NBER WORKING PAPER SERIES

MONETARY POLICY FOR AN OPEN ECONOMY:
AN ALTERNATIVE FRAMEWORK WITH OPTIMIZING AGENTS AND STICKY PRICES

Bennett T. McCallum
Edward Nelson

Working Paper 8175
http://www.nber.org/papers/w8175

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
March 2001

We thank Chris Allsopp and David Vines for valuable comments on an earlier draft. The views expressed herein are those of the authors and not necessarily those of the National Bureau of Economic Research, Bank of England or the Monetary Policy Committee.

Monetary Policy for an Open Economy:
An Alternative Framework with Optimizing Agents and Sticky Prices
Bennett T. McCallum and Edward Nelson
NBER Working Paper No. 8175
March 2001
JEL No. E52, E58, F41

ABSTRACT

The "new open-economy macroeconomics" seeks to provide an improved basis for monetary and exchange-rate policy through the construction of open-economy models that feature rational expectations, optimizing agents, and slowly adjusting prices of goods. This paper promotes an alternative approach for constructing such models by treating imports not as finished consumer goods but rather as raw-material inputs to the home economy's productive process. This treatment leads to a clean and simple theoretical structure that has some empirical attractions as well. A particular small-economy model is calibrated and its properties exhibited, primarily by means of impulse response functions. The preferred variant is shown to feature a pattern of correlations between exchange-rate changes and inflation that is more realistic than provided by a more standard specification. Important recent events are interpreted in light of the alternative models.

Bennett T. McCallum
Graduate School of Industrial Administration
Carnegie Mellon University
Pittsburgh, PA 15213
and NBER
Tel: +1 412 268 2347
Email: bm05@andrew.cmu.edu

Edward Nelson
MPC Unit HO-3
Bank of England
Threadneedle Street
London EC2R 8AH
United Kingdom
and Centre for Economic Policy Research
Tel: +44 20 7601 5692
Email: ed.nelson@bankofengland.co.uk

1. Introduction

A major area of research activity in recent years is one that has been called “the new open-economy macroeconomics.”[1] What is meant by this term is research based on dynamic open-economy macro models that feature rational expectations, optimizing agents, and slowly-adjusting prices of goods.[2] Pioneering publications in the area were provided by Obstfeld and Rogoff (1995, 1996), while other notable contributions include Betts and Devereux (1997, 1998), Kollmann (1997, 1999), Gali and Monacelli (1999), Ghironi (1999), Benigno and Benigno (2000), Chari, Kehoe, and McGrattan (2000), Smets and Wouters (2000), and Corsetti and Pesenti (2001).[3]

Despite the impressive volume of work, however, there are actually rather few examples of models in this category that are both truly dynamic and realistically quantitative, i.e., ones that incorporate parameter values estimated from time series data or calibrated in a careful and explicit manner.[4] One objective of the present paper, accordingly, is to provide an accessible description of one such model—originally developed in McCallum and Nelson (1999a)—and to explore the properties of some significant variants. A second purpose, moreover, is to outline and promote a strategy regarding the treatment of imported goods that is analytically simpler than the one typically adopted, is superior empirically in several respects, and, at the same time, has important policy-relevant implications.

In particular, in the model discussed below, imports are treated not as finished consumer goods, as is typical in the literature, but instead as raw-material inputs to the home economy’s productive process. This alternative treatment leads to a cleaner and

---

[1] Much of this literature can be found on the “New Open Economy Macroeconomics Homepage” created by Brian Doyle (http://www.geocities.com/brian_m_doyle/open.html), and the web page on “Monetary Policy Rules in Open Economies,” created and maintained by Gianluca Benigno, Pierpaolo Benigno, and Fabio Ghironi (http://socrates.berkeley.edu/~gbenigno/mpoe.htm). An informative survey is Lane (1999).

[2] In other words, these models feature “sticky prices” of goods and services, rendered plausible by the assumption of monopolistic competition in the sale of individual commodities. Asset prices, on the other hand, are assumed to adjust promptly.

[3] One important precursor is Taylor (1988, 1993a), which includes a large (although incomplete) dose of individual optimization. Another is Svensson and van Wijnbergen (1989). Also, the international real-business-cycle literature (e.g. Backus, Kehoe, and Kydland, 1992) differs mainly in its assumption of full price flexibility.

[4] Such examples do include the papers mentioned in paragraph 1, with the exception of the Obstfeld-Rogoff contributions, which are primarily theoretical, and the one by Corsetti and Pesenti.

simpler theoretical structure, relative to more standard treatments, and is empirically attractive in ways that will be discussed below.

The outline of the paper is as follows. We begin in Section 2 by laying out the basic structure of our model of a small open economy in a fashion that is intended to emphasise its simplicity. A presentation of the properties of various versions of the model appears in Section 3 and an application to exchange rate and inflation dynamics in Section 4. Section 5 considers policy-relevant implications of our approach, and Section 6 concludes.

2 Basic Model

In this section we describe the basic version of our model. Since the optimizing, general equilibrium analysis has already been worked out in McCallum and Nelson (1999a), here we take an informal expository approach.[5] The model's equations can be derived from an infinite-horizon framework in which households choose optimal paths for their consumption and asset holdings, and in which each household produces a good over which it has some market power. It is well known that the household's optimization leads in such a model to a first-order condition for consumption that can be expressed or approximated in the form

$$c_t = \mathrm{E}_t c_{t+1} + b_0 + b_1(R_t - \mathrm{E}_t \Delta p_{t+1}) + v_t. \qquad (1)$$

In equation (1), $b_1 < 0$, 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.[6] R_t is the nominal interest rate on home-country one-period securities (private or government), $\mathrm{E}_t\Delta p_{t+1}$ is the inflation rate expected for next quarter (so $R_t - \mathrm{E}_t\Delta p_{t+1}$ is the short-term real interest rate), and v_t is a stochastic shock term that pertains to household preferences regarding present vs. future consumption. If this shock is serially correlated, then it gives some inertial behavior to the path of consumption over and above that imparted into consumption by the other variables on the right-hand-side of (1). In closed-economy analysis, relation (1) is often combined with a log-linearized, per-household, overall resource constraint to yield an "expectational IS function," to use the term of Kerr and King (1996). This step

---

[5] An appendix that includes technical derivations is available from the authors.

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

presumes that investment and capital are treated as exogenous. The most common version of that assumption is that the capital stock is fixed; since that assumption is rather standard in the new open-economy macro (NOEM) literature, we shall adopt it here.[7]

For our open-economy application, one might be tempted to write the resource constraint as

$$y_t = \omega_1 c_t + \omega_2 g_t + \omega_3 x_t - \omega_4 im_t, \tag{2'}$$

where y_t, g_t, x_t, and im_t are logarithms of real output, government consumption, exports, and imports while ω_1, ω_2, ω_3, and ω_4 are steady state ratios of consumption, government purchases, exports, and imports to output.[8] But if imports are exclusively material inputs to the production of home-country goods, and $Y = \ln^{-1} y$ is interpreted as units of output, then the relevant identity is

$$y_t = \omega_1 c_t + \omega_2 g_t + \omega_3 x_t. \tag{2}$$

This is, of course, the same as (2') with $\omega_4 = 0$. Either of these versions can be thought of as the resource constraint for our model.

We require that import demand be modelled in an optimizing fashion. Toward that end, assume that production of all consumer goods is effected by households that are constrained by a production function of the constant elasticity of substitution (CES) form, with labor and material imports being the two variable inputs. Then the cost- minimizing demand for imports equals

$$im_t = y_t - \sigma q_t + \text{const.}, \tag{3}$$

where σ is the elasticity of substitution between materials and labor in production, and where "const." denotes *some* constant.[9] Also, q_t is the price of imports in terms of

---

[7] Exceptions include Chari, Kehoe, and McGrattan (2000) and Kollmann (1997, 1999). Woodford (2000) shows that the combined behavior of investment and consumption in a closed-economy, dynamic general equilibrium model is well approximated by the consumption equation (1) alone, provided the interest-rate elasticity in (1) is calibrated to take into account the interest sensitivity of investment. Nevertheless, as McKibbin and Vines (2000) stress, an explicit separate treatment of consumption and investment is crucial for analysing certain issues.

