THE ADVANTAGE OF TYING ONE'S HANDS: REVISITED[‡]

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ABSTRACT

Fixing the exchange rate is often seen as an appealing strategy to gain credibility and keep inflation under control. But what is the impact of this policy on welfare? We answer this question using a microfounded, New Keynesian monetary model for a small open economy, to study the outcome of three alternative strategies for a central bank that targets both output and inflation: a policy of pure commitment; a discretionary policy where the exchange rate is free to fluctuate; and a strategy that pegs the nominal exchange rate. We first compare their impact on the policymaker's rule-of-thumb, quadratic objective and then on the agent's utility. In contrast to previous work, in which the policymaker maximizes a rule-of-thumb function, time-consistent monetary policy leads to a lower loss than a policy that ties the policymaker's hands by stabilizing the exchange rate. However, the strategy that fixes the exchange rate is ranked first when the policymaker maximizes the agent's utility. Copyright © 2007 John Wiley & Sons, Ltd.

1. INTRODUCTION

A key issue in open economy macroeconomics is whether a central bank should 'tie its hands' by pegging the domestic price of a foreign currency. Recent international developments show that it is difficult to formulate final recommendations. For instance, the Annual Report on Exchange Rate Arrangements and Exchange Rate Restrictions produced by the IMF points out that there have been significant movements in the evolution of exchange rate regimes but it is hard to relate those with specific country conditions. A way to identify what conditions may provide an incentive for a central bank to 'tie its hands' is to use economic theory. In principle, a stable exchange rate allows the policymaker to import credibility from a foreign economy, but can be obtained only at the price of reduced independence in monetary policy. An article by Giavazzi and Pagano (1988), 'The Advantage of Tying One's Hands', first addresses this issue in the context of the European Monetary System. Now the debate over stable versus free-to-float exchange rates needs to be reconsidered in light of the development of the literature on the credibility of monetary policy, of the evolution of the concept of stable exchange rates, and of the new theoretical framework used to perform macroeconomic analysis. In this paper, we reconsider the advantage of tying the monetary authority's hands, incorporating these points in the analysis as follows. First, as emphasized in Clarida *et al.* (1999), when considering a flexible exchange rate regime, the monetary authority needs to determine whether there may be gains from enhancing credibility, either through formal commitment to a policy rule or through a

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discretionary policy that achieves roughly the same end. While Giavazzi and Pagano (1988) assume that the monetary authority has perfect commitment, we investigate both these alternatives. Second, in line with recent literature such as Benigno *et al.* (2006) and Husain *et al.* (2005), we refer to a 'stable exchange rate' as a regime in which the central bank maintains a hard peg to a foreign currency. Giavazzi and Pagano (1988) apply the concept of a stable exchange rate to a soft peg regime where the monetary authority maintains an exchange rate mechanism with a free-to-float real exchange rate inside fixed parities. This type of exchange rate arrangement has lost its practical appeal in recent years.[1] Third, to perform this exercise we use a microfounded, dynamic, stochastic, general equilibrium, New Keynesian model for a small open economy based on McCallum and Nelson (1999) and Galì and Monacelli (2005), in which monetary policy is endogenously modelled, with the nominal interest rate as the policy instrument. Giavazzi and Pagano (1988) develop the analysis using an *ad hoc* determinist macroeconomic framework with no real effects for monetary policy. Our setting allows for richer dynamic effects of monetary policy and exchange rate regimes.

The identification of the optimal strategy for the exchange rate regime depends on the system of instruments, intermediate targets and final goals adopted by the policymaker. We assume the central bank is a benevolent institution. However, even within the economists that claim in favour of public interest, it is not granted what objective function the policymaker should elect in order to compare different policies. Rotemberg and Woodford (1997, 1999) and Woodford (2003, Chapter 6), in a closed-economy context, derive the objective function from a quadratic Taylor approximation of the representative agent's utility. In the open economy context, such an approximation is possible only under very specific assumptions as stressed in Clarida *et al.* (2002). Hence, the objective functions commonly employed in the Open Economy Macroeconomics literature are either a rule-of-thumb that has inflation and output as objectives or the unconditional expected value of the representative agent's utility.[2] In this paper, we adopt both specifications to define the monetary authority's objective function and compare the outcome of three alternative monetary policy strategies: a discretionary policy; a policy that credibly commits to the optimal rule where the exchange rate is free to float; and a monetary strategy with a pegged exchange rate. The analysis leads itself to two interesting insights. First, in the case in which the monetary authority has a rule-of-thumb quadratic loss function, a flexible exchange rate regime with formal commitment to a policy rule becomes the dominant alternative. This differs from the results in Giavazzi and Pagano (1988), where a fixed exchange rate dominates the other alternative. Second, a central bank that instead aims at improving the representative agent's welfare should choose a fixed exchange rate over discretionary policy.

The findings of our paper are robust to alternative calibrations of the structural parameters of the model, except for changes in the degree of openness of real markets. Indeed, the ranking between the discretionary policy and the pegged exchange rate strategy is affected by the size of the degree of openness. When this parameter is not small, as suggested in Soffritti (2002), a time-consistent monetary policy leads to a lower loss for the central bank than in the case in which the nominal exchange rate is pegged.

The paper is organized as follows. Section 2 derives the model and presents the rule-of-thumb monetary authority loss function. Section 3 discusses the equilibria under the three alternative monetary regimes. Section 4 presents the baseline calibration for the structural parameters. Section 5 compares the three alternatives when both the central bank loss and utility-based functions are used as a ranking criterion. Section 6 concludes.

2. THE MODEL

The model combines elements of the open-economy framework in McCallum and Nelson (1999) and Galì and Monacelli (2005). More specifically, this paper undertakes the optimizing IS-LM specification in McCallum and Nelson (1999), while it mainly shares the small open economy framework by Galì and Monacelli (2005) for the rest of the model. We allow for a continuum of firms defined on [0,1], a representative household, and a monetary authority. Only final goods are produced and consumed in the home economy, which also trades with the rest of the world. The monopolistic competitive firms experience

price rigidities as in Calvo (1983). Monetary policy is conducted by setting the nominal interest rate. Financial markets are complete.[3]

2.1. Prices

Let S_t be the nominal exchange rate (i.e. the domestic price of one unit of foreign currency) and Q_t be the real exchange rate. Thus, s_t and q_t satisfy $q_t \equiv s_t + p_t^* - p_t$, where p_t and p_t^* are the consumer price indices in the domestic and foreign economies, respectively. The first difference of the last equation yields

$$\Delta s_t = \Delta q_t + (\pi_t - \pi_t^*) \tag{1}$$

where $\pi_t \equiv p_t - p_{t-1}$ and $\pi_t^* \equiv p_t^* - p_{t-1}^*$ are domestic and foreign consumption price index (CPI) inflation rates. We define the terms of trade (in logs), $\log V_t$, as $v_t \equiv p_{F,t} - p_{D,t}$, where the term v_t is the price of the basket of imported goods in units of domestic goods, and $p_{F,t}$ and $p_{D,t}$ are the level of foreign and domestic price, respectively. Since the home economy is small, the variables characterizing the rest of the world can be constructed to be exogenous and independent of domestic policy. We therefore assume that the share of imports in the consumption basket of the rest of the world is negligible. Hence, $C_t^* \cong C_{F,t}^*$ and $P_t^* \cong P_{F,t}^*$. We make the same assumption about the share of domestic bonds held by foreign investors.

