

# When should Monetary Policy Target the Exchange Rate?\*

Pietro Cova<sup>†</sup>

Jens Søndergaard<sup>‡</sup>

## Abstract

This paper evaluates the welfare effect of simple (but not optimal) monetary targeting rules in a stochastic two-country open-economy model featuring producer price stickiness and imperfect competition. We point out specific cases when the central bank would prefer to stabilize the exchange rate rather than domestic producer prices as recommended by Obstfeld and Rogoff (2002b), Clarida et al. (2002) and Gali and Monacelli (2002). Our results suggest that an exchange rate peg is particularly desirable when the country is small and faces an elastic export demand curve. Unlike earlier contributions, we evaluate welfare using a second order approximation of the model's structural equilibrium conditions as well as of the welfare function.

*JEL Classification:* F41 F42 F52

*Keywords:* Optimal Monetary Policy, Open Economy Macroeconomics

First Draft: August 2003

Current Draft: January 2004

Word Count (approximate) : 7432

---

\*We are grateful to Gianluca Benigno, Matthew Canzoneri, Giancarlo Corsetti, Robert Cumby, Behzad Diba, Michel Juillard and Massimiliano Pisani for helpful discussions and comments on earlier versions of the paper. We have also benefited from comments by seminar participants at the Banca d'Italia, University of Copenhagen (EPRU) and the CEPR 6th Conference of the Analysis of International Capital Markets RTN. Søndergaard's work on this paper is part of a research network on 'The Analysis of International Capital Markets: Understanding Europe's Role in the Global Economy', funded by the European Commission under the Research Training Network Programme (Contract No. HPRN-CT-1999-00067). All remaining errors are obviously ours.

<sup>†</sup> *Georgetown University.* Correspondence to: Georgetown University, Department of Economics, 37th & O St, Washington DC 20057. Email: covap@georgetown.edu, Homepage: <http://www.georgetown.edu/users/covap/>. Tel: +1 (202) 687 5830, Fax: +1 (202) 687 6102.

<sup>‡</sup> *Georgetown University.* Correspondence to: Georgetown University, Department of Economics, 37th & O St, Washington DC 20057. Email: sondergj@georgetown.edu, Homepage: <http://www.georgetown.edu/users/sondergj/>. Tel: +1 (202) 687 5830, Fax: +1 (202) 687 6102.

# 1 Introduction

Should domestic monetary policy target the nominal exchange rate? Or should the central bank adopt an inward-looking monetary policy and target only domestic output prices? Several recent papers including Clarida et al. (2002), Gali and Monacelli (2002), Obstfeld and Rogoff (2002b) have argued in favor of the latter option since it will close the output gap entirely and thus attain the level of output and employment that would prevail in a flexible price world.<sup>1</sup> However, Corsetti and Pesenti (2001b) and Devereux and Engel (2003) stress that inward-looking policies are not always optimal when prices are preset in local currency and firms' profits are exposed to currency fluctuations. Excessive exchange rate volatility can then be detrimental to country welfare.

In this paper, we show that a policy of exchange rate stabilization can be desirable even when prices are pre-set in the producer currency. Our model is a standard stochastic two-country open-economy model featuring producer price stickiness and imperfect competition also used in earlier contributions such as Clarida et al. (2002) and Obstfeld and Rogoff. However, our work differs from previous work in a crucial way: Rather than assuming a unitary value for the intratemporal elasticity of substitution over traded goods, we choose to work with a more general CES preference specification. By allowing for non unitary elasticity values, we are able to highlight specific cases when the domestic central bank would prefer to stabilize the exchange rate rather than domestic output prices. Specifically, we find that an exchange rate peg is desirable when the domestic country is small, open and faces an elastic export demand curve, i.e an intratemporal elasticity of substitution exceeding one. As traded goods become more elastic, a policy of output price stabilization leads to a greater variability in employment and thus higher uncertainty about marginal costs. In order to protect his markups, the producer would want to charge higher average prices but cannot do so under a policy of internal price stabilization. Inefficient markup fluctuations will occur and an 'inward-looking' policy cannot be optimal.<sup>2</sup>

On the contrary, a unilateral exchange rate peg allows the producer to charge higher average prices in response to higher marginal cost uncertainty. As the elasticity of substitution increases, his markups are then less affected by real disturbances. Compared to the case of producer price targeting, an exchange rate peg implies a more appreciated expected terms

of trade and hence lower expected employment and consumption. For small countries facing elastic export demand curves, the welfare gains from lower expected employment outweigh the losses associated with lower expected consumption.

Interestingly, the reason why a small country would want to fix the exchange rate differs markedly from more traditional arguments (Giavazzi and Pagano, 1988) which, especially in a European context, have emphasized fixed exchange rate policies as a way of importing monetary credibility. In this paper, monetary authorities are assumed to *precommit* to either a policy of domestic producer price stabilization or a unilateral exchange rate peg. As such, there is no credibility problem in our framework. The case for fixing exchange rates in our work is closely related to the point made by Benigno and Benigno (2003a) and in Corsetti and Pesenti (2001a) that central banks in an open economy can use "sticky prices to manipulate the terms of trade to their own country's advantage (Benigno and Benigno, 2003a)". Our results suggest that the incentive to exploit this so-called terms of trade externality increases with the intratemporal elasticity of substitution and decreases with domestic country size.

The key parameter driving our results is the intratemporal elasticity of substitution. For non unitary values of this parameter, it is not possible to derive closed form solutions. We therefore rely on a local approximation around a nonefficient steady state, i.e. no appropriate subsidies are introduced to eliminate the steady state monopolistic distortions. This raises a methodological issue since the country-specific welfare measure we want to derive should capture the effect of second order moments on the means of all our endogenous variables. As explained in Benigno and Woodford (2003), a correct welfare evaluation therefore requires a second order Taylor approximation to the structural equilibrium conditions of the model as well as to the welfare function. For this purpose, we evaluate welfare using both the computational approach based on perturbation methods described in Schmitt-Grohe and Uribe (2004), Collard and Juillard (2000) and Kim et al. (2003) as well as the analytical approach described in Benigno and Woodford (2003). Both solution techniques support our finding namely that a unilateral exchange rate peg welfare dominates producer price targeting when the country is small, open and faces an elastic export demand curve.

The rest of the paper is organized as follows: Section 2 highlights the main features of the now standard model. Section 3 presents the solution technique while section 4 discusses the calibration parameters. Section 5 reports the results from the computational as well as

the analytical approach. Section 6 contains the conclusion and suggests directions for further research.

## 2 A Stochastic Two-Country Model

The model is a stochastic two-country open-economy model featuring producer price stickiness and imperfect competition. We assume that the world consists of two economies namely a domestic and a foreign. Each economy is inhabited by infinitely-lived households  $i \in [0, 1]$  and monopolistic firms  $j \in [0, 1]$ . Domestic households and domestic firms are distributed along the continuum  $[0, n)$  while foreign households and firms reside on the interval  $[n, 1]$ . As always foreign variables in what follows below are denoted with an asterisk.

### 2.1 Consumer Preferences

The lifetime utility of a representative domestic household is defined as:

$$U_t(i) \equiv E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \left[ \frac{C_{\tau}(i)^{1-\rho}}{1-\rho} - \kappa \frac{1}{1+\chi} N_{\tau}(i)^{1+\chi} \right] \quad (1)$$

where the parameter  $\kappa$  is the weight on disutility from working and  $\chi$  represents the inverse of the elasticity of labor supply. We assume that the utility gains from holding real money are zero and therefore leave out real money balances from the utility function.<sup>3</sup>  $C(i)$  is the household's consumption aggregate of domestic and foreign produced consumption goods, which is expressed as:

$$C_t(i) = \left[ \gamma^{\frac{1}{\eta}} C_{Ht}(i)^{\frac{\eta-1}{\eta}} + (1-\gamma)^{\frac{1}{\eta}} C_{Ft}(i)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

Similarly the foreign household's aggregate consumption preferences are also described by a CES index:

$$C_t^*(i) = \left[ (\gamma^*)^{\frac{1}{\eta}} C_{Ht}^*(i)^{\frac{\eta-1}{\eta}} + (1-\gamma^*)^{\frac{1}{\eta}} C_{Ft}^*(i)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

The parameter  $\eta$  is the elasticity of substitution between domestic and foreign produced traded goods. The parameter  $\gamma$  ( $\gamma^*$ ) represents the expenditure weight of home (foreign) produced

consumption goods in the aggregate consumption index. As will become clearer in the section describing the calibration we will allow the domestic and foreign weight to differ ( $\gamma \neq \gamma^*$ ).

Households are assumed to maximize (1) subject to the following budget constraint:

$$\begin{aligned} & \int_0^n [P_{H,t} C_{H,t}(i) + P_{F,t} C_{F,t}(i)] di + E_t \{Q_{t,t+1} B_{t+1}(i)\} \\ & \leq B_t(i) + W_t N_t(i) + \int_0^n \pi_t(i, j) dj \end{aligned} \quad (2)$$

where  $B_{t+1}(i)$  is a state-contingent claim held at the end of period  $t$ ,  $Q_{t,t+1}$  is the stochastic discount factor for nominal payoffs and  $\pi_t(i, j)$  are profits of firm  $j$  received by household  $i$  in period  $t$ . The remaining terms in the budget constraint describe the household's consumption expenditure and labor income.

The domestic household's optimization problems can be summarized by the following standard first-order conditions with respect to (domestic and foreign) consumption goods, labor supply and bond holdings:

$$C_t^{\frac{1}{\eta}-\rho}(i) (\gamma)^{\frac{1}{\eta}} C_{H,t}^{-\frac{1}{\eta}}(i) = \lambda_t(i) P_{H,t} \quad (3)$$

$$C_t^{\frac{1}{\eta}-\rho}(i) (\gamma)^{\frac{1}{\eta}} C_{F,t}^{-\frac{1}{\eta}}(i) = \lambda_t(i) P_{F,t} \quad (4)$$

Domestic labor supply is governed by

$$W_t = \frac{N_t^X(i)}{\lambda_t(i)} \quad (5)$$

where we are assuming that all agents work for all the domestic firms and hence receive the same wage rate.

Finally, the domestic Euler equation states that for each possible state of nature that may occur in the next period, the following condition has to hold:

$$\lambda_t(i) = \beta I_t E_t [\lambda_{t+1}(i)] \quad (6)$$

where

$$I_t = E_t [Q_{t,t+1}]^{-1}$$

is the nominal (gross) return on the state-contingent bond that will be paid to the representative household irrespective of the state in  $t + 1$ .

Note that foreign households face a symmetric optimization problem and have access to the same state-contingent nominal bond. Complete markets imply then that in each period and for each possible future state of nature the following condition always holds:

$$\frac{U_C(C_t)}{P_t} = \frac{U_{C^*}^*(C_t^*)}{S_t P_t^*} \quad (7)$$

where  $S_t$  is the home currency price of one unit of foreign currency.

