

# **The Monetary Policy Transmission Mechanism in Industrial Countries**

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## **1. Introduction**

The main objective of this paper is to develop a simplified but substantive analysis of the monetary policy transmission mechanism that is currently relevant for most industrialized economies. The discussion will accordingly presume that institutions and policy procedures are of the general type utilized in the United States, Japan, and the Euro Area. Some attention will be paid, however, to smaller industrial economies for which foreign trade is larger in relation to domestic production.

As indicated, the paper's objectives are largely substantive, involving an attempt to determine which aspects of the transmission mechanism for monetary policy are most crucial. The topic is one, however, that requires a significant amount of methodological discussion. Issues relating to the type of models and analysis to be employed are of fundamental importance, and will therefore be considered explicitly in what follows.<sup>1</sup>

Indeed, it may be useful to begin with a statement of what is meant by the term "monetary transmission mechanism." That this term evokes different responses from different scholars is well illustrated by a symposium on "The Monetary Transmission Mechanism" featured in the Fall 1995 issue of the Journal of Economic Perspectives. In the papers of that symposium, Bernanke and Gertler (1995) focus on the credit channel; Meltzer (1995) promotes monetarist emphasis on the importance of recognizing multiple assets; Taylor (1995) outlines a particular econometric framework for studying the transmission mechanism; Obstfeld and Rogoff (1995) discuss foreign exchange-rate policy and financial crises; and Mishkin (1995) provides a brief overview. More generally, many writers on the

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<sup>1</sup> For additional discussion of methodological issues, see McCallum (2001a), from which portions of this paper have been adapted.

subject restrict their attention to the effects of monetary policy shocks,<sup>2</sup> while some are concerned only with effects on real variables. In the present paper, however, the concept of the transmission process to be considered includes effects on both real and nominal variables and emphasizes strongly the regular, systematic component of monetary policy. The implied definition, therefore, is similar to that expressed by Taylor (1995, p. 11): “the process through which monetary policy decisions are transmitted into changes in real GDP and inflation.”

An outline of the paper is as follows. In Section 2, it is argued that study of the systematic component of monetary policy actions is much more important than the study of the unsystematic component—a.k.a., policy shocks. Next, Section 3 presents an open-economy model to serve as our basic framework for analysis. Quantitative calibration of the model is described in Section 4, together with a brief summary of how its properties compare with those of actual economies. Then Section 5 develops the paper’s main results in terms of the monetary transmission process. The strategy is to alter crucial parameter values pertaining to different aspects of the transmission process and examine the effects on the model economy’s properties. Section 6 focuses on two specific issues; these concern exchange rate management and the non-observability of potential output. Finally, a brief conclusion appears as Section 7.

## **2. Shocks versus Systematic Policy**

There exists a large volume of literature, much of it highly sophisticated, in which the effects of monetary policy on output, prices, and other variables are discussed entirely in terms of policy shocks.<sup>3</sup> In this context, policy shocks represent the random, unsystematic

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<sup>2</sup> See, for example, Cochrane (1994), Sims (1992), and Christiano, Eichenbaum, and Evans (1999).

<sup>3</sup> A prominent survey of this portion of the literature is provided by Christiano, Eichenbaum, and Evans (1999).

component of the monetary authorities' actions, i.e., the portion that is not related to the state of the economy, current or past. A leading theme of McCallum (2001a) is that emphasis on the shock component has been overdone; that while both shocks and the systematic component of behavior are of interest, it would be much more fruitful to emphasize the latter. This point of view has been taken by other analysts, including Taylor (1995), Rotemberg and Woodford (1997, 1999), Dotsey (1999), and Bernanke, Gertler, and Watson (1997), but needs to be stressed because of the sheer volume of literature that differs in this crucial respect.

The simplest way of arguing for an emphasis on the systematic component of policy is to recognize that quantitatively the unsystematic portion of policy-instrument variability is quite small in relation to the variability of the systematic component. In industrial economies, monetary policy is usually implemented by periodic<sup>4</sup> adjustment of a short-term interest rate that serves as the central bank's instrument (or "operating target"). There have been many attempts to estimate the policy rules that describe this process, relationships that are variants of the famous Taylor rule (1993). An illustration is provided by the prominent study by Clarida, Gali, and Gertler (1998) of policy behavior since 1979 by central banks of the G-3 nations. In particular, that paper's "baseline" estimates of monthly Bundesbank, Bank of Japan, and Federal Reserve reaction functions indicated that the fraction of monthly interest-instrument variability that is unexplained by systematic determinants was only 1.9, 3.0, and 1.6 percent, respectively. Also, Rotemberg and Woodford (1997) and McCallum and Nelson (1999a) found in the U.S. quarterly data that only about 5 percent of instrument variability was unexplained over roughly the same period.

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<sup>4</sup> For example, week-to-week adjustment of the Federal Funds rate in the United States.

A more satisfactory method of demonstrating the relative unimportance of the shock component in industrial economies would be, however, to develop a quantitative macroeconomic model suitable for monetary policy analysis and then use it to determine the effect of eliminating monetary shocks altogether. An exercise of that type will therefore be presented below, in Section 5.

Having argued that it is more important to focus on the systematic portion of monetary policy actions, rather than on shocks, we are then by logical necessity driven toward the study of structural models, designed to be policy invariant. In particular, we conclude that vector-autoregression (VAR) models, of a type that has often been used for monetary policy analysis in the past, are fundamentally unsatisfactory. The reason is that even “identified” or “semi-structural” VAR systems do not give rise to behavioral equations that can be presumed to be structural, i.e., policy invariant. The purpose of identified VARs is to identify the unsystematic component of monetary policy, not to generate policy-invariant equation systems.<sup>5</sup> But it is the latter that is crucial for modelling the effects of systematic or anticipated policy actions. In the following section, accordingly, we will present an open-economy macroeconomic model that is intended to be structural, and therefore appropriate for analysis of alternative (systematic) policy rules.