Firms produce output to meet aggregate demand and set the price in the currency of the country where they are located. The Law of One Price holds, so that $S_t P_{D,t}^*(j) = P_{D,t}(j)$ and $S_t P_{F,t}^*(j) = P_{F,t}(j)$, for $j \in [0,1]$. Given these assumptions, the real exchange rate can be written as $q_t = p_{F,t} - p_t = v_t + (p_{D,t} - p_t)$.[4]

To generate real effects of monetary policy we introduce price rigidities as in Calvo (1983). Let $\bar{p}_{D,t}(j)$ be the optimal log-price set at time t by domestic firm j. The possibility of a price adjustment is distributed as a Poisson random variable with parameter $0 \leqslant \vartheta \leqslant 1$. At each time t, there is a constant probability ϑ that a given firm j in the home economy adjusts its price. Therefore, ϑ^h ($h > 0$) is the probability that $\bar{P}_{D,t}(j)$ is the firm j's price at time $t + h$. Under this setting, $p_{D,t}$ satisfies

$$\bar{p}_{D,t+1} = [p_{D,t} - \vartheta p_{D,t-1}]/(1 - \vartheta) \tag{2}$$

where $\bar{p}_{D,t} = \bar{p}_{D,t}(j)$ holds under symmetry in price setting.

2.2. The domestic household

The representative household's utility depends positively on consumption and real money balances. Time spent at work reduces utility. The representative household is a price-taking agent in the markets for commodities and labour. Preferences are additive and time separable. The representative household maximizes the utility function

$$\max E_t \left\{ \sum_{h=0}^{\infty} \beta^h [C_{t+h}^{1-\sigma}/(1-\sigma) - N_{t+h}^{1+\tau}/(1+\tau) + \chi \ln(M_{t+h}/P_{t+h})] \right\} \tag{3}$$

with respect to consumption, C_{t+h}, employment, N_{t+h}, and real money balances, M_{t+h}/P_{t+h}. Parameters σ and τ represent the elasticities of marginal utility with respect to consumption and labour supply, respectively. Parameter β is the discount factor.

The timing of the events is as follows: the representative household enters time t with M_t nominal money balances; bond markets open; and cashes financial assets from previous period, B_t. It receives labour remuneration, $W_t N_t$, buys consumption goods, $P_t C_t$, and receives nominal transfers, T_t. The representative household also carries nominal money, M_{t+1}, into time $t + 1$ and invests in discounted final assets carried into time $t + 1$, $B_{t+1}/(1 + i_t)$. The term i_t represents the nominal interest rate at time t. The budget constraint that captures this sequence is

$$M_{t+1} = M_t + T_t - B_{t+1}/(1 + i_t) + B_t + W_t N_t - P_t C_t \tag{4}$$

Since consumption can be either in domestic or foreign goods, the price of one unit of consumption satisfies

$$\int_0^1 P_{D,t}(j) C_{D,t}(j) \, dj + \int_0^1 P_{F,t}(j) C_{F,t}(j) \, dj = P_{D,t} C_{D,t} + P_{F,t} C_{F,t} = P_t C_t$$

where

$$C_t \equiv [(1-\lambda)^{1/\eta} C_{D,t}^{(\eta-1)/\eta} + \lambda^{1/\eta} C_{F,t}^{(\eta-1)/\eta}]^{\eta/(\eta-1)}$$

parameter λ represents the share of total consumption allocated to imported goods, and parameter $\eta > 0$ represents the constant intratemporal elasticity of substitution between domestic and foreign bundles.[5] The indices $C_{F,t}$ and $C_{D,t}$ are defined in terms of the commodities produced by different firms of the same economy as $C_{D,t} \equiv (\int_0^1 C_{D,t}(j)^{(\delta-1)/\delta} \, dj)^{\delta/(\delta-1)}$, $C_{F,t} \equiv (\int_0^1 C_{F,t}(z)^{(\delta-1)/\delta} \, dz)^{\delta/(\delta-1)}$. Parameter $\delta > 1$ captures the constant elasticity of substitution across different commodities of the same basket. The CPI that results from minimizing the expenditure needed to buy one unit of consumption, C_t, ought to satisfy $P_t \equiv [(1-\lambda)P_{D,t}^{1-\eta} + \lambda P_{F,t}^{1-\eta}]^{1/(1-\eta)}$. The CPI P_t can be derived from the definition of C_t and is not exogenously assumed.

Under the assumption that the terms of trade, at the steady state, satisfy $V = 1$, the last equation leads to the following relationship, written in log-linear terms:

$$p_t - p_{D,t} = \lambda v_t \tag{5}$$

If we define the producer price index (PPI) for the domestic economy as $p_{D,t} - p_{D,t-1}$, equation (5) yields

$$\pi_t = \pi_{D,t} + \lambda \Delta v_t \tag{6}$$

and it shows that CPI and PPI inflation are linearly related along with the change in the terms of trade.

The domestic household optimally chooses $C_{D,t}$ and $C_{F,t}$ to satisfy the demand functions $C_{D,t} = (1-\lambda)C_t(P_{D,t}/P_t)^{-\eta}$ and $C_{F,t} = \lambda C_t(P_{F,t}/P_t)^{-\eta}$, which, in log-linear terms, become $c_t - c_{D,t} = -\lambda \eta v_t$ and $c_t - c_{F,t} = \eta(1-\lambda)v_t$. The last two equations can be combined with (5) to produce $c_t - c_{F,t} = \eta \ (p_{F,t} - p_t)$, implying that, *ceteris paribus*, when the CPI index increases relative to the foreign price index, total consumption must decrease relative to $c_{F,t}$.

The representative household maximizes utility (3) subject to the budget constraint (4). First-order conditions with respect to C_t and N_t yield

$$1/R_t = \beta P_t C_t^\sigma E_t(C_{t+1}^{-\sigma}/P_{t+1}) \tag{7}$$

and

$$C_t^{-\sigma} W_t/P_t = N_t^\tau \tag{8}$$

Equation (7) in log-linear terms leads to the New Keynesian IS curve that relates aggregate consumption to the risk-free real domestic interest rate

$$c_t = E_t(c_{t+1}) - 1/\sigma[r_t - E_t(\pi_{t+1})] \tag{9}$$

To complete the description of the real demand side of the domestic economy, we define indices for total output and labour supply as $Y_t \equiv (\int_0^1 Y_t(j)^{(\delta-1)/\delta} \, dj)^{\delta/(\delta-1)}$ and $N_t \equiv (\int_0^1 N_t(j)^{(\delta-1)/\delta} \, dj)^{\delta/(\delta-1)}$. As in Gali and Monacelli (2005), we assume that, under complete risk sharing, the market clearing condition for good j is $Y_t(j) = C_{D,t}(j) + C_{D,t}^*(j)$, for each $j \in [0,1]$. This leads to an equation for the differential between domestic and foreign output as $y_t - y_t^* = (1-\lambda)/\phi\sigma v_t$, where, under the standard calibration, the coefficient $\phi \equiv (1-\lambda)/[1 + \lambda(2-\lambda)(\sigma\eta - 1)]$ is positive and smaller than one. Therefore, consumption can be expressed as a weighted average of domestic and world output as

$$c_t = \phi y_t + (1-\phi)y_t^* \tag{10}$$

Let y_t^n denote the levels of real activity in the absence of nominal rigidities. If we combine equation (10) with equation (9), the New Keynesian IS curve for the domestic economy can be written as

$$x_t \simeq E_t(x_{t+1}) - [1/(\phi\sigma)][r_t - E_t(\pi_{t+1})] + E_t(\Delta y_{t+1}^n) + [(1-\phi)/\phi]E_t(\Delta y_{t+1}^*) \tag{11}$$

where $x_t \equiv (y_t - y_t^n)$ measures the gap of real output from its natural level. This is the first of the two variables that the policymaker attempts to stabilize through monetary policy.

