlations between output and inflation irrespective of whether prices are sticky or flexible. Thus Mankiw's reasoning for favoring a sticky price model over a flexible price model is not persuasive.

This is not to say that the methodology advocated by Gali or the idea that nominal rigidities characterize the economic environment are invalid. Understanding the nature of the price-setting process is of paramount importance for conducting appropriate monetary policy and comparing model impulse response functions with those found in the data is a potentially valuable tool in helping to discriminate between flexible and sticky price models. Gali's initial attempt provides a productive way to think about this issue, and his emphasis on conditional correlations is a useful refinement. However, the cited papers' conclusions– that the particular impulse response functions and correlations emphasized are helpful in understanding price-setting behavior– are not robust to the specification of monetary policy.

The paper proceeds as follows. Section 1 sketches the underlying model common to the analysis. A key feature of the model is the presence of price rigidities. Section 2 describes the various monetary policy rules under investigation. One is a simple money growth rule and the others fall into the general category of Taylor-type rules. In particular, both the rule estimated by Clarida, Gali, and Gertler when monetary policy was under the leadership of Paul Volcker and Alan Greenspan and the rule estimated by Taylor (1993) are investigated. The Clarida, Gali and Gertler rule postulates that the Fed responds to deviations of expected inflation from target and current output from its potential value. The rule also stipulates a degree of interest rate smoothing. Taylor's rule depicts the Fed as responding to four-quarter deviations of average inflation from target and to departures of output from potential. Section 3 analyzes the response of the model economy to a technology shock and an aggregate demand shock. Depending on the rule employed by the monetary authority, the responses are quite different. Section 4 concludes.

1. The Model

For the purpose of this investigation, I use a framework that embeds sticky prices into a dynamic stochastic model of the economy. The underlying model is similar to that of Gali (1999), with two exceptions. The first is that price rigidity is introduced through staggered contracts. The second is that capital is included. Under flexible prices the underlying economy behaves as a classic real business cycle model. The model is, therefore, of the new neo-classical synthesis variety, and displays features that are common to much of the current literature using sticky price models[2]. Agents have preferences over consumption, work effort, and leisure, and own and rent productive factors to firms. For convenience, money is introduced via a demand function rather than entering directly in utility (as in Gali) or through a shopping time technology. Firms are monopolistically competitive and face a fixed schedule for changing prices. Specifically, one-quarter of the firms change their price each period, and each firm can change its price only once a year. This type of staggered time-dependent pricing behavior, referred to as a Taylor contract, is a common methodology for introducing price stickiness into an otherwise neoclassical model.

1.1. Consumers

Consumers maximize the following utility function

$$U = E_0 \sum_{t=0}^{\infty} \beta^t [\ln(C_t) - \chi_n n_t^{\zeta} - \chi_u U_t^{\eta}]$$

where $C = [\int_0^1 c(i)^{(\varepsilon-1)/\varepsilon} di]^{\varepsilon/(\varepsilon-1)}$ is an index of consumption, n is the fraction of time spent in employment, and U is labor effort.

Consumers also face the following intertemporal budget constraint

$$P_t C_t + P_t I_t \leq W_t n_t + V_t U_t + r_t P_t K_t + D_t,$$

and the capital accumulation equation

$$K_{t+1} = (1-\delta)K_t + \phi(I_t/K_t)K_t,$$

[2] Examples of this literature are Goodfriend and King (1998), Chari, Kehoe and McGrattan (1998), and Dotsey, King and Wolman (1999).

where $P = [\int_0^1 p(i)^{1-\varepsilon} di]^{1/(1-\varepsilon)}$ is the price index associated with both the aggregator C and an analogous investment aggregator I, W is the nominal wage for an hour of work, V is the nominal payment for a unit of effort, r is the rental rate on capital, δ is the rate that capital, K, depreciates, and D are nominal profits remitted by firms to households. The function ϕ is concave and depicts the fact that capital is costly to adjust.[3]

The relevant first order conditions for the consumers' problem are given by

$$(W_t/P_t) = \chi_n \varsigma n_t^{\varsigma-1}, \tag{1a}$$

$$(V_t/P_t) = \chi_u \eta n_t^{\eta-1}, \tag{1b}$$

and

$$(1/C_t\phi_t') = \beta E_t(1/C_{t+1}\phi_{t+1}')[r_{t+1}\phi_{t+1}' + (1-\delta) + \phi_{t+1} + \phi_{t+1}'(\frac{I_{t+1}}{K_{t+1}})]. \tag{1c}$$

Equation 1c employs the short hand notation ϕ_t and ϕ_t' to indicate the function and its first derivative evaluated at time t investment-to-capital ratios.

The demand for money,M, posited rather than derived, is given by

$$\ln(M_t/P_t) = \ln Y_t - \eta_R R_t. \tag{2}$$

The nominal interest rate, is denoted R and η_R is the interest semi-elasticity of money demand. One could derive the money demand curve from a shopping time technology without affecting the results in the paper.

