Monetary Policy and Tobin Taxes: A Welfare Analysis

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Abstract

This paper studies the choice of monetary policy regime in a small open economy with noise traders in forex markets. We focus on two simple rules: fixed exchange rates and inflation targeting. We contrast the above two rules against optimal policy with commitment under productivity shocks. In general, the presence of noise traders increases the desirability of a fixed exchange rate regime. We also evaluate the welfare impact of Tobin taxes on capital flows. These taxes help unambiguously in the absence of productivity shocks; their welfare impact under productivity shocks depends on the monetary regime in place and trade elasticity between domestic and foreign goods.

KEYWORDS: Noise traders; Fixed exchange rates; Tobin taxes, Optimal monetary policy.

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1 Introduction

There exists a large body of literature on market microstructure models that examine the role of noise traders in generating excess volatility in the foreign exchange (forex) market. This paper incorporates noise traders into a New Keynesian model of a small open economy with incomplete markets. We welfare-rank two simple rules, namely fixed exchange rate (PEG) and inflation targeting (IT), by identifying the rule that in terms of welfare is closest to the optimal monetary policy under commitment. In addition, we examine the welfare implications of imposing Tobin taxes on capital flows.

We show that the differences in welfare across these regimes can be mapped with the real exchange rate volatility that the regimes allow relative to what the optimal policy calls for. The optimal policy response to supply-side shocks entails a significantly lower volatility of the real exchange rate in the presence of noise traders than in their absence. As a result, a PEG outperforms an IT regime. Further, we find that when domestic and foreign goods are substitutes in household consumption, Tobin taxes improve welfare under an IT regime, whereas welfare declines under a PEG. When the two goods are compliments, Tobin taxes help under both regimes.

Our work is related to Jeanne and Rose (2002) who in a simple flexible price setup show that it is optimal to stabilize the exchange rate as floating exchange rates attract noise traders and increase overall volatility. Their paper thus rationalizes the benefit of having a credible fixed exchange rate regime. Shi and Xu (2009) build on Jeanne and Rose (2002) to study the effect of a transactions tax on international bond trade. They find that such a tax affects exchange rate volatility only if it changes the share of noise traders in the market. However, these two papers have no inflation or output dynamics and rely on ad-hoc welfare metrics.

Our framework on the other hand includes output and inflation dynamics summarized as expectational IS and Phillips curve. Optimal policy maximizes a quadratic approximation of the household's utility, a feature of recent papers on optimal monetary policy in small open economies (see, for example, Gali and Monacelli, 2005; De Paoli, 2009a and 2009b). This not only facilitates a simple insightful presentation of optimal policies, but also permits a straightforward comparison of simple ad-hoc rules with the former. Our work is closely related with De Paoli (2009b) who shows that in a small open economy with incomplete markets a domestic IT regime outperforms a PEG when the elasticity of substitution between domestic and foreign goods is high, and *vice versa* when the elasticity is low. In contrast, we show that with noise in the forex market a PEG dominates an IT regime unambiguously.

The rest of the paper proceeds as follows. Section 2 develops the basic model with noise traders. Section 3 studies and welfare ranks the alternative monetary policy arrangements. Section 4 provides a summary of the results and concludes.

2 The Model

2.1 Households

The framework is a small open economy with incomplete markets and closely follows De Paoli (2009b). The world economy is populated with a continuum of household of unit mass, where the fraction of the population in the segment $[0, n)$ belong to the home country (H) and the remainder of the world population in the segment $[n, 1]$ belong to the country (F). The utility function of the representative household in country (H) is

$$U_t = E_t \sum_{s=t}^{\infty} \beta^{s-t} \left[\frac{C_t^{1-\rho}}{1-\rho} - \frac{1}{n} \int_0^n \frac{\epsilon_t^{-\eta} y_t^{1+\eta}}{1+\eta} dj \right] \tag{1}$$

where C_t is individual consumption stream, ρ is the coefficient of relative risk aversion, η is equivalent to the inverse of the elasticity of labor supply, and ϵ is the shock to productivity. The consumption aggregate for countries (H) and (F) are given by:

$$C = \left[\nu^{1/\theta} C_H^{\frac{\theta-1}{\theta}} + (1-\nu)^{1/\theta} C_F^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}, \ C^* = \left[\nu^{*\frac{1}{\theta}} C_H^{*\frac{\theta-1}{\theta}} + (1-\nu^*)^{1/\theta} C_F^{*\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} \tag{2}$$

The parameter $\theta > 0$ is the elasticity of substitution between consumption of Home- and Foreign-produced goods (henceforth, trade elasticity), C_H and C_F, respectively; σ is the elasticity of substitution *within* goods produced at Home as well as within goods imported from Foreign. The parameter determining Home consumer's preferences for Foreign goods, $1 - v$, is a function of the relative size of Foreign, $1 - n$, and of the degree of openness, λ. Specifically, $1 - \nu = (1 - n)\lambda$. This specification gives rise to home bias in consumption, as a result of which there are deviations from purchasing power parity. Foreign preferences are defined symmetrically with $\nu^* = n\lambda$; to differentiate from Home, its variables are denoted with an asterisk. The home (foreign) consumption of domestic and foreign produced goods are given by C_H (C_H^*) and C_F (C_F^*) respectively where:

$$C_H = \left[\left(\frac{1}{n} \right)^{\frac{1}{\sigma}} \int_0^n c(z)^{\frac{\sigma-1}{\sigma}} dz \right]^{\frac{\sigma}{\sigma-1}}, \qquad C_F = \left[\left(\frac{1}{1-n} \right)^{\frac{1}{\sigma}} \int_n^1 c(z)^{\frac{\sigma-1}{\sigma}} dz \right]^{\frac{\sigma}{\sigma-1}} \tag{3}$$

$$C_H^* = \left[\left(\frac{1}{n} \right)^{\frac{1}{\sigma}} \int_0^n c^*(z)^{\frac{\sigma-1}{\sigma}} dz \right]^{\frac{\sigma}{\sigma-1}}, \qquad C_F^* = \left[\left(\frac{1}{1-n} \right)^{\frac{1}{\sigma}} \int_n^1 c^*(z)^{\frac{\sigma-1}{\sigma}} dz \right]^{\frac{\sigma}{\sigma-1}} \tag{4}$$

where $\sigma > 1$ is the elasticity of substitution across the differentiated goods. Let P_H and P_F denote the price indices for Home- and Foreign-produced consumption aggregates, respectively, and let P denote the price index for Home's overall consumption aggregate. The corresponding price indices are

$$P = \left[\nu P_H^{1-\theta} + (1-\nu) P_F^{1-\theta} \right]^{1/(1-\theta)} \tag{5}$$

$$P^* = \left[\nu^* P_H^{*1-\theta} + (1-\nu^*) P_F^{*1-\theta} \right]^{1/(1-\theta)} \tag{6}$$

where

$$P_H = \left[\frac{1}{n} \int_0^n p(z)^{1-\sigma} dz \right]^{1/(1-\sigma)}, \qquad P_F = \left[\frac{1}{1-n} \int_n^1 p(z)^{1-\sigma} dz \right]^{1/(1-\sigma)} \tag{7}$$

$$P_H^* = \left[\frac{1}{n} \int_0^n p^*(z)^{1-\sigma} dz \right]^{1/(1-\sigma)}, \qquad P_F^* = \left[\frac{1}{1-n} \int_n^1 p^*(z)^{1-\sigma} dz \right]^{1/(1-\sigma)} \tag{8}$$

Following De Paoli (2009b) we assume the law of one price holds and is given by:

$$p(h) = Sp^*(h) \text{ and } p(f) = Sp^*(f) \tag{9}$$

where S_t denotes the nominal exchange rate defined as the amount of Home currency units required to buy one unit of the Foreign currency. It follows from equations (7) - (9), that $P_X = SP_X^*$ for $X = H,\ F$. However the consumption home bias (in particular, $v \neq v^*$) implies that the PPP does not hold, $P \neq SP^*$. Then the real exchange rate can be expressed as $Q \equiv \frac{S\ P^*}{P}$, where P^* is the Foreign counterpart of P, and S is the nominal exchange rate.