[8] As resource constraints such as these are log-linear approximations of the linear relationships between the corresponding unlogged variables, they can also be regarded as describing the percentage deviations of these unlogged variables from their steady-state values. So (e.g.) y_t can be thought of as the percentage deviation of detrended output (Y_t) from its steady-state level. Under the log interpretation, constant terms should be included.

[9] Thus the expressions "const." in different equations appearing below will typically refer to different constant magnitudes.

consumption goods. In other words, $Q_t = \ln^{-1} q_t$ is 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 imports. Then if p_t, s_t, and p_t^* are logs of these variables, we have

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

Symmetrically, we assume that export demand is given as

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

where y_t^* denotes production abroad and σ^* is the elasticity of substitution in production abroad.

Let us 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

$$y_t = (1-\alpha)a_t + (1-\alpha)n_t + \alpha\, im_t + \text{const.},$$

where n_t and a_t are logs of labor input and a labor-augmenting technology shock term, respectively. We suppose for simplicity that households supply labor inelastically, with each supplying one unit per period. Thus, under price flexibility, we would have $n_t = 0$ and the flexible-price, natural rate (or "capacity") value of y_t will be

$$\bar{y}_t = (1-\alpha)\, a_t + \alpha\, [\,\bar{y}_t + \sigma q_t] + \text{const.},$$

or

$$\bar{y}_t = a_t - [\sigma\alpha/(1-\alpha)]\, q_t + \text{const.} \qquad (6)$$

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. An appreciation of the real exchange rate causes a change in the cost-minimizing mix of factor inputs, leading to a larger quantity of imports employed in production, and also to an increase in potential output. 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 im_t given by (3).

In such a setting, the precise way in which prices adjust has a direct impact on demand, in a manner to be detailed shortly, and consequently on production. There are various models of gradual price adjustment utilised in the recent literature that are intended to represent optimizing behavior.[10] In our analysis below we shall explore two candidates; for present purposes we need to list one representative.[11] Principally because it is the most popular model of price setting in current work with general equilibrium models (e.g. Roberts, 1995; Rotemberg and Woodford, 1997), we use the Calvo (1983) model, here expressed in the form

$$\Delta p_t = \beta E_t \Delta p_{t+1} + \lambda(y_t - \bar{y}_t), \tag{7}$$

where $0 < \beta < 1$ is a discount factor, and $\lambda > 0$. A standard feature of most current open-economy models is a relation implying uncovered interest parity (UIP). Despite its prominent empirical weaknesses, accordingly, we adopt one here:

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

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

It remains to describe how monetary policy is conducted. In the spirit of most recent research in monetary economics, we presume that the monetary authority conducts policy in a manner suggested by the Taylor (1993b) rule, i.e., by adjusting a one-period nominal interest rate in response to prevailing (or forecasted future) values of inflation and the output gap, $\tilde{y}_t = y_t - \bar{y}_t$:

$$R_t = \mu_0 + \Delta p_t + \mu_1 (\Delta p_t - \pi^*) + \mu_2 \tilde{y}_t + e_{Rt}, \tag{9}$$

where π^* is the monetary authority's inflation target. Our quantitative results in Section 3 and 4 will be based on an estimated variant of this rule.

Thus we have a simple log-linear system in which the nine structural relations (1)–(9) determine values for the endogenous variables y_t, $\bar{y}_t$, Δp_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 as exogenous—as are the shock processes for v_t, u_t, e_{Rt}, and ξ_t. We suggest that this is probably the simplest and cleanest model extant that includes the essential NOEM features.

---

[10] See McCallum and Nelson (1999b).

[11] In our previous open-economy work, we used a third variant—the "P-bar" model—which is briefly discussed in McCallum and Nelson (1999b).

Of course, it would be possible to append a money demand function such as

$$m_t - p_t = \gamma_0 + \gamma_1 y_t + \gamma_2 R_t + \eta_t, \tag{10}$$

and one of this general form—perhaps with c_t replacing y_t—would be consistent with optimizing behavior.[12] 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, it is possible to calculate the (log of the) balance on goods and services account as

$$net_t = x_t - (im_t + q_t), \tag{11}$$

where it is assumed that the steady state trade balance is zero ($\omega_3 = \omega_4$). Also, we can calculate the log of the GDP deflator as

$$p_t^{DEF} = [p_t - \omega_3(s_t + p_t^*)]/(1 - \omega_3). \tag{12}$$

These represent extra features, however, that need not be included with the basic model (1)–(9).

Most open-economy macro models treat imports as finished consumer goods.[13] Here, by contrast, we treat all imports as material inputs to the production process for domestically produced goods.[14] An advantage of this modelling strategy is that the relevant price index for produced goods is the same as the consumer price index (CPI), 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 dichotomisation, that export and import goods are perfectly substitutable in production. Furthermore, in an extended version of this paper (available on request) we argue that the evidence suggests that (under conservative assumptions) productive inputs actually comprise a larger fraction of U.S. imports than do consumer goods (including services).[15] Thus, the emphasis in our model on imports' role as raw materials appears reasonable.

---

[12] See McCallum and Nelson (1999b).

[13] An alternative, used by Obstfeld and Rogoff (1995), is to specify that imports are not physically different form goods produced in the economy under study. More common is to assume that the consumption good in each country (or more precisely its Dixit-Stiglitz aggregate) is distinct.

[14] Weale *et al* (1989) is an early example of work that incorporated imported intermediate goods into a forward-looking structural model.

[15] For a very brief summary of the results, see McCallum (2000), which includes a model presentation similar to that in this section.

3 Model Properties

In this section we present impulse response analysis for our model. The calibration of the model (hereafter referred to as the MN model) is given in Table 1, and closely follows our (1999a) paper.[16] For the policy rule, instead of (9), we use the following:

$$4^*R_t = 0.23\mathrm{E}_{t-1}\, 4^*(\Delta y_t + \Delta p_t - \pi^*) + 0.81\; 4^*R_{t-1} + e_{Rt} \qquad (9')$$

We found that this specification better described US monetary policy behavior over 1979–1997, using quarterly data, than did a Taylor-type rule.[17] Note that expectations based on period $t-1$ information are used in place of current variables on the right hand side of (9'), in order to reflect operationality—i.e., data actually available to the central bank.

Table 2 reports the standard deviations of four key variables in the model: the annualized nominal interest rate and inflation rate (4^*R_t and $4^*\Delta p_t$), the quarterly change in the nominal exchange rate (Δs_t), and the level of output (y_t). Also reported are the corresponding statistics from US data for 1973–1998 (with the output variable measured by detrended log GDP). The data and model standard deviations are reasonably close, with the exception of that for Δs_t, which is excessive in the model. However, for a realistic setting of the shock variances, the variability of Δs_t tends to be lower in our model than it is in standard NOEM setups (such as the Gali-Monacelli model, studied in Section 4).

To provide information concerning the model's dynamic properties, we now present impulse response functions for various shocks—beginning with a surprise 100 basis point increase in interest rates (a temporary, unit impulse to the e_{Rt} shock term in policy rule (9')). Figure 1 plots the responses of y_t, Δp_t, R_t, q_t, s_t, and net exports (net_t) to the policy shock. In the top-left panel it is seen that a one percentage point upward shock to the interest rate drives output down by about 0.3%, with the largest response coming

---

[16] The main exception is that we have used the basic consumption equation (1), and calibrated it according to our (1999b) estimates. In McCallum and Nelson (1999a) we instead used Fuhrer's (2000) more general consumption equation that allowed for habit formation in preferences.

[17] Rules like (9'), which essentially target nominal GDP growth, may also have some advantages over Taylor-type rules if there is considerable error in measuring potential output, and therefore the output gap term in the Taylor rule. On this, see McCallum (1999), Orphanides (1999), and our (1999a, 1999b) papers.