1.2. Firms

There is a continuum of firms indexed by j that produce goods, $y(j)$,using a Cobb-Douglas technology that combines labor and capital according to,

$$y(j) = a_t k(j)^\alpha l(j)^{1-\alpha}, \tag{3}$$

[3]Capital adjustment costs are included primarily for the purpose of making the impulse response functions smoother. As is typical in models with staggered price setting, the impulse response functions can be rather choppy as firms cycle through the price adjustment process.

where a is a technology shock that is the same for all firms and l is effective labor which is a function of hours and effort given by $l_t = n_t^{\theta} U_t^{1-\theta}$. Each firm rents capital, and hires labor and labor effort in economy-wide competitive factor markets. The cost-minimizing demands for each factor are given by

$$\psi_t a_t (1-\alpha)\theta (k_t(j)/l_t(j))^{\alpha} (U_t/n_t)^{1-\theta} = W_t/P_t, \quad (4a)$$

$$\psi_t a_t (1-\alpha)(1-\theta)(k_t(j)/l_t(j))^{\alpha} (U_t/n_t)^{-\theta} = V_t/P_t, \quad (4b)$$

and

$$\psi_t a_t \alpha (l_t(j)/k_t(j))^{1-\alpha} = r_t, \quad (4c)$$

where ψ is real marginal cost. The above conditions imply that capital-labor ratios and employment-effort ratios are equal across firms and that $U/n = ((1-\theta)/\theta)(W/V)$. Using the latter relationship and equations 1a and 1b yields the reduced form production function $y(j) = a_t A k(j)^{\alpha} n(j)^{\varphi}$, where $\varphi = \theta(1-\alpha) + (\psi/\eta)(1-\theta)(1-\alpha)$ and A is a function of the parameters $\theta, \chi_n, \chi_u, \psi$, and η.

Although firms are competitors in factor markets, they possess some monopoly power over their own product and face downward-sloping demand curves of $y(j) = (p(j)/P)^{-\varepsilon} Y$, where $p(j)$ is the price that firm j charges for its product. This demand curve results from individuals minimizing the cost of purchasing the consumption and investment indices represented by C and I. The model also includes an autonomous disturbance to aggregate demand, X, and the autonomous demand for each firm's product is of the same form as that for consumption and investment. Thus $Y = C + I + X$.[4] Firms are allowed to adjust their price once every four periods, and choose a price that will maximize the expected value of the discounted stream of profits over that period. Specifically, a firm that sets its price in period t to

$$\max_{p_t(j)} E_t \sum_{\tau=t}^{t+3} (\lambda_\tau/\lambda_t)\omega_\tau(j),$$

where real profits at time τ, $\omega_\tau(j)$, are given by $[p_t^*(j) y_\tau(j) - \psi_\tau P_\tau y_\tau(j)]/P_\tau$,and λ is the multiplier associated with the consumer's budget constraint.

The result of this maximization is that an adjusting firm's price is given by

[4] An aggregate demand disturbance could also be generated through shocks to preferences. The results presented in section 3 would be essentially unchanged.

$$p_t^*(j) = \frac{\varepsilon}{\varepsilon - 1} \frac{\sum_{h=0}^{3} \beta^h E_t\{(\lambda_{t+h}/\lambda_t)\psi_{t+h}(P_{t+h})^{1+\varepsilon} Y_{t+h}\}}{\sum_{h=0}^{3} \beta^h E_t\{(\lambda_{t+h}/\lambda_t)(P_{t+h})^{\varepsilon} Y_{t+h}\}}. \tag{5}$$

Further, the symmetric nature of the economic environment implies that all adjusting firms will choose the same price. One can see from equation (5) that, in a regime of zero inflation and constant marginal costs, firms would set their relative price $p^*(j)/P$ as a constant markup over marginal cost of $\frac{\varepsilon}{\varepsilon-1}$. In general, a firm's pricing decision depends on future marginal costs, the future aggregate price level, future aggregate demand, and future discount rates. For example, if a firm expects marginal costs to rise in the future, or if it expects higher rates of inflation, it will choose a relatively higher current price for its product.

The aggregate price level for the economy will depend on the prices charged by the various firms. Since all adjusting firms choose the same price, there will be four different prices charged for the various individual goods. Each different price is just a function of when that price was last adjusted. The aggregate price level is, therefore, given by

$$P_t = [\sum_{h=0}^{3}(1/4)(p_{t-h}^*)^{1-\varepsilon}]^{(1/(1-\varepsilon))}. \tag{6}$$

1.3. Steady State and Calibration

An equilibrium in this economy is a vector of prices p_{t-h}^*, wages, rental rates, and quantities that solve the firm's maximization problem, and the consumer's optimization problem, and in which the goods, capital, and labor markets clear. Furthermore, the pricing decisions of firms must be consistent with both the aggregate pricing relationship (6) and the behavior of the monetary authority described in the next section. When examining how the economy behaves when the central bank changes its policy rule, the above description of the private sector will remain invariant across policy rules and experiments.

