

A Monetary Policy Rule for Automatic Prevention of a Liquidity Trap

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1. Introduction

Among monetary economists, a major topic of interest during recent years has been the possibility of a liquidity trap, i.e., a situation in which monetary policy stimulus cannot be obtained by the usual method of lowering the setting of the central bank's interest rate instrument because that rate is at its lower bound of zero. It would be better, I suggest, to use the term "zero lower bound situation," rather than "liquidity trap," since the latter seems to imply a priori that there is no available mechanism for generating monetary policy stimulus. In any event, dozens of papers on the subject have appeared, including notable items by Rotemberg and Woodford (1997), Wolman (1998), Krugman (1998), Reifschneider and Williams (1999), McCallum (2000), Goodfriend (2000), Orphanides and Williams (2000), Svensson (2001), Benhabib, Schmitt-Grohe, and Uribe (2001), Jung, Teranishi, and Watanabe (2001), Coenen and Wieland (2003), Woodford (2003), Eggertsson and Woodford (2003, 2004), and Auerbach and Obstfeld (2003, 2004). Recent experiences in Japan have, of course, added intense concern from the practical perspective.

One of the more prominent results to come out of this literature is an irrelevance proposition pertaining to open-market purchases, put forth by Eggertsson and Woodford (2003), according to which "quantitative easing" is to no avail. Instead, "the key to effective central-bank action to combat a deflationary slump is the management of expectations" (2003, p. 8). At face value, this proposition seems to contradict results by Auerbach and Obstfeld (2003), Coenen and Wieland (2003), and others who find a role for open market purchases of "unconventional" assets.¹ It will be argued below, however, that there is no actual theoretical inconsistency; that the different papers presume different types of policy

experiments.² One crucial distinction is whether or not there is a change in the policy rule implied by the experiment. If there is a credible rule change in an expansionary direction, then—as is shown below—monetary policy can be effective in bringing an economy out of a zero lower bound (ZLB) situation.

This last statement supposes, however, that the policy change in question is fully understood and believed so that a new rational expectations equilibrium becomes operative immediately. This, however, appears to be a highly dubious proposition. Accordingly, it would seem to be of some importance to consider how a central bank could regularly follow a policy rule that would keep the economy out of a ZLB situation automatically. A major objective of the present paper is, accordingly, to develop one such rule. That will be done in Section 3, after Section 2 begins by expanding upon the topics just mentioned. Then in Sections 4 and 5 an example open economy model will be specified and calibrated. Simulation results with this model and our proposed policy rule are reported in Section 6, so as to explore the properties of the rule. Relevant issues are discussed in Section 7 and a brief conclusion follows.

2. Alternative Policy Experiments

It is expositionally useful to begin with the policy experiment of Eggertsson and Woodford (2003), henceforth referred to as E&W. It involves analysis of the stabilization properties of an interest rate policy regime that is specified to incorporate “quantitative easing.” That term is taken by E&W (2003) to mean that the monetary base supply function, which supports (i.e., implements) their interest rate rule, includes an unusual nonlinear component that calls for extra open market purchases whenever the interest rate is zero.

¹ Assets, that is, that are not perfect substitutes for the short-term security that is normally used in open market operations.

These purchases are evidently reversed, however, as soon as the interest rate rises above zero. (The interest rate in question is “the riskless nominal interest rate on one-period obligations...” (E&W 2003, p. 10)) One could simply view this function as a base-money-supply policy rule, include the base money stock as a variable, and solve the model in a standard and familiar RE fashion if it were not for the non-linear component and the non-linear restriction that the interest rate must be non-negative.³ What E&W do with the resulting model is to show that the behavior of prices and output in the model’s RE equilibrium is independent of parameters describing the unusual quantitative-easing component of the base supply rule. Whatever the extent of the additional base-money supply specified by this component, then, there will be no effect on inflation or output in the RE equilibrium. That is the E&W irrelevance proposition. Note, crucially, that it pertains to the nature of a single ongoing RE equilibrium for a given policy rule that involves certain specified behavior when the ZLB is operative, not to the adoption of a new rule.

The policy experiment considered by Auerbach and Obstfeld (2003) is quite different. It begins with a policy rule in place, one that specifies a constantly growing level of the monetary base, and the economy in a ZLB situation with the interest rate (R_t) equal to zero. Then the authors postulate a change in the base money rule, either a one-time upward shift in the path of the base or an increase in its slope (the rate of growth of the base)—in either case a change that is sustained permanently. The experiment presumes a foreseen upward jump in the natural real rate of interest after 5 periods that would bring the ZLB episode to an end in any event, but each of the two considered policy rule changes would have effects on the path

² This point is also made by Eggertsson and Woodford (2003, 2004), but in a different way.

³ The model used by E&W is rather standard, relative to the recent monetary policy literature, but is slightly more “monetarist” than most in that the utility function, which includes real money balances as an argument, is not assumed to be separable.

of prices and possibly output in the interim. The increased base growth-rate policy also has the effect of bringing the ZLB episode with $R_t = 0$ to an end sooner than would otherwise be the case. The Auerbach and Obstfeld results are of particular interest because the model utilized is in most respects similar to that of E&W.

In light of the foregoing discussion, I would suggest that the basic difference in outcomes is that the E&W experiment concerns the effects of an unusual design feature of one maintained policy rule whereas the Auerbach and Obstfeld experiment has to do with effects of a change from one policy rule to another. In one case the monetary rule has an interest rate instrument and in the other case the monetary base, but it appears that this distinction is not crucial. As hinted above, I believe that E&W could utilize a policy rule specified as a base rule that includes an analogous quantitative easing component and develop a similar irrelevance result for that case. Furthermore, for a change in a monetary rule to be effective when an economy is in a ZLB situation, it is not necessary for the rule to be one that governs base quantities; it could as well be an interest rate rule that is altered.

For an extremely simple illustration of this last point, it will be sufficient to use a closed-economy model with full price flexibility. Consider the following two-equation system, which is so familiar as to require very little explanation at this point:⁴

$$(1) \quad y_t = b_0 + b_1(R_t - E_t \Delta p_{t+1}) + E_t y_{t+1} + v_t$$

$$(2) \quad R_t = \mu_0 + \Delta p_t + \mu_1(\Delta p_t - \pi^*) + \mu_2 y_t.$$

Here y_t and p_t denote the logs of output and the price level so Δp_t is inflation and R_t is the one-period nominal interest rate. The term v_t represents a preference shock that is generated by an exogenous stochastic process, which is assumed to be AR(1)—i.e., autoregressive of

order one—with parameter ρ . Equation (2) is a Taylor-style rule in which the central bank is depicted as setting an interest rate instrument R_t each period so as to tighten policy when inflation exceeds its target value π^* and/or when output is high. In (1)(2), y_t should be interpreted as the output gap, $y_t - \bar{y}_t$, with \bar{y}_t for simplicity assumed constant at the value zero. With flexible prices we then have $y_t = 0$ in each period. Thus there are only two endogenous variables to be determined by the system, R_t and Δp_t . This model should be understood to also include the requirement that Δp_t must not approach $-\infty$ as $t \rightarrow \infty$, because of a transversality condition that obtains in the underlying optimizing model.

To obtain a rational expectations (RE) solution, we first substitute out R_t and using $y_t = 0$ obtain

$$(3) \quad 0 = b_0 + b_1[\mu_0 - \mu_1\pi^* + (1 + \mu_1)\Delta p_t - E_t\Delta p_{t+1}] + v_t.$$

The minimum state variable (MSV) solution is of the form

$$(4) \quad \Delta p_t = \phi_0 + \phi_1 v_t,$$

implying $E_t\Delta p_{t+1} = \phi_0 + \phi_1\rho v_t$. Then substitution into (3) and application of a standard undetermined coefficient procedure yields the requirement that

$$(5) \quad 0 = b_0 + b_1[\mu_0 - \mu_1\pi^* + (1+\mu_1)(\phi_0 + \phi_1 v_t) - \phi_0 - \phi_1\rho v_t] + v_t$$

holds identically for all realizations of v_t . That implies unique values for ϕ_0 and ϕ_1 and gives the MSV solution

$$(6) \quad \Delta p_t = \pi^* - (b_0 + b_1\mu_0)/\mu_1 - [b_1(1-\rho+\mu_1)]^{-1}v_t.$$

Of course, Taylor (1993) and many others prescribe that the central bank set $\mu_0 = r$, the long-run average real rate of interest, and we observe from (1) that this rate equals $-b_0/b_1$. So

⁴ Explanation of a model that includes (1)(2) as a special case will be provided below. The present system differs from the model of E&W primarily by positing flexible prices, which is irrelevant to the current point.

adherence to this recommendation implies that the second term on the right-hand side of (6) vanishes and we have $\Delta p_t = \pi^* - [b_1(1-\rho+\mu_1)]^{-1}v_t$ as the MSV solution for inflation.