### **3. Analytical Framework**

The model that will be used below is one that was developed by McCallum and Nelson (1999a) 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 a “new open-economy macroeconomic model”—i.e., is

based on dynamic optimizing analysis assuming sticky price adjustments and solved assuming rational expectations—that has been calibrated to match certain characteristics of the economies of interest (here, typical industrial economies).<sup>6</sup> 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, as is common, 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 has previously been presented in McCallum and Nelson (1999a), here I will take an informal expository approach designed to facilitate understanding of the model’s basic structure.

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

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

where  $c_t$  is the log of a Dixit-Stiglitz consumption-bundle aggregate of the many distinct goods that a typical household consumes in period  $t$ .<sup>7</sup> In (1),  $r_t$  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. The parameter  $b_1$  is negative, with its absolute value equal to the intertemporal elasticity of substitution in consumption. In closed economy analysis, relation (1) is often combined with a log-

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<sup>5</sup> This crucial point is evidently accepted by most creators and practitioners of the identified VAR approach, including Bernanke, Gertler, and Watson (1997) and Christiano, Eichenbaum, and Evans (1999). Also see Bernanke (1986) and Blanchard and Watson (1986).

<sup>6</sup> This literature is the open-economy extension of models reflecting the “New Neoclassical Synthesis,” to use the term coined by Goodfriend and King (1997).

<sup>7</sup> Thus  $c_t = \ln C_t$  with  $C_t = [\int C_t(z)^{(\theta-1)/\theta} dz]^{0/(\theta-1)}$ , where  $\theta > 1$ ,  $z$  indexes distinct goods, and the integral is over  $(0,1)$ , while the corresponding price index is  $P_t = [\int P_t(z)^{1-\theta} dz]^{1/(1-\theta)}$ .

linearized, per-household, overall resource constraint to yield an “expectational IS function,” to use the term of Kerr and King (1996). 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 assumption 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 while  $\omega_1$ ,  $\omega_2$ ,  $\omega_3$ , and  $\omega_4$  are 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, then the relevant resource constraint is

$$(2) \quad y_t = \omega_1 c_t + \omega_2 g_t + \omega_3 x_t.$$

It is desirable that import demand be modelled in an optimizing fashion. Toward that end, we assume that output of all consumer goods is effected by producers that are constrained by production functions all of the same CES form, with labor and material imports being the two variable inputs. Then the cost-minimizing demand for imports is<sup>8</sup>

$$(3) \quad im_t = y_t - \sigma q_t + \text{const.}$$

where  $\sigma$  is the elasticity of substitution between materials and labor in production, and where “const.” denotes some constant.<sup>9</sup> Also,  $q_t$  is the log price of imports in terms of produced

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<sup>8</sup> There is also a small adjustment included for the effects of imperfect competition on this relationship.

<sup>9</sup> That is, the expressions “const.” in different equations appearing below will typically refer to different constant magnitudes.

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

$$(4) \quad q_t = s_t - p_t + p_t^*.$$

Symmetrically, we assume that export demand is given as

$$(5) \quad x_t = y_t^* + \sigma^* q_t + \text{const.}$$

where  $y_t^*$  denotes production abroad and  $\sigma^*$  is the price elasticity of demand from abroad for home-country goods.

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

$$y_t = \alpha_1 a_t + \alpha_1 n_t + \alpha_2 \text{im}_t + \text{const.},$$

where  $n_t$  and  $a_t$  are logs of labor input and a labor-augmenting technology shock term, respectively. Suppose for simplicity 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  $y_t$  would be  $\bar{y}_t = \alpha_1 a_t + \alpha_2 \text{im}_t + \text{const.}$  so that  $\bar{y}_t = \alpha_1 a_t + \alpha_2 [\bar{y}_t - \sigma q_t] + \text{const.}$ , or

$$(6) \quad \bar{y}_t = (1 - \alpha_2)^{-1} \alpha_1 a_t - [\sigma \alpha_2 / (1 - \alpha_2)] q_t + \text{const.}$$

But while  $\bar{y}_t$  would be the economy’s output in period  $t$  if prices could adjust promptly in response to any shock, we assume that prices adjust only sluggishly. And if the economy’s demand quantity as determined by the rest of the system ( $y_t$ ) differs from  $\bar{y}_t$  then the former quantity prevails—and workers depart from their (inelastic) supply schedules so as to provide whatever quantity is needed to produce the demanded output, with  $\text{im}_t$  given by (3).

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

$$(7) \quad \Delta p_t = (1+\beta)^{-1} (\beta E_t \Delta p_{t+1} + \Delta p_{t-1}) + \kappa(y_t - \bar{y}_t) + u_t, \quad \kappa > 0$$

where  $\beta$  is a discount factor and  $u_t$  is a behavioral disturbance. This form of equation has been fairly prominent,<sup>10</sup> 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 current open-economy models is a relation implying uncovered interest parity (UIP). Despite its prominent empirical weaknesses, accordingly, the basic M&N model incorporates one:

$$(8) \quad R_t - R_t^* = E_t \Delta s_{t+1} + \xi_t.$$

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

It remains to describe how monetary policy is conducted. In most recent research in monetary economics, it is presumed 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,  $\tilde{y}_t = y_t - \bar{y}_t$ :

$$(9) \quad R_t = (1-\mu_3) [\mu_0 + \Delta p_t + \mu_1 (\Delta p_t - \pi^*) + \mu_2 \tilde{y}_t] + \mu_3 R_{t-1} + e_t.$$

Here  $\mu_3 > 0$  reflects interest rate smoothing. Quantitative results reported by M-N (1999a,

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<sup>10</sup> See Fuhrer and Moore (1995), Galí and Gertler (1999), and Woodford (2003).

