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Money Supply and Interest Rate Policy in a New-Keynesian Framework 1/

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Abstract

The central role of interest rates in the implementation of monetary policy has become more pronounced in recent years. Therefore, monetary policy should probably be viewed as including both the control of some monetary aggregate (money supply policy) and of some nominal interest rate (interest rate policy). This paper provides a unified treatment of both money supply and interest rate policy in a closed-economy, sticky-prices model, with special emphasis on temporary policies. It is shown that a temporary rise in the controlled interest rate initially lowers inflation but eventually leads to higher inflation.

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431

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Contents

Summary

In the implementation of monetary policy interest rates have assumed a more pronounced role in recent years. As a result, monetary policy should probably be viewed as comprising both money supply policy (the control of some monetary aggregate) and interest rate policy (the control of some key exogenous nominal interest rate). This paper provides a unified treatment of both types of policies in the context of a closed-economy, sticky-prices model. The analysis focuses on temporary policies and their effects on output and inflation.

In order to study interest rate policy, policymakers are assumed to control the interest rate on an asset that provides liquidity services, which is identified here as demand deposits. As a result, policymakers can vary the nominal interest rate on this liquid asset without necessarily changing the rate of growth of the money supply (defined as currency plus demand deposits). While a permanent increase in the controlled interest rate reduces inflation in the short run, it has no effect on steady-state inflation. Both a temporary reduction in the rate of expansion of the money supply and a temporary increase in the controlled interest rate are shown to succeed in lowering inflation in the short run at the cost of a recession. In the case of money supply policy, inflation remains lower than initially throughout the adjustment process. In contrast, in the case of interest rate policy, inflation eventually rises over and above its initial level. The analysis thus suggests that interest rate policy is not a good substitute for money-supply policy in achieving a lasting reduction in the inflation rate.

I. Introduction

Interest rates have traditionally played a key role in the conduct of monetary policy. In recent years, the emphasis on controlling interest rates has become even more pronounced. Higher inflation, for instance, usually leads policymakers to raise short-term interest rates. Monetary policy should therefore no longer be viewed as consisting mainly of controlling some monetary aggregate, but also of controlling some key short-term interest rate. The purpose of this paper is to provide a unified treatment of both types of monetary policy--which are defined as money supply policy and interest rate policy--in a sticky-prices model that has come to be identified with the New-Keynesian view. It constitutes the rational-expectations counterpart to the New-Classical position (epitomized by Lucas (1981)). Money supply policy consists of changing the rate of growth of the (exogenous) money supply; interest rate policy consists of changing some key (exogenous) nominal interest rate. Special emphasis is placed on the latter because--as recently documented by Batten et al (1990)--it seems to be the dominant policy in G-5 countries. In Latin American countries, interest rates hikes on highly liquid assets, achieved by remunerating banks' reserves, have also played an important role (see, for instance, Rodriguez (1988)).

Expectations are assumed to be rational and prices are posited to be revised in a non-synchronous fashion (as in Phelps (1978), Taylor (1979, 1980) and Calvo (1983), for example). To keep matters within reasonable analytical limits, we employ the staggered-prices model developed by Calvo (1983) and embed it in a closed-economy IS-LM framework. This has the advantage of reducing the dynamic system of Calvo (1983) by one differential equation, which allows us to examine the impact of temporary policy--the focal policy point of the paper--in a relatively simple fashion.

An analytical hurdle for studying interest rate policy is that it may easily lead to equilibrium indeterminacy, independently of whether prices are flexible (Sargent and Wallace (1975)) or sticky (Calvo (1983)). Determinacy can be recovered, though, by simultaneously setting money supply targets (as in McCallum (1981), Calvo (1982), Canzoneri, Henderson, and Rogoff (1983), Goodfriend (1987), Gagnon and Henderson (1988), and Reinhart (1990), among others). These targets, however, cannot be independently set from one another, for, otherwise, the system would, in general, become overdetermined. This implies that to study the effect of a change in the interest-rate target one has to simultaneously modify the money supply target. Thus, it is not clear whether one wants to think of the effects of a change in the interest rate target, for example, as just the consequence of interest rate policy.

In the present paper, the effects of money supply and interest rate policy are much easier to identify because the structure of the model allows us to change one of the targets while keeping the other constant. Determinacy is ensured by assuming that the monetary authority can affect the interest rate of a limited set of financial assets (as in Calvo and Végh (1990a,b)). Furthermore, it is assumed that those assets are imperfect substitutes with the rest of the private-sector financial portfolio. We feel comfortable with this (largely ad-hoc) assumption because uniqueness of equilibrium is recovered by throwing in just a "pinch of liquidity" in the assets whose interest rate is controlled by the central bank.

Both permanent and temporary changes in the rate of growth of the money supply (money supply policy) and the controlled interest rate (interest rate policy) are examined. In the long run, the inflation rate does not depend on the controlled interest rate. Therefore, only a permanent reduction in the rate of growth of the money supply succeeds in lowering the inflation rate in the long run. However, the short run effects of a permanent reduction in the rate of growth of the money supply and a permanent increase in the controlled interest rate are similar: inflation is brought down at the cost of a sharp recession.

The effects on output and inflation of temporary money supply and interest rate policy differ substantially. A temporary reduction in the rate of growth of the money supply reduces inflation and output in the short run. Furthermore, inflation remains below its initial value during the entire adjustment process. Similarly, output also remains below its full employment level during the whole adjustment path. A temporary rise in the controlled interest rate also reduces inflation and output in the short-run. However, the inflation rate eventually surpasses its initial level. Thus, fighting inflation by raising the controlled interest rate will lead to higher inflation in the future. Output will eventually rise above its full employment level. The reasons for the different behavior of output and inflation are the following. First, since the rate of growth of the money supply does not change when interest rate policy is pursued, the initial fall in inflation requires a later increase of the inflation rate over and above its initial level for real money balances to return to their initial level. Second, changes in the controlled interest rate exert a direct effect on output, which is absent under money supply policy. Specifically, an increase in the interest rate raises the demand for the liquid asset. Since real money supply is fixed, a rise in the nominal interest rate borne by the non-liquid bond is needed to equilibrate the money market, which raises the real interest rate and reduces output.

In summary, the main lesson that would follow from the analysis is that raising interest rates is not a good substitute for a reduction in the rate of expansion of the money supply. Higher interest rates succeed in reducing inflation only in the short-run. Moreover, when the interest rate hike is temporary, inflation initially falls but then comes back with a vengeance, surpassing the level that led policymakers to raise interest rates to begin with.

An interesting feature of the model is that the phenomenon of stagflation can arise as a result of temporary changes in monetary and interest rate policy. Keynesian models have traditionally had a hard time accounting for this phenomenon. This simple New-Keynesian framework, however, generates "inverse" Phillips-curve relationships; that is, inflation and aggregate demand may be negatively correlated along equilibrium paths.

The paper proceeds as follows. The basic model and interpretations are presented in Section 2. Money supply policy is discussed in Section 3, whereas interest rate policy is examined in Section 4. Final remarks close the paper in Section 5.

II. The Model

This section introduces the model and sets up the dynamic system that will provide the basic analytical framework for the examination of money supply and interest rate policy.