Table 1: Calibration

Preference parameters	*Shock processes*
$b_1 = -0.2$	ρ_a (AR(1) of technology shock) = 0.95
$\beta = 0.99$	ρ_v (AR(1) of IS shock) = 0.30
	ρ_{y^*} (AR(1) of foreign output) = 1.0
Production parameters	ρ_κ (AR(1) of UIP shock) = 0.50
$\theta = 6$	
$\sigma = 0.333$	*Innovation variances*
Other parameters	$\sigma_{ea}^2 = (0.007)^2$
$\omega_1 = 0.89$, $\omega_2 = 0$, $\omega_3 = \omega_4 = 0.11$	$\sigma_{ey}^{*2} = (0.02)^2$
$\sigma^* = 0.333$	$\sigma_{ev}^2 = (0.01)^2$
$\lambda = 0.086$	$\sigma_{e\kappa}^2 = (0.04)^2$

Table 2: Model statistics

	Standard deviations of:			
	4^*R_t	$4^*\Delta p_t$	Δs_t	y_t
MN model	2.45	3.00	10.04	2.30
US data 1973 Q1–1998 Q4	3.28	3.43	3.12	2.65

Note: Model statistics are averages across 100 model simulations. The simulations use a policy shock standard deviation of 0.8% (annualized). In the data, R_t is the federal funds rate, p_t and s_t are measured as in Section 4 below, and y_t is measured by linearly detrended log real GDP.

in the period of the shock and then dying out quite slowly. Inflation drops in the period of the shock and returns to its initial value at much the same rate as output—a characteristic of the Calvo model of price setting. Both the real and the nominal exchange rate appreciate promptly in response to the monetary tightening. As time passes, the real exchange rate returns to its original value but there is a permanent nominal appreciation. Finally, the fall in income and the decrease in the real price of imports outweigh the price effect on import and export quantities, leading to an expansion in net exports. This is the direction of change that one expects from a monetary policy tightening, but the magnitude and timing seem questionable. That observation leads us to note that our (1999a) value for σ^*, the price elasticity of export demand, is only 0.333. Since that is also the price elasticity of import demand, the

Marshall-Lerner condition is not satisfied. Accordingly, we now assume that $\sigma^* = 1.0$, which leads to satisfaction of the Marshall-Lerner condition. Impulse response functions for a policy shock with this altered value are shown in Figure 2. There the net export balance does undergo a fall, while the responses of other variables are altered very little. For the rest of this section, this revised value for σ^* is utilized.

Figures 3 and 4 report impulse response functions for shocks to the UIP relation and to income/production abroad. In the former, we see that an "exchange rate shock"—a depreciation—leads to a temporary net-export boost, to a small but prolonged expansion in output, and to a brief rise in inflation. In the latter, an increase in demand from abroad—which is highly persistent—generates long-lasting increases in output and net exports and small but prolonged real exchange rate depreciation.

A major weakness apparent in Figures 1–4 is that there is not much persistence in inflation in response to any of these shocks. Accordingly, since the data for the US and other countries exhibit strongly persistent inflation, we would like to modify our model in a manner that will overcome this failure. The most straightforward way of doing so is to adopt a different model of gradual price adjustment, one that tends to impart inertia. We do so in Section 4, where we present some results based on a price-setting specification that is close to that of Fuhrer and Moore (1995).

4 Application: Dynamics of Nominal Variables

In this section we present an application of our model that illustrates some advantages—both in terms of its simplicity and empirical performance—of our open-economy approach over alternative, more standard NOEM models. The empirical regularity that we concentrate upon is the dynamics of two key nominal variables—inflation and the nominal exchange rate. The different treatment of imports in our model leads to a better match with the empirical evidence.

The "standard" NOEM model that we use as a benchmark with which to compare the MN model is that of Gali and Monacelli (GM) (1999) which, like our model, is "small open economy" in nature. A log-linearized version of the GM model is:

$$y_t = (1-\alpha_m)c_t + \alpha_m c_t^* + \alpha_m\chi(2-\alpha_m)tt_t \qquad (13)$$

$$tt_t = R_t - E_t\Delta p_{t+1}^H + E_t tt_{t+1} + \kappa_t \qquad (14)$$

$$c_t = \mathrm{E}_t c_{t+1} + b_1(R_t - \mathrm{E}_t \Delta p_{t+1}) + v_t \tag{15}$$

$$\Delta p_t^H = \beta \mathrm{E}_t \Delta p_{t+1}^H + \lambda mc_t \tag{16}$$

$$mc_t = [(1/\sigma) + (1-\alpha_m)]c_t + \alpha\phi y_t^* + \alpha[1+\phi\chi(2-\alpha)]tt_t - (1+\phi)a_t - (1/(\sigma(1-\rho_v))v_t \tag{17}$$

$$q_t = (1-\alpha_m)tt_t \tag{18}$$

$$\Delta p_t = \Delta p_t^H + \alpha_m(tt_t - tt_{t-1}) \tag{19}$$

$$\Delta s_t = \Delta q_t + \Delta p_t \tag{20}$$

Here c_t^*, y_t^*, tt_t, and mc_t are the log-deviations of rest-of-world consumption, rest-of-world output, the terms of trade, and real marginal cost from their steady-state values, and Δp_t^H is the log-change in the nominal price of domestically produced goods. Foreign prices and interest rates are assumed constant.

The version of the MN model that we use for comparisons consists of six structural equations: the consumption condition (1), the Calvo pricing equation (7), the definition of potential output (6), UIP condition (8), identity (20), and the following analogue to equation (13),

$$y_t = \omega_1 c_t + (1 - \omega_1)\eta q_t + (1 - \omega_1)b y_t^*, \tag{21}$$

which can be obtained by substituting the export demand function (5) into our resource constraint (2). Both the GM and the MN model would be completed by a monetary policy rule and specification of the four shock processes.

The GM model has a strong claim to be viewed as a canonical NOEM model, owing to its elegance and tractability. The model can be expressed as a compact log-linear system and is also sufficiently dynamic to allow some comparisons with data.[18] Even so, inspection of the model's equations indicate that it is noticeably more complicated than the MN model. Because imports enter as final goods in the GM model, the model's assumptions about price stickiness refer to the price of domestically produced goods, rather than the overall consumer price index. Therefore, the Calvo price setting equation links domestic-goods inflation Δp_t^H to real marginal costs (equation (16)), and equation (19) is required to obtain an expression for aggregate CPI inflation

(Δp_t).[19] By contrast, in our model (as in standard closed-economy models), Calvo price setting can be written directly as an equation linking aggregate CPI inflation to the output gap (equation (7)), with no further equations or substitutions needed. The different setup in the GM model also changes the form in which it is convenient to express certain key equations; hence in the GM model, the UIP condition (equation (14)) is written as a difference equation for the terms of trade rather than for the nominal exchange rate. Overall, the GM model has two more endogenous variables than the MN model (i.e., the GM model requires keeping track of three variables—Δp_t^H, mc_t, and tt_t—that do not appear explicitly in the MN model, while the MN model has to keep track of potential output, which does not appear explicitly in the GM model).

We now present some quantitative comparisons between the GM and MN models. We have made some necessary adjustments to the GM model, as given by Gali and Monacelli (1999), for comparability with our own setup. Thus we have included IS and UIP shocks in the GM model (both specified to follow the same time-series processes as in the MN model). We have also made the technology shock a_t follow the same process as it does in the MN model; set $b_1 = -0.2$, so that the interest sensitivity of consumption in the two models are identical;[20] and made the share of imports in GDP (α_m) the same value (0.11) that it is in the MN model. For simplicity we have made the c_t* process in the GM model identical to the y_t* process in our model. The parameter χ is chosen so that the coefficient on the terms of trade in equation (13) is the same as that on the real exchange rate in equation (21); aggregate demand thus has approximately the same real exchange-rate elasticity in each model.

In comparing the predictions of the GM and MN models, we focus upon the transmission of exchange rate changes to inflation—i.e., the extent to which each model supports the position that nominal exchange rate depreciations lead to increases in the

---

[18] Indeed, we have selected this particular model for comparison purposes in part because it follows a clear and convenient log-linear structure that is easy to reproduce from the Gali-Monacelli paper.

[19] Equation (16) can be derived from optimal behavior by monopolistically competitive producers in an environment of staggered contracts for prices of domestically produced goods. As for equation (7), we assume $\lambda = 0.086$, the same value used by GM.

[20] We keep GM's choice of $\phi = 1.0$ for their model, which makes households' desired labor supply elastic.

home economy's CPI inflation rate.[21] In this regard, it is useful to consider the effects of risk premium (UIP) shocks specifically—since these shocks affect variables other than the nominal exchange rate (s_t) only via their effect on s_t. But, as the exchange rate may act as a conduit through which other shocks (such as policy shocks) are transmitted to inflation, the discussion below would apply also to exchange rate changes produced by those shocks.