2000) are based on estimated or calibrated versions of this rule, in most cases with  $E_{t-1}$  applied to  $\tilde{y}_t$  and  $\Delta p_t$  so as to be somewhat realistic in terms of information available to actual central banks.

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:

$$(10) \quad r_t = R_t - E_t \Delta p_{t+1}.$$

Thus we have a simple log-linear system in which the ten structural relations (1)-(10) determine values for the endogenous variables  $y_t$ ,  $\bar{y}_t$ ,  $\Delta p_t$ ,  $r_t$ ,  $R_t$ ,  $q_t$ ,  $s_t$ ,  $c_t$ ,  $x_t$ , 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  $\xi_t$ .<sup>11</sup>

With respect to monetary policy, note that it would be possible to append a money demand function such as

$$(11) \quad m_t - p_t = \gamma_0 + \gamma_1 y_t + \gamma_2 R_t + \eta_t,$$

and one of this general form—perhaps with  $c_t$  replacing  $y_t$ —would be consistent with optimizing behavior.<sup>12</sup> But, as many writers have noted, that equation would serve only to determine the values of  $m_t$  that are needed to implement the  $R_t$  policy rule.

With the structure given above, a useful measure of the foreign trade balance on goods and services account—i.e., net exports—is

$$(12) \quad net_t = x_t - (im_t + q_t),$$

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<sup>11</sup> 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 Pesenti (2003), and Smets and Wouters (2002).

<sup>12</sup> See McCallum and Nelson (1999b) or many other papers.

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

$$(13) \quad p_t^{\text{DEF}} = [p_t - \omega_3(s_t + p_t^*)]/(1 - \omega_3).$$

Before moving on, it should be noted that an advantage of our strategy of modelling imports as material inputs to the production process is that the relevant price index for produced goods is identical to the consumer price index, which implies that the same gradual price adjustment behavior is relevant for all domestic consumption. In addition, it avoids the unattractive assumption, implied by the tradeable vs. non-tradeable goods dichotomization, that export and import goods are perfectly substitutable in production.

Such theoretical 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 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).<sup>13</sup>

#### **4. Calibration and Model Properties**

There is one way in which the model developed in McCallum and Nelson (1999a) differs significantly from the 10-equation formulation just presented. Specifically, the M&N (1999a) model 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

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<sup>13</sup> 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%.

leads to equation (1), we 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 (1):

$$(14) \quad c_t = h_0 + h_1 c_{t-1} + h_2 E_t c_{t+1} + h_3 E_t c_{t+2} + h_4 (\log \lambda_t) + v_t.$$

In the latter,  $\lambda_t$  is the Lagrange multiplier on the household's budget constraint, which obeys

$$(15) \quad \log \lambda_t = \text{const.} + E_t \log \lambda_{t+1} + r_t,$$

and there are constraints relating the  $h_j$  parameters to others in the system.<sup>14</sup> 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.

Calibration of the model draws on M&N (1999a) but differs in several ways that are appropriate for present purposes. For the parameter governing spending behavior, I retain here the  $h = 0.8$  value taken from an early version of Fuhrer (2000), but for my base case have adopted the assumption that  $\gamma$ , 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).<sup>15</sup> For  $\sigma$ , 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  $\alpha_2$  is taken to equal  $\omega_3$ , 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

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<sup>14</sup> For details and additional discussion, see M&N (1999a), Amato and Laubach (2004), and the basic study by Fuhrer (1998).

<sup>15</sup> The parameter in question,  $\gamma$ , is the intertemporal elasticity of substitution in consumption when  $h = 0$ .

case, and can be altered to represent differing degrees of openness. For the base-case share of government consumption I take  $\omega_2 = 0.2$ .

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. Policy rule parameters should be thought of in relation to realistic values close to  $\mu_1 = 0.5$ ,  $\mu_2 = 0.5$ , and  $\mu_3 = 0.8$ , the latter reflecting considerable interest rate smoothing. In most cases, expectations based on  $t-1$  data are used for the  $\Delta p_t$  and  $\tilde{y}_t$  variables appearing in the policy rule, in order to make the latter more plausibly operational, in a practical sense.

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 (1999a). The innovation standard deviations (SD) are 0.03 and 0.007, respectively.<sup>16</sup> The UIP risk premium term  $\xi_t$  and the consumption shock  $v_t$  are generated by an AR(1) processes with AR parameter 0.5 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 transmission process, we should briefly investigate its properties to establish, if possible, that they are at least moderately consistent with our understanding of the characteristics of industrial economies. The basic tools for such a project are comparisons, with respect to actual economies, of model-implied

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<sup>16</sup> These and other values given in this paragraph are expressed in terms of quarterly fractional units.

standard deviations and autocorrelations of key variables, together with impulse response functions of key variables with respect to shock innovations.<sup>17</sup>

The first such results are shown in Table 1. There we report standard deviation (SD) and first-order autocorrelation values for four crucial variables as implied by the baseline case of our model and as obtaining in actual quarterly data for the United States, the euro area, Japan, and the United Kingdom. It will be seen that the model provides a reasonably good match to the actual data, in the sense that that standard deviations lie in the range of the actual values and that autocorrelation values are high (except for  $\Delta s_t$  in both model and actuality. [The SD values in all tables are reported in annualized percentage, not fractional, units.] Also, it will be shown in the next section that the model's simulated SD values reflect alternative policy rule parameters in a manner that is analytically reasonable.