The supply side follows Calvo's (1983) staggered-prices model. Calvo's (1983) formulation is in the spirit of the staggered-contracts models of Phelps (1978) and Taylor (1979, 1980), although it does not actually depend on the existence of nominal contracts. There exist a large number (actually, a continuum) of identical firms that produce a non-storable good. Suppose that each firm cannot change prices at every point in time because, say, it is prohibitively costly to do so. Instead, a firm may change prices only when it receives a stochastic price-signal. The probability of receiving such a signal x periods from now is $\delta\exp(-\delta x)$, where $\delta>0$. When it comes the time to set its price, each firm takes into account the expected future path of the average price of the good and the path of excess demand in the market. More formally, we assume that firms receiving the price-change signal at time t set their price according to:

$$V_t = \delta \int_t^{\infty} [P_s + \beta E_s] \exp[-\delta(s-t)]ds, \qquad \beta>0, \tag{1}$$

where V_t is the logarithm of the price quotation set at t, P is the logarithm of the price level, and E is aggregate demand. (Although expected values belong in equation (1), actual values have been used because of the assumption of perfect foresight.) If price-change signals are uncorrelated across price-setters, the proportion of prices that are set at time t-s turns out to be $\delta\exp[-\delta(t-s)]$. The price level is defined as the weighted average of prices currently quoted; thus,

$$P_t = \delta \int_{-\infty}^{t} V_s \exp[-\delta(t-s)]ds, \tag{2}$$

While P_t is a predetermined variable--because it is given by past price quotations--V_t is not. Differentiating equations (1) and (2) with respect to time yields (a dot over a variable denotes its time derivative)

$$\dot{V}_t = \delta[V_t - P_t - \beta E_t], \tag{3}$$

$$\pi_t = \delta[V_t - P_t], \tag{4}$$

where $\pi \equiv \dot{P}$, and is interpreted as the inflation rate. 1/ It follows from (3) and (4) that

$$(5) \qquad \dot{\pi}_t = -bE_t,$$

where $b \equiv \delta^2 \beta > 0$. Equation (5) says that the rate of change in the rate of inflation is negatively related to excess demand. It thus can be viewed as a "higher order," inverse Phillips curve. Intuitively, the higher is excess demand at time t, the higher will be the prices set by those firms that revise their prices at time t. As a result, the higher will be the inflation rate at time t, because, as indicated by equation (4), the inflation rate is a function of the difference between the (log of the) newly-set prices, V, and the (log of the) price level. The excess demand at time t is not taken into account by those firms setting their prices at time t'>t. Therefore, the higher is excess demand at t, the sharper is the drop in the inflation rate, which is what equation (5) asserts.

The demand side of the model is a standard IS-LM framework modified to eliminate the inflation rate indeterminacy associated with a pegged interest rate. 2/ Two alternative set-ups will be considered which, from an analytical point of view, amount to the same but differ in their interpretation.

(i) Suppose that, in carrying out their purchases, consumers utilize two liquid assets: cash (H) and interest-bearing demand deposits (Z). 3/ To simplify the analysis, we abstract from the banking system and assume that both assets are issued by the government. The government's total liabilities will be referred to as money (M); that is, M≡H+Z. This is equivalent to viewing the government as issuing liquidity-bearing bonds that are acquired exclusively by financial institutions. Financial institutions, in turn, issue demand deposits to their customers. In a world of competitive and costless banking with no reserve requirements, demand deposits will bear the same rate of interest as bonds. In fact, it is as though these government liabilities were "broken down" into small pieces by financial institutions and sold to the public.

The government controls the interest rate on Z, denoted by i, by letting the composition of its total liabilities, M, be demand-deter mined. In addition, there is a "pure" bond (in the sense that it does

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1/ Notice that, by the law of large numbers, π is non-stochastic.

2/ We feel comfortable with this "ad-hoc" specification because the same results would obtain if demands for assets and goods were derived from optimizing consumers, as follows from Calvo and Végh (1990b). Therefore, this paper's specification enables us to convey the same message with a much more tractable model.

3/ This set-up is in the spirit of Calvo and Végh (1990a,b), who assume that the consumer is subject to a "liquidity-in-advance constraint" that includes both cash and demand deposits.

not yield liquidity services) whose interest rate is I. 1/ The consumer's demand for cash and demand deposits are given by (for simplicity, linear functional forms are adopted):

(6) $$h_t = \alpha_1 y_t - \alpha_2 I_t,$$

(7) $$z_t = \alpha_3 y_t - \alpha_4 (I_t - i_t),$$

where h and z stand for real cash balances and demand-deposits, respectively; y denotes income; and α_i, i=1,2,3,4, denote positive constants. The demands for h and z depend positively on income and negatively on the opportunity cost of holding each asset. Combining (6) and (7) yields the demand for cash and demand-deposits; that is, the demand for money:

(8) $$m_t = \alpha_5 y_t - \alpha_6 I_t + \alpha_4 i_t,$$

where m≡h+z, $\alpha_5 \equiv \alpha_1+\alpha_3$ and $\alpha_6 \equiv \alpha_2+\alpha_4$. The demand for money depends positively on i because an increase in i reduces the opportunity cost of holding h. We feel this interpretation would be particularly relevant for developing countries where it is not unusual for the Central Bank to pay interest on much of its liabilities. (Rodriguez (1988), for instance, emphasizes this point for the case of Argentina.)

(ii) Suppose that the Central Bank follows a non-borrowed reserves procedure. In other words, the authorities control the reserves of the banking system that are not supplied through the discount window. Borrowed reserves (or discount loans) are assumed to be an increasing function of the difference between the market interest rate, I, and the discount rate, i. Hence, assuming, for simplicity, that reserve requirements are one-hundred percent, the money supply can be expressed as:

(6′) $$m_t = \ell_t + \alpha_4 (I_t - i_t),$$

where ℓ denotes non-borrowed reserves. The demand for money is given by:

(7′) $$m_t = \alpha_5 y_t - \alpha_3 I_t.$$

Combining (6′) and (7′) yields

(8′) $$\ell_t = \alpha_5 y_t - \alpha_6 I_t + \alpha_4 i_t,$$

where $\alpha_6 \equiv \alpha_3+\alpha_4$. Equation (8′) can be viewed as a "derived demand" for non-borrowed reserves, and is formally the same as equation (8). However, the interpretation of the effects of i on ℓ in equation (8′) is

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1/ In what follows, the interest rate I will be referred to as the pure nominal interest rate to distinguish it from i, which will be referred to simply as the nominal interest rate.

different from the interpretation of the effects of i on m in equation (8). Other things being equal, an increase in the discount rate, i, decreases borrowed reserves and thus the money supply. Equilibrium in the money market requires an increase in ℓ. In this set-up, the authorities can control i by giving up the control over the money supply. We feel this second interpretation would be particularly relevant for industrialized countries. (Batten et al, for instance, examine how the United States switched in 1979 to controlling the supply of non-borrowed reserves.)

For the sake of concreteness, we will henceforth stay with the first interpretation. Therefore, the discussion will be based on equation (8). But, naturally, since the model is formally the same, switching to the second interpretation is straightforward.

The IS schedule is given by

$$(9) \qquad y_t = \alpha_7 - \alpha_8(I_t - \pi_t).$$

Combining equations (8) and (9) yields aggregate demand:

$$(10) \qquad y_t = \phi_0 + \phi_1\pi_t + \phi_2 m_t - \phi_3 i_t,$$

where $\phi_0 \equiv \alpha_7/A$, $\phi_1 \equiv \alpha_8/A$, $\phi_2 \equiv (\alpha_8/\alpha_6)/A$, $\phi_3 \equiv (\alpha_8\alpha_4/\alpha_6)/A$, and $A \equiv 1+(\alpha_8\alpha_5/\alpha_6)$. The only unfamiliar term that appears in equation (10) is the last term on the right-hand side. An increase in i has a <u>negative</u> effect on aggregate demand because, other things being equal, it leads to a higher I and thus to a higher real interest rate, r (where $r \equiv I - \pi$).

