The Road to Adopting the Euro: Monetary Policy and Exchange Rate Regimes in New EU Member Countries*

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Abstract

This paper examines the choice of exchange rate regime in Central and Eastern European countries during the process of accession to the European Monetary Union (EMU). In a general equilibrium model of an emerging market economy, we show that a real exchange rate appreciation due to the Balassa-Samuelson effect shifts the output gap/inflation variance trade-off, increasing the cost of managing or fixing the exchange rate. As a consequence, the current EMU admission requirements of limiting both exchange rate and inflation movements constrain the policy choice while providing no additional benefit to countries credibly committed to joining the euro area. We show that policy rules that allow for more exchange rate flexibility than the current EMU requirement lower the volatility of both the inflation rate and the output gap. Alternative admission requirements proposed for new European Union members, such as an easing of the inflation criterion, underestimate the costs deriving from larger business cycle volatility.

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1 Introduction

In May 2004, ten countries - Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia - joined the European Union (EU). These countries also announced plans to join the European Monetary Union (EMU) and adopt the euro as official currency within four to six years (ECB [23]). Before adopting the euro, the new members are required to achieve exchange rate stability by participating for at least two years in the ERM-II, the target zone exchange rate arrangement between the euro area and EU members outside the euro area. New EU members are also required to meet the Maastricht convergence criteria for the adoption of the euro. According to the inflation criterion, the annual inflation rate of EMU candidates must not exceed by more than 1.5 percent the average of the three lowest inflation countries in the euro area.

The ERM-II is compatible with several monetary policy regimes. This paper analyzes the consequences of large productivity gains for the choice of exchange rate regime in the new EU members during the process of accession to the EMU.

Central and Eastern European countries are expected to experience - and have been already experiencing - high productivity growth and a sustained appreciation of the real exchange rate (the so-called *Balassa-Samuelson effect*). Using a dynamic stochastic general equilibrium model calibrated for the Czech Republic, we show that the response of real variables to a productivity-driven appreciation of the real exchange rate 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-traded good under both a fixed exchange rate and an inflation targeting regime. Because the long-term productivity gain is anticipated, the increase in consumption is financed through a large capital inflow.

The choice of monetary policy has important implications for the dynamics of nominal variables: it allocates the productivity-driven real exchange appreciation among an increase in the non-traded good price inflation and an appreciation of the nominal exchange rate. Therefore, as it is well understood in the literature and in the policy debate (Buiter and Grafe [4], Begg et al. [3]), new EU member countries could face a trade-off between complying with the Maastricht inflation criterion and limiting movements of the exchange rate against the euro, as required by membership in the ERM-II.

Because of nominal rigidities different monetary policy regimes also imply different costs in terms of real variables volatility over the business cycle.

The general equilibrium framework allows us to compute the exchange rate-inflation variance trade-off as a function of the monetary policy regime, and evaluate the impact of the Balassa-Samuelson effect on the probability of compliance with the EMU admission criteria. Under the assumption that the monetary authority follows a Taylor rule, the inflation-output gap variance trade-off shifts relative to the case in which the Balassa-Samuelson effect is not at work. This equilibrium variance effect has important consequences for the choice of the exchange rate regime, making a fixed exchange rate more costly in terms of output gap *and* inflation volatility over the business cycle. We then analyze the business cycle implications of relaxing either the exchange rate stability requirement or the Maastricht inflation criterion. We conclude that allowing for a sustained appreciation of the nominal exchange rate would reduce the volatility of both the output gap and inflation.

The paper is organized as follows. Section 2 reviews the recent literature on the Balassa-Samuelson effect. Section 3 describes the model. Section 4 discusses the parametrization. Section 5 examines the impact of a trend appreciation of the real exchange rate under alternative monetary policies and the implications for capital inflows. Section 6 describes the variance trade-offs conditional on a Taylor rule. Section 7 concludes.