In our model, a change in s_t produced by a risk premium shock will affect inflation solely through its effect on the output gap $y_t - \bar{y}_t$. A depreciation (i.e., a rise in s_t—and, in the absence of complete price flexibility, in q_t as well) tends to raise $y_t - \bar{y}_t$ for two reasons: higher y_t due to higher export demand from the depreciation; and the negative effect of real depreciations on potential output $\bar{y}_t$. Of these effects, the export demand effect on y_t is common to both our model and the standard model; therefore, it cannot account for different properties of the two models, so we focus instead on the channel from depreciations to $\bar{y}_t$. For a given technology shock, a depreciation raises the cost of producing domestic goods in the MN specification and therefore reduces potential output (equation (6)), which will raise the inflation rate for the period during which the excess of output over potential persists.

In the GM model, by contrast, import prices directly enter the CPI (equation (19)), and therefore the exchange rate depreciation produced by a UIP shock affects inflation "directly," not just via the output gap.

The different transmission of exchange-rate changes to inflation in the two models reflects the differing ways in which each treats a long-standing tension in macroeconomics, namely the role of relative prices (such as the exchange rate) in aggregate price level analysis. That relative price changes need not imply aggregate price level changes, in the absence of monetary accommodation, was stressed by early quantity theorists, including Wicksell (1906, p. 156). As Milton Friedman (1974) famously observed, with regard to other relative price changes,

---

[21] From a strict point of view, we consider it incoherent to refer to "effects of exchange-rate changes on inflation" because exchange rates are endogenous variables, whose relationships with other variables are different for different shocks. But averages of these relationships are implied by any complete calibration. And we believe that the type of consideration at hand appears so often in professional and journalistic writings that it needs to be explicitly addressed and analysed.

> "The special conditions that drove up the price of oil and food required purchasers to spend more on them, leaving them less to spend on other items. Did that not force other prices to go down or to rise less rapidly than otherwise? Why should the *average* level of all prices be affected significantly by changes in the price of some things relative to others?"

Batten and Ott (1983) applied this argument specifically to exchange rate changes, and argued that the proposition that "a depreciating currency generates domestic inflation" was a "myth;" neither the price level nor the inflation rate, they argued, would be raised in the long run by a depreciation unless the depreciation was accompanied by monetary expansion.

Ball and Mankiw (1995) pose the problem in terms of the equation of exchange identity, $MV = PY$: for a given volume of aggregate nominal spending (MV) a rise in the price of a subset of the consumer price index (such as imports in the GM model) can raise the *aggregate* CPI (P) only if it alters the mix of total spending towards higher prices and lower aggregate output (Y).

It is enlightening to consider how the alternative models obtain the property that depreciations can produce inflation, instead of the purely relative price changes sketched by Friedman. In the GM model, the reason is that, under an interest rate policy rule, the depreciation leads to a rise in M_t. Under an interest rate rule, nominal money rises passively[22] to sustain the level of nominal spending consistent with the higher P_t. Households do not then have "less to spend on other items." This setup has the implication that money and monetary growth are closely associated with exchange rate change at the business cycle frequency, which seems unattractive empirically for most industrial countries (see, e.g., Rogoff, 1999).

In our model, exchange rate depreciations, by raising production costs, can be inflationary. But a crucial distinction from the GM and other standard models is that the inflationary impact of depreciations[23] is limited by the extent to which they affect aggregate supply. Their impact is not linked to the weight given to imports in the CPI. In terms of the equation of exchange, depreciations raise P_t in the MN model because they reduce Y_t for a given P_tY_t; while in the GM model, depreciations raise P_t because an endogenous increase in M_t permits P_tY_t to rise. In spirit, though not in detail, our

---

[22] Via a money demand equation like (10).

[23] Apart from the higher export demand due to the depreciation noted earlier.

approach can be considered to be similar to that of Ball and Mankiw's (1995) "Relative Price Changes as Aggregate Supply Shocks."

The different ways in which the alternative models treat the link between nominal exchange rates and inflation lead to different implications for the dynamic relationship between the two variables. We argue that empirically the relationship between nominal exchange rate change and inflation is typically very loose at the business cycle frequency, and that our model—but not the GM model—has no difficulty in reproducing this basic fact. Let us therefore examine the empirical evidence, using *International Financial Statistics* (*IFS*) data on nominal exchange rate and consumer price indices for several industrial countries.[24]

Correlations between Δp_t, the log-difference of consumer prices, and current (Δs_t) and lagged (Δs_{t-k}) changes in the log nominal exchange rate, are reported in Table 3.[25] For most countries, the sample period for calculating the correlations begins in 1973 with the demise of Bretton Woods. For Australia and New Zealand, which did not adopt floating exchange rates against the US or other countries until the mid-1980s, results are also reported for their more recent floating-rate sample period; and for France, Germany, and Italy, results are reported for the subsample commencing with the onset of the European Monetary System in 1979.

The overall impression we receive from Table 3 is the *weakness* of the bivariate correlations, regardless of lag length. A strong association between inflation and nominal exchange rate depreciation would lead to a high positive correlation, but for most countries, this correlation is rather close to zero. Even for those countries for which there is a statistically significant positive correlation—France, Germany, Italy, and New Zealand—the size of the correlation itself tends to be low, always below 0.3 for the full

---

[24] The exchange rate series used is the *IFS* index of the nominal effective exchange rate (quarterly average). The exception is the United States, where we use a main-trading-partners index of the nominal exchange rate downloaded from the Federal Reserve Bank of St Louis' FRED database. (A quarterly series was obtained by averaging the monthly observations of this series, which begins in January 1973). The *IFS* quarterly average of consumer prices is used as the price index for each country. For Germany and the United Kingdom, we found that the resulting inflation series exhibited seasonality, so we obtained a seasonally adjusted series using OLS regression on seasonal dummies. For the computations of the annual results in Table 4 below, we used annual averages of the quarterly series used in Table 3.

[25] These correlations are of more interest than those between inflation and future Δs_t, since the issue we focus upon is what alternative models say about how shocks are transmitted from the exchange rate to

sample. The only prominent exception to the weakness of the correlations is the 0.46 correlation between inflation and the previous quarter's exchange-rate change for Germany for 1979–1998.

A possible objection is that gradual pass-through of exchange-rate changes to inflation might imply that the empirical relationship between inflation and exchange rate depreciations is tighter if lower frequency data are considered. But if we look at annual data for the same countries (Table 4), the weakness of the correlations persists for the majority of the countries. For France, Germany, Italy, and New Zealand, it is true that the correlations are higher than they were on quarterly data. In the French and Italian cases, however, there appears to be a significant correlation between base money growth and nominal exchange rate change.[26] This could mean that the results for those countries in Table 4 are still consistent with the arguments of Friedman (1974) and Batten and Ott (1983) given above; their contention that exchange rate depreciation does not lead to inflation refers to the case where the depreciation is not accompanied or produced by monetary expansion.

The exchange rate is only one channel through which shocks are transmitted to the inflation rate, so the low bivariate correlations reported in Tables 3 and 4 may simply reflect the fact that these other channels (such as the output gap) are not being held constant. But we will show that, although it includes an output gap as well as an exchange rate channel, the GM model implies (for a realistic setting of shocks) a much tighter relationship between exchange-rate changes and inflation than holds empirically.

To investigate this, we now look at the same correlation in the GM model and in our open-economy model. We use a common monetary policy rule for both models, namely rule (9') of Section 3.[27] The policy shock standard deviation is set to 0.8% (annualized), which is the approximate estimated residual standard deviation for that estimated equation.

---

current and future inflation. But consideration of the (Δp_t, Δs_{t+k}) correlations would not overturn our findings.

[26] The correlation for 1979–1998 between Δs_t and the log-difference of currency in circulation is 0.46 for France and 0.41 for Italy.

[27] We have verified that our results in this section are robust to alternative plausible rules, such as those estimated for the US by Clarida, Gali, and Gertler (2000).