To close the model, define $E \equiv y - y^*$, where y^* is the full-employment level of output (that is, that level of output at which there are no pressures for the inflation rate to rise or fall). It will be assumed that output is always demand-determined. Substituting $E \equiv y - y^*$ into equation (5) and making use of equation (10) yields

$$(11) \qquad \dot{\pi}_t = b[y^* - \phi_0 - \phi_1\pi_t - \phi_2 m_t + \phi_3 i_t].$$

Finally, equilibrium in the money market implies that

$$(12) \qquad \dot{m}_t = (\mu_t - \pi_t)m_t,$$

where $\mu \equiv (\dot{M}/M)$. Given the rate of growth of nominal money balances, μ, and the nominal interest rate, i, which are policy parameters, equations (11) and (12) constitute a dynamic system in the inflation rate, π, and real money balances, m. Given these two variables, equations (9) and (10) yield the dynamic paths of the pure nominal interest rate, I, and output, y. Finally, the dynamic paths of real cash balances, h, and real demand-deposits, z, follow from equations (6) and (7). By definition, "money supply policy" consists of changing the rate of growth of the money supply, μ, while keeping constant the nominal interest rate, i; and "interest rate policy" consists of changing the nominal interest rate, i, while keeping constant the rate of growth of the money supply, μ.

The steady-state of the system is given by (upper bars denote steady-state values):

(13) $\bar{\pi} = \bar{\mu}$,

(14) $\bar{m} = -(\alpha_7\alpha_6/\alpha_8) + (1/\phi_2)y^* - \alpha_6\bar{\mu} + \alpha_4\bar{i}$,

(15) $\bar{y} = y^*$,

(16) $\bar{I} = (\alpha_7/\alpha_8) - (1/\alpha_8)y^* + \bar{\mu}$,

(17) $\bar{r} = (\alpha_7/\alpha_8) - (1/\alpha_8)y^*$,

(18) $\bar{m} = -(\alpha_2\alpha_7/\alpha_8) + [\alpha_1+(\alpha_2/\alpha_8)]y^* - \alpha_2\bar{\mu}$,

(19) $\bar{h} = -(\alpha_4\alpha_7/\alpha_8) + [\alpha_3+(\alpha_4/\alpha_8)]y^* - \alpha_4\bar{\mu} + \alpha_4\bar{i}$.

Figure 1 illustrates the dynamic system in π and m, which is saddle-path stable (see Appendix). The saddle-path is represented by schedule A'A' which goes through point A. Knowledge of the paths of π and m, however, will not prove in general sufficient to determine the path of y. Therefore, it is necessary to construct a second dynamic system in y and m. Differentiating equation (10) and using $\dot{\pi}_t=b(y^*-y_t)$ we obtain:

(20) $$\dot{y}_t = \phi_1 b(y^*-y_t) + \phi_2\dot{m}_t$$

Solving for π_t from (10) and substituting it into (12) yields:

(21) $$\dot{m}_t = [\mu_t+(\phi_0/\phi_1)-(y_t/\phi_1)+(\phi_2/\phi_1)m_t-(\phi_3/\phi_1)i_t]m_t$$

The system given by (14) and (15) is illustrated in Figure 2, where the saddle-path is depicted by schedule A'A' going through point A (see Appendix). From Figures 1 and 2, we can already infer that, following unexpected and permanent changes in either μ or i, output and inflation will move in the same direction, as more naïve formulations of the Phillips curve would predict. As we will see, however, output and inflation can move in opposite directions following temporary changes in either μ or i. Therefore, <u>no specific co-movement between output and inflation can be predicted without an exact knowledge of the timing and nature of the change in either money supply policy or interest rate policy</u>.

III. Money Supply Policy

This section examines money supply policy; that is, changes in the rate of growth of money supply, μ, keeping constant i_t at the value $\bar{i}$. Specifically, the analysis concentrates on reductions in μ because we wish to compare μ and i as price-stabilization tools.

a. Permanent reduction in the rate of growth of the money supply

As a benchmark, consider the simplest case: an unanticipated and permanent reduction in μ. More formally, suppose that initially (that is, prior to t=0, which we take as the "present") $\mu_t=\mu^h$ and that at t=0 μ_t is reduced to μ^ℓ. 1/ The initial steady-state is point A in Figure 1. The reduction in μ shifts the $\dot{m}=0$ locus to the left so that the new steady-state is given by point C where $\bar{\pi}$ is lower and $\bar{m}$ is higher. (Schedule C'C' depicts the saddle path corresponding to point C.) On impact, the inflation rate falls precipitously from A to B and then both the inflation rate and real money balances travel along the saddle path towards point C. The path of output can be inferred without resorting to Figure 2. By equation (10), output falls on impact due to the fall in the inflation rate, which raises the real interest rate. Given that both inflation and real money balances increase thereafter, output rises as well. The real interest rate, being the mirror image of output (see equation (9)), increases on impact and then falls over time. The pure nominal interest rate, I, falls on impact, as follows from (8). Since r increases on impact, the fall in I is always smaller than that of π. During the adjustment path, I decreases over time to its lower steady-state (assuming, for the sake of concreteness, that α_5 is close to zero, which implies that I moves in a direction opposite to that of m, as shown in the Appendix). 2/ 3/ Intuitively, the reduction in the rate of monetary growth implies lower steady-state inflation and thus higher steady-state real money balances. For real money balances to grow over time, the inflation rate needs to fall on impact by more than the rate of monetary growth does. As a result, the real interest rate rises, which causes a sharp decline in output.

The response of the economy to a permanent reduction in μ is therefore the same that obtains in Calvo's (1983) model, which is a reassuring feature given our simpler formulation. We now enter new territory and study temporary money supply policy.

b. Temporary decrease in the rate of growth of the money supply

Consider now a temporary decrease in μ. Suppose that initially (that is, for t<0), $\mu_t=\mu^h$. At t=0, μ_t is reduced to μ^ℓ up to t=T at which time it increases back to μ^h. Formally, for t≥0, money supply policy is given by

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1/ Throughout the paper, superscripts "h" and "ℓ" refer to "high" and "low" values of policy parameters, respectively.

2/ In what follows--and unless otherwise specified--this assumption will be maintained when referring to I.

3/ For the sake of brevity, and since it is not the main focus of the paper, specific reference will not be made to the responses of real cash balances, h, and real demand-deposits, z, whose steady-state values follow from (18) and (19) and dynamic paths from (6) and (7).