Suppose, then, that an economy is of form (1)(2) except that it also includes the requirement that $R_t \geq 0$. Then (6) would be the RE solution if the parameter values and the distribution of v_t were such that this inequality was never binding. But suppose that such is not the case and that the economy is in a ZLB situation with $R_t = 0$. Then suppose that in some period there is a policy change that amounts to an increase in the target inflation rate π^* to a value high enough that the ZLB will never be effective in the future. Then the new RE equilibrium will yield immediately an inflation rate high enough to escape the ZLB situation. By contrast, an increased value of the policy parameter μ_1 would in that situation have no constructive effect toward bringing the economy out of the ZLB.

The simplicity and starkness of the foregoing example will probably lead many readers to object, to say something like “But that is totally implausible; the economy’s agents would be very unlikely to know about, understand, and believe in the policy change even if the central bank has every intention of carrying it out.” With that objection I would entirely agree. More generally, many proponents of the hypothesis of rational expectations find it attractive mainly for consideration of alternative maintained policy rules, i.e., for application to situations prevailing after some time has passed (since any previous rule change) and the economy has settled into a new stochastic equilibrium. To these economists—e.g., Lucas (1980, p. 205), Lucas and Sargent (1981, p. xxxvii)—immediate application of RE after a policy change seems dubious. Partly for this reason, E&W (2003), McCallum (2000), Jung, et. al. (2002), and a few others have concentrated attention on rules for preventing a liquidity

trap, rather than (or in addition to) schemes for escaping a trap in which an economy finds itself locked. In that spirit we move on to the discussion of a new rule proposal.

3. A Rule for Use At or Away From the ZLB

Let us now turn to the main topic of the present paper, which is the development and exploration of a monetary policy rule that is appropriate for use at all times, whether or not short-term nominal interest rates are at their ZLB. The basic idea is simply to combine two component rules, designed for normal and ZLB conditions, by means of a weighted average of their respective instrument settings. The first of these two component rules could be written as a standard Taylor-type formulation as follows:

$$(7) \quad R_t = r + \Delta p_t + \mu_1(\Delta p_t - \pi^*) + \mu_2(y_t - \bar{y}_t) + e_t, \quad \mu_1, \mu_2 \geq 0.$$

Here R_t is a short-term nominal interest rate instrument and, for simplicity, we have entered the current value of inflation and the output gap as the variables to which the rule responds.⁵ In (7) π^* is the target for inflation and r is the long-term average real rate of interest, while e_t is a random policy shock that reflects unsystematic behavior by the monetary authority. We suppose that in normal times, when the ZLB on R_t is not binding, the central bank wishes to utilize (7) as its monetary policy rule.

When R_t is at its lower bound of zero, however, the central bank will be unable to respond as implied by (7) if the gap measures $\Delta p_t - \pi^*$ and $y_t - \bar{y}_t$ together call for a reduction. In previous work, including McCallum (2000) and (2003), I have accordingly suggested a rule for adjusting the foreign exchange rate, s_t in logarithmic terms, in such occasions. The version of this rule given in the more recent of these two papers is as follows:

⁵ It would be possible to use instead expected future values or lagged expectations of current values, etc.

$$(8) \quad \Delta s_t = \Delta q + \Delta p_t - \mu_1(\Delta p_t - \pi^*) - \mu_2(y_t - \bar{y}_t) - e_t, \quad \mu_1, \mu_2 \geq 0.$$

Here we have minus signs on the two gap measures because an increase in the value of $\Delta s_t - \Delta p_t$ represents a loosening, not a tightening, of monetary policy.⁶

Next we take a weighted average of the two preceding expressions, after changing the signs on all terms in (8). Let $1 - \theta$, with $0 \leq \theta \leq 1$, be the weight on the R_t instrument. Then the resulting rule is as follows:

$$(9) \quad [(1-\theta)R_t + \theta(-\Delta s_t)] = (1-\theta)r - \theta\Delta q + (1-2\theta)\Delta p_t + \mu_1(\Delta p_t - \pi^*) + \mu_2(y_t - \bar{y}_t) + e_t.$$

To facilitate understanding of the latter, first suppose that the interest rate R_t equals zero, i.e., is at its ZLB. Then (9) becomes a rule for setting the value of the rate of exchange rate depreciation, Δs_t . The formula might look a bit strange, but when $R = 0$, an implied steady-state relationship is $r = -\Delta p$. Then using the latter with (9) and rearranging we obtain

$$(10) \quad \Delta s_t = \Delta q + \Delta p_t - (\mu_1/\theta)(\Delta p_t - \pi^*) - (\mu_2/\theta)(y_t - \bar{y}_t) - (1/\theta)e_t.$$

Clearly, the latter is of exactly the same form as the Δs_t rule (8), although it has a different numerical value for two of the response coefficients.

What about the interpretation of (9) when R_t is not at the ZLB? To gain an intuitive idea regarding this case, suppose that the nominal exchange rate were to behave in conformity with the current inflation rate and the long run average rate of real exchange rate depreciation. Suppose, that is, that $\Delta s_t = \Delta p_t + \Delta q$ holds on a period-by-period basis. Then substitution into (9) yields

$$(11) \quad R_t = r + \Delta p_t + (\mu_1/(1-\theta))[\Delta p_t - \pi^*] + (\mu_2/(1-\theta))[y_t - \bar{y}_t] + (1/(1-\theta))e_t,$$

⁶ Here and in what follows $S_t = \log^{-1}s_t$ is the home country price of foreign exchange. Also, Δq is the trend rate of growth of the real exchange rate minus the average inflation rate abroad.

which has the form of a standard Taylor-type rule! So (9) works in an entirely intuitive manner in both of these reference cases

How would the composite rule (9) be implemented? To do so, the central bank would each period make purchases (or sales) in the money market or foreign exchange market—or both—so as to adjust $(1-\theta)R_t - \theta s_t$ to the value indicated by (9), taking s_{t-1} as given. In this regard, note that buying money market securities tends to drive R_t downward and s_t upward, so both components of the weighted average $[(1-\theta)R_t + \theta(-\Delta s_t)] \equiv MC_t$ move in the same (downward) direction. Alternatively, buying foreign exchange would tend to drive s_t upward and R_t downward, so again both components move in the desired direction. Clearly, when instead a monetary tightening is desired, it would be possible to sell money market securities and/or foreign exchange, moving MC_t in the upward direction.⁷

It is likely that at this point many readers will have guessed the reason for using the symbol MC_t to denote our composite measure. It is that this measure has the characteristics often attributed to a “monetary conditions index.” The latter concept has been viewed rather unfavorably by most monetary economists in recent years, but that does not necessarily make it an undesirable policy indicator. It is my impression that the typical mode of presentation has made the concept appear to be dimensionally incoherent,⁸ for most proponents have used written expressions such as $(1-\theta)R_t - \theta s_t$, rather than $(1-\theta)R_t + \theta(-\Delta s_t)$.⁹ But in such cases the authors may actually have had in mind an exchange rate expressed in relation to some reference value, which leaves open the possibility that the dimensions of the two terms are in

⁷ Of course there are limits on a central bank’s ability to increase MC_t , since it will hold only finite stocks of foreign and domestic assets.

⁸ Thus I, for one, have been disturbed by the practice of taking a weighted average of two terms that have the units 1/years and yen/dollar, for example. But if the latter is expressed in rate of change form, as in (9), it too can have the units 1/years.

⁹ See, e.g., Ball (1999), Gerlach and Smets (2000), and the recent contribution by Detken and Gaspar (2003).

fact consistent.