2 EMU Accession and the Balassa-Samuelson Effect

Faster productivity growth in new EU members relative to the EU can produce a trend appreciation of the real exchange rate through the *Balassa-Samuelson effect* (Balassa [2]). Most of the productivity gains during the convergence to EU per-capita income levels are expected to show up in the tradable good sector. Higher productivity translates into higher wages. Assuming perfect labor mobility across sectors, wages in the non-tradable sector have to rise to comply with wage equalization. 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 (the so-called *Baumol-Bowen* effect). If the Law of One Price holds for tradable goods, faster productivity growth in the tradable sector relative to the EU translate into 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^*) consumer price index (CPI).

Empirical analysis of the Balassa-Samuelson effect in new EU member countries and a discussion of the theoretical background can be found in De Gregorio et al. [16], Canzoneri et al. [7], Cipriani [9], Arratibel et al. [1], Csajbok and Csermely [14], Egert [21], Egert et al. [22], Cihak and Holub [8], Nenovsky and Dimitrova [34], Fischer [24], Buiter and Grafe [4], Pelkmans et al. [36] and Rogers [38] [39].

The literature estimates the tradable sector productivity growth differential between the euro area and new EU members to be between 1 and 4 percent, with most of the estimates above 2 percent. The trend appreciation of the real exchange rate in many of these economies is extensively documented, ranging in the 1992-1998 period from 25 percent in Hungary to nearly 300 percent in Estonia and Latvia (De Broeck and Slok [15]). Figure 1 shows the behavior of relative productivity and real exchange rate in the new EU members (excluding Cyprus and Malta) starting in 1996. Relative productivity has been growing in all new EU members, indicating that the process of catch-up is still ongoing, and the real exchange rate has been appreciating steadily.

However, there is disagreement as to whether productivity growth differentials can fully explain the often larger movements observed in real exchange rates (see Mihaljek [33]). 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 accession country relative to the euro area; (2) changes in the tradable and non-tradable goods' shares in the consumption basket; and (3) the relative price of tradable goods in a common currency. Only movements in the first component represent the Balassa-Samuelson effect. Egert et al. [22] find that price level convergence in Central and Eastern European countries is taking place, at least in part, through an increase in tradable good prices. Clearly, if firms can price-discriminate across countries, the law of one price for tradable goods will not hold (see Devereux and Engel [19] for implications of local currency pricing in an open economy model, and Canzoneri et al. [6] for empirical evidence in OECD economies). Coricelli et al. [13], though, find evidence of a strong pass-through from nominal exchange rates to domestic inflation in Hungary, Slovenia, Czech Republic and Poland. Since many prices of tradable goods contain non-tradable components, part of the increase in tradable good prices may also be accounted for by the Balassa-Samuelson effect.

Additional issues that make accurate estimates of the Balassa-Samuelson effect extremely difficult. The evolution of CPI-based real exchange rates in transition economies is affected by price adjustments for quality improvements, increases in the demand for tradable goods, the large share of food items and regulated prices in domestic CPI, and the possibility that exchange rates were largely undervalued in the early stages of the transition.

While the discussion in the literature focuses on the magnitude and consequences of the Balassa-Samuelson effect, the quantitative analysis of its implications for monetary policy choices is very limited. Until very recently, only few estimated macroeconomic models for Central and Eastern European countries were available, mainly based on non-optimizing frameworks (see Merlevede et al. [32]). Devereux [18] is the closest model to the one developed in this paper, although the focus of his analysis is on the role of terms of trade shocks in new EU members. Laxton and Pesenti [29] examine alternative Taylor rules in a general equilibrium model calibrated to the Czech Republic. A modeling framework similar in spirit can also be found in the exchange-rate based stabilization literature (e.g. Mendoza and Uribe [31] and Uribe [42]).

3 The Model

We build a model of a small open economy along the lines of Obstfeld and Rogoff [35], Devereux [17] [18], Devereux and Lane [20], Gali and Monacelli [25]. Our goal is to develop a model that fits some important characteristics of emerging market economies, including vulnerability to external shocks through imported consumption goods, intermediate inputs and the foreign component of capital goods, the dynamics of volatile capital inflows, and rapid productivity growth.