Figure 1. Money Supply Policy: Dynamics in the (π,m) Plane

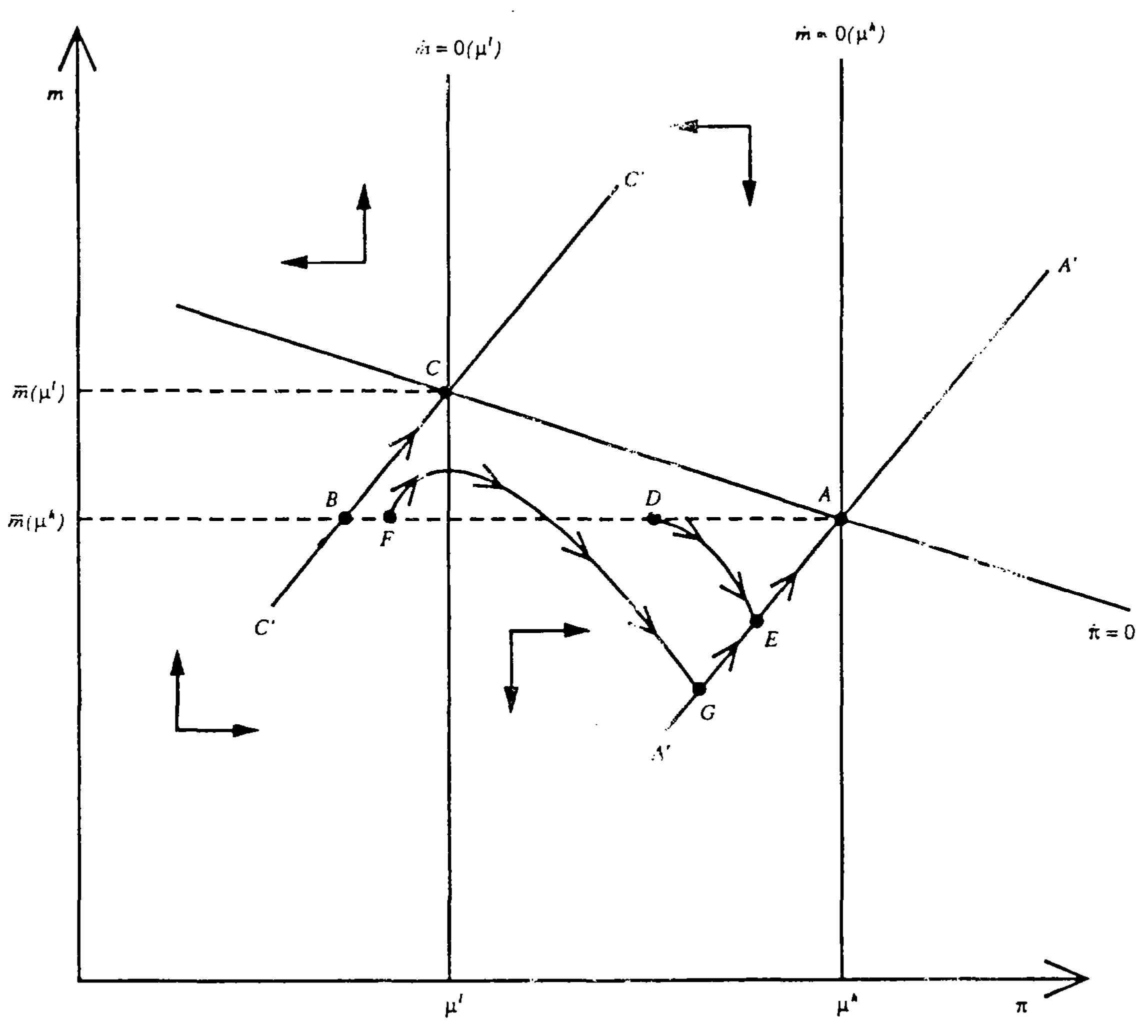
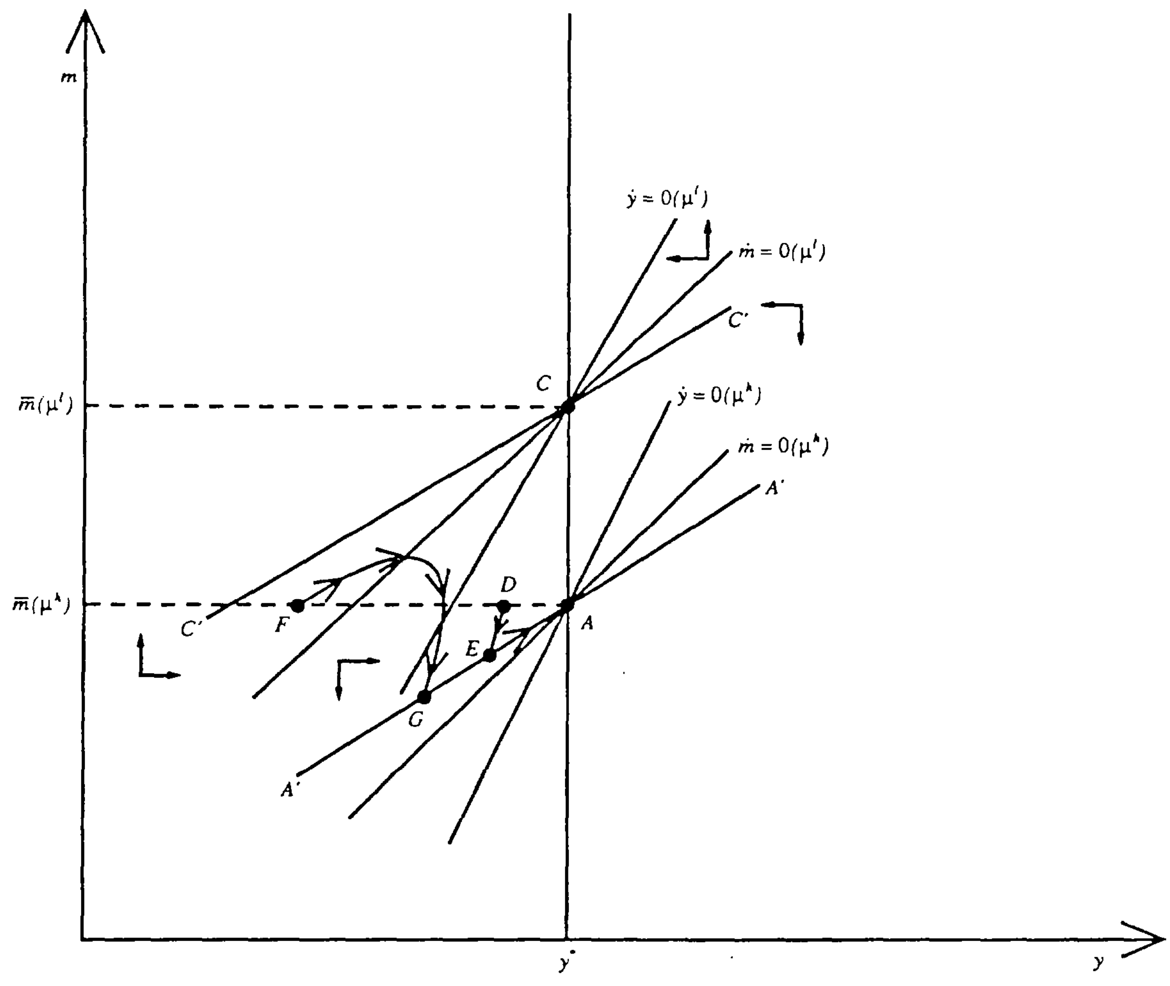


Figure 2. Money Supply Policy: Dynamics in the (y,m) Plane



(22a) $\mu_t = \mu^{\ell}$, $0 \leq t < T$,

(22b) $\mu_t = \mu^h$, $t \geq T$,

where $T > 0$, and $\mu^h > \mu^{\ell}$. A key analytical issue that arises whenever temporary or anticipated changes in policy variables are considered is the continuity of endogenous variables at t=T. It follows from equation (4) that π_t is continuous at t=T because both V_t and P_t are continuous at t=T. The inflation rate cannot jump at time T because newly-set prices, V, cannot jump in response to anticipated changes in the path of the price level or aggregate demand, as indicated by equation (1). Since real money balances cannot jump at t=T, the continuity of the inflation rate at time T implies that of output, as follows from equation (10).