In terms of impulse response functions, Figure 1 reports the responses of six variables to a unit shock in the monetary policy rule. 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

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<sup>17</sup> Reported SD and autocorrelation values are averages across 200 stochastic simulations, each of length 200.

values. The nominal interest rate rises, as governed by the policy rule, to help to stabilize these movements in 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 plot 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 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 depict the nature of the monetary policy transmission mechanism.

## **5. Monetary Transmission Mechanism: Main Results**

Let us begin with an explicit documentation of the claim made in Section 2 to the effect that the unsystematic, policy-shock component of monetary policy is of minor importance, relative to the regular systematic component. Toward that end, we examine the

consequences of changing our base-case model in only one respect, viz., by eliminating altogether the monetary policy shock component. Thus we conduct a simulation mimicking that of the first column of Table 1 (our baseline case) but with the standard deviation of  $e_t$  set equal to zero, rather than 0.0017. The resulting standard deviations of the four endogenous variables considered in Table 1 become, respectively, 2.60, 2.04, 2.19, and 18.75 (for  $\Delta p_t$ ,  $\tilde{y}_t$ ,  $R_t$ , and  $\Delta s_t$ ). Thus we see that the extent of reduction in variability is about 1-2 percent in terms of standard deviations, relative to the base case. I would suggest that such magnitudes are basically negligible. Furthermore, the value that was adopted in Section 4 for the standard deviation of  $e_t$  is itself larger than values estimated by researchers who have limited their study of U.S. data to the period after the 1979-1982 episode that involved a substantial regime change, and change in operating procedures, by the Federal Reserve. See, in this regard, Rudebusch (2002) and English, Nelson, and Sack (2003).

We move on, then, to discussion of systematic aspects of the transmission mechanism. I begin by emphasizing the demonstration, briefly mentioned above, of the effectiveness of the systematic component of monetary policy in the model at hand. This is done by showing that an increase in the coefficient attached to the inflation term in the policy rule,  $\mu_1$ , results in a substantial reduction in the variability of inflation in the dynamic system consisting of the model and the policy rule. In the first row of cells of Table 2, we see that increasing  $\mu_1$  from 0.5 to 5.0 reduces the standard deviation of quarterly inflation rates, measured in annualized percentages, from 2.62 to 1.57. A further increase in  $\mu_1$  to 50 further reduces inflation variability, whereas reductions in  $\mu_1$  lead to increases, as can readily be seen. Over much of the range an increase in  $\mu_1$  also reduces the variability of the output gap,  $\tilde{y}_t$ , but for very large values of  $\mu_1$  additional increases serve to increase the variability of the

gap. Also in the first row (of cells), we see that increases in  $\mu_1$  decrease the variability of the interest rate instrument,  $R_t$ , when  $\mu_1$  is small but sharply increase its variability when  $\mu_1$  is large. Throughout this baseline case, the variability of the rate of depreciation of the exchange rate,  $\Delta s_t$ , is highly insensitive to the magnitude of  $\mu_1$ .

In discussions of the monetary transmission mechanism, it is common to find references to various transmission “channels.” In general equilibrium analysis, however, the concept of a transmission channel is rather ambiguous, since the behavior of all variables is interrelated and a change in a single parameter may affect several marginal conditions. One way of coping with this ambiguity, while retaining some of the flavor of the channel concept, is to consider the effects of major changes in crucial structural parameters. For our first such comparison of that type, suppose that the magnitude of  $\gamma$ , which would be the intertemporal elasticity of substitution in the absence of habit effects in consumption, was reduced by a factor of 100 thereby sharply reducing the sensitivity of consumption spending to changes in the real rate of interest. The results of this change in specification can be found in the second row of Table 2. There we see that the stabilizing power of monetary policy for a given set of policy parameters is greatly reduced, with the standard deviation of inflation almost doubling for the case with  $\mu_1 = 0.5$ .<sup>18</sup> The stabilizing power of monetary policy is not eliminated, however, and in fact the sensitivity of inflation variability to the parameter  $\mu_1$  is greater than in the baseline case, as can be seen by looking across columns (in rows 1 and 2). To achieve a given level of stabilization, however, much larger fluctuations in interest rates must be accepted.

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<sup>18</sup> There is a small reduction in output gap variability, but not enough to invalidate the text’s statement.

How is it that the interest rate rule (9) for monetary stabilization works as well as it does, with the slope of the IS function (with respect to the interest rate) reduced to  $1/100^{\text{th}}$  of its baseline value? The answer is provided by the foreign trade “channel.” An altered interest rate has little influence on consumption, but via the UIP relationship has its normal effect on the nominal and real exchange rates. Thus a monetary policy response that raises  $R_t$  brings about a quick appreciation of the real exchange rate. This reduces the quantity of home goods demanded abroad and thereby reduces total demand for home-country goods. Accordingly, a tightening of monetary policy in response to (say) an above-average inflation rate leads to a reduction in aggregate demand, even though there is almost no interest rate effect on consumption demand.

In the third row of Table 2 we suppress instead this foreign trade effect, by reducing the average level of export and import quantities, relative to domestic production, by a factor of 100. This change reduces the effectiveness of monetary policy, though not by as much as the change in row 2. In row 4, however, we include both of these alterations, each of which tends to reduce the effectiveness of monetary policy via one channel. Here we see that the combined effect is very large. The standard deviation of inflation is nine times as large as in the case with  $\mu_1 = 0.5$ , and the variability of the output gap is also greater (by over 50 percent). To reduce the standard deviations of the inflation and gap variables to something close to their baseline values (as in the final column) requires an extreme degree of interest rate variability—about twenty times that of row 1.