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 basket includes two goods: a foreign good (F), that must be imported, and the domestic good (H). Consumers own the sector-specific capital and can save by holding real money balances and domestic/foreign nominal bonds. Investment goods in the H and N sectors are obtained by combining tradable goods H and F - and the non-tradable good. However, shares and elasticities of substitution of the investment aggregates are different from the consumption aggregate. Given the structure of investment, an increase in capital in the H or N sector requires an increase in production in both the H and N sectors. The domestic tradable sector H uses domestic value added - a Cobb-Douglas aggregate of labor and capital - and an imported intermediate input. Output in the N sector is obtained combining labor and capital. To introduce a role for monetary policy, we assume nominal price-rigidities in the non-tradable sector.

The model includes a high degree of differentiation between the tradable and non-tradable production sector and a variety of channels through which external shocks affect the domestic economy. Four distinguishing features make the model appropriate for Central and Eastern European transition economies. First, the domestic tradable good is both exported and consumed by domestic households. In countries like the Czech Republic and Hungary, the share of consumption in imported goods is, in fact, well below 15 percent. Second, goods' shares in the consumption and investment baskets are different. The model can account for the fact that intermediate inputs and capital goods are the main components of total imports. In the Czech Republic and Hungary, for example, intermediate goods are the largest component of imports - above 50 percent - making these economies potentially very exposed to external shocks. In addition, foreign goods enter also the non-tradable sector production function through capital accumulation, since investment goods are an aggregate of N, H and F goods. Third, the model allows for different elasticities of substitution between T and N goods and between H and F 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 H sector relative to the N 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, Investment, and Price Composites

Household 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:

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

where $0 \leq \gamma_{cn} \leq 1$ is the share of the N good and $\rho_{cn} > 0$ is the elasticity of substitution between N and T goods. The tradable consumption good is a composite of home and foreign tradable goods, $C_{H,t}$ and $C_{F,t}$, respectively:

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

where $0 \leq \gamma_{ch} \leq 1$ is the share of the H good and $\rho_{ch} > 0$ is the elasticity of substitution between H and F goods. The non-tradable consumption good N is an aggregate defined over a continuum of differentiated goods:

$$C_{N,t} = \left[\int_0^1 C_{N,t}^{\frac{\varrho-1}{\varrho}}(z)dz \right]^{\frac{\varrho}{\varrho-1}} \quad (3)$$

with $\varrho > 1$. Investment in the non-tradable and domestic tradable sector is defined in a similar manner - a composite of N, H, and F goods. However, we assume that shares and elasticities may differ from those of the consumption composites (the superscript J refers to the sector):

$$I_t^J = \left[(\gamma_{in})^{\frac{1}{\rho_{in}}} \left(I_{N,t}^J \right)^{\frac{\rho_{in}-1}{\rho_{in}}} + (1-\gamma_{in})^{\frac{1}{\rho_{in}}} \left(I_{T,t}^J \right)^{\frac{\rho_{in}-1}{\rho_{in}}} \right]^{\frac{\rho_{in}}{\rho_{in}-1}}, J = N, H \quad (4)$$

$$I_{T,t}^J = \left[(\gamma_{ih})^{\frac{1}{\rho_{ih}}} \left(I_{H,t}^J \right)^{\frac{\rho_{ih}-1}{\rho_{ih}}} + (1-\gamma_{ih})^{\frac{1}{\rho_{ih}}} \left(I_{F,t}^J \right)^{\frac{\rho_{ih}-1}{\rho_{ih}}} \right]^{\frac{\rho_{ih}}{\rho_{ih}-1}}, J = N, H \quad (5)$$

$$I_{N,t}^J = \left[\int_0^1 \left(I_{N,t}^J \right)^{\frac{\varrho-1}{\varrho}}(z)dz \right]^{\frac{\varrho}{\varrho-1}} \quad (6)$$

Households' demand functions imply that the composite good price indices can be written as:

$$P_t^c = \left[(\gamma_{cn}) (P_{N,t})^{1-\rho_{cn}} + (1-\gamma_{cn}) \left(P_{T,t}^c \right)^{1-\rho_{cn}} \right]^{\frac{1}{1-\rho_{cn}}}$$

$$P_{T,t}^c = \left[(\gamma_{ch}) (P_{H,t})^{1-\rho_{ch}} + (1-\gamma_{ch}) (P_{F,t})^{1-\rho_{ch}} \right]^{\frac{1}{1-\rho_{ch}}}$$

$$P_{N,t} = \left[\int_0^1 P_{N,t}^{1-\varrho}(z)dz \right]^{\frac{1}{1-\varrho}}$$

where P_t^c, $P_{T,t}^c$, and $P_{N,t}$ are the consumer price index (CPI), the price index for T consumption goods, and the price index for N consumption goods, respectively. Investment price indices (P_t^i, $P_{T,t}^i$, and $P_{N,t}$) can be similarly obtained. The real exchange rate is then defined as $q_t^c = \frac{P_{T,t}^c}{P_{N,t}}$.