2.3. The domestic firm

At time t each domestic firm uses domestic labour to produce goods with the simple deterministic technology $Y_t(j) = N_t(j)$. If we aggregate the production technology using the indices for total output and labour supply, and expressing the outcome in log-linear terms, it yields

$$y_t = n_t \tag{12}$$

Let MC_t denote the nominal marginal cost and μ_t the log-deviation of $MC_t/P_{D,t}$ from the balanced-growth path. The nominal (log-linear) marginal cost under symmetric price setting leads to $\mu_t + p_{D,t} = w_t$, which, using equation (8), can be written as $\mu_t = (p_t - p_{D,t}) + \tau y_t + \sigma c_t$, which, after considering equation (10), yields

$$\mu_t \approx \lambda v_t + \gamma y_t + \sigma(1 - \phi)y_t^* \tag{13}$$

where $\gamma \equiv (\tau + \sigma\phi)$. The problem of the firm that sets a new price, $\bar{P}_{D,t}(j)$, is to maximize the present value of current and future expected profits $E_t\{\sum_{h=0}^{\infty} (\beta\vartheta)^h [Y_{t+h}(j)/(1 + r_{t,t+h})][\bar{P}_{D,t}(j) - MC_{t+h}(j)]\}$, subject to

$$Y_{D,t+h}(j) = (\bar{P}_{D,t}(j)/P_{D,t+h})^{-\delta} Y_{t+h} \tag{14}$$

for each $h = 0, 1, 2, \ldots$. Equation (14) is the optimization constraint that results from the assumption that each firm supplies on demand. Here $r_{t,t+h}$ represents the one-period nominal interest rate holding for $[t, t + h]$. The first-order condition with respect to $\bar{P}_{D,t}(j)$ gives $\bar{P}_{D,t}(j) = (1 - \beta\vartheta)E_t\{\sum_{h=0}^{\infty} (\beta\vartheta)^h [\mu_{t+h}(j) + P_{D,t+h}]\}$, which can be expressed as

$$\bar{P}_{D,t+1}(j) = [\bar{P}_{D,t}(j)/\beta\vartheta] + (1 - 1/\beta\vartheta)[\mu_t(j) + P_{D,t}] \tag{15}$$

Equation (15) shows that firm j needs to collect information relative to time t, when setting its price at $t + 1$.

Combining equations (2) and (15) allows us to express the current PPI inflation as a function of future PPI inflation and real marginal costs for the domestic economy as $\pi_{D,t} = \beta E_t(\pi_{D,t+1}) + \theta\mu_t(j)$. The parameter $\theta \equiv (1 - \vartheta)(1 - \beta\vartheta)(1/\vartheta)$ expresses the trade-off between nominal and real variables, and generates the non-neutrality of monetary policy in the short run. Using equations (13) and (6) together with the last equation, we can write the New Keynesian Phillips curve (NKPC) for the domestic economy as

$$\pi_t = \beta E_t(\pi_{t+1}) + \theta\gamma x_t + \lambda[\Delta v_t - \beta E_t(\Delta v_{t+1})] + \theta\lambda v_t + \theta\sigma(1 - \phi)y_t^* + u_t \tag{16}$$

where u_t is an *ad hoc* cost-push pricing disturbance that satisfies $u_t = \rho_u u_{t-1} + \hat{u}_t, 0 < \rho_u < 1$ and $\hat{u}_t \sim (0, \sigma_u)$. Note that, unless a disturbance hits the foreign economy, output y_t^* plays no role in the domestic NKPC.

2.4. Objective of policy action

The choice of an appropriate function to describe the central bank's objective is still an open question in the literature. In a closed-economy setting, Rotemberg and Woodford (1997, 1999) show that a standard quadratic expression of deviations of output and inflation from target is consistent with a wide range of representative household utility. Indeed, a welfare function can be obtained as a second-order approximation of the household utility function. In the open economy literature, such an approximation is possible only under very specific assumptions as stressed in Clarida *et al.* (2002).[6] For this reason, in the first part of the analysis we use a quadratic loss function. The central bank's optimal behaviour is to stabilize nominal and real intermediate targets as

$$L = -\frac{1}{2}E_t\left\{\sum_{h=0}^{\infty} \beta^h[\alpha x_{t+h}^2 + (1 - \alpha)\pi_{t+h}^2]\right\} \tag{17}$$

where $0 \leqslant \alpha \leqslant 1$ is the central bank preference for output relative to CPI inflation stability. The case of α equal to zero corresponds to strict inflation targeting.

Equation (17) is widely used in the literature and it assures a tractable solution of the problem. However, this formulation is based on the following assumptions. First, it presumes that CPI inflation rate is the optimal inflation target, while the debate on what inflation to target is still open, as discussed in Carlstrom

et al. (2006) and Soffritti (2002). Second, positive deviations from target are as costly as negative deviations. Chadha and Schellekens (1999) point out that, if we relax this assumption, some of the subsequent results do not hold.

In Giavazzi and Pagano (1988), the monetary authority's objective function differs from the one described here. In their formulation, output stabilization is not an intermediate objective of monetary policy, and inflation targeting is the only concern of the monetary authority. We also use output stabilization because monetary policy has real effects, and this formulation is closer to the objectives of modern central banks.

2.5. The model for the world economy

The utility functions of domestic and foreign households are assumed to be identical. To insulate the world economy from domestic shocks, we assume that imports represent a negligible share of foreign aggregate consumption, so that $C_t^* \simeq Y_t^*$ and $\pi_t^* = \pi_{D,t}^*$. Therefore, purchasing power parity (PPP) does not hold. Given these assumptions, the log-linear version of the consumption Euler equation for the foreign economy can be written as a standard IS curve for a closed economy $y_t^* = E_t(y_{t+1}^*) - (1/\sigma^*)[r_t^* - E_t(\pi_{t+1}^*)]$.

We assume that foreign firms adopt a deterministic CRTS production technology, identical to the one in the domestic economy. Firms are monopolistically competitive and set the price as in Calvo (1983). This leads to a version of the NKPC identical to the one in a closed-economy case

$$\pi_t^* = \beta E_t(\pi_{t+1}^*) + \theta(\sigma^* + \tau)y_t^* + u_t^* \tag{18}$$

where the pricing shock is distributed as $u_t^* = \rho_u^* u_{t-1}^* + \widehat{u}_t^*, 0 < \rho_u^* < 1$ and $\widehat{u}_t^* \sim (0, \sigma_u^*)$.

