# Monetary Policy,
# Exchange Rate Flexibility,
# and Exchange Rate Pass-Through

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## Introduction

This paper develops a dynamic general-equilibrium (DGE) model of a small open economy to investigate alternative monetary rules, differing primarily in the degree to which they allow for exchange rate flexibility. A central argument of the paper is that the nature of the trade-off between fixed and floating exchange rates may be quite different in mature industrial economies than in emerging-market economies. The critical distinction is the degree to which movements in the exchange rate pass through to domestic consumer prices. With very high exchange rate pass-through, all monetary rules face a significant trade-off between output (or consumption) volatility and the volatility of inflation. Policies that stabilize output require high exchange rate volatility, which implies high inflation volatility. But with limited or delayed pass-through, this trade-off is much less pronounced. A flexible exchange rate policy that stabilizes output can do so without high inflation volatility. We also argue that the best monetary policy rule in an open economy is one that stabilizes non-traded goods price inflation. Finally, we show that a policy of strict inflation targeting is much more desirable in an economy with limited pass-through.

> The pass-through of exchange rates to inflation was much higher in Mexico than in Canada, Australia, or New Zealand. And this has to do a lot with history, with credibility of monetary policies, and this is one of the big challenges that we

> are facing today in Mexico in the conduct of monetary policy. And we have to really build sufficient credibility so that this pass-through from exchange rate movements to inflation ceases to be such an automatic reaction.
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> —Guillermo Ortiz, Governor, Central Bank of Mexico
> 24 June 1999

Since the Mexican and Asian crises, there has been a very public debate about the costs and benefits of floating exchange rates for emerging-market economies. Some writers argue that the main lesson to be derived from the crises of the 1990s is that exchange rates should be allowed to float freely (Woo, Sachs, and Schwab 2000; Chang and Velasco 1998; Obstfeld and Rogoff 1995a). Others dispute the benefits of floating exchange rates, since floating exchange rates may be associated with discretionary monetary policy and macroeconomic instability (Calvo 1999b); or exchange rate volatility might disrupt financial markets that exhibit "liability dollarization" (Eichengreen and Hausmann 1999); or floating exchange rates may be replaced with de facto exchange rate pegging (Calvo and Reinhart 2000), thus making an economy vulnerable to a currency crisis.

The aim of this paper is to identify the main trade-offs between policies that allow for exchange rate flexibility and those that try to target the exchange rate. Our model is a two-sector, small open economy, where nominal rigidities are present in the form of sticky non-traded goods prices. The economy is subject to a series of external shocks, to which it must adjust—whatever the exchange rate policy being followed.

A central argument of the paper is that the nature of the trade-off between fixed and floating exchange rates may be quite different in mature industrial economies like Canada or Australia and emerging-market economies such as Mexico, Brazil, or Malaysia. The critical difference between these examples is the degree to which movements in the exchange rate pass through to domestic consumer prices. As suggested by the Ortiz quotation, movements in exchange rates typically feed quickly into price levels in emerging-market economies, or at least do so a lot more quickly than in OECD economies. For stable, high-income economies, a wealth of recent evidence (see Engel 1999 for evidence and references) has established that consumer prices show very little short-run response to movements in exchange rates. For the case of the United Kingdom, Canada, Mexico, and Korea, Table 1 illustrates the results of a regression of monthly consumer price index (CPI) inflation rates on lagged exchange rate changes vis-à-vis the U.S. dollar. For Canada and the United Kingdom, the lagged exchange

**Table 1**
**Monthly inflation rates and exchange rate changes**

| | Constant | Lagged ER change | S.E.E. | $R^2$ |
|---|---|---|---|---|
| Canada | 0.0167** | 0.0458 | 0.001 | 0.001 |
| | (7.75) | (0.71) | | |
| U.K. | 0.001** | 0.005 | 0.0002 | 0.0004 |
| | (6.53) | (0.74) | | |
| Mexico | 0.0056** | 0.1125** | 0.004 | 0.18 |
| | (14.34) | (5.27) | | |
| Korea | 0.0017** | 0.029** | 0.0002 | 0.26 |
| | (9.49) | (6.55) | | |

Notes: Dependent variable is monthly CPI inflation rate.
Sample 1990(1)–2000(7).
** = significant at 5 per cent.

rate change has no explanatory power, at the monthly frequency, for CPI inflation. But for Mexico and Korea, the coefficient on lagged exchange rate changes is highly significant. The pass-through for Mexico is over 10 per cent, but smaller for Korea. Thus, our working hypothesis is that exchange rate pass-through is very rapid for emerging markets, but slow for advanced economies.

How does this change the nature of the monetary policy-making problem? Much of the literature on monetary policy in open economies (Svensson 2000; Ball 1998, 2000) has been based on the premise that the rate of CPI inflation is instantaneously affected by movements in exchange rates. For policy-makers concerned about inflation, this represents both an opportunity and a constraint on optimal monetary policies. But, as suggested in the previous paragraph, this hypothesis is not wholly accurate, except for emerging-market economies.

Our methodology is to compare the properties of a series of different monetary rules in the face of exogenous external shocks to the small economy.[1] Two types of Taylor rules are introduced, one that partially targets the nominal exchange rate and one a standard Taylor rule. We also examine a rule that stabilizes the domestic rate of CPI inflation (strict inflation targeting) and a rule that pegs the exchange rate. Finally, we

1. Monacelli (1999) has also contrasted monetary policy rules in an open economy with full pass-through to those with imperfect pass-through. Our model differs in a number of ways: we focus on a two-sector "dependent-economy" model, examine a wider range of shocks, and allow for a wider range of monetary policy rules, including fixed exchange rates. We also directly compare welfare across the different exchange rate regimes, as well as calibrate our model to the case of emerging-market economies.

examine the properties of a rule that stabilizes the rate of non-traded goods inflation. This is the two-sector open economy analogue to the optimal monetary rule identified by Goodfriend and King (1997) in that it eliminates all variability in the real marginal cost for non-traded firms, and therefore attains the equilibrium of the hypothetical economy without nominal rigidities.

The main result of the analysis is that the trade-off between exchange rate regimes (or monetary policy rules) may be quite different for an emerging-market economy with very high exchange rate pass-through than for an advanced economy with limited short-run exchange rate pass-through. In the emerging-market case, a flexible exchange rate rule (such as the Taylor rule or the rule that stabilizes non-traded inflation) will help to stabilize the real economy in the face of external shocks. By facilitating adjustment in both the real exchange rate and real interest rate, these rules can cushion the economy from the impact of external shocks. The markup-stabilization rule appears to be the best rule to achieve this result. But, to stabilize GDP and consumption, the rule has to allow a high volatility in the nominal exchange rate and, therefore, high inflation volatility. There is a clear trade-off between output/consumption volatility and inflation volatility. If the authorities are concerned with consumer price inflation[2] (over and above non-traded goods inflation), then the flexible exchange rate regime brings some costs as well as benefits. Moreover, the same logic implies that a policy of strict inflation targeting is quite undesirable in an open economy, since it effectively amounts to a requirement of fixing the exchange rate. It stabilizes inflation at the expense of a lot of output instability.

The situation is quite different when pass-through is limited. We model this process by assuming that foreign firms follow a practice of setting prices in domestic currency and only gradually adjust to exchange rate changes. In this environment, we find that there is no trade-off between output volatility and inflation volatility. In fact, a flexible exchange rate can deliver lower output variance and lower inflation variance than a fixed exchange rate regime. Of all the rules considered, the markup-stabilization rule minimizes the variance of output, consumption, and inflation.

The explanation of these results is easy to see. When exchange rate changes do not fully affect consumer prices, then external shocks that cause

2. In our model, there is really no reason why consumers should be concerned with CPI inflation if the inflation rate of non-traded goods is stabilized. Realistically, however, it is highly likely that central banks will be concerned more generally with CPI inflation.

exchange rate movements have a smaller effect on internal relative prices facing households and a smaller effect on domestic inflation. Consequently, both inflation and the real economy tend to be stabilized. At the same time, since exchange rates still immediately affect interest rates (through uncovered interest rate parity (UIRP)), the monetary policy rule under flexible exchange rates can still use nominal exchange rates to help stabilize the economy. Thus, in effect, the exchange rate can be used without inflationary consequences. The conclusion is that the monetary policy problem is much more favourable in an economy with limited pass-through, and this tilts the balance strongly towards floating exchange rates.

A corollary of these findings is that a policy of strict inflation targeting is much less costly in an economy with limited pass-through, since inflation can be stabilized while still allowing for a considerable degree of nominal exchange rate volatility.

A general finding of the paper, in comparing monetary rules, is that the rule that stabilizes non-traded goods price inflation performs the best. It is a straightforward, coherent rule, and simply says that the authorities should not pay attention directly to the exchange rate or traded goods prices in setting interest rates.[3] There is an additional attractive feature of the rule. A Taylor-type rule in an open economy may be destabilizing in the presence of internal shocks to the monetary policy decision-making structure. If we thought of such shocks as related to credibility or risk-premium shocks, there might be a case for a currency board or a dollarization to eliminate this type of instability. But the rule that stabilizes non-traded goods price inflation also automatically neutralizes such internal monetary policy shocks. To the extent that such a rule can be made credible, it has an advantage over a pegged exchange rate, since it also helps to stabilize the economy in the face of external shocks.

Section 1 develops the basic model, which is a two-sector, small open dependent-economy model. The model is calibrated and simulations are reported in section 2. Section 3 discusses the difference between alternative monetary rules for the volatility of inflation, output, and other variables, and examines welfare comparisons across regimes. Conclusions follow.

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3. There is a parallel between a non-traded goods inflation rule and the central bank practice of focusing on core inflation, excluding goods whose prices display high short-term volatility. To the extent that these goods, such as food and energy, are imported, the focus on non-traded goods inflation and core inflation may lead to similar results.

# 1 The Model

We will describe the model of a small open economy that will be used to compare alternative monetary policy rules. The structure is a standard two-sector dependent-economy model. Two goods are produced: a domestic non-traded good, and an export good, the price of which is fixed on world markets. This is probably the best representation of the macroeconomic environment of emerging-market economies. Although the real exchange rate is determined by domestic macroeconomic equilibrium, the economy has no international market power in traded goods.

A central aspect of the model is the presence of nominal rigidities. Price stickiness introduces a role for monetary policy and a non-trivial comparison between exchange rate regimes. But, unlike the standard analysis of price stickiness in closed-economy models (e.g., Goodfriend and King 1997, Rotemberg and Woodford 1998), in a small open economy, prices in the traded goods sector are determined by world prices. Non-traded goods prices are set in advance by domestic firms, however, and adjust only gradually to shocks.

There are three groups of actors in the economy: consumers, firms, and the monetary authority.