3.2 Households

The preferences of the representative household are given by

$$U = E_t \sum_{i=0}^{\infty} \beta^i \left\{ \log C_{t+i} - \ell \frac{\left(H_{t+i}^s \right)^{1+\eta_H}}{1+\eta_H} + \chi_m \frac{\left(\frac{M_{t+i}}{P_{t+i}^c} \right)^{1-1/\zeta}}{1-1/\zeta} \right\} \quad (7)$$

where H_t^s is the labor supply

$$H_t^s = H_t^N + H_t^H \tag{8}$$

η_H is the inverse of the labor supply elasticity, $\frac{M_t}{P_t^c}$ are real money balances, and ζ is the elasticity of substitution of real money balances.

Let W_t^N (W_t^H) denote the nominal wage in the N (H) 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 N (H) sector, Π_t nominal profits from the ownership of firms in the monopolistically competitive N sector, and T_t nominal government lump-sum taxes. The household's budget constraint is then given by

$$P_t^c C_t + e_t B_t^* v_t^* + B_t v_t + P_t^i I_t^N + P_t^i I_t^H + M_t = W_t^H H_t^H + W_t^N H_t^N + \tag{9}$$

$$e_t B_{t-1}^* + B_{t-1} + M_{t-1} + P_{N,t} R_t^N K_{t-1}^N + P_{H,t} R_t^H K_{t-1}^H + \Pi_t - T_t$$

The household's revenues come from supplying labor and renting capital to firms in the N and H sectors, from holdings of domestic money and domestic/foreign bonds, and from firms' profits. These revenues are then used to purchase consumption and investment goods, or saved in domestic and foreign assets.

The household is assumed to maximize the inter-temporal utility function (7) subject to (1), (2), (3), (4), (5), (6), (8), (9), and the law of accumulation of the capital stocks:

$$K_t^N = \Phi\left(\frac{I_t^N}{K_{t-1}^N}\right) K_{t-1}^N + (1-\delta) K_{t-1}^N \tag{10}$$

$$K_t^H = \Phi\left(\frac{I_t^H}{K_{t-1}^H}\right) K_{t-1}^H + (1-\delta) K_{t-1}^H \tag{11}$$

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

The solution to the household decision problem gives the following first order conditions (FOCs):

Euler equation

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

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

Uncovered interest parity condition

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

Intra-temporal consumption allocations

$$C_{N,t} = \frac{\gamma_{cn}}{1-\gamma_{cn}}\left(\frac{P_{T,t}^c}{P_{N,t}}\right)^{\rho_{cn}} C_{T,t} \quad ; \quad C_{H,t} = \frac{\gamma_{ch}}{1-\gamma_{ch}}\left(\frac{P_{F,t}}{P_{H,t}}\right)^{\rho_{ch}} C_{F,t} \tag{14}$$

Labor supply

$$\lambda_t^C \frac{W_t^N}{P_t^c} = \ell\,(H_t)^{\eta_H} \quad ; \quad \lambda_t^C \frac{W_t^H}{P_t^c} = \ell\,(H_t)^{\eta_H} \tag{15}$$

The labor supply optimality conditions imply that $\frac{W_t^N}{P_t^c} = \frac{W_t^H}{P_t^c}$.