Another matter that requires brief attention is the notion of interest rate smoothing, which is widely viewed as a practice much utilized by actual central banks. Can inertial behavior of R_t be accommodated by rules such as (9)? Certainly there would be no analytical problem created by writing a partial adjustment equation for MC_t , with the adjustment moving the actual value of MC_t toward a value such as that on the right-hand side of (9). Alternatively, one could apply smoothing only to the R_t component, by writing (7) in a partial adjustment form before taking a weighted average of (7) and (8). In this case the rule would be written as

$$(9') \quad [(1-\theta)R_t + \theta(-\Delta s_t)] = (1-\mu_3)(1-\theta)r - \theta\Delta q - [(1-\theta)(1-\mu_3) + \theta]\mu_1\pi^* \\ + [(1-\theta)(1-\mu_3)(1+\mu_1) + \theta(\mu_1-1)]\Delta p_t + [(1-\theta)(1-\mu_3) + \theta]\mu_2(y_t - \bar{y}_t) + \mu_3R_{t-1} + e_t,$$

which will be used below. Here (and in what follows) μ_3 is the interest rate smoothing parameter ($0 < \mu_3 < 1$).

4. Model Specification

In order to explore the properties of a rule such as (9) or (9'), one needs to combine it with an appropriately specified model of an economy and then conduct analytical exercises to determine how the economy is predicted to perform with different variants of the rule. Clearly the model needs to pertain to an open economy, and most contemporary analysts would prefer that it be a rational expectations model based on optimizing behavior by the economy's individual households and firms. The model that will be used below is one that was developed by McCallum and Nelson (1999) and utilized subsequently by them (2000) in an exploration of relationships between CPI inflation and exchange rate depreciation. This "M&N" model is not econometrically estimated, but is calibrated to match important selected

characteristics of the economies of interest. It differs from many other contributions in the area, however, in the manner in which imported goods are treated. In particular, the M&N model treats imports not as finished goods, but instead as raw-material inputs to the home economy's producers. This alternative modelling strategy leads to a cleaner and simpler theoretical structure, relative to the standard treatment, and is empirically attractive. Since the optimizing, general equilibrium analysis is spelled out in McCallum and Nelson (1999), here I will take an informal expository approach designed to facilitate understanding of the model's structural equations.

It is well known that optimizing analysis leads, in a wide variety of infinite-horizon models possibly involving imperfect competition, to a consumption Euler equation that can be expressed or approximated in the form

$$(12) \quad c_t = E_t c_{t+1} + b_0 + b_1 r_t + v_t, \quad b_1 < 0,$$

where c_t is the log of a Dixit-Stiglitz consumption-bundle aggregate C_t of the many distinct goods that a typical household consumes in period t . In (12), r_t is the real interest rate on home-country one period bonds (private or government) and v_t is a stochastic shock term that pertains to household preferences regarding present vs. future consumption. In closed economy analysis, relation (12) is often combined with a log-linearized, per-household, overall resource constraint to yield an "expectational" or "optimizing" IS function. That step presumes that investment and capital are treated as exogenous. The simplest version of that assumption is that the capital stock is fixed; since endogenizing capital greatly complicates the analysis, the constant-capital specification will be used here.

For an open-economy extension, one might be tempted to write the economy's per-capita resource constraint as $y_t = \omega_1 c_t + \omega_2 g_t + \omega_3 x_t - \omega_4 im_t$, where y_t , g_t , x_t , and im_t are

logarithms of real output, government consumption, exports, and imports with ω_1 , ω_2 , ω_3 , and ω_4 representing steady-state shares of output for consumption, government purchases, exports, and imports. But if imports are exclusively material inputs to the production of home-country goods, and $Y_t = \ln^{-1} y_t$ is interpreted as units of output, not value added, then the relevant resource constraint is

$$(13) \quad y_t = \omega_1 c_t + \omega_2 g_t + \omega_3 x_t.$$

For import demand to be modelled in an optimizing fashion, assume that output of consumer goods is effected by producers all with production functions of the same CES form, with labor and material imports being the two variable inputs. Then the cost-minimizing demand for imports is¹⁰

$$(14) \quad \text{im}_t = y_t - \sigma q_t + \text{const.}$$

where σ is the elasticity of substitution between materials and labor in production, and where “const.” denotes some constant.¹¹ Also, q_t is the log price of imports in terms of produced consumption goods. We will refer to $Q_t = \ln^{-1} q_t$ as the real exchange rate. Let P_t and S_t be the home country money price of goods and foreign exchange, with P_t^* the foreign money price of home-country imports. Then if p_t , s_t , and p_t^* are logs of these variables, we have

$$(15) \quad q_t = s_t - p_t + p_t^*.$$

Symmetrically, we assume that export demand is given as

$$(16) \quad x_t = y_t^* + \sigma^* q_t + \text{const.}$$

where y_t^* denotes income abroad and σ^* is the price elasticity of demand from abroad for home-country goods.

¹⁰ In the model used below there is also a small adjustment included for the effects of imperfect competition.

Now consider output determination in a sticky-price version of the model. Taking a log-linear approximation to the home-country production function, we have

$$y_t = \alpha_1 a_t + \alpha_2 n_t + \alpha_3 im_t + \text{const.},$$

where n_t and a_t are logs of labor input and a labor-augmenting technology shock term, respectively. For simplicity suppose that labor supply is inelastic, with 1.0 units supplied per period by each household. Thus with full price flexibility we would have $n_t = 0$ and the flexible-price, natural rate (or “potential”) value of y_t will be $\bar{y}_t = \alpha_1 a_t + \alpha_2 im_t + \text{const.}$ so that $\bar{y}_t = \alpha_1 a_t + \alpha_2 [\bar{y}_t - \sigma q_t] + \text{const.}$, or

$$(17) \quad \bar{y}_t = (1 - \alpha_2)^{-1} \alpha_1 a_t - [\sigma \alpha_2 / (1 - \alpha_2)] q_t + \text{const.}$$

But while \bar{y}_t would be the economy’s output in period t if prices could adjust promptly, we assume that prices adjust only sluggishly. Then if the economy’s demand quantity as determined by the rest of the system differs from \bar{y}_t , the former quantity y_t prevails—with workers departing from their (inelastic) supply schedules so as to provide whatever quantity is needed to produce the demanded output, with im_t given by (14).

In such a setting, the precise way in which prices adjust has a direct impact on demand and consequently on production. There are various models of gradual price adjustment utilized in the recent literature that are intended to represent optimizing behavior in the context of nominal adjustment costs. In the analysis that follows, I will use

$$(18) \quad \Delta p_t = (1 + \beta)^{-1} (\beta E_t \Delta p_{t+1} + \Delta p_{t-1}) + \kappa (y_t - \bar{y}_t) + u_t, \quad \kappa > 0$$

where β is a discount factor and u_t is a behavioral disturbance. This form of equation has

¹¹ That is, the expressions “const.” in different equations appearing below will typically refer to different constant magnitudes.

been fairly prominent,¹² primarily because it tends to impart a more realistic degree of inflation persistence than does the Calvo-Rotemberg model (which is theoretically more attractive). For an extensive discussion of relevant issues, see Woodford (2003).

A standard feature of most open-economy models is a relation implying uncovered interest parity (UIP). Despite its prominent empirical weaknesses, accordingly, the basic M&N model incorporates one:

$$(19) \quad R_t - R_t^* = E_t \Delta s_{t+1} + \xi_t.$$

We include a time-varying “risk premium” term ξ_t , however, that may have a sizeable variance and may be autocorrelated.

In previous applications of this model it has been assumed, as in most recent research in monetary economics, that the monetary authority conducts policy by adjusting a one-period nominal interest rate in response to prevailing (or forecasted future) values of inflation and the output gap, $\tilde{y}_t = y_t - \bar{y}_t$, as in (7) above. For present purposes, however, we will be using the rule (9’), now written as

$$(20) \quad [(1-\theta)R_t + \theta(-\Delta s_t)] = (1-\mu_3)(1-\theta)r - \theta\Delta q - [(1-\theta)(1-\mu_3) + \theta]\mu_1\pi^* \\ + [(1-\theta)(1-\mu_3)(1+\mu_1) + \theta(\mu_1-1)]\Delta p_t + [(1-\theta)(1-\mu_3) + \theta]\mu_2(y_t - \bar{y}_t) + \mu_3 R_{t-1} + e_t,$$

of which (7)—possibly with smoothing—is a special case when $\theta = 0$.