The foreign central bank adopts a discretionary monetary policy that aims to maximize the forward-looking objective function that reflects the central bank's attempt to stabilize output and inflation as $L^* = -(1/2)[\alpha^* y_t^{*2} + (1 - \alpha^*)\pi_t^{*2}] +$ i.d.p., where i.d.p. captures all elements, mainly expectations, that are independent of the discretionary monetary policy. In principle there is no reason to expect the parameter of preference α^* to be identical to α for the domestic economy. Indeed, to capture the idea that the domestic economy stabilizes inflation by importing credibility from a lower-inflation foreign economy, as in Clarida *et al.* (1999), we set $\alpha^* > \alpha$.

Following the same procedure as Clarida *et al.* (1999), maximizing L^* subject to equation (18) leads to the following closed-form equations for inflation and the output gap $\pi_t^* = \omega_{\pi^*} u_t^*$ and $y_t^* = -q\omega_{\pi^*} u_t^*$, where $\omega_{\pi^*} \equiv 1/(1 - \varepsilon\beta\rho_{u^*}) > 1$, and $q \equiv (1/\alpha^*)(1 - \alpha^*)(\sigma^* + \tau)\theta > 0$. The optimal feedback response for the real interest rate that implements the optimal policy is determined by inserting the closed-form equations for π_t^* and y_t^* in the IS curve for the foreign economy

$$r_t^* - E_t(\pi_{t+1}^*) = [\sigma^* q(1 - \rho_{u^*})/\rho_{u^*}]E_t(\pi_{t+1}^*) = \omega_{r^*} u_t^* \tag{19}$$

where in order to simplify notation, we set $\omega_{r^*} \equiv \sigma^* q(1 - \rho_{u^*})\omega_{\pi^*} > 0$. The last equation shows that the discretionary policy calls for an active rule that requires the central bank to raise (lower) the real interest rate every time inflation is expected to increase (decrease).

2.6. Natural level of output

In this paragraph we derive an explicit equation for the natural level of output, y_t^n, so that we can derive how the domestic IS schedule reacts to foreign shocks. If prices are flexible, the domestic real mark-up collapses to its 'natural' level $\mu = \ln[\delta/(\delta - 1)] = \lambda v_t^n + \gamma y_t^n + \sigma(1 - \phi)y_t^*$ which, with the combination of the difference between domestic and foreign output, leads to an equation for y_t^n only in terms of y_t^* as

$$y_t^n = \frac{[\ln(\delta) - \ln(\delta - 1)](1 - \lambda)}{[\gamma(1 - \lambda) + \lambda\phi\sigma]} - \frac{[\sigma(1 - \phi)(1 - \lambda) - \lambda\phi\sigma]}{[\gamma(1 - \lambda) + \lambda\phi\sigma]}y_t^*$$

This shows that, as long as foreign prices are sticky, the natural output of the domestic economy fluctuates only in response to foreign disturbances.

First difference of y_t^n yields $E_t(\Delta y_t^n) = -[(1 - \phi)(1 - \lambda) - \lambda\phi]/[\gamma(1 - \lambda) + \lambda\phi\sigma]\sigma E_t(\Delta y_t^*) = 0$, so that we can write the domestic New Keynesian IS curve as $x_t \simeq E_t(x_{t+1}) - (1/\phi\sigma)[r_t - E_t(\pi_{t+1})] + [(1 - \phi)/\phi]$

$E_t(\Delta y_{t+1}^*)$. In light of (6) and the closed-form equations for π_t^* and y_t^*, this last equation can be expressed more explicitly as

$$x_t \simeq E_t(x_{t+1}) - 1/(\phi\sigma)[r_t - E_t(\pi_{D,t+1})] + (\lambda/\sigma\phi)E_t(\Delta v_{t+1}) - [(1-\phi)\omega_{r*}/\sigma\phi]u_t^* \tag{20}$$

which captures the behaviour of the domestic representative household in reaction to international real markets.

2.7. Financial markets

Under perfect capital mobility, the domestic price of a risk-free bond is determined in equilibrium to satisfy the uncovered interest parity (UIP) condition. Under international risk sharing we can write $r_t - r_t^* = E_t(\Delta s_{t+1})$. Using equation (1), UIP can be written in terms of PPI inflation as: $r_t - E_t(\pi_{D,t+1}) = r_t^* - E_t(\pi_{t+1}^*) + E_t(\Delta v_{t+1})$ which, given the assumption about foreign monetary policy, becomes

$$r_t - E_t(\pi_{D,t+1}) = \omega_{r*}u_t^* + E_t(\Delta v_{t+1}) \tag{21}$$

Equations (20) and (21) describe the 'demand side' of the small open economy and serve as constraints on the domestic monetary policy. The combination of equations (20) and (21) yields $x_t = E_t(x_{t+1}) - [(1-\lambda)/\phi\sigma]E_t(\Delta v_{t+1}) - (\omega_{r*}/\sigma)u_t^*$.

3. OPTIMAL POLICIES

In this section we determine the closed-form equilibrium for the three alternative monetary policy strategies. First, we consider a policy that credibly commits to the optimal rule. Due to the lack of commitment technology in practice, this serves as a benchmark case. Second, we analyse a time-consistent discretionary policy. In both cases, the exchange rate is perfectly flexible. Finally, we examine a monetary strategy in which the nominal exchange rate is pegged.

3.1. Optimal policy under commitment

As in Clarida *et al.* (1999), the policy problem for the central bank can be written as

$$\max_{\{\pi_{t+h}, x_{t+h}, v_{t+h}\}_{h=0}^{\infty}} -\frac{1}{2}E_t\left\{\sum_{h=0}^{\infty} \beta^h[\alpha x_{t+h}^2 + (1-\alpha)\pi_{t+h}^2]\right\} \tag{22}$$

subject to the following conditions:

$$x_t = E_t(x_{t+1}) - (1/\phi\sigma)[r_t - E_t(\pi_{D,t+1})] + (\lambda/\sigma\phi)E_t(\Delta v_{t+1}) - [(1-\phi)\omega_{r*}/\sigma\phi]u_t^*$$

$$\pi_t = \beta E_t(\pi_{t+1}) + \theta\gamma x_t + \lambda[\Delta v_t - \beta E_t(\Delta v_{t+1})] + \theta\lambda v_t + \theta\sigma(1-\phi)y_t^* + u_t$$

$$r_t - E_t(\pi_{D,t+1}) = \omega_{r*}u_t^* + E_t(\Delta v_{t+1})$$

where, as specified above, $y_t^* = -q\omega_{\pi*}u_t^*$. In equilibrium, inflation and the output gap satisfy

$$x_{t+h}^c = -\frac{(1-\alpha)}{\alpha}\left[\left(\theta\gamma + \frac{\lambda\phi\sigma}{1-\lambda}\right)\pi_{t+h}^c + \theta\gamma\sum_{j=0}^{h-1}\pi_{t+j}^c - \left(\frac{\beta\lambda\phi\sigma}{1-\lambda}\right)\pi_{t+h+1}^c\right] \tag{23}$$

The superscript c denotes the equilibrium under commitment. Equation (23) captures the forward-looking nature of the equilibrium under commitment. Under this arrangement, the optimal strategy for the central bank is to adjust the level of output in response to future CPI inflation.