Table 3: Nominal Exchange Rate Change / Inflation Correlations, Quarterly Data

		Correlations, Δp_t and Δs_{t-k}				
Country	Sample Period	$k = 0$	$k = 1$	$k = 2$	$k = 3$	$k = 4$
Australia	1973Q1–1998Q4	0.064	0.010	0.036	–0.101	–0.029
Australia	1984Q1–1998Q4	0.026	0.029	–0.024	0.060	–0.029
Canada	1973Q1–1998Q4	–0.031	0.010	–0.074	–0.028	0.004
France	1973Q1–1998Q4	0.225[a]	0.226[a]	0.145	0.157	0.064
France	1979Q2–1998Q4	0.325[a]	0.323[a]	0.254[a]	0.325[a]	0.230[a]
Germany	1973Q1–1998Q4	0.166	0.258[a]	0.115	0.013	0.001
Germany	1979Q2–1998Q4	0.260[a]	0.460[a]	0.284[a]	0.126	0.125
Italy	1973Q1–1998Q4	0.285[a]	0.228[a]	0.235[a]	0.244[a]	0.116
Italy	1979Q2–1998Q4	0.245[a]	0.222[a]	0.229[a]	0.207	0.174
Japan	1973Q1–1998Q4	0.050	0.147	0.106	0.063	–0.010
New Zealand	1973Q1–1998Q4	0.146	0.218[a]	0.150	0.222[a]	0.031
New Zealand	1985Q1–1998Q4	–0.100	0.076	–0.195[a]	0.049	–0.242
United Kingdom	1973Q1–1998Q4	–0.003	0.072	0.075	0.032	–0.043
United States	1973Q2–1998Q4	–0.103	–0.078	0.063	0.064	0.055

a. Significant at 0.05 level.

Table 4: Nominal Exchange Rate Change / Inflation Correlations, Annual Data

		Correlations, Δp_t and Δs_{t-k}		
Country	Sample Period	$k = 0$	$k = 1$	$k = 2$
Australia	1973–1998	0.020	–0.069	–0.075
Australia	1984–1998	–0.191	0.133	0.286
Canada	1973–1998	–0.082	–0.029	0.033
France	1973–1998	0.336	0.142	0.091
France	1979–1998	0.467[a]	0.316	0.281
Germany	1973–1998	0.223	0.062	–0.340
Germany	1979–1998	0.491[a]	0.289	–0.185
Italy	1973–1998	0.398[a]	0.280	0.168
Italy	1979–1998	0.393	0.286	0.269
Japan	1973–1998	0.167	0.103	0.007
New Zealand	1973–1998	0.179	0.306	0.259
New Zealand	1985–1998	–0.125	0.325	0.504
United Kingdom	1973–1998	0.135	0.031	–0.150
United States	1973–1998	–0.140	0.131	0.217

a. Significant at 0.05 level.

We therefore solved and simulated two alternative open-economy specifications, running each under two alternative price-setting specifications. The two price setting specifications used were Calvo and a version of Fuhrer-Moore (FM) (1995). The reason for our use of Fuhrer-Moore as well as Calvo pricing is that the latter has been criticised as implying far too little inertia in inflation dynamics (see Mankiw (2000) for a recent discussion). For the MN model, using the Fuhrer-Moore type price setting instead of Calvo means replacing $\beta E_t \Delta p_{t+1}$ equation (7) with the mixed backward/forward term $\beta[0.5\Delta p_{t-1} + 0.5E_t\Delta p_{t+1}]$, with symmetric weights on lagged and expected future inflation. For the GM model, it involves a corresponding replacement of the $\beta E_t \Delta p^H_{t+1}$ term in (16), leading to

$$\Delta p_t^H = \beta[0.5\Delta p_{t-1}^H + 0.5E_t\Delta p_{t+1}^H] + \lambda mc_t\,, \tag{22}$$

instead of equation (16).

We then calculated the correlations imploed by the models between quarterly inflation (Δp_t) and nominal exchange rate change, Δs_{t-k}. For each model, the results reported in Table 5 are averages of statistics across 100 simulations of 200 observations of artificial data.

Examination of Table 5 indicates that the correlations are sensitive to the choice of price-setting specification, and even more so to the choice of open-economy specification. Specifically, the contemporaneous correlation between Δp_t and Δs_t is strong in the GM model—0.83 when the Calvo price setting is used, 0.70 under FM price setting. The empirical evidence presented in Tables 3 and 4 provided no support for such a tight relationship (at any lag). Our alternative specification, on the other hand, implies a looser—and more realistic—relationship between inflation and exchange rate change. The correlations between the two series (at any lag of Δs_t) tend to be positive but weak; similarly, in the data in Table 3, the maximum correlation between Δp_t and Δs_{t-k} is no higher than 0.33 in 13 out of 14 cases.

Because our model constrains the extent to which inflation is driven by the exchange rate, it is also more successful at generating inflation persistence. This is evident in Figures 5–6, which plot the vector autocorrelation function for $[\Delta s_t\ \Delta p_t]'$ for the GM and MN models. Figure 5 uses Calvo price setting; Figure 6, FM price setting.

Table 5: Nominal Exchange Rate Change / Inflation Correlations, Models

Correlations, Δp_t and Δs_{t-k}										
Price-setting specification: Calvo										
	GM Model					MN Model				
	$k = 0$	$k = 1$	$k = 2$	$k = 3$	$k = 4$	$k = 0$	$k = 1$	$k = 2$	$k = 3$	$k = 4$
	0.83	–0.00	0.01	0.03	0.02	0.21	0.12	0.07	0.05	0.03
Price-setting specification: Fuhrer-Moore										
	GM Model					MN Model				
	$k = 0$	$k = 1$	$k = 2$	$k = 3$	$k = 4$	$k = 0$	$k = 1$	$k = 2$	$k = 3$	$k = 4$
	0.70	0.04	0.10	0.08	0.06	0.07	0.13	0.13	0.12	0.08

In the GM model, Δs_t fluctuations so dominate Δp_t behavior that inertia in domestic goods inflation generally fails to produce inflation persistence. Indeed, the autocorrelations of Δp_t are close to zero in that model, regardless of price setting specification. By contrast, in the MN model, assumptions about gradual price adjustment on the part of domestic price-setters translate directly into assumptions about gradual adjustment of the aggregate consumer price index. As a result, Δp_t exhibits a high degree of persistence, close to that in the data, and does so for both price-setting specifications.

Figures 7 and 8 depict the responses of inflation to a monetary policy shock (an unanticipated 100 basis point increase in R_t) in the GM and MN models. Calvo price setting (Figure 7) tends to produce a strong spike in inflation in the period of the shock. This is not consistent with much empirical evidence from VARs. Of the two open-economy specifications, the GM model produces a much larger—and therefore less plausible—reaction of inflation, because the policy tightening produces a large appreciation that in turn substantially reduces inflation in the model. In Figure 8, FM pricing does produce a gradual response of inflation in the MN model, but not in the GM model. Again, this lack of smoothness reflects the dominance of Δs_t movements for Δp_t behavior in the GM model.[28]

5. Relevance for Policy

The dynamic relationship between exchange rates and inflation implied by the structure of the MN model helps shed light on the experience of some small OECD economies during the East Asian currency crisis of 1997–1998, discussed in more detail in McKibbin and Vines (2000). Australia, Canada, and New Zealand experienced double-digit depreciations of their trade-weighted exchange rates during this period. For a time, the monetary authorities of Canada and New Zealand tightened monetary policy in the belief (which, with hindsight, looks mistaken) that such a move was required to meet their inflation target. In Australia, on the other hand, monetary policy was not tightened. Of the three countries, the monetary policy response in Australia appears to have been the most appropriate, in that it was consistent with continued strong economic growth and maintenance of inflation on target.[29]

In Figure 9, we depict a simple experiment intended as a stylised version of the effect of a shock such as the Asian crisis. We plot the responses of s_t, $4^*\Delta p_t$, y_t and 4^*R_t to a 5% shock to the UIP condition (8) in our model. The UIP shock produces a 10% depreciation of s_t that wears off over time. Annualized inflation $4^*\Delta p_t$ rises by a comparatively modest amount, less than 1 percentage point. The depreciation leads to an export boom and hence a rise in output y_t. The interest rate R_t, which continues to be determined by the policy rule (9'), actually *declines* by around 10 basis points (annualized) in the wake of the shock. The reason is that the temporary rise in the level of output produces anticipations of lower future Δy_t, thus reducing expected nominal income growth, to which monetary policy responds. While the result that R_t declines is special to rule (9'), and would not hold if we had used rules (such as (9)) that respond to current values of inflation or the output gap level, our finding that the exchange rate depreciates by a large amount but inflation rises only moderately is robust to alternative policy rules.