The steady state is solved for the following parametrization. Labor's share, $1-\alpha$, is set at $2/3$, $\zeta = 9/5, \beta = .984, \varepsilon = 10, \delta = .025, \eta_R = 0$, and agents spend 20 percent of their time working. These parameter values imply a steady state ratio of I/Y of 18 percent, and a value of $\chi = 18.47$. The choice of $\zeta = 9/5$ implies a labor supply elasticity of 1.25, which complies with recent work by Mulligan(1998). A value of $\varepsilon = 10$ implies a steady state markup of 11 percent, which is consistent with the empirical work in Basu and Fernald (1997) and Basu and Kimball (1997).

The interest sensitivity of money demand is set at zero. The demand for money is generally acknowledged to be fairly interest insensitive in the short run with zero being the extreme case. Since the ensuing analysis concentrates on interest rate rules, the value of this parameter is unimportant. The adjustment cost function is parameterized so that the elasticity of the investment capital ratio with respect to Tobin's q is .25. This value is consistent with the estimate provided in Jermann (1998). The remaining parameter of importance is φ. Gali claims that a reasonable value for it lies between 1 and 2, implying increasing returns to employment. Since the general nature of the results presented in section 3 are not sensitive to this parameter, I set it to 1.5.

The economy is buffeted by two disturbances, a shock to technology and a shock to aggregate demand. The technology shock is modeled as a random walk with a standard deviation of one percent, while the demand shock is depicted as stationary with a mean of zero and an autocorrelation parameter of .5. The shock that is analyzed is a one percent increase in the demand for output. The nonstationarity of the technology shock and the stationarity of the demand shock are, therefore, consistent with the identifying assumptions used in Gali (1999).

2. Monetary Policy

To study the effects the systematic part of monetary policy has on the transmission of the various shocks to the economy, I shall investigate the model economy's behavior under three types of policy rules. The first is a simple money stock rule, in which money follows a random walk with drift. The drift term is parameterized so that the economy experiences a steady state inflation rate of 2 percent. This inflation rate is held constant across all three rules.

The other two rules employ an interest rate instrument, thus falling into the category broadly labelled as Taylor (1993) type rules. The first rule allows the monetary authority both to respond to expected deviations of inflation from target and expected deviations of current output from its steady state or potential level. Because shocks are assumed to be contemporaneously observed in this model, the specification allows policy responses to current movements in output. This rule is parameterized based on the estimations carried out in Clarida, Gali, and Gertler (1997) for the Volcker-Greenspan period. Their estimation also implies that the Fed is concerned with smoothing the behavior of the nominal interest rate; that behavior is incorporated into the following specification,

$$R_t = \overline{r} + \pi^* + .7R_{t-1} + .59(E_t\pi_{t+1} - \pi^*) + .04(Y_t - \overline{Y_t}). \qquad (7)$$

The second rule is backward looking and allows the Fed to respond to deviations of inflation from target and output levels from the steady state level of output. Specifically, I use the parameters in Taylor (1993)

$$R_t = \overline{r} + \pi^* + 1.5(\overline{\pi}_t - \pi^*) + .5(Y_t - \overline{Y_t}), \qquad (8)$$

where $\overline{\pi}$ is the average rate of inflation over the last four quarters, π^* is the inflation target of 2 percent, and $\overline{Y}_t$ is the steady state level of output. Under this rule, when inflation is running above target or output is above trend, monetary policy is tightened and the nominal interest is raised. I also consider a slight variant of (8) in which the central bank responds to output growth over the last four quarters rather than departures of output from its steady state value. This rule will be referred to as a *modified* Taylor rule[5].

The experiments in the ensuing section show how the model economy's response to shocks depends on the specification of the systematic portion of monetary policy. Importantly, the results indicate that statements such as those of Gali and Mankiw involve a complicated joint hypothesis. Depending on the monetary rule in place, conditional correlations can vary both in magnitude and sign. In general, one can say nothing about the underlying structure of price setting–sticky or flexible– from the correlations emphasized by these authors.[6]

3. A Comparison of the Policy Rules

This section demonstrates how the model economy reacts to the two shocks involving disturbances to technology and output demand. The underlying specification of the private sector is invariant in all experiments; only the specification of monetary policy is changed. As conventional in modern macroeconomics, the model's

[5]Because the coefficient on output gap term is so small in the Clarida, Gali and Gertler specification, there is almost no perceptible difference between impulse responses that use the output gap as opposed to output growth. Indeed omitting this term entirely has almost no effect on the behavior of the model economy under this policy rule.

[6]By concentrating on the sensitivity of the economy's responses to various shocks under different policies, the paper has a different emphasis from much of the recent work on systematic policy. The analysis is, therefore, similar in emphasis to recent papers by McCallum (1999) and Christiano and Gust (1999).

behavioral equations are linearized and the resulting system of expectational difference equations are solved numerically using the procedures outlined in King and Watson (1998).

