Monetary Policy Choices in Emerging Market Economies: the Case of High Productivity Growth*

Fabio M. Natalucci † Federico Ravenna ‡

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Abstract

We develop a general equilibrium model of an emerging market economy where productivity growth differentials between tradable and non-tradable sectors result in an equilibrium appreciation of the real exchange rate—the so-called Balassa-Samuelson effect. The paper explores the dynamic properties of this economy and the welfare implications of alternative policy rules. We show that the real exchange rate appreciation limits the range of policy rules that, with a given probability, keep inflation and exchange rate within predetermined numerical targets. We also find that the Balassa-Samuelson effect raises by an order of magnitude the welfare loss associated with policy rules that prescribe active exchange rate management.

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†Federal Reserve Board, Division of Monetary Affairs, MS 81, Washington, DC 20551. E-mail: fabio.m.natalucci@frb.gov

‡Department of Economics, University of California-Santa Cruz, CA 95064 and Federal Reserve Bank of San Francisco, 101 Market Street, San Francisco, CA 94105. Email: fravenna@ucsc.edu

1 Introduction

In the last forty years, the relationship between economic growth and real exchange rate has been explored extensively in the literature. One of the most popular explanations for long-term movements of the real exchange rate is the Balassa-Samuelson (B-S) hypothesis. According to this hypothesis, fast economic growth is associated with an appreciation of the real exchange rate because of larger productivity growth differentials between tradable and non-tradable sectors in developing countries relative to high-income countries. Empirical research has shown that this phenomenon is particularly relevant for emerging market economies (EMEs) and countries in transition from centrally planned to market economies, where large productivity gains tend to be (at least initially) concentrated in the tradable sector.

To the extent that a productivity-driven appreciation of the real exchange rate can manifest itself as an appreciation of the nominal exchange rate and/or higher inflation, the choice of monetary and exchange rate policy has important implications for the dynamics of nominal variables. This issue is important for Eastern and Central European countries that joined the European Union (EU) in 2004 and are set to join the Euro area sometime in the future. These countries could potentially face an important trade-off between complying with two Euro area admission criteria: the inflation limit set by the Maastricht Treaty, and the membership in the Exchange Rate Mechanism (ERM), limiting movements of the nominal exchange rate against the Euro. More generally, the issue is important for EMEs engaged in active management of their nominal exchange rate—for example, some fast-growing Asian countries—as the equilibrium appreciation of the real exchange rate has the potential to generate unwanted inflation pressures.

Using a general equilibrium model of an EME, we evaluate alternative monetary and exchange rate regimes in the event of a productivity-driven appreciation of the real exchange rate. We investigate both the dynamic properties of this economy and the welfare implications of these alternative policies. Our main findings are the following. First, we show that the response of real variables is largely independent of the monetary policy regime. The economy experiences a consumption boom, a surge in imports, and an increase in the production of the non-tradable good under both a fixed exchange rate regime and an inflation targeting regime. Because the long-term productivity gain is anticipated, the increase in consumption is financed through a large capital inflow. Second, the general equilibrium framework allows us to compute an inflation-exchange rate volatility trade-off as a function of the monetary policy regime and to analyze the extent to which this volatility trade-off is influenced by the B-S effect. We find that the equilibrium appreciation of the real exchange rate regime narrows considerably the range of policy rules which, with a given probability, keep the exchange rate and the inflation rate within specified numerical targets. Third, we show that the B-S effect has important consequences for the relative welfare performance of alternative policy rules. More specifically, we find that the B-S effect increases by an order of magnitude the welfare loss (relative to the best-performing rule) associated with monetary policy rules which prescribe an aggressive reaction to deviations of the exchange rate from a desired target level.

The paper is organized as follows. Section 2 reviews the recent literature on the B-S effect. Section 3 describes the model and section 4 evaluates the macroeconomic consequences of an equilibrium appreciation of the real exchange rate under alternative monetary and exchange rate regimes. Section 5 derives the inflation-exchange rate variance trade-off and performs welfare comparisons under alternative policy rules. Section 6 concludes. The Appendix contains a detailed description of the model equilibrium conditions, parameterization, and solution algorithm.

2 Balassa-Samuelson Effect and Macroeconomic Implications

Faster productivity growth in EMEs relative to more advanced countries can produce a trend appreciation of the real exchange rate through the so-called *Balassa-Samuelson effect* (Balassa [2]). Most of the productivity gains experienced by developing countries are concentrated in the tradable good sector. Higher productivity translates into higher wages; assuming perfect labor mobility across sectors, wages in the non-tradable sector need to rise as well. Firms in the non-tradable sector, facing relatively lower productivity gains, are then forced to increase prices. The ratio of tradable to non-tradable prices $\frac{P_T}{P_N}$ (the internal real exchange rate) will then decline. If the law of one price holds for tradable goods, a larger productivity growth differential between the tradable and non-tradable sector relative to the rest of the world implies an appreciation of the CPI-based real exchange rate $\frac{EP^*}{P}$, that is, a decrease in the nominal exchange rate E adjusted for price level differences between domestic (P) and foreign (P^*) CPI.

The group of countries that joined the EU in May 2004 is an example of economies that have been experiencing high productivity growth relative to the Euro-area—indicating that the process of catch-up is still ongoing—and a sustained appreciation of the real exchange rate (see Figure 1).[1] These ten countries—Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia—are expected, at some point, to adopt the Euro as their official currency. Because entry into the Economic and Monetary Union (EMU) requires compliance with the Maastricht convergence criteria, the experience of the new EU members is an interesting case study which allows us to analyze how the equilibrium appreciation of the real exchange rate interacts with the choice of the monetary and exchange rate regime.[2]

The B-S effect has been explored also in other EMEs where strong economic growth is combined with a sustained appreciation of the real exchange rate. For example, Ito et al. [29] test the B-S hypothesis using data from APEC economies. They show that Japan, South Korea, Taiwan and, in part, Hong Kong and Singapore followed a similar industrialization pattern—the Balassa-Samuelson path—increasing over time the weight of high value-added exports. Not all fast-growing countries in the region, however, experienced an appreciation of the real exchange rate. They interpret these findings as suggesting that the applicability of the B-S hypothesis depends on the development stage of the economy.

More generally, there is disagreement as to whether productivity growth differentials can fully explain large appreciations of the real exchange rate (see, for example, Mihaljek [37]). In fact, changes in the CPI-based real exchange rate can be disaggregated into three components: (1) the ratio of the relative price $\frac{P_T}{P_N}$ in the developing country relative to the more advanced country; (2) changes in the shares of tradable and non-tradable goods in the consumption basket; and (3) the relative price of tradable goods in a common currency. Only movements in the first component correspond to the B-S effect. Egert et al. [24] find that price level convergence in Central and Eastern European countries is taking place, at least in part, through an increase in the price of tradable goods. Clearly, if firms can

[1] The vast literature on this topic estimates that the tradable sector productivity growth differential between the Euro-area and new EU members is between 1 percent and 4 percent, with most of the estimates above 2 percent. The trend appreciation of the real exchange rate in many of these economies has been documented extensively, ranging from 25 percent in Hungary to nearly 300 percent in Estonia and Latvia in the 1992-98 period (De Broeck and Slok [17]).

[2] Empirical analysis of the B-S effect in new EU member countries and a discussion of the theoretical background can be found in De Gregorio et al. [18], Canzoneri et al. [8], Arratibel et al. [1], Csajbok and Csermely [15], Egert [23], Egert et al. [24], Cihak and Holub [9], Fischer [26], Buiter and Grafe [5], Pelkmans et al. [42] and Rogers [43] [44].

price-discriminate across countries, the law of one price for tradable goods does not hold.[3] Coricelli et al. [12], however, find evidence of a strong pass-through from nominal exchange rates to domestic inflation in Hungary, Slovenia, Czech Republic and Poland. Since the cost of non-tradable inputs can affect in various degrees the price of tradable goods (as documented for EU countries by Crucini et al. [14]), part of the increase in tradable good prices may also be accounted for by the B-S effect.

While the discussion in the literature generally focuses on the magnitude of the B-S effect, the quantitative analysis of its implications for monetary policy is fairly limited. Devereux [20] is the closest to the model developed in this paper, even though the focus of his analysis is on the role of terms of trade shocks in new EU members. Laxton and Pesenti [35] examine alternative Taylor rules in a general equilibrium model calibrated to the Czech Republic.

3 The Model

We build a model of a small open economy along the lines of Obstfeld and Rogoff [41], Devereux [19] [20], Devereux and Lane [22], Gali and Monacelli [27]. Our goal is to have a framework that fits important characteristics of EMEs, including rapid productivity growth; vulnerability to external shocks through imported consumption goods, intermediate inputs, and the foreign component of capital goods; and large capital inflows.

The small open economy produces a non-tradable good (N) and a domestic tradable good (H). The latter is also produced abroad and its price is exogenously determined in the world market. Consumers work in both production sectors. Their preferences are defined over a basket of tradable (T) and non-tradable (N) goods. The tradable good is itself a basket of two goods: an imported foreign good (F) and a domestically-produced good (H). Consumers own the sector-specific capital, investment goods are obtained by combining the tradable and non-tradable goods. Given the structure of investment, an increase in capital in any sector requires an increase in production in all sectors. The domestic tradable sector inputs are domestic value added—a Cobb-Douglas aggregate of labor and capital—and an imported intermediate input. Output in the non-tradable sector is obtained by combining labor and capital. To introduce a role for monetary policy, we assume nominal price-rigidities in the non-tradable sector.

[3] See Devereux and Engel [21] for implications of local currency pricing in an open economy model, and Canzoneri et al. [7] for empirical evidence in OECD economies.

Four distinguishing features make the model appropriate for EMEs. First, the domestic tradable good is both exported and consumed by domestic households. As a result, consumption of tradable goods does not have to be met exclusively with imports. Second, the model can account for the fact that intermediate inputs and capital goods are the main components of total imports, making the economy potentially very exposed to external shocks. In addition, foreign goods enter also the production function of the non-tradable good through capital accumulation. Third, the model allows for different elasticities of substitution between tradable and non-tradable goods, and between domestic and foreign-produced goods. Fourth, in order to analyze the implications of the Balassa-Samuelson effect for inflation and nominal exchange rate, we introduce a technology shock that causes long-run excess productivity growth in the domestic tradable sector relative to the non-tradable sector. The fact that the shock generates expectations of a prolonged increase in the productivity growth rate has important implications for the intertemporal allocation of consumption and investment.