## 1.1 Consumers

The economy is populated by a continuum of consumer/households of measure unity. The representative consumer has preferences given by:

$$U = E_0 \sum_{t=0}^{\infty} \beta u(C_t, H_t, m_t), \tag{1}$$

where $C_t$ is a composite consumption index, such that $C_t = C(C_{Nt}, C_{Mt})$, where $C_{Nt}$ represents consumption of non-traded goods, and $C_{Mt}$ is consumption of an imported foreign good. $H_t$ is labour supply, and $m_t = M_t/P_t$ represents real balances, with $M_t$ being nominal money balances and $P_t$ the CPI. We will impose specific functional forms on the function $U(C, H, m)$. Let the functional form of $u$ be given by:

$$u(C, H, m) = \frac{C^{1-\sigma}}{1-\sigma} - \eta\frac{H^{1+\psi}}{1+\psi} + \chi\frac{m^{1-\varepsilon}}{1-\varepsilon}.$$

In addition, if we let composite consumption take the form:

$$C_t = (a^{1/\rho} C_{Nt}^{1-1/\rho} + (1-a)^{1/\rho} C_{Mt}^{1-1/\rho})^{\frac{\rho}{\rho-1}},$$

then the implied CPI is:

$$P = (aP_{Nt}^{1-\rho} + (1-a)P_{Mt}^{1-\rho})^{\frac{1}{1-\rho}}.$$

Finally, assume that consumption is differentiated at the individual goods level, so that:

$$C_{jt} = \left(\int_0^1 C_{jt}(i)^{i-\lambda} di\right)^{1/(1-\lambda)},$$

where $\lambda > 1$, $j = H, M$.

Consumers are assumed not to face any capital-market imperfections.[4] Therefore, the consumer can borrow directly in terms of foreign currency at a given interest rate, $i_{t+1}^*$, for period *t*. Consumer revenue flows in any period come from their supply of labour to firms for wages $W_t$, transfers $T_t$, from government, profits from firms in the non-traded sector $\Pi_t$, return on capital that is rented to firms in each sector, domestic money, less their debt repayment from last period, $D_t$. They then obtain new loans from foreign capital markets and use these loans to consume, invest in new capital, and acquire new money balances. Their budget constraint is thus:

$$P_t C_t + (1 + i_t^*) S_t D_t + P_t(I_{Nt} + I_{Xt}) + M_t$$
$$= W_t L_t + \Pi_t + S_t D_{t+1} + M_{t-1} + T_t + P_t R_{Nt} K_{Nt} + P_t R_{Xt} K_{Xt}. \quad (2)$$

Capital stocks in the export and non-traded sectors evolve according to:

4. Much of the recent post-crisis literature on emerging markets has stressed the imperfections and instability of capital markets. See, e.g., Cespedes, Chang, and Velasco (2000); Aghion, Bacchetta, and Banerjee (2000); Devereux and Lane (2000); Cook (2000); and others. But how much this should affect the monetary policy problem is open to debate. Cespedes, Chang, and Velasco and Devereux and Lane show that introducing collateral constraints on foreign-investment financing and a “currency mismatch” in balance sheets does not affect the qualitative conclusions with respect to optimal monetary policy in an otherwise conventional model of a small open economy (such as the model here). Cook, however, finds a different result, using an alternative specification.

$$K_{Xt+1} = \phi\left(\frac{I_{Tt}}{K_{Tt}}\right)K_{Xt} + (1-\delta)K_{Xt}, \tag{3}$$

$$K_{Nt+1} = \phi\left(\frac{I_{Nt}}{K_{Nt}}\right)K_{Nt} + (1-\delta)K_{Nt}, \tag{4}$$

where the function $\phi$ satisfies $\phi' > 0$, and $\phi'' < 0$. This reflects the presence of adjustment costs of investment. Under this specification, capital cannot move between sectors at any given time period, but capital in each sector adjusts over time.

The household will choose non-traded and imported goods consumption to minimize expenditure, conditional on total composite demand, $C_t$. Demand for non-traded and imported goods is then:

$$C_{Nt} = a\left(\frac{P_{Nt}}{P_t}\right)^{-\rho}C_t \qquad C_{Mt} = (1-a)\left(\frac{P_{Mt}}{P_t}\right)^{-\rho}C_t.$$

The consumer optimum can be characterized by the following conditions.

$$\frac{1}{(1+i^*_{t+1})}C_t^{-\sigma} = E_t\beta\frac{S_{t+1}}{S_t}\frac{P_t}{P_{t+1}}C_{t+1}^{-\sigma}. \tag{5}$$

$$\frac{W_t}{P_t} = \eta C_t^{\sigma}H_t^{\psi}. \tag{6}$$

$$\left(\frac{M_t}{P_t}\right)^{-\varepsilon} = \chi C_t^{-\sigma}(1-E_t d^h_{t+1}). \tag{7}$$

$$\frac{C_t^{-\sigma}}{\varphi'(i_{Nt})} = E_t\beta C_{t+1}^{-\sigma}\left(R_{Nt+1} + \frac{(1-\delta+\varphi'(i_{Nt+1})i_{Nt+1})}{\varphi'(i_{Nt+1})}\right). \tag{8}$$

$$\frac{C_t^{-\sigma}}{\varphi'(i_{Tt})} = E_t\beta C_{t+1}^{-\sigma}\left(R_{Xt+1} + \frac{(1-\delta+\varphi'(i_{Tt+1})i_{Tt+1})}{\varphi'(i_{Tt+1})}\right). \tag{9}$$

Equation (5) represents the Euler equation for optimal consumption. Equation (6) is the labour-supply equation, while equation (7) gives the implicit money-demand function. Money demand depends on domestic nominal interest rates. The domestic nominal discount factor is defined as:

$$d^h_{t+1} = \frac{C^{-\sigma}_{t+1}}{C^{-\sigma}_t}\frac{P_t}{P_{t+1}}. \tag{10}$$

Note that the combination of equations (5) and (10) gives the representation of UIRP for this model. Finally, conditions (8) and (9) describe the optimal investment choice for the household, where the consumer separately accumulates capital stock for use in the non-traded and traded goods sectors.

## 1.2 Production firms

Production is carried out by firms in the non-traded and export sectors. The sectors differ in their production technologies. The non-traded sector uses labour and specific capital to produce. An individual firm in the non-traded sector has technology:

$$Y_{Nit} = A_N K^a_{Nit} L^{1-\alpha}_{Nit}, \tag{11}$$

where $A_N$ is a productivity parameter.

Traded goods production uses both imported intermediate inputs, $I_{Mt}$, and domestic value added, $V_t$, to produce, using the technology:

$$Y_{Xt} = (\vartheta V^{1-1/\phi}_t + (1-\vartheta) I^{1-1/\phi}_{Mt})^{\phi/\phi - 1}. \tag{12}$$

Domestic value added is obtained from capital and labour according to:

$$V_t = A_X K^{\gamma}_{Xt} L^{1-\gamma}_{Xt}. \tag{13}$$

Cost-minimizing behaviour then implies the following equations:

$$W_t = MC_{Nt}(1-\alpha)\frac{Y_{Nit}}{H_{Nit}}, \tag{14}$$

$$R_{Nt} = MC_{Nt}\alpha\frac{Y_{Nit}}{K_{Nt}}, \tag{15}$$

$$W_t = P_{Xt}(1-\gamma)\frac{V_t}{H_{Xt}}\vartheta\left(\frac{Y_{Xt}}{V_t}\right)^{\frac{1}{\phi}}, \tag{16}$$

$$R_{Xt} = P_{Xt}\gamma\frac{V_t}{K_{Xt}}\vartheta\left(\frac{Y_{Xt}}{V_t}\right)^{\frac{1}{\phi}}, \tag{17}$$

$$P_{1Mt} = P_{Xt}\gamma(1-\vartheta)\left(\frac{Y_{Xt}}{I_{Mt}}\right)^{\frac{1}{\phi}}, \tag{18}$$

where $MC_{Nt}$ denotes the nominal marginal production cost for a firm in the non-traded sector (which is common across firms). Equations (14) and (16) describe the optimal employment choice for firms in each sector. Equations (15) and (17) describe the optimal choice of capital. Note that the price of the traded export good is $P_{Xt}$. Movements in this price, relative to $P_{Mt}$ and $P_{1Mt}$, represent terms-of-trade fluctuations for the small economy. Finally, equation (18) represents the condition for the optimal choice of intermediate inputs.

## 1.3 Price-setting

Firms in the non-traded sector set prices in advance. Following the method of Calvo (1983) and Yun (1996), assume that firms face a probability $(1-\kappa)$ in every period of altering their price, independent of how long their price has been fixed. Following standard aggregation results, the non-traded goods price follows the partial-adjustment rule:

$$P_{Nt}^{1-\lambda} = (1-\kappa)\tilde{P}_{Nt}^{1-\lambda} + \kappa P_{Nt-1}^{1-\lambda}, \tag{19}$$

where $\tilde{P}_{Nt}$ represents the newly set price for a firm that does adjust its price at time *t*.

The evolution of $\tilde{P}_{Nt}$ is then governed by (the approximation):

$$\tilde{P}_{Nt} = (\Gamma-\beta\kappa)MC_{Nt} + E_t\beta\kappa\tilde{P}_{Nt+1}. \tag{20}$$

Taking a linear approximation of equations (17) and (18), assuming an initial steady state where the rate of change of $P_{Nt}$ is constant, we can derive the familiar forward-looking inflation equation:

$$\pi_{Nt} = \lambda mcn_t + E_t\pi_{Nt+1}, \tag{21}$$

where $mcn_t$ represents the log deviation of real marginal cost in the non-traded sector, $MC_t/P_{Nt}$, from its steady-state level (of unity). Equation (19) is analogous to the forward-looking inflation equation in Clarida, Galí, and Gertler (1999). The key difference here is that both marginal costs and inflation are specific to the non-tradable sector.

## 1.4 Monetary policy rules

Assume that the monetary authority uses a short-term interest rate as the monetary instrument. Given the interest rate, the money supply will be determined endogenously by the aggregate demand for money arising from the consumer sector (i.e., equation (5)). Thus, the analysis of monetary rules can ignore the money supply, since it is determined as a residual. It is important, however, that interest rate rules are set to ensure a unique price level and exchange rate and to avoid the issue of "real indeterminacy" that can arise under some interest rate rules in sticky-price models.[5] Under all calibrations of the model, as discussed below, a unique equilibrium is obtained.

The general form of the interest rate rule used may be written as:

$$(d_{t+1}^{h})^{-1} = \left(\frac{P_{Nt}}{P_{Nt-1}}\frac{1}{1+\bar{\pi}_n}\right)^{\mu_{\pi n}}\left(\frac{P_t}{P_{t-1}}\frac{1}{1+\bar{\pi}}\right)^{\mu_{\pi}}\left(\frac{Y_t}{\bar{Y}}\right)^{\mu_y}\left(\frac{S_t}{\bar{S}}\right)^{\mu_s}$$

$$(1+\bar{i})\exp(u_t), \tag{22}$$

where it is assumed that $\mu_{\pi n} \geq 0, \mu_{\pi} \geq 0, \mu_y \geq 0, \mu_s \geq 0$. The parameter $\mu_{\pi n}$ allows the monetary authority to control the inflation rate in the non-traded goods sector around a target rate of $\pi_n$. The parameter $\mu_{\pi}$ governs the degree to which the CPI inflation rate is targeted around the desired target of $\bar{\pi}$. Then $\mu_y$ and $\mu_s$ control the degree to which interest rates attempt to control variations in aggregate output and the exchange rate, around their target levels of $\bar{Y}$ and $\bar{S}$, respectively. The term $\exp(u_t)$ represents a shock to the domestic monetary rule.