## 2.2 Firms and Optimal Price Setting

### 2.2.1 Production technologies, Intermediate and Final Output and Price Indexes

Firms are assumed to be monopolistic producers of domestic and foreign brands, indexed by  $j \in [0, 1]$ . The  $[0, n)$  interval is populated by domestic firms, while foreign firms lie on the  $[n, 1]$  interval. The production process for domestic brands relies on a simple linear technology in a composite labor input of all the domestic households, i.e.

$$\begin{aligned} Y_{H,t}(j) &= Z_{H,t} L_{H,t}(j) \\ L_{H,t}(j) &= \int_0^n L_{H,t}(i, j) di \end{aligned} \quad (8)$$

Foreign firms use a similar production technology, which requires a foreign composite labor input. We assume that productivity is country-specific and that it follows a trend-stationary AR(1) process of the following form:

$$\begin{pmatrix} Z_{Ht} \\ Z_{Ft}^* \end{pmatrix} = \begin{pmatrix} A_{11} & 0 \\ 0 & A_{22} \end{pmatrix} \begin{pmatrix} Z_{Ht-1} \\ Z_{Ft-1}^* \end{pmatrix} + \varepsilon_t \quad (9)$$

whereas the country-specific shocks,  $\varepsilon_t = (\varepsilon_t^H, \varepsilon_t^F)$ , has the variance-covariance matrix  $V(\varepsilon_t)$ .

The brands produced in both countries can be thought of as intermediate goods, which are then sold to a domestic and to a foreign competitive firm. The domestic competitive firm bundles these intermediate goods into final goods according to the following CES indexes:<sup>4</sup>

$$Y_{H,t} = \left[ \left( \frac{1}{n} \right)^{\frac{1}{\theta}} \int_0^n Y_{H,t}(j)^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}}$$

$$Y_{F,t} = \left[ \left( \frac{1}{1-n} \right)^{\frac{1}{\theta}} \int_n^1 Y_{F,t}(j)^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}}$$

The parameter  $\theta$  measures the elasticity of substitution across brands, which is assumed to be greater than one. For simplicity, we also impose that  $\theta$  is the same for both domestic and foreign produced brands.

The corresponding price indexes for the above domestic and foreign final goods sold on the home markets are:

$$P_{H,t} = \left[ \left( \frac{1}{n} \right) \int_0^n P_{H,t}(j)^{1-\theta} dj \right]^{\frac{1}{1-\theta}}$$

$$P_{F,t} = \left[ \left( \frac{1}{1-n} \right) \int_n^1 P_{F,t}(j)^{1-\theta} dj \right]^{\frac{1}{1-\theta}}$$

Thus, each individual firm acts as a monopolistic producer and faces a downward sloping demand - derived from the competitive firm's profit maximization problem - for its brand of the following Dixit-Stiglitz (1977) form:

$$Y_{H,t}(j) = \frac{1}{n} \left[ \frac{P_{H,t}(j)}{P_{H,t}} \right]^{-\theta} Y_{H,t} \quad (10)$$

$$Y_{F,t}(j) = \frac{1}{1-n} \left[ \frac{P_{F,t}(j)}{P_{F,t}} \right]^{-\theta} Y_{F,t}$$

Demand for each brand  $j$  is positively related to aggregate demand -  $Y_{H,t}$  and  $Y_{F,t}$  respectively - and inversely related to relative prices. The relative price elasticity of demand for a single brand is increasing in the elasticity of substitution across the different brands,  $\theta$ . The prices for the final goods sold on the foreign markets have the same functional forms and foreign firms face similar demand conditions. Thus, given that both domestic and foreign brands are traded worldwide we assume that the law of one price holds for each individual brand  $j$  and for all the final goods, i.e.

$$P_{H,t} = S_t P_{H,t}^* \quad (11)$$

$$P_{F,t} = S_t P_{F,t}^* \quad (12)$$

where  $S_t$  is the home currency price of one unit of foreign currency. The domestic terms of trade is therefore defined as

$$TOT_t = \frac{S_t P_{F,t}^*}{P_{H,t}} \quad (13)$$

We further allow for the existence, in each country, of another competitive industry that combines the domestic and foreign final goods -  $(Y_{H,t}, Y_{F,t})$  for the home economy and  $(Y_{H,t}^*, Y_{F,t}^*)$  for the foreign economy - into the composite or aggregate consumption goods:

$$C_t = \left[ \gamma^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + (1-\gamma)^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \quad (14)$$

$$C_t^* = \left[ (\gamma^*)^{\frac{1}{\eta}} C_{F,t}^{*\frac{\eta-1}{\eta}} + (1-\gamma^*)^{\frac{1}{\eta}} C_{H,t}^{*\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \quad (15)$$

and then sells them to the home and foreign households at the aggregate prices:

$$P_t = \left[ \gamma P_{H,t}^{1-\eta} + (1-\gamma) P_{F,t}^{1-\eta} \right]^{\frac{1}{1-\eta}} \quad (16)$$

$$P_t^* = \left[ \gamma^* P_{H,t}^{*1-\eta} + (1-\gamma^*) P_{F,t}^{*1-\eta} \right]^{\frac{1}{1-\eta}} \quad (17)$$

Since preferences are asymmetric across countries, PPP does not hold at the aggregate level ( $P_t \neq S_t P_t^*$ ). In this case, the risk-sharing condition in (7) implies that the ratio of marginal utilities equals the consumption-based real exchange rate.

### 2.2.2 Optimal Price Setting

We assume that firms set prices in a staggered fashion as in Calvo (1983). Thus, only a restricted number of domestic and foreign monopolistic producers, fractions  $1-\alpha$  and  $1-\alpha^*$  respectively, are able to reset their prices in each period. The optimal pricing equation of the domestic firms resetting their prices in period  $t$  takes the following form:

$$\tilde{P}_{H,t}(j) = \frac{\theta}{\theta-1} \frac{E_t \sum_{\tau=t}^{\infty} (\alpha\beta)^{\tau-t} \lambda_{\tau} P_{H,\tau}^{\sigma} Y_{H,\tau} \left( \frac{W_{\tau}}{Z_{H,\tau}} \right)}{E_t \sum_{\tau=t}^{\infty} (\alpha\beta)^{\tau-t} \lambda_{\tau} P_{H,\tau}^{\sigma} Y_{H,\tau}} \quad (18)$$

where  $\tilde{P}_{H,t}(j)$  is the new price set by domestic firm  $j$  in period  $t$ , which will be in effect in period  $k > t$  with probability  $\alpha^{k-t}$ .



The above optimal pricing rule holds for all the firms that can reset prices in period  $t$ . This allows us to impose that  $\tilde{P}_{H,t}(j) = \tilde{P}_{H,t}$  for all the period  $t$  price-setting firms distributed on the  $[0, n)$  interval and to derive the following expression for the aggregate price level of domestic final goods  $P_{H,t}$ :

$$P_{H,t} = \left[ (1 - \alpha) \left( \tilde{P}_{H,t} \right)^{1-\theta} + \alpha (P_{H,t-1})^{1-\theta} \right]^{\frac{1}{1-\theta}} \quad (19)$$

Equation (19) states that the aggregate domestic price level is a weighted average of new prices  $\tilde{P}_{H,t}$  set in period  $t$  and the lagged value of the aggregate domestic price level. An equivalent optimal price-setting condition holds for producers in the foreign country.

### 2.3 Monetary Policy

We assume that the domestic central bank can either precommit to a unilateral exchange rate peg (PEG) or to a rule which stabilizes producer prices (DIT). In both cases, the foreign central bank is assumed to have no choice and always precommits to targeting his own producer prices (FIT). We therefore abstract from the game-theoretic aspects of monetary policy rules explored elsewhere in the literature and leave this issue for future research. As in Benigno and Benigno (2003a), we do not restrict monetary policy to a specific Taylor rule linking the nominal interest rate to specific target variables. Instead, we assume that the domestic central bank has direct control over either producer prices (DIT) or nominal exchange rates (PEG).<sup>5</sup>

### 2.4 Goods Markets and Equilibrium

Our model is closed by imposing that in each period domestic and foreign goods markets clear in equilibrium, i.e.

$$nY_{H,t}(i) = nC_{H,t}(i) + (1 - n)C_{H,t}^*(i) \quad (20)$$

$$(1 - n)Y_{F,t}(i) = nC_{F,t}(i) + (1 - n)C_{F,t}^*(i) \quad (21)$$

Equations (9), (11), (12), (19) as well as its foreign counterpart and (20), (21) characterize together with the domestic and the foreign optimality conditions for households and firms and the respective monetary policy rules the equilibrium outcome for the model.

## 2.5 Welfare Analysis

Following Benigno and Benigno (2003a) we assume that the domestic monetary authorities rank the alternative monetary policy rules specified in Section 2.3 by comparing the expected welfare levels determined by each of them. Domestic and foreign expected welfare can be expressed as:

$$W_t = E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \left[ \frac{C_{\tau}^{1-\rho}}{1-\rho} - \frac{1}{n} \int_0^n \frac{(N_{H,t})^{1+\chi}}{1+\chi} dj \right]$$

$$W_t^* = E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \left[ \frac{C_{\tau}^{*1-\rho}}{1-\rho} - \frac{1}{1-n} \int_n^1 \frac{(N_{F,t}^*)^{1+\chi}}{1+\chi} dj \right]$$

## 3 Approach and Solution Techniques

Since the model does not yield a closed form solution, we will resort to approximation methods. However, as explained in Sutherland (2002), the traditional log-linearization technique is not well suited for welfare analysis since it precludes us from capturing the effect of second order moments on first order moments. For instance, a first order approach would not enable us to analyze the effect of exchange rate volatility on expected consumption and hence on welfare. For this purpose, we employ both the computational approach based on perturbation methods described in Schmitt-Grohe and Uribe (2004), Collard and Juillard (2000) and Kim et al (2003) as well as the analytical approach described in Benigno and Woodford (2003).

The computational method can be summarized as follows: We first employ a Newton-type optimization technique to derive the steady state solution of our nonlinear system of equations.<sup>6</sup> We then take a first order Taylor approximation of the model's structural equilibrium equations around this deterministic steady state. Next, we evaluate whether the Blanchard-Kahn stability conditions are satisfied. Having verified that the system is stable, we then take a second order Taylor approximation of the same structural equations around the non-efficient steady state. The system of equations is solved using the Schmitt-Grohe and Uribe (2004) approach.<sup>7</sup> The solution is then used to derive the implied first and second order moments of the endogenous variables.<sup>8</sup>

The analytical approach is described in Benigno and Woodford (2003). It essentially relies on taking a second order approximation to all the structural equilibrium conditions as well as to the welfare function. Combining the second-order approximations to eliminate the linear terms in the quadratic approximations to the welfare functions, yields a micro-founded loss-function for the domestic central bank where the welfare losses depend on quadratic deviations of terms of trade, domestic and foreign output and inflation rates from their respective target values. Compared to the computational approach, the Benigno and Woodford (2003) method yields a direct analytical expression for the loss function that better allows for intuitive interpretations.