3.1. Technology Shocks

The response of the model economy to technology shocks is given in figures 1 and 2. Figure 1 concentrates on response of hours, output, and average productivity, while figure 2 examines the relationship between inflation and output. The differences across policy rules is striking. When money growth is held fixed, employment initially falls in response to a permanent change in productivity. With no deviation in money from steady state there can be no deviation in nominal output from steady state. Because prices are sticky, they do not decline significantly. Therefore, output fails to increase by as much as the increase in productivity, and it takes less labor to produce the necessary output. This is the mechanism stressed by Gali. On the other hand, if the central bank follows the rule estimated by either Clarida, Gali, and Gertler or by Taylor, monetary policy is very accommodative of the technology shock, so much so that the price level increases and output actually overshoots its new steady state level. The large increase in output requires additional labor, implying that labor productivity and labor hours are positively correlated as they are in a simple RBC model. Thus, under reasonably specified monetary policy rules, one cannot distinguish the price setting behavior of firms from the conditional correlation emphasized in Gali. The sensitivity of this correlation to systematic monetary policy is additionally highlighted in the bottom right-hand panel of figure 1. If the central bank employs a modified Taylor rule by responding to output growth instead of deviations of output from potential output, then the impulse responses more closely resemble those obtained under the constant money growth rate rule. The resemblance occurs because monetary policy is not as accommodative in the modified Taylor rule. The modified rule calls for the central bank to tighten policy in response to output growth, which increases by more than the corresponding magnitude of output relative to potential. In equilibrium, this feature of the modified rule actually requires the monetary authority to raise the nominal interest rate less than it would if it followed the standard Taylor rule.

To muddy the waters further, Christiano and Todd (1996) are able to generate a negative conditional correlation between employment and labor productivity in an RBC model that is augmented with a time-to-plan investment technology.

Thus, one must conclude that this particular correlation is not very informative in identifying the feature of the economy that Gali seeks to uncover.

The impulse responses in figure 2 show that inflation-output correlations are also sensitive to the specification of monetary policy. In both the Clarida, Gali, and Gertler and Taylor specifications inflation is positively correlated with output. By contrast in the constant money growth rule and modified Taylor rulespecification inflation is negatively correlated with output. The exact same relationships hold in a flexible price model. Therefore,Mankiw's (1989) appeal to Phillips curve relationships as a way of identifying pricing behavior is problematic.

3.2. Demand Shocks

The response of the model economy to a temporary autonomous increase in demand is displayed in figures 3 and 4. With respect to the behavior of output, employment, and labor productivity all three interest rate rules imply similar behavior of the model economy. All three variables increase upon impact and then gradually return to steady state. This behavior, however, is exactly the behavior displayed in a flexible price model. Given that the Fed is behaving in a manner roughly consistent with these rules, the impulse response functions of these variables to a demand shock are not informative about the extent of price stickiness.

With respect to the behavior of inflation, the form of the monetary rule matters. In this case, the standard Taylor rule is less accommodative of the demand shock than the other two interest rate rules and the correlation between output and inflation is negative. The standard rule is less accommodative than the modified Taylor rule because future output deviations from steady state are generally larger than the growth rate of output, implying tighter future monetary policy under the standard rule. In equilibrium, though, the nominal interest rate rises by less under the standard Taylor rule. As in the case of the technology shocks, the inflation-output correlations are of the same sign when prices are flexible. Once again the presence or absence of a Phillips curve relationship is of little help in distinguishing between flexible and sticky price models.

4. Conclusion

There are a number of points established by the analysis presented in this paper. First and foremost is that the systematic component of monetary policy is important in determining the economy's reaction to shocks. In fact, the behavior of the model economy can differ so drastically across policies that forming some intuition about the underlying behavior of the private sector, such as whether prices adjust flexibly or are sticky, cannot be divorced from one's assumption about central bank behavior. In the limit, if the central bank were following the optimal policy prescribed in King and Wolman (1999), that policy would produce real behavior identical with the underlying real business cycle model. Of more relevance to my analysis is the observation that a standard real business cycle model produces a positive correlation between labor productivity and hours, which is inconsistent with the data. Yet the same is true for a sticky price model when the monetary authority follows either the rule estimated by Clarida, Gali, and Gertler (1999) or the one by Taylor (1993). This apparent inconsistency between model and data is, therefore, a poor reason to favor one type of model over the other, even though under a money stock rule the sticky price model does produce a negative correlation. The fact is that the Fed has probably never followed a money stock rule, so that intuition drawn under such a rule may be of little value. In light of the results presented above, discriminating among models based on impulse response functions is a subtle exercise that requires an accurate depiction of monetary policy.

References

[1] Basu, Susanto, and John Fernald, "Returns to Scale in U.S. Production: Estimates and Implications," *Journal of Political Economy,* vol. 105 (April 1997), pp.249-283.