Figure 1 depicts the outcome of a temporary reduction in μ. The initial steady-state is given by point A. Since neither the inflation rate nor real money balances can jump at t=T, the dynamic system must hit the saddle path A'A' at time T in order to return to the initial steady-state; otherwise, the system would not converge. The relevant directional arrows during the transition are those corresponding to steady-state C. 1/ Qualitatively, the following two cases may occur:

(i) Suppose that the temporary reduction in μ will be of short duration (that is, T is small). Then the system jumps to point D, travels along an unstable branch during the transition to hit the saddle path (point E) at t=T, and then proceeds along the saddle path towards point A. Thus, the inflation rate falls on impact and increases thereafter. The path of real money balances is not monotonic. Real money balances decrease during the transition and increase afterwards. The fact that real money balances and inflation move in opposite directions during the transition suggests that output may adjust in a non-monotonic way. To examine the path of output, consider Figure 2, where A continues to denote the initial steady-state and C continues to denote the steady-state that results from an unanticipated and permanent rise in μ. A small T would imply a path like ADEA in Figure 2. Output falls on impact from A to D, decreases during the transition until it hits point E, and then increases towards A. Therefore, if the stabilization attempt is short-lived, the economy slips deeper into recession after the initial fall in output, before beginning to recover. Note that during the transition we have stagflation (that is, rising inflation and declining output). The real interest rate jumps upwards on impact, increases during the transition, and falls afterwards. The pure nominal interest rate, I, falls on impact, increases during the transition overshooting its steady-state value, and falls thereafter.

The results may be interpreted as follows. The reduction in the rate of monetary growth leads price-setters to expect lower inflation and lower

1/ The term "transition" will be used to refer to the period [0,T).

aggregate demand in the future. Since price-setters are forward-looking, they immediately lower their individual prices, which leads to a reduction in the inflation rate. As a result of the fall in inflation, the real interest rate rises and, hence, output falls. Since the period of time during which the lower rate of growth of the money supply will prevail is expected to be short, firms adjust their prices downward only by a small amount. Hence, the fall in the inflation rate is not as large as the fall in the rate of growth of the money supply, and real money balances begin to fall. After the initial fall, inflation rises over time because price-setters set higher prices than initially, as the end of the period of low money-supply growth draws nearer. During the transition, two opposite forces act on the real interest rate: the rising inflation tends to reduce it, while declining real money balances tend to increase it. The latter effect prevails, since inflation has not fallen by much and therefore the fall in real money balances is large. As a result, output falls over time during the transition.

ii) Suppose T is large; that is, the rate of monetary growth is reduced for a long period of time. Then, in terms of Figure 1, the system jumps from A to F on impact, and then follows the path FGA. After falling on impact, inflation increases during the whole adjustment process, as in the previous case. Unlike the previous case, real money balances increase at first, before falling during the rest of the adjustment process. Once again, this suggests a non-monotonic adjustment for output. Consider path AFGA in Figure 2 which would be consistent with path AFGA in Figure 1 since, during the transition, real money balances increase at first and then decreases. Output falls on impact, increases thereafter for a while but may fall again before the transition is over. Thus, in the last phase of the transition the economy may experience stagflation. 1/ The pure nominal interest rate, I, falls on impact, decreases at first, then increases overshooting its steady-state value, and falls thereafter. The key difference with the previous case is that output begins to recover immediately after the initial fall. The reason is that the rise in real money balances reinforces the positive effect of rising inflation on output.

If policymakers announced a permanent reduction in the rate of growth of the money supply, but the public believed that at time T the higher rate of growth of the money supply would resume, the same dynamics effects during the transition period would result. Furthermore, if policymakers validate expectations at time T by actually increasing the rate of growth of the money supply, the whole transition path of the economy would be the same as that which obtains for the case of a temporary reduction in the rate of growth of the money supply. In this interpretation, the results derived above may be restated as follows. First, a non-credible reduction in the rate of growth of the money supply succeeds in lowering the inflation rate throughout all of the adjustment

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1/ This is not necessarily the case. As may be inferred from Figure 1, output may rise during all of the transition.

path. Second, the less credible the policy is (that is, the smaller is T), the smaller is the fall in inflation, and the smaller is the fall in output. Therefore, lack of credibility is not costly in the sense that smaller gains are also accompanied by smaller costs.

IV. Interest Rate Policy

This section examines interest rate policy; that is, changing the nominal interest rate, i, while maintaining the rate of growth of the money supply constant at the value $\bar{\mu}$. As suggested in the Introduction, this paper's model can be used to study the consequences of pegging the nominal interest rate, i. This implies that it is not necessary to resort to specifying money supply rules tied to the interest rate target in order to get rid of the indeterminacy of the inflation rate, as in Barro (1987), Calvo (1982), Canzoneri, Henderson, and Rogoff (1983), Gagnon and Henderson (1988), Goodfriend (1987), and Reinhart (1990), among others. It is instructive to see first how the indeterminacy arises and then how it is taken care of in our model. 1/ Assume that there is only cash (that is, $z \equiv 0$ and $h \equiv m$), and that the interest rate which is targeted is thus the pure rate, I. Replacing equation (9) into equation (5) yields (recalling that $E \equiv y - y^*$)

$$\dot{\pi}_t = b[y^* - \alpha_7 + \alpha_8(\bar{I} - \pi_t)], \tag{23}$$

which is a stable differential equation in π. Given that π is a jumping variable, the stability of (23) implies that no unique equilibrium path for π exists. Comparing equations (11) and (23), one sees how this problem is avoided in our model. By assuming that the interest rate which is controlled is that of a liquid asset (in the sense that it is used for transaction purposes), the rate of change of the inflation rate, $\dot{\pi}$, depends on the money supply, m--in addition to π--as equation (11) indicates, which prevents the indeterminacy problem from arising. 2/

1/ As Calvo (1983) shows, the indeterminacy of the inflation rate also arises if demands for money and goods are derived from optimizing consumers. Hence, since the lack of microfoundations on the demand side is not the source of the problem, it is meaningful to tackle this issue in a non-optimizing model, which allows for a simple analytical framework. Moreover, the basic results would not change if demands were derived from optimizing consumers subject to "liquidity-in-advance" constraints, as shown in Calvo and Végh (1990b).

2/ We certainly do not wish to claim that this way of getting around the indeterminacy problem is better than specifying policy rules. The usefulness of each approach probably depends on the purposes at hand. The advantage of the approach taken in this paper is that interest rate policy can be studied independently of money supply policy.

a. Permanent increase in the interest rate

Suppose that the economy is initially at steady-state A in Figure 3 and consider a permanent increase in the interest rate, i: prior to t=0 $i_t=i^\ell$, and for t≥0 $i_t=i^h$, where $i^h>i^\ell$. As a result, the locus $\dot{\pi}=0$ shifts upwards as illustrated in Figure 3. Point C represents the new steady-state, where steady-state inflation remains unchanged at $\bar{\mu}$ and steady-state real money balances are higher. On impact, inflation falls to point B and then the system proceeds along the saddle path towards C. From equation (10) it follows that output falls on impact because of the rise in the interest rate, i, and the fall in inflation. It then increases towards y^* because both inflation and real money balances rise. The steady-state value of the pure nominal interest rate I is not affected by the rise in i (see equation (16)). On impact, I may jump upwards or downwards. Formally, the initial jump in I follows from combining equations (9) and (10) (where Δ denotes discrete changes):

(24) $$\Delta I = \{(\alpha_8\alpha_5/\alpha_6)/[1+\alpha_8\alpha_5/\alpha_6]\}\Delta\pi + (\phi_3/\alpha_8)\Delta\bar{i}.$$

To see that both cases can indeed occur, set α_5 to zero (that is, the demand for real money balances does not depend on income). Then, the rise in i increases I. In contrast, suppose that α_5 becomes very large. Then, ϕ_3 tends to zero and the coefficient of $\Delta\pi$ in (24) tends to unity, which implies that the pure nominal interest rate, I, falls almost by the same amount that inflation does. Therefore, the initial rise in the real interest rate, r, that accompanies the initial fall in output may be associated with a higher (or unchanged) I and a fall in π, or with a fall in I which is less than the fall in π. If α_5 is small, I jumps on impact and then decreases towards its steady-state.