## 4 Calibration

The parameters in our benchmark welfare calculation are similar to the calibration described in Gali and Monacelli (2002). The discount factor is set at  $\beta = 0.99$  which corresponds to a steady state interest rate of 4% in a quarterly model. The risk-aversion coefficient is set at  $\rho = 1$ . The persistence parameters in the technology process are set to  $A_{11} = A_{22} = 0.9$ . Gali and Monacelli (2002) calibrate the productivity process on the basis of estimates for Canada and the United States. Therefore they assume the standard deviations of country-specific technology shocks to be  $\sigma_H = \sigma_F = 1\%$  with a cross-country correlation of 0.77. This implies a covariance of  $\sigma_{HF} = 0.000077$ .

[Insert Table 1 about here]

The elasticity of substitution across differentiated goods is set at  $\theta = 6$  which implies an average steady-state markup of 20%. The weight on the disutility of labor  $\kappa$  is assumed to be 1 and the Frisch labor supply elasticity  $\frac{1}{\chi}$  is set to 0.33 ( $\chi = 3$ ). The degree of price stickiness is captured by the parameter  $\alpha$ . Following the work of Gali et al (2001), it is assumed to be 0.75, which implies an average contract duration of 4 quarters. According to Gali and Monacelli, the share of imports in Canadian GDP is 40%. They therefore set  $\gamma$  in the domestic aggregate consumption index, equation (14), to 0.6. Since they calibrate their model on a small open economy, we assume that the size of the domestic economy is  $n = 0.005$  or 0.5% of the larger foreign economy.

The intratemporal elasticity of substitution across traded goods is assumed to be unitary in the Gali and Monacelli (2002) calibration. However, there is great uncertainty about the true value

of this elasticity. The RBC literature usually assumes values between 0.9 and 2 while more recent work by Lai and Trefler (2002) finds estimates for the elasticity of substitution around 5.50.<sup>9</sup> Rather than settling on one parameter value, we present results for values ranging from 1 to 10. The foreign expenditure weight  $\gamma^*$  is pinned down by the condition that the trade balance has to be balanced in the steady state.

## 5 Results

### 5.1 Why is Producer Price Targeting suboptimal?

A central result in our analysis is that producer price targeting can be a suboptimal policy rule for the domestic country.<sup>10</sup> This suboptimality occurs as the elasticity of substitution increases and the domestic country becomes relatively smaller. One way to understand this result is to consider how domestic employment responds to, say, a positive domestic productivity shock. Figure 1 shows the impulse response functions of several variables including domestic employment to a domestic (normalized) positive productivity shock. The functions were generated with the above calibration parameters except that we impose symmetric country sizes ( $n = 0.5$ ) and that the domestic and the foreign central banks are assumed to target their producer prices. We explore how the impulse responses vary to different values of the intratemporal elasticity of substitution. Several results stand out: For the benchmark case usually considered in the literature ( $\eta = 1$ ), domestic employment is completely insulated from the productivity shock while the terms of trade responds in a one-to-one relationship. However, as the elasticity of substitution increases and goods become elastic, domestic employment responds more and the terms of trade less to a productivity shock. The higher variability of employment affects the domestic producer's price setting decision. From his point of view, higher employment variability implies higher uncertainty about his marginal costs. In order to protect markups, the producer would want to charge higher average prices but cannot do so under a policy of internal price stabilization. Therefore markup fluctuations will occur why an 'inward-looking' policy might be suboptimal for high values of  $\eta$ .

[Insert Figure 1 about here]

The impulse response functions in Figure 2 explore how the results change when the domestic country size varies. In this experiment, the elasticity of substitution was fixed at  $\eta = 6$ . Note

that the domestic employment and the terms of trade respond more to a domestic productivity shock, as the domestic country size decreases. Again, the domestic producer in the small country would want to set higher prices in order to protect his markups but is prevented from doing so by the 'inward-looking' policy.

[Insert Figure 2 about here]

## 5.2 Welfare comparisons

### 5.2.1 Results from the computational methods

We now apply the computational methods outlined in Schmitt-Grohe and Uribe (2004) to calculate welfare under the two alternative monetary regimes.<sup>11</sup> In one regime, the domestic and the foreign central bank both pursue 'inward-looking' policies (DIT,FIT). In the other, the domestic monetary authorities peg their currency while the foreign central bank targets foreign producer prices (PEG,FIT).

Figure 3 reports country-specific welfare for the two monetary regimes when countries are equally sized. While welfare is calculated for different values of the intratemporal elasticity of substitution, all other parameters take on the values described in Table 2. The upper and lower panel report respectively values for domestic and foreign welfare. The dash-dotted line represents welfare when the domestic central bank pegs (upper panel) and the foreign monetary authority (lower panel) targets producer prices. The solid line refers to welfare when both the domestic (upper panel) and the foreign (lower panel) country pursue 'inward-looking' policies. The results clearly suggest that a unilateral exchange rate peg is never optimal. Domestic and foreign welfare is higher in the case where both central banks target their producer prices i.e. in the (DIT,FIT) regime.

[Insert Figure 3 about here]

Figure 4 plots welfare for the case where the size of the domestic country is small ( $n = 0.005$ ) relative to the foreign country. A number of results arise: First, domestic welfare in the (DIT,FIT) regime decreases as its export demand curve becomes more elastic. On the contrary, under a unilateral peg domestic welfare increases with higher intratemporal elasticity of substitution. For elasticity values higher than 5.5 – not an unreasonable assumption given the estimates in Trefler and Lai (2002) – the domestic country is better off welfare-wise in

the (PEG,FIT) monetary regime. Note, however, that the welfare difference across the two regimes is quite small.<sup>12</sup> Second, the lower panel of Figure 4 indicates that being an anchor country is not without costs: Welfare for the foreign country is lower in the (PEG,FIT) regime compared to the scenario where both central banks target their own producer prices. However, the foreign welfare loss is practically nil.

[Insert Figure 4 about here]

The role of relative country sizes is explored in Figure 5. Country-specific welfare is calculated for different values of the domestic country size  $n$  ranging from 0.15% up to 10%. Throughout the experiment, the intratemporal elasticity of substitution,  $\eta$ , is assumed to equal 6. The upper panel reports the difference in domestic welfare across the two regimes calculated as welfare under (PEG,FIT) minus welfare under (DIT,FIT). We note that the difference is positive when the domestic country is small ( $n < 0.03$ ).<sup>13</sup> This implies that domestic welfare under a unilateral peg is higher compared to the case where both central banks target their producer prices. As the size of the domestic country increases, the difference becomes negative and the (DIT,FIT) regime increasingly welfare dominates a unilateral exchange rate peg. The lower panel contains the foreign welfare difference across the two regimes. The numbers confirm that the foreign country is always worse off welfare-wise being the anchor country.

[Insert Figure 5 about here]

To gain some additional insights into our result, Figure 6 plots the first moments and second moments of the terms of trade, domestic consumption, domestic employment and domestic notional prices.<sup>14</sup> We calculate moments for different values of  $\eta$  across the two monetary regimes. Further, the values were derived using the standard calibration and assuming that the size,  $n$ , of the domestic country equals 0.005. The upper panel reports the percent differences in means across regimes. A negative number indicates that the corresponding mean value is lower under the exchange rate peg (PEG,FIT) relative to the 'inward-looking' (DIT,FIT) regime. Note that the means were calculated from a second order approximation and thus capture the effect of second order moments on first order moments. The lower panel contains the corresponding standard deviations.

Two interesting results emerge from Figure 6: First, when both central banks target their producer prices (DIT,FIT), a higher intratemporal elasticity of substitution leads to a higher variability in domestic employment.<sup>15</sup> But since the monetary regime prevents domestic producers from charging higher prices, there is no variability in the domestic notional prices. Second, in an exchange rate peg low values of  $\eta$  imply a high domestic employment variability. Hence the incentive to raise average producer prices is higher. In fact, when the elasticity of substitution is low, the expected notional domestic price is high. The higher expected domestic prices translate into a more appreciated (expected) terms of trade and thus lower expected domestic employment and consumption. When does a unilateral peg welfare dominate? The answer depends on the tradeoff between the welfare gains from lower expected employment and the welfare losses associated with lower expected consumption. Figure 4 suggest that this is the case exactly when the elasticity,  $\eta$ , exceeds 5.5

[Insert Figure 6 about here].

### 5.2.2 Results from the analytical method<sup>16</sup>

We now proceed to evaluate welfare using the analytical approach described in Benigno and Woodford (2003). This essentially relies on taking a second order approximation to all the structural equilibrium conditions as well as to the welfare function. As shown in the technical appendix, we follow Benigno and Benigno (2003b) closely and derive a quadratic micro-founded loss function (22) for the domestic central bank.<sup>17, 18</sup>

$$\begin{aligned}
L_t = & \Lambda_{YH} \left( \hat{Y}_{H,t} - \tilde{Y}_{H,t} \right)^2 + \Lambda_{YF} \left( \hat{Y}_{F,t} - \tilde{Y}_{F,t} \right)^2 + \Lambda_T \left( \hat{T}_t - \tilde{T}_t \right)^2 \\
& + \Lambda_{YH,T} \left( \hat{Y}_{H,t} - \tilde{Y}_{H,t} \right) \left( \hat{T}_t - \tilde{T}_t \right) + \Lambda_{YF,T} \left( \hat{Y}_{F,t} - \tilde{Y}_{F,t} \right) \left( \hat{T}_t - \tilde{T}_t \right) \\
& + q_{\pi_h} \pi_{H,t}^2 + q_{\pi_f} \pi_{F,t}^{*2}
\end{aligned} \tag{22}$$

The domestic welfare losses will depend on quadratic deviations of terms of trade,  $\hat{T}_t$ , domestic output,  $\hat{Y}_{H,t}$ , foreign output,  $\hat{Y}_{F,t}$ , domestic producer inflation,  $\pi_{H,t}$ , and foreign producer inflation,  $\pi_{F,t}^*$ , from their respective target values  $\tilde{T}_t, \tilde{Y}_{H,t}, \tilde{Y}_{F,t}$ .<sup>19</sup> The parameters  $(\Lambda_{YH}, \Lambda_{YF}, \Lambda_T, \Lambda_{YH,T}, \Lambda_{YF,T}, q_{\pi_h}, q_{\pi_f})$  are crucial since they determine the relative loss contribution due to deviations around each target variable. As shown in the technical appendix, these weights are nonlinear functions of the underlying structural parameters of the model.

We are particularly interested in how the loss contributions from terms of trade deviations and inflation variability changes as the intratemporal elasticity of substitution ( $\eta$ ) increases and the domestic country size ( $n$ ) falls.<sup>20</sup> This could further support our finding in section 5.2 that a small country facing an elastic export demand curve would prefer a unilateral exchange rate peg. Recall from Figure 6, that a unilateral peg reduces the volatility in the terms of trade while increasing domestic producer price variability. On the other hand, a policy of internal price stabilization implies no volatility in domestic producer prices but greater fluctuations in the terms of trade.

[Insert Figure 7 about here].