To complete the model, we need only to include the Fisher identity, $(1 + r_t) = (1 + R_t) / (1 + E_t \Delta p_{t+1})$, which we approximate in the familiar fashion:

$$(21) \quad r_t = R_t - E_t \Delta p_{t+1}.$$

Thus we have a simple log-linear system in which the ten structural relations (12)-(21)

¹² See Fuhrer and Moore (1995), Gali and Gertler (1999), and Woodford (2003).

determine values for the endogenous variables y_t , \bar{y}_t , Δp_t , r_t , R_t , q_t , s_t , c_t , x_t , and im_t .

Government spending g_t and the foreign variables p_t^* , y_t^* , R_t^* are taken to be exogenous—as are the shock processes for v_t , a_t , e_t , and ξ_t .¹³

One might note parenthetically a few features of the model. First, it would be possible to append a money demand function such as

$$(22) \quad m_t - p_t = \gamma_0 + \gamma_1 y_t + \gamma_2 R_t + \eta_t,$$

and one of this general form—perhaps with c_t replacing y_t —could be consistent with optimizing behavior. But, as many writers have recognized, that equation would serve only to determine the values of m_t that are needed to implement the R_t policy rule. Second, with the structure given above, a useful measure of the foreign trade balance on goods and services account—i.e., net exports—is

$$(23) \quad net_t = x_t - (im_t + q_t),$$

where it is assumed that $\omega_3 = \omega_4$. This measure is used in what follows. Also, it is possible to calculate the log of the GDP deflator as

$$(24) \quad p_t^{DEF} = [p_t - \omega_3(s_t + p_t^*)]/(1 - \omega_3).$$

Finally, it might be said that an advantage of the M&N strategy of modelling imports as material inputs to the production process is that the relevant price index for produced goods is the same as the consumer price index, which implies that the same gradual price adjustment behavior is relevant for all domestic consumption. Such advantages would not constitute a satisfactory justification, of course, if in fact most imports were consumption goods. This is not the case, however, at least for the United States. Instead, an examination

¹³ During the past few years, several quantitative optimizing open-economy models have been developed that are more sophisticated and complex than ours. Outstanding examples include Kollmann (2002), Laxton and

of the data suggests that (under conservative assumptions) intermediate productive inputs actually comprise a larger fraction of U.S. imports than do consumer goods (including services).¹⁴

There is one way in which the model developed in M&N (1999) differs significantly from the 10-equation formulation just presented. Specifically, the former includes a somewhat more complex form of consumption vs. saving behavior, one that features habit formation. Thus in place of the time-separable utility function that leads to equation (12), M&N assumed that each period- t utility term includes $C_t/(C_{t-1})^h$, with $0 \leq h < 1$, rather than C_t alone. That specification gives rise to the following replacement for (12):

$$(25) \quad c_t = h_0 + h_1 c_{t-1} + h_2 E_t c_{t+1} + h_3 E_t c_{t+2} + h_4 (\log \lambda_t) + v_t.$$

In the latter, λ_t is the Lagrange multiplier on the household's budget constraint, which obeys

$$(26) \quad \log \lambda_t = \text{const.} + E_t \log \lambda_{t+1} + r_t,$$

and there are constraints relating the h_j parameters to others in the system.¹⁵ Inclusion of this feature results in a model in which there is somewhat more persistence in consumption and output fluctuations than with the basic formulation. In the present study, accordingly, I have again included this habit-formation modification in the base-case model.

5. Calibration and Model Properties

Calibration of the model draws on M&N (1999) but differs in several ways that are appropriate for present purposes. For the parameter governing spending behavior, I retain

Pesenti (2003), and Smets and Wouters (2002).

¹⁴ For the year 1998, imported consumer goods amounted to \$453 billion while imports of business inputs came to \$624 billion, approximately. These figures are based on an examination of categories reported in the August 1999 issue of the Survey of Current Business. For several categories it is clear whether they are composed predominantly of consumer or business goods. For others, judgemental assignments were required. Those assignments are as follows, with the reported figure being the fraction of the category classified as "business inputs:" Automotive vehicles, engines, and parts, 25%; Travel, 25%; Passenger fares, 25%; Foods, feed, and beverages, 50%; and Other private services, 75%.

here the $h = 0.8$ value taken from an early version of Fuhrer (2000), but for my base case have adopted the assumption that γ , the counterpart of $-b_1$ in (1) equals 0.5, rather than $1/6$, in order to reflect the greater responsiveness of investment spending (as the latter is not included explicitly in the model).¹⁶ For σ , the elasticity of substitution in production (and therefore the elasticity of import demand with respect to Q_t), I now use 0.6 (instead of 0.333) so that, with the same absolute value used for the elasticity of export demand with respect to Q_t), the Marshall-Lerner condition is satisfied. In (6), the imported inputs share parameter α_2 is taken to equal ω_3 , the share of exports in domestic production. The steady state value of this share of imports (and exports) to domestic production is taken to be 0.15 in our base case, and can be altered to represent differing degrees of openness. For the base-case share of government consumption I take $\omega_2 = 0.2$. Finally, in the price adjustment relation the specification is that $\kappa = 0.03$. The latter value is based on my reading of a wide variety of studies, plus conversion into non-annualized fractional terms for a quarterly model. Also, quasi-realistic parameters for a Taylor-style interest rate policy rule will be thought of as values close to $\mu_1 = 0.5$, $\mu_2 = 0.5$, and $\mu_3 = 0.8$, the latter reflecting considerable interest rate smoothing. Below I refer to these as “standard” values.

The stochastic processes driving the model’s shocks must also be calibrated, of course. For both foreign output and the technology shock, I have specified AR(1) processes with AR parameters of 0.95, rather than the 1.0 values used in M&N (1999). The innovation standard deviations (SD) are 0.03 and 0.007, respectively.¹⁷ The UIP risk premium term ξ_t and the consumption shock v_t are generated by an AR(1) processes with AR parameter 0.5

¹⁵ For details and additional discussion, see M&N (1999a), Amato and Laubach (2004), and the basic study by Fuhrer (2002).

¹⁶ The parameter in question, γ , is the intertemporal elasticity of substitution in consumption when $h = 0$.

and innovation standard deviations of 0.02 and 0.01. Government consumption (in logs) follows an AR(1) process, with AR parameter 0.97 and innovation SD of 0.02. Finally, the u_t and e_t shock processes are taken to be white noise with SD values of 0.002 and 0.0017, respectively.

Before using the foregoing model to discuss the policy rule (20) developed above, we should briefly investigate its properties with $\theta = 0$ (i.e., with a Taylor-style R_t rule) to establish, if possible, that they are at least moderately consistent with our understanding of the characteristics of actual economies. Consider first the values shown in Table 1, where each cell reports standard deviations (SDs), in annualized percentage units, of quarterly observations on the four variables Δp_t , \tilde{y}_t , R_t , and Δs_t . These SDs are averages across 400 simulations of length 200 (with 50 start-up periods discarded), so they approximate population magnitudes. Since constant terms are all set to zero, the SD values indicate the variability of the four variables and can also be thought of as representing root-mean-square targeting errors, for cases in which the policy rule is intended to keep some variable close to a chosen target value. Looking across the first row of cells, we see that increased values of μ_1 , the policy coefficient attached to inflation, lead to reductions in the average targeting errors for inflation—just as the Taylor style rule is intended to do. Over part of the range increased μ_1 values also reduce the variability of the output gap, but with large μ_1 magnitudes there is a readily apparent tradeoff (between inflation and output gap stabilization). We also see that increased activism with the interest rate instrument, represented by larger μ_1 values, gives rise to greater variability of the interest rate instrument itself, R_t . Exchange rate depreciation variability is almost unaffected by the magnitude of μ_1 when small, but

¹⁷ These and other values given in this paragraph are given in terms of quarterly fractional units.

increases sharply when μ_1 becomes extremely large. All of these features of the simulation results are consistent with one's understanding of how the model should work.