Finally, let Y denote the Home output. The preference structure leads to the total demand for a differentiated good h (f), produced in country H (F)

$$Y_t^d(h) = \left[\frac{p_t(h)}{P_{H,t}}\right]^{-\sigma} \left\{ \left(\frac{P_{H,t}}{P_t}\right)^{-\theta} \left[(1-\lambda)(C_t) + \lambda \left(\frac{1}{Q_t}\right)^{-\theta} C_t^* \right] \right\} \tag{10}$$

Then, following De Paoli (2009b), (10) or the demand side of the small open economy (as $n \to 0$) can be written in the log-linear form, with small case letters denoting log deviations from steady states of their corresponding upper case variables, as

$$y_t = (1-\lambda)c_t + \lambda c_t^* + \gamma q_t \tag{11}$$

where $\gamma = \frac{\theta\lambda(2-\lambda)}{1-\lambda}$, q is the real exchange rate expressed in log-linear terms and c_t^* is the foreign consumption.

2.2 Price setting

Prices are set following the standard Calvo formulation the optimal choice of producers who can set price at time t can be summarized by

$$E_t \left\{ \sum_T (\alpha\beta)^{T-t} U_C(C_T) \underbrace{\left(\frac{\tilde{p}_t(h)}{P_{H,t}}\right)^{-\sigma} Y_T}_{\widetilde{y}_t(h)} \left[\frac{\tilde{p}_t(h)}{P_{H,T}} \frac{P_{H,T}}{P_T} - \mu_T \frac{V_y(y_{t,T}(h), \varepsilon_t)}{U_C(C_T)} \right] \right\} = 0 \tag{12}$$

where α is the fraction of firms do not change prices and $\widetilde{p}(h)$ is the optimally adjusted price. Also, the price index evolves

$$(P_{H,t})^{1-\sigma} = \alpha P_{H,t-1}^{1-\sigma} + (1-\alpha)\widetilde{p}_t(h)^{1-\sigma} \tag{13}$$

Combining (12) and (13), the supply side of the economy can be represented in log linear form as

$$\pi_t = k\left(\rho c_t + \eta y_t + \frac{\lambda}{1-\lambda} q_t - \eta \epsilon_t\right) + \beta E_t \pi_{t+1} \tag{14}$$

where $k = (1-\alpha\beta)(1-\alpha)/\alpha(1+\sigma\eta)$.

2.3 International bond markets

To introduce noise traders into the model, we first assume that Home households cannot directly participate in Foreign bond markets but they can trade domestically in risk free bonds (B) denominated in Home currency. The budget constraint of the Home household is given by

$$P_t C_t + \frac{B_t}{1+i_t} = \Pi_t^f + B_{t-1} + (1 - T_t) P_{H,t} Y_t + P_{H,t} Tr_t, \tag{15}$$

where i_t is the nominal interest rate, T_t is the income tax, and Tr_t are lump-sum transfers from the government. While households trade in the Home-currency bond market, trade in Foreign-currency bonds is carried out by specialized forex dealers who trade in the interest of households by utilizing households' investments in the Home-currency bond market. Thus, Π_t^f in (15) above denotes net profit of forex traders that they fully rebate to the households.

Following Jeanne and Rose (2002), forex traders are modelled as overlapping generation of investors who live for two periods. In the first period they borrow funds from the households and purchase Foreign-currency bonds B_F. In the second period, they liquidate foreign bonds to repay loans from Home bond market, and transfer all profits net of taxes to households' accounts. To avoid non-stationarity in the model, following Schmidtt-Grohé and Uribe (2003), we assume that Foreign interest rate earned by forex traders is subject to an intermediation cost, ψ, decreasing in traders' real foreign asset position, i.e., $\psi' < 0$. Specifically, gross Foreign interest rate earned by traders is $1 + \widehat{i}_t^* = (1 + i_t^*)\, \psi\left(\frac{B_{F,t} S_t}{P_t}\right)$, where i_t^* is the nominal interest for Foreign residents.[1] Thus, a Home forex trader born in period $t-1$ borrows and invests $\frac{S_{t-1} B_{F,t-1}}{1+\widehat{i}_{t-1}^*}$ of Home currency to receive $B_{F,t-1}$ units of foreign currency in t. After repaying $\frac{S_{t-1} B_{F,t-1}}{1+\widehat{i}_{t-1}^*}(1 + i_{t-1})$ to its lenders, the trader's net Home-currency return per unit of Foreign bonds is:

$$\varpi_t = S_t - S_{t-1} \frac{1 + i_{t-1}}{1 + \widehat{i}_{t-1}^*}$$

As one of our objectives is to evaluate Tobin taxes as a policy instrument, we assume that a trader purchasing $B_{F,t}$ pays an up-front real foreign capital trading tax of $\Phi_t = \frac{\tau}{2}\left(\frac{S_t \ B_{F,t}}{P}\right)^2$

[1] As in De Paoli (2009b), we assume that the spread $\widehat{i}_t^* - i_t^*$ is renumerated to the international intermediaries who rebate it equally among foreign housheolds.

levied and collected by the government in units of Home goods.[2] As a result, a trader j born at t maximizes the expected present value of profits:

$$\max_{B_{F,t}} E_t^j \left[\beta \left(\frac{C_{t+1}}{C_t} \right)^{-\rho} \frac{P_t}{P_{t+1}} \left\{ \varpi_{t+1} B_{F,t}^j - P_{H,t} \frac{\tau}{2} \left(\frac{S_t B_{F,t}^j}{P_t} \right)^2 \right\} \right] \tag{16}$$

where E_t^j refers to the conditional expectation of trader j at time t.[3] The trader's optimal choice of $B_{F,t}^j$ follows from

$$E_t^j \left[\beta \left(\frac{C_{t+1}}{C_t} \right)^{-\rho} \frac{P_t}{P_{t+1}} \left\{ \varpi_{t+1} - \tau \frac{S_t^2 B_{F,t}^j}{P_t} \frac{P_{H,t}}{P_t} \right\} \right] = 0, \tag{17}$$

which shows that the traders' optimal investment depends upon their exchange rate expectations and, as one would expect, the demand for foreign bonds is decreasing in the Tobin tax. Following De Long et al. (1990), we assume that a fraction $G \in [0, 1]$ of the forex dealers are noise traders. Their expectations about the future real exchange rate are noisy in the sense that they may deviate from the rational expectations by a noise shock. This leads to differences in the expectations between noise traders and informed traders resulting in irrational, non-fundamentals-driven trade. This non-fundamental trade is useful for discussing potential gains from financial transaction taxes: if noise trading introduces an excess volatility in the real economy, a transactions tax which may be expected to curb noise trading may thereby also reduce noise-trade-driven excess real volatility. Formally, the informed traders form the model-consistent rational forecast:

$$E_t^I [q_{t+1} - q_t] = E_t [q_{t+1} - q_t], \tag{18}$$

whereas the noise traders have

$$E_t^N [q_{t+1} - q_t] = E_t [q_{t+1} - q_t] + \upsilon_t, \tag{19}$$

[2] The assumption on Φ is standard in the literature and is made to prevent traders from receiving subsidies by taking a short position.