3.1 Consumption and Investment Aggregates

Households' preferences are defined over the index C_t, a composite of non-tradable and tradable good consumption, $C_{N,t}$ and $C_{T,t}$ respectively:

$$C_t = \left[(\gamma_n)^{\frac{1}{\rho_n}} (C_{N,t})^{\frac{\rho_n - 1}{\rho_n}} + (1-\gamma_n)^{\frac{1}{\rho_n}} (C_{T,t})^{\frac{\rho_n - 1}{\rho_n}} \right]^{\frac{\rho_n}{\rho_n - 1}} \tag{1}$$

where $0 \leq \gamma_n \leq 1$ is the share of the non-tradable good and $\rho_n > 0$ is the elasticity of substitution between non-tradable and tradable goods. The tradable consumption good is a composite of home and foreign tradable goods, $C_{H,t}$ and $C_{F,t}$, respectively:

$$C_{T,t} = \left[(\gamma_h)^{\frac{1}{\rho_h}} (C_{H,t})^{\frac{\rho_h - 1}{\rho_h}} + (1-\gamma_h)^{\frac{1}{\rho_h}} (C_{F,t})^{\frac{\rho_h - 1}{\rho_h}} \right]^{\frac{\rho_h}{\rho_h - 1}} \tag{2}$$

where $0 \leq \gamma_h \leq 1$ is the share of the domestic tradable good and $\rho_h > 0$ is the elasticity of substitution between domestic and foreign tradable goods. The variables P_t, $P_{T,t}$, $P_{F,t}$ and $P_{N,t}$ indicate the corresponding consumption price indices. The non-tradable consumption good N and the tradable consumption good F are Dixit-Stiglitz aggregates defined over a continuum of differentiated goods $z \in [0,1]$ with elasticity of substitution ρ. We assume full pass through for the foreign-produced tradable good aggregate, purchased at the exogenously given price $P^*_{F,t}$. Investment aggregates I^J_t,

$I_{T,t}^J$, $I_{N,t}^J$ for sector $J = N, H$ are homogeneous with the corresponding consumption aggregates.

3.2 Households

We consider a cashless economy where the preferences of the representative household are given by

$$V = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ D_t(\ln C_t) - \ell \frac{(L_t)^{1+\eta_L}}{1+\eta_L} \right\} \tag{3}$$

where D_t is an exogenous preference shock, η_L is the inverse of the labor supply elasticity and $L_t = L_t^N + L_t^H$ is labor hours.

Let W_t^N (W_t^H) denote the nominal wage in the non-tradable (domestic tradable) sector, e_t the nominal exchange rate, B_t (B_t^*) holdings of discount bonds denominated in domestic (foreign) currency, v_t (v_t^*) the corresponding price, R_t^N (R_t^H) the real return to capital that is rented to firms in the non-tradable (domestic tradable) sector, and Π_t nominal profits from the ownership of firms in the monopolistically competitive non-tradable sector. The household's budget constraint is:

$$P_t C_t + e_t B_t^* v_t^* + B_t v_t + P_t I_t^N + P_t I_t^H = W_t^H L_t^H + W_t^N L_t^N + \tag{4}$$
$$e_t B_{t-1}^* + B_{t-1} + P_{N,t} R_t^N K_{t-1}^N + P_{H,t} R_t^H K_{t-1}^H + \Pi_t$$

Capital is accumulated by the household according to the law of motion:

$$K_t^J = \Phi \left(\frac{I_t^J}{K_{t-1}^J} \right) K_{t-1}^J + (1-\delta) K_{t-1}^J \qquad J = N, H \tag{5}$$

We assume that capital, contrary to labor, is immobile across sectors. Capital accumulation incurs adjustment costs, with $\Phi'(\bullet) > 0$ and $\Phi''(\bullet) < 0$.

3.3 Firms

The monopolistically competitive firm z in the non-tradable sector combines labor and capital according to the production function:

$$Y_{N,t}(z) = A_t^N [K_{t-1}^N(z)]^{\alpha_n} \left[L_t^N(z) \right]^{1-\alpha_n} \tag{6}$$

A_t^N is an exogenous productivity shock. Given the real marginal cost $MC_t^N(z)$ and the aggregate demand schedule $Y_{N,t}(z) = \left[\frac{P_{N,t}(z)}{P_{N,t}}\right]^{-\varrho} (C_{N,t} + I_{N,t}^H + I_{N,t}^N)$, firm z maximizes expected discounted profits by choosing the optimal price $P_{N,t}(z)$. We assume firms reset the price with probability $(1-\vartheta)$ in each period, following the Calvo [6] time-dependent pricing model.

The tradable good H is produced both at home and abroad in a perfectly competitive environment, where the law of one price holds and the foreign price $P^*_{H,t}$ follows an exogenous stochastic process. Domestic producers combine an imported intermediate good $X_{M,t}$ with exogenous price $P^*_{M,t}$, and domestic value added $V_{H,t}$, according to the production function:

$$Y_{H,t} = \left[(\gamma_v)^{\frac{1}{\rho_v}} (V_{H,t})^{\frac{\rho_v - 1}{\rho_v}} + (1-\gamma_v)^{\frac{1}{\rho_v}} (X_{M,t})^{\frac{\rho_v - 1}{\rho_v}} \right]^{\frac{\rho_v}{\rho_v - 1}} \tag{7}$$

Domestic value added is produced using labor and capital as inputs:

$$V_{H,t} = A^H_t \left(K^H_{t-1}\right)^{\alpha_h} \left(L^H_t\right)^{1-\alpha_h} \tag{8}$$

where A^H_t is an exogenous productivity shock.

3.4 Monetary Authority

The domestic monetary authority follows an open-economy version of the Taylor rule:

$$\frac{(1+\bar{i}_t)}{(1+i_{ss})} = \left(\frac{1+\pi_t}{1+\pi_{ss}}\right)^{\omega_\pi} \left(\frac{e_t}{e_{ss}}\right)^{\omega_e} \left(\frac{Y_t}{Y_{ss}}\right)^{\omega_Y} \tag{9}$$

where ω_π, $\omega_e, \omega_Y \geq 0$ are the feedback coefficients to CPI inflation, nominal exchange rate, and GDP in units of domestic consumption aggregate (Y_t), $\bar{i}_t$ is the target short-term interest rate, and the subscript ss indicates the steady-state value of a variable.

The choice of the feedback coefficients allows us to specify alternative monetary policy rules. $\omega_\pi > 0$ implies that the central bank is responding to deviations of CPI inflation from the target. $\omega_Y > 0$ indicates that the central bank stabilizes GDP around its steady state. $\omega_e > 0$ implies that the central bank is engaging in exchange rate management by reacting to deviations of e_t from the target level e_{ss}. The higher the feedback coefficients, the more aggressively the central bank is responding to such deviations. A fixed exchange rate regime can be expressed as the limiting case $\omega_e \to \infty$.

We also assume interest rate smoothing, so that the domestic short-term interest rate at time t is equal to

$$(1+i_t) = \left[\left(1+\bar{i}_t\right)\right]^{(1-\chi)} \left[(1+i_{t-1})\right]^{\chi} \varepsilon_{i,t} \tag{10}$$

where $\chi \in [0, 1)$ is the degree of smoothing and $\varepsilon_{i,t}$ is an exogenous shock to monetary policy.

4 The Balassa-Samuelson Effect in General Equilibrium

This section investigates the implications of a persistent increase in the productivity growth rate of the tradable sector for the small open economy. The model is solved by finding the rational expectations equilibrium of the log-linear approximation around the steady state. All variables in the solution are expressed as log-deviations from the steady state, except for NX_t and B_t^*, which are expressed as percentage of steady-state tradable good output Y_H. A complete description of the baseline parameterization is in the Appendix. Section 6 discusses a number of alternative parameterizations to replicate the production and international trade structure of various EMEs.

We construct the B-S shock as follows. We assume that the relative productivity of the tradable sector $(A_H/A_N)_t$ grows at a decreasing rate starting in $t = 0$ for 10 years, until it reaches a new stationary level. Over the 10-year period, the average growth rate of the sectorial productivity differential is 2.65 percent per year[4]. The long-run dynamics of relative productivity is anticipated by the forward-looking agents from $t = 1$ onward.

4.1 Fixed vs. Floating Exchange Rate Regimes

Figure 2 shows the response of the economy to the B-S shock under two alternative regimes: A fixed exchange rate regime and an inflation targeting regime. Under the *fixed exchange rate regime* , the coefficient ω_e is assigned an arbitrarily high value. Under the *CPI inflation targeting regime*, we set $\omega_\pi = 2$, $\omega_e = 0$.[5] Note that, under both regimes, the interest rate smoothing parameter is equal to 0.8, while $\omega_Y = 0$.

Consider the fixed exchange rate first. Productivity gains in the domestic tradable sector generate a large appreciation of the real exchange rate. The shock implies an initial surge in non-tradable inflation—as the productivity growth differential is anticipated after time 0—and in the CPI

[4] The implicit assumption is that the 2.65 percent productivity growth is relative to a zero-growth foreign economy. We can always re-interpret this as *excess* relative productivity growth against the foreign economy.

[5] We refer to inflation-based instrument policy rules as inflation targeting monetary regimes. There is, however, considerable controversy about the operational definition of inflation targeting.

inflation rate. Since the nominal exchange rate is fixed, CPI inflation rises on impact and decreases slowly (due to price stickiness) to a long-term level of about 2 percent. The B-S effect requires that the relative price of tradable to non-tradable goods decreases—i.e., the real exchange rate appreciates—according to the relative productivity in the two sectors. Since the price of the tradable good is determined in the world market and the nominal exchange rate is fixed, this can only be achieved via a steady increase in the price of the non-tradable goods. This explains the long-term impact of the shock on the CPI inflation, which lasts for as long as the relative productivity of the tradable sector is increasing.

The rise in tradable good consumption is financed from abroad, as shown by the initial drop in the production of the tradable good and by the large foreign debt. This dynamic behaviour matches the experience of many EMEs, that undergo a consumption boom and a large current account deficit as they catch-up with advanced economies. Given the low degree of intra-temporal substitution, both tradable and non-tradable good consumption rise, even though the price of non-tradable goods is higher. Output and investment in the non-tradable sector grows, driven by the boom in aggregate demand. Output and investment in the domestic tradable sector, after an initial drop, start growing as well to take advantage of the increased productivity. Two features of the model explain this pattern. First, intra-temporal substitutability between tradables and non-tradables is limited. Households can increase their total consumption by shifting resources to the non-tradable sector and by importing the tradable good. In a model where the tradable good could not be imported, they would have to increase production of both goods. Second, productivity in the tradable sector is expected to grow. Households can safely accumulate foreign debt to increase consumption today and repay the debt in the future, because the cost of the tradable good H relative to non tradable goods will decrease over time.