With respect to the magnitudes themselves, we focus on the second cell in the top row, where $\mu_1 = 0.5$ and the R_t smoothing parameter equals 0.8, for these are the policy-rule values that are intended to be roughly representative of ones found in actual economies such as those of the United States, the euro area, the UK, etc. Doing so, we note that the reported SD values [2.35, 1.96, 2.48, 18.51] are encouragingly similar to statistics for actual economies including the United States over 1955-1996 [2.41, 2.23, 2.80, 12.48] or the euro area 1980-2002 [1.44, 0.83, 1.63, 19.28] or the UK 1972-2001 [6.8, 2.3, 3.1, 14.6].¹⁸

Also revealing are properties of impulse response functions. In that regard, Figure 1 reports the responses of six model variables to a unit shock in the monetary policy rule for the reference case just described. Since that type of shock is an unexpected upward blip in the interest rate instrument, R_t , it represents an unexpected and unsystematic tightening in monetary policy. Figure 1 indicates that such an event would induce a fall in output that is gradually eliminated, a fall in the inflation rate that returns smoothly to its original level over a number of periods (quarters), a sharp appreciation in nominal and real exchange rates, and an increase in net exports. These are all responses that accord with economists' standard understanding of the effects of an unexpected tightening of monetary policy. Next, in Figure 2, we depict the impulses in response to a positive disturbance in the IS function, i.e., an increase in consumers' desire to consume in the present (relative to the future). In this case, both output and inflation rise and only gradually return to their original values. The nominal interest rate rises, as governed by the policy rule, to help to stabilize these movements in

¹⁸ For details, see McCallum (2004), which also shows reasonably good matches with respect to the first autocorrelations of these four variables for the economies mentioned (and also Japan).

output and inflation. The real exchange rate appreciates and only slowly returns to its original level. Also, net exports fall, as a result of the increased income levels that imply an increased magnitude of import demand.

In Figure 3, we find responses to a positive technology shock. Real income increases and returns to its initial level only very slowly, since the shock is highly persistent—close to a random walk. Inflation falls slightly, and monetary policy lets the one-period interest rate fall in order to stabilize inflation—to which it responds more strongly than output. The trade balance deteriorates, since import demand is boosted by the increased level of income, and the real exchange value of domestic goods falls, since they are relatively cheaper to produce than before the shock. Finally, in Figure 4 we depict a shock to uncovered interest parity, i.e., an unexpected and unsystematic exogenous depreciation of the nominal exchange rate. Since prices are sticky, this translates into an unexpected depreciation also in the real exchange rate. That induces an increase in net exports and therefore an increase in domestic output, with a very small rise in inflation.

In sum, the responses in Figures 1-4 seem reasonably consistent with those that one would expect from a sensible macro/monetary model of an open economy, and thereby provide substantial encouragement to use of that model for the purpose at hand, i.e., to investigate the stabilizing properties of the MC policy rule (20).

6. Simulation Results

The objective now is to presents results, based on analysis of the model just described, illustrating the properties of the MC equation (20) as a monetary policy rule. Ideally, one would like to conduct this analysis with an extended version of the model that includes the nonlinear constraint $R_t \geq 0$. At present I do not have the necessary

computational resources to proceed in this fashion, so only linear-model results will be reported below. They seem to be sufficient, however, to make the essential points. These are as follows:

(i) Under conditions implying that monetary policy via an interest rate rule would be immobilized by the ZLB constraint, the MC rule will provide policy actions that are strongly stabilizing..

(ii) Under conditions such that the ZLB constraint is not relevant, the MC rule would not significantly—if at all—hinder monetary policy.

Together, these two points appear to establish the potential desirability of the MC rule (20).

To develop point (i), the procedure is to conduct simulations in which (20) is the policy rule and the interest rate R_t is held fixed at a constant value. For this to be done, one of the structural equations of the model must as a computational matter be eliminated. As in McCallum (2000), the one chosen is the UIP condition (19). As in that previous case, however, the actual conceptual step is not the elimination of UIP but its extension to a more general condition involving some element of the “portfolio balance” theory together with recognition that it is operationally redundant.¹⁹ (Discussion is provided below.) The relevant simulation results are presented in Tables 2 and 3. In the first of these the policy parameters μ_2 and μ_3 are held fixed at the values 0.5 and 0.8, respectively, so that the results are comparable to those in the upper cell row of Table 1. With $\theta = 1$, as in the first cell row of Table 2, the MC rule is simply a rule for setting the rate of depreciation of the exchange rate. The figures in this cell row indicate that with μ_1 at the “realistic” value of 0.5, both inflation and the output gap are excessively variable (in relation to actuality and to the comparable

values in Table 1). But the entries in the first cell row of Table 2 also show clearly that inflation is effectively stabilized by moving to increased (more aggressive) values of μ_1 , a result implying that effective stabilization can be provided by the exchange rate rule. But, as implied above, use of smaller values for θ in the rule have effects that, when $R_t = 0$, are somewhat similar to those from adoption of larger μ_1 magnitudes. Thus while keeping $\mu_1 = 0.5$ we look with interest to the other cell rows in Table 2, where smaller θ values are specified, and find much improved performance. With $\theta = 0.1$, for example, the SD values for inflation and the output gap are reduced to magnitudes close to those in the second column of Table 1. In fact, with $\theta = 0.025$, the MC rule values with $\mu_1 = 0.5$ dominate those in Table 1. The same is true, moreover, for $\mu_1 = 0.05$. With large values of μ_1 , however, small θ settings have the effect of making Δs_t excessively responsive to fluctuations in inflation and the output gap, leading to large SD values for this instrument variable.

The foregoing comparisons are all based on the assumption that $\mu_3 = 0.8$, i.e., that there is considerable smoothing of short-term interest rates. Table 3 provides values analogous to those of Table 2 but with $\mu_3 = 0$, i.e., no smoothing. In this case there is apparently no possibility of literally dominating the Table 1 results, i.e., obtaining lower variability for all four variables, Δp_t , \tilde{y}_t , R_t , and Δs_t . Results are reasonably encouraging, nevertheless, with small values of θ and μ_1 . In any event, the main point of interest is not whether performance is better than with an R_t instrument in the absence of any ZLB problem. It is, instead, whether the rule (20) can provide stabilizing power even with R_t immobilized by the ZLB constraint. Table 3, like Table 2, indicates that such stabilization is indeed

¹⁹ In this case the exogenous variability provided by the UIP shock term ξ_t is not eliminated, but instead is transferred to the policy rule (and included in addition to the e_t term).

provided, since the SD of inflation falls sharply as we move to the right (by increasing the μ_1 parameter values) or downward (by decreasing θ).

The second task, involving point (ii), is to show that, in the absence of a ZLB situation, use of MC rule (20) would not seriously hinder the stabilizing effects of monetary policy, relative to the standard case with an interest rate instrument. The relevant simulations now do not impose any ZLB feature at all. The results for the case with interest rate smoothing ($\mu_3 = 0.8$) are shown in Table 4. These are to be compared with the SD values in the top cell row of Table 1, which are for the standard interest rate rule with smoothing. Consider column two, with the realistic value of 0.5 for μ_1 . With $\theta = 1.0$, we have the case in which the MC rule amounts to a pure exchange-rate rule and we find that variability of inflation and the output gap is distinctly higher than in Table 1 for the same μ_1 value. But if we set $\theta = 0.1$, as in row two of Table 4, the MC results improve sharply and would no longer be considered to be significantly worse, relative to the case with a pure R_t rule. So this result tends to establish the point at hand, that serious deterioration is not induced by use of the MC rule when it is unnecessary. Furthermore, the results are better even than that, for with $\theta = 0.025$, the SD values from rule (20) are as low or lower (than in Table 1) for all four variables. Thus the MC rule is unambiguously more effective than the R_t rule in this particular case, even without taking any account of the former's crucial advantage, namely, to be usable in cases in which the ZLB constraint is in effect.²⁰

Analogous results are presented in Table 5 under the assumption that $\mu_3 = 0$, rather than $\mu_3 = 0.8$. The conclusions are much the same. With respect to the results in both Tables 4 and 5 it must be recognized that comparisons that do not impose any ZLB constraint are

not the same as the ones that would be fully appropriate theoretically, i.e., comparisons of the R_t and MC rules with solutions that have the ZLB constraint binding occasionally. But it would appear that the comparison being made is conservative (in the sense of working against our argument) since there is less weight assigned to the interest rate component by the MC rule than with the reference case, and this component's stabilizing power should actually be excluded.