Next, in row five we return both the trade share and the interest responsiveness of consumption to their baseline values, and instead decrease the value of the price-adjustment parameter  $\kappa$  to  $1/100^{\text{th}}$  of its baseline magnitude. This change reduces the extent to which the

output gap affects price changes. It has only a moderate effect on the effectiveness of monetary policy with small values of  $\mu_1$ , 0.5 and below, but leads to extremely poor macro behavior (in terms of output gap and interest rate variability) if  $\mu_1$  is large. In terms of old-fashioned concepts of aggregate demand and supply, one would say that this change does not effect the transmission of monetary policy to aggregate demand, but makes inflation highly unresponsive to changes in aggregate demand, so that inflation stabilization requires a great deal of output-gap variability.

The opposite modification is explored in row six of Table 1, where  $\kappa$  is increased to 100 times its baseline value. This is a change toward full price flexibility, i.e., the absence of price level stickiness. Resulting values of the standard deviation of the output gap are accordingly small, but the variability of inflation becomes very large.

## **6. Two Policy Issues**

Perhaps the most fundamental purpose of a model such as that developed above is to examine the predicted consequences of alternative policy strategies. In that regard, one of the main issues in monetary policy concerns the role of the (nominal) exchange rate. Should, for example, a nation adopt a fixed exchange rate? The first thing to be said about such a policy is that it implies that monetary policy be directed primarily at maintenance of the exchange rate rather than at control of inflation (and, to some limited extent, the output gap). In terms of our analytical framework, for example, a fixed exchange rate would be expressed in terms of a policy rule that added  $s_t - s^*$  on the right side, with a very large coefficient attached to this variable.<sup>19</sup> Instead of policy rule (9), for example, we might have

$$(9') \quad R_t = (1-\mu_3) [\mu_0 + \Delta p_t + \mu_1 (\Delta p_t - \pi^*) + \mu_2 \tilde{y}_t + \mu_4 (s_t - s^*)] + \mu_3 R_{t-1} + e_t,$$

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<sup>19</sup> Here we are taking  $s^*$  to be the target value of the log of the exchange rate  $s_t$ .

with  $\mu_4$  large in relation to  $\mu_1$ ,  $\mu_2$ , and  $\mu_3$ . That formulation suggests that monetary policy continues to be conducted by operations in the money market; if instead operations were carried out in the foreign exchange market one would replace (9) with a rule specifying period-by-period settings for  $s_t$  or  $\Delta s_t$ . To obtain an impression of some of the consequences of such a monetary policy, let us use (9') as our model's policy rule and conduct simulations with various values of  $\mu_4$ . Results are shown in Table 3. In all cases, the other  $\mu$  parameters are kept at their baseline values. The first column gives baseline results, with  $\mu_4 = 0$ , from Table 2. From the values in the first row (of cells), we see that progressively stronger responses to departures of  $s_t$  from its target (i.e., par) value bring about progressively larger variability measures for inflation and the output gap. Also, interest rate variability rises quite sharply. In the second row, the same type of results are reported for a specification in which it is the rate of exchange rate depreciation, not the level of the exchange rate, that is stabilized. In both cases the standard deviation of  $\Delta s_t$  is reduced sharply as  $\mu_4$  is increased, as can be seen from the fourth entry of the various cells. The (log) level of the exchange rate,  $s_t$ , is also effectively stabilized. The standard deviation values for the final three columns in the first row are 12.40, 4.29, and 0.75, respectively.

In Table 3, the quantitative extent of the increases in inflation and output gap variability is not extremely large. It is important to keep in mind, accordingly, that the type of experiment being considered is one in which there is no inconsistency whatsoever between the inflation target and the exchange rate target. Thus, a constant exchange rate entails an inflation target equal to the average rate of appreciation of the real exchange rate. If these do not agree, then either the exchange rate target or the inflation target must be sacrificed. In practice, such situations often lead to attempts to manage one or the other of these nominal

variables by means of direct controls. Such attempts create market distortions that are often more deleterious than the target misses would be.

One additional policy experiment concerns a topic that I believe to be of considerable importance for central bank policy making. It involves the fact that actual central banks do not have at their disposal reliable measures of “potential” output, and thus the output gap. I have argued before (e.g., McCallum, 2001b) that the problem is more serious than suggested by the term “measurement error.” Rather than reflecting merely a lack of current information, the problem is essentially conceptual in nature, stemming from the existence of various concepts of the relevant reference value (the “potential” or “capacity” or “natural rate” or “NAIRU” or “market-clearing” or “flexible price” or “trend” rate) of output. Since reliance on any particular concept will persist over time, mistakes will not have the trivial dynamic properties of pure noise.

The most common concept in actual use, I would conjecture, is some trend rate of output. But the concept relevant to the price adjustment equation, according to recent theoretical analysis, is the flexible-price concept. Accordingly, I have made calculations representing an analytical experiment to determine the consequences of such a mistake. As explained in McCallum (2001b), the appropriate analytic procedure is to use  $E_{t-1}y_t$  in the policy rule instead of  $E_{t-1}\tilde{y}_t$ . The results are reported in Table 4, under the assumption that  $\mu_1 = 0.5$  and  $\mu_3 = 0.8$  throughout, with various values considered for  $\mu_2$ , the coefficient on the mis-identified output gap measure. There it is apparent that there are no serious consequences for small values of  $\mu_2$ , but if the latter is set at 5 the variability of inflation and the interest rate instrument become very large—and with  $\mu_2 = 50$  the outcomes are disastrous. The conclusion that I draw from this exercise is that it would be very unwise to

respond strongly to measures of the output gap, a conclusion that agrees with that developed along different lines by Orphanides (2002, 2003).