Figure 7 plots the values of the coefficients on domestic producer inflation,  $q_{\pi_h}$  (solid line) and on terms of trade deviations  $\Lambda_T$  (dotted line) for different values of  $\eta$ . The upper panel of Figure 7 considers the case where countries are symmetric ( $n = 0.5$ ). All other parameters are equal to the values summarized in Table 2. As the intratemporal elasticity of substitution increase, the loss from terms of trade variability,  $\Lambda_T$ , rises while the loss from inflation variability,  $q_{\pi_h}$ , declines. However for all values of  $\eta$ , the loss contribution from domestic inflation variability clearly outweighs the losses arising from terms of trade variability. This supports our finding in Figure 3, that in the case of symmetric country sizes the domestic central bank would rather choose to target domestic producer prices rather than fix the exchange rate.

The lower panel explores the case where the domestic country is relatively small ( $n = 0.005$ ). Here the loss from domestic inflation variability,  $q_{\pi_h}$ , is also decreasing in  $\eta$  while the loss contribution from terms of trade deviations,  $\Lambda_T$  increases. However, for values of  $\eta$  above 6 we note that  $\Lambda_T$  exceeds  $q_{\pi_h}$  suggesting that the domestic central bank would prefer an exchange rate peg in order to minimize terms of trade deviations. Fixing the exchange rate does entail greater domestic producer price variability. But as the coefficient  $q_{\pi_h}$  turns negative when the intratemporal elasticity of substitution exceeds 6, more variability in prices actually improves domestic welfare.

Finally, Figure 8 confirms the role played by the relative domestic country size  $n$ .<sup>21</sup> The loss contribution arising from terms of trade deviations increasingly dominates the losses from producer inflation variability as the domestic country gets smaller. This suggests that smaller countries would want to choose an exchange rate peg and minimize terms of trade deviations.



[Insert Figure 8 about here].

## 6 Conclusion and suggestions for further work

Recently a number of papers have argued that optimal monetary policy for open economies should be purely inward-looking. This paper revisits the choice of monetary policy rules in an open economy setting. We find that stabilizing internal prices is not an optimal policy when the country is small, open and faces an elastic export demand curve (high intratemporal elasticity of substitution). As goods become more elastic, a policy of internal price stabilization leads to greater variability in employment and thus higher uncertainty about marginal costs. When the central bank stabilizes producer prices, the domestic producer cannot respond to the greater marginal cost uncertainty by charging on average higher prices. Inefficient markup fluctuations will occur and an 'inward-looking' policy cannot be optimal.

On the contrary, a unilateral exchange rate peg allows the producer to charge higher average prices and his markups are then less affected by real disturbances. Compared to the case of producer price targeting, an exchange rate peg implies a more appreciated expected terms of trade and hence lower expected employment and consumption. For small countries facing elastic export demand curves, the welfare gains from lower expected employment outweigh the losses associated with lower expected consumption.

The case for fixing exchange rates in our work is closely related to the point made by Benigno and Benigno (2003a) and in Corsetti and Pesenti (2001a) that central banks in an open economy can use "sticky prices to manipulate the terms of trade to their own country's advantage". The incentive to exploit this so-called terms of trade externality increases with the intratemporal elasticity of substitution and decreases with domestic country size.

We deliberately choose the most parsimonious model featuring only traded goods producers in order to accentuate the role played by the terms of trade externality. This modelling choice comes at several costs: First, in reality central banks do target a broader price index including also the price of nontraded goods. Second, we abstract from other plausible sources of nominal rigidity such as wage and export price stickiness. Finally, another interesting venue for future research would be to assume that international financial markets are incomplete.

## References

- Backus, D., P. Kehoe and F. Kydland** (1995), International Business Cycles: Theory and Evidence, in T. F. Cooley (eds.), *Frontiers of Business Cycle Research*, Princeton University Press.
- Benigno, G. and P. Benigno** (2003a), Price Stability in Open Economies, *Review of Economic Studies*, 70(4), 743-764.
- Benigno, G. and P. Benigno** (2003b), Designing Targeting Rules for International Monetary Policy Cooperation, *European Central Bank Working Paper No. 279*.
- Benigno, P. and M. Woodford** (2003), Optimal Monetary and Fiscal Policy: A Linear-Quadratic Approach, in M. Gertler and K. Rogoff, eds., *NBER Macroeconomics Annual 2003*, vol. 18, forthcoming. .
- Calvo, G.** (1983), Staggered Prices in a Utility Maximizing Framework, *Journal of Monetary Economics*, 12, 383-398
- Canzoneri, M., R. Cumby and B. Diba** (2002), Recent Developments in the Macroeconomic Stabilization Literature: Is Price Stability a Good Stabilization Strategy? in A. Sumra, J. Chadha and C. Nolan (eds.), *Dynamic Macroeconomic Analysis: Theory and Policy in General Equilibrium*, Cambridge University Press, forthcoming.
- Chari, V. V., P. Kehoe and E. McGrattan** (2000), Sticky Price Models of the Business Cycle: Can the Contract Multiplier Solve the Persistence Problem?, *Econometrica* 68, 5, 1151-1179.
- Clarida, R., J. Gali and M. Gertler** (2002). A Simple Framework for International Monetary Policy Analysis, *Journal of Monetary Economics*, 49(5), 879-904
- Collard, F., and M. Juillard** (2000), Perturbation Methods for Rational Expectations Models, *Discussion paper, CEPREMAP, Paris*, [fabrice.collard@cepremap.cnrs.fr](mailto:fabrice.collard@cepremap.cnrs.fr).
- Corsetti, G., L. Dedola and S. Leduc** (2003), International Risk-Sharing and the Transmission of Productivity Shocks, *unpublished manuscript*.
- Corsetti, G., and P. Pesenti** (2001a), Welfare and Macroeconomic Interdependence, *Quarterly Journal of Economics* 116 (2), 421-446
- Corsetti, G., and P. Pesenti** (2001b), International Dimensions of Optimal Monetary Policy, *National Bureau of Economic Research Working Paper No 8230*

- Devereux, M.**, and **C. Engel** (2003). Monetary Policy in the Open Economy Revisited: Price Setting and Exchange Rate Flexibility. *Review of Economic Studies* forthcoming
- Dixit, A.** and **J. Stiglitz** (1977), Monopolistic Competition and Optimum Product Diversity, *American Economic Review*, 67, 297-308
- Heston, A. R. Summers** and **B. Aten** (2002), Penn World Table Version 6.1, *Center for International Comparisons at the University of Pennsylvania (CICUP)*.
- Gali, J.**, **M. Gertler** and **D. López-Salido** (2001), European Inflation Dynamics, *European Economic Review*, 45 (7), 1237 - 1270.
- Gali, J.** and **T. Monacelli** (2002). Optimal Monetary Policy and Exchange Rate Variability in a Small Open Economy, *National Bureau of Economic Research Working Paper No. 8905*
- Giavazzi, F** and **M. Pagano** (1988), The advantage of tying ones hands: EMS Discipline and Central Bank Credibility, *European Economic Review*, 32, 1055-1082.
- Goodfriend, M.** and **R. King** (2000). The Case for Price Stability, *National Bureau of Economic Research Working Paper No. 8423*
- Heathcote, J.** and **F. Perri** (2002), Financial Autarky and International Business Cycles, *Journal of Monetary Economics*, 49, 601-627
- Kim J.**, **S. Kim**, **E. Schaumburg**, and **C. Sims** (2003), Calculating and Using Second Order Accurate Solutions of Discrete Time Dynamic Equilibrium Models, *unpublished manuscript, Princeton University*
- Lai, H.** and **D. Trefler** (2002), The Gains from Trade with Monopolistic Competition: Specification, Estimation and Mis-Specification, *National Bureau of Economic Research Working Paper No. 9169*
- Obstfeld, M.** and **K. Rogoff** (2002a), Risk and Exchange Rates, in E. Helpman and E. Sadka (eds.), *Volume of Essays in Honor of Assaf Razin*, Cambridge University Press
- Obstfeld, M.** and **K. Rogoff** (2002b), Global Implications of Self-Oriented National Monetary Rules, *Quarterly Journal of Economics* 117, 503-535.
- Pesenti, P.** and **D. Laxton** (2003), Monetary Rules for Small, Open, Emerging Economies, *Journal of Monetary Economics* 50 (5)
- Reinhart, C.** and **K. Rogoff** (2004), The Modern History of Exchange Rate Arrangements: A Reinterpretation, *Quarterly Journal of Economics*, forthcoming.
- Schmitt-Grohé, S.** and **M. Uribe** (2004), Solving Dynamic General Equilibrium Models

Using a Second Order Approximation to the Policy Function, *Journal of Economic Dynamics and Control*, 28, 755-775

**Sutherland, A.**, (2002), A Simple Second-Order Solution Method for Dynamic General Equilibrium Method, *unpublished manuscript, University of St. Andrews*

**Woodford, M.**, (2003), *Interest and Prices: Foundations of a Theory of Monetary Policy*, Princeton University Press

## Notes

<sup>1</sup>Their case for floating exchange rates is similar to Friedman (1953): Nominal exchange rate movements provide the appropriate terms of trade adjustment when goods prices are rigid.

<sup>2</sup>Corsetti and Pesenti (2001b) also argue that producer price targeting can be "suboptimal". However, they assume prices are preset in local currency and hence firms' profits are exposed to currency fluctuations. Our "suboptimality" result holds in a setup where prices are preset in the currency of the producer.

<sup>3</sup>Benigno & Benigno (2002) also leave real money balances out of the utility function and interpret their model as a cash-limiting economy where the utility gains from holding real money goes to zero.

<sup>4</sup>For a formal discussion on the role played by the competitive firm or "bundler", see Chari, Kehoe and McGrattan (2000) or Canzoneri, Cumby and Diba (2002)

<sup>5</sup>The consumer Euler equations can then be used to derive the interest rate adjustment required to control either prices (DIT) or the exchange rate (PEG).

<sup>6</sup>The equations used the model are listed in Section 2.4

<sup>7</sup>Sutherland (2002) provides an alternative to the Schmitt-Grohe and Uribe (2004) approach.

<sup>8</sup>We use the Dynare toolbox to employ the Schmitt-Grohe and Uribe (2004) approach as well as to generate the first and second order moments.

<sup>9</sup>For instance Heathcote & Perri (2002) set the parameter equal to 0.9 while Backus, Kydland and Kehoe (1995) assume 1.5. Corsetti, Dedola and Leduc (2003) calibrate their model to match the volatility of the real exchange rate relative to output by varying the elasticity. They focus on two values namely 0.86 and 1.06

<sup>10</sup>Benigno and Benigno (2003b) also show that the optimality of producer price targeting does not necessarily hold for a more general model specification.

<sup>11</sup>The Technical Appendix briefly summarizes the principles behind the Schmitt-Grohe and Uribe (2004) approach.

<sup>12</sup>We have explored the welfare differences across regimes in an extension to this model which features imported goods that are used as intermediate inputs. Here exchange rate volatility will also affect the optimal input mix. Not surprisingly, we do find that such a setup yields higher welfare differences. Similarly, we have also done a sensitivity analysis changing various parameters (i.e. higher labor supply elasticity and lower domestic expenditure weights  $\gamma$ ). In both cases, a peg welfare dominates for values of the intratemporal elasticity of substitution,  $\eta$ , higher 3.5. These results are available upon request.