The main findings presented to this point are that the MC rule does provide effective stabilization even with R_t at the ZLB and that the MC rule can perform at least nearly as well as the R_t rule when the ZLB is irrelevant. There are many ways in which one would like to check the robustness of these findings with respect to alterations in the model utilized. One that will be considered here is to introduce a somewhat more realistic assumption with respect to information available to the model's monetary policy makers. In particular, it will be assumed that the central bank cannot observe current values of inflation and the output gap when choosing instrument settings for the current period. In rule (20), that is, $E_{t-1}\Delta p_t$ and $E_{t-1}\tilde{y}_t$ will be used in place of actual values of Δp_t and \tilde{y}_t . Results are shown in Table 6, all based on the policy-rule parameter values $\mu_1 = 0.5$, $\mu_2 = 0.5$, and $\mu_3 = 0.8$. In the first column we find SD values under the assumption that the ZLB is irrelevant. The pure interest rate rule case appears in the last cell row ($\theta = 0$), and the other rows show that with small values of θ there is no substantial deterioration in performance from use of the MC rule (20). Then in column two we have results for the case in which the ZLB condition $R_t = 0$ is imposed. Here again we see that the MC rule is effective, in the sense that SD values for inflation and the output gap are reduced as the specified value of θ is decreased, despite the assumed

²⁰ A caveat should be mentioned, namely, that the results of our simulations are subject to sampling error.

immobilization of the interest rate.

The one other model modification that is explored in the present paper concerns the economy's openness, as measured by ω_3 , the average share of output that is exported (and imported). In the simulations for Table 6, this share is doubled to 0.30. The results reported in columns three and four are analogous to those in columns one and two. And again they are supportive of the suggestion that the MC rule (20) could be useful in improving macroeconomic performance for an economy that has some danger of a ZLB constraint arising.

7. Analytical Issues

There are a few theoretical issues, bypassed in the foregoing presentation, that need to be discussed. The first of these has to do with the “elimination” of the UIP condition (19) in the solutions in which the ZLB constraint is imposed. In that regard, most analysts (including myself) would normally include UIP as one component of an open-economy macroeconomic model—despite the existence of much empirical evidence that is, at least on the surface, strongly inconsistent with UIP on a quarter-to-quarter basis. So how can UIP legitimately be avoided here? The answer is as follows.

It is well known that to be consistent with the data, UIP relations must include a discrepancy term, typically referred to as a risk premium. Thus included in (19) is a risk premium ξ_t that has a large variance relative to other shock terms and furthermore is serially correlated. Often ξ_t is treated as exogenous, but there are plausible reasons for believing that it would be related to the relative amounts of outside domestic and foreign nominal liabilities

Differences of less than 2-3 percent between values should not, accordingly, be taken too seriously.

outstanding. For example, a hypothesis widely entertained during the 1970s might be expressed as

$$(27) \quad \xi_t = \lambda[B_t - (B_t^* + s_t)] + \zeta_t$$

where B_t and B_t^* are logs of domestic and foreign government debt (including base money) and ζ_t is an exogenous stochastic shock term. Substituting and recognizing that lags could be involved, we then write

$$(28) \quad R_t - R_t^* = (E_t s_{t+1} - s_t) + \lambda(L)[B_t - B_t^* - s_t] + \zeta_t,$$

which is similar to equations prominent in several older writings of Dornbusch (e.g., 1987, p. 7). This “portfolio balance” hypothesis has receded from its earlier prominence because various empirical studies failed to find empirical support. But it is, I suggest, quite reasonable to believe that some such relation obtains in fact, probably with weak or transitory effects of the $B_t - B_t^*$ variable. And if such is the case, then our procedure above is fully justified. For (28) indicates that even with $R_t = 0$, s_t can be affected by central bank purchases of foreign exchange since they alter the value of $B_t - B_t^*$. Yet the precise specification of relation (28) need not be known, and the relation need not be included in the model, for exactly the same reason that money demand functions are not needed in analyses that presume use of an interest rate instrument. Thus appending (28) to the model would have no effect on the implied behavior of Δp_t , x_t , y_t , or Δs_t ; it would merely specify the magnitude of open-market purchases of foreign exchange needed to implement the MC policy rule (20).

Another issue neglected above concerns the argument, developed in the context of a closed economy model, of Benhabib, Schmitt-Grohe, and Uribe (2001). In a series of papers, these authors have suggested that a ZLB situation could arise for reasons quite different from

those presumed above. In our analysis, as in that of Krugman (1998), Eggertsson and Woodford (2003, 2004), Auerbach and Obstfeld (2004), Coenen and Wieland (2003), and most other writers on the ZLB issue, it is assumed that the relevant RE solution is one in which inflation fluctuates around the target value specified by the usual interest rate policy rule. If the target inflation rate plus the steady state real rate of interest is a moderately high value, such as 4-5 percent per year, unusually large shocks would be required to push the system to the vicinity of the ZLB. By contrast, Benhabib, Schmitt-Grohe, and Uribe suggest that there are multiple RE equilibria and the relevant one may instead be located at the ZLB value of R_t , even in the absence of shocks. My position, argued most extensively in McCallum (2002), is that this ZLB equilibrium is not plausible, because it fails to be E-stable in the sense developed by Evans and Honkapohja (2001). Such a failure implies that this (apparent) RE equilibrium would not be learnable in a setting that recognizes that individuals are not miraculously endowed with knowledge of the economy's parameters, but need to learn about them over time by observation of the economy's behavior. The usual RE equilibrium, focused upon by the other papers mentioned above, is by contrast E-stable and learnable under standard assumptions. On the basis of this contrast, I would argue that the usual RE equilibrium is the only one of these two that is plausible as a description of the behavior of an actual economy.

8. Conclusions

Let us close with a brief summary of the paper's arguments. It begins by emphasizing the difference between policy rule changes, intended to help escape an existing ZLB situation, and maintained policy rules designed so as to avoid the "liquidity trap" aspects of a ZLB situation. Analysis assuming that rule changes would be quickly

recognized, understood, and believed—so that a new RE equilibrium would be relevant immediately—seems implausible. Accordingly, the paper focuses not on policy changes for escaping a liquidity trap, but on the design of a policy rule that should retain stabilization effectiveness for monetary policy even if the economy is temporarily shocked into a situation in which the zero lower bound on nominal interest rates makes demand stimulation via interest rate reductions infeasible.

The particular policy rule considered in detail is one that uses as its instrument or indicator variable a weighted average of the usual short-term interest rate and the rate of depreciation of the nominal exchange rate. With a small weight attached to the depreciation term, inclusion of the latter would be nearly irrelevant in normal situations. But when the ZLB condition $R_t = 0$ prevails, then adjustments in the weighted average—which has some similarities to a monetary conditions index—require large movements in the depreciation rate (effected by central bank purchases of foreign exchange). These would be affect aggregate demand by another channel, and would provide stabilization power.

Stabilizing properties of this MC rule are studied by means of stochastic simulations with a model of a small open economy developed by McCallum and Nelson (1999). The latter differs from other small-scale models based on optimizing behavior (but with sticky prices) by treating imports as inputs to the economy's production processes, rather than as consumer goods. The simulations indicate that: (i) under conditions implying that monetary policy via an interest rate rule would be immobilized by the ZLB constraint, the MC rule will provide strong stabilizing policy actions; yet (ii) under conditions such that the ZLB constraint is not relevant, the MC rule would not significantly—if at all—hinder monetary

policy. Together, these two sets of results are supportive of the idea that a monetary policy of the MC type could be useful for an economy with a low target inflation rate.