Consider now a flexible exchange rate regime. Because the nominal exchange rate is now allowed to appreciate, the initial effect on CPI inflation is negative, driven by a drop in the tradable good component and a smaller increase in the non-tradable good component. The long-term inflation rate remains positive but smaller than under the fixed exchange rate regime[6]. The burden of the real appreciation is carried by the nominal exchange rate:

[6] The impulse response shows the deviation from the steady-state inflation rate, which we assume to be equal to the rest of the world. Because the nominal exchange rate in this regime is completely flexible—i.e., the economy can exhibit a steady-state nominal appreciation against the foreign currency—the policy maker could effectively choose any steady-state inflation rate by changing the steady-state money supply policy.

within two years, it has appreciated by approximately 10 percent. The output increase in the non-tradable sector is reduced by over 40 percent. Since large price hikes in the non-tradable sector call for a contractionary policy under the inflation targeting regime, firms in equilibrium keep price inflation under control. The decrease in mark-ups associated with price inflation is smaller than under an exchange rate peg, limiting demand for the non-traded good. The import increase is larger though, so that the drop in consumption is smaller than the drop in production. After few quarters, however, the difference in the response of consumption and output under the two policy regimes has disappeared.

4.2 Balassa-Samuelson Effect and Capital Inflows

The B-S effect generates large capital inflows under both exchange rate regimes. In EMEs, however, large capital inflows can be spurred by other economic developments, such as capital markets liberalization and expectations of exchange rate appreciation, or reductions in risk premia resulting in capital gains for bond holders. To compare the scale of capital flows under these circumstances relative to inflows generated by the B-S effect, we consider a temporary but persistent unanticipated 100 basis points reduction in the foreign interest rate—a shock that can be interpreted as a reduction in the country sovereign risk premium (see Devereux [20]). Figure 3 shows the dynamics of the economy for the two different exchange rate policies. In both cases, foreign borrowing continue to increase for a long time after the initial shock. However, regardless of the exchange rate regime, after one year net foreign borrowing is only one eighth of the capital inflows associated with the B-S effect (figure 2). An interesting implication of this result is that large capital inflows do not necessarily expose EMEs to the danger of capital flow reversals. A large stock of foreign debt could be, in part, an equilibrium phenomenon stemming from the process of productivity catch-up. Were this the case, these inflows would likely be less sensitive to sudden shifts in market sentiment.

5 Policy Choices and the Balassa-Samuelson Effect

In this section, we compare alternative simple policy rules by deriving the implied inflation/exchange rate variance trade-off and computing the household welfare conditional on domestic and foreign shocks and on the expected path of excess productivity growth in the tradable good sector. We obtain three results. First, we argue that the B-S effect has important implications for the probability that a given policy rule will keep both the exchange rate and the inflation rate within a specified numerical target. Second, we show that the B-S effect modifies the relative welfare performance of alternative simple policy rules. Third, we analyze the extent to which these results depend on the trade and production structure of the economy.

5.1 Unconditional Volatility

Computation of variance trade-offs and welfare requires assumptions about the exogenous shocks that drive the dynamics of the economy. In the model economy, business cycle fluctuations are generated by four domestic shocks (total factor productivity in the tradable and non-tradable good sector, shifts in household preferences, and interest rate innovations) and four foreign shocks (price of the domestically-produced tradable good, price of the imported intermediate input, price of the imported tradable good, and interest rate on foreign-denominated debt). The parameterization of the exogenous stochastic processes follows the recent literature on micro-founded open-economy models with nominal rigidities (Gali and Monacelli [27], Kollman [31] [32], Laxton and Pesenti [35], Monacelli [38] [39]), and is described in the Appendix.

Table 1 compares unconditional moments and steady state ratios across five different parameterizations. We show results for two alternative policy rules: a fixed exchange rates regime and a managed exchange rate regime where the central bank follows a Taylor rule and responds to deviations of CPI inflation, output and nominal exchange rate from the steady-state values. Under the baseline parameterization and flexible exchange rate regime, the volatility of output is considerably higher than in OECD economies. Kollman [31] reports an average GDP standard deviation of 1.52 percent for Japan, UK, and Germany over the 1973-1994 period. The volatility of output in our model (2.34 percent) is in line with values obtained for emerging markets. Neumeyer and Perri [40] find an average GDP volatility for Argentina, Brazil, Korea, Mexico, and the Philippines equal to 2.79 percent over the period 1994-2001. Among the eight Central and Eastern European new EU members, GDP volatility ranged from 0.72 percent (Hungary) to 2.83 percent (Lithuania) in the 1998-2002 period (Darvas and Szapary [16]).

A similar difference between OECD countries and EMEs is found with regard to the standard deviation of consumption—equal to 1.45 percent in Kollman [31], 3.63 percent in Neumeyer and Perri [40], and 2.77 percent in our model—and net exports—equal to 0.92 percent across five OECD small open economies, 2.40 percent across five emerging markets economies (Neumeyer and Perri [40]), and 2.59 percent in our model. The policy rule implies a large volatility for the nominal exchange rate, equal to 8.02 percent (Kollman [31] reports an average value of 9.13 percent for Japan, UK, and Germany over the 1973-1994 period).

The volatility of inflation for the tradable goods aggregate is about twice as large as the volatility of the non-tradable good inflation. This result is a consequence of our price-setting assumption, with nominal rigidity in the non-tradable good sector and perfect flexibility for all tradable goods. If prices for the imported consumption good F are also assumed to be sticky—as a result of local currency pricing (LCP)—the volatility of the tradable good inflation declines. CPI inflation volatility, however, declines by a smaller amount because the imported good F is only 20 percent of the tradable consumption and investment aggregate.

5.2 Business Cycle Volatility Conditional on Productivity Growth Differentials

Figure 4 shows the quarterly inflation/nominal exchange rate variance trade-off given the policy rule:

$$i_t = \chi i_{t-1} + (1-\chi)[\omega_\pi \pi_t + \omega_e e_t] \tag{11}$$

for values of the coefficient $\omega_e \in [700, 0.01]$. This range includes policy rules that keep the exchange rate virtually fixed at the steady-state value and policy rules that allow a high volatility of the exchange rate while targeting aggressively the inflation rate. The interest-smoothing coefficient χ is equal to 0.8. We set the coefficient ω_π equal to 3.5 to prevent the weight of the exchange rate objective from driving the response of the monetary authority for all but the smallest values of ω_e.

Because the shocks are normally distributed, we can compute the implied probability that a variable falls within a given range around the target—in this case equal to the steady state—as a function of the variance of the variable itself. The vertical line corresponds to the variance of e_t that guarantees that the nominal exchange rate will be within a ± 2.25 percent range (± 15 percent range for the right-most vertical line) around the steady state in any quarter with a 95 percent probability. Any policy rule that generates a lower variance of e_t—points to the left of the vertical probability boundary—keeps the nominal exchange rate within the range with a probability greater than 95 percent. Below the horizontal probability boundary are the combinations

(σ_e, σ_π) that, with a 95 percent probability, generate a quarterly inflation rate differential with the rest of the world smaller than 1 percent[7]. For a policy maker following the rule defined in equation (11), figure 4 shows that there is a wide range of policies that allow both the nominal exchange rate and the inflation rate to remain within the given range around the numerical target. For many policy rules, this probability is greater than 95 percent[8].

This result does not hold in the presence of the B-S effect. Figure 5 plots the variance trade-off conditional on the assumption that productivity growth in the tradable sector relative to the non-tradable sector is higher by an average of 2.65 percent per annum over the 10-year period of the simulation. First, this excess productivity growth shifts the variance frontier. More importantly, the policy rule adopted by the monetary authority has notable implications for the *average* inflation and nominal exchange rate observed over the sample period (as shown in figure 2). As a consequence, conditional on the B-S effect, alternative policy rules influence both the volatility of endogenous variables *and* the probability boundaries. The lower the weight on the exchange rate stabilization objective, the larger the *average* nominal exchange rate appreciation resulting from the B-S effect. Rules allowing a more flexible exchange rate, therefore, lower the volatility level required to keep the exchange rate within the target range (i.e., points on the probability boundary for e). Similarly, rules with a larger weight on deviations of the exchange rate from the target lead to higher *average* CPI inflation and thus lower the inflation volatility required to keep inflation within the target range at a given probability level. For example, a rule such that $\sigma_\pi = 0.36$—corresponding to the inflation volatility generated by the rule with the smallest weight on the exchange rate—requires $\sigma_e = 1.1$ (the left-most point on the exchange rate probability boundary) to ensure that $\Pr(-15\% < e < +15\%) = 95\%$. Figure 5 shows that, contrary to the standard case, any rule that meets the inflation objective would barely meet or not meet at all the $\pm 15\%$ exchange rate objective at a 95 percent probability level. No rule would meet both the inflation objective and the

[7] To evaluate the policy trade-off, we choose numerical targets that mimic the exchange rate and inflation admission criteria that new EU member states have to comply with in order to join the Euro-area. The ± 2.25 percent range corresponds to the original ERM agreement, while the ± 15 percent range is required by ERM-II.

[8] In building the inflation differential variable, we assume that the tradable goods produced in the home country are a negligible fraction of the foreign consumption basket, as common in small open economy models (see Gali and Monacelli [27]), and set π^* equal to the steady-state value of the domestic inflation. An alternative assumption would be to set $\pi^* = \alpha \pi_F^*$ where α is the share of tradable goods in the foreign CPI. For any value of α, the results reported here would be reinforced.

more stringent ±2.25% exchange rate objective.

5.3 Welfare

A growing literature analyzes the welfare implications of alternative monetary policy regimes in open economy models with nominal rigidities. Analytical results are available only in simple cases (see Gali and Monacelli [27] and Benigno and Benigno [4]). Most of the literature finds small welfare losses for sub-optimal policy regimes. For example, Gali and Monacelli [27] find welfare losses in the order of a hundredth to a tenth of 1 percentage point of steady-state consumption when the monetary authority follows non-optimized simple rules, with a peg yielding the worst performance. Kollman [32] [33] obtains welfare losses for suboptimal policies up to $0.7-0.8$ percent of steady-state consumption when shocks to the uncovered interest parity condition are included in a small open economy, and up to 0.5 percent for a peg in a two-country model.