This function allows for a variety of monetary rules. When $\mu_{\pi} = \mu_y = \mu_s = 0$, and $\mu_{\pi_n} \to \infty$, the monetary authorities pursue a policy of strict inflation targeting in the non-traded goods sector. From equation (19), we see that this will ensure that the real markup is constant. Intuitively, if the monetary policy acts to ensure that there is never a need to adjust prices, then there are no consequences of price stickiness. This point has been made

5. See Woodford (2001) for conditions on interest rate rules required for uniqueness in the price level. Also see Clarida, Galí, and Gertler (1999).

by Goodfriend and King (1997) and others. Therefore, this policy will replicate the real equilibrium of an economy with flexible prices.

When $\mu_{\pi_n} = \mu_s = 0$, the authority follows a form of Taylor rule, where interest rates are adjusted to respond to deviations of CPI inflation and aggregate output from some target levels. When $\mu_{\pi_n} = 0$, the authority follows a modified Taylor rule in which the exchange rate is targeted in addition to CPI inflation and output. When $\mu_{\pi_n} = \mu_y = \mu_s = 0$ and $\mu_\pi \to \infty$, the monetary authority pursues strict CPI inflation targeting. Finally, when $\mu_{\pi_n} = \mu_y = \mu_\pi = 0$ and $\mu_s \to \infty$, the authority follows a pegged exchange rate.

## 1.5 Optimal monetary policy

What objective function should the monetary authorities have in this economy? Speaking generally, the model has a natural welfare index: the expected utility of households in the small economy. An optimal monetary policy would be one that maximizes expected utility. But, recent literature on the analysis of monetary policy in sticky-price DGE models has developed a more direct approach to the formulation of monetary policy objective functions. Goodfriend and King point out that, leaving out issues related to the Friedman rule (or, equivalently, assuming positive nominal interest rates), an optimal monetary policy should stabilize the markup of prices over marginal costs (real marginal cost). This is explained as follows. The only way in which a sticky-price economy differs from a flexible-price economy is that the markup of price over marginal cost is variable. With flexible prices, firms would set a constant and time-invariant markup (because of the Constant Elasticity of Substitution utility function). A monetary rule that stabilizes the markup replicates the flexible-price economy. If the equilibrium of the flexible-price economy is Pareto-efficient, this must represent the optimal monetary rule. In fact, the flexible-price economy will not typically have an efficient equilibrium, because of the presence of monopolistic competitive pricing. But since the monetary policy rule cannot affect the average markup of price over marginal cost in any case (at least in the linearized version analyzed here), the best rule for monetary policy is to reduce the variance of the markup to zero, thereby replicating the flexible-price economy.

Subsequent literature refined this rule (Clarida, Galí, and Gertler 1999; Woodford 2001) by linking movements in the price-cost markup to deviations of output from its potential level or the level that it would attain in a flexible-price economy. Woodford shows that in an economy where price-setting is staggered, inflation generates an additional welfare loss, independent of the gap between output and potential output (i.e., the unexploited gains from trade due to sticky prices). This loss arises from the dispersion in relative goods prices, leading to an inefficient allocation of resources between sectors. In this framework, Woodford's analysis implies that expected utility may be approximated by a quadratic function of output deviations from potential output and inflation deviations from zero. Both Woodford and Clarida, Galí, and Gertler then point out that in the absence of direct shocks to the pricing equation, an optimal monetary policy would set inflation to zero. This would stabilize the markup of price over marginal cost, as suggested by Goodfriend and King, and simultaneously keep output at its potential level and reduce the dispersion of relative prices to zero.

In the present model, in the case of immediate pass-through from the exchange rate to imported goods prices (i.e., $\kappa^* = 0$), a monetary policy rule that ensured a constant price-cost markup for non-traded goods firms would replicate the equilibrium of a flexible-price economy. In this case, an appropriate welfare index would be a combination of output deviations from potential, and inflation in the non-traded goods sector. This could be achieved by zero inflation in non-traded goods prices. In the economy with slow pass-through of exchange rate changes, the situation is more complicated, because even without sticky prices in the non-traded goods sector, monetary rules can have real effects through their impact on exchange rates. This may lead the monetary authority to be more generally concerned with CPI inflation and nominal exchange rate variability. But derivation of a welfare objective for monetary policy along the lines of Woodford is quite complicated because of the presence of investment, the two-sector structure, and imperfect pass-through.

Rather than take a stand on the exact form of the monetary authority objective function, we consider the implications of alternative monetary regimes for volatility in the major macro aggregates, including output, consumption, and inflation volatility. In some cases, inferences may be made about desirable monetary policy regimes without precise knowledge of the weights that the authority puts on inflation versus output volatility in its loss function. We also provide a ranking of alternative policies using household expected utility.

## 1.6 Local currency pricing

The law of one price must hold for both export goods, so that:

$$P_{Xt} = S_t P^*_{Xt}. \tag{23}$$

For import goods, however, we allow for the possibility that there is some delay between movements in the exchange rate and the adjustment of imported goods prices. Note that this is still consistent with the constraint that the economy is small and without market power in the traded goods sector. The assumption is that foreign suppliers may choose to follow a pricing policy that stabilizes the prices of imports in terms of local currency. Domestic consumers, however, take the local currency price of imported goods as given.

Without loss of generality, we may assume that imported goods prices are adjusted in the same manner as are prices in the non-traded sector. That is, a measure $1-\kappa^*$ of foreign firms adjust their prices in every period. Thus, the imported good price index for domestic consumers moves as:

$$P_{Mt}^{1-\lambda} = (1-\kappa^*)\tilde{P}_{Mt}^{1-\lambda} + \kappa^* P_{Mt-1}^{1-\lambda}, \tag{24}$$

where $\tilde{P}_{Mt}$ represents the newly set price for a foreign firm that does adjust its price at time *t*.

The evolution of $\tilde{P}_{Mt}$ is then governed by (the approximation):

$$\tilde{P}_{Mt} = (1-\beta\kappa^*)S_t P^*_{Mt} + E_t \beta\kappa^* \tilde{P}_{Mt+1}. \tag{25}$$

The interpretation of equation (26) is that the foreign firm wishes to achieve the same price in the home market as in the foreign market. But it may incur a lag in adjusting its price. The coefficient $\kappa^*$ determines the delay in the pass-through of exchange rates to prices in the domestic market. Using the same approach as with equations (20) and (21), the familiar inflation equation can be derived:

$$\pi_{Mt} = \lambda(\hat{s}_t + \hat{p}^*_{Mt} - \hat{P}_{Mt}) + E_t \pi_{Mt+1}, \tag{26}$$

where $\pi_{Mt}$ is the inflation rate in domestically denominated traded goods prices, $\hat{s}_t$ and $\hat{p}^*_{Mt}$, and represents the log deviation of the exchange rate and foreign traded goods prices from steady state.

## 1.7 Equilibrium

In each period, the non-traded goods market must clear. Thus, we have:

$$Y_{Nt} = a\left(\frac{P_{Nt}}{P_t}\right)^{-\rho}(C_t + I_{Nt} + I_{Xt}). \tag{27}$$

Equation (27) indicates that demand for non-traded goods comes from consumers, both for consumption and investment demand. In a similar manner, we may describe the evolution of the economy's net debt, $D_t$, as:

$$S_t D_{t+1} = S_t D_t(1 + i_t^*) - P_{Xt}Y_{Xt} + (1-a)\left(\frac{P_{Mt}}{P_t}\right)^{-\rho}$$

$$(c_t + I_{Nt} + I_{Xt}). \tag{28}$$

Labour market clearing for the household sector implies:

$$H_{Nt} + H_{Xt} = H_t. \tag{29}$$

Finally, to recover the nominal price of non-traded goods and imported goods, we use the conditions:

$$P_{Nt} = \pi_{Nt} + P_{Nt-1}, \tag{30}$$

$$P_{Mt} = \pi_{Mt} + P_{Mt-1}, \tag{31}$$

with the initial prices $P_{N-1}$ and $P_{M-1}$ being given.

The economy's equilibrium may be described as the sequence of functions given by:

$C(\theta_t), H(\theta_t), S(\theta_t), d^h(\theta_t), Y_N(\theta_t), Y_X(\theta_t), V_X(\theta_t), H_N(\theta_t), K_N(\theta_{t-1})$,

$H_X(\theta_t), K_X(\theta_{t-1}), I_X(\theta_t), I_N(\theta_t), I_M(\theta_t), R_{Nt}(\theta_t), R_{Xt}(\theta_t)$,

$\pi_N(\theta_t), \pi_{Tt}(\theta_t), mcn(\theta_t), D(\theta_t), W(\theta_t), P_M(\theta_t), P_X(\theta_t), M(\theta_t)$, and

$P_{Nt}(\theta_t)$.

Here, $\theta_t$ is the period $t$ information set. This represents a system of 25 functions that correspond to the solutions of the 25 equations (3) to (18), (21), (22) (23), (26), and (27) to (31), given the CPI definition and the definition of the shock processes (discussed below).

The model is solved by linear approximation, using the Schur decomposition method of Klein (2000).

## 2 Calibration and Solution

We now derive a solution for the model through calibration and then simulation, using standard linear approximation techniques. The calibration parameter values are listed in Table 2. Most values are quite standard. Rather than calibrating to any single national data set, we choose a set of consensus parameter values that are generally applied to developing economies. In some instances, where there is no direct evidence, we use common parameter assumptions from the macro general-equilibrium literature.

It is assumed that the intertemporal elasticity of substitution in both consumption and real balances is 0.5. The consumption intertemporal elasticity is within the range of the literature, and the equality between the two elasticities ensures that the consumption elasticity of money demand equals unity, as estimated by Mankiw and Summers (1986). The elasticity of substitution between non-traded and imported goods in consumption is an important parameter on which there is little direct evidence. Following Stockman and Tesar (1995), we set this to unity. The elasticity of labour supply is also set to unity, following Christiano, Eichenbaum, and Evans (1997). In addition, the elasticity of substitution between varieties of goods determines the average price-cost markup in the non-traded sector. Since we have no direct evidence on markups for emerging-market economies, we follow standard estimates from the literature in setting a 10 per cent markup, so that $\lambda = 11$.

Assuming that the economy starts out in a steady state with zero consumption growth, the world interest rate must equal the rate of time preference. We set the world interest rate equal to 6 per cent annually, an approximate number used in the macro real business cycle literature; at the quarterly level, therefore, this implies a value of 0.985 for $\beta$.