[3] The trader j's ex-post profits that are transferred to the households are however given as

$$\Pi_{j,t+1}^f = \varpi_{t+1} B_{F,t}^j - P_{H,t} \frac{\tau}{2} \left(\frac{S_t B_{F,t}^j}{P_t} \right)^2$$

and $\Pi_{t+1}^f = \sum_j \Pi_{j,t+1}^f$

where v_t is white noise with variance σ_v^2.

2.4 Market Clearing

Market clearing in the domestic bond market requires

$$\frac{B_t}{1+i_t} = \frac{S_t B_{F,t}}{1+\widehat{i_t^*}}, \tag{20}$$

where the LHS is the amount of funds invested by households in Home bonds and the RHS is the Home-currency value of Foreign bonds purchased by forex traders. The government runs a balanced budget which implies

$$P_{H,t}\left(T_t Y_t - Tr_t\right) + P_{H,t-1}\Phi_{t-1} = 0. \tag{21}$$

Combining (15), (20) and (21), we get the economy's current account which can be expressed in log-linear form as

$$\beta b_t = b_{t-1} - \frac{\lambda}{1-\lambda} q_t + y_t - c_t \tag{22}$$

Combining equations (17)-(19) we get

$$i_t - i_t^* = E_t \Delta s_{t+1} + G v_t - (\tau + \delta)\, b_t \tag{23}$$

where G is the fraction of noise traders, δ denotes the elasticity of borrowing cost ψ with respect to $\frac{B_{F,t}S_t}{P_t}$. Equation (23) is the uncovered interest parity condition between Home and Foreign economies. The noise term v_t can alternatively be interpreted as shock to the risk premium purely due to forex market disturbances.[4] In the last term, $-\delta b_t$ reflects that a higher bond holding reduces the interest premium $\hat{i}_t^* - i_t^*$ charged by foreign investors, and by parity reduces the interest rate in the domestic bond market. A higher τ, by reducing the demand for bonds, requires a lower $\hat{i}_t^*$ in equilibrium if b_t is unchanged.

Equations (11), (14), (22), and (23) summarize the model's equilibrium conditions. An analogous set of expressions characterize the world economy. In what follows, we focus solely on shocks to the Home economy and assume that the world economy is in steady state with $c_t^* = \pi_t^* = 0$.

[4] See, for example, Aldolfson (2008) and Dennis et. al. (2009).

3 Monetary Policy

Having characterized the decentralized equilibrium, we are now set to evaluate and compare alternative monetary rules. Before studying the impact of noise trading on these rules under general preferences as specified in (1) and (2), we first nest our results with those highlighted by Gali and Monacelli (2005) and De Paoli (2009a, 2009b) for unit elasticity of intertemporal and intratemporal consumption substitution i.e., $\rho = \theta = 1$. This particular case allows for a straightforward analytical exposition of optimal policies, as discussed below.

3.1 Implementing efficient/flexible-price allocations under unit trade elasticity ($\theta = 1$)

Notice from (14) that with flexible prices, i.e., $\alpha = 0$ and $k \rightarrow \infty$. The first term within brackets on the RHS of (14) represents the log deviation of real marginal cost (as a ratio of domestic prices) from its steady state value, i.e., the mark up. By keeping the real marginal cost fixed at its steady state mark up value implies $\pi_t = 0$ for all t. Thus, complete price stability obtains flexible price allocations since firms have no desire to change prices. Under complete asset markets, Gali and Monacelli (2005) show that when intertemporal as well as intratemporal elasticities of consumption substitution equal unity, second order approximation of utility function is isomorphic to that in a closed economy: it is independent of terms of trade (and therefore the real exchange rates) and depends only upon domestic inflation and output gap. By stabilizing domestic inflation, output gap is also stabilized, and the first best is achieved. This is done by setting labor subsidies such that the effective steady mark up equals $\frac{1}{1-\lambda}$ and then setting inflation to zero for all times. Essentially, this policy eliminates inefficiency due to monopolistic competition as well as due to price rigidities.

De Paoli (2009b) further shows that the above result is invariant to the structure of asset markets and continues to hold even under autarky when the trade elasticity $\theta = 1$.[5] Since the welfare function in our model coincides with that obtained by De Paoli (2009b) when $\theta = 1$, a policy of complete price stability continues to be efficient even when noise traders

[5] That a perfect risk sharing occurs through terms of trade movements, even in the absence of asset trade, when home and foreign goods have a unit elasticity of substitution was first shown by Cole and Obstfeld (1991).

are present in forex markets.

3.2 Optimal monetary policy when $\theta \neq 1$

We now derive the policymaker's objective function as a second order approximation of the household's utility function and then study optimal monetary policy under commitment when $\theta \neq 1$. This is the case studied by De Paoli (2009b) and our objective here is to show how the results change under noise trading in forex markets.

Following De Paoli (2009b), we derive the loss function of the central bank as a second order approximation of the utility function:

$$L_w = \frac{1}{2}\left[y_t\ q_t\right] L_y \left[y_t\ q_t\right]' + \left[y_t\ q_t\right] L_e \epsilon_t + \frac{1}{2} l_\pi \pi_t^2 \tag{24}$$

where $L_y = [l_{yy}\ l_{yq};\ l_{yq}\ l_{qq}]$, $L_e = [l_{y\epsilon}; l_{q\epsilon}]$. The coefficients l's are functions of fundamental parameters of the economy.[6] Essentially the loss function indicates that the central bank aims at balancing fluctuations in output, inflation, and real exchange movements. Intuitively, the presence of staggered prices and monopolistic competition implies there are gains in minimizing output and inflation fluctuations. In addition, in an open economy, there is an incentive to manage fluctuations in the real exchange rate to minimize the wedge between the marginal utility of consumption and the marginal utility of production.

As evident, with $\theta \neq 1$ a real exchange rate term appears in the welfare function. Then a policy of complete price stability is no longer optimal.[7] The optimal policy now minimizes (24) subject to (11), (14), (22) and (23). As shown in De Paoli (2009b), in a special case where $\delta = \tau = 0$, the first order conditions for the problem can be summarized as[8]

$$W_q E_t \Delta\left(q_{t+1} - q_{t+1}^T\right) + W_y E_t \Delta\left(y_{t+1} - y_{t+1}^T\right) + W_\pi E_t \pi_{t+1} = 0 \tag{25}$$

where X_{t+1}^T denotes a targeting value for variable X. According to the above rule, optimal policy responds to movements in output, inflation, and real exchange rate. Even though the

[6] See Appendix for details.