Inter-temporal investment choice

$$\begin{aligned}\lambda_t^C \frac{P_t^i}{P_t^c} Q_t^J &= \beta E_t\{\lambda_{t+1}^C\left(\frac{P_{J,t+1}}{P_{t+1}^c} R_{t+1}^J\right) + \lambda_{t+1}^C \frac{P_{t+1}^i}{P_{t+1}^c} Q_{t+1}^J [\Phi\left(\frac{I_{t+1}^J}{K_t^J}\right) \\ &\quad -\frac{I_{t+1}^J}{K_t^J}\Phi'\left(\frac{I_{t+1}^J}{K_t^J}\right) + (1-\delta)]\},\ J\ is\ N, H\end{aligned} \tag{16}$$

where Q_t^J is Tobin's Q and is defined as

$$Q_t^J = \left[\Phi'\left(\frac{I_t^J}{K_{t-1}^J}\right)\right]^{-1} \quad J = N, H \tag{17}$$

Intra-temporal investment allocations;

$$I_{N,t}^J = \frac{\gamma_{in}}{1-\gamma_{in}}\left(\frac{P_{T,t}^i}{P_{N,t}}\right)^{\rho_{in}} I_{T,t}^J, J = N, H \tag{18}$$

$$I_{H,t}^J = \frac{\gamma_{ih}}{1-\gamma_{ih}}\left(\frac{P_{F,t}}{P_{H,t}}\right)^{\rho_{ih}} I_{F,t}^J, J = N, H \tag{19}$$

Since we restrict our attention to monetary regimes where either the nominal exchange rate or the nominal interest rate is the policy instrument, money demand plays no role other than pinning down the nominal money stock. We therefore omit the FOC for real money balances.

3.3 Firms

3.3.1 Non-tradable (N) Sector

The non-tradable sector is populated by a continuum of monopolistically competitive firms owned by households. Each firm $z \in [0,1]$ combines labor and capital according to the production function:

$$Y_{N,t}(z) = A_t^N [K_{t-1}^N(z)]^{\alpha_n} \left[H_t^N(z)\right]^{1-\alpha_n} \tag{20}$$

A_t^N is an exogenous productivity shock. Cost minimization gives the standard factor demands:

$$\frac{W_t^N}{P_{N,t}} = MC_t^N(z)\,[1-\alpha_n]\,\frac{Y_{N,t}(z)}{H_t^N(z)} \tag{21}$$

$$R_t^N = MC_t^N(z)\alpha_n \frac{Y_{N,t}(z)}{K_{t-1}^N(z)} \tag{22}$$

where $MC_t^N(z)$ is the real marginal cost for firm z.

Given the first order conditions (21), (22) and the aggregate demand schedule $Y_{N,t}(z) = \left[\frac{P_{N,t}(z)}{P_{N,t}}\right]^{-\varrho} Y_{N,t}$ firm z maximizes expected discounted profits by choosing the optimal price $P_{N,t}(z)$. We assume a Calvo [5] pricing rule, with $(1-\vartheta)$ being the probability of being able to reset the price in each period. Aggregation over firms and log-linear approximation gives a widely-used forward-looking price adjustment equation for non-tradable good inflation[1].

3.3.2 Domestic Tradable (H) Sector

The tradable good H is produced both at home and abroad in a perfectly competitive environment, where the Law of One Price holds:

$$P_{H,t} = e_t P_{H,t}^* \tag{23}$$

where $P_{H,t}^*$ follows an exogenous stochastic process. Domestic producers combine an imported intermediate good, $X_{M,t}$, and domestic value added, $V_{H,t}$, according to the production function:

$$Y_{H,t} = \left[(\gamma_v)^{\frac{1}{\rho_v}} (V_{H,t})^{\frac{\rho_v-1}{\rho_v}} + (1-\gamma_v)^{\frac{1}{\rho_v}} (X_{M,t})^{\frac{\rho_v-1}{\rho_v}}\right]^{\frac{\rho_v}{\rho_v-1}} \tag{24}$$

[1] The aggregate log-linear inflation equation is given by $\pi_{N,t} = \lambda mc_t^N + \beta E_t \pi_{N,t+1}$ where $\lambda = \frac{(1-\vartheta)(1-\beta\vartheta)}{\vartheta}$ (see Gali and Monacelli [25]).

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

$$V_{H,t} = A_t^H \left(K_{t-1}^H\right)^{\alpha_h} \left(H_t^H\right)^{1-\alpha_h} \tag{25}$$

where A_t^H is an exogenous productivity shock.