<sup>13</sup>Interestingly Obstfeld and Rogoff (2002a) find that small countries do not benefit from an exchange rate peg. Their welfare analysis, however, relies on a setup which allows for a closed form solution by assuming a unitary value of the intratemporal elasticity of substitution.

<sup>14</sup>The 'notional price' is really the optimal price defined as  $\tilde{P}_{H,t}(j)$  in equation (19).

<sup>15</sup>The evidence in Figure 1 already suggested this would be the case.

<sup>16</sup>We are indebted to Gianluca Benigno for invaluable input on this section.

<sup>17</sup>Note, however, that the model in Benigno and Benigno (2003b) differs from ours in one crucial aspect: Since they assume the domestic country size equals the domestic expenditure weight ( $n = \gamma$ ), foreign and domestic preferences are symmetric. This implies that PPP holds at the aggregate level  $P_t = S_t P_t^*$ . In our model with asymmetric country sizes and preferences, aggregate PPP may not necessarily hold.

<sup>18</sup>The technical appendix can be downloaded from our homepages.

<sup>19</sup>Note that variables with a 'hat' represent log deviations from the steady state while variables with a 'tilde' are log deviations of target variables from the steady state.

<sup>20</sup>We therefore abstract from the loss contributions due to the covariance terms. Our numerical analysis revealed that the coefficients of the covariance terms are close to zero.

<sup>21</sup>In drawing the plot, we assume that the intratemporal elasticity of substitution equals 8.

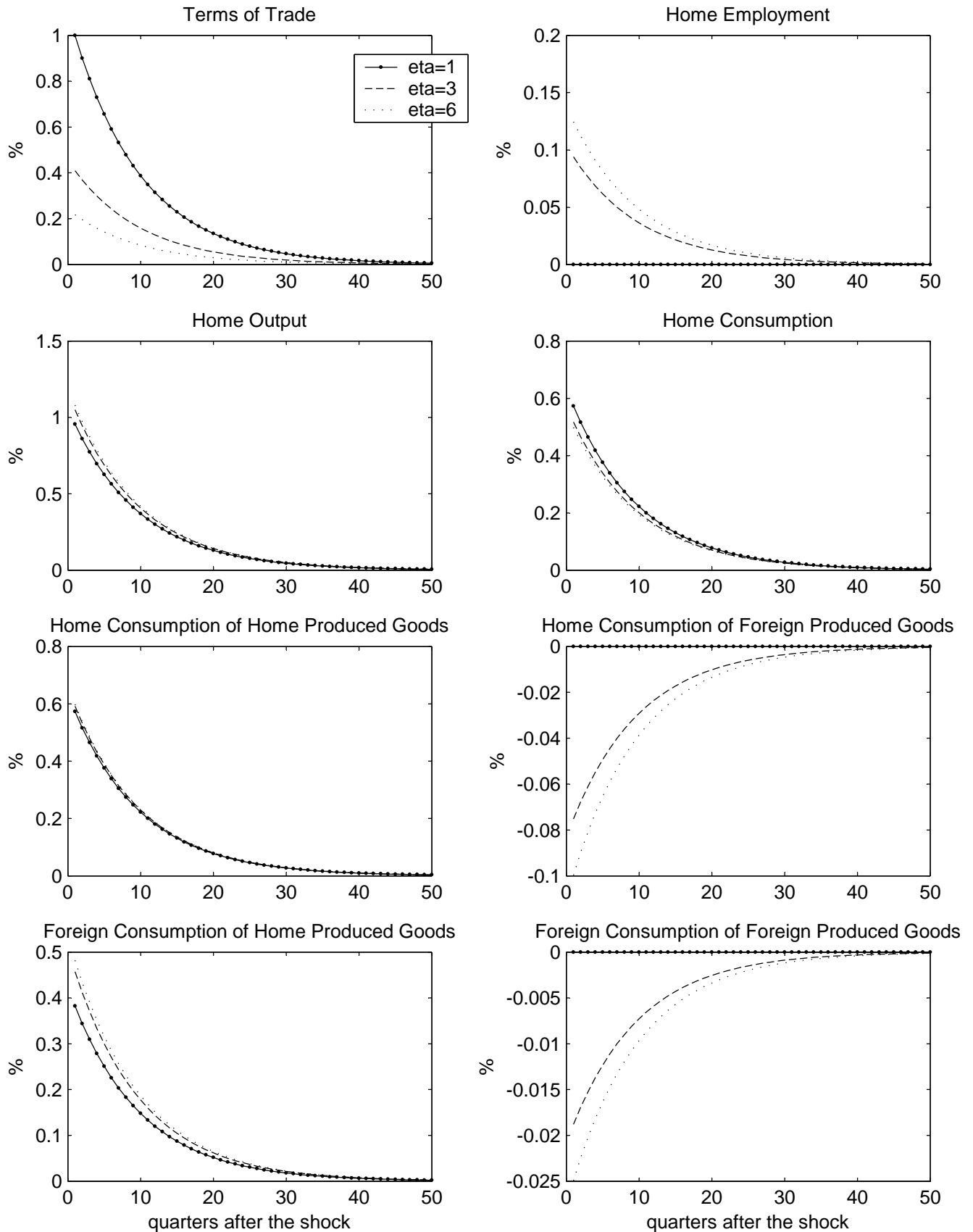
## Tables

Table 1: Calibration Parameters for the Benchmark Case

Parameter	Description	Value
$\beta$	Discount Factor	0.99
$\rho$	Intertemporal Elasticity of Substitution	1
$n$	Relative size of domestic economy	0.005
$\theta, \theta^*$	Elasticity of substitution across brands	6
$\chi$	Inverse of Frisch Elasticity of Labor Supply	3
$\alpha, \alpha^*$	Calvo price stickiness parameter	0.75
$\gamma$	Domestic Openness Parameter	0.6
$\gamma^*$	Foreign Openness Parameter	Varies
Technology Process		
$\begin{pmatrix} A_{11} & 0 \\ 0 & A_{22} \end{pmatrix}$	AR(1) coefficients	$\begin{pmatrix} 0.9 & 0 \\ 0 & 0.9 \end{pmatrix}$
$\sigma_H, \sigma_F$	Standard deviation of shocks	1%
$\sigma_{HF}$	Covariance of shocks	0.000077

Notes for Table 1: The parameters are similar to the calibration in Gali & Monacelli (2002).

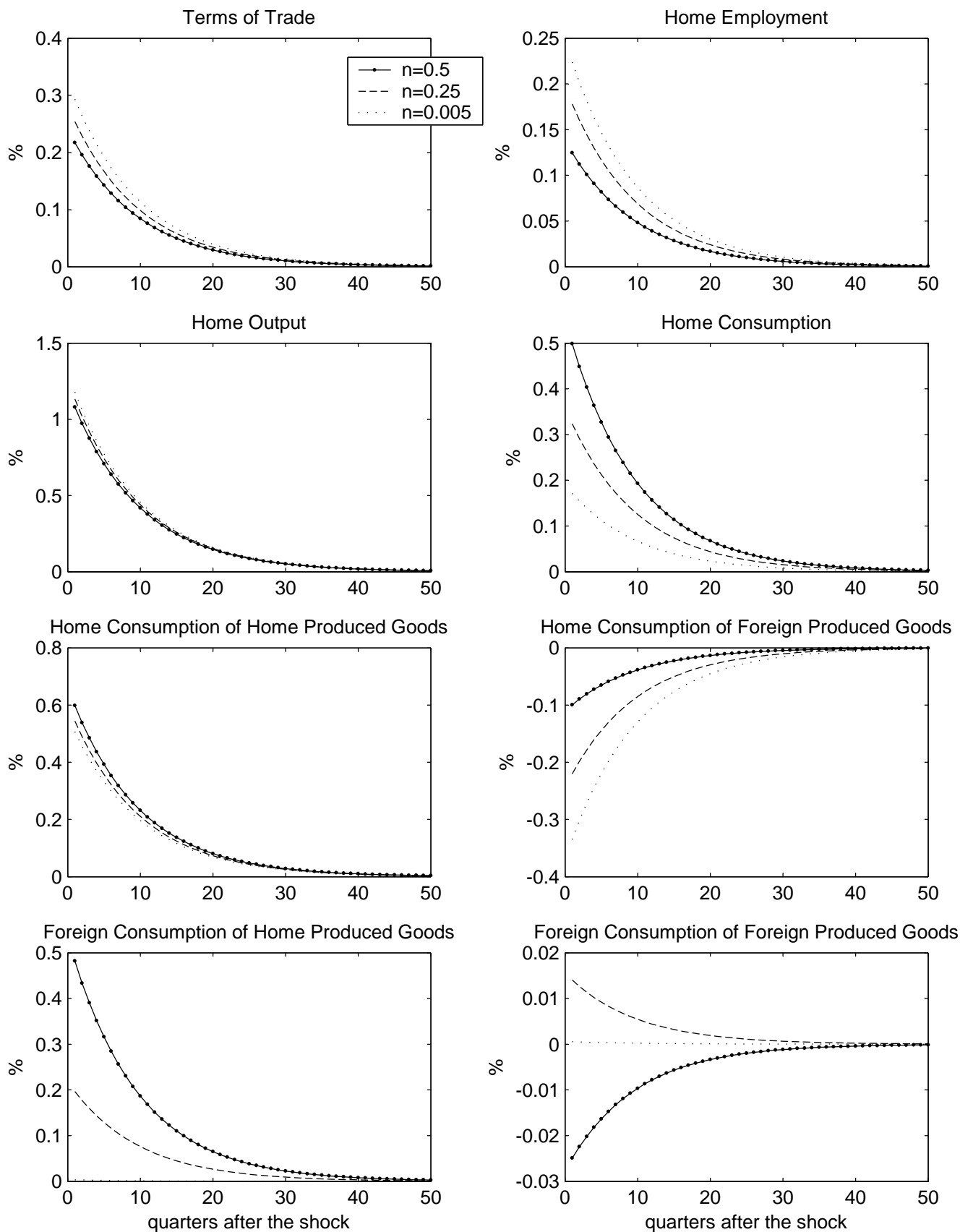
Figure 1: Effects of a (normalized) asymmetric 1% rise in domestic productivity



Note: This figure explores the effects of a (normalized) asymmetric domestic productivity shock for different values of the intratemporal elasticity of substitution. Countries are symmetric ( $n=0.5$ ). All other parameters are explained in the text. Domestic and foreign central banks are each assumed to target their producer prices.