[2] ______, and Miles Kimball, "Cyclical Productivity and Unobserved Input Variation," NBER working paper 5915, 1997.

[3] _______, John Fernald, and Miles Kimball, "Are Technology Improvements Contractionary?" Board of Governors of the Federal Reserve System International Finance Discussion Papers Number 625, September 1998.

[4] Chari, V.V., Patrick Kehoe, and Ellen McGrattan, "Sticky Price Models of the Business Cycle: Can the Contract Multiplier Solve the Persistence Problem?," Federal Reserve Bank of Minneapolis Staff Report 217, May 1998.

[5] Christiano, Lawrence J., and Christopher J. Gust, " Taylor Rules in a Limited Participation Model," NBER working paper 7017, March 1999.

[6] Christiano, Lawrence J., and Richard M. Todd, "Time to Plan and Aggregate Fluctuations," Federal Reserve Bank of Minneapolis *Quarterly Review,* (Winter 1996), pp. 14-27.

[7] Clarida, Richard, Jordi Gali, and Mark Gertler, "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory," manuscript, May 1997.

[8] Dotsey, Michael, "The Importance of Systematic Monetary Policy for Economic Activity," Federal Reserve Bank of Richmond *Economic Quarterly,* (Summer 1999), pp.41-60.

[9] _____________, Robert G. King, and Alexander L. Wolman, "State Dependent Pricing and the General Equilibrium Dynamics of Money and Output," *Quarterly Journal of Economics,* vol. CXIV (May 1999), pp.655-690.

[10] Gali, Jordi, "Technology, Employment, and the Business Cycle: Do Technology Shocks Explain Aggregate Productivity?," *The American Economic Review* vol. 89 (March 1999), pp. 249-271.

[11] Goodfriend, Marvin S., and Robert G. King, "The New Neoclassical Synthesis and the Role of Monetary Policy," *National Bureau of Economics Macroeconomics Annual 1997,* pp. 231-293.

[12] Jermann, Urban J., "Asset Pricing in Production Economies," *Journal of Monetary Economics,* vol. 41 (April 1998), pp. 257-276.

[13] King, Robert G., and Mark W.Watson, "The Solution of Singular Linear Difference Systems Under Rational Expectations," *International Economic Review,* vol. 39, (November 1998), pp. 1015-1026.

[14] _____________, and Alexexander L. Wolman, "What Should the Monetary Authority Do When Prices are Sticky?" in *Monetary Policy Rules*, ed. John B. Taylor National Bureau of Economic Research 1999, pp. 349-398.

[15] Mankiw, N. Gregory, "Real Business Cycles: A New Keynesian Perspective," *Journal of Economic Perspectives,* vol. 3 (Summer 1989), pp. 79-90.

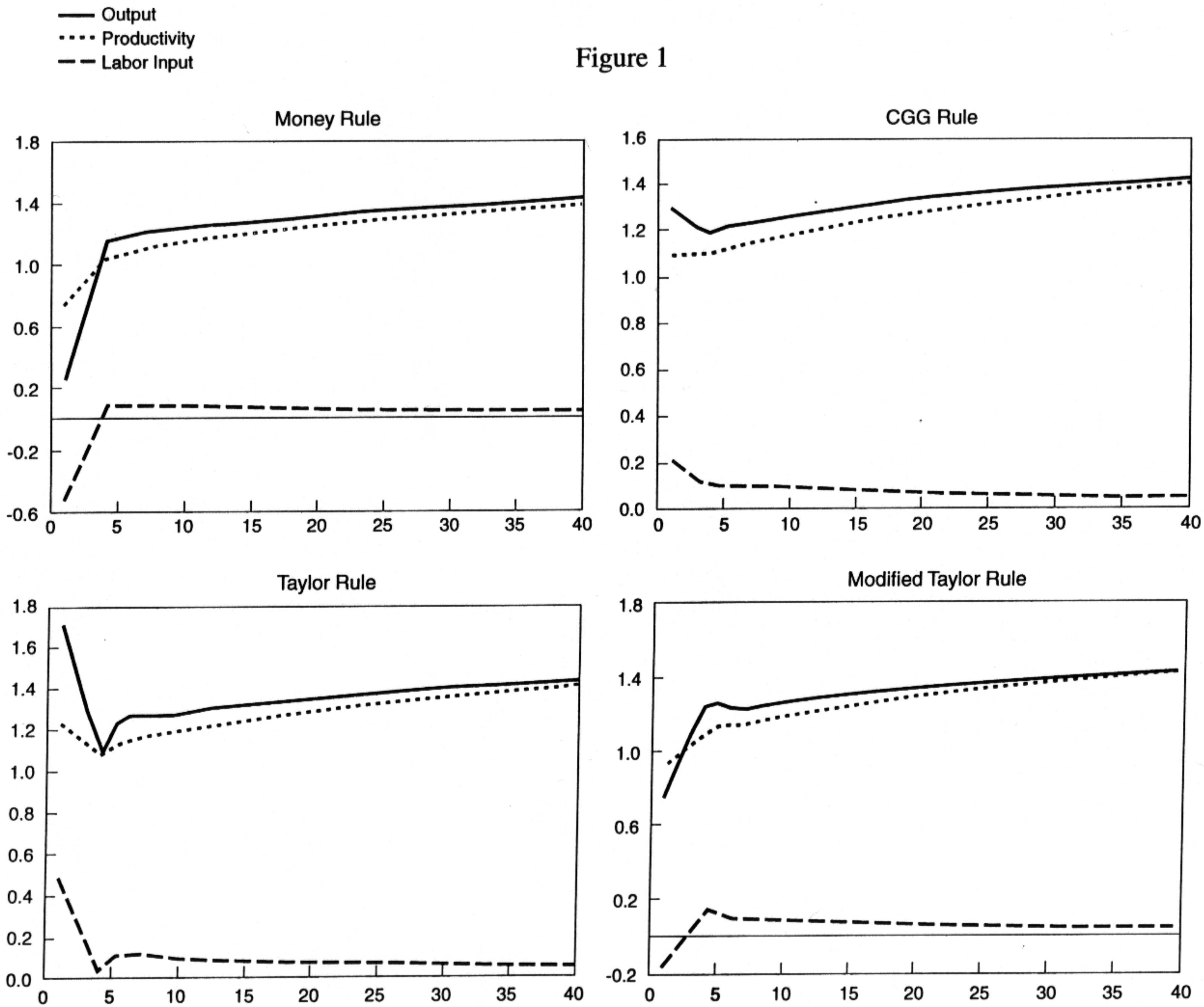
[16] McCallum, Bennett T., "Analysis of the Monetary Transmission Mechanism: Methodological Issues," manuscript, February 1999.