The factor intensity parameters are important in determining the dynamics of the model. These types of parameters are typically calibrated in DGE models by identifying the employment share of GDP. But since it is quite likely that this share differs across sectors, it is necessary to obtain separate wage shares at the sectoral level. We follow Devereux and Cook (2000) in

**Table 2**
**Calibration of model**

| Parameter | Value | Description |
|---|---|---|
| $\sigma$ | 2 | Inverse of elasticity of substitution in consumption |
| $\varepsilon$ | 2 | Inverse of elasticity of substitution in real balances |
| $\beta$ | 0.985 | Discount factor (quarterly real interest rate is $\frac{(1-\beta)}{\beta}$ ) |
| $\rho$ | 1.0 | Elasticity of substitution between non-traded goods and import goods in consumption |
| $\eta$ | 1.0 | Coefficient on labour in utility |
| $\psi$ | 1.0 | Elasticity of labour supply |
| $\gamma$ | 0.7 | Share of capital in export sector |
| $\delta$ | 0.025 | Quarterly rate of capital depreciation (same across sectors) |
| $\alpha$ | 0.3 | Share of capital in non-traded sector |
| $\upsilon$ | 0.5 | Share of value added in export good production |
| $\phi$ | 0.5 | Elasticity of substitution between intermediate inputs and value added in export good production |
| $\lambda$ | 10 | Elasticity of substitution between varieties (for both goods) |
| $a$ | 0.5 | Share on non-traded goods in CPI |
| $\kappa$ | 0.75 | Probability of non-traded firms price remaining unchanged |
| $-\frac{\phi''}{\phi'}\frac{I}{K}$ | 0.5 | Elasticity of $q$ with respect to $I/K$ ratio (inversely related to investment adjustment cost) |

assuming that the non-traded sector is more labour-intensive than the export sector. Specifically, we take the labour share in the non-traded sector to be 70 per cent of value added, while the labour share in the export sector is 30 per cent of value added.

In combination with the model's other parameters, $a$, which governs the share of non-traded goods in the CPI, determines the share of non-traded goods in GDP. Typically, this is significantly smaller for open developing economies than for OECD economies. Devereux and Cook (2000) and Devereux and Lane (2000), estimate, for Malaysia and Thailand, that the share of non-traded goods in total GDP is 55 per cent and 54 per cent, respectively. For Mexico, Schmitt-Grohe and Uribe (2000) estimate a share of 56 per cent. Roughly following these studies, we set $a$ at 0.5 to imply a share of non-traded goods to GDP of 50 per cent. In addition, we set the share of imported materials in export production to be equal to that of value added, and we assume that the elasticity of substitution between value added and intermediate imports is 0.5.

To determine the degree of nominal rigidity in the model, the value $\kappa$, which governs the speed of price adjustment in non-traded goods, must be chosen. Again, in the absence of direct evidence on this, we follow the literature (e.g., Chari, Kehoe, and McGrattan 1998) and set $\kappa = 0.75$, so that prices completely adjust after approximately four quarters. As is standard practice, we set the adjustment cost of capital (elasticity of Tobin's q with respect to the investment-capital ratio) to imply a standard deviation of investment relative to GDP in a reasonable range.

The degree to which exchange rate and foreign price shocks are passed through to domestic imported goods prices is governed by the parameter $\kappa^*$. As discussed above, this is a difficult parameter to pin down empirically. Estimates of pass-through of exchange rate changes to imported goods prices tend to be different from the observed effects of exchange rate changes on more aggregated price indexes. For instance, Goldberg and Knetter (1997) estimate that the median rate of pass-through in the United States is 50 per cent for manufacturing industries. But other macro evidence for the United States suggests a virtual absence of any effects of exchange rate changes on domestic goods prices (Engel 1999). Similarly, the Engel and Rogers (1996) study suggests few short-run effects of exchange rate changes on relative goods prices between the United States and Canada. This suggests that there is a considerable degree of local-currency pricing in traded goods industries in OECD countries. Within the structure of the present model, this evidence would suggest that $\kappa^*$ is positive—foreign exporting firms do not immediately adjust their prices to exchange rate changes. In the absence of very precise estimates of $\kappa^*$, we follow a rule of thumb in setting $\kappa^* = \kappa$ for our calibration of an advanced economy. The rationalization for this number is that it agrees with Engel's finding that for the United States and its major industrial trading partners, there is virtually no difference in the characteristics of the prices of traded and non-traded goods.

On the other hand, as suggested above, the pass-through from exchange rates to prices is likely to be much higher for emerging markets. Evidence from the Asian and Mexican crises indicates a rapid transmission of exchange rate depreciation to imported goods prices. Again, however, precise estimates of the extent of pass-through have not been obtained. To fix ideas, we make the extreme assumption that the pass-through is immediate for our calibrated emerging-market economy. Thus, we set $\kappa^* = 0$ for the emerging-market model. Therefore, the law of one price obtains at all times. Both foreign price shocks and exchange rate changes have immediate implications for local prices of imported goods.

## 2.1 Shocks

The model implies that the economy is exposed to three types of external shocks: (i) shocks to foreign prices, (ii) shocks to the foreign interest rate, and (iii) terms-of-trade shocks. The first and third shocks are obviously interrelated. Conceptually, however, there is a difference between balanced movements in the world price level and shocks to the relative price of the domestic country export good. We let price shocks be represented by equal shocks to all foreign prices, i.e., to $P^*_{Mt}$, and $P^*_{Xt}$, and $P^*_{1Mt}$. Terms-of-trade shocks are represented by shocks to:

$$\frac{P^*_{Xt}}{P^*_{Mt}} \text{ and } \frac{P^*_{Xt}}{P^*_{1Mt}}.$$

Since shocks to these last two variables have almost identical effects, we assume that they are equivalent. Thus, the consumer and producer import price indexes are assumed to be the same.

In section 2.2, we will measure the size of these shocks for a group of Asian countries. At present, we wish to give an intuitive account of the basic properties of the model when subjected to each external shock.

### *2.1.1 The impact of external shocks under alternative monetary regimes*

We now illustrate the workings of the model in response to the different external shocks, under each monetary rule. The monetary rules are categorized in Table 3. The markup rule stabilizes the rate of inflation in non-traded goods, as discussed above. Two Taylor-type rules are also discussed. Finally, there is a strict CPI inflation-targeting rule and a pegged exchange rate rule.

## 2.2 Interest rate shocks

Figure 1 describes the response of the economy to a foreign interest rate shock when pass-through from exchange rates to imported goods prices is immediate. The shock represents a 100-basis-point rise in $i^*_t$, which is assumed to follow an AR(1) process with parameter 0.57. (The shocks are calibrated more directly below.)

As discussed in Devereux and Cook (2000), the response to a foreign interest rate shock is to generate both an internal and external reallocation of

**Table 3**
**Monetary rules**

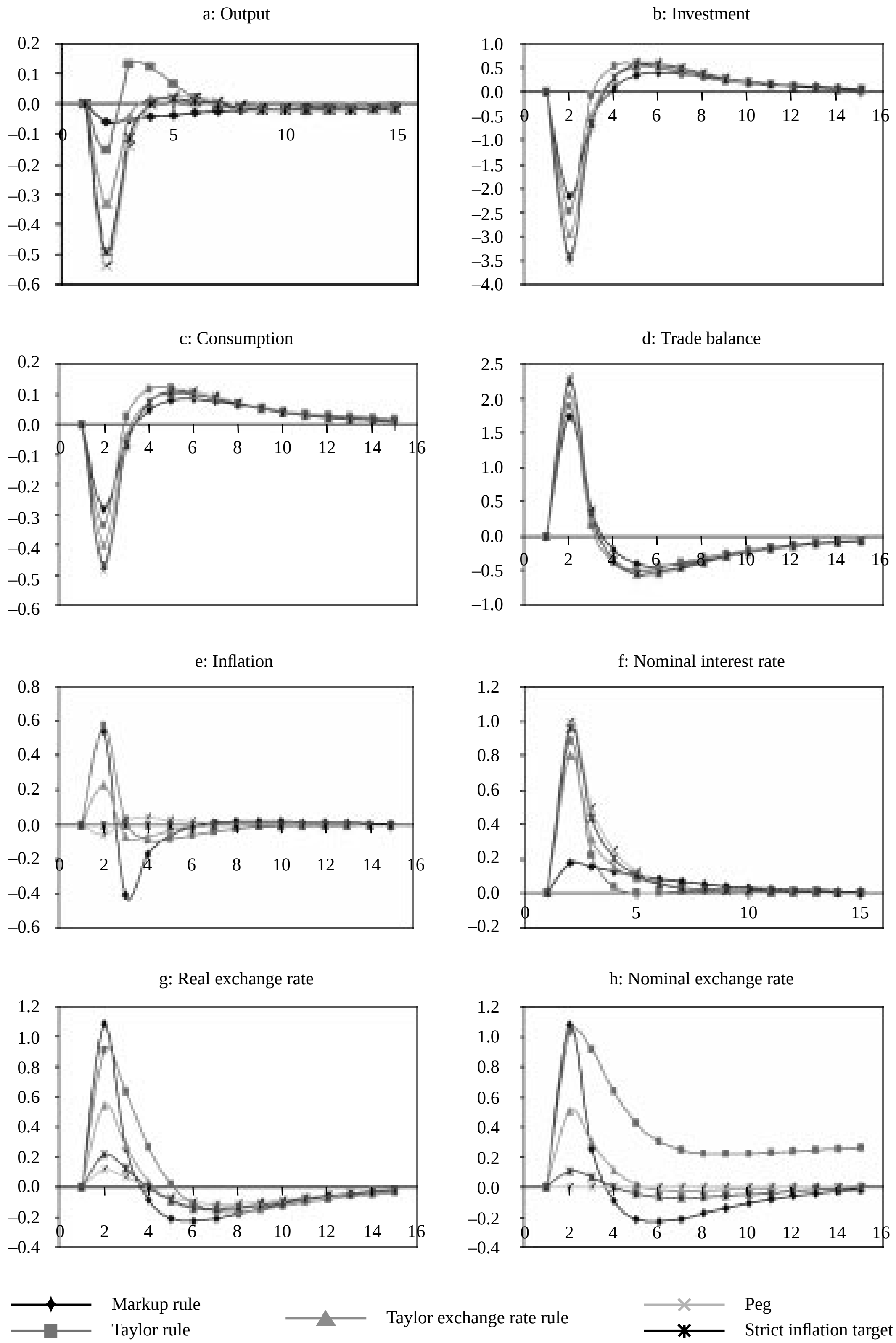
| | $\mu_{\pi n}$ | $\mu_{\pi}$ | $\mu_{y}$ | $\mu_{s}$ |
|---|---|---|---|---|
| Markup | $\to\infty$ | 0.0 | 0.0 | 0 |
| Taylor | 0 | 1.5 | 0.5 | 0 |
| Taylor (e rate) | 0 | 1.5 | 0.5 | 1 |
| Peg | 0 | 0.0 | 0.0 | $\to\infty$ |
| Price stability | 0 | $\to\infty$ | 0.0 | 0 |

resources in the economy. The interest rate disturbance reduces domestic absorption, generating a current account surplus. The fall in absorption also forces a real exchange rate depreciation, leading to a reallocation of factors from non-traded towards export good production. Thus, there is both an internal and external transfer. For all monetary policy rules, the same phenomenon is observed: absorption falls, the trade balance improves, and overall GDP falls.