For the family of policy rules defined by equation (11), our model implies welfare losses of the same order of magnitude as in the literature. However, if the B-S effect is at work, the welfare losses associated with alternative policy rules are significantly higher. To measure the welfare implications of alternative policy regimes, we compare the welfare level generated by policy a with a reference level of welfare r which is generated by the best performing rule within the family of policies defined by equation (11) for different values of ω_e. Under the policy regime r and a the household welfare is, respectively:

$$
\begin{aligned}
V_0^r &= E_0 \sum_{t=0}^{\infty} \beta^t \left\{ D_t(\ln C_t^r) - \ell \frac{(L_t^r)^{1+\eta_L}}{1+\eta_L} \right\} \\
V_0^a &= E_0 \sum_{t=0}^{\infty} \beta^t \left\{ D_t(\ln C_t^a) - \ell \frac{(L_t^a)^{1+\eta_L}}{1+\eta_L} \right\}
\end{aligned}
$$

Following Schmitt-Grohe and Uribe [46] we measure the welfare cost of policy a relative to policy r as the fraction λ of the expected consumption stream under policy r that the household would be willing to give up to be as well off under policy a as under policy r, that is:

$$
V_0^a = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ D_t[\ln C_t^r(1-\lambda)] - \ell \frac{(L_t^r)^{1+\eta_L}}{1+\eta_L} \right\}
$$

The fraction λ is computed from the solution of the second order approximation to the model equilibrium relationships around the deterministic steady state. The welfare levels V_0^a and V_0^r are evaluated at the steady state—which is the same for all policies—conditional on the future expected path of productivity growth in the tradable good sector.[9]

Figure 6 shows the welfare loss λ. The best-performing policy rule places the smallest weight on the exchange rate. Because the relationship between ω_e and σ_e is monotonic, the policy rules can be conveniently indexed by σ_e, where $\sigma_e = 0$ corresponds to a virtually fixed exchange rate (for $\omega_e = 700$). In the baseline parameterization, in the absence of the B-S effect, a peg results in a loss of 0.073 percent of the consumption stream associated with the best-performing policy. When the B-S effect is at work, however, the loss from pegging the exchange rate increases to 2.77 percent. This loss is around 2 percent for a policy rule that keeps the exchange rate within a $\pm 2.25\%$ range around the steady state with a 95 percent probability (not shown).

The interpretation of this result is not straightforward: in an open economy, an optimizing policymaker has the incentive to stabilize the markup and reduce the price dispersion in the sector with nominal rigidities, as well as to influence the relative prices to improve the household utility. We can gain some intuition for the welfare result by noting that alternative policy rules imply large and persistent differences in the evolution of relative prices. Figure 2 shows that the dynamics of the real exchange rate differs considerably—by about 5 percentage points on impact—under a peg or an inflation targeting regime. As a result, large differences in the response of endogenous variables persist for two years or more. For example, under the fixed exchange rate regime, consumption is about 3 percentage points higher, on impact, than under the inflation targeting regime, while non-tradable good inflation is roughly 8 percentage points higher. These differences, in turn, imply different welfare outcomes for alternative policies.

An important policy lesson from our welfare analysis is that emerging markets that experience an equilibrium appreciation of the real exchange rate have a strong incentive to choose a policy rule that targets the inflation rate and essentially disregards movements in the nominal exchange rate—the best-performing policy rule within the family of simple instrument rules (11). Given that the economy is small relative to the rest of the world, any welfare improvement is highly desirable because it comes at no cost for the foreign country.[10] On a similar note, our welfare analysis suggests that

[9] See Schmitt-Grohe and Uribe [46] for a discussion of how to obtain a second order accurate approximation to λ from the second order expansion of V_0^r and V_0^a around the deterministic steady state.

[10] We thank an anonymous referee for pointing this out.

amending the EMU convergence criteria to account for the B-S effect would likely benefit the new EU members.

5.4 Alternative Parameterizations

We consider three alternative parameterizations, which correspond to different assumptions about the trade structure of our small open economy, and the case of LCP. First, we increase ρ_n from 0.5 to 0.9, so that the tradable and non-tradable good are closer substitute. Second, we lower γ_v from 0.65 to 0.3, so that the share of domestic value added in the production of the domestic tradable good is smaller and the economy is more open to trade. Third, we increase γ_n from 0.4 to 0.55, thus raising the share of non-tradable good consumption in total consumption.

Implications for the model unconditional volatilities are summarized in Table 1. When $\rho_n = 0.9$, the degree of substitutability between tradable and non-tradable goods is notably larger. In this case, the steady-state share of non-tradable consumption (investment) declines considerably, from 63 (68) to 45 percent (50 percent). A larger fraction of domestic inputs is now employed in the tradable-good sector. Because increased production of tradable-good requires a larger amount of intermediate imported good, and given the different consumption preferences, the economy is characterized by a larger ratio of imports to GDP (76 percent).

Setting γ_v equal to 0.3 implies a jump in the import-to-GDP ratio, from 60 percent to 123 percent, while the shares of non-tradable consumption and investment remain unchanged relative to the baseline parameterization. This parameterization implies that the economy is very open to trade, and volatility increases for all variables.

When γ_n is raised from 0.4 to 0.55, the share of the non-tradable good in the consumption composite increases from 63 percent to 74 percent. Most of domestic production occurs now in the non-tradable sector; international trade is more limited—the share of imports to GDP drops from 60 percent to 50 percent—although it remains fairly important because the imported intermediate good has limited substitutability with domestic value added in the production of the domestic tradable good.

Given that alternative trade and production structures result in a different response of the economy conditional to the B-S effect, we can expect the relative welfare performance of alternative policy rules to be affected as well. Figure 6 shows that this intuition is correct. For all parameterizations, there exists a direct relationship between the weight placed by the monetary authority on the exchange rate stabilization goal and the welfare loss. In an economy where tradable and non-tradable goods are close substitutes ($\rho_N = 0.9$), the relative welfare loss of a peg is only half as large as the welfare loss of the peg in the baseline parameterization. The higher degree of substitution makes differences in the dynamics of consumption and investment across policy rules less costly (in terms of household utility). In equilibrium, such differences can be accommodated with smaller price changes; this implies a smaller volatility of non-tradable good inflation, therefore reducing suboptimal price dispersion and markup fluctuations.

In an economy where the non-tradable consumption share is higher ($\gamma_N = 0.55$), active exchange rate management is relatively more costly. The monetary authority has a stronger incentive to stabilize non-tradable-good inflation, because in this economy shocks (and the B-S effect) have a larger impact on demand for the non-tradable goods, leading to inefficient price changes. In addition, the larger γ_N, the smaller the effect of the policy response to exchange rate deviations, because the share of imported goods in consumption is relatively smaller.

Local Currency Pricing Cross-border price differentials across countries have been extensively documented.. An enormous literature has analyzed the degree of pass-through of nominal exchange rate fluctuations into the price of imported goods, showing that incomplete pass-through is pervasive, especially at short horizons and in consumer prices.

To introduce local currency pricing we assume that the foreign-produced good F is purchased by a continuum of monopolistically competitive firms in the import sector as an input for production[11]. Each firm z can costlessly differentiate an imported good X_F to produce a consumption good $C_F(z)$ and an investment good $I_F(z)$ using the production technology $Y_F(z) = X_F(z)$, where $X_F(z)$ denotes the amount of input imported by firm z. The domestic-currency price $P_F(z)$ is set by solving a Calvo [6] optimal pricing problem. $C_{F,t}$ and $I^J_{F,t}$ are Dixit-Stiglitz aggregates defined over the $z \in [0, 1]$ goods with elasticity of substitution equal to ρ. As Monacelli [39] pointed out, this production structure generates deviations from the law of one price in the short run, while asymptotically the pass-through from the price of the imported good to the price of the consumption and investment basket is complete.

In our model, the assumption of LCP for imported consumption and

[11] While we model incomplete pass-through using nominal rigidities in the import sector, alternative modeling choices, such as accounting for the existence of distribution costs, have been explored in the literature (see Corsetti et al. [13])

investment goods, C_F and I_F respectively, has important consequences for the behaviour of prices and quantities in the foreign tradable good sector. Nontheless, LCP has a very muted impact on the dynamics of aggregate tradable and non-tradable quantities following a B-S shock, and on the unconditional moments (see Table 1). This result stems from the fact that the share of foreign tradable goods in the tradable consumption and investment basket is fairly small (20 percent). In addition, tradable goods account for less than half of total steady-state consumption and investment basket[12]. Interestingly, LCP does affect the relative welfare loss of alternative policy rules (see figure 6) when the B-S effect is at work. Under LCP, a peg is relatively less costly. This outcome is not the result of higher welfare under the peg relative to the producer currency pricing (PCP) case; it is due, instead, to a *lower* welfare level associated with the best-performing policy rule relative to the PCP case.

Consider the impact of the sole excess productivity growth in the tradable good sector. When the exchange rate is fixed, the importer's nominal marginal cost $e_t P_F^*$ is constant—P_F^* is at its steady state value—and an economy under LPC behaves like an economy under PCP. When the monetary authority targets deviations of inflation from its target, welfare (relative to the fixed exchange rate regime) does not improve as much as in the PCP case. In response to gains in productivity, the nominal exchange rate appreciates. If the law of one price holds, P_F decreases by the same amount. In this case, the relative price $\frac{P_F}{P_H}$—that is, the terms of trade S_F—is fixed by construction in the absence of any other shock. With LCP, however, foreign good inflation π_F is sticky. P_F decreases by a smaller amount, the terms of trade S_F rises, and the household consumes a smaller amount of imported good C_F. Note that it is movements in relative prices induced by the LCP assumption that generate this result, and therefore account for the lower level of utility. It seems reasonable to conclude that incomplete pass-through could play a more significant role in the welfare results if the share of the imported good priced under LCP were larger.

[12] Note that since the tradable good H is both imported and exported, it is not possible to assume LCP in the domestically-produced tradable sector. It would be possible to assume LCP for the intermediate imported good. In many emerging markets, however, a large share of intermediate imports consists of goods priced on world markets, such as crude inedible materials, fuels, minerals.

6 Conclusion

We develop a general equilibrium model of an EME where productivity growth differentials between the tradable and non-tradable sector generates an equilibrium appreciation of the real exchange rate. Our goal is to evaluate the dynamic properties of this economy and the welfare implications of alternative monetary and exchange rate regimes.

When the long-term productivity gain is anticipated, the economy experiences a consumption boom financed through a large capital inflow, a surge in imports, and an increase in the production of the non-tradable good under both a fixed exchange rate regime and an inflation targeting regime.

We show that the B-S effect greatly amplifies the welfare loss (relative to the best-performing rule) of rules that dictate a strong policy response to movements of the nominal exchange rate, and illustrate how the production and international trade structure affects the welfare implications of alternative policies. Emerging markets that experience a productivity-driven appreciation of the real exchange rate have a strong incentive to choose a policy rule that targets the inflation rate and essentially disregards movements in the nominal exchange rate.

Finally, we find that the equilibrium appreciation of the real exchange rate restricts the set of policy rules that, at a given probability level, keep inflation and exchange rate within predetermined numerical targets. These findings suggest that, when the performance of policy makers is evaluated using specific numerical targets—as in the case of Central and Eastern European countries set to join the Euro-area sometime in the future—these targets should be amended to account for the B-S effect. The experience of the new EU members is an interesting case study, because macroeconomic convergence—defined according to the numerical targets set in the Maastricht criteria—is formally required for entry into the EMU. Our results indicate that the equilibrium appreciation of the real exchange rate experienced by these countries has the potential to lower the probability of compliance with the EMU accession requirements.