## **6. Conclusion**

It may be useful to conclude with a brief summary of the paper's arguments and results. It begins by considering concepts of the monetary policy transmission process and adopting one that pertains to effects on both real and nominal variables and emphasizes the regular, systematic component of monetary policy. Emphasis on the systematic portion of policy behavior, rather than on policy shocks, is appropriate basically because shocks evidently account for a very small fraction of monetary policy instrument variability in industrial economies. It follows that policy analysis needs to be based on structural models, rather than VAR systems, because the latter do not give rise to behavioral relationships that can plausibly be regarded as policy invariant. Accordingly, a particular open-economy model, based on that of McCallum and Nelson (1999a, 2000) and designed to be structural, is outlined and calibrated for illustrative analysis.

In general equilibrium analysis the concept of a monetary policy transmission channel is somewhat ambiguous, but simulation exercises can nevertheless be designed so as to retain some of the flavor of the channel concept. The procedure is to focus on a particular channel by altering hypothetically the magnitude of some structural parameter crucial to that channel by a very large extent and observing the effects on the model's properties. For example, reducing the slope of the model's "IS" function (with respect to the real interest rate) by a factor of 100 nearly eliminates the "interest rate channel" and makes inflation control substantially less effective. Several such exercises are conducted and the results are examined. In addition, two policy issues of basic importance are considered. One of these

concerns the effects on inflation and output-gap variability of a monetary policy that is directed primarily at maintenance of a fixed exchange rate, rather than at the control of inflation. The other involves the fact that actual central banks do not have reliable measures—or even agreed-upon concepts—of potential output. Both of these are of central importance for monetary policy makers.

**Table 1****Properties of Baseline Model and Actual Economies**

	Basic model	United States <sup>a</sup> 1955.1- 1996.4	Euro area <sup>c</sup> 1980.1- 2002.4	Japan <sup>d</sup> 1972.1- 1998.4	U.K <sup>e</sup> 1972.1- 2001.4
SD of $\Delta p_t$	2.62	2.41	1.44	4.83	6.8
SD of $\tilde{y}_t$	2.09	2.23	0.83	3.49	2.3
SD of $R_t$	2.33	2.80	1.63	3.13	3.1
SD of $\Delta s_t$	18.90	12.48 <sup>b</sup>	19.28 <sup>e,f</sup>	17.96 <sup>e,f</sup>	14.6
1st autocorr $\Delta p_t$	0.81	0.87	0.66	0.81	0.74
1st autocorr $\tilde{y}_t$	0.67*	0.97	0.82	0.90	0.90
1st autocorr $R_t$	0.90	0.96	0.94	0.95	0.93
1st autocorr $\Delta s_t$	-0.22	0.24 <sup>e,f</sup>	0.31 <sup>e,f</sup>	0.30 <sup>e,f</sup>	0.17

Entries are standard deviations (in annualized percentage points) or autocorrelations for quarterly observations of indicated variables.

\*The value is 0.80 for a measure comparable to those reported for all economies except that of the United States.

Sources: <sup>a</sup>McCallum (2001a), <sup>b</sup>McCallum and Nelson (2000), <sup>c</sup>Casares (2004), <sup>d</sup>Calculation by author, <sup>e</sup>Calculation by Edward Nelson, <sup>f</sup>Dates 1972.1-2003.4.

**Table 2**  
**Performance Measures with Alternative Transmission Specifications**

Entries in each cell are standard deviations of  $\Delta p_t$ ,  $\tilde{y}_t$ ,  $R_t$ ,  $\Delta S_t$

	$\mu_1 = 0.005$	$\mu_1 = 0.05$	$\mu_1 = 0.5$	$\mu_1 = 5.0$	$\mu_1 = 50.0$
base case	3.91	3.64	2.62	1.57	0.98
	2.43	2.37	2.09	1.66	1.75
	3.01	2.81	2.33	3.17	6.70
	19.27	19.08	18.90	19.11	21.45
$\gamma = 0.005$	9.71	8.63	5.13	1.99	1.04
	2.78	2.62	1.98	1.27	1.55
	8.63	7.93	6.15	6.40	10.34
	20.90	20.62	22.02	27.92	34.61
$\omega_3=0.0015$	4.38	4.07	3.03	1.79	1.11
	2.56	2.49	2.23	1.74	1.65
	3.40	3.21	2.86	4.06	9.42
	19.14	19.16	19.35	21.08	27.84
$\omega_3=0.0015$ and $\gamma=0.005$	54.49	47.31	24.09	9.75	3.64
	3.82	3.75	3.33	2.65	1.83
	52.91	47.63	33.34	47.93	118.89
	56.55	56.56	94.26	212.76	449.98
$\kappa=0.0003$	7.03	6.27	4.72	3.09	1.97
	2.80	2.87	4.50	13.66	38.96
	6.52	5.68	4.51	7.80	35.56
	20.84	20.25	19.22	32.81	123.88
$\kappa = 3.0$	28.84	27.78	22.56	10.60	5.33
	1.53	1.48	1.24	0.69	0.45
	4.71	4.63	4.75	6.32	7.69
	37.39	36.13	31.09	22.90	21.65

In all cases parameters include:  $\mu_2 = 0.5$ ,  $\mu_3 = 0.8$

**Table 3**  
**Performance Measures with Exchange Rate Targets**

Entries in each cell are standard deviations of  $\Delta p_t$ ,  $\tilde{y}_t$ ,  $R_t$ ,  $\Delta s_t$

	$\mu_4 = 0.0$	$\mu_4 = 0.5$	$\mu_4 = 5.0$	$\mu_4 = 50.0$
$s_t$ in rule	2.62	2.68	3.09	3.09
	2.09	2.14	2.45	2.53
	2.33	2.41	5.83	8.48
	18.90	13.29	5.74	1.14
$\Delta s_t$ in rule	2.62	2.36	2.65	3.06
	2.09	2.05	2.30	2.52
	2.33	2.45	7.00	9.00
	18.90	16.96	6.57	0.82