[17] Mulligan, Casey B. "Substitution over Time: Another Look at Life Cycle Labor Supply," *National Bureau of Economics Macroeconomics Annual 1999,* pp. 75-134.

[18] Sarte, Pierre-Daniel, "On the Identification of Structural Vector Autoregressions," Federal Reserve Bank of Richmond *Economic Quarterly,* vol. 83 (Summer 1997), pp. 45-67.

[19] Taylor, John B., "Discretion Versus Policy Rules in Practice," *Carnegie-Rochester Conference on Public Policy,* vol. 39 (1993), pp. 195-214.

Figure 1



Output
Productivity
Labor Input
Money Rule
CGG Rule
Taylor Rule
Modified Taylor Rule

Figure 2

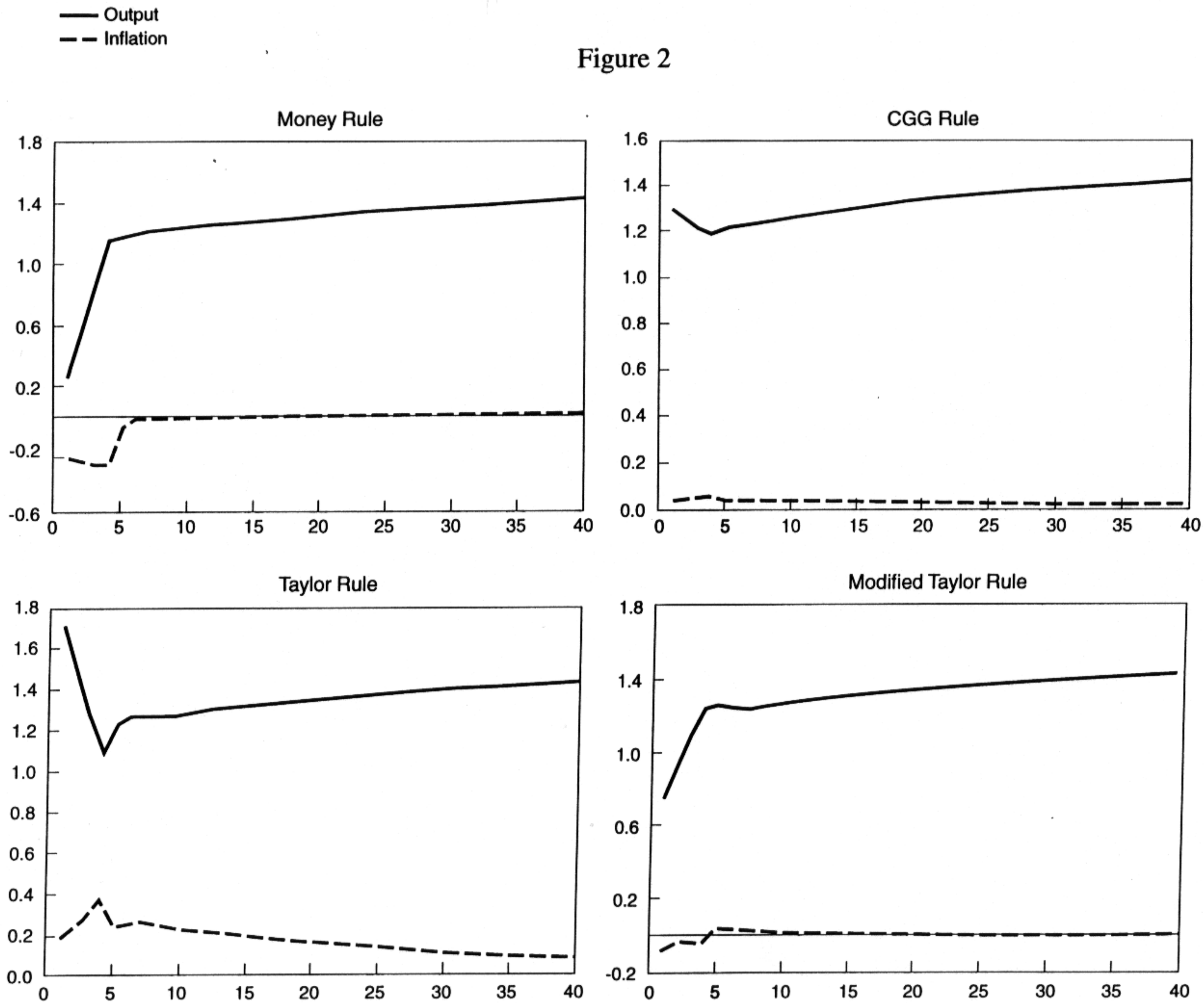
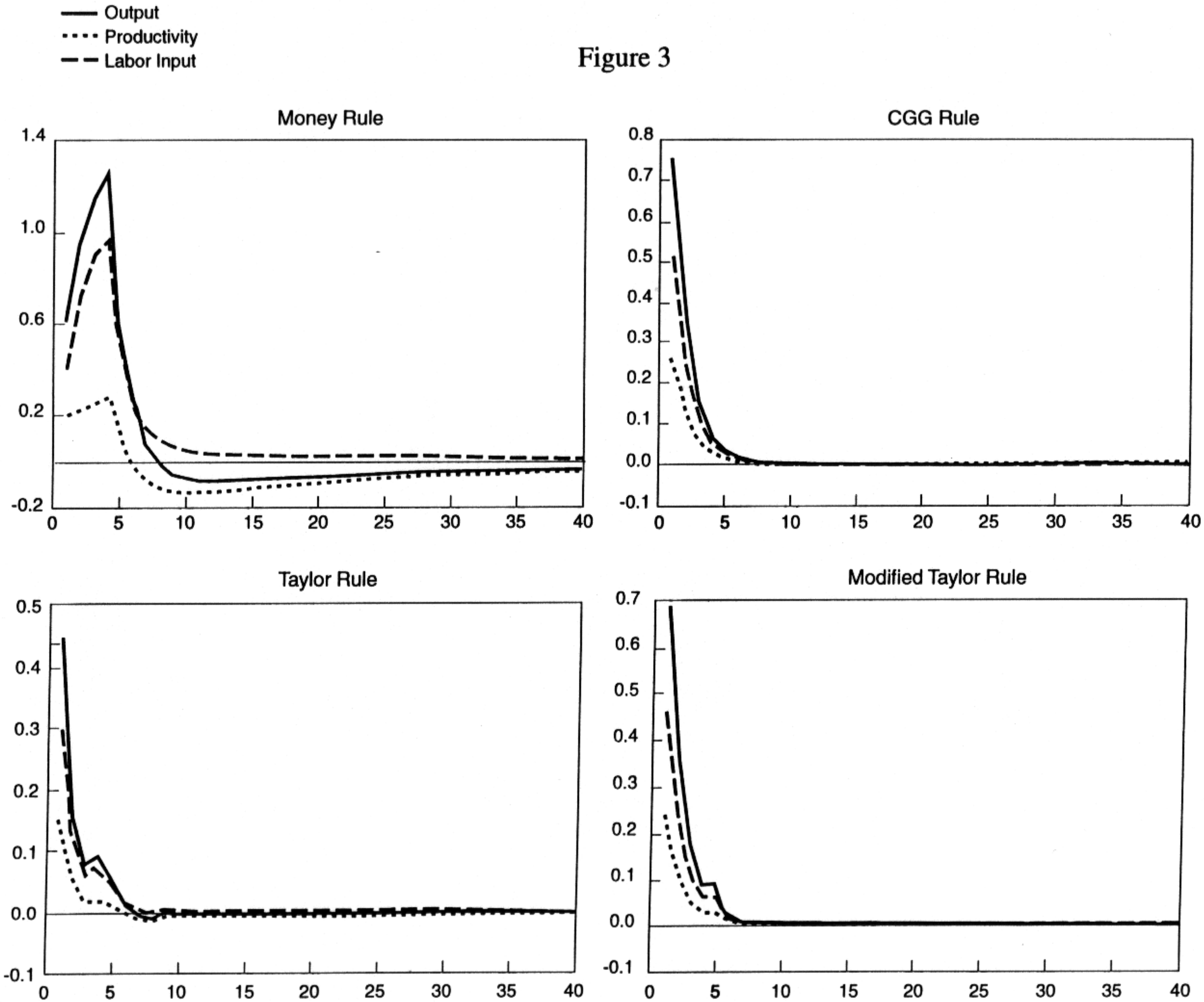
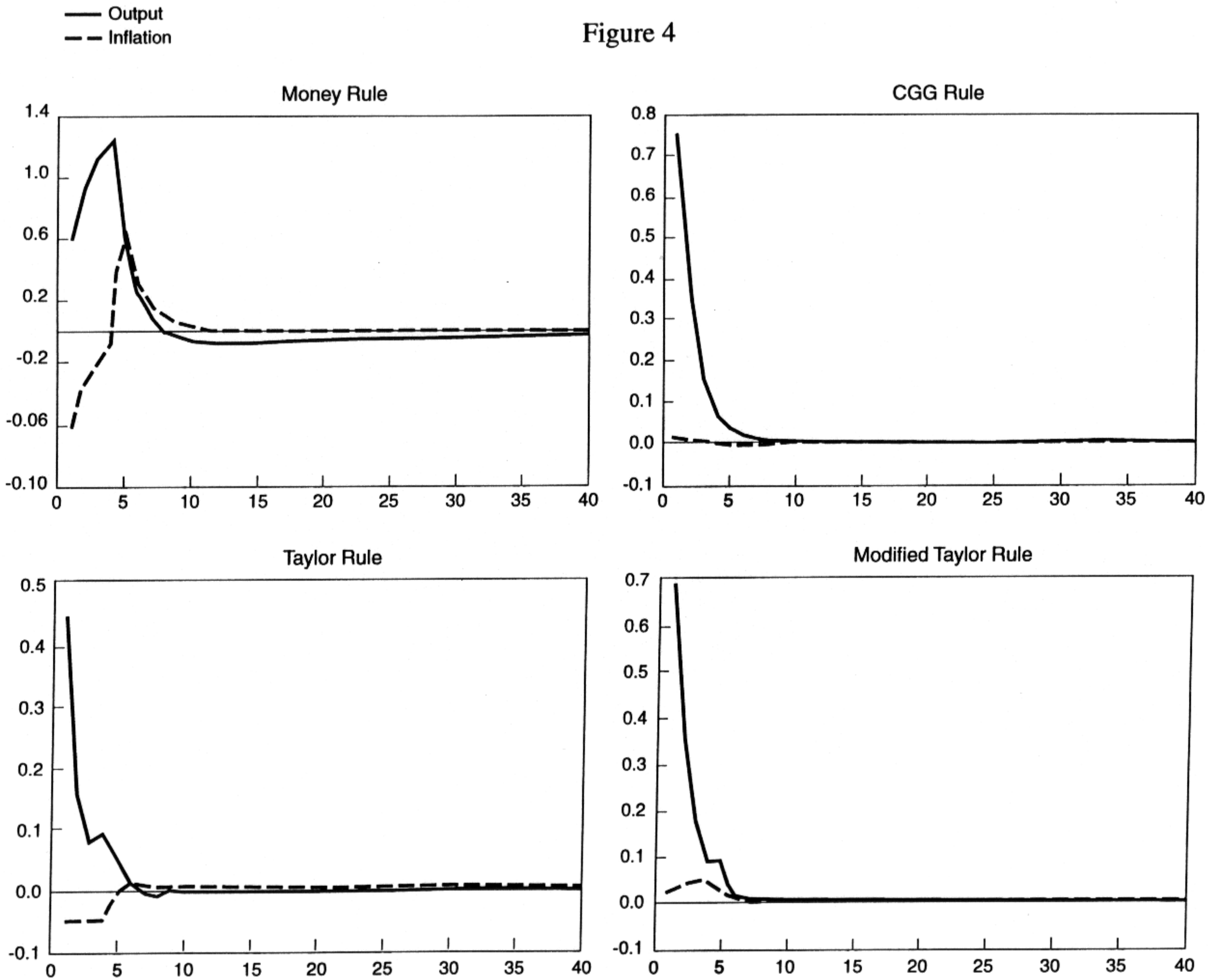

Output
Inflation
Money Rule
CGG Rule
Taylor Rule
Modified Taylor Rule
1.8
1.4
1.0
0.6
0.2
-0.2
-0.6
1.6
1.2
0.8
0.4
0.0
0
5
10
15
20
25
30
35
40

Figure 3



Output
Productivity
Labor Input
Money Rule
CGG Rule
Taylor Rule
Modified Taylor Rule

Figure 4



Output
Inflation
Money Rule
1.4
1.0
0.6
0.2
-0.2
-0.06
-0.10
0
5
10
15
20
25
30
35
40
CGG Rule
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
Taylor Rule
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
Modified Taylor Rule
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1