Cost minimization gives the factor demands:

$$\frac{W_t^H}{P_{H,t}} = (1-\alpha_h)\left(\gamma_v\right)^{\frac{1}{\rho_v}} \frac{V_{H,t}}{H_t^H} \left(\frac{Y_{H,t}}{V_{H,t}}\right)^{\frac{1}{\rho_v}} \tag{26}$$

$$R_t^H = \alpha_h \left(\gamma_v\right)^{\frac{1}{\rho_v}} \frac{V_{H,t}}{K_{t-1}^H} \left(\frac{Y_{H,t}}{V_{H,t}}\right)^{\frac{1}{\rho_v}} \tag{27}$$

$$\frac{P_{M,t}}{P_{H,t}} = (1-\gamma_v)^{\frac{1}{\rho_v}} \left(\frac{Y_{H,t}}{X_{M,t}}\right)^{\frac{1}{\rho_v}} \tag{28}$$

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

3.4 Foreign Sector

The Law of One Price is assumed to hold for foreign goods F and M:

$$P_{F,t} = e_t P_{F,t}^* \tag{29}$$

$$P_{M,t} = e_t P_{M,t}^* \tag{30}$$

$P_{F,t}^*$ and $P_{M,t}^*$ follow exogenous stochastic processes.

Following Schmitt-Grohe and Uribe [40] 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:

$$(1+i_t^*) = (1+\tilde{\imath}_t^*) g(-B_{H,t}) \tag{31}$$

where $B_{H,t} = \frac{e_t B_t^*}{P_{H,t}}$ and $g(\cdot)$ is a positive, increasing function. Eq. (31) ensures the stationarity of the model.

3.5 Government Budget Constraint

We assume government expenditures in H and N goods, $G_{H,t}$ and $G_{N,t}$, follow an exogenous stochastic process and are financed by lump-sum taxes and money creation. The government is required to balance the budget at every point in time, i.e.

$$P_{H,t}G_{H,t} + P_{N,t}G_{N,t} = M_t - M_{t-1} + T_t \tag{32}$$

3.6 Monetary Policy

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

$$\frac{\left(1+\bar{i}_t\right)}{(1+i_{ss})} = \left(\frac{1+\pi_t}{1+\pi_{ss}}\right)^{\omega_\pi} \left(\frac{e_t}{e_{ss}}\right)^{\omega_e} \tag{33}$$

where ω_π, $\omega_e \geq 0$ are the feedback coefficients to CPI inflation and nominal exchange rate, respectively. Here $\bar{i}_t$ is the target short-term interest rate, π_t is CPI inflation at time t, and i_{ss}, π_{ss}, and e_{ss} are the steady state values of the interest rate, CPI inflation and nominal exchange rate.

The choice of the parameters ω_π and ω_e allows us to specify alternative monetary policies. $\omega_\pi > 0$ implies that the Central Bank is responding to positive deviations of CPI inflation from the target. $\omega_e > 0$ indicates that the central bank is engaging in exchange rate management by reacting to deviations of e_t from the target level of e_{ss}. The higher the feedback parameters, the more aggressively the Central Bank is responding to such deviations. A fixed exchange rate regime can be expressed as the limiting case $\omega_e \rightarrow \infty$. While Taylor rules including the output gap among the feedback variables could be welfare-improving, we focus on policy rules of the form (33) since the EMU accession criteria force the policy-maker to face an explicit trade-off between the objectives of inflation and exchange rate stabilization.

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

$$(1+i_t) = \left[\left(1+\bar{i}_t\right)\right]^{(1-\chi)} \left[(1+i_{t-1})\right]^{\chi} \varepsilon_t^{mp} \tag{34}$$

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

3.7 Market Clearing

The resource constraint in the non-tradable and domestic tradable sector is given by

$$Y_{N,t} = C_{N,t} + I_{N,t}^N + I_{N,t}^H + G_{N,t} \tag{35}$$

$$Y_{H,t} = AB_{H,t} + C_{H,t}^* \tag{36}$$

$$AB_{H,t} = C_{H,t} + I_{H,t}^N + I_{H,t}^H + G_{H,t} \tag{37}$$

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

$$NX_{H,t} = C^*_{H,t} - \frac{P_{F,t}}{P_{H,t}} \left(C_{F,t} + I^N_{F,t} + I^H_{F,t} \right) - \frac{P_{M,t}}{P_{H,t}} X_{M,t} \tag{38}$$