But the magnitude of the response to an interest rate disturbance is affected quite strongly by the monetary rule. The response of the economy under a strict inflation target and a pegged exchange rate regime is almost the same. Domestic absorption falls by much more than under the markup rule or the two Taylor rules. Under the pegged exchange rate or the strict inflation target, the inflation rate is effectively stabilized. This means that the domestic real interest rate rises by the same magnitude as the exogenous foreign interest shock. However, the other three rules use the nominal exchange rate variability to cushion the real interest rate impact of the changes. The markup rule allows an immediate but transitory nominal exchange rate depreciation, which generates an expected appreciation. This dramatically limits the magnitude of the nominal interest rate rise. While the anticipated appreciation translates into an anticipated rate of CPI deflation, this is of a smaller magnitude than the anticipated appreciation itself. Figure 1g establishes that at the time of the shock, there is an expected real exchange rate appreciation, which reduces the real interest rate impact of the shock. But the expected real appreciation is much less for the fixed exchange rate rule and the price stability rule.

A clear implication of Figure 1, however, is that the monetary rules that provide stability in the real economy do so at the expense of inflation stability. The markup rule completely stabilizes the inflation rate in the non-traded goods sector, but requires high variability of the nominal exchange rate and therefore generates a highly volatile overall price level. There is a

**Figure 1**
**Interest rate shock—full pass-through**



trade-off between output stability and inflation stability. The trade-off can be seen most clearly by comparing the simple Taylor rule with the Taylor rule that includes an exchange rate response. The latter achieves a lower response of inflation, but at the expense of a higher first period fall in GDP.

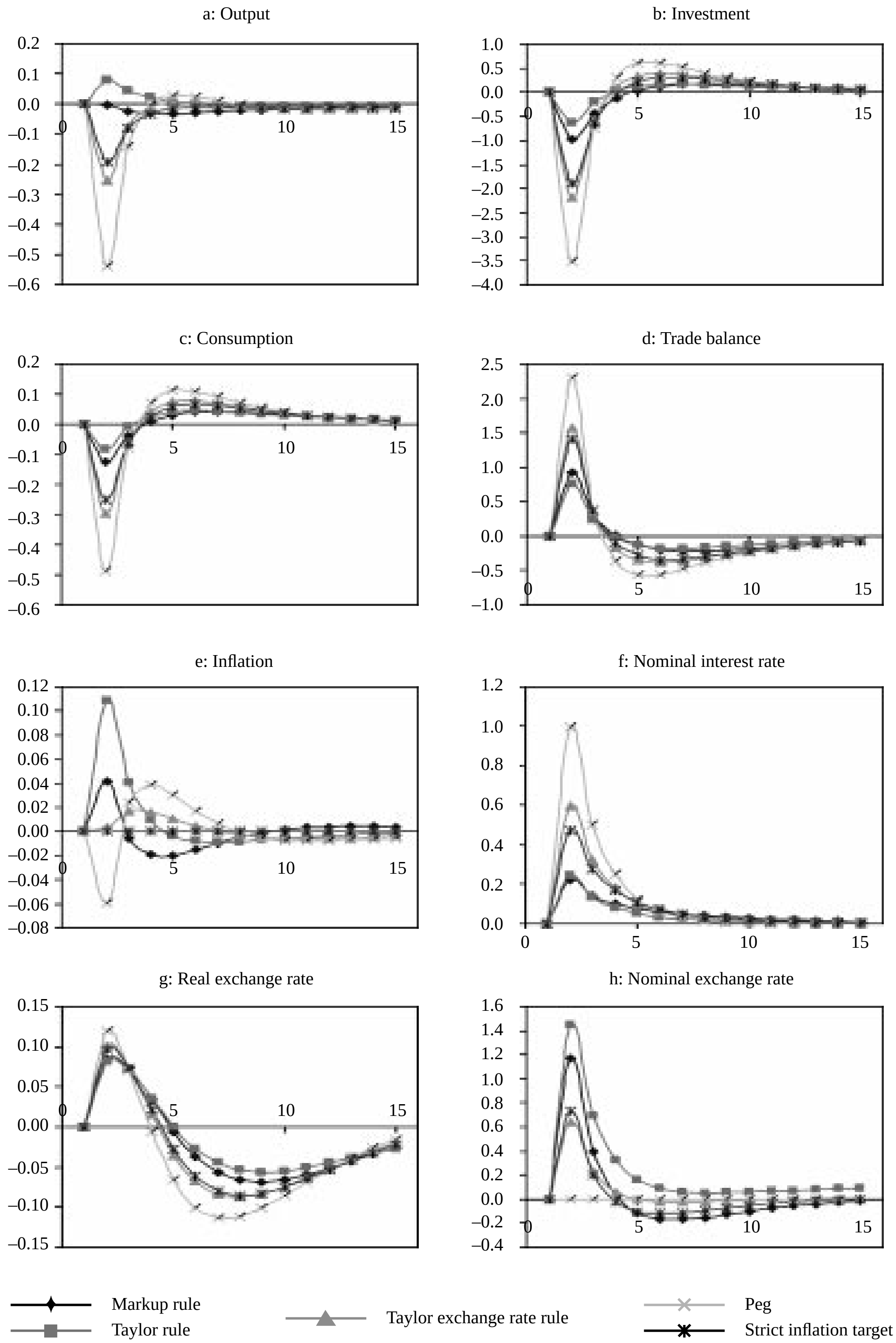
Figure 2 illustrates the case of delayed pass-through. With delayed pass-through, changes in exchange rates feed into the CPI only at the rate of overall price adjustment. Under the case of fixed exchange rates, the degree of pass-through is irrelevant, so the results are identical to those in Figure 2. For the markup rule and the two versions of the Taylor rule, however, the lower pass-through stabilizes the rate of inflation. Under the markup rule, the movement in inflation is only 10 per cent of the movement with immediate pass-through. This acts in two ways to stabilize the real economy. The muted impact on internal relative prices reduces the degree of expenditure switching and leads to a smaller contraction in non-traded goods production. But, the lower response of inflation now allows for a lower real interest rate response to the foreign interest rate shock. Under the markup rule, for instance, the expected rate of deflation in the period of the shock is much less than in the immediate pass-through model. This cushions the real interest rate response.

A further implication of the limited pass-through model is that it opens up a substantial difference between a price stability rule and the pegged exchange rate rule. The aggregate CPI can now be stabilized while still allowing significant movement in the nominal exchange rate. This implies, from Figure 2, that the goal of price stability is still consistently cushioning the nominal and real interest rate response to the shock. As a result, absorption and output under the price stability rule are much less variable than the pegged exchange rate rule.

Note that the flexible exchange rate monetary rules require very large nominal exchange rate variability. The nominal exchange rate response to the interest rate shock is higher than in the case of immediate pass-through. Thus, as observed in previous literature (Betts and Devereux 2000), limited pass-through tends to exacerbate exchange rate volatility. But it does so with consequences, since exchange rates do not immediately feed into CPI inflation.

The conclusion from this case is that in the presence of limited pass-through of exchange rate changes to import prices, there is no trade-off between output stability and inflation stability, at least in the response to interest rate shocks. A flexible exchange rate policy of the type analyzed here can

**Figure 2**
**Interest rate shock—delayed pass-through**



cushion the output response to an external interest rate shock without requiring more inflation instability. In fact, the (absolute) response of inflation is greater under a fixed exchange rate (which forces a deflation) than under the flexible exchange rate markup rule. Moreover, a rule following a goal of strict CPI price stability is still consistent with a stabilizing role for the nominal exchange rate.

## 2.3 Terms-of-trade shocks

Figures 3 and 4 describe the response of the model to terms-of-trade shocks. The shock is a 1 per cent fall in the terms of trade that persists with AR(1) coefficient 0.5. Figure 3 describes the model with immediate pass-through, while Figure 4 illustrates the case of delayed pass-through. We see that the general conclusions of the previous subsection apply. With immediate pass-through, the markup monetary rule stabilizes output and absorption, but does so by generating a high response of the exchange rate and of CPI inflation. The markup rule allows for a sharp, but transitory, nominal depreciation. The anticipated appreciation allows for a fall in the real and nominal interest rate. By contrast, the Taylor rule implies a persistent nominal depreciation. The nominal interest rate rises, and the real interest rate is unchanged. Again, the price stability rule and the pegged exchange rate rule are essentially the same.

With limited pass-through, Figure 4 shows that the real effects of the terms-of-trade shock are mitigated (for all rules except the pegged exchange rate). Given the very low inflation impact of the nominal depreciation, the Taylor rule becomes much more expansionary. In fact, all rules except the pegged exchange rate now generate a fall in the nominal interest rate. In terms of stabilizing output, consumption, and investment in response to the terms-of-trade deterioration, the Taylor rule and the price stability rules are essentially equivalent when there is limited pass-through.

Again, note that the nominal exchange rate responds by substantially more when there is limited pass-through, while inflation responds by substantially less. Thus, the trade-off between output stability and inflation stability disappears.

## 2.4 Price shocks

Figures 5 and 6 illustrate the impact of foreign price shocks. The price shock is modelled as a shock to the growth rate of foreign goods prices (both export and import), which leaves the terms of trade unchanged. Thus, letting