3.2. Optimal policy under discretion

When a commitment technology is not available for policy actions, the central bank treats private expectations as independent from its own actions. In a discretionary regime, the central bank is able to control the money supply through its policy instrument. The policy problem for the central bank can therefore be written as

$$\max_{\{\pi_t, x_t, v_t\}} -(1/2)[\alpha x_t^2 + (1-\alpha)\pi_t^2] + \text{i.d.p.} \tag{24}$$

subject to the same conditions in the case of commitment, with $\text{i.d.p.} \equiv -\frac{1}{2}E_t\{\sum_{h=1}^{\infty} [\alpha x_{t+h}^2 + (1-\alpha)\pi_{t+h}^2]\}$, which captures the elements of the objective function that are independent of domestic policy. The combination of the first-order conditions for the output gap and inflation yields

$$x_{t+h}^d = -[(1-\alpha)/\alpha][\theta\gamma + (\lambda\beta\phi\sigma)/(1-\lambda)]\pi_{t+h}^d \tag{25}$$

where $h \geqslant 0$ and the superscript d denotes the solution under discretion. In what follows, we shorten equation (25) as $x_{t+h}^d = \Theta\pi_{t+h}^d$. Since the coefficient Θ is negative, discretionary policy calls for a lean-against-the-wind strategy, in which the central bank pushes output below target every time inflation is positive (and vice versa).

The feedback rule for the risk-free interest rate under discretionary policy can be obtained by substituting equation (25) into the IS schedule (9) after accounting for the Phillips curve (16). It becomes the following Taylor-type rule for an open economy:

$$r_t = \varpi_\pi E_t(\pi_{t+1}) + f[v_{t-1}, E_t(\Delta v_{t+1}), u_t, u_t^*] \tag{26}$$

where $\varpi_\pi = 1 - \phi\sigma\Theta[1 - (\beta/1 - \theta\gamma\Theta)] > 1$. Hence, the optimal policy requires the instrument to respond to expected inflation in order to pin down a unique equilibrium. Equation (26) shows that the real interest rate also depends on domestic, u_t, and foreign, u_t^*, shocks, on both the past level and the expected change of the terms of trade, v_{t-1} and $E_t(\Delta v_{t+1})$ respectively.

3.3. Optimal policy under a fixed exchange rate

In what follows, we assume that the domestic central bank is committed to a rule that keeps the nominal exchange rate fixed, and that there is a system that enhances its current credibility. If the exchange rate is fixed, then $s_t = s$ for all time t. This assumption affects the model in two ways.

First, the growth in terms of trade collapses to the difference between foreign and domestic inflation

$$\Delta v_t = \pi_t^* - \pi_{D,t} \tag{27}$$

This equation, together with (6), simplifies the equation for the change in terms of trade so that it depends only on domestic and foreign inflation

$$v_t = [1/(1-\lambda)](\pi_t^* - \pi_t) + v_{t-1} \tag{28}$$

This equation serves as an additional constraint that the domestic central bank must consider when determining the monetary policy in the case of constant exchange rate. Equations (27) and (28) are consistent with an equation for CPI inflation as a weighted average between $\pi_{D,t}$ and π_t^* as $\pi_t = \lambda\pi_t^* + (1-\lambda)\pi_{D,t}$, which uses the degree of openness in real markets as a weight.

Second, the assumption about foreign monetary policy, along with equation (21), forces the domestic interest rate to follow the exogenous process $r_t = E_t(\pi_{t+1}^*) + \omega_{r^*}u_t^*$. However, once we combine this policy rule with the rule for the foreign interest rate stated in equation (19), it is straightforward to show that the solution is consistent with multiple (infinite) values for the constant exchange rate. To ensure determinacy of the equilibrium under commitment to a constant exchange rate, we assume that the domestic central bank adopts the following rule, in addition to UIP: $r_t - r_t^* = \varepsilon s_t$, $\varepsilon > 0$, which produces $s_t = s = 0$ at all time t.

A central bank that pegs the domestic price of a foreign currency solves an optimizing problem that replicates the one presented under pure commitment. However, since the exchange rate is fixed, the non-

stochastic constraint (28) holds. If we substitute equation (28) into the NKPC (16), it yields

$$\pi_t = \beta E_t(\pi_{t+1}) + \theta\gamma x_t + \lambda[\Delta v_t - \beta E_t(\Delta v_{t+1})] + [\theta\lambda/(1-\lambda)](\pi_t^* - \pi_t) + \theta\lambda v_{t-1} + \theta\sigma(1-\phi)y_t^* + u_t$$

In equilibrium, the combination of the first-order conditions for inflation and output gap determines the following relationship:

$$
\begin{aligned}
x_{t+h}^s = & -\frac{(1-\alpha)\xi}{\alpha}\left[\left(\theta\gamma + \frac{\lambda\phi\sigma[1+\beta(1-\xi)]}{1-\lambda}\right)\pi_{t+h}^s - \left(\frac{\beta\lambda\phi\sigma}{1-\lambda}\right)\pi_{t+h+1}^s\right. \\
& \left. + \left(\theta\gamma + \lambda\phi\sigma\left[\left(1-\frac{1}{\xi}\right) + \beta(1-\xi)\right]\Big/(1-\lambda)\right)\sum_{j=0}^{h-1}\xi^j\pi_{t+h}^s\right]
\end{aligned}
\tag{29}
$$

where $\xi \equiv (1-\lambda)/[1-\lambda(1-\theta)] \geqslant 1$ and $\xi \equiv 1$ when the small economy becomes an autarky in real markets. The superscript s is used to denote the equilibrium under a constant exchange rate.

4. MODEL CALIBRATION

As in King and Rebelo (1999), we set the discount factor β at 0.99. In the model, parameter λ captures the domestic degree of openness in real markets. From the definition of $C_{D,t}$ and $C_{F,t}$, it is apparent that when $P_{D,t} = P_{F,t}$ (as it occurs in steady state), λ represents the share of total consumption allocated to imported goods. It is common in the literature to set λ at 0.5, but we carry out an extensive robustness analysis and also consider cases when λ is equal to 0.2 and 0.7.[7] Parameter η measures the intratemporal elasticity of substitution between the bundles of domestic and foreign goods. To calibrate η we follow Trefler and Huiwen (2002) who estimate this parameter equal to 6, a value that is greater than 1.5 usually used in the literature. Parameter $\sigma = -C_t U_{CC}/U_C$ is the coefficient of relative risk aversion in the representative household's preferences for consumption, which we set equal to 1 (to give a log-utility in consumption) and equal to 5. We use these values as estimated in Hall (1988). The second parameter characterizing the representative household's utility is $\tau = N_t U_{NN}/U_N$, the elasticity of marginal utility of labour. We follow Benigno (2001) and set τ not greater than 5 to fit the empirical data on labour supply. The average mark-up under monopolistic competition is captured by parameter μ. We set $\mu = 1.15$ to be consistent with δ equal to 7.67, the estimates of the elasticity of substitution presented by Rotemberg and Woodford (1999). The average contract duration is about three quarters in the United States as well as in other countries, which corresponds to a probability of a price adjustment ϑ equal to 0.33.

Numerical values for the persistence and variability of productivity shocks, ρ_u and σ_u, are taken as estimated in Ireland (1997) for the US economy. We set $\rho_u = 0.975$ and $\sigma_u = 0.00633$ which are in line with studies by Burnside *et al.* (1993) and King and Rebelo (1999). The parameter α captures the central bank's relative preference for output stability. By assumption, the domestic central bank is unable to reduce inflation and attempts to import price stability from the rest of the world. To assume that the foreign central bank is more successful at attaining nominal stability, we set the parameters of preference of domestic and foreign central bank, α and α^*, equal to $\frac{1}{3}$ and $\frac{2}{3}$, respectively.