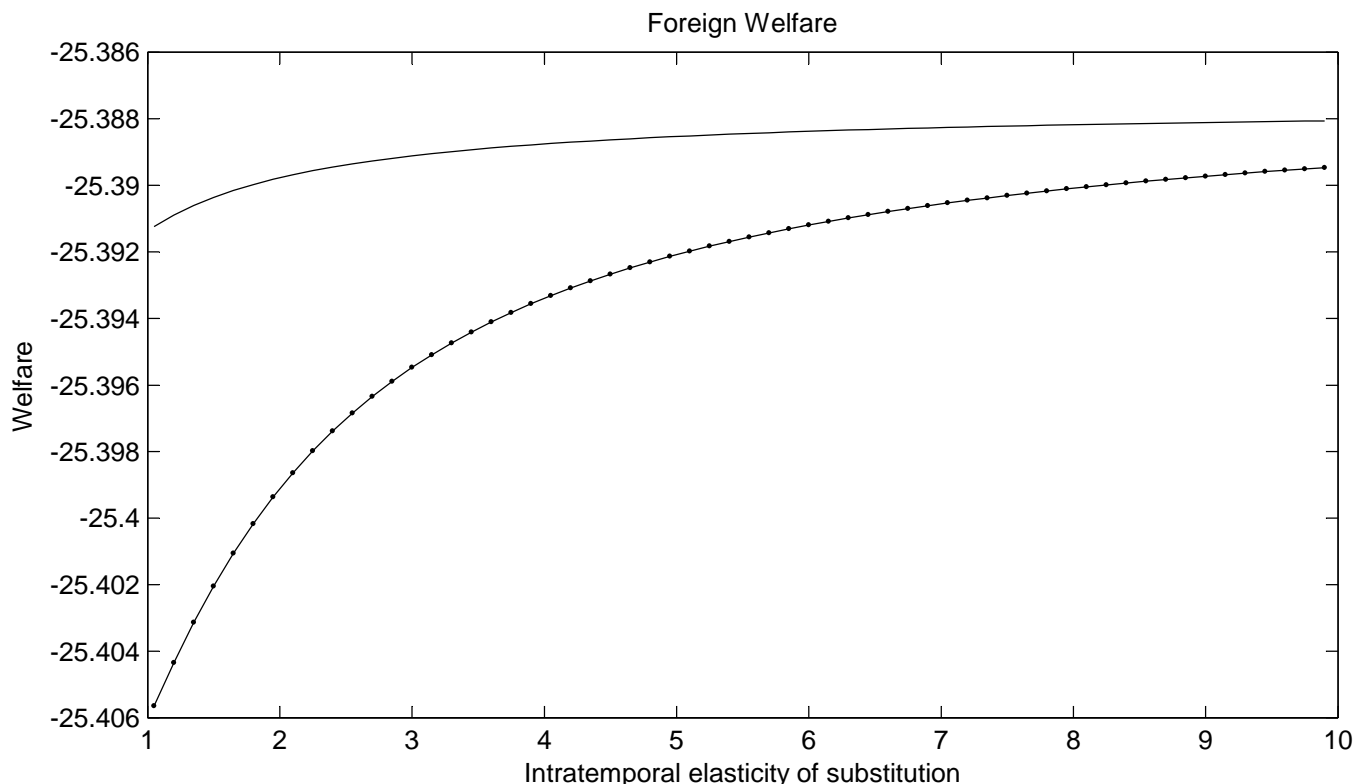
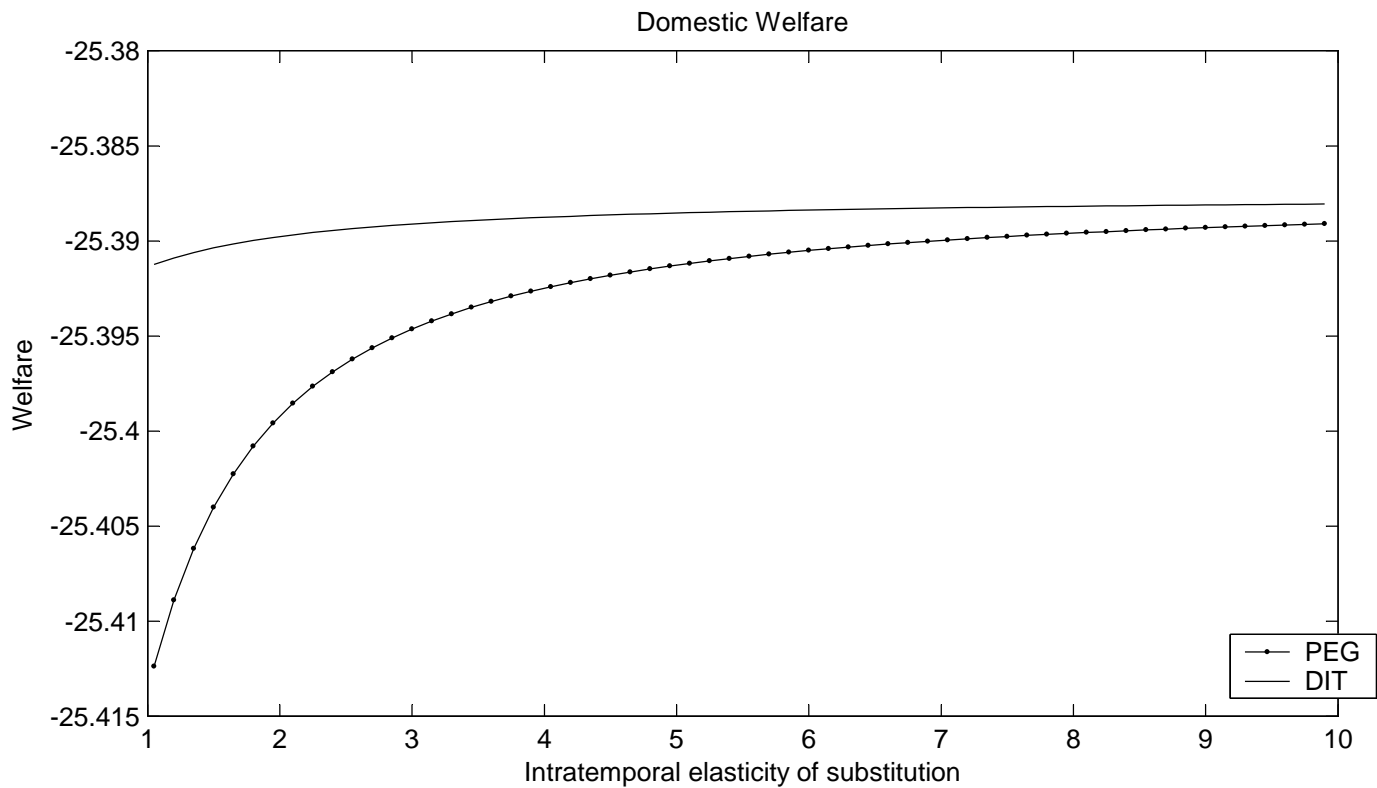


Figure 2: Effects of a (normalized) asymmetric 1% rise in domestic productivity



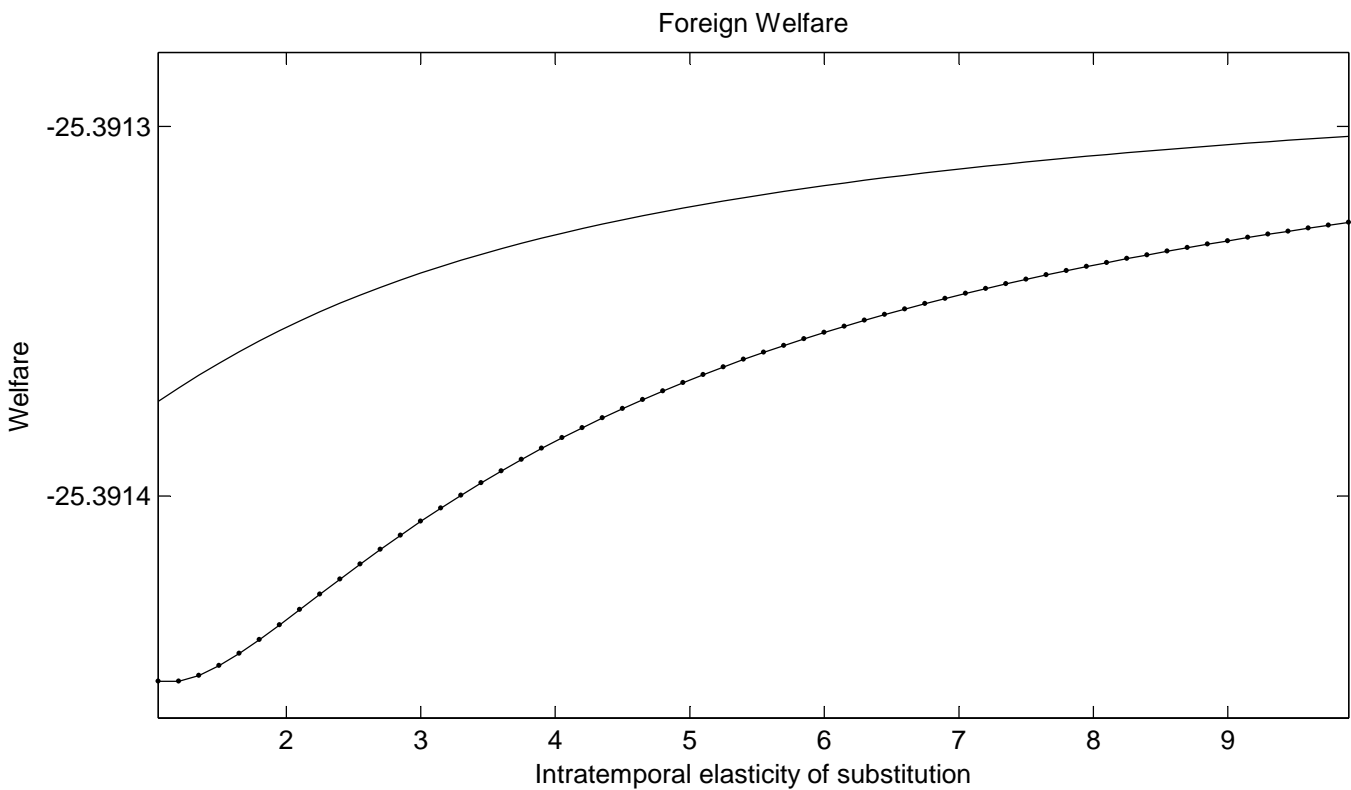
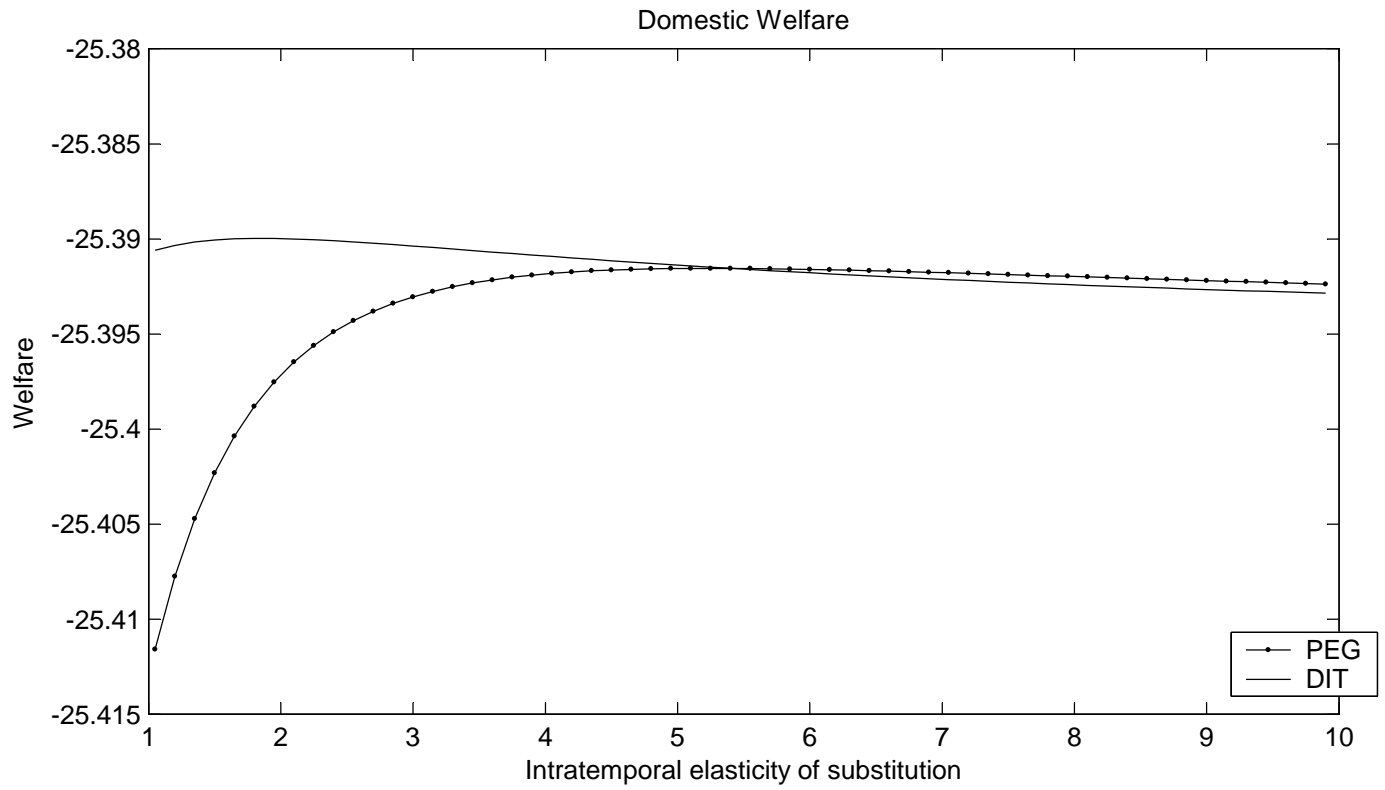
Note: The figure explores the effects of a (normalized) asymmetric domestic productivity shock for different values of the relative size of the domestic country ( $n$ ). The intratemporal elasticity of substitution is assumed to equal 6. Domestic and foreign central banks are each assumed to target their producer prices.