The intuition behind the effects of a rise in the nominal interest rate, i, is as follows. The rise in the nominal interest rate, i, reduces the opportunity cost of holding demand deposits and therefore increases the demand for steady-state real demand deposits, and thus the demand for steady-state real money balances. For real money balances to grow, the inflation rate must fall on impact below the unchanged rate of growth of money supply. As in the case of a permanent reduction in the rate of growth of the money supply, the fall in inflation causes the real interest rate to increase, which reduces output. Note, however, that there is an additional channel through which the nominal interest rate affects output--as follows from (10)--because the rise in i also increases, other things being equal, the real interest rate. This latter channel will play a crucial role when temporary changes in the nominal interest rate take place because, while μ affects y <u>indirectly</u> (that is, through the inflation rate), i affects output <u>directly</u>, thus causing output to jump at t=T.

Figure 3. Interest Rate Policy: Dynamics in the (π, m) Plane

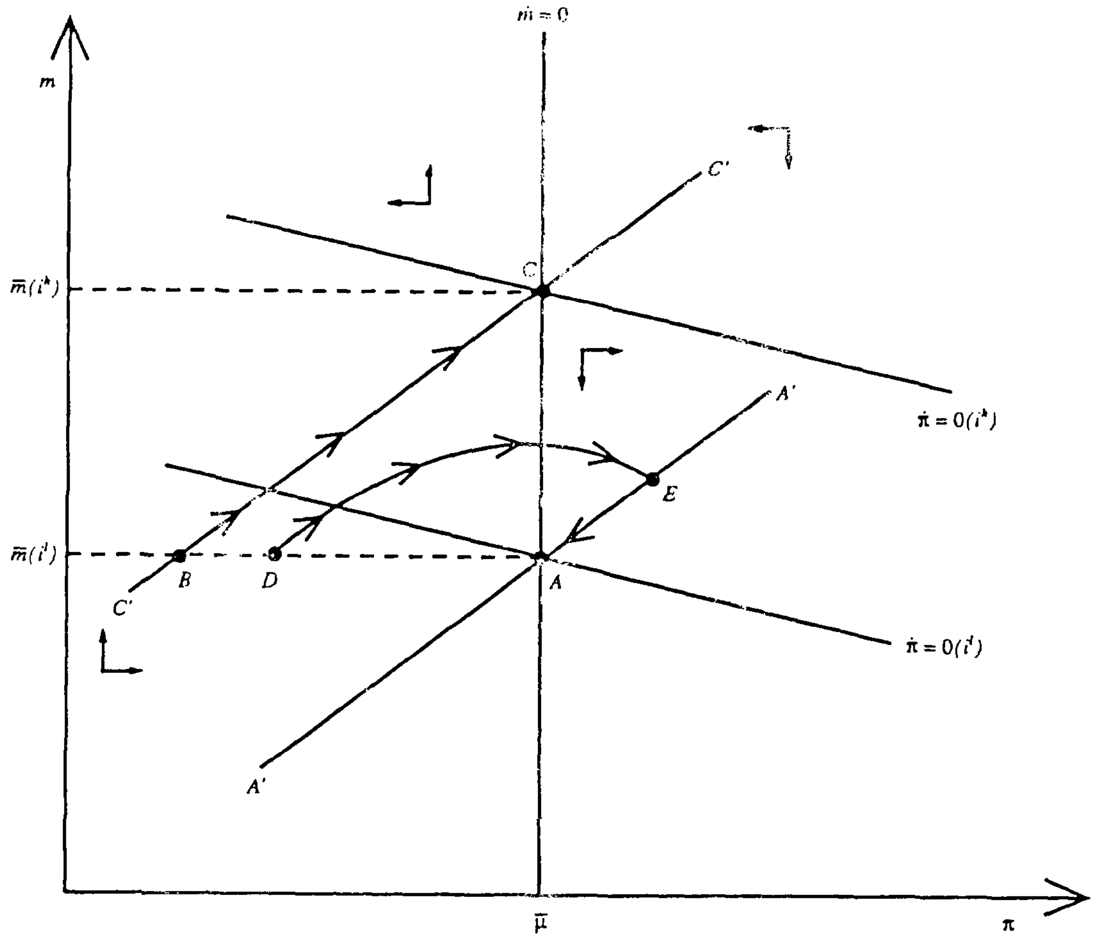
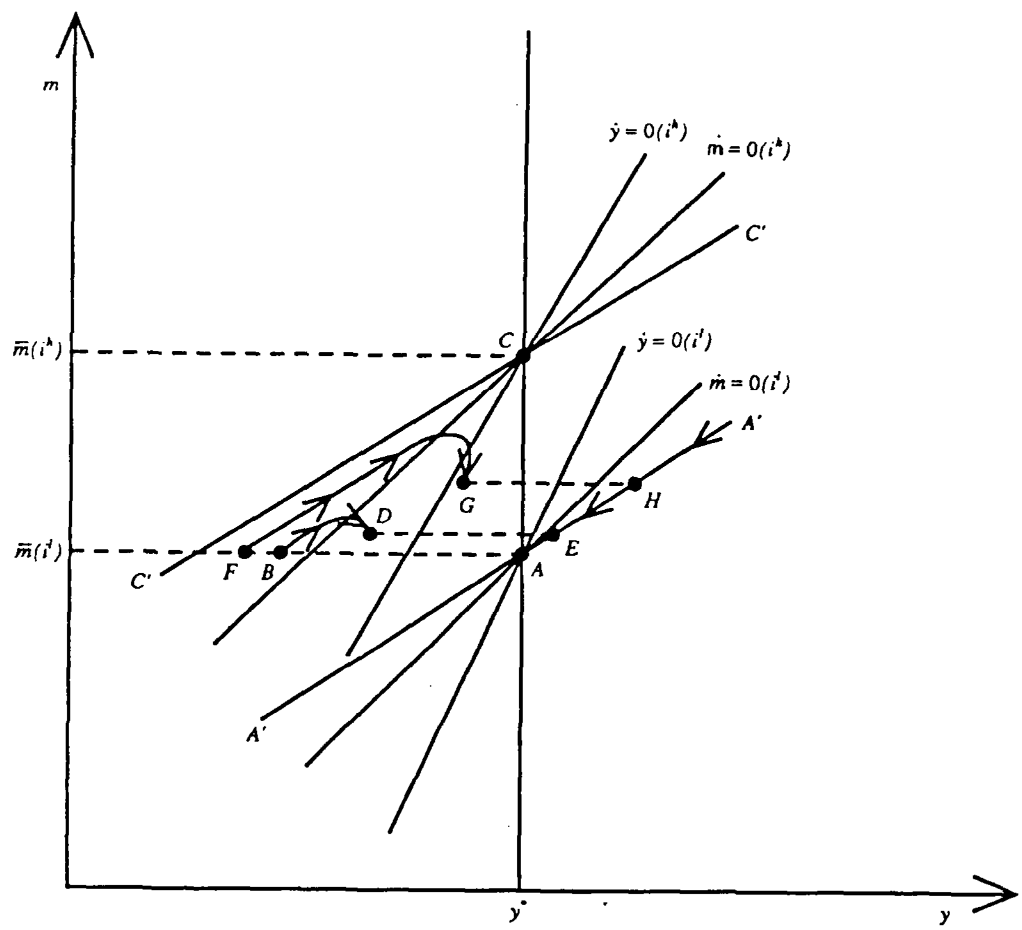