Table 1
 Results with Standard Interest Rate Rule
 Cell entries are standard deviations of Δp_t , \tilde{y}_t , R_t , and Δs_t

	$\mu_1 = 0.05$	$\mu_1 = 0.5$	$\mu_1 = 5.0$	$\mu_1 = 50.0$
$\mu_3 = 0.8$	3.28	2.35	1.36	0.74
	2.19	1.96	1.69	2.35
	2.82	2.48	3.82	11.26
	18.59	18.51	19.35	27.70
$\mu_3 = 0.0$	6.27	2.92	1.35	0.58
	2.07	1.68	1.54	3.01
	7.03	4.70	7.80	28.16
	19.14	18.56	21.97	46.82

Table 2
 Results with MC Rule (20) when $\Delta R_t = 0$ (with $\mu_3 = 0.8$)
 Cell entries are standard deviations of Δp_t , \tilde{y}_t , and Δs_t

	$\mu_1 = 0.05$	$\mu_1 = 0.5$	$\mu_1 = 5.0$	$\mu_1 = 50.0$
$\theta = 1.0$	34.41	9.87	2.32	0/79
	13.28	4.53	2.38	2.73
	31.75	10.38	11.02	38.21
$\theta = 0.1$	3.44	2.65	1.31	0.48
	2.44	2.27	2.20	3.54
	8.33	9.45	19.81	65.56
$\theta = 0.025$	1.60	1.38	0.78	0.26
	1.81	1.86	2.47	4.64
	14.69	17.26	36.44	103.75
$\theta = 0.01$	1.16	1.02	0.57	0.16
	1.63	1.81	2.94	5.33
	22.17	26.10	53.72	128.61

Table 3
 Results with MC Rule (20) when $\Delta R_t = 0$ (with $\mu_3 = 0.0$)
 Cell entries are standard deviations of Δp_t , \tilde{y}_t , and Δs_t

	$\mu_1 = 0.05$	$\mu_1 = 0.5$	$\mu_1 = 5.0$	$\mu_1 = 50.0$
$\theta = 1.0$	34.41	9.87	2.32	0.79
	13.28	4.53	2.38	2.73
	31.75	10.38	11.02	38.21
$\theta = 0.1$	1.51	1.30	0.74	0.24
	1.79	1.83	2.55	4.77
	15.78	18.42	38.99	108.04
$\theta = 0.025$	1.03	0.90	0.48	0.11
	1.63	1.90	3.31	5.66
	28.46	33.24	67.52	141.37
$\theta = 0.01$	0.95	0.82	0.40	0.08
	1.71	2.06	3.72	5.94
	36.29	42.46	83.21	152.08

Table 4

Results with MC Rule (20) with No ZLB (with $\mu_3 = 0.8$)
 Cell entries are standard deviations of Δp_t , \tilde{y}_t , R_t , and Δs_t

	$\mu_1 = 0.05$	$\mu_1 = 0.5$	$\mu_1 = 5.0$	$\mu_1 = 50.0$
$\theta = 1.0$	10.39	3.63	1.45	0.62
	2.63	2.41	2.17	3.15
	12.84	9.32	10.97	19.87
	9.36	1.65	6.22	29.87
$\theta = 0.1$	2.92	2.26	1.29	0.69
	2.16	1.94	1.73	2.51
	2.61	2.69	4.26	12.63
	16.94	16.42	17.30	24.41
$\theta = 0.025$	3.13	2.31	1.34	0.73
	2.19	1.96	1.69	2.39
	2.61	2.41	3.88	11.60
	18.22	18.01	18.87	27.91
$\theta = 0.01$	3.20	2.31	1.36	0.74
	2.19	1.95	1.68	2.37
	2.73	2.41	3.84	11.39
	18.38	18.39	19.19	27.69

Table 5

Results with MC Rule (20) with No ZLB (with $\mu_3 = 0.0$)
 Cell entries are standard deviations of Δp_t , \tilde{y}_t , R_t , and Δs_t

	$\mu_1 = 0.05$	$\mu_1 = 0.5$	$\mu_1 = 5.0$	$\mu_1 = 50.0$
$\theta = 1.0$	10.39	3.63	1.45	0.62
	2.63	2.41	2.17	3.15
	12.84	9.32	10.97	19.87
	9.36	1.65	6.22	29.87
$\theta = 0.1$	5.79	2.74	1.28	0.55
	2.03	1.67	1.57	3.05
	6.91	4.94	7.74	27.14
	18.28	17.57	20.67	45.76
$\theta = 0.025$	6.19	2.88	1.33	0.57
	2.06	1.65	1.55	3.01
	6.98	4.69	7.72	27.96
	18.97	18.47	21.52	46.89
$\theta = 0.01$	2.30	2.91	1.33	0.58
	2.07	1.67	1.54	3.02
	6.98	4.69	7.68	28.20
	19.10	18.58	21.72	47.17

Table 6
 Results with MC Rule (20) with Model Alterations ($\mu_1 = 0.5$; $\mu_3 = 0.8$)
 Cell entries are standard deviations of Δp_t , \tilde{y}_t , R_t , and Δs_t

	Case with $E_{t-1}\Delta p_t$ and $E_{t-1}\tilde{y}_t$ in policy rule. No ZLB.	Case with $E_{t-1}\Delta p_t$ and $E_{t-1}\tilde{y}_t$ in policy rule. ZLB, $R_t = 0$	Case with $\omega_3 = 0.30$ No ZLB	Case with $\omega_3 = 0.30$ ZLB, $R_t = 0$
$\theta = 1.0$ Δs_t rule	3.66 2.51 9.31 1.46	9.85 4.61 0.00 10.30	3.23 2.21 9.26 1.55	9.69 4.70 0.00 10.33
$\theta = 0.1$	2.49 2.08 2.56 16.77	3.00 2.54 0.00 10.43	2.13 2.26 2.68 15.56	2.32 2.30 0.00 7.82
$\theta = 0.025$	2.58 2.07 2.25 18.54	1.75 2.18 0.00 17.78	2.16 2.32 2.24 17.23	1.12 1.86 0.00 11.18
$\theta = 0.01$	2.61 2.30 2.29 18.78	1.41 2.07 0.00 25.29	2.19 2.35 2.27 17.51	0.89 1.92 0.00 15.08
$\theta = 0.0$ R_t rule	2.62 2.09 2.33 18.99		2.20 2.36 2.28 17.67	