**Table 4**  
**Performance Measures with Incorrect Measure of Potential Output**

Entries in each cell are standard deviations of  $\Delta p_t$ ,  $\tilde{y}_t$ ,  $R_t$ ,  $\Delta s_t$

	$\mu_2 = 0.005$	$\mu_2 = 0.05$	$\mu_2 = 0.5$	$\mu_2 = 5.0$	$\mu_2 = 50$
$E_{t-1}y_t$ in rule	2.65	2.68	2.89	8.46	44.55
	2.19	2.19	2.12	1.99	1.97
	2.22	2.26	2.58	7.97	44.55
	18.98	18.84	19.06	22.10	50.22

Figure 1

Impulse Responses, Basic Model, Shock to Policy Rule

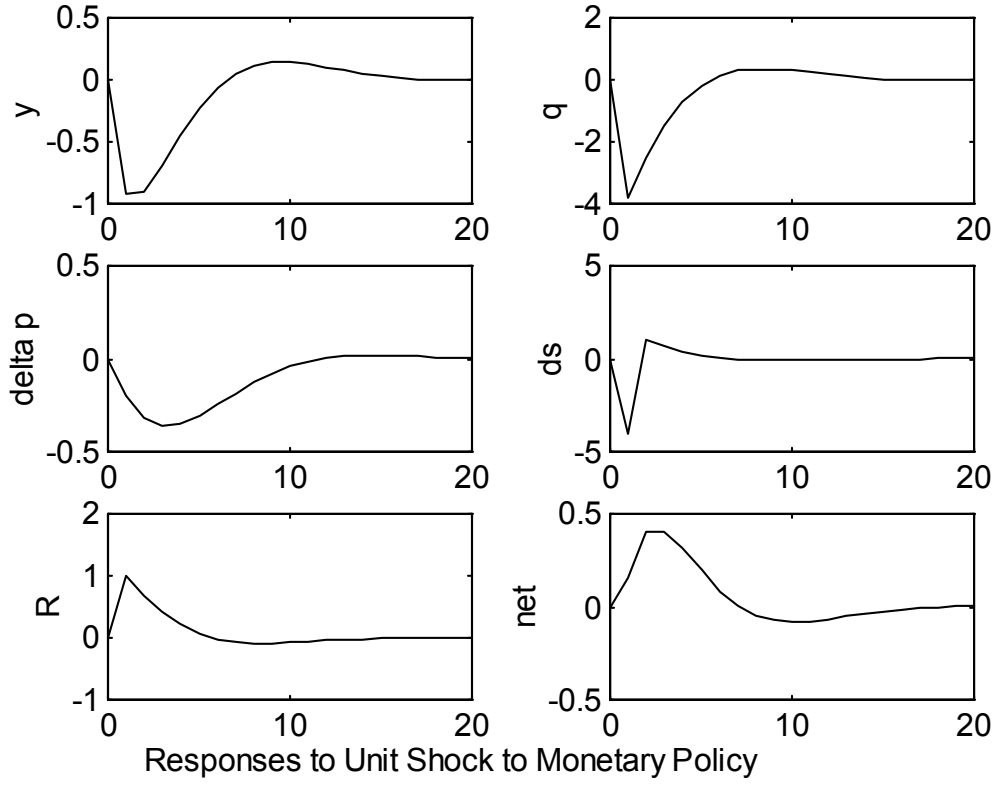
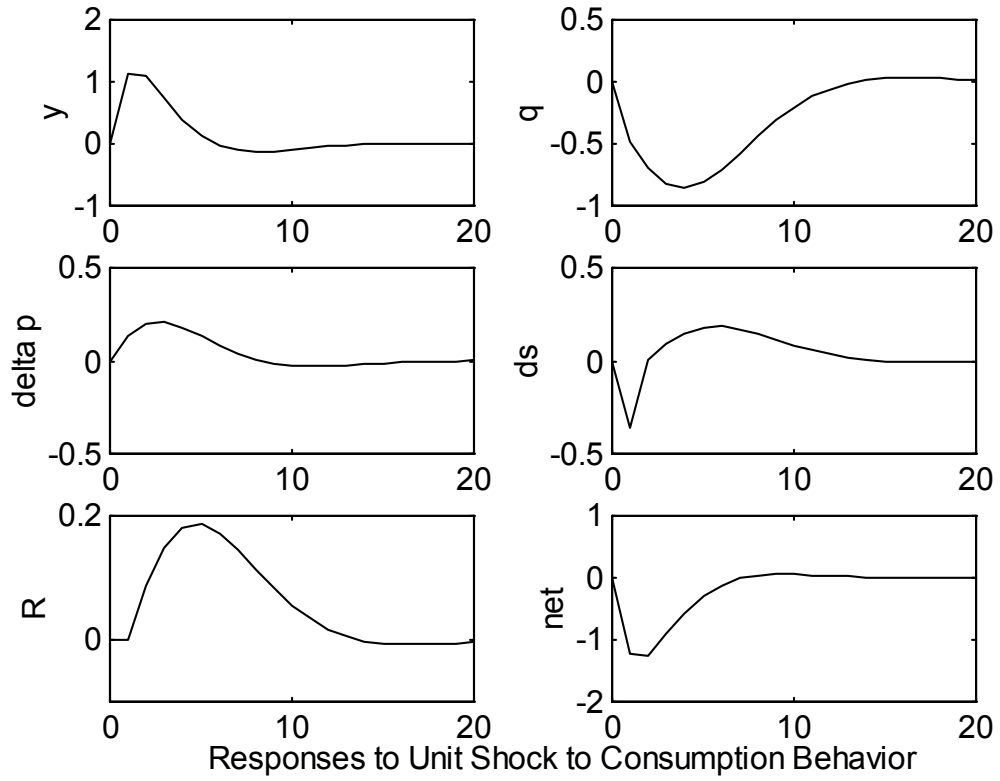