5. RANKING REGIMES

In this paragraph we pose the following question: how could a central bank benefit from 'tying its hands' by pegging the domestic price of the foreign currency, compared to a discretionary policy? We address this issue from the perspective of a monetary authority that bases its decision either on rule-of-thumb loss function (loss criterion) or on the representative household's utility function (welfare criterion).

5.1. Loss criterion

In this section we rank the different exchange rate regimes using a quadratic loss function (17). The central bank's objective function is expressed to simplify the numerical simulations. We assume that the policymaker maximizes equation (17), where no information about the future is available. Let σ_π^2 and σ_x^2 denote the unconditional variance of CPI inflation and the output gap, respectively. Provided that the closed-form solution for π_t and x_t is a linear combination of white-noise disturbances, the (absolute value of the) unconditional expectation of equation (17) can be written as

$$E(L) = [(1/2)(1-\beta)][\alpha\sigma_x^2 + (1-\alpha)\sigma_\pi^2] \tag{30}$$

This equation is used as the ranking criterion based on the policymaker's objective function. Simulations of equation (30) are based on the *ex-post* average values of σ_x^2 and σ_π^2, computed for 2000 repetitions over a 1000-period time span. Figures 1–3(a) plot the outcome of the simulations as a function of different values for structural parameters σ, η and λ. Domestic and foreign disturbances are allowed to occur contemporaneously, but independently. The main findings are the following. First, the central bank objective is an increasing function of σ, η and λ. The greater the parameter of relative risk aversion, σ, the more the consumption becomes responsive to pricing shocks, other things being equal. Domestic consumption is related to domestic output, through equation (10), and domestic output affects inflation, through equation (16), thus an increase in the variability of domestic consumption increases in domestic output and inflation. The same can be said for the intratemporal elasticity of substitution, η. Indeed, the greater the η, the more the foreign goods are perceived as substitutes of domestic commodities. Thus, after a price disturbance, domestic consumption becomes more volatile, as do domestic output and inflation. The degree of openness of real markets, λ, displays a similar mechanism. The greater the λ, the more the domestic consumption is sensitive to shocks, provided that they occur independently.

Second, each diagram shows that, provided that λ is not too small (say not smaller than 0.35), a monetary policy that pegs the nominal exchange rate always leads to a greater loss than a discretionary policy. This is in line with De Fiore and Liu (2005) who find that openness plays an important role in equilibrium determinacy under inflation–targeting interest rules, because the degree of openness affects the transmission mechanism of monetary policy. This last result is the opposite of what Giavazzi and Pagano (1988) find in their paper, in which a deterministic set-up is used to model a nominal exchange rate that is free to fluctuate between realignments at given dates. In their set-up, the impact of policy actions on the objective of the central bank arises from its ability to control the incentive to generate inflation surprises, which was typical for many countries operating in the European Monetary System. This in turn induces private agents to expect lower inflation relative to the time-consistent alternative. Such a discrepancy with the findings of this paper is no surprise, given the different theoretical frameworks and definition of a stable exchange rate. The following proposition summarizes the main findings:

Proposition 1. *For plausible values of λ, time-consistent monetary policy leads to a greater loss than a policy that credibly pegs the nominal exchange rate.*

5.2. Welfare criterion

In this section we rank the different exchange rate regimes according to the representative household's utility function. A rational policymaker makes an appropriate specification of the welfare criterion by focusing on the unconditional expectation of the representative household's utility. As welfare depends explicitly on consumption and labour effort we can use the natural level of output to rewrite equations (10) and (12) as $c_t = \phi x_t + (1-\phi)y_t^* + \phi y_t^n$ and $n_t = x_t + y_t^n$.

To simplify the analysis, we re-write the utility flow. In the long-run, along the economy's steady state, nominal rigidities are absent and real marginal costs ought to satisfy $MC/P = \mu = \delta/(\delta-1)$. Hence, equation (8) yields $N = \zeta C^{-\sigma/\tau}$ and $\zeta \equiv [\delta/(\delta-1)]^{-1/\tau}$. To make the analysis straightforward we adopt two assumptions commonly used in the literature. First, we set the steady-state level of aggregate consumption
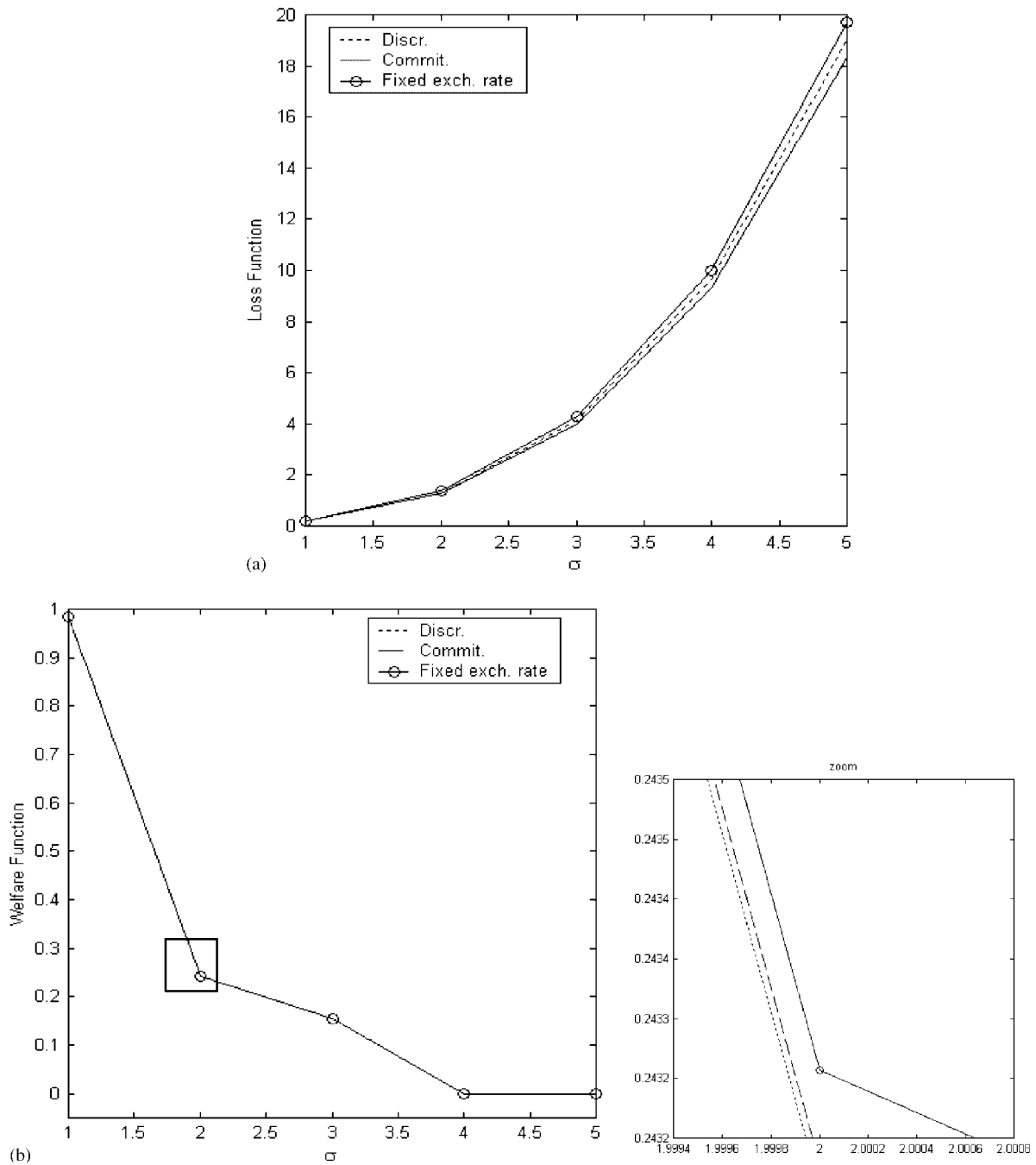
Figure 1. (a) Loss criterion as a function of σ and (b) utility criterion as a function of σ.