Figure 1

Impulse Responses, R_t Rule, Shock to Policy Rule

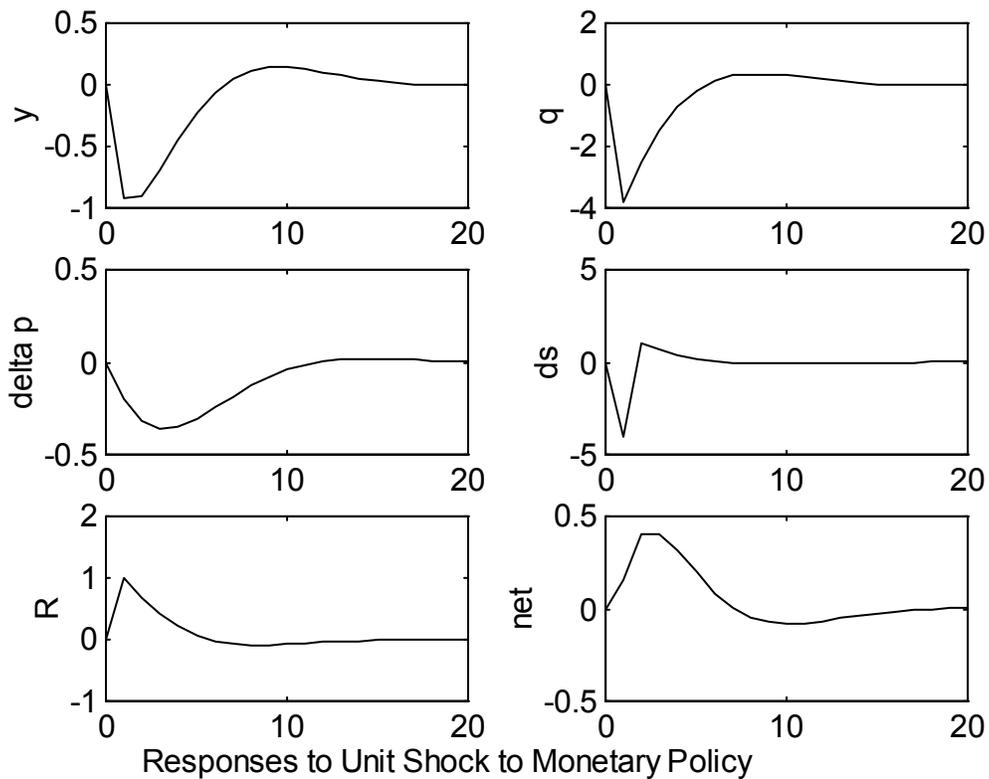


Figure 2

Impulse Responses, R_t Rule, Shock to IS Function

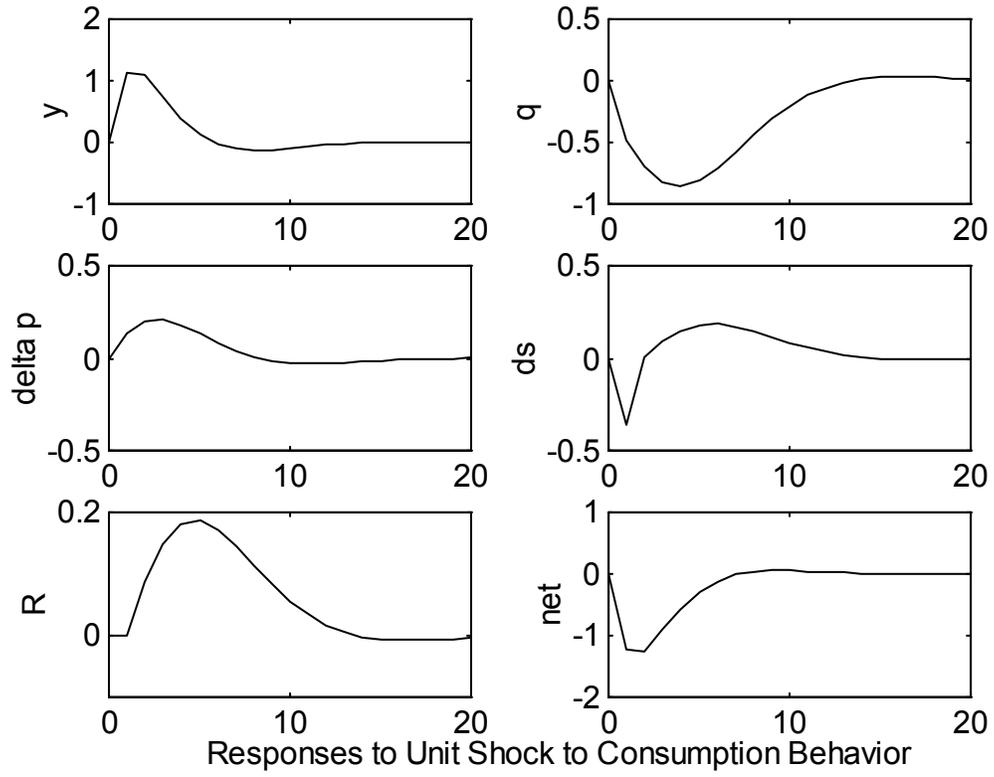


Figure 3

Impulse Responses, R_t Rule, Shock to Technology

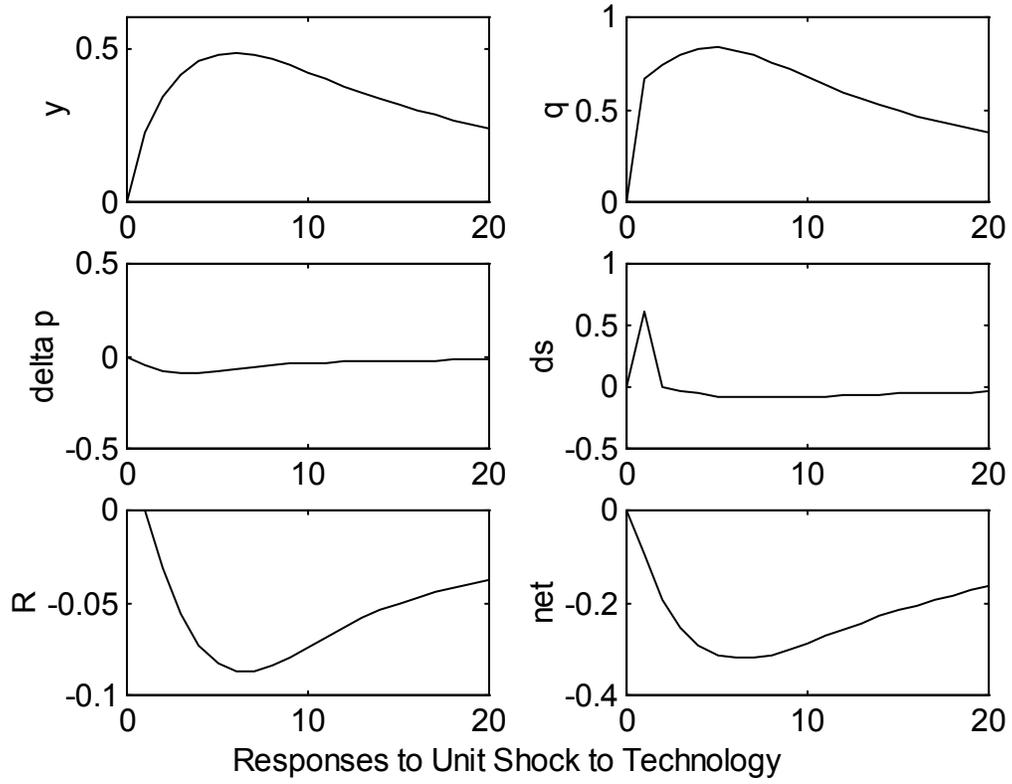
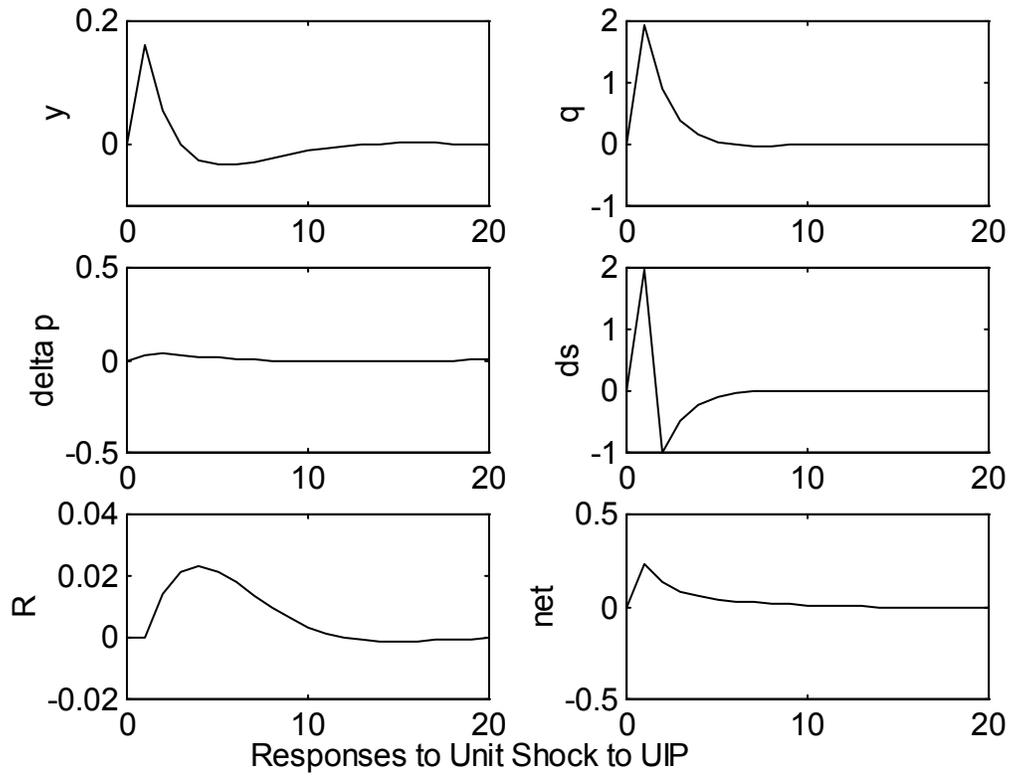


Figure 4

Impulse Responses, R_t Rule, Shock to Exchange Rate



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