Figure 2

Impulse Responses, Basic Model, Shock to IS Function



**Figure 3**

**Impulse Responses, Basic Model, Shock to Technology**

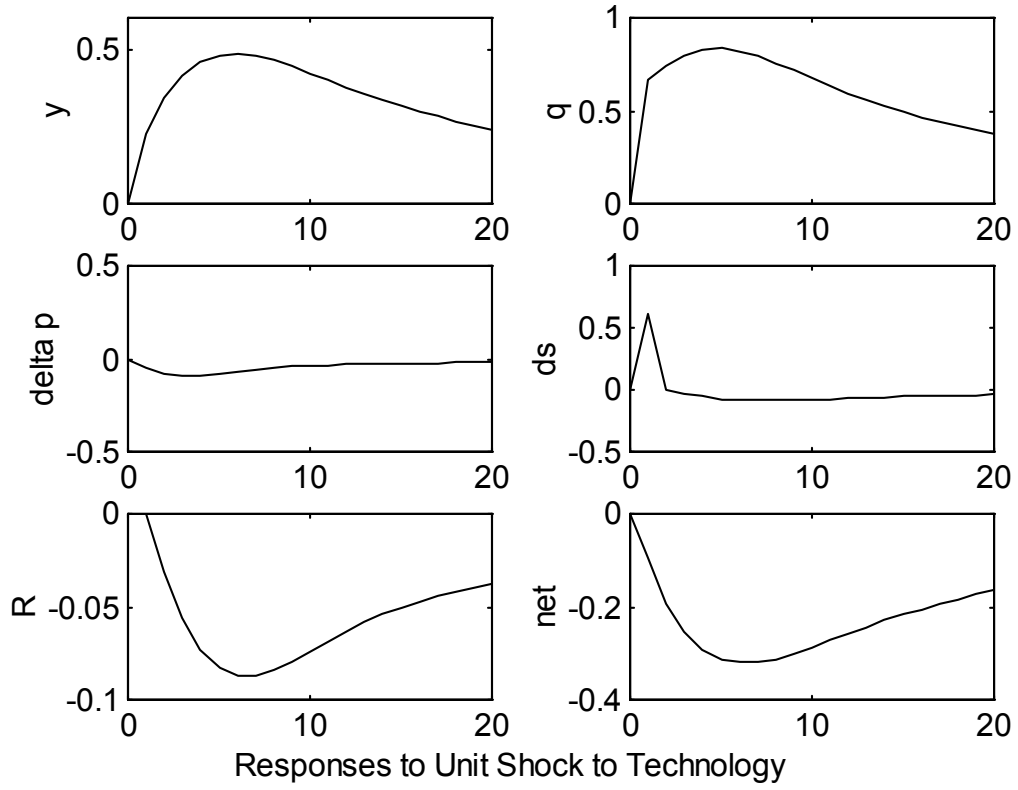
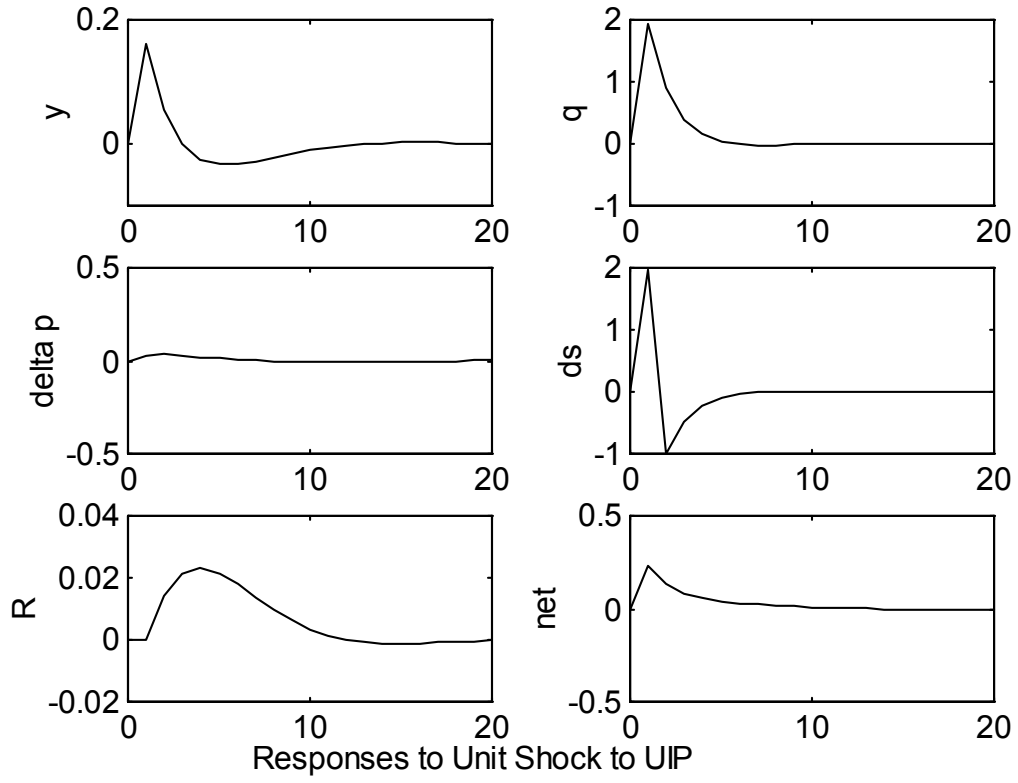


Figure 4

Impulse Responses, Basic Model, Shock to Exchange Rate



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