---

[28] Inflation dynamics also look smoother in the MN than in the GM model if we examine impulse response functions for a risk premium (UIP) shock. We focus on the effects of a policy shock because this shock, unlike the UIP shock, is white noise, so impulse response functions more clearly reflect differences in the models' dynamic structure (rather than shock dynamics).

By contrast, the same shock in the GM model leads to a rise in annualized inflation of over 5 percentage points. The responses for the GM model are not reported in Figure 9 because the inflation response in the GM model dwarfs that in the MN model, distorting the scale of the graph.[30] Thus, of the two models, only the MN model can provide an explanation for why an episode such as the Asian crisis can be associated with a sharp depreciation but little rise in either inflation or nominal interest rates. More generally, it appears that our model performs better than the more standard Gali-Monacelli model in terms of matching the dynamic behavior of nominal variables.

A more general point about our model for policy is that its implications regarding the control of inflation in an open economy differ sharply from those of standard NOEM models. In those models, the introduction of open-economy elements radically changes the price-setting behavior in the economy. Because imports are final goods in these models, the Phillips curve states that total consumer price inflation depends not only on the output gap but also on the real exchange rate or the terms of trade. In evaluating the implications of a domestic or foreign shock for inflation, it is insufficient for the monetary authority to consider only the shock's effect on the output gap. Controlling inflation in an open economy thus involves considering channels that arise from the openness of the economy.

By contrast, in our framework, it is useful to think of the implications for inflation of any shock in terms of its effect on the output gap alone. In this sense, our model implies less of a contrast between controlling inflation in an open economy and controlling inflation in a closed economy. The effect of open-economy elements in our model is to increase the variety of shocks in the model that affect the output gap, not to create a separate channel besides the output gap through which monetary policy affects inflation. In general, our model provides little support for inflation-targeting central banks to be driven to large increases in interest rates in the face of even significant exchange rate

---

[29] For discussions of this episode, see (e.g.) Bean (2000, pp. 77–78) and McKibbin and Vines (2000).

[30] The interest rate responses, on the other hand, are not too different in the GM and MN models, provided policy rule (9') is used. They are very different if the Taylor rule (9), which responds to current inflation, is used. As an example, consider rule (9) specialised to the case $\mu_1 = 0.5$, $\mu_2 = 0$ (corresponding to pure inflation targeting). A 5% UIP shock then leads to a rise in annualized inflation of 5% in the GM model and a nominal interest rate increase of 750 basis points (annualized), compared to rises of only 0.5% and 80 basis points, respectively, in the MN model.

depreciations, unless the depreciations are associated with large increases in output above potential.

6 Conclusion

In this paper we have discussed variants of an optimizing open-economy model that we first used in McCallum and Nelson (1999a). Compared to more standard models in the new open economy macroeconomics (NOEM) literature, the model treats imports in a way that offers advantages both in terms of simplicity and empirical performance. The model's dynamic properties as judged by impulse response functions seem quite sensible. Most notably, the model appears to be considerably more realistic regarding inflation dynamics than standard alternatives. This is a crucial property given that NOEM models have been designed primarily for monetary policy analysis.

References

Backus, David K., Patrick J. Kehoe, and Finn E. Kydland (1992). "International Real Business Cycles," *Journal of Political Economy* 100, 745–775.

Ball, Laurence, and N. Gregory Mankiw (1995). "Relative Price Changes as Aggregate Supply Shocks," *Quarterly Journal of Economics* 109, 161–193.

Batten, Dallas S., and Mack Ott (1983). "Five Common Myths about Floating Exchange Rates," *Federal Reserve Bank of St. Louis Review* 65, 5–15.

Bean, Charles (2000). "The Australian Economic "Miracle": A View from the North." In D. Gruen and S. Shrestha (eds.), *The Australian Economy in the 1990s*. Ambassador Press. 73–114.

Benigno, Gianluca, and Pierpaolo Benigno (2000). "Monetary Policy Rules and the Exchange Rate." Manuscript, Bank of England.

Betts, Caroline, and Michael Devereux (1997). "The International Monetary Transmission Mechanism: A Model of Real Exchange Rate Adjustment under Pricing-to-Market." Manuscript, University of British Columbia.

Betts, Caroline, and Michael Devereux (1998). "The International Effects of Monetary and Fiscal Policy in a Two-Country Model." Manuscript, University of British Columbia.

Calvo, Guillermo A. (1983). "Staggered Prices in a Utility-Maximising Framework," *Journal of Monetary Economics* 12, 383–398.

Chari, V.V., Patrick J. Kehoe, and Ellen McGrattan (2000). "Can Sticky-Price Models Generate Volatile and Persistent Real Exchange Rates?." NBER Working Paper No. 7869.

Clarida, Richard, Jordi Gali, and Mark Gertler (2000). "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory," *Quarterly Journal of Economics* 115, 147–180.

Corsetti, Giancarlo, and Paolo Pesenti (2001). "Welfare and Macroeconomic Interdependence," *Quarterly Journal of Economics* 116, forthcoming.

Friedman, Milton (1974). "Perspectives on Inflation," *Newsweek*, June 24. Reprinted in M. Friedman, *There's No Such Thing as a Free Lunch*. Open Court, 1975, 113–115.

Fuhrer, Jeffrey C. (2000). "Habit Formation in Consumption and Its Implications for Monetary-Policy Models," *American Economic Review* 90, 367–390.

Fuhrer, Jeffrey C., and George R. Moore (1995). "Inflation Persistence," *Quarterly Journal of Economics* 109, 127–159.

Gali, Jordi, and Tommaso Monacelli (1999). "Optimal Monetary Policy and Exchange Rate Volatility in a Small Open Economy." Manuscript, Boston College.

Ghironi, Fabio (1999). "Alternative Monetary Rules for a Small Open Economy: The Case of Canada." Manuscript, Federal Reserve Bank of New York.

Kerr, William, and Robert G. King (1996). "Limits on Interest Rate Rules in the IS Model," *Federal Reserve Bank of Richmond Economic Quarterly* 82, 47–75.

Kollmann, Robert (1997). "The Exchange Rate in a Dynamic-Optimizing Current Account Model with Nominal Rigidities: A Quantitative Investigation." Manuscript, IMF.

Kollmann, Robert (1999). “Explaining International Comovements of Output and Asset Returns: The Role of Money and Nominal Rigidities.” Manuscript, IMF.

Lane, Philip (1999). “The New Open Economy Macroeconomics: A Survey.” Manuscript, Trinity College Dublin; *Journal of International Economics*, forthcoming.

Mankiw, N. Gregory (2000). “The Inexorable and Mysterious Trade-Off Between Inflation and Unemployment.” NBER Working Paper No. 7884.

McCallum, Bennett T. (1999). “Issues in the Design of Monetary Policy Rules.” In J.B. Taylor and M. Woodford (eds.), *Handbook of Macroeconomics, Volume 1C*. North Holland. 1483–1530.

McCallum, Bennett T. (2000). “Inflation Targeting and the Liquidity Trap.” Manuscript, Carnegie Mellon University.

McCallum, Bennett T., and Edward Nelson (1999a). “Nominal Income Targeting in an Open-Economy Optimizing Model,” *Journal of Monetary Economics* 43, 553–578.

McCallum, Bennett T., and Edward Nelson (1999b). “Performance of Operational Policy Rules in an Estimated Semi-Classical Structural Model.” In J.B. Taylor (ed.), *Monetary Policy Rules*. University of Chicago Press. 15–45.

McKibbin, Warwick, and David Vines (2000). “The Need for Both Intertemporal Optimization and Stickiness in Real-World Policy Models,” *Oxford Review of Economic Policy* (forthcoming).

Obstfeld, Maurice, and Kenneth Rogoff (1995). “Exchange Rate Dynamics Redux,” *Journal of Political Economy* 103, 624–660.

Obstfeld, Maurice, and Kenneth Rogoff (1996). *Foundations of International Macroeconomics*. Cambridge MA: MIT Press.

Orphanides, Athanasios (1999). "The Quest for Prosperity Without Inflation." Manuscript, Federal Reserve Board.

Roberts, John M. (1995). "New Keynesian Economics and the Phillips Curve," *Journal of Money, Credit, and Banking* 27, 975–984.