[7] With complete asset markets, De Paoli (2009a) shows that when $\theta > 1$, the small open economy has an incentive to have its real exchange rate appreciated, which in equilibrium can be achieved by stabilizing real/nominal exchange rates. A real exchange rate appreciation shifts demand towards imports and thus causes less disutility from labor. Consumption does not suffer because of market completeness and welfare improves as a result. Conversely, a real depreciation works better when $\theta < 1$.

[8] As has been extensively noted in the literature there are challenges to implementing this as a rule as there are issues of determinacy that crop up.

weights W of optimal policy are a function of the structural parameters of the model, one can show that the welfare is critically affected by the nature of the shock and the magnitude of the Tobin tax. It is worth noting that the efficient level of output in this case is given by $y_t^T = -\frac{\left(\gamma + \frac{1-\lambda}{\rho}\right)}{W_y}\epsilon_t$ and therefore a function only of productivity shocks, the target level of real exchange rate is zero (see appendix for details).

In the absence of noise traders, i.e., with $G = 0$ in equation (23), De Paoli (2009b) has shown – in a complete reversal of the results obtained under complete asset markets in De Paoli (2009a) – that domestic inflation targeting dominates fixed exchange rates under productivity shocks for sufficiently high trade elasticities with $\theta > 1$.[9][10]

3.3 Monetary policy under noise trading in forex markets

We now contrast an IT regime ($i_t = \chi\pi_t$) and a PEG ($\Delta s_t = 0$) with the optimal policy characterized by (25).[11] Below, we perform numerical simulations and compare equilibrium dynamics of inflation, output, consumption, and real exchange rates, in order to build intuition and quantify welfare losses under the two rules relative to the optimal policy under commitment with the timeless perspective (Woodford 1999). Following much of the literature (see, for example, Gali and Monacelli (2005), De Paoli (2009a, 2009b)) we compute the loss function under optimal policy as well as for the two rules IT and PEG by evaluating their unconditional expectations.[12] We then evaluate the impact of Tobin taxes on welfare.

Our objective is to evaluate policies when the economy is subject to productivity shocks ϵ_t and there are noise traders in the forex market. To build intuition, however, we first evaluate

[9] De Paoli also considers fiscal and mark-up shocks with similar results.

[10] Here, unlike under complete markets, an exchange rate stabilization by appreciating real exchange rate reduces demand for domestic goods and its negative income effect more than erodes the welfare gains from reduced disutility of labor.

[11] De Paoli (2009b) considers a strict inflation targeting rule wherein domestic inflation is always set to zero. However, as has been documented in the literature, there are challenges to implementing this policy as a simple rule and issues related with determinacy crop up. We therefore adopt the more practical flexible inflation targeting rule.

[12] Using unconditional expectation essentially eliminates the timeless perspective policy's dependence on the initial state. There is a debate in the literature on the choice of unconditional welfare measure *vis-à-vis* its conditional measure in this case. Dennis (2010) proposes an alternative measure of conditional loss and then shows that under this measure discretion outperforms timeless perspective policy. We compare optimal committment policy with the two rules IT and PEG (with committment), and the exercises we undertake are consistent with this objective. As we do not study discretionary policy, we feel that the issues raised by Dennis (2010) are not germane to our paper.

welfare under alternative policies in the presence of noise traders but without productivity shocks, then under productivity shocks but no noise traders. Finally, we rank the two rules when both shocks occur simultaneously.

The exercises below are conducted with the baseline parameters shown in Table 1. To avoid clutter, we study impulse responses (with one shock at a time) for the case with $\theta > 1$ by setting $\theta = 1.5$. With both shocks in the model, we present the welfare and volatility results for $\theta = 2$ as well as $\theta = 0.5$.

3.3.1 With noise traders, without productivity shocks

Consider a temporary increase in v_t. However, the efficient level of output without a productivity shock remains unchanged. Therefore, the optimal policy calls for insulating the real side of the economy. Figure 1.A shows that the movement in inflation, output and real exchange rates are minimal under optimal policy. Intuitively, the depreciation of the real exchange rate due to a rise in v_t increases aggregate demand. In order to stabilize demand, optimal policy raises interest rate to lower domestic consumption that implies higher savings and higher bond holdings. A rise in interest rate thus stabilizes output as well as inflation. In addition, a rise in interest by raising expected exchange rate appreciation partially offsets the real depreciation. It is easily checked that a rise in interest rate along with a real depreciation and increase in bond holdings is consistent with (23).

In contrast, real exchange depreciates substantially under the IT regime leading to a sharp increase in demand, whereas the dynamics under the PEG are similar to those exhibited under optimal policy. The PEG, by stabilizing exchange rate allows the interest rate to absorb the rise in v_t. The consequent rise in interest rate stabilizes domestic demand and inflation. This can be seen in Table 2, which reports the standard deviations and the welfare loss, expressed as a percentage of steady state consumption, under the alternative monetary regimes. The lower inflation and output variability under the PEG brings it closer to the optimal policy and as a result it outperforms the IT regime.

Table 2 shows that welfare under all regimes improves with an increase in Tobin tax. Intuitively, an increase in Tobin tax reduces the demand for foreign bonds while a positive risk premium shock increases the demand for foreign bonds. Ceteris paribus, raising Tobin taxes offsets rise in v_t in the forex market. Required policy interest rate changes are muted as a result, in turn, without much affecting output and inflation.

3.3.2 With productivity Shocks, without noise traders

Now consider a temporary rise in productivity. Figure 1.B shows that under an optimal policy inflation stays flat while the output rises. Intuitively, a rise in productivity calls for an increase in output as in De Paoli (2009b) due to an increase in its efficient level. This is engineered by a decrease in policy interest rate that also lets real exchange rate depreciate. As a result, the demand for Home goods rises thus raising its output. Since the output, domestic consumption, and real exchange rate comove with the productivity shock, the real marginal cost and inflation (see (14)) remain stabilized.

Since the optimal policy entails inflation stabilization, the dynamics exhibited by the IT regime closely mimic those under the optimal policy. The PEG on the other hand, by unduly stabilizing real exchange rate (Table 2), constrains interest rate and output movements. It leads to a substantial deflation and muted rise in domestic consumption and Home output. As a result, as in De Paoli (2009b), the IT regime welfare dominates a PEG (Table 2).

As evident from Table 2, a positive Tobin tax reduces welfare under all regimes. Intuitively, as savings (and bond holdings) comove with productivity shock (income effect) a positive Tobin tax stabilizes nominal (and therefore real) exchange rates excessively relative to what optimality commands.[13]

3.3.3 With productivity shocks and noise trading in forex markets

Consider now the following structure of shocks

$$\begin{aligned} \epsilon_t &= \rho_\varepsilon \epsilon_{t-1} + e_{\epsilon,t}, \qquad (26) \\ v_t &= e_{v,t}, \end{aligned}$$

where $e_{\epsilon,t}$ and $e_{v,t}$ are uncorrelated i.i.d. white noise shocks.

[13] As can be seen from (23), for a given intreest rate, a postive Tobin tax requires an appreciation (depreciation) under positive (negative) productivity shock if b comoves with ϵ.

Table 3 clearly indicates that under this scenario the PEG dominates the IT regime for $\theta = 2$ as well as $\theta = 0.5$. For $\theta > 1$, productivity shocks call for real exchange rate flexibility with inflation stability, whereas the risk premium shocks require the opposite. For the shock variances exhibited in Table 1, it turns out that risk premium shock takes precedence over productivity shock in the determination of optimal policy response. As a result, the PEG dominates the IT regime for $\theta = 2$.