Figure 4. Interest Rate Policy: Dynamics in the (y,m) Plane



b. Temporary Increase in the Nominal Interest Rate

Consider a temporary increase in the nominal interest rate. Initially (that is, for $t<0$), $i_t=i^\ell$. For $t\geq0$, interest rate policy is given by

(25a) $$i_t = i^h, \qquad 0\leq t<T,$$

(25b) $$i_t = i^\ell, \qquad t\geq T,$$

where $T>0$, and $i^h>i^\ell$. The directional arrows drawn in Figure 3, which are the relevant ones for the transition, correspond to point C. Since neither the inflation rate nor real money balances can jump at time T, the system must hit the saddle path A'A' at time T. A typical path that would result from a temporary increase in the nominal interest rate is ADEA, as illustrated in Figure 3. The inflation rate falls on impact from point A to point D, and increases afterwards overshooting its steady-state value. 1/ The inflation rate attains its maximum at time T (point E in Figure 3) before decreasing towards μ. 2/ Interestingly enough, therefore, although a stabilization plan based on temporarily increasing the nominal interest rate will prove a "success" at the beginning, it will end up being considered a "failure", and may actually lead policymakers to believe that the rise in the interest rate was not "enough" to begin with. 3/

Intuitively, the increase in the interest rate leads price-setters to expect lower aggregate demand in the future, because the higher interest rate induces consumer to increase their real money holdings, which necessitates a fall in the inflation rate. Since price-setters are forward looking, they immediately lower their prices, which leads to a reduction in today's inflation rate. As a result, real money balances

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1/ Note that, unlike the case of a temporary increase in the rate of growth of the money supply, the length of time during which i is higher makes no qualitative difference for the paths of m and π. The reason is that since μ is given, the fall in the inflation rate on impact always implies that real money balances increase at the beginning of the transition no matter what the magnitude of T is.

2/ In the context of a small open economy with flexible exchange rates and prices, the (measured) inflation rate also falls on impact and rises afterwards overshooting its steady-state value, as shown in Calvo and Végh (1990c). The only difference is that at $t=T$, the inflation rate falls precipitously to μ, while in the present context it thus so steadily over time.

3/ The overshooting of the inflation rate could induce policymakers to further raise interest rates. Policy rules that tie interest rate increases to the inflation rate could be easily incorporated into the present framework.

begin to increase. After the initial fall, inflation begins to rise over time since price-setters set higher prices as the end of the period during which the interest rate is high approaches. Since the nominal interest rate returns to its initial level at time T, the inflation rate must overshoot its steady-state value at some point in time for real money balances to return to their initial level.

The fall in the nominal interest rate at t=T implies that the paths of output, the pure nominal interest rate, and the real interest rate are discontinuous at that point. The pure nominal interest rate, I, increases on impact, decreases, and then increases during the transition (recall that $\dot{I}$ has the opposite sign than $\dot{m}$), falls below its steady-state value at t=T, and increases thereafter. (The jump of I at t=T is given by (24) if $\Delta\pi$ is set to zero.) Output takes an upward jump at t=T (equal to $\Delta y=-\phi\Delta 3i$) when i falls back to its initial value because, due to the continuity of π, the real interest rate falls together with I at t=T. In terms of Figure 4, this implies that the <u>initial</u> jump in output has to be larger than the horizontal shift in the $\dot{m}=0$ schedule (which, as can be verified, equals ϕ_3). For if y were to jump to the right of the $\dot{m}=0$ schedule, it would imply that the <u>jump at T</u> cannot be equal to ϕ_3, as a look at Figure 4 reveals. Naturally, the situation just described is the only one which is consistent with Figure 3--since m increases at the beginning of the transition. Viewed from the perspective of equation (10), it is also clear that the initial jump in y must be larger (in absolute value) than $\phi_3\Delta i$ because of the fall in π. As Figure 4 shows, the rise in i shifts both the $\dot{m}=0$ and $\dot{y}=0$ schedules upwards by the same distance. That this should be the case follows from the fact that the steady-state level of output is not affected by i. As regards the behavior of y, the magnitude of T matters. We thus distinguish between the following two cases:

(i) Suppose that T is small. This would give rise to a path like ABDEA in Figure 4. Output falls sharply on impact from A to B, increases for a while reaching D at t=T, then jumps to E overshooting its steady-state level, and finally travels along the saddle path towards A. Unlike the case of a temporary increase in μ, even for very small T, output will fall sharply at t=0 and then increase almost as sharply at T. (More formally, $y_{t=0}$ as a function of T is discontinuous at T=0 and $y_{t=T}$ is discontinuous for any T>0.) <u>1</u>/ The change in output at t=0 is always higher (in absolute value) than at t=T because, while the effect of i is the same, π jumps at t=0 while it is continuous at t=T. Furthermore, even if the initial fall in output depends on T--because the larger T is, the larger is the fall in π--the upward jump at t=T does not depend on T. Noting that $\pi_{t=0}$ is a continuous function of T, T≥0, the following conclusion is reached: <u>if the nominal interest rate is increased for a short-period of time, the fall in inflation on impact will be rather modest while the reduction in output will be substantial</u>. The reason is

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<u>1</u>/ By definition, T=0 corresponds to the case in which the change in the nominal interest rate is permanent.

that the increase in the interest rate has a direct effect on output, as follows from equation (10), which does not depend on T. In contrast, the initial fall in inflation depends on T because price-setters will lower their prices according to the time during which the interest rate is expected to remain high. Therefore, the smaller is T, the shorter is the time during which aggregate demand will be down, and hence the smaller is the mark-down in prices.

(ii) Suppose that T is large. Then, the system would follow a path like AFGHA in Figure 4. On impact, output jumps from A to F. It then increases until it crosses the $\dot{y}=0$ schedule and then decreases for a while reaching the point G at t=T at which time it jumps to point H which lies on the saddle path. Since y falls for a while before t=T, the economy is experiencing stagflation because, as already shown, π increases for $0 \leq t < T$.

If the temporary increase in the nominal interest rate, i, is interpreted as arising from a non-credible announcement by policymakers, the above results may be summarized as follows. First, a non-credible rise in the nominal interest rate implies that, after falling on impact, inflation overshoots its steady-state value. Second, the less credible is the policy, the smaller will be the initial fall in inflation. However, output always falls sharply. Therefore, unlike the case of money supply policy, lack of credibility is costly in the sense that the gains in terms of reduced inflation tend to vanish, while the output cost does not.