Assuming that domestic bonds are in zero net supply, the current account (in nominal terms) reads as

$$e_t B^*_t = \left(1 + i^*_{t-1} \right) e_t B^*_{t-1} + P_{H,t} NX_{H,t} \tag{39}$$

Finally, labor market clearing requires

$$H^d_t = H^N_t + H^H_t = H^s_t \tag{40}$$

4 Model Parametrization

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 in percentage of steady state tradable good output Y_H. Exogenous variables follow AR(1) processes. The model is calibrated on quarterly data for the Czech Republic. Details on data sources are contained in the Statisitical Appendix.

4.1 Preferences

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. We set the elasticity of labor supply 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 index, ρ_{cn}, is taken from Stockman and Tesar [41] and set equal to 0.5. The elasticity of substitution between foreign and domestic goods in the tradable consumption index, ρ_{ch}, is set equal to 1.5 following the international RBC literature. The share of non-tradable goods in total consumption, γ_{cn}, is 0.45. This corresponds to the weight of non-tradable goods in the Czech Republic CPI. Combined with the relevant technology parameters, the share of domestic goods in the tradable consumption index, γ_{ch}, is chosen such that the consumption-to-GDP ratio matches the average ratio over the period 1990-2001 - about 0.52.

4.2 Technology

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. Given the lack of empirical evidence on transition economies' labor shares in the two sectors, we follow Cooks and Devereux [12] and assume that the tradable sector is more capital-intensive than the non-tradable sector, setting $\alpha_h = 0.67$ and $\alpha_n = 0.33$. In the absence of a direct estimate for the Czech Republic, we follow standard estimates for OECD countries and choose a steady state mark-up in the non-tradable sector equal to 1.1. 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. Even though we don't have an estimate for this parameter, we think it is reasonable to assume a low value, given the trade structure of the Czech Republic. The elasticity of substitution between tradable and non-tradable goods in total investment, ρ_{in}, and the elasticity of substitution between foreign and domestic goods in the tradable component of investment, ρ_{ih}, are assigned the same values of the corresponding consumption indexes. The share of non-tradable goods in the investment index I_t^J, γ_{in}, is chosen such that the ratio of investment to GDP is roughly 0.3 and the share of non-tradable goods to GDP is 0.56 - based on our estimates for the Czech Republic. The share of domestic goods in the tradable component of investment, γ_{ih}, and the share of domestic value added in the domestic tradable sector, γ_v, are chosen such that, in a balanced-trade steady state with unitary terms of trade, the commodity composition of imports matches, as close as possible, the available data for the Czech Republic. The price-adjustment speed 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], a choice prompted also by the larger share of government-regulated prices in transition economies. The unconditional probability ϑ of non-adjusting prices in any period is set equal to 0.85.

4.3 Government Sector

The steady state ratio of government expenditure to output, $\frac{G_J}{Y_J}$, for $J = H, N$, is assumed to be equal to 10 percent.

We consider three alternative exchange rate regimes: (1) *Fixed exchange rate*, by setting an arbitrary large value to ω_e; (2) *CPI inflation targeting*[2],

[2] We refer to inflation-based instrument policy rules as inflation targeting monetary

by setting $\omega_\pi = 2$; (3) *CPI inflation targeting with managed exchange rate*, by setting $\omega_\pi = 2$ and $\omega_e > 0$. The interest rate smoothing parameter is assigned the value of 0.8. These values are consistent with estimates of inflation-based Taylor rules for OECD open economies (see Ravenna [37] and Clarida et al. [11]).