Table 3 shows that when $\theta = 2$, a positive Tobin tax lowers welfare under the PEG while the reverse is the case under the IT regime. Recall from our preceding discussion that with only productivity shocks (but no noise traders) the IT regime outperforms the PEG; now it is the presence of noise traders in addition that makes the PEG superior. Imposing Tobin taxes in addition stabilize real exchange rate excessively and thus reduce welfare under the PEG. In contrast, since the IT performs poorly precisely because of real exchange rate instability, Tobin taxes help the IT perform better.

That the PEG dominates the IT regime for $\theta = 0.5$ comes as no surprise since De Paoli (2009b) has shown this to hold for sufficiently low θ under productivity shocks. The logic offered is that (i) stabilizing real exchange rate causes its appreciation and (ii) with incomplete markets and with Home and Foreign goods complements in consumption (i.e., $\theta < 1$), a real exchange rate appreciation improves welfare through a positive income effect. As a result, the relative desirability of PEG vis-à-vis IT increases further when $\theta = 0.5$ relative to $\theta = 2$. As evident in Table 3, imposing Tobin taxes further improve welfare by stabilizes real exchange rates, irrespective of the regime in place.[14]

4 Conclusions

The objective of this paper is twofold. First, we rank two classic rules, fixed exchange rates and inflation targeting, in a small open economy with incomplete markets and noise traders in the forex market. Second, we evaluate the impact of Tobin taxes under each of these two rules.

[14] Our results are robust to changes in the variance and persistence of risk premium shocks as well as trade openness and activeness of IT policy. The results are not reported here due to space limitations. They can be obtained from the authors on request.

The key message of the paper is that the presence of noise traders in the forex market increases the desirability of fixed exchange rates vis-à-vis inflation targeting, irrespective of the trade elasticity between domestic and foreign goods. More specifically, with noise traders in the forex market and with shocks to productivity, a fixed exchange rate regime dominates inflation targeting even when the two goods are substitutes, reversing the result highlighted by De Paoli (2009b). The simple intuition is that the presence of noise traders generate excess volatility of real exchange rates, which is neutralized by fixing exchange rates.

Tobin tax acts as an additional instrument to stabilize real exchange rates further. When domestic and foreign goods are substitutes, these taxes overstablize the real exchange rate under a fixed exchange rate regime and perform poorly, whereas under inflation targeting they improve welfare by providing some stability to the real exchange rate. On the other hand, when the domestic and foreign goods are complements, Tobin taxes improve performance irrespective of the regime in place – a result which is in line with the findings in De Paoli (2009b).

A shortcoming of this paper is that the number of noise traders is assumed to be exogenous. One potential direction for future research would be to endogenize the entry of noise traders and reevaluate the performance of the two classic rules and Tobin taxes within this paper's setup.

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A Appendix

A.1 Real exchange rate

With $p_{H,t} = \hat{P}_{H,t} - \hat{P}_t$, the consumer price index $P_t = \left[(1-\lambda) P_{H,t}^{1-\theta} + \lambda P_{F,t}^{1-\theta}\right]^{\frac{1}{1-\theta}}$ can be log-linear approximated by

$$p_{H,t} = -\frac{\lambda}{1-\lambda} q_t \tag{A.1}$$

and second order approximated by

$$0 = E_0 \sum \beta^t \left[f_y' \boldsymbol{y}_t + \frac{1}{2} \boldsymbol{y}_t' F_y \boldsymbol{y}_t + \boldsymbol{y}_t' F_\epsilon \epsilon_t \right] + t.i.p. + O^3 \tag{A.2}$$

where

$$f_y' = \left[\begin{array}{cccc} 0 & 0 & -(1-\lambda) & -\lambda \end{array}\right]$$
$$F_y' = \lambda(\theta - 1) \left[\begin{array}{cccc} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 \\ 0 & 0 & -1 & 1 - \frac{\lambda}{1-\lambda} \end{array}\right]$$
$$F_\epsilon' = \left[\begin{array}{cccc} 0 & 0 & 0 & 0 \end{array}\right]$$
$$\boldsymbol{y}_t' = \left[\begin{array}{cccc} y_t & c_t & p_{H,t} & q_t \end{array}\right]$$

A.2 Current Account

In the Appendix we follow De Paoli (2009b) in deriving first and second order approximations to the equilibrium conditions of the model. The budget constraint of the home household is

$$P_t C_t + \frac{B_t}{1+i_t} = \Pi_t^f + B_{t-1} + (1-T_t) P_{H,t} Y_t + P_{H,t} Tr_t \tag{A.3}$$

where Π_t^f denotes the transfer from the financial market given by

$$\Pi_t^f = S_t B_{F,t-1} - S_{t-1} \frac{B_{F,t-1}}{(1+\widehat{i_{t-1}^*})} (1+i_{t-1}) - P_{H,t-1} \Phi_{t-1} \tag{A.4}$$

The market clearing of the domestic bond market requires

$$\frac{B_t}{1+i_t} = \frac{S_t B_{F,t}}{\left(1+\widehat{i}_t^*\right)} \tag{A.5}$$

The government's balanced budget requires

$$0 = P_{H,t}\left(T_t Y_t - Tr_t\right) + P_{H,t-1}\Phi_{t-1} \tag{A.6}$$

Combining (A.3) - (A.6), we get the following current account

$$P_t C_t + \frac{S_t B_{F,t}}{1+\widehat{i}_t^*} = S_t B_{F,t-1} + P_{H,t} Y_t \tag{A.7}$$

With a definition the real bond balance $B_R \equiv \frac{SB_F}{P}$ and the Euler equation, (A.7) can be re-expressed as

$$B_{R,t}\beta E_t\left[C_{t+1}^{-\rho}\frac{S_{t+1}}{S_t}\frac{P_t}{P_t+1}\right] = C_t^{-\rho}\frac{S_t}{S_{t-1}}\frac{P_{t-1}}{P_t}B_{R,t-1} + C_t^{-\rho}\left[\frac{P_{H,t}}{P_t}Y_t - C_t\right]$$

Furthermore, with $B_t \equiv B_{R,t}E_t\left[C_{t+1}^{-\rho}\frac{S_{t+1}}{S_t}\frac{P_t}{P_t+1}\right]$, the current account can be rewritten as

$$\beta B_t = B_{t-1} + C_t^{-\rho}\left[\frac{P_{H,t}}{P_t}Y_t - C_t\right] \tag{A.8}$$