V. Final Remarks

This last section discusses three issues: first, the equivalence between interest rate policy and changes in the level of the money stock; second, the effectiveness of money supply and interest rate policy in fighting inflation; and, third, how interest rate policy in an open economy compares to interest rate policy in the present model.

a. Controlling the level of the money stock

It can be shown that, in the context of this model, reducing the level of the money supply, M, yields similar effects to those which obtain by raising the nominal interest rate, i. Intuitively, the equivalence derives from the fact that both a reduction in the level of the money supply and an increase in the nominal interest rate create an excess demand for money. The question arises therefore as to why would policymakers prefer to use interest rate policy rather than controlling the level of the money stock. One important practical reason might be that M includes bank deposits, which are the counterpart of bank loans. Therefore, a reduction in the level of the money supply would force banks to call back credit lines thus generating an important contraction of bank credit, which would push into bankruptcy firms and financial institutions alike. Analytically, this could be captured by assuming that the level of real money balances plays a productive role. While real money balances would fall on impact if the level of the money supply is lowered, a rise in the nominal interest rate would have no effect on impact on real money balances. Therefore, the supply of output would fall in the former case, which would aggravate the consequences of a fall in aggregate demand.

It should be noted that if the demands for cash and demand deposits are derived from utility-maximizing consumers, as in Calvo and Végh (1990b), the degree of substitution between cash and demand deposits critically affects the equivalence between lowering the level of the money stock and raising the nominal interest rate. If cash and demand deposits, for instance, are held in fixed proportions, an increase in the nominal interest rate has no effect whatsoever, while a reduction in the level of the money supply would reduce output and inflation. Furthermore, the similarity between these two policies breaks down in the context of an open economy. In an open economy with predetermined exchange rates, where Ricardian equivalence holds, changes in the level of the money supply would have no effects; however, temporary changes in the nominal interest rate would have real effects (see Calvo and Végh (1990a)). Even under flexible exchange rates, the results of the two policies may be quite different: Calvo and Végh (1990b) show that, if cash and demand deposits are demanded in fixed proportions, an increase in the nominal interest rate always causes an <u>increase</u> in aggregate demand on impact, whereas a reduction in the level of the money supply may cause a <u>reduction</u> in aggregate demand.

b. Interest rate policy versus money supply policy

As far as permanent changes in the rate of growth of the money supply and the nominal interest rate are concerned, the key difference is that while a reduction in μ results in lower steady-state inflation, an increase in i has no effect on steady-state inflation. This is a natural consequence of the fact that the steady-state rate of inflation is independent of the nominal interest rate, i. The adjustment path looks qualitatively similar. In both cases output falls precipitously on impact and recovers gradually afterwards. Inflation also falls sharply on impact and increases thereafter.

When temporary changes in μ or i are considered, interesting differences arise. Inflation falls on impact in both cases. However, under interest rate policy, inflation <u>overshoots</u> its steady-state value--independently of the duration of the interest rate hike--before beginning to fall when the transition is over. In contrast, under money supply policy, inflation remains below its steady-state value during the whole adjustment path. It follows that, even when used temporarily, money supply policy is still more effective in reducing inflation because it succeeds in bringing inflation below its original level during the whole adjustment path. The situation is, in a sense, reversed when output effects are considered. Under temporary money supply policy, output falls on impact and remains below its full-employment level throughout the adjustment. In contrast, when the interest rate is increased, output falls on impact but then when the interest rate returns to its original level, output jumps over and above its full-employment level and decreases thereafter.

Another important difference is that interest rate policy is more risky than money supply policy in the following sense. A reduction in the money supply that the public believes will last for a very short while will have almost no effect on inflation, but the effect on output will be negligible as well. In contrast, an increase in the nominal interest rate that is expected to last only for a very short period of time will have almost no effect on inflation either but will cause a sharp recession. The analysis thus suggests that policymakers that enjoy little credibility may be better off resorting to money supply policy.

c. Interest rate policy in open and closed economies

As regards specifically the effects of interest rate policy, this paper can be viewed as having isolated the recessionary effect of raising nominal interest rates given that, as we have seen, output always falls on impact. In contrast, Calvo and Végh (1990a,b)--in the context of a small-open economy with flexible prices--have shown that increases in the interest rate are always expansionary under predetermined exchange rates and may also be expansionary under flexible exchange rates. The effects of an increase in the nominal interest rate on aggregate demand basically depend on whether the supply of real money balances is predetermined or not. In this paper's model, the real money supply is fixed on impact, so that the excess demand for real money balances that results from the higher interest rate necessitates an increase in the pure nominal interest to equilibrate the money market. This increases the real interest rate and causes aggregate demand to fall. In an open economy with flexible prices, real money balances may jump on impact under either flexible or predetermined exchange rates. Therefore, the outcome will be determined by the effects on aggregate demand of intertemporal substitution effects.

The response of the inflation rate to a temporary increase in the nominal interest rate in the small open economy with flexible prices studied in Calvo and Végh (1990c) is similar to that which obtains in this paper's model. The (measured) rate of inflation falls on impact, but then begins to increase and surpasses the initial level. 1/

The next stage in our research agenda will be to open the economy with sticky-prices to trade in goods and capital, along the lines of Calvo and Végh (1990d). In such a context, we are likely to re-encounter the expansionary effect absent in the present study and thus we should be able to examine how it interacts with the recessionary effect.

1/ Strictly speaking, the price level falls on impact while the inflation rate increases on impact. However, since price data is collected at discrete intervals, the initial fall in the price level will show as an initial fall in the rate of inflation.

Appendix

1. Dynamics in the (π, m) plane.

The linear approximation around the steady-state of the dynamic system given by equations (11) and (12) is

(A.1) $$\dot{\pi}_t = -b\phi_1(\pi_t - \bar{\pi}) - b\phi_2(m_t - \bar{m}),$$

(A.2) $$\dot{m}_t = -\bar{m}(\pi_t - \bar{\pi}).$$

The determinant of the matrix associated with the linear approximation is thus $-b\phi_2\bar{m}$ which, being negative, indicates that there exist one positive and one negative real root. Hence, the system exhibits saddle-path stability. The locus $\dot{m}=0$ is given by $\pi=\bar{\mu}$. The slope of the $\dot{\pi}=0$ locus is $(-\phi_1/\phi_2)<0$.

2. Dynamics in the (y, m) plane.

The linear approximation around the steady-state of system (20) and (21) is

(A.3) $$\dot{y}_t = [-\phi_1 b - (\phi_2/\phi_1)\bar{m}](y_t - y^*) + (\phi_2^2\bar{m}/\phi_1)(m_t - \bar{m}),$$

(A.4) $$\dot{m}_t = (-\bar{m}/\phi_1)(y_t - y^*) + (\phi_2\bar{m}/\phi_1)(m_t - \bar{m}).$$

The associated determinant is $-b\phi_2\bar{m}<0$, indicating saddle-path stability. The slope of the $\dot{y}=0$ locus is

(A.5) $$dm/dy = (1/\phi_2)[\phi_1 b + (\phi_2/\phi_1)\bar{m}]/(\phi_2/\phi_1)\bar{m} > 0,$$

while that of the $\dot{m}=0$ is

(A.6) $$dm/dy = 1/\phi_2 > 0.$$

It follows that the $\dot{y}=0$ locus is steeper than the $\dot{m}=0$ locus.

3. Dynamic path of I.

Solving for I_t from (8), differentiating with respect to time, and using (10) one obtains:

(A.7) $$\dot{I}_t = (\alpha_5/\alpha_6)\phi_1\dot{\pi}_t - (1/\alpha_6 A)\dot{m}_t.$$

It follows from the dynamic system (A1)-(A2) that when $\alpha_5=0$, $\dot{\pi}_t$ is a finite number. By continuity, this will still be the case when $\alpha_5 \to 0$. Therefore, (A.7) shows that, as $\alpha_5 \to 0$, $\dot{I}_t \to -(1/\alpha_6)\dot{m}_t$ (note that $A \to 1$).

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