Rogoff, Kenneth (1999). "Monetary Models of Dollar/Yen/Euro Nominal Exchange Rates: Dead or Undead?," *Economic Journal* 109, 655–659.

Rotemberg, Julio J. (1982). "Sticky Prices in the United States," *Journal of Political Economy* 90, 1187–1211.

Rotemberg, Julio J., and Michael Woodford (1997). "An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy," *NBER Macroeconomics Annual* 12, 297–346.

Smets, Frank, and Raf Wouters (2000). "Optimal Monetary Policy in an Open Economy: An Application to the Euro Area." Manuscript, European Central Bank.

Svensson, Lars E.O., and Sveder van Wijnbergen (1989). "Excess Capacity, Monopolistic Competition, and International Transmission of Monetary Disturbances," *Economic Journal* 99, 785–805.

Taylor, John B. (1988). "The Treatment of Expectations in Large Multicountry Econometric Models." In R.C. Bryant (ed.), *Empirical Macroeconomics for Interdependent Economies*. Washington, D.C.: Brookings Institution. 161–179.

Taylor, John B. (1993a). *Macroeconomic Policy in a World Economy*. New York: W.W. Norton.

Taylor, John B. (1993b). "Discretion Versus Policy Rules in Practice," *Carnegie-Rochester Series on Public Policy* 39, 195–214.

Weale, Martin, Andrew Blake, N. Christodoulakis, James Meade, and David Vines (1989). *Macroeconomic Policy: Inflation, Wealth and the Exchange Rate*. Unwin Hyman.

Wicksell, Knut (1906). *Lectures on Political Economy, Volume II: Money*. Translated by E. Classen, edited by Lionel Robbins. Routledge, 1935.

Woodford, Michael (2000). "A Neo-Wicksellian Framework for the Analysis of Monetary Policy." Manuscript, Princeton University.