**Figure 3**
**Terms-of-trade shock—full pass-through**

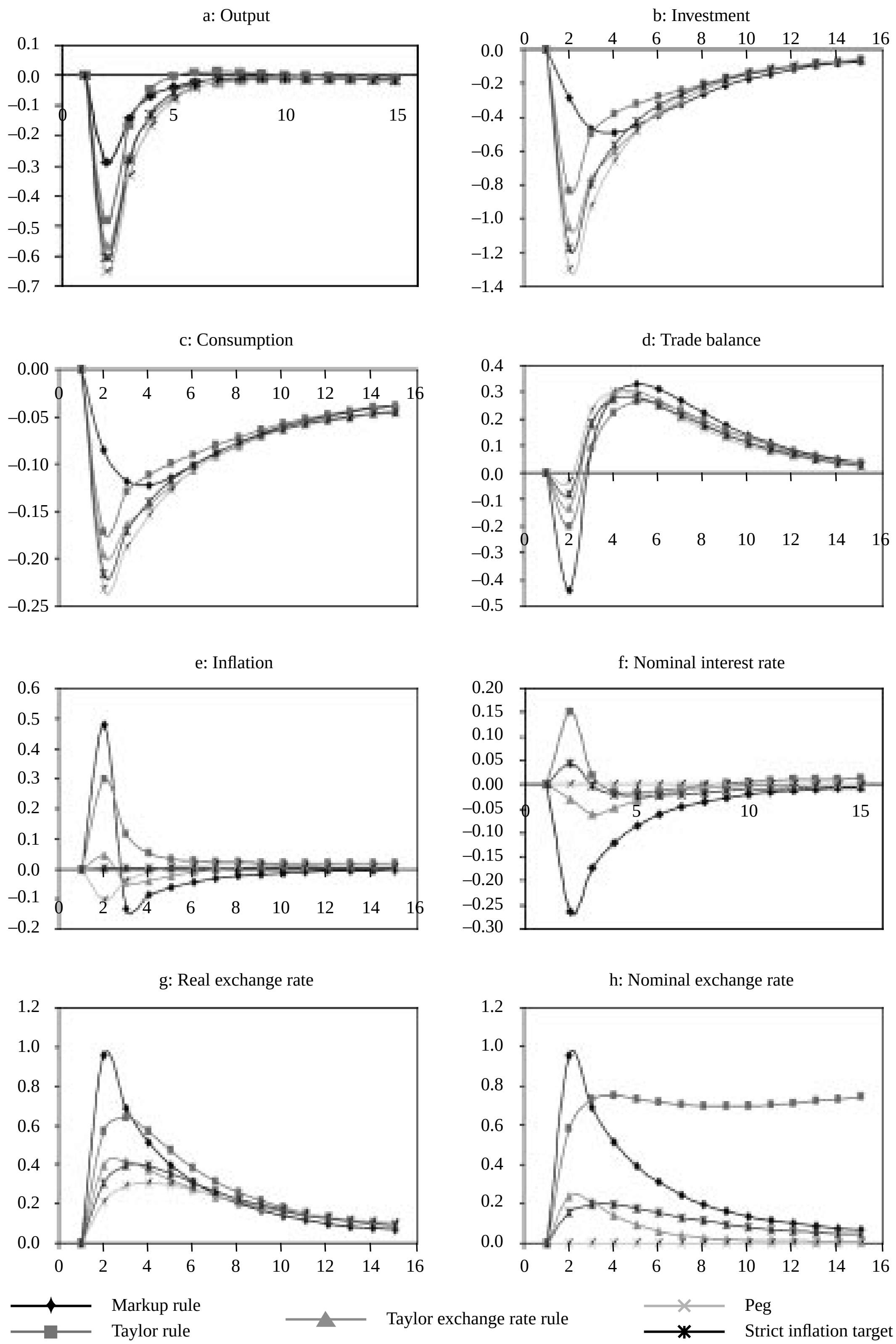


**Figure 4**
**Terms-of-trade shock—delayed pass-through**

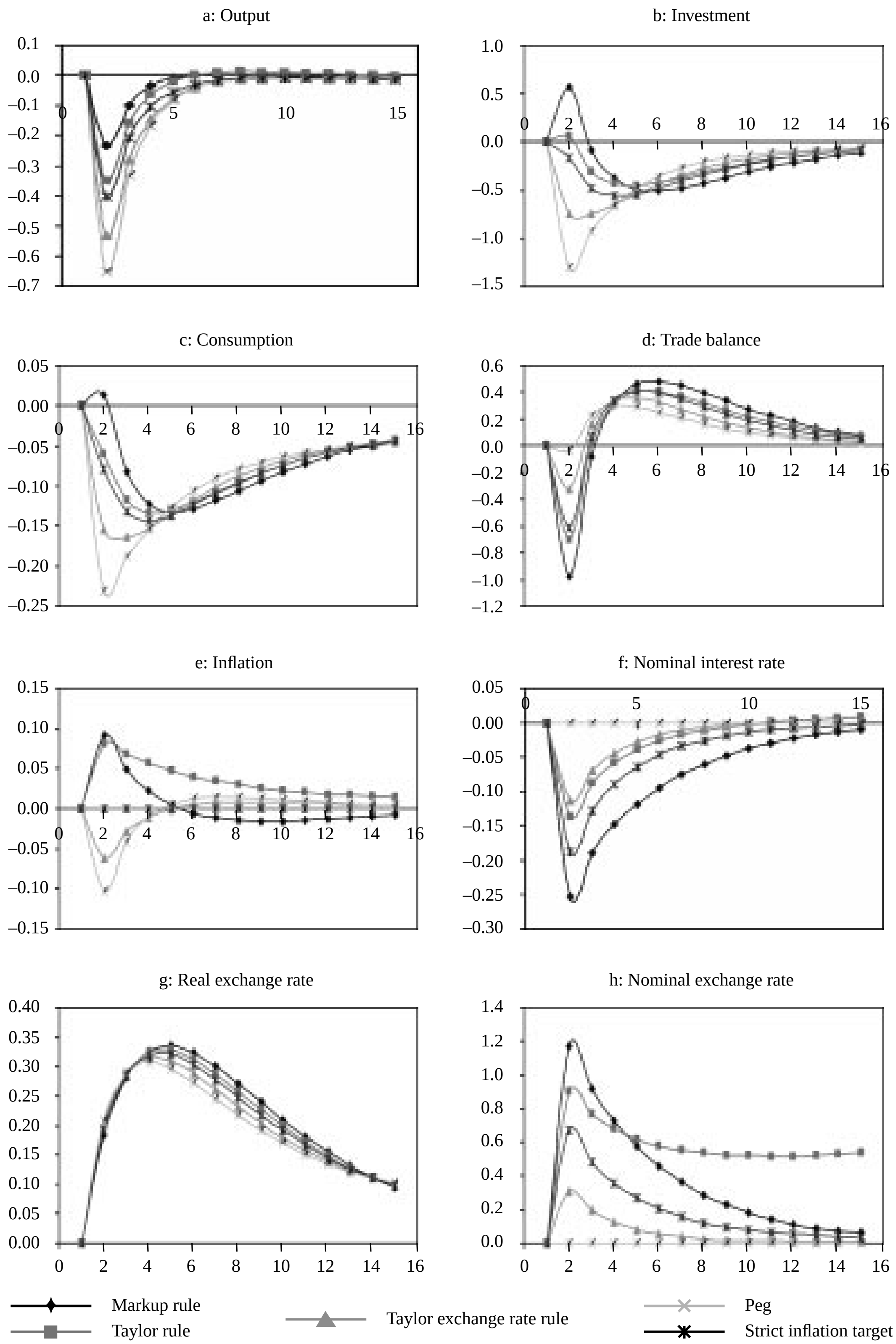


**Figure 5**
**Foreign price shock—full pass-through**

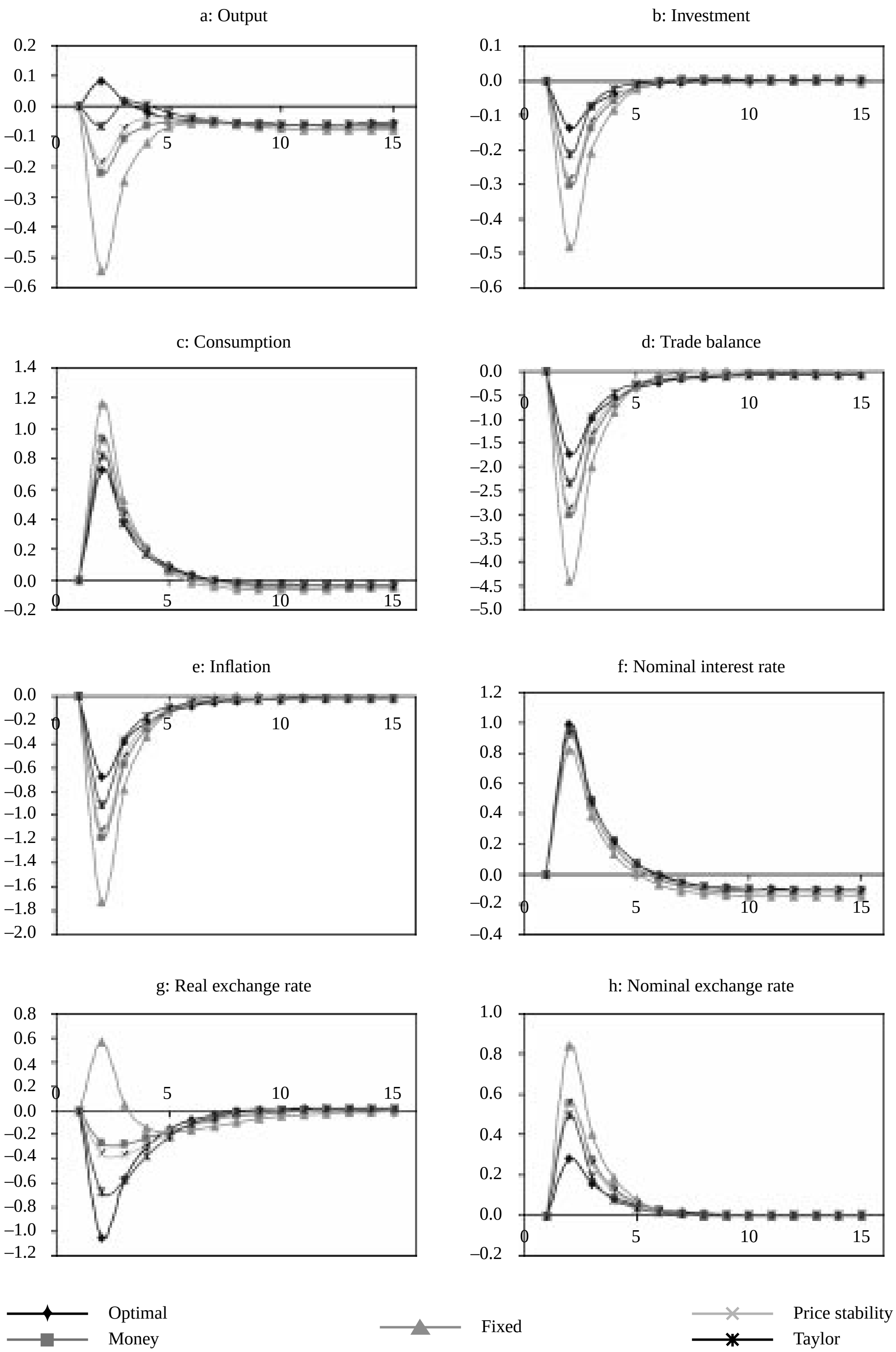
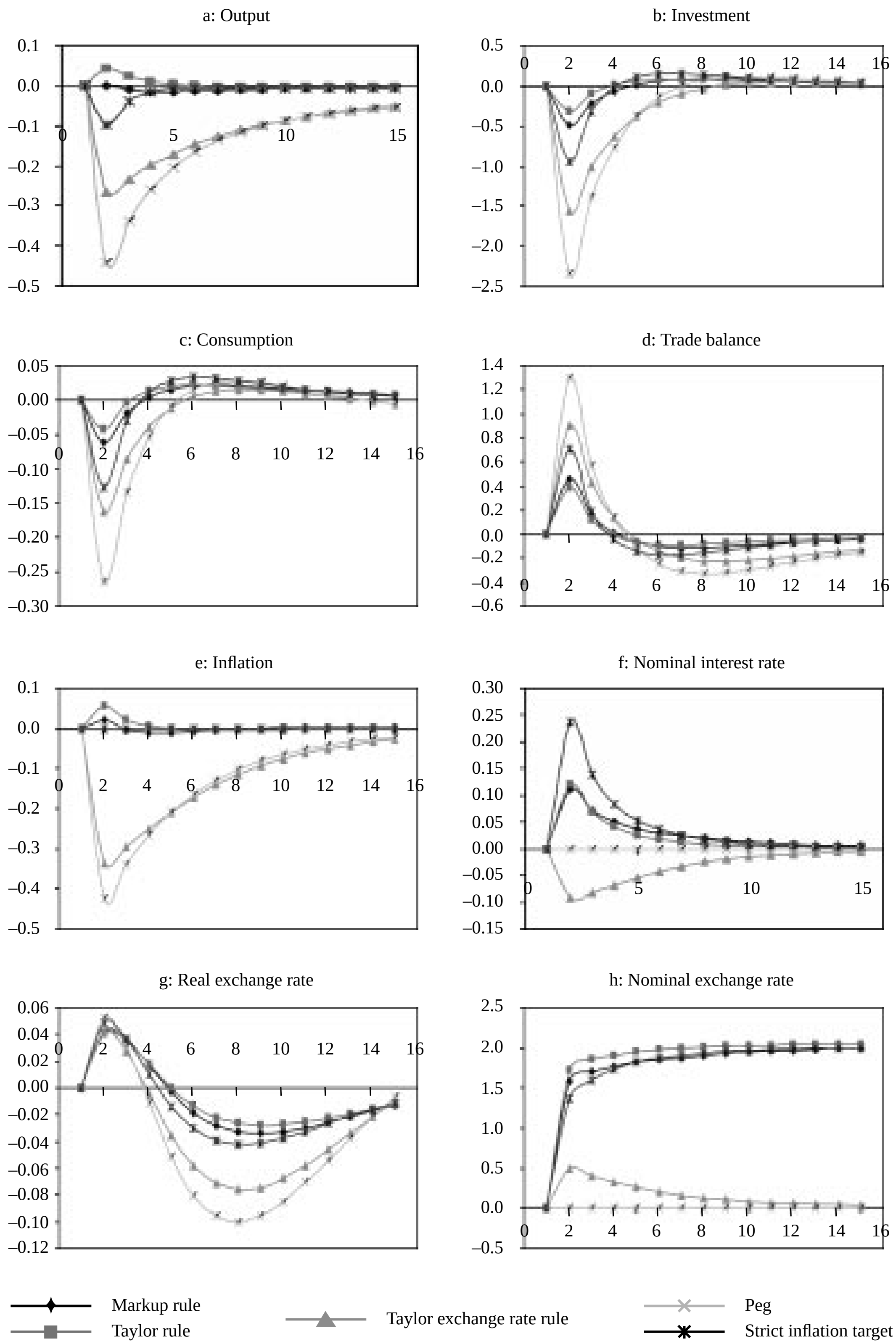