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7 Appendix

7.1 Model Equilibrium Conditions

Household The solution to the household decision problem gives the following first order conditions (FOCs) for $J = N, H$:

$$\lambda_t^C = \beta E_t \left\{ \lambda_{t+1}^C \left(1 + i_t\right) \frac{P_t}{P_{t+1}} \right\} \tag{12}$$

where $\lambda_t^C = \frac{D_t}{C_t}$ is the marginal utility of total consumption and $(1+i_t) = \frac{1}{v_t}$;

$$E_t \left\{ \lambda_{t+1}^C \frac{P_t}{P_{t+1}} \left[(1+i_t) - (1+i_t^*) \frac{e_{t+1}}{e_t} \right] \right\} = 0 \tag{13}$$

$$C_{N,t} = \frac{\gamma_n}{1-\gamma_n} \left(\frac{P_{T,t}}{P_{N,t}} \right)^{\rho_n} C_{T,t} \quad ; \quad C_{H,t} = \frac{\gamma_h}{1-\gamma_h} \left(\frac{P_{F,t}}{P_{H,t}} \right)^{\rho_h} C_{F,t} \tag{14}$$

$$\lambda_t^C \frac{W_t^N}{P_t} = \ell \left(L_t \right)^{\eta_L} \quad ; \quad \lambda_t^C \frac{W_t^H}{P_t} = \ell \left(L_t \right)^{\eta_L} \tag{15}$$

$$\lambda_t^C Q_t^J = \beta E_t \{ \lambda_{t+1}^C \left(\frac{P_{J,t+1}}{P_{t+1}} R_{t+1}^J \right) + \lambda_{t+1}^C Q_{t+1}^J [\Phi \left(\frac{I_{t+1}^J}{K_t^J} \right) - \frac{I_{t+1}^J}{K_t^J} \Phi' \left(\frac{I_{t+1}^J}{K_t^J} \right) + (1-\delta)] \} \tag{16}$$

where Q_t^J is Tobin's Q and is defined as $Q_t^J = \left[\Phi' \left(\frac{I_t^J}{K_{t-1}^J} \right) \right]^{-1}$;

$$I_{N,t}^J = \frac{\gamma_n}{1-\gamma_n} \left(\frac{P_{T,t}}{P_{N,t}} \right)^{\rho_n} I_{T,t}^J \quad ; \quad I_{H,t}^J = \frac{\gamma_h}{1-\gamma_h} \left(\frac{P_{F,t}}{P_{H,t}} \right)^{\rho_h} I_{F,t}^J \tag{17}$$

Firms Cost minimization for the non-tradable production sector implies:

$$\frac{W_t^N}{P_{N,t}} = MC_t^N(z) \left[1 - \alpha_n \right] \frac{Y_{N,t}(z)}{L_t^N(z)} \tag{18}$$

$$R_t^N = MC_t^N(z) \alpha_n \frac{Y_{N,t}(z)}{K_{t-1}^N(z)} \tag{19}$$

Given the first order conditions (18), (19), the aggregate demand schedule, $Y_{N,t}(z) = \left[\frac{P_{N,t}(z)}{P_{N,t}} \right]^{-\varrho} (C_{N,t} + I_{N,t}^H + I_{N,t}^N)$, and market clearing conditions, firm z profit maximization implies the log-linear first order condition $\pi_{N,t} = \lambda mc_t^N + \beta E_t \pi_{N,t+1}$ where $\lambda = \frac{(1-\vartheta)(1-\beta\vartheta)}{\vartheta}$.

Cost minimization for the tradable production sector gives the factor demands:

$$\frac{W_t^H}{P_{H,t}} = (1-\alpha_h) \left(\gamma_v \right)^{\frac{1}{\rho_v}} \frac{V_{H,t}}{L_t^H} \left(\frac{Y_{H,t}}{V_{H,t}} \right)^{\frac{1}{\rho_v}} \tag{20}$$

$$R_t^H = \alpha_h \left(\gamma_v \right)^{\frac{1}{\rho_v}} \frac{V_{H,t}}{K_{t-1}^H} \left(\frac{Y_{H,t}}{V_{H,t}} \right)^{\frac{1}{\rho_v}} \tag{21}$$

$$\frac{P_{M,t}}{P_{H,t}} = (1-\gamma_v)^{\frac{1}{\rho_v}} \left(\frac{Y_{H,t}}{X_{M,t}} \right)^{\frac{1}{\rho_v}} \tag{22}$$

where $P_{M,t}$ is the domestic currency price of the imported intermediate good.

Market Clearing The resource constraint in the non-tradable and domestic tradable sectors is given by

$$Y_{N,t} = (C_{N,t} + I^N_{N,t} + I^H_{N,t}) \int_0^1 \left[\frac{P_{N,t}(z)}{P_{N,t}} \right]^{-\varrho} dz \tag{23}$$

$$Y_{H,t} = AB_{H,t} + C^*_{H,t} \tag{24}$$

$$AB_{H,t} = C_{H,t} + I^N_{H,t} + I^H_{H,t} \tag{25}$$

where $AB_{H,t}$ is domestic absorption and $C^*_{H,t}$ are net exports of the H good. The trade balance, expressed in units of good H, can be written as

$$NX_{H,t} = C^*_{H,t} - \frac{e_t P^*_{F,t}}{P_{H,t}} X_{F,t} - \frac{P_{M,t}}{P_{H,t}} X_{M,t} \tag{26}$$

where $X_{F,t} = \int_0^1 Y_{F,t}(z) dz$. Assuming that domestic bonds are in zero net supply, the current account (in nominal terms) reads as[13]

$$e_t B^*_t = \left(1 + i^*_{t-1}\right) e_t B^*_{t-1} + P_{H,t} NX_{H,t} \tag{28}$$

Finally, labor market clearing requires $L^d_t = L^N_t + L^H_t = L^s_t$.

7.2 Parameterization

The quarterly discount factor β is set equal to 0.99, which implies a steady-state real world interest rate of 4 percent in a steady state with zero inflation. The elasticity of labor supply is set equal to $\frac{1}{2}$, and the ratio of average hours worked relative to total hours equal to $\frac{1}{3}$. The elasticity of substitution between tradable and non-tradable goods in the consumption and investment index, ρ_n, is set equal

[13] Following Schmitt-Grohe and Uribe [45], the nominal interest rate at which households can borrow internationally is given by the exogenous world interest rate $\tilde{\imath}^*$ plus a premium, which is assumed to be increasing in the real value of the country's stock of foreign debt:

$$(1 + i^*_t) = (1 + \tilde{\imath}^*_t) g(-B_{H,t}) \tag{27}$$

where $B_{H,t} = \frac{e_t B^*_t}{P_{H,t}}$ and $g(\cdot)$ is a positive, increasing function. Eq. (27) ensures the stationarity of the model. The endogenous risk premium in equation (27) is parameterized so that for a 10 percent increase in the ratio of net foreign debt to steady-state GDP, the interest rate at which domestic agents can borrow abroad increases by 0.4 percent, a conservative figure for emerging markets.

to 0.5 as in Stockman and Tesar [47]. We assume that the foreign and domestic goods in the tradable consumption index are closer substitutes, setting ρ_h=1.5.

The aggregate consumption (and investment) index parameter γ_n is equal to 0.4. This implies that the steady-state share of non-tradable goods in total consumption is 63 percent. This value is comparable with the data on GDP by origin in the Czech Republic, one of the new EU member states with the highest GDP per capita. Note that the share of non-tradable goods in CPI data is typically smaller: This share, in fact, excludes a large part of GDP consumed by the government sector. Lipinska [36] reports that the weight of non-tradable goods in the CPI of the new EU member states ranges from 37 percent (Estonia) to 49 percent (Slovenia) over the 2000-05 period, and is 51 percent for EU-15. Data on GDP by origin in emerging markets suggest values close to the model parameterization.[14] The share of the domestically produced tradable good H in the tradable good consumption composite is set to 0.8, implying C/Y equal to 47 percent.

We assume there are no capital adjustment costs in steady state. The elasticity of Tobin's Q with respect to the investment-capital ratio is taken to be 0.5. The quarterly depreciation rate of capital, δ, is assigned the conventional value of 0.025. Following Cooks and Devereux [11] the tradable sector is assumed to be more capital-intensive than the non-tradable sector, with $\alpha_h = 0.67$ and $\alpha_n = 0.33$. The elasticity of substitution ρ_v between the imported intermediate good $X_{M,t}$ and domestic value added $V_{H,t}$ is set equal to 0.5.

The share of domestic value added in the tradable good production function, γ_v, is such that in a balanced-trade steady state the ratio of imports to GDP is 60 percent. Among the new EU member states, this share ranges from 35 percent (Poland) to 86 percent (Estonia) (Lipinska [36], ECB [25]). The speed of price-adjustment in the non-tradable sector is assumed to be slower than in the US, and on the upper end of estimates for European countries reported by Clarida et al. [10]. The unconditional probability $(1 - \vartheta)$ of adjusting prices in any period is set equal to 0.2. With larger values, CPI inflation would be too volatile, given that the share of non-tradable consumption goods—whose price cannot be adjusted in every period—is about two-thirds. The steady-state mark-up in the non-tradable sector is set equal to 10 percent, consistent with macroeconomic evidence for OECD countries. In the baseline model, we assume full pass through for all traded goods. In the LCP case,the markup and the price-adjustment speed in the consumption good import sector are assumed identical to the non-traded good sector.

The exogenous stochastic processes for the total factor productivity shock in the tradable and non-tradable good sector, the household preference shifter, the foreign-

[14] We assume 20 percent of domestic non-tradable output is absorbed by the government sector in steady state.

currency price of the tradable goods H and F and the imported intermediate input, and the foreign interest rate follow an AR(1) specification in logs:

$$\begin{aligned}
a_t^H &= \rho_{a^H} a_{t-1}^H + \varepsilon_{a^H,t} \\
a_t^N &= \rho_{a^N} a_{t-1}^N + \varepsilon_{a^N,t} \\
d_t &= \rho_d d_{t-1} + \varepsilon_{d,t} \\
p_{H,t}^* &= \rho_{p_H} p_{H,t-1}^* + \varepsilon_{p_H,t} \\
p_{F,t}^* &= \rho_{p_F} p_{F,t-1}^* + \varepsilon_{p_F,t} \\
p_{M,t}^* &= \rho_{p_M} p_{M,t-1}^* + \varepsilon_{p_M,t} \\
i_t^* &= \rho_{i^*} i_{t-1}^* + \varepsilon_{i^*,t}
\end{aligned}$$

where $\varepsilon_{j,t}$ is normally distributed with variance $\sigma_{\varepsilon_j}^2$. The productivity shock innovation volatility is set in both sectors equal to $\sigma_a = 0.008$ with $\rho_a = 0.95$. These values are in line with the international business cycle literature, and close to the ones in Gali and Monacelli [27] and Monacelli [38], and to the average estimate in Kollman [32] for UK, Japan, Germany over the 1973-1994 sample. The coefficients for the unobservable preference shock process d_t are left as free parameters, and are adjusted to ensure sufficient volatility in domestic output. We set $\rho_d = 0.85$ and $\sigma_d = 0.009$. These values are larger than those in Laxton and Pesenti [35] ($\rho_d = 0.7$ and $\sigma_d = 0.004$) and similar to the values reported by Monacelli [38]. To parameterize the process for the foreign interest rate we use Eurostat data on the average money market rate in the EU-15, resulting in estimates of $\rho_{i^*} = 0.95$ and $\sigma_{i^*} = 0.001$. The exogenous innovation $\varepsilon_{i,t}$ in the monetary policy rule follows an i.i.d. process, and its standard deviation is set at $\sigma_i = 0.001$, a low value that reflects the evidence on the small role played by non-systematic monetary policy in business cycle fluctuations in a number of countries.