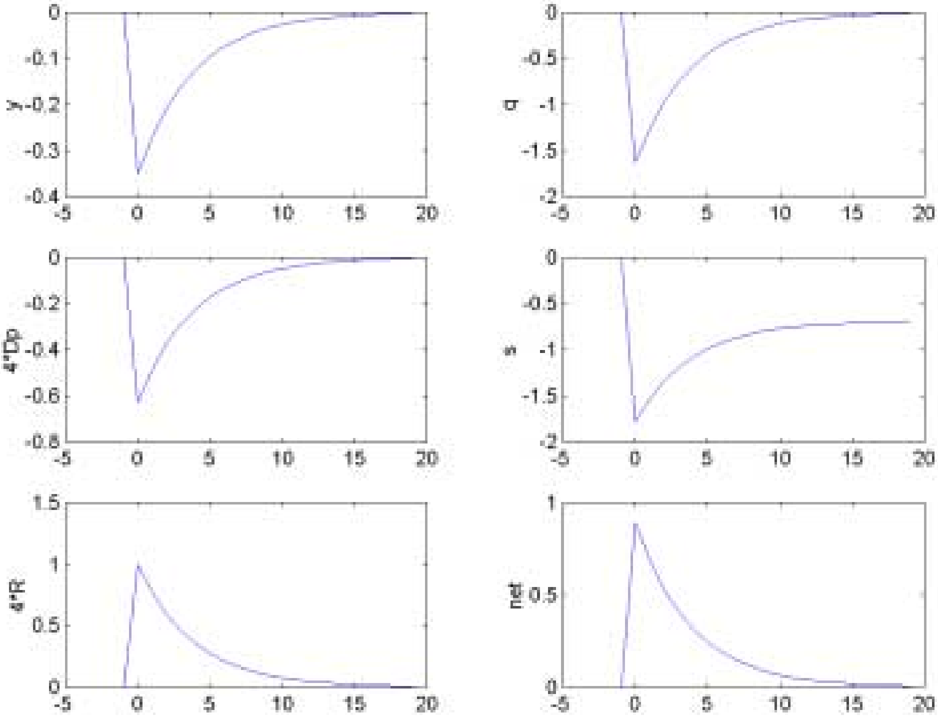

Figure 1: Responses to Unit Shock to Policy Rule

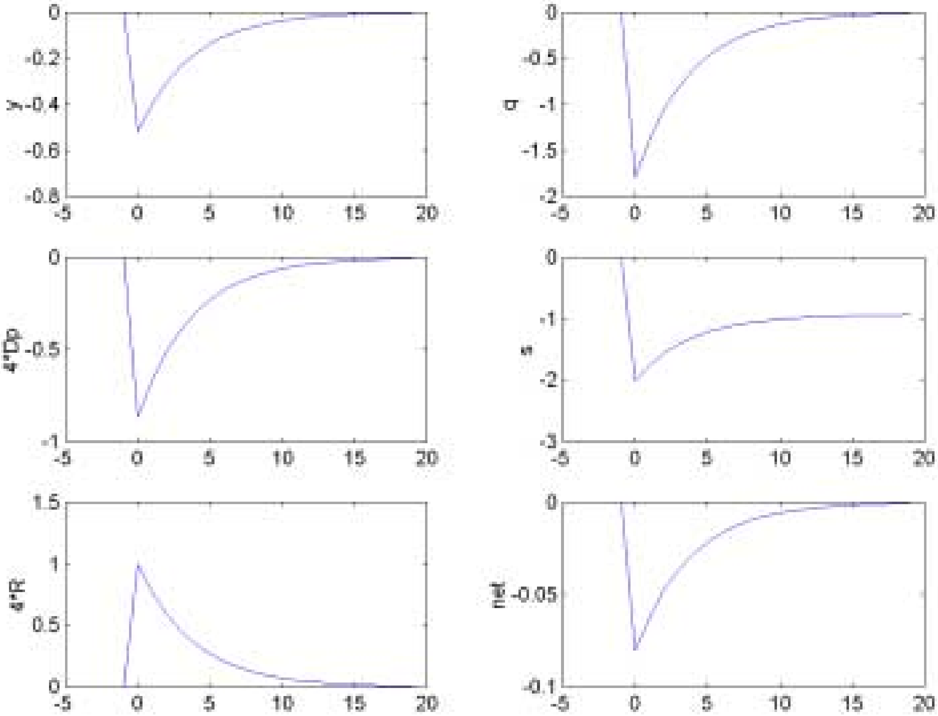

Figure 2: Responses to Unit Shock to Policy Rule, sigma star = 1.0

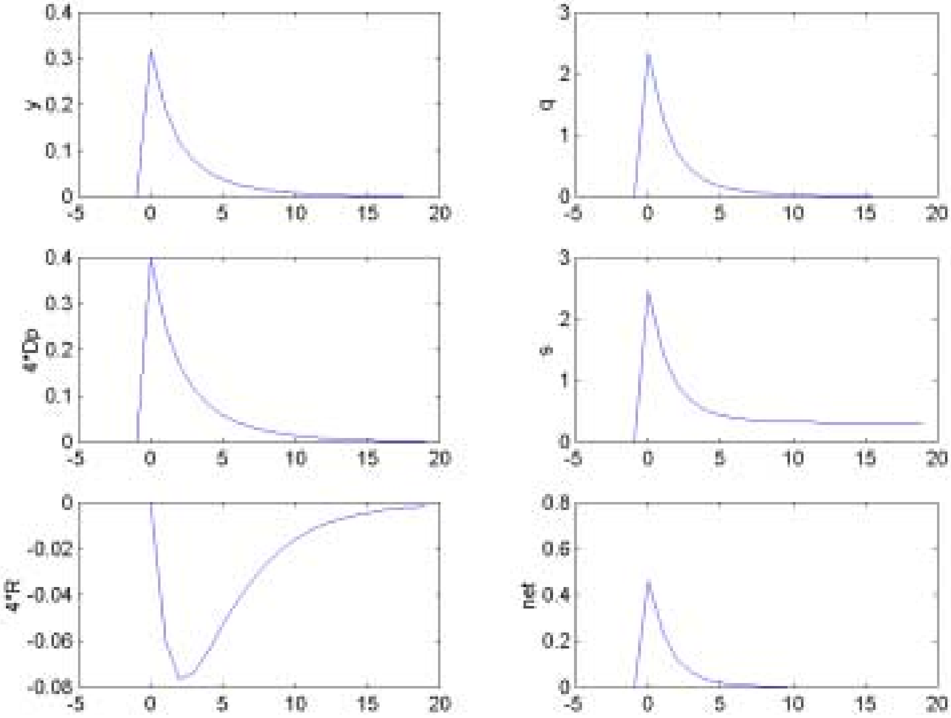

Figure 3: Responses to Unit Shock to UIP Condition, sigma star = 1.0

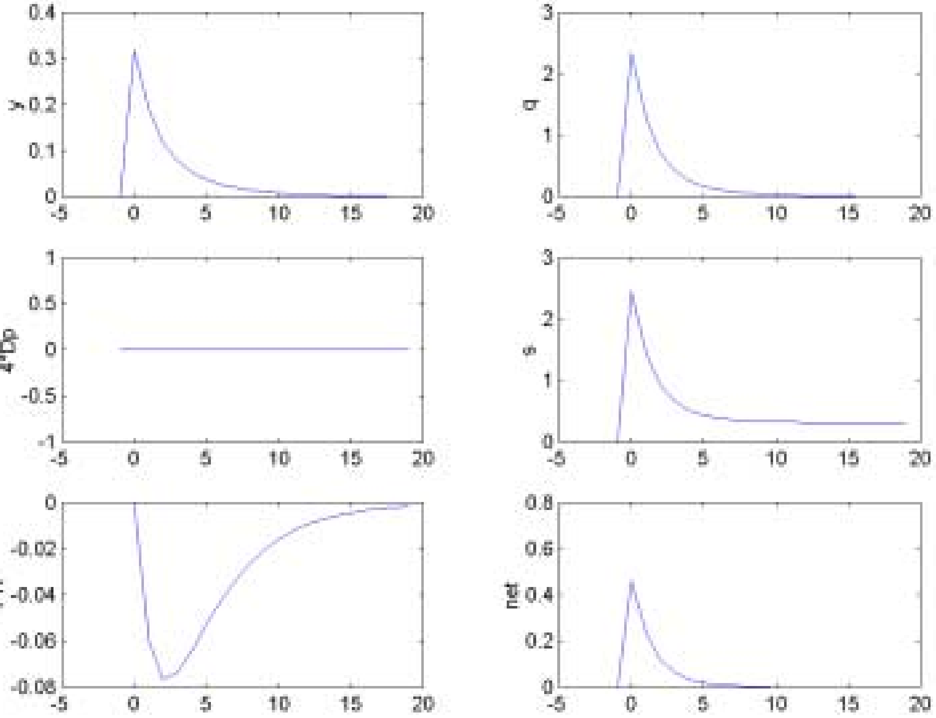

Figure 4: Responses to Unit Shock to ystar, sigma star = 1.0

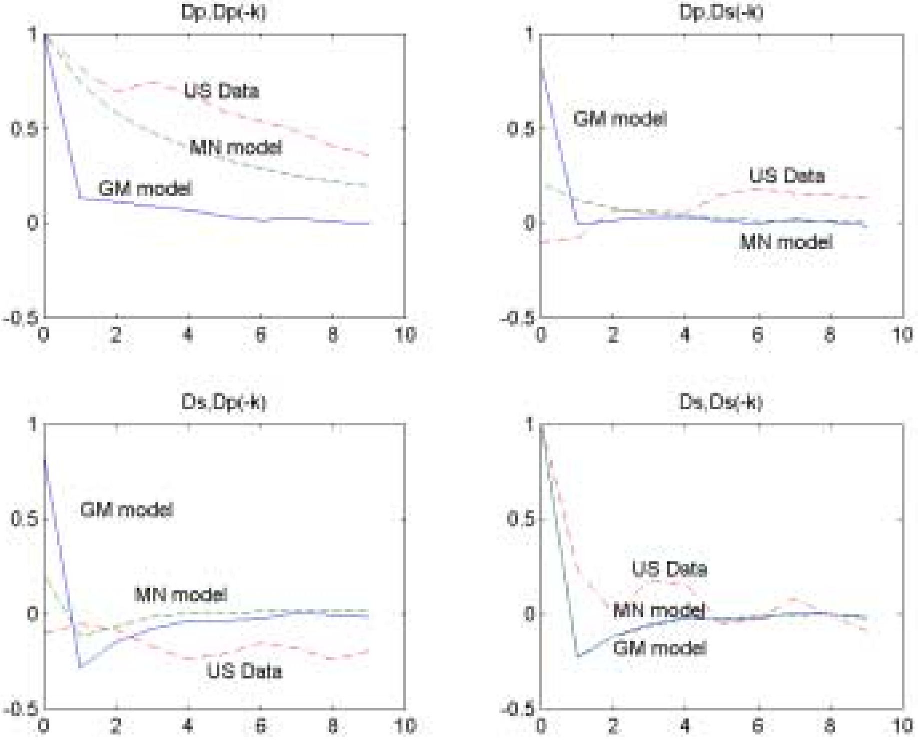

Figure 5: Vector Autocorrelations: Calvo price setting

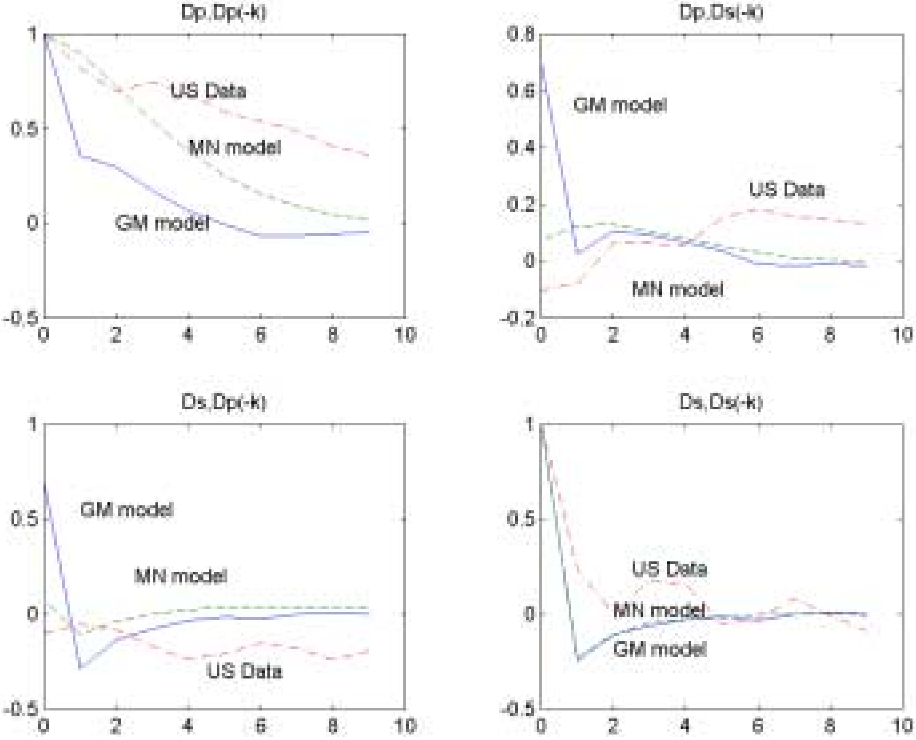

Figure 6: Vector Autocorrelations: FM price setting

Fig. 7: Dp responses to policy shock: Calvo price setting

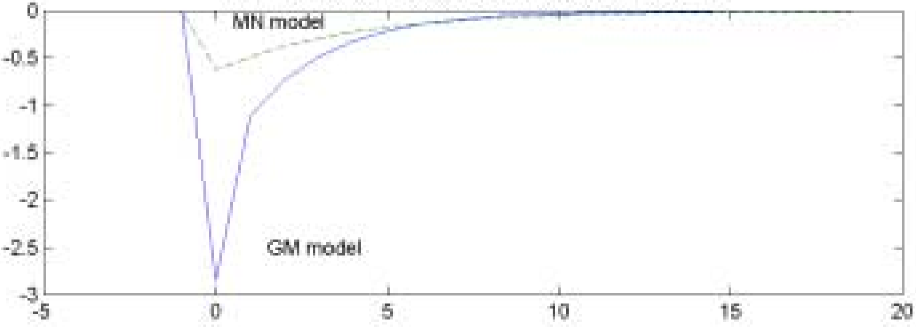

Fig. 8: Dp responses to policy shock: Fuhrer-Moore price setting