**Figure 6**
**Foreign price shock—delayed pass-through**



$\Delta P_t^* = \rho_1 \Delta P_{t-1}^* + \varepsilon_t$, Figure 5 illustrates the impact of a negative one-unit shock to $\varepsilon_t$ with $\rho_1 = 0.5$. The effect of this shock can be thought of as a combination of a level shift in the foreign price and a rise in the foreign real interest rate.[6] For the monetary rules that do not concern themselves with the nominal exchange rate (markup, Taylor, and price stability rules), the only impact of the price shock is a real interest rate increase. These rules require a permanent increase in the nominal exchange rate to offset the fall in the foreign price level. But in terms of real effects, the results for these rules are the same as in Figures 1 and 2. For the pegged exchange rate and the Taylor rule with exchange rate response, however, the nominal exchange rate is either kept constant or forced to return to its initial position. Both rules, therefore, imply a domestic deflation to restore equilibrium, and both require a greater fall in output than the other rules. In the case of external price shocks, nominal exchange rate stability is no longer consistent with inflation stability. The absolute response of inflation is greatest under a pegged exchange rate.

Again, as before, the effect of delayed pass-through is to reduce the inflationary impact of the foreign prices shocks, while stabilizing the real economy. Even a pegged exchange rate achieves some inflation stability following a foreign price shock, when pass-through is limited, since the direct impact of the price shock is not immediately felt in consumer prices.

## 2.5 Internal shocks

A common criticism of floating exchange rates is that they may be associated with destabilizing internal shocks arising from domestic monetary policy uncertainty. In the standard Mundell-Fleming analysis, the presence of domestic nominal disturbances may tip the balance in favour of an exchange rate peg, since such shocks can be effectively eliminated by fixing the exchange rate. Recently, Calvo (1999a) has made the point that monetary policy instability in Latin America may offer a strong case for the desirability of currency boards or dollarization.

What does the model imply about the effects of internal shocks? We may model such shocks as disturbances to interest rates associated with the

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6. To understand why the real interest rate must increase, imagine that the nominal exchange rate depreciated to keep the CPI constant in response to the declining path of foreign prices. This would leave the expected inflation rate unchanged, but would imply a positive expected rate of depreciation, increasing the nominal (and, therefore, real) interest rate.

rule (22). Such disturbances can be entirely offset by an exchange rate peg, since the interest rate must adjust to continually equal the foreign interest rate. Under a Taylor rule, however, such monetary shocks affect real output and consumption.

But, by stabilizing non-traded goods prices, the markup rule also completely insulates the economy from internal shocks to the interest rate process! This is easy to see. Since the markup rule replicates the equilibrium of a flexible price economy, it supports an economy where monetary neutrality holds. Shocks to the nominal interest rate process do not affect real interest rates or any real magnitudes. Thus, the markup rule provides the same insulation from internal interest rate shocks as does a pegged exchange rate. But since the markup rule does a much better job of insulating the economy from external shocks, it is therefore much preferable to a peg, at least when the authority does not display an extreme dislike of inflation volatility (as in the case of full pass-through).

## 3 Quantitative Analysis of the Effects of Alternative Monetary Rules

In this section, we investigate quantitative and welfare implications of alternative monetary rules. This requires a stand on the magnitude and importance of the shocks. The approach taken is as follows. The interest rate shock is identified as the U.S. prime rate. This is a reasonably good measure of the foreign interest rate that is faced by emerging markets. Of course, there may be country-specific risk premiums affecting the borrowing costs of many emerging markets. Calvo (1999b) also suggests that these country risk premiums may themselves be related to the monetary regime—reflecting the degree of perceived international confidence in a country's monetary or fiscal regime. But there are significant difficulties in the measurement of these premiums. Consequently, we abstract from these. While it is likely that the analysis therefore underestimates the magnitude of interest rate shocks affecting emerging markets, this would not substantially affect the trade-off between fixed and floating exchange rates, since greater interest rate volatility would not only increase the stabilization benefits of floating exchange rates but increase the implied inflation variability as well.

Terms-of-trade shocks are measured as the ratio of export-to-import price deflators. We take an average terms of trade for Asia from the International Financial Statistics (IFS) of the IMF. Finally, we measure imported goods price shocks as the U.S. dollar price of import goods for Asia, again from the IFS.[7] The three-variable system—consisting of prime, U.S. dollar import prices, and terms of trade—is estimated as autoregressive. The results are contained in Table 4; they are used to calibrate the shock processes for the model.

Table 5 illustrates the difference between the various monetary rules for the volatility of GDP, the real exchange rate, consumption, investment, inflation, marginal cost, and the nominal exchange rate. The top section shows the results in the case of full pass-through, while the bottom panel shows the case of limited pass-through. With full pass-through, there is an inverse relationship between output/consumption volatility and inflation/nominal exchange rate volatility. The markup rule minimizes output and consumption volatility, but produces very high inflation and nominal exchange rate volatility. Output and consumption volatility is highest under a pegged exchange rate, but inflation volatility is very small under this rule. In addition, the difference between a peg and a strict inflation target is quite small.

The model also suggests that the quantitative effects of exchange rate flexibility may be substantial. Using a Taylor rule stabilizes output by about 60 per cent, and stabilizes consumption by about 18 per cent, relative to a fixed exchange rate. Stabilizing non-traded goods inflation reduces output volatility by two-thirds, and consumption volatility almost by half, although inflation volatility is doubled, relative to the pegged exchange rate.

When pass-through is lagged, the results are sharply different. The rule that stabilizes non-traded goods inflation now minimizes both output/consumption volatility and inflation volatility. Thus, on this dimension, the markup rule dominates a pegged exchange rate. Output and consumption volatility is lower for the three rules that do not target the exchange rate. There is also much less of a difference between the markup rule, the Taylor rule, and the price stability rule as regards overall output volatility.

As suggested in the previous section, Table 5 illustrates that, for the floating exchange rate rules, nominal exchange rate volatility is much higher with lagged pass-through. Nominal exchange rate volatility increases by 15 to 20 per cent in all cases. At the same time, the real exchange rate, measured as the domestic relative price of non-traded goods, is far less volatile, since

7. The following Asian countries are considered: Hong Kong, India, Indonesia, Korea, Pakistan, Papua New Guinea, Singapore, Sri Lanka, and Thailand.

**Table 4**
**VAR estimates: Asia**

| Variable | Prime | Dlog (Pm) | Dlog (Px/Pm) |
|---|---|---|---|
| Prime (–1) | 0.89 | –0.002 | 0.0 |
| | (31.1) | (–1.61) | (0.3) |
| Dlog (Pm(–1)) | 6.2 | 0.35 | 0.047 |
| | (1.97) | (2.75) | (0.48) |
| Dlog (Px/Pm(–1)) | 5.63 | 0.13 | –0.17 |
| | (1.3) | 0.01 | (1.3) |
| C | 0.88 | 0.017 | –0.003 |
| | (3.2) | (1.59) | (–0.3) |

| Residual covariance matrix | Prime | Dlog (pm) | Dlog (Px/Pm) |
|---|---|---|---|
| Prime | 0.3 | 0.0027 | 0.0009 |
| Dlog (Pm) | 0.0027 | 0.00048 | –0.00017 |
| Dlog (Px/Pm) | 0.001 | –0.00017 | 0.00028 |

**Table 5**

| | | Markup | Taylor | Taylor (e rate) | Peg | Price stability |
|---|---|---|---|---|---|---|
| Full pass-through | $\sigma_y^2$ | 0.5 | 0.9 | 1.1 | 1.5 | 1.3 |
| | $\sigma_{rer}^2$ | 3.9 | 2.8 | 1.9 | 1.6 | 1.2 |
| | $\sigma_c^2$ | 1.5 | 1.9 | 2.0 | 2.3 | 2.2 |
| | $\sigma_\pi^2$ | 3 | 2.3 | 1.1 | 1.5 | 0.0 |
| | $\sigma_s^2$ | 4.9 | 4.5 | 1.8 | 0.0 | 2.8 |
| | Expected utility | –55.6793 | –55.6819 | –55.6874 | –55.689 | –55.6871 |

| | | Markup | Taylor | Taylor (e rate) | Peg | Price stability |
|---|---|---|---|---|---|---|
| Limited pass-through | $\sigma_y^2$ | 0.6 | 0.7 | 1.0 | 1.5 | 0.7 |
| | $\sigma_{rer}^2$ | 0.7 | 0.8 | 0.8 | 0.8 | 0.8 |
| | $\sigma_c^2$ | 0.8 | 1.0 | 1.8 | 2.3 | 1.4 |
| | $\sigma_\pi^2$ | 0.3 | 0.9 | 0.6 | 0.9 | 0.0 |
| | $\sigma_s^2$ | 5.8 | 5.9 | 1.9 | 0.0 | 4.0 |
| | Expected utility | –55.6771 | –55.6796 | –55.6832 | –55.69 | –55.6784 |

both non-traded prices and export good prices adjust much more slowly in response to all shocks.