To parameterize the stochastic process for the foreign prices we use data for a fast growing accession country, the Czech Republic, over the period 1994-2002. The time series for p_j^*, $j = F, M$, is obtained from detrended import commodity price indices converted in units of foreign currency (euro) using the Nominal Effective Exchange Rate . To aggregate the price indices by commodity, we classify Crude Materials excluding Fuels, Mineral Fuels and Related Products, Chemicals and Related Products, Manufactured Good, 50% of Miscellaneous Manufactured Articles as *intermediate goods*; Machinery and Transport Equipment as *capital goods*; Food and Live Animals, Beverages and Tobacco, Animal and Vegetable Oils, and 50% of Miscellaneous manufactured articles as *consumption goods*. Because in our model the foreign tradable good F is part of both the investment and the consumption basket, we assume that p_F^* is an aggregate of capital and consumption good price indices. The weights for the foreign intermediate and consumption goods' price indices are the 1997-2006 average Commodity Composition of Imports as reported by IMF [28], the Czech Statistical Office, and the Czech National Bank (July 2006 data). p_H^* is obtained from the aggregate export price index converted in units of foreign currency using the Nominal Effective Exchange Rate.

7.3 DSGE Model Solution Algorithm. Moments and Welfare Computation

The DSGE model is solved by taking first- and second-order approximations around the deterministic steady state using the Dynare set of routines. Moments in frontier graphs are computed for 500 simulations of a 40-quarters path. The probability boundaries are computed using a Gaussian distribution. The probability level for the variance boundaries indicated in the figures 4 to 6 is an upper bound in the Balassa-Samuelson case. The Balassa-Samuelson shock generates a persistent drop (appreciation) in the real exchange rate P_T/P_N. Therefore the distribution of CPI inflation (exchange rate) has a positive (negative) skew relative to the standard case, and more probability mass for values of the variable above (below) the average.

In the welfare calculation the paper assumes that the expected path of productivity growth belongs to the information set when agents are choosing the optimal plan. To this end, we use the FORECAST Dynare instruction, which adds to the list of state variables future values of the deterministic productivity growth path in the tradable good sector (see Juillard [34]). The horizon over which the excess productivity growth in the tradable-good sector is expected is limited to 50 quarters to avoid explosive paths under some parameterizations. The possibility of explosive paths when simulating DSGE models solved using higher-order approximation is a well known problem (see Kim, Kim, Schaumburg, and Sims [30] for a discussion). Under model parameterizations stable in long simulations, the welfare results are not significantly affected by the forecast horizon.

Table 1: Moments and steady state ratios under alternative parameterizations

	Baseline ρ_n=0.5 γ_v=0.65 γ_n=0.4	LCP	ρ_n=0.9	γ_v=0.3	γ_n=0.55
	Flexible exchange rates				
Standard Deviation %					
Output	**2.34**	**2.25**	**2.72**	**3.98**	**2.25**
Consumption	**2.77**	**2.71**	**3.12**	**3.85**	**2.69**
Inflation CPI	**0.72**	**0.66**	**0.86**	**0.88**	**0.70**
Inflation - non tradable good	**0.65**	**0.64**	**0.56**	**0.81**	**0.70**
Inflation - tradable good	**1.32**	**1.12**	**1.34**	**1.72**	**1.33**
Net exports	**2.59**	**2.54**	**2.52**	**3.00**	**2.57**
Nominal exchange rate	**8.02**	**7.80**	**9.07**	**9.86**	**7.86**
	Pegged exchange rates				
Output	**2.71**	**2.75**	**2.95**	**4.51**	**2.64**
Consumption	**3.02**	**3.06**	**3.17**	**4.14**	**2.98**
Inflation CPI	**0.68**	**0.66**	**0.84**	**0.87**	**0.62**
Inflation - non tradable good	**0.59**	**0.59**	**0.52**	**0.93**	**0.60**
Inflation - tradable good	**1.34**	**1.25**	**1.34**	**1.34**	**1.34**
Net exports	**2.29**	**2.26**	**2.34**	**2.47**	**2.28**
Steady State Ratios					
Imports/Output	**60%**	**60%**	**76%**	**123%**	**50%**
Consumption-non tradable good/ Total Consumption	**63%**	**63%**	**45%**	**63%**	**74%**
Investment-non tradable good/ Total Investment	**68%**	**68%**	**50%**	**68%**	**78%**
Output-non tradable good/ Total Output	**56%**	**56%**	**38%**	**39%**	**69%**

Note: All series are logged (with the exception of inflation rates and net exports) and Hodrick-Prescott filtered. The net export variable is the Hodrick-Prescott filtered ratio to real output. Inflation rates are quarterly values. LCP indicates Local Currency Pricing for the imported consumption (c_f) and investment (I_f) good. ρ_n is elasticity of substitution between tradable and non- tradable goods. γ_v is share of domestic value added in tradable good domestic output. γ_n is share of non-tradable good in consumption and investment aggregate basket. Monetary policy rule for flexible exchange rate case: $i(t)=0.8*[i(t-1)] + 0.2*[\pi(t)+0.4*y(t)+0.1e(t)]$.

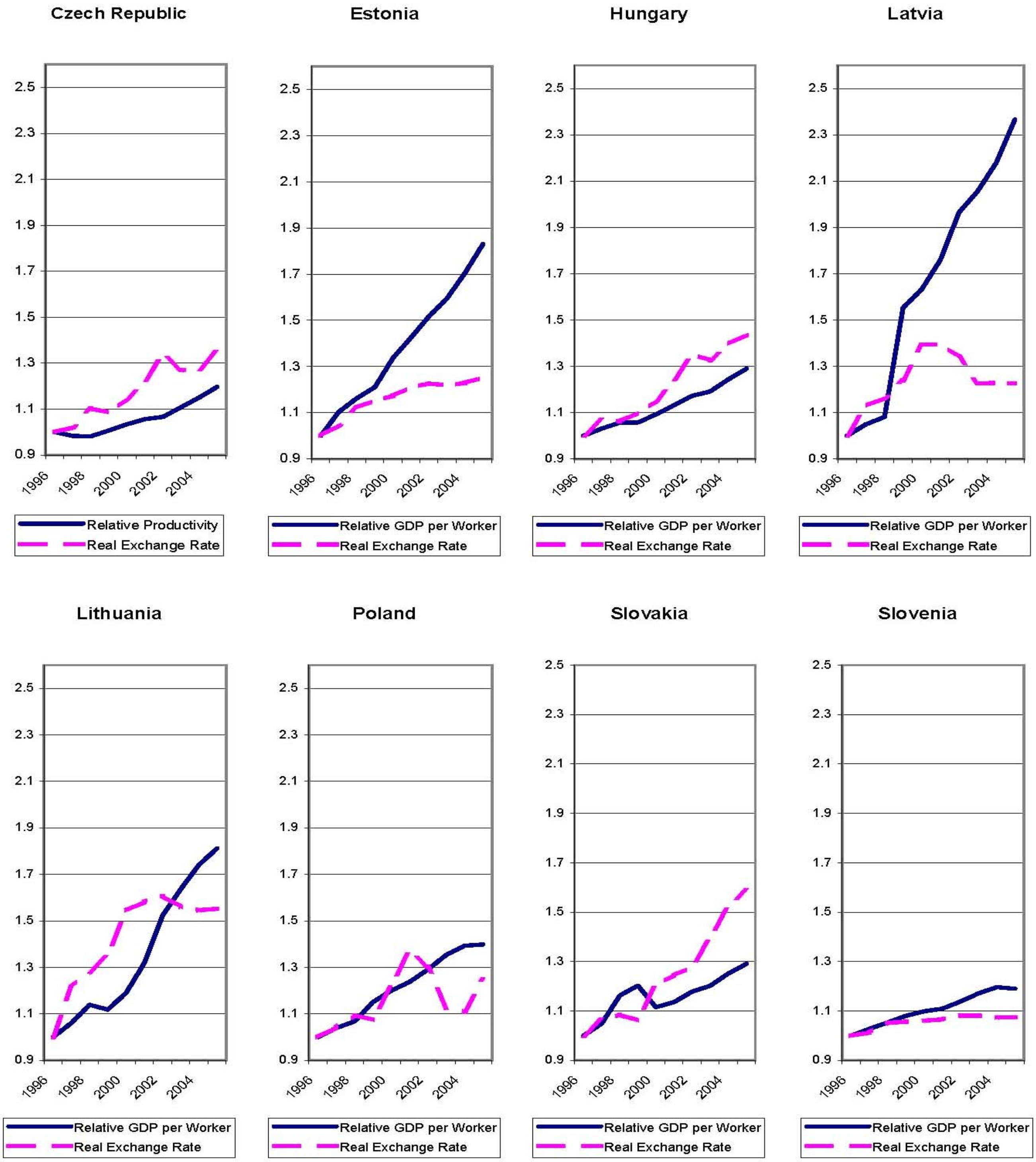

Figure 1: Solid: GDP per worker relative to Euro-area GDP per worker. Relative GDP per worker is normalized to one in base year 1996. Dashed: real exchange rate against the Euro (ratio of the domestic Harmonized CPI to the European Monetary Union CPI evaluated in domestic currency). Source: IMF-IFS, Eurostat, Haver.