C equal to one. Second, as real money balances have a negligible weight in the household utility function, we can safely ignore them.

Let σ_c^2 and σ_n^2 denote the unconditional variance of consumption and labour effort. The unconditional expectation of U_t can be expressed as a function of these two second moments as [8]

$$E(U_t) = [1/(1-\sigma)][\exp\{[(1-\sigma)^2/2]\sigma_c^2\}] - [\zeta^{1+\tau}/(1+\tau)][\exp\{[(1+\tau)^2/2]\sigma_n^2\}] \tag{31}$$
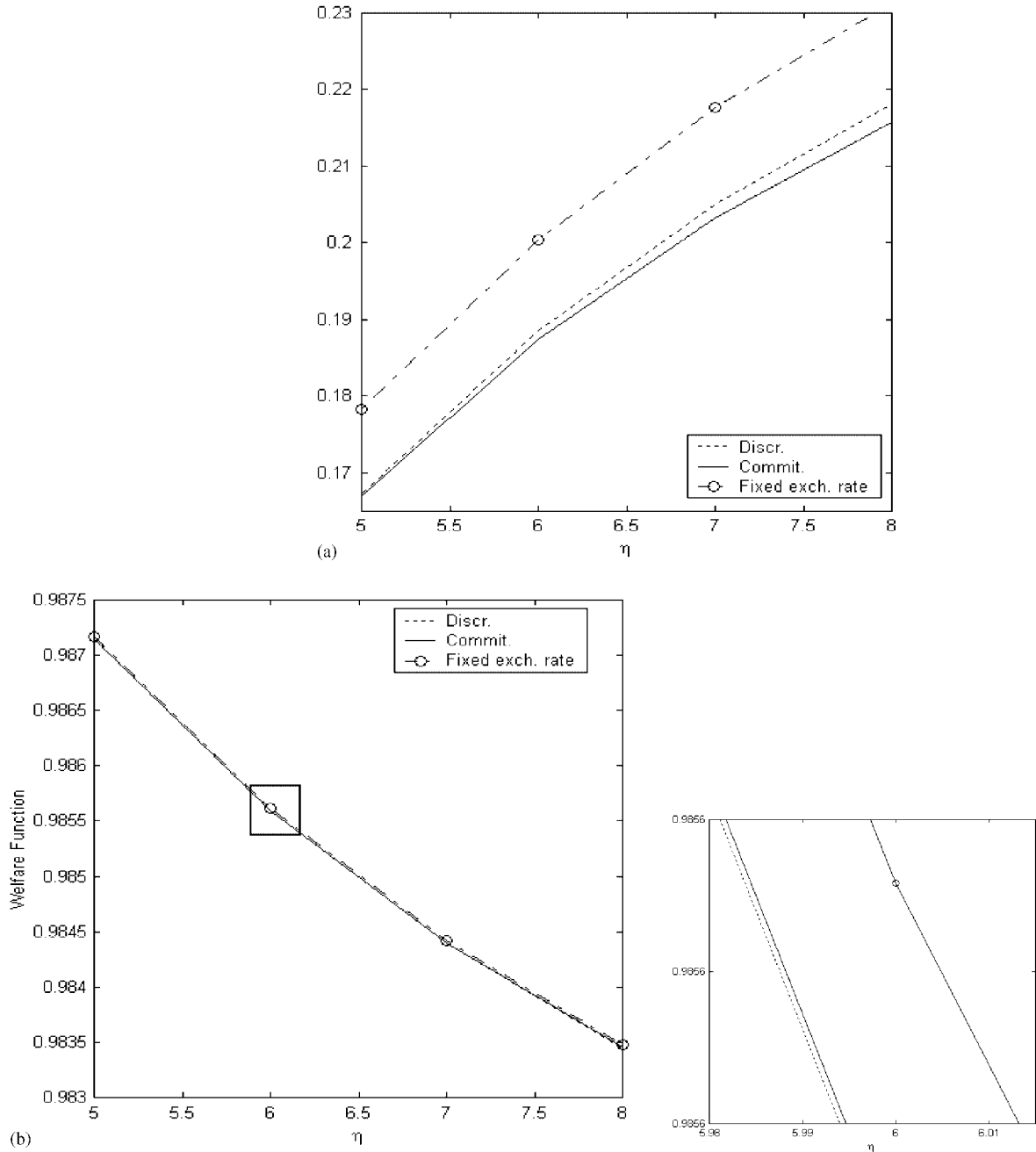
Figure 2. (a) Loss criterion as a function of η and (b) utility criterion as a function of η.

Simulations of equation (31) are based on the *ex-post* average values of σ_x^2 and σ_π^2, computed for 2000 repetitions over a 1000-period time span. Figures 1–3(b) plot the outcome of these simulations as a function of different values for the structural parameters σ, η and λ, the empirical estimation of which is still controversial in the economic literature.