Figure 3: Welfare under different Monetary Policy Rules (Symmetric countries)



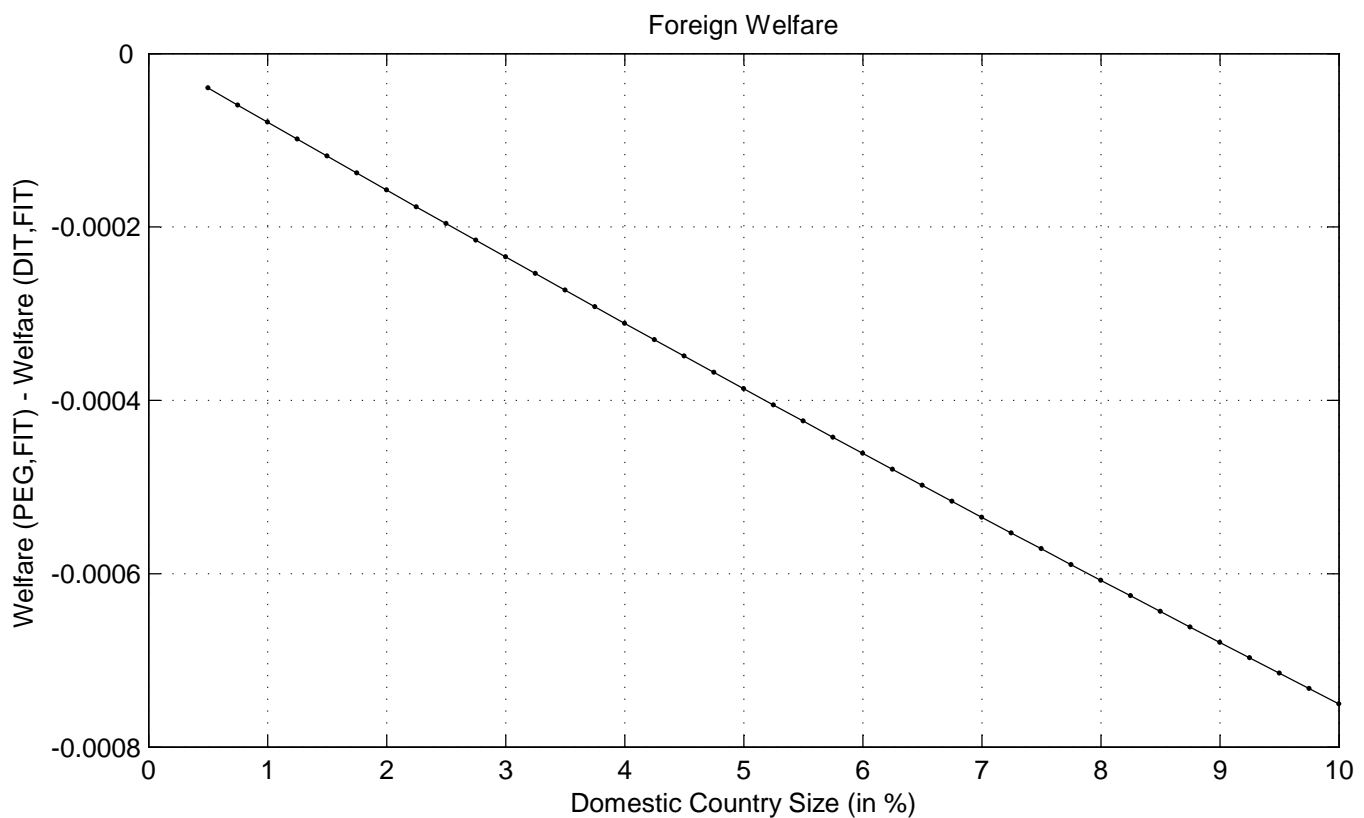
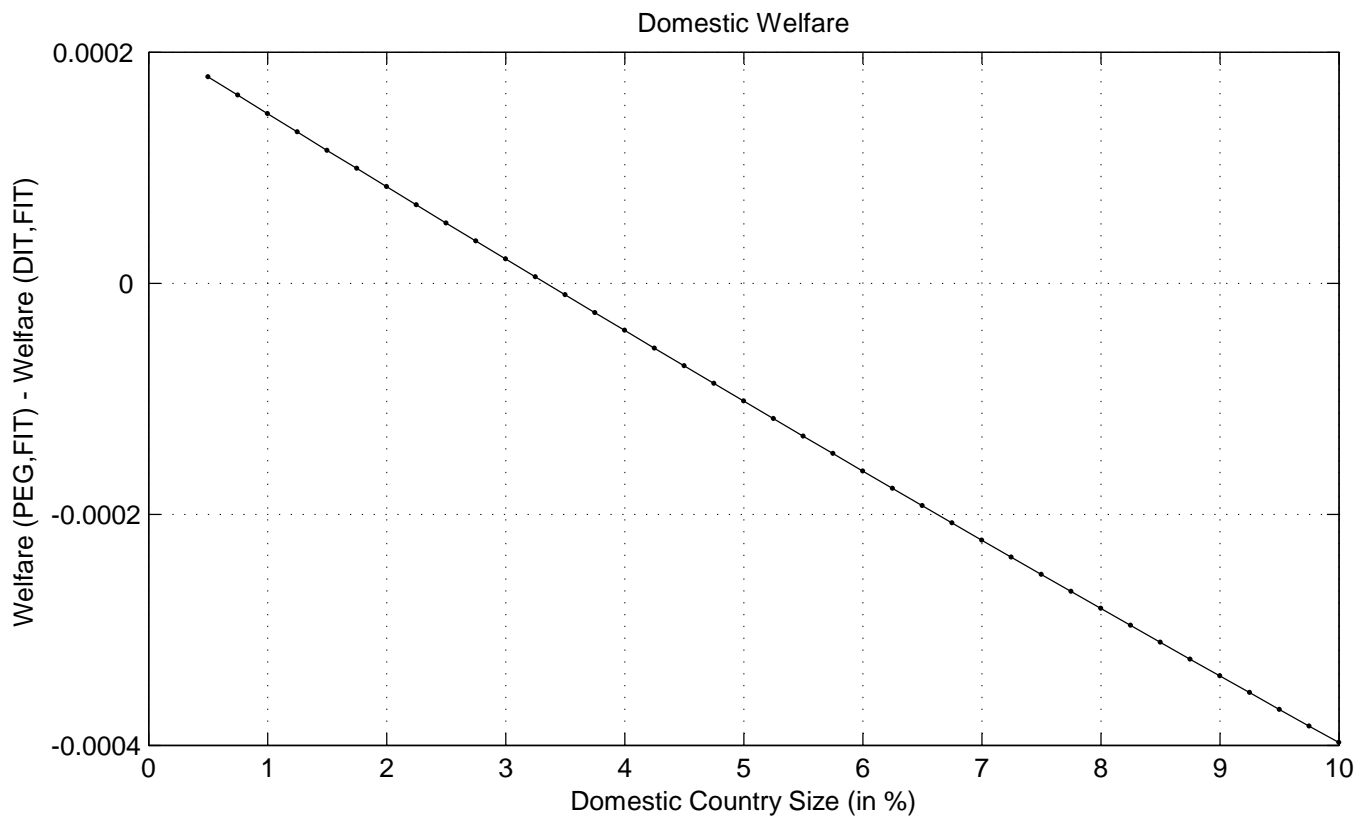
Note: Welfare is the conditional expected present discounted value of utility.  
Home and Foreign countries are assumed to be symmetric ( $n=0.5$ )

Figure 4: Welfare under different Monetary Policy Rules (Asymmetric Country Sizes)