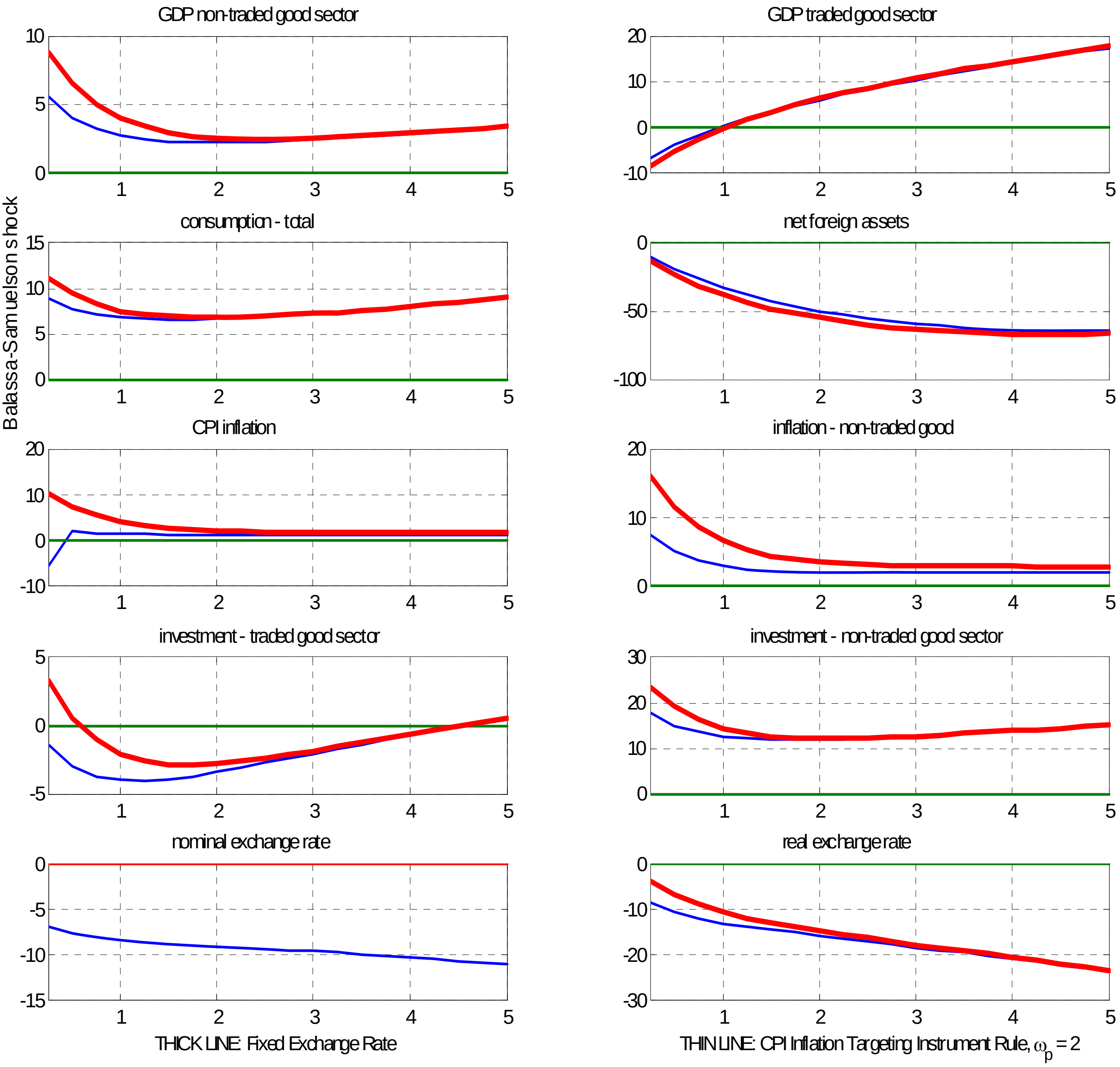

Figure 2: Impulse response function to a persistent productivity growth shock in the domestic tradable good production sector. Productivity grows by 30% over a 10-year period. Instrument rule coefficients in inflation targeting policy : $\omega_\pi = 2,\ \omega_e = 0, \chi = 0.8$. Time measured in years.

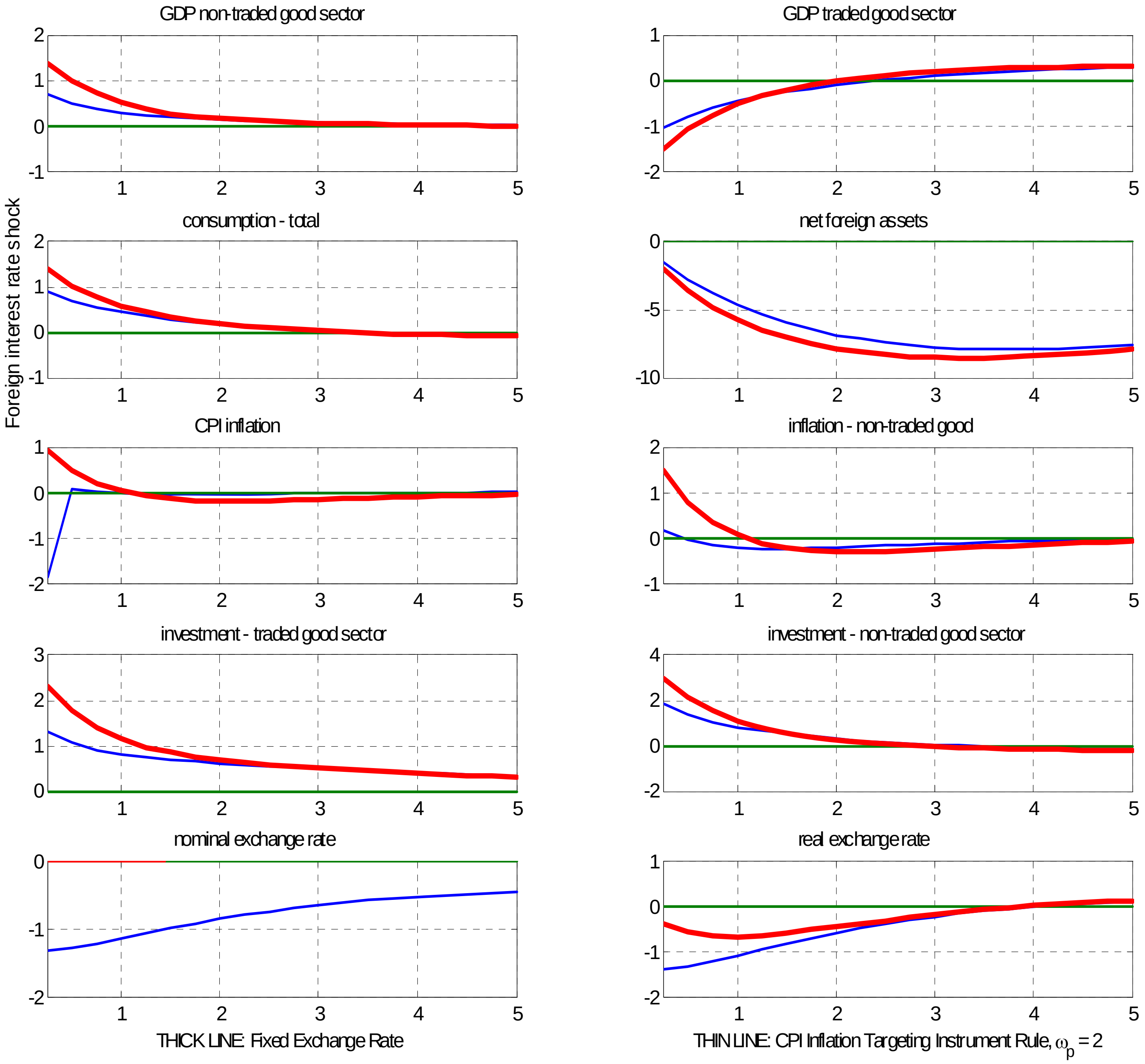

Figure 3: Impulse response function to 1% drop in the annualized foreign interest rate risk-premium . The shock follows an AR(1) process with autocorrelation coefficient equal to 0.95. Instrument rule coefficients in inflation targeting policy: $\omega_\pi = 2,\ \omega_e = 0, \chi = 0.8$. Time measured in years.

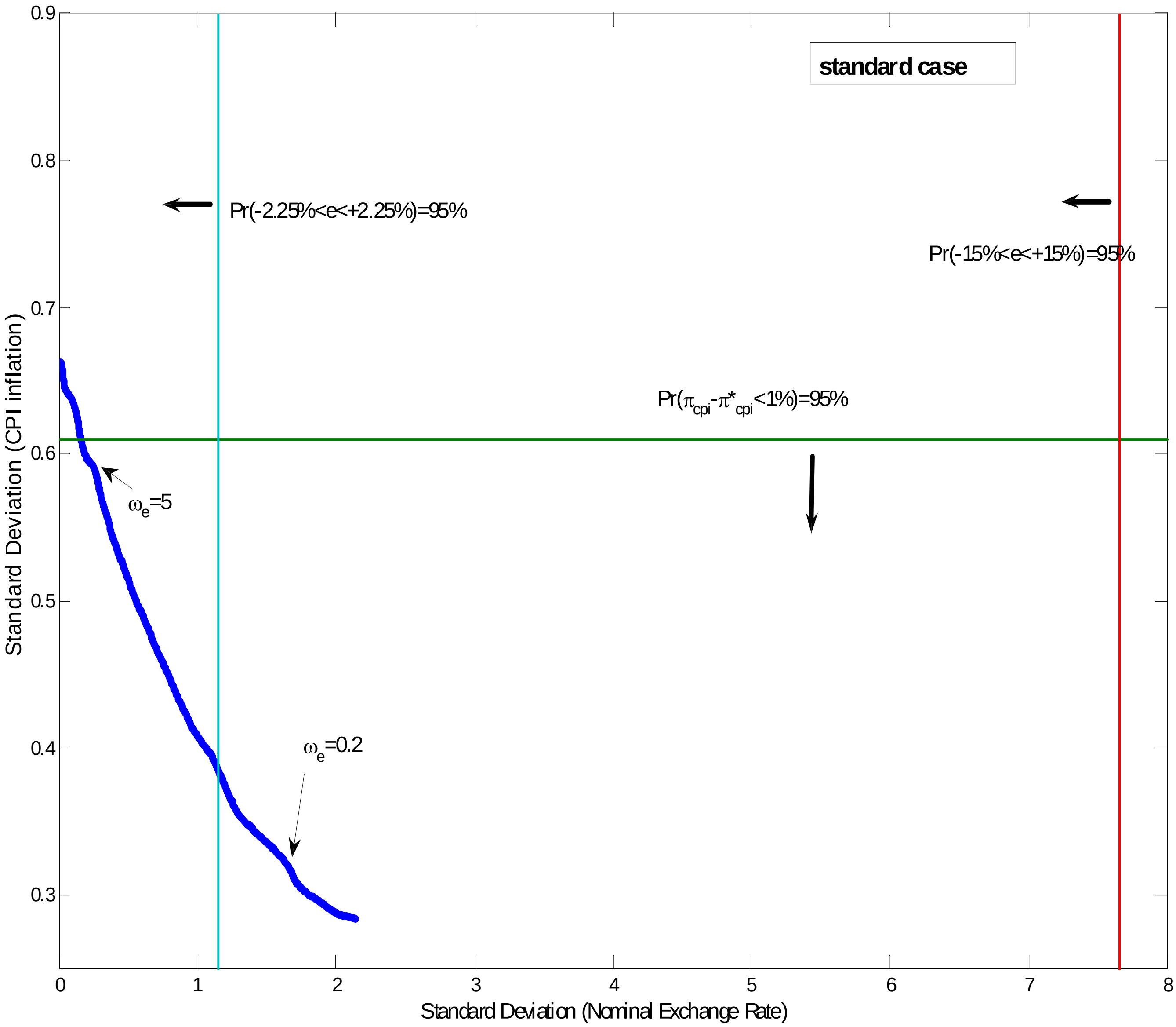

Figure 4: Inflation/exchange rate volatility trade-off for baseline parameterization (see Table 1). Monetary policy rule: $i_t = \chi i_{t-1} + (1-\chi)(\omega_\pi \pi_t + \omega_e e_t)$. Coefficient values: $\omega_\pi = 3.5, \chi = 0.8, \omega_e$ varies between 700 (corresponding to $\sigma_e = 0$) and 0.001 (corresponding to $\sigma_e = 2.2$). Two intermediate values for ω_e marked in chart. Tradable sector productivity follows an AR(1) process. Thin lines show probability boundaries. Points to the left or below the α-probability boundary are combinations (σ_π, σ_e) such that the probability of the realization ξ in any quarter, $\Pr(\xi)$, is larger than α. The Technical Appendix reports the exogenous shocks parameters.