The main findings are the following. First, welfare is a monotonic and decreasing function of η and σ. The reason is the following: when allowing the intratemporal elasticity of substitution to vary, parameter σ
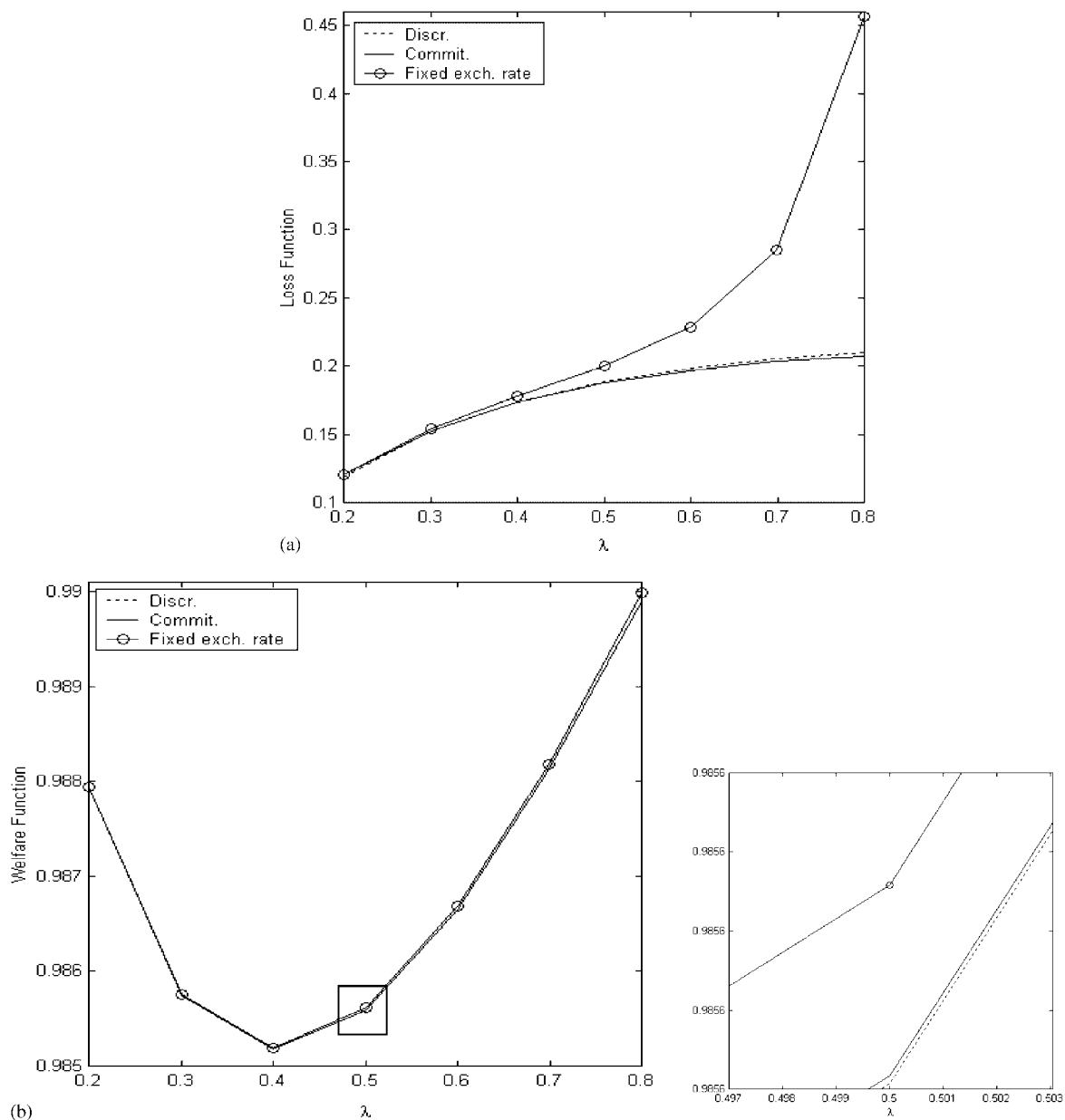
Figure 3. (a) Loss criterion as a function of λ and (b) utility criterion as a function of λ.

is unitary. In this case, the (inverse of the) variance of real output serves as a proxy of the welfare criterion. For an increasing η, the composition of the consumption basket following a pricing disturbance becomes more important. As a consequence, the variability of real output and labour effort increases and utility decreases. Things are similar when we allow the parameter of risk aversion to increase. Indeed, the greater the σ, the more volatile is the response of consumption to any given sequence of shocks. The link between consumption and welfare is straightforward.

Second, welfare is not monotonic for different values of the degree of openness, λ. This result is generated by the composition of the consumption basket, C_t, along with the fact that domestic and foreign shocks are

drawn from two independent probability distributions. For a small λ, the variability of aggregate consumption mainly reflects the volatility of $C_{D,t}$ which, as from its definition, primarily depends on domestic shocks. Instead, for a greater value of λ, foreign disturbances become relatively more important, due to their impact on $C_{F,t}$. When the parameter λ increases, the loss of utility resulting from reducing the consumption of domestic commodities, outweighs the gain from increasing the share of imports in the consumption basket.

Third, sensitivity analysis shows that pegging the nominal exchange rate leads to the best performance for a benevolent policymaker, independent of the parameter that we allow to vary. Indeed, this policy produces a flow of utility that always dominates the other two alternatives. When we consider a flexible exchange rate regime, the gain from committing to the optimal rule outweighs the loss from not having the right to redefine the optimal action at each point of time. Therefore, independent of the fact that we follow a 'welfare criterion' rather than a 'loss criterion', unconstrained monetary policy always leads to a better performance than its time-consistent alternative. The following proposition summarizes the main findings:

Proposition 2. *A central bank that aims at the agent's welfare should adopt a policy that pegs the nominal exchange rate. Welfare is a decreasing function of the intratemporal elasticity of substitution and of the elasticity of marginal utility in consumption, but it is in a non-monotonic relationship with the degree of openness of real markets.*

6. CONCLUSIONS

The debate over stable versus free-to-float exchange rate needs reconsideration in light of recent developments in the literature and on the new tools used in open economy macroeconomics, since the original contribution by Giavazzi and Pagano (1988). In this paper, we investigate whether the monetary authority of a small open economy should 'tie its hands' and peg the domestic price of a foreign currency, as an alternative to just leaving the exchange rates free to fluctuate. We study this issue from the perspective of a benevolent monetary authority that bases its decisions either on a rule-of-thumb objective function or on the agent's utility. We carry out this exercise by modelling the way in which a small open economy responds to domestic and foreign pricing shocks, and comparing how the dynamics of the economy impact on the monetary authority's objectives. The analysis is based on a microfounded, New Keynesian model where monetary policy is endogenously modelled with the nominal interest rate as the policy instrument.

We find that if the policymaker is benevolent and aims at the agent's utility (welfare criterion), they should prefer a stable exchange rate over the discretionary regime. This finding is insensitive to different calibrations of the structural parameters of the model. Instead, if the policymaker's objective is to minimize a standard quadratic loss function of deviation of real output and inflation from targets (loss criterion), a policy that generates exogenous expectations is actually preferable to the one that pegs the exchange rate. This result is the opposite to what Giavazzi and Pagano (1988) find. Although it is robust across many calibrations of the parameters of the model, it is sensitive to size of the degree of openness of the domestic economy to international real trade. These findings suggest that the choice between a stable or free-to-float exchange rate is not a simple one. The way in which a monetary authority sets its objectives and the degree of exposure of the real economy are key factors to be considered in the analysis.

NOTES

1. For more details see Mussa *et al*. (2000) and references therein.
2. As a recent example see Sutherland (2005) and references therein.
3. With $E_t(X_{t+h})$ we characterize the mathematical expectation of a variable X at time $t + h$, conditional on the information available at time t. By dropping the time subscript, we identify the steady-state level of the same variable. We denote the percentage deviation of X_t from X with lower case such as $x_t \equiv (X_t - X)/X \simeq \ln(X_t) - \ln(X)$. The superscript $*$ denotes a variable that pertains to the foreign economy. Subscripts D and F identify domestic and foreign variables pertaining to a given economy. All nominal variables (except foreign prices and foreign interest rate) are denoted in units of domestic currency.
4. This formulation implicitly assumes producer currency pricing. Corsetti and Pesenti (2005) provide a useful discussion of the degree of exchange pass-through in the context of monetary policy.
5. In principle λ could potentially be endogenous, depending on the type of shock. We leave this extension open for future research.
6. More specifically, the conditions required are $\sigma = \delta = \eta = 1$.
7. We consider this range of values because the degree of openness, as measured by the average share of imports in GDP, ranges for instance from 20% in Australia to about 70% in the Czech Republic.
8. The expression holds under the assumption $\sigma \neq 1$.

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