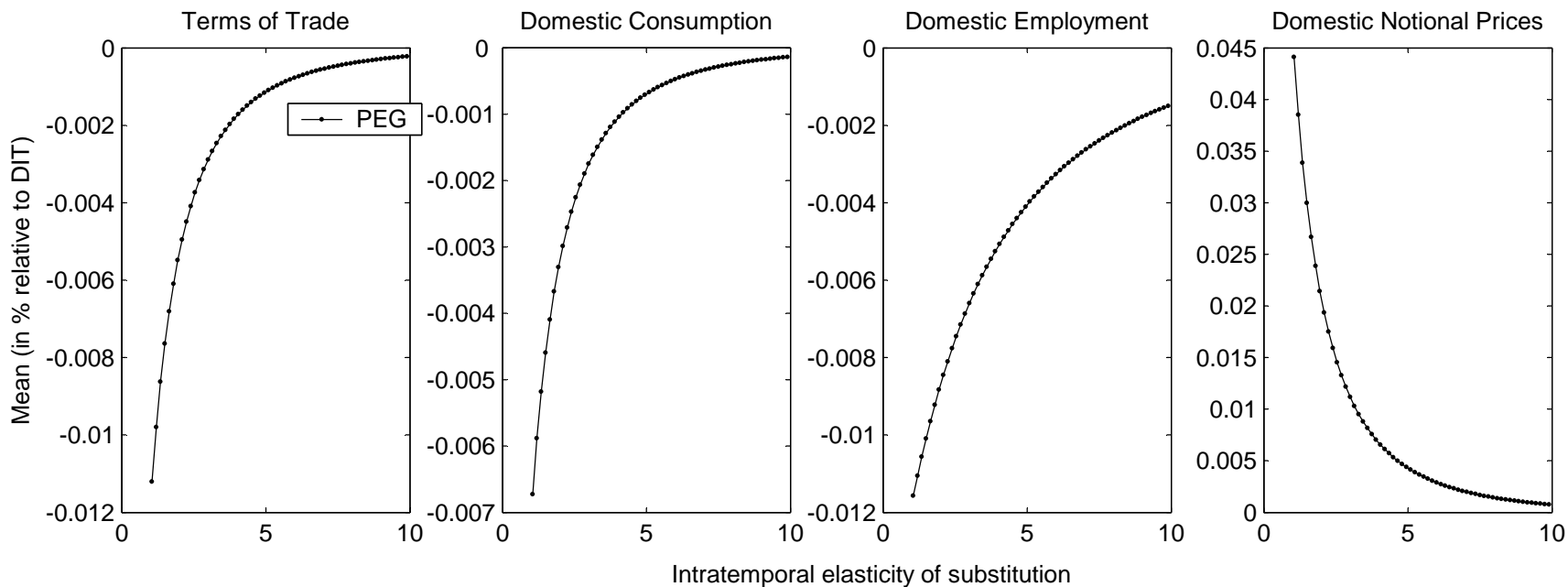
Note: Welfare is the conditional expected present discounted value of disutility. The relative size of the domestic country is assumed to be  $n=0.005$ .

Figure 5: Welfare Gains from a Unilateral Exchange Rate Peg



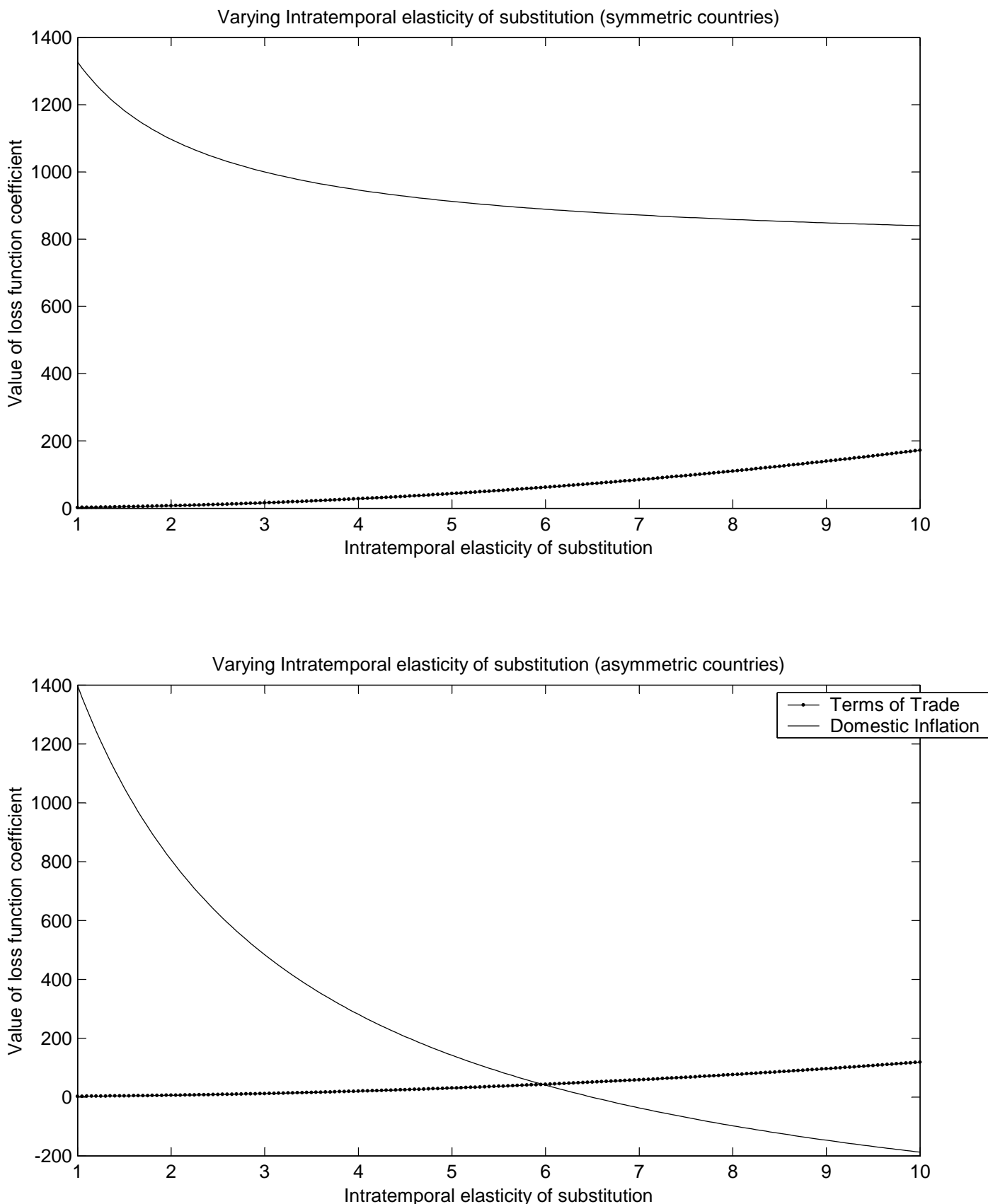
Note: This figure calculates the welfare difference between the two alternative monetary regimes for different values of the relative size of the domestic country ( $n$ ). The intratemporal elasticity of substitution is assumed to equal 6.

Figure 6: Moments of Terms of Trade, Domestic Notional Prices, Employment and Consumption



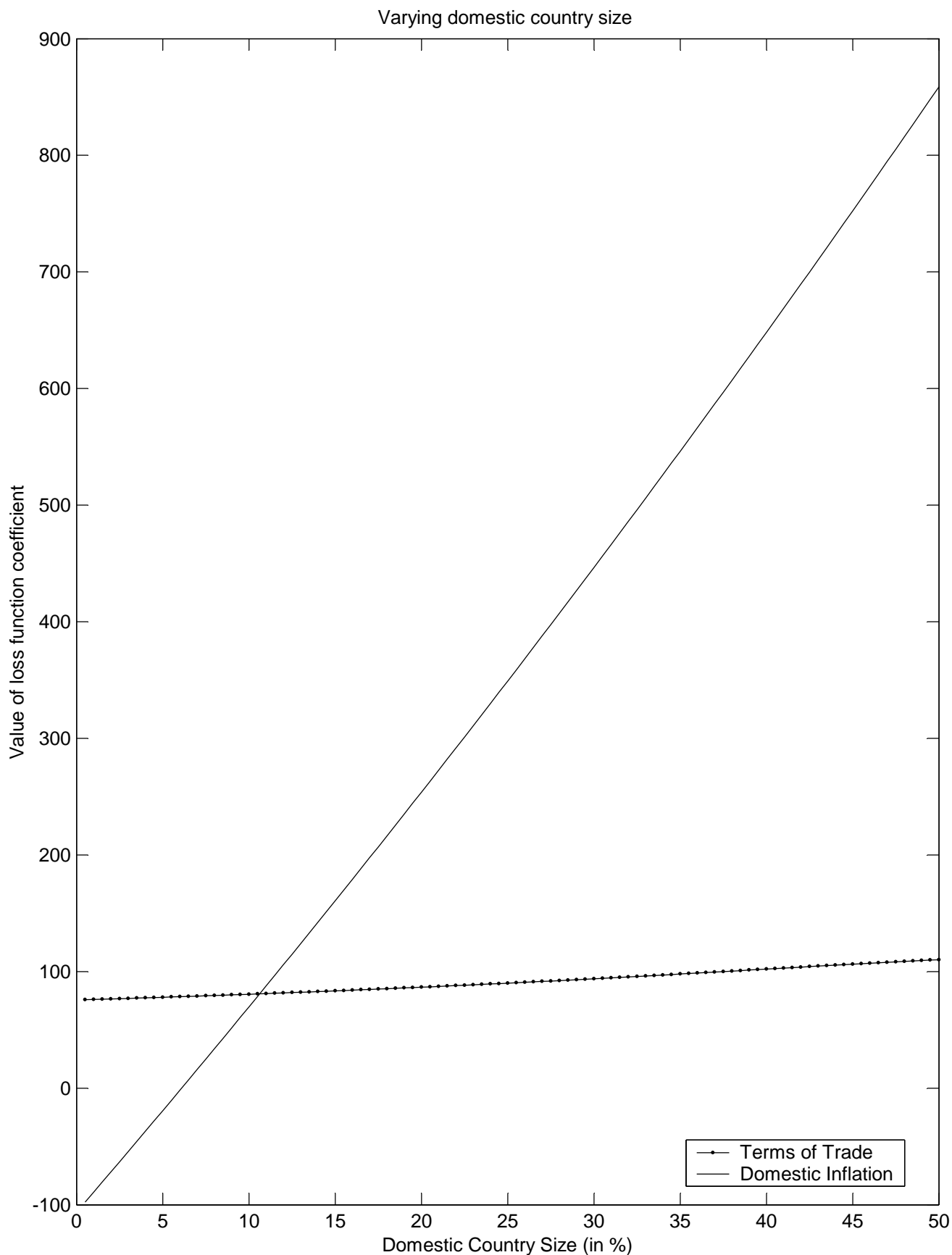
Note: Mean denotes the conditional expectation of the variable. Moments were generated assuming the parameters in our benchmark calibration. Thus size  $n=0.005$

Figure 7: Weights in the Loss Function of volatility in Terms of Trade and Inflation



Note: This figure explores how the loss function coefficients change with the intrateporal elasticity of substitution. All other parameters are as in our benchmark calibration. In the lower panel, the relative size parameter,  $n$ , equals 0.005. In the top panel, it equals 0.5 (symmetric countries)

Figure 8: Weights in the Loss Function of volatility in Terms of Trade and Inflation



Note: This figure explores how the loss coefficients change with relative country size. The intratemporal elasticity of substitution is assumed to equal 8. All other parameters are as in our benchmark calibration.