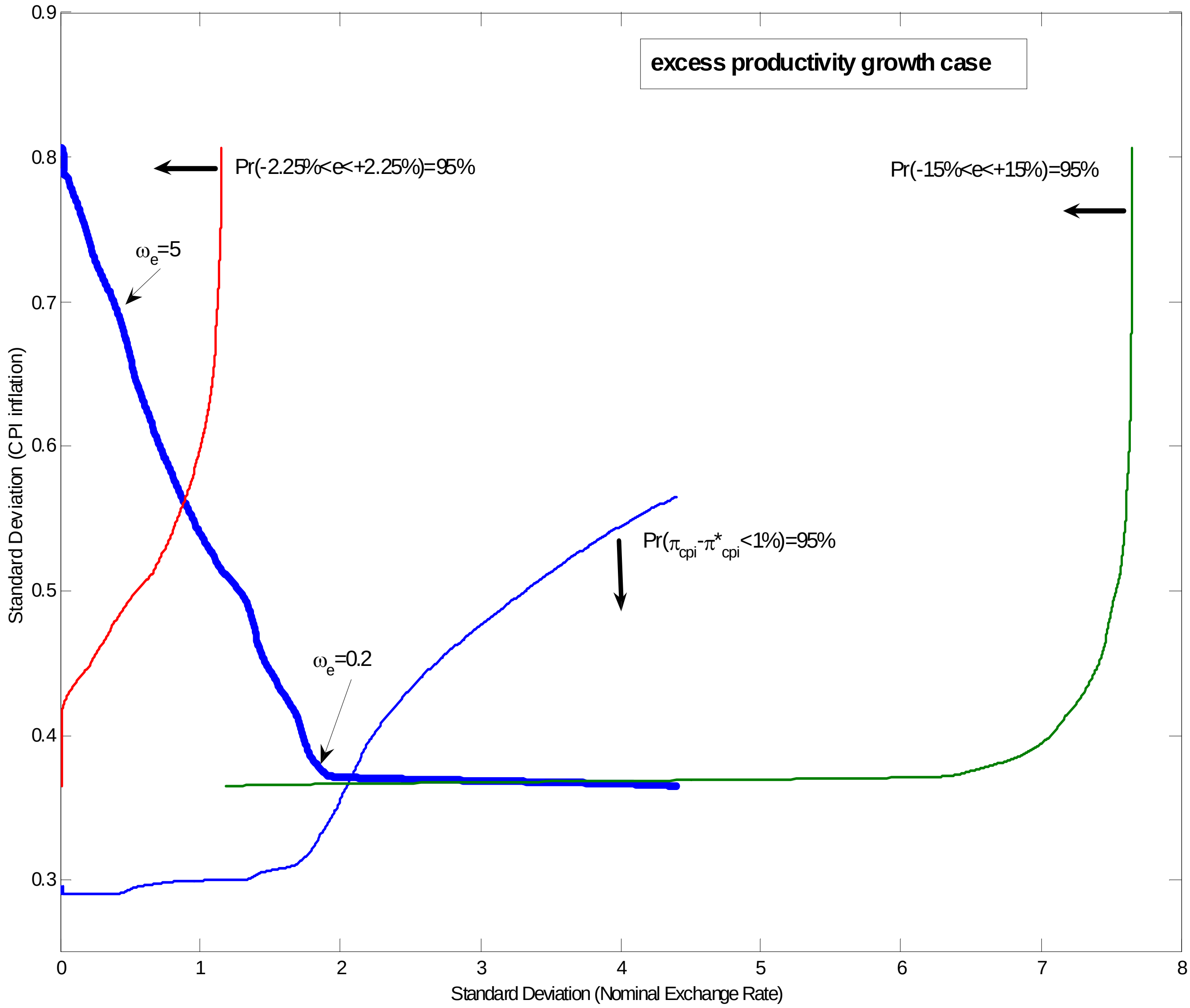

Figure 5: Inflation/exchange rate volatility trade-off for baseline parameterization (see Table 1). Monetary policy rule: $i_t = \chi i_{t-1} + (1-\chi)(\omega_\pi \pi_t + \omega_e e_t)$. Coefficient values: $\omega_\pi = 3.5, \chi = 0.8, \omega_e$ varies between 700 (corresponding to $\sigma_e = 0$) and 0.001 (corresponding to $\sigma_e = 4.4$). Two intermediate values for ω_e marked in chart. Tradable sector productivity grows on average by 2.65% per year (30% over a 10-year period). For each level of σ_π the exchange rate probability boundary (thin lines) plots the level of σ_e such that the probability in any quarter of exchange rate realizations falling in the $[-15\%, +15\%]$ and $[-2.25\%, +2.25\%]$ interval with respect to the target (initial steady state) is 95%. For each level of σ_e the inflation probability boundary plots the level of σ_π such that the probability in any quarter of a smaller than 1% differential relative to foreign inflation is 95%. Probability boundaries assume that any rule generating a given value for σ_e $[\sigma_\pi]$ implies the same value for $E_0(\pi)$ $[E_0(e)]$ as the policy rule used to build the volatility trade-off. Moments obtained averaging 500 samples of length equal to 10 years.

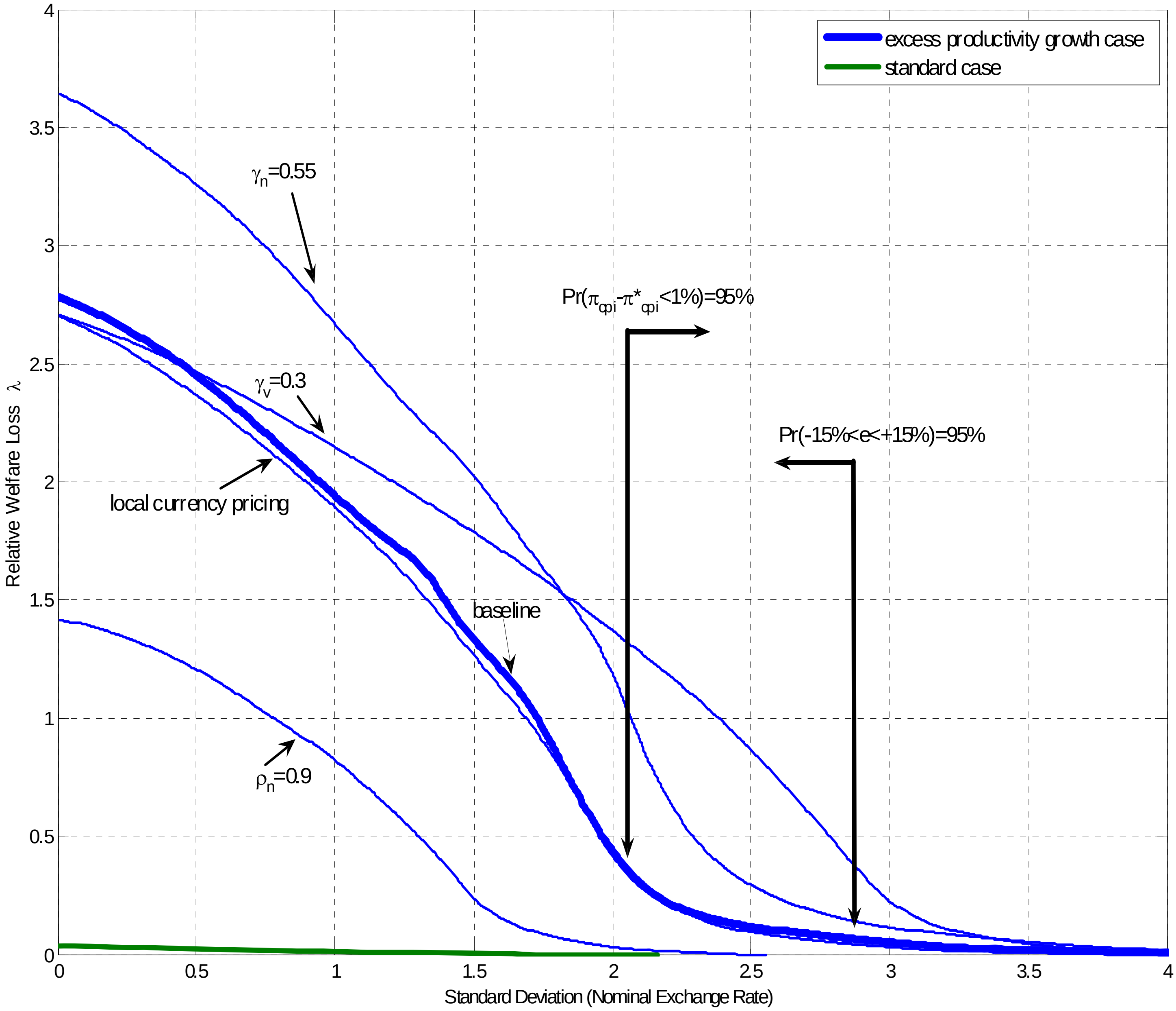

Figure 6: Conditional welfare loss λ relative to the best-performing policy for the instrument rule: $i_t = \chi i_{t-1} + (1-\chi)(\omega_\pi \pi_t + \omega_e e_t)$ with coefficient values $\omega_\pi = 3.5, \chi = 0.8, \omega_e$ varying between 700 and 0.001. Policy rules are indexed by the implied exchange rate volatility. Best-performing rule: $\omega_e = 0.001$. Welfare loss computed as the percentage λ of expected consumption stream conditional on the best-performing policy that the household would be willing to give up to be indifferent between the best-performing and the alternative policy. Indicated in the plot is the implied nominal exchange rate volatility of policy rules such that the probability of the realization ξ in any quarter, $\Pr(\xi)$, is larger than 95%. Probability computed for the baseline parameterization.