Finally, Table 5 also includes welfare calculations across monetary rules. These are calculated by averaging repeated draws of utility over 100 quarters, evaluated at the consumer's discount factor.[8] In the case of full pass-through, the markup rule and the Taylor rule are almost equivalent, although the markup rule results in slightly higher utility. Both rules are clearly better, in utility terms, than the Taylor rule with exchange rate response, the pegged exchange rate rule, or the price stability rule. Again, with delayed pass-through, the markup rule leads (marginally) to highest utility. Utility is higher in this case for the markup rule, the Taylor rule, and the price stability rule. Also note that with delayed pass-through, the price stability rule gives utility almost the same as the markup and Taylor rules. In utility terms, therefore, a price stability rule does much better in a regime of limited pass-through.

These results confirm the general message of the paper: the fixed versus floating exchange rate trade-off is substantially different in an economy with high pass-through of exchange rates to traded goods prices than in an economy where pass-through is delayed. Given that pass-through is likely to be much faster in emerging markets, for reasons of policy credibility or small size, this makes the choice of fixed versus flexible exchange rates quite different for emerging markets than for advanced economies.

## Conclusions

We have described the monetary policy trade-off between regimes that target the exchange rate and those that allow the exchange rate to adjust freely. Our main result is that the trade-off depends sharply on whether there is a high degree of pass-through from exchange rates to import good prices. A secondary result is that a policy of strict inflation targeting is much easier to implement in an economy with lagged pass-through, since the CPI can be stabilized without destabilizing the real economy. Finally, we outline a simple and efficient monetary policy rule for an open economy that is a

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8. As in other literature (e.g., Obstfeld and Rogoff 1995b), the utility of real balances is ignored in this calculation. The utility estimates could be transformed into consumption-equivalent comparisons across the different policy regimes. But, as is well-known in this literature (e.g., Lucas 1987), the magnitude of welfare differences across different regimes in business cycle models is extremely small. Thus, we merely report the rankings of utility across regimes.

natural extension of work with sticky prices in the closed-economy literature. This rule simply stabilizes the non-traded goods price level.

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# Discussion

*Kevin Moran*

## General Comments

I read the paper with great interest. And I think it contains enough to keep people at the Bank of Canada occupied for months—even years—with refining, detailing, and analyzing all relevant aspects of the model. A lot can be accomplished with this approach, and one hopes that work using this model as one of the basic set-ups will continue at the Bank.

It is a small open economy model, with non-traded and traded goods, price-taking at the traded-goods level, and sticky-price behaviour at the non-traded goods level. There are three types of external shocks: a world interest rate shock, a terms-of-trade shock, and a world price shock. The set-up could easily be expanded to accommodate domestic shocks (in money demand or technology).

The paper analyzes several possible monetary rules, arising from either an exchange rate pegging framework or from a flexible exchange rate spirit (Taylor rule, Taylor rule reacting to the exchange rate, inflation targeting, and targeting of inflation in non-traded goods). The paper stresses that we are not faced with a choice between fixed and flexible exchange rates, but rather with a choice between fixed exchange rates and the many possible policies compatible with flexible exchange rates.

The paper argues that if you have i) domestic price rigidity, ii) little or no pass-though from movements in the nominal exchange rate to domestic inflation, but iii) these movements still influence interest rates through uncovered interest parity (UIP), then monetary policy possesses some elements of a free lunch, because the nominal exchange rate movements can be used to cushion external shocks without causing inflation. If, on the other hand, pass-through from these exchange rate movements is immediate, the cushioning of external shocks comes at the expense of inflation, and the usual trade-off between variability in inflation and variability in output must be confronted.

## What About Money?

Money is determined as a residual in the analysis and not even presented in the graphs: that hurts! More seriously, why would I want to see what happens to *M*? There are two reasons.

First, taking the model as a positive exercise (possibly by using some estimated rule from the data, as in Clarida, Galí, and Gertler 1998), I could check whether the model replicates the usual two stylized facts: money leads output, and money is negatively (contemporaneously) correlated with nominal interest rates.

Second, in a world where *M* is mostly endogenous (created by banks), we would have (real) money related to loans and to real activity. Could the fact that most of *M* appears in the economy as the counterpart to loans constrain monetary policy rules and thus modify the best reaction of monetary policy to shocks?

## UIP and Exchange Rate Risk

A central feature of the model is that in reaction to outside shocks, monetary authorities can let the currency depreciate rather than modify domestic interest rates (the UIP hypothesis). The model, however, contains no puzzling behaviour from capital markets or exchange rate markets and probably contains very little exchange rate risk as defined by Engel (1999) (forward rates are more than likely very close to future spot rates). With regard to the conduct of monetary policy in practice, this may be an over-optimistic statement that introduces a bias against a policy of pegging the exchange rate.

One way to assess the extent of this potential problem is to add some noise to the nominal exchange rate. The chartists and fundamentalists of the foreign exchange market, as envisioned in this volume's Djoudad et al. model, could well provide that noise.

This may be an unfair criticism of the paper, since these problems affect the majority of open economy models I have seen. It would be interesting to know, however, the author's views on the significance of the failure of most models to generate significant amounts of exchange rate risk. Should this be an important avenue of research? Five years ago, it seemed that the observed high variability of the real and nominal exchange rate was incompatible with optimizing models. Now, thanks to the work of Devereux and others, it appears that this problem has, to a large extent, been resolved. Should exchange rate risk be next?

## Small Open Economy

From my understanding, small open economy models with infinitely lived agents have problems with net foreign assets. These models do not lead to a unique determination of those assets in the steady state, and any level for those assets is consistent with a different steady state. This problem was among the factors that led the Bank of Canada to adopt an overlapping generations (OLG)-based framework as the basis of its main policy model. How, then, should this problem be taken care of?

If this constituted a problem, should it be reported in the simulations? What was the starting point—where net foreign assets are zero? And does it matter for the computations of expected utility? If an economy is, on average, in debt, decreases in world interest rates have positive income effects; whereas, if an economy is, on average, a net creditor, such decreases may carry negative income effects.

## Welfare Measures and Unstable Rules

The paper states that the expected utility is not transformed into its consumption equivalent, because these numbers would be too small. However, the paper still goes on to comment on the rankings of rules according to the expected utility (alongside the more common ranking according to the variability of inflation and output) they imply. This step puzzles me. The facts are that, according to our utility functions, people are virtually indifferent to modest fluctuations and, therefore, smoothing out these fluctuations cannot significantly increase their welfare.

What can be done? If we think that fluctuations *do* matter, utility functions be damned, why not produce relative measures, i.e., measure the cost of a period of wild fluctuations (from 1929 to 1945, for example) and report our subsequent welfare measures in GDEUs (Great Depression-equivalent units).

Or maybe the role of good monetary policy rules is not to further smooth out fluctuations that are already fairly smooth, but rather to avoid bad outcomes, such as when the economy embarks on a path of self-fulfilling, explosive inflation (maybe as a result of the “expectations-trap” circuit described in

Christiano and Gust 2000). Including unstable rules in the analysis alongside the stable one analyzed here might produce more dramatic welfare results.

## Exchange Rate Pass-Through and Fixed Prices

Devereux's paper makes the case that in some countries (Mexico is used as an example), the pass-through from exchange rates to prices is immediate; therefore, it includes simulations where $\kappa^*$ is zero, while leaving $\kappa$ constant. This means that Mexican importers immediately adjust their prices to changes in their costs, but Mexican producers of non-traded goods still do not. Is this a valid experiment? The data may say otherwise, but I would have thought that in Mexico, whether they come from exchange rate or domestic marginal costs, all cost shocks would be transferred rather quickly to prices so that the correct experiment may be to lower both $\kappa$ and $\kappa^*$.

This leads us to the process of fixing prices. What exactly is it? Do $\kappa$ and $\kappa^*$ represent a structural/technological constraint? Or are they related to the monetary policy rule? Taylor (2000) argues that the pass-through from cost shocks to prices is related to monetary policy, and that good rules will be characterized by firms not passing through the cost increase, because they know it will be transitory. This leads me to once again suggest that the inclusion of bad (i.e., unstable) rules would be helpful because, in such a world, firms might immediately increase prices when shocks to the exchange rate occur, since they fear the depreciation will last a long time.

The type of pass-through occurring in an economy is an important factor in the determination of the best monetary policy rule. For this reason, there is an urgent need for reliable and comprehensive theories of price rigidity. The literature seems to have explored only a few of Blinder's (1994) 12 possible reasons why firms don't increase prices quickly. Perhaps some of the neglected theories are worth a second look.

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# General Discussion

Serge Coulombe wondered about the regional impact of flexible exchange rate movements in response to terms-of-trade changes. Lawrence Schembri replied that the adjustment of the flexible nominal exchange rate still preserves the relative price change and, thus, the incentive for inter-industry adjustments, which may have a regional impact.

Simon van Norden noted that there may be first- as well as second-moment effects of a fluctuating nominal exchange rate. Could foreign exchange risk premiums, for example, alter the cost of capital for an open economy under flexible exchange rates? Schembri agreed that such an effect could exist, particularly for countries with high stocks of foreign debt. Michael Devereux argued that a credible monetary rule should not be expected to lead to a substantial risk premium. David Longworth, commenting on Michael Devereux's paper, noted that the non-optimizing literature tends to give similar results. He added that one of the justifications for using core inflation rates is specifically to ignore or to minimize the effects of pass-through, which may be easier to accomplish in more mature economies. Emerging economies, on the other hand, must deal with the price index people use—which is typically the CPI.

Charles Freedman questioned Devereux's assumption that pass-through is low in mature economies. He argued that this is conditional on the credibility of monetary policy, which affects the anchoring inflationary expectations. The important distinction, therefore, may be between more and less stable inflationary expectations, rather than between mature and emerging economies.

Kevin Clinton noted that there have been big reductions in inflation in some emerging economies. He wondered whether pass-through may have been correspondingly reduced and its extent overestimated by the data from the transition from high to low inflation periods.

Devereux agreed that the extent of pass-through is endogenous. According to his model, however, it should not matter how high the average rate of inflation is. If markets are competitive and there is pass-through, a large estimated pass-through coefficient should be obtained by the regression, whether or not there is high inflation. He also thought that the pass-through estimates were biased upwards by high inflation countries in the sample.

Michael Bordo suggested that in the past, monetary shocks were a large part of the story. Schembri, however, argued for a focus on commodity price shocks, since they are likely to be more relevant to the current environment of fluctuating commodity prices and stable central bank policies.