Combined with (A.1), the first order log-linear approximation to the current account equation (A.8) around a symmetric equilibrium with zero bond is

$$\beta b_t = b_{t-1} - \frac{\lambda}{1-\lambda}q_t + y_t - c_t$$

where $b_t = \frac{B_t - \overline{B}}{\overline{B}}$ and $\overline{B} = \frac{\overline{Y}^{-\rho}\overline{Y}}{1-\beta}$. This is (22) in text. The second order approximation to (A.8) is

$$b_t = (1-\beta)\left[b_y'\boldsymbol{y}_t + \frac{1}{2}\boldsymbol{y}_t'B_y\boldsymbol{y}_t + +\boldsymbol{y}_t'B_\epsilon\epsilon_t\right] + \beta E_t b_{t+1} + t.i.p + O^3 \tag{A.9}$$

where

$$B_y = \begin{bmatrix} -1 & \rho & -1 & 0 \\ -1 & 1-2\rho & \rho & 0 \\ -1 & \rho & -1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$$b_y' = \begin{bmatrix} -1 & 1 & -1 & 0 \end{bmatrix}$$

$$B_\epsilon' = [\ 0 \quad 0 \quad 0 \quad 0\ ]$$

A.3 Phillips curve

The first order condition of optimal price setting is

$$E_t \left\{ \sum_T (\alpha\beta)^{T-t} U_C(C_T) \underbrace{\left(\frac{\tilde{p}_t(h)}{P_{H,t}} \right)^{-\sigma} Y_T}_{\widetilde{y}_t(h)} \left[\frac{\tilde{p}_t(h)}{P_{H,T}} \frac{P_{H,T}}{P_T} - \mu_T \frac{V_y(y_{t,T}(h), \varepsilon_t)}{U_C(C_T)} \right] \right\} = 0 \quad \text{(A.10)}$$

where

$$(P_{H,t})^{1-\sigma} = \alpha P_{H,t-1}^{1-\sigma} + (1-\alpha)\, \widetilde{p}_t(h)^{1-\sigma} \quad \text{(A.11)}$$

Following Benigno and Benigno (2003) and De Paoli (2009), it can be shown that (A.10) and (A.11) can be first order approximated by

$$\pi_t = k \left(\rho c_t + \eta y_t + \frac{\lambda}{1-\lambda} q_t - \eta \epsilon_t \right) + \beta E_t \pi_{t+1} \quad \text{(A.12)}$$

where $\pi_t = p_{H,t} - p_{H,t-1}$. This is (14) in the text. The second order approximation to the Phillips curve is given by

$$V_0 = E_0 \sum \beta^t \left[a'_y \boldsymbol{y}_t + \frac{1}{2} \boldsymbol{y}'_t A_y \boldsymbol{y}_t + \boldsymbol{y}'_t A_\epsilon \epsilon_t + \frac{1}{2} a_\pi \pi_t^2 \right] + t.i.p + O^3 \quad \text{(A.13)}$$

where

$$a'_y = \begin{bmatrix} \eta & \rho & -1 & 0 \end{bmatrix}$$

$$A_y = \begin{bmatrix} \eta(2+\eta) & \rho & -1 & 0 \\ \rho & -\rho^2 & \rho & 0 \\ -1 & \rho & -1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$$A'_\epsilon = \begin{bmatrix} -\eta(1+\eta) & 0 & 0 & 0 \end{bmatrix}$$

$$a_\pi = (1+\eta)\,\sigma/k$$

$$V_t = k^{-1} \left[\pi_t + v_\pi \pi_t^2 + v_z \pi_t Z_t \right]$$

For v_π, v_z, and Z_t, see Appendix to Benigno and Benigno (2003).

A.4 Demand

The first order approximation to the demand for small open economy goods, (10), combined with (A.1) is

$$y_t = (1-\lambda)\, c_t + \lambda c_t^* + \gamma q_t \tag{A.14}$$

where $\gamma = \frac{\theta\lambda(2-\lambda)}{1-\lambda}$. This is (11) in the text. The second order approximation is

$$0 = \sum \beta^t \left[d_y' \boldsymbol{y}_t + \frac{1}{2} \boldsymbol{y}_t' D_y \boldsymbol{y}_t + \boldsymbol{y}_t' D_\epsilon \epsilon_t \right] + t.i.p + O^3 \tag{A.15}$$

where

$$d_y' = \begin{bmatrix} -1 & 1-\lambda & -\theta & \theta\lambda \end{bmatrix}$$

$$D_y = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & (1-\lambda)\,\lambda & 0 & -\theta\,(1-\lambda)\,\lambda \\ 0 & 0 & 0 & 0 \\ 0 & -\theta\,(1-\lambda)\,\lambda & 0 & \theta^2\,(1-\lambda)\,\lambda \end{bmatrix}$$

$$D_\epsilon' = \begin{bmatrix} 0 & 0 & 0 & 0 \end{bmatrix}$$

A.5 Uncovered interest parity

The first order condition of the traders is given by

$$0 = E_t^j \left[\beta \left(\frac{C_{t+1}}{C_t} \right)^{-\rho} \frac{P_t}{P_{t+1}} \left\{ \varpi_{t+1} - \frac{P_{H,t}}{P_t} \frac{\tau S_t^2 B_{F,t}^j}{P_t} \right\} \right]$$

After substituting the definition of ϖ_t and foreign household's Euler equation, we get,

$$0 = E_t^j \left[\beta \left(\frac{C_{t+1}}{C_t} \right)^{-\rho} \frac{P_t}{P_{t+1}} \left\{ \frac{S_{t+1}}{S_t} - \frac{P_{H,t}}{P_t} \frac{\tau S_t B_{F,t}^j}{P_t} \right\} - \beta \left(\frac{C_{t+1}^*}{C_t^*} \right)^{-\rho} \frac{P_t^*}{P_{t+1}^*} \right] \tag{A.16}$$

The noise trader's information set is given by

$$E_t^N \left[\Delta q_{t+1} \right] = E_t \left[\Delta q_{t+1} \right] + v_t$$

$$\Delta q_{t+1} = \Delta s_{t+1} + \pi_{t+1}^* - \pi_{CPI,t+1}$$

where $\pi_{CPI,t} = \log\left(P_{t+1}/P_t\right)$.Taking linear approximation of (A.16), we get

$$\begin{aligned}
\tau b_t^j &= E_t^j\left[\rho\left(c_{t+1}^* - c_t^*\right) - \rho\left(c_{t+1} - c_t\right) - \delta b_t + \underbrace{\Delta s_{t+1} + \pi_{t+1}^* - \pi_{CPI,t+1}}_{\Delta q_{t+1}}\right] \\
&= E_t\left[\rho\left(c_{t+1}^* - c_t^*\right) - \rho\left(c_{t+1} - c_t\right) - \delta b_t\right] + \Delta q_{t+1} + D_{G_j} v_t
\end{aligned}$$

where $D_{G_j} = 1$ if j is a noise trader, 0, otherwise. Aggregating this over j, we have

$$(\tau + \delta)\, b_t = \rho\left(c_{t+1}^* - c_t^*\right) - \rho\left(c_{t+1} - c_t\right) + \Delta q_{t+1} + G v_t \tag{A.17}$$

where $G = \sum_j D_{G_j}$ =fraction of noise traders. Furthermore, (A.17) can be reexpressed in nominal term using Euler equations as follows:

$$i_t - i_t^* = E_t \Delta s_{t+1} + G v_t - (\tau + \delta)\, b_t \tag{A.18}$$

This is (23) in the text.

A.6 Loss function

Following Benigno and Benigno (2003) and De Paoli (2009b), the utility function can be second order approximated by

$$\begin{aligned}
U &= E_0 \sum_t \beta^t \left[\frac{C_t^{1-\rho}}{1-\rho} - \frac{1}{n}\int_0^n \frac{\epsilon_t^{-\eta}\left(y_t^j\right)^{1+\eta}}{1+\eta}\right] \\
&\simeq U_C C E_0 \sum \beta^t \left[w_y' \boldsymbol{y}_t - \frac{1}{2}\boldsymbol{y}_t' W_y \boldsymbol{y}_t - \boldsymbol{y}_t' w_\epsilon \epsilon_t - \frac{1}{2} w_\pi \pi_t^2\right] + t.i.p + O^3
\end{aligned}$$

where

$$\begin{aligned}
W_y &= \begin{bmatrix} \frac{1+\eta}{\mu} & 0 & 0 & 0 \\ 0 & \rho - 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \\
w_y' &= \begin{bmatrix} -\frac{1}{\mu} & 1 & 0 & 0 \end{bmatrix}, \\
w_\epsilon &= -\frac{\eta}{\mu}
\end{aligned}$$

Using a second order approximation to the equilibrium conditions, the first order term, $w_y' \boldsymbol{y}_t$ is eliminated and the loss function is obtained:

$$L = -U \simeq U_C C E_0 \sum \beta^t \left[\frac{1}{2} \boldsymbol{y}_t' L_y \boldsymbol{y}_t + \boldsymbol{y}_t L_\epsilon \epsilon_t + \frac{1}{2} l_\pi \pi_t^2 \right] + t.i.p + O^3$$

where

$$\begin{aligned}
L_y &= W_y + L_{x1} A_y + L_{x2} D_y + L_{x3} F_y + L_{x4} B_y \\
L_\epsilon &= w_\epsilon + L_{x1} A_\epsilon + L_{x2} D_\epsilon + L_{x3} F_\epsilon + L_{x4} B_\epsilon \\
l_\pi &= w_\pi + L_{x1} a_\pi \\
L_x &\equiv \left[\begin{array}{cccc} L_{x1}; & L_{x2}; & L_{x3}; & L_{x4} \end{array} \right] \\
&= \left[\begin{array}{cccc} a_y & d_y & f_y & b_y \end{array} \right]^{-1} w_y
\end{aligned}$$

To write the loss function in terms of y, q, and π, we apply the following transformation using (A.1) and (A.14):

$$\boldsymbol{y}_t = N \left[\begin{array}{cc} y_t & q_t \end{array} \right]'$$

where

$$N = \left[\begin{array}{cc} 1 & 0 \\ \frac{1}{1-\lambda} & -\frac{\theta\lambda(2-\lambda)}{(1-\lambda)^2} \\ 0 & -\frac{\lambda}{1-\lambda} \\ 0 & 1 \end{array} \right]$$

Therefore, the loss function can be reduced into

$$L = U_c C E_0 \sum \beta^t \left[\frac{1}{2} \left[\begin{array}{cc} y_t & q_t \end{array} \right] \boldsymbol{L}_y \left[\begin{array}{cc} y_t & q_t \end{array} \right]' + \left[\begin{array}{cc} y_t & q_t \end{array} \right] \boldsymbol{L}_\epsilon \epsilon + \frac{1}{2} l_\pi \pi_t^2 \right] + t.i.p + O^3$$

where

$$\begin{aligned}
\boldsymbol{L}_y &= N' L_y N \equiv \left[\begin{array}{cc} l_{yy} & l_{yq} \\ l_{yq} & l_{qq} \end{array} \right] \\
\boldsymbol{L}_\epsilon &= N' L_\epsilon = \left[\begin{array}{cc} l_{y\epsilon}; & l_{q\epsilon} \end{array} \right]
\end{aligned}$$

and

$$l_{yy} = \frac{(-1+\mu+\eta\mu+\rho)\left(\eta(1+\theta(-2+\lambda))(-1+\lambda)^2 - \left(-1+\lambda+\theta\left(2-5\lambda+2\lambda^2\right)\right)\rho\right)}{(-1+\lambda)^2\mu(\eta(1+\theta(-2+\lambda)-\lambda)+\rho-2\theta\rho+\lambda(-1+\theta\rho))}$$

$$l_{yq} = \frac{\theta\lambda(-1+\mu+\eta\mu+\rho)\left(1+\lambda^2(3-4\theta\rho)+\lambda^3(-1+\theta\rho)+\lambda(-3+4\theta\rho)\right)}{(-1+\lambda)^3\mu(\eta(1+\theta(-2+\lambda)-\lambda)+\rho-2\theta\rho+\lambda(-1+\theta\rho))}$$

$$l_{qq} = -\frac{\theta\lambda(-1+\mu+\eta\mu+\rho)\begin{pmatrix} (-1+\lambda)^2\left(1-3\lambda+\lambda^2\right)+\theta^2(-2+\lambda)^3\lambda\rho \\ -\theta(-1+\lambda)\left(-2+\lambda^3(1+\rho)-\lambda^2(5+4\rho)+\lambda(6+4\rho)\right) \end{pmatrix}}{(-1+\lambda)^4\mu(\eta(1+\theta(-2+\lambda)-\lambda)+\rho-2\theta\rho+\lambda(-1+\theta\rho))}$$

$$l_{y\epsilon} = -\frac{\eta(1+\theta(-2+\lambda))(-1+\mu+\eta\mu+\rho)}{\mu(\eta(1+\theta(-2+\lambda)-\lambda)+\rho-2\theta\rho+\lambda(-1+\theta\rho))}$$

$$l_{q\epsilon} = 0$$

A.7 Optimal policy

The optimal commitment policy can be obtained by solving the following Lagrangian:

$$\begin{aligned} \min\ L = \sum \beta^t \Big[& L \\ & + \varphi_{1,t}\left\{\pi_t - k\left(\rho c_t + \eta y_t + \frac{\lambda}{1-\lambda}q_t - \eta\varepsilon_t\right) - \beta E_t\pi_{t+1}\right\} \\ & + \varphi_{2,t}\left\{y_t - (1-\lambda)c_t - \lambda c_t^* - \gamma q_t\right\} \\ & + \varphi_{3,t}\left\{(\tau+\delta)b_t - \rho\left(E_t c_{t+1}^* - c_t^*\right) - E_t q_{t+1} + q_t - Gv_t + \rho\left(E_t c_{t+1} - c_t\right)\right\} \\ & + \varphi_{4,t}\left\{\beta b_t - b_{t-1} + \frac{\lambda}{1-\lambda}q_t - y_t + c_t\right\}\Big] \end{aligned}$$

The first order conditions for this problem is

$$\Delta\varphi_{1,t} = -l_\pi \pi_t \tag{A.19}$$

$$0 = l_{yy}y_t + l_{yq}q_t + l_{y\epsilon}\epsilon_t - k\eta\varphi_{1,t} + \varphi_{2,t} - \varphi_{4,t} \tag{A.20}$$

$$0 = l_{yq}y_t + l_{qq}q_t + l_{q\epsilon}\epsilon_t - k\frac{\lambda}{1-\lambda}\varphi_{1,t} - \gamma\varphi_{2,t} + \left(\varphi_{3,t} - \frac{\varphi_{3,t-1}}{\beta}\right) + \frac{\lambda}{1-\lambda}\varphi_{4,t} \tag{A.21}$$

$$0 = -k\rho\varphi_{1,t} - (1-\lambda)\varphi_{2,t} - \rho\left(\varphi_{3,t} - \frac{\varphi_{3,t-1}}{\beta}\right) + \varphi_{4,t} \tag{A.22}$$

$$E_t\ \Delta\varphi_{4,t+1} = \frac{(\delta+\tau)}{\beta}\varphi_{3,t} \tag{A.23}$$

When $\tau = \delta = 0$, $E_t\Delta\varphi_{4,t+1} = 0$. Thus, combining (A.21) and (A.22), we get,

$$0 = E_t\begin{bmatrix} l_{yq}\Delta y_{t+1} + l_{qq}\Delta q_{t+1} + l_{q\epsilon}\Delta\epsilon_{t+1} - k\left(\frac{\lambda}{1-\lambda}+1\right)\Delta\varphi_{1,t+1} \\ -\left(\gamma + \frac{1-\lambda}{\rho}\right)\Delta\varphi_{2,t+1} \end{bmatrix} \tag{A.24}$$

Also, from (A.19) and (A.20), we obtain

$$E_t \Delta \varphi_{2,t+1} = -E_t \left[l_{yy} \Delta y_{t+1} + l_{yq} \Delta q_{t+1} + l_{y\epsilon} \Delta \epsilon_{t+1} + k \eta l_\pi \pi_{t+1} \right] \tag{A.25}$$

Using (A.24) and (A.25), we get the optimal policy

$$0 = E_t \left[W_y \left(\Delta y_{t+1} - y_{t+1}^T \right) + W_q \left(\Delta q_{t+1} - q_{t+1}^T \right) + W_\pi \pi_{t+1} \right]$$

where

$$\begin{aligned}
W_y &= l_{yq} + \left(\gamma + \frac{1-\lambda}{\rho} \right) l_{yy} \\
W_q &= l_{qq} + \left(\gamma + \frac{1-\lambda}{\rho} \right) l_{yq} \\
W_\pi &= \left(\frac{1}{1-\lambda} \right) + \left(\gamma + \frac{1-\lambda}{\rho} \right) \eta \\
y_t^T &= -\frac{\left(\gamma + \frac{1-\lambda}{\rho} \right)}{W_y} \epsilon_t \\
q_t^T &= -\frac{l_{q\epsilon}}{W_q} \epsilon_t = 0
\end{aligned}$$

Table 1: Baseline Parameters

Parameter	Value	Remarks
λ	0.4	Trade openness
β	0.99	Discount factor (annual real interest rate of 4%)
η	1.6	Inverse Frisch elasticity of labor supply
α	0.75	Calvo sticky price parameter: average of 4 quarters of price rigidity
θ	1.5	Elasticity of substitution between domestic and foreign goods
δ	0.01	Elasticity of risk premium with respect to foreign debt size
σ	6	Elasticity of substitution among differentiated intermediate goods
ρ	2	Coefficient of relative risk aversion
γ	$\theta\lambda\ (2 - \lambda) / (1 - \lambda)$	
k	$(1 - \alpha\beta)(1 - \alpha)/\alpha(1 + \sigma\eta)$	
ρ_{ϵ}	0.95	Persistence of productivity shock
$\sigma_{\epsilon}, \sigma_{v}$	0.07	Standard deviation of productivity and risk premium shocks
χ	2.5	Activeness of interest rate targeting

Table 2: Welfare Loss and Variance of Key Variables

Policy	**Parameter**	**Welfare loss**	$\mathbf{var}(\boldsymbol{q})$	$\mathbf{var}(\boldsymbol{y})$	$\mathbf{var}(\boldsymbol{\pi})$
Risk premium Shock					
IT	$\tau = 0$	0.0018	9.95E-04	2.54E-03	6.17E-07
PEG		-4.45E-07	9.26E-07	8.78E-05	1.05E-07
OP		-0.00022	8.34E-05	5.41E-05	2.00E-09
IT	$\tau = 0.01$	0.0017	9.54E-04	2.45E-03	6.04E-07
PEG		-1.00E-06	8.83E-07	8.56E-05	1.00E-07
OP		-0.00021	7.95E-05	5.11E-05	2.07E-09
Productivity Shock					
IT	$\tau = 0$	-0.0155	0.0017	0.0117	1.23E-05
PEG		-0.0130	0.0011	0.0083	8.97E-06
OP		-0.0189	0.0018	0.0124	1.16E-08
IT	$\tau = 0.01$	-0.0131	0.0015	0.0112	1.50E-05
PEG		-0.0121	0.0010	0.0081	8.18E-06
OP		-0.0171	0.0016	0.0120	7.62E-09

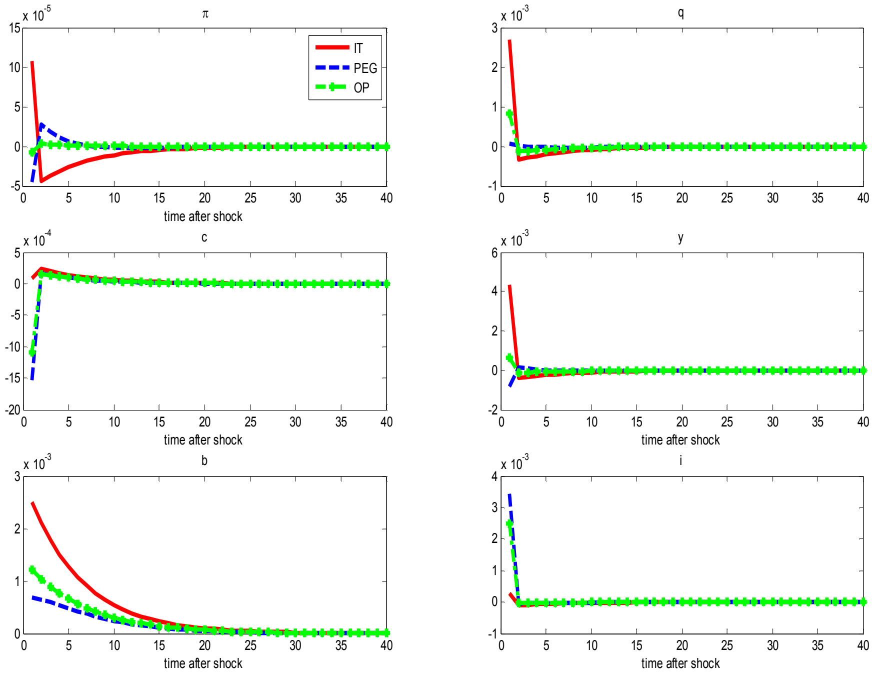
Table 3: Welfare Loss and Variance When Both Shocks Are Turned On

Policy	$\boldsymbol{\tau = 0}$	**Parameter**	**Welfare loss**	$\mathbf{var}(\boldsymbol{q})$	$\mathbf{var}(\boldsymbol{y})$	$\mathbf{var}(\boldsymbol{\pi})$
IT		θ=2	0.1025	0.0464	0.1687	2.27E-04
PEG			0.0334	0.0017	0.0368	5.03E-05
IT		θ=0.5	-0.2076	0.0078	0.0006	1.05E-05
PEG			-0.4845	0.0016	0.0006	3.04E-06

Policy	$\boldsymbol{\tau = 0.01}$	**Parameter**	**Welfare loss**	$\mathbf{var}(\boldsymbol{q})$	$\mathbf{var}(\boldsymbol{y})$	$\mathbf{var}(\boldsymbol{\pi})$
IT		θ=2	0.0930	0.0407	0.1522	1.80E-04
PEG			0.0349	0.0015	0.0364	4.68E-05
IT		θ=0.5	-0.3157	0.0089	0.0007	1.52E-06
PEG			-0.5249	0.0016	0.0006	3.28E-06

Figure 1: Impulse Response of Key Variables

A. Risk Premium Shock



B. Productivity Shock