5 General Equilibrium Consequences of the Balassa-Samuelson Effect

In this section we investigate the consequences of a persistent increase in the tradable sector productivity growth rate in the small open economy. The Balassa-Samuelson (B-S) shock is constructed as follows. We assume that the relative productivity of the tradable sector $(A_H/A_N)_t$ grows at decreasing rates for 10 years, until it reaches a new stationary level. Over the 10 years, the average growth rate of the sectoral productivity differential is 2.65 percent per year[3]. No other productivity shock affects the economy in subsequent periods: the initial shock at $t = 0$ generates the entire dynamics, which is anticipated by the forward-looking agents from $t = 1$ onward. Without loss of generality, we assume that there is no productivity growth differential in the non-tradable sector between the euro area and the new EU members.

5.1 Fixed vs Floating Exchange Rate Regimes

Figure 2 shows the impact of the B-S shock under two alternative regimes. Consider a 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 steady productivity growth is anticipated after time 0 - and in the CPI inflation rate. Since the nominal exchange rate is fixed, CPI inflation rises well beyond the inflation criterion limit. In the following periods, the inflation rate 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

regimes. However, there is considerable controversy about the operational definition of inflation targeting.

[3] The implicit assumption is that the 2.65 percent productivity growth is relative to a zero-growth in the Euro area. We can always re-interpret this as *excess* productivity growth relative to the Euro area.

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 good H and by the growing foreign indebtedness. This is an important feature of the model, as new EU members have experienced a consumption boom and are running substantial current account deficits. 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 in the non-tradable sector grows, driven by the boom in aggregate demand. Output in the domestic tradable sector, after an initial drop, starts growing 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 they could not import the H good, 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, since the cost of good H will decrease over time relative to non tradable goods.

Consider now a flexible exchange rate regime. The figure shows the case of a policy-maker targeting CPI inflation (with $\omega_\pi = 2$ and $\omega_e = 0$). Since the nominal exchange rate is now allowed to appreciate, the initial effect on CPI inflation is negative, driven by a drop in the tradable component of CPI inflation and a smaller increase in the non-tradable component. The long-term inflation rate is positive but smaller than under a fixed exchange rate[4]. The burden of the real appreciation is carried by the nominal exchange rate: after two years it has appreciated by approximately 10 percent. Relative to the fixed exchange rate regime, the initial reduction of the real interest rate is smaller. The output increase in the non-tradable sector is reduced

[4] The impulse response shows the deviation from the steady state inflation rate, which we assume equal to the Euro area inflation rate. Since the nominal exchange rate in this regime is completely flexible - i.e., the economy can have a steady state nominal appreciation against the foreign currency - the policy maker could effectively choose any steady state inflation by changing his steady state money supply policy. This is not the case whenever the nominal exchange rate is managed, since that would require stationarity in the *level* of the exchange rate rather than in the depreciation/appreciation rate.

by over 40 percent. Since large price hikes in the non-tradable sector call for a contractionary policy in the inflation targeting regime, in equilibrium firms contain price inflation. The decrease in mark-ups associated with price inflation is smaller than under an exchange rate peg, and limits 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 the response of consumption and output under the two policy regimes has disappeared.

5.2 Balassa-Samuelson Effect and Capital Inflows

The literature on EU enlargement often raises concerns about (excessive) capital inflows, which might expose new EU members to potentially large and dangerous capital flow reversals (Begg et al. [3]). Large capital inflows in countries expected to join the EMU are encouraged by the liberalization of capital markets, expectations of exchange rate appreciation, and interest rates declining to EU levels (the so-called *convergence play*). We argue that the largest share of capital inflows is related to the productivity catch-up process, and therefore less sensitive to shorter-term factors such as perceived changes in the riskiness of investing in new EU member countries.

To replicate the convergence play in our model economy, we consider a temporary but persistent unanticipated one hundred 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 [18]). Figure 3 shows the dynamics of the economy for two different policies. In the case of a fixed exchange rate regime, the economy starts borrowing from abroad and the real exchange rate appreciates. As the nominal exchange rate is prevented from appreciating and the domestic nominal interest rate falls, nominal price rigidities causes a large drop in the real interest rate, fueling a rise in consumption and investment. Output in the non-tradable sector increases, generating persistent but low inflation in the initial six quarters. On the contrary, output in the domestic tradable sector drops. As in the case of a persistent productivity shock, consumption smoothing behavior explains this dynamics[5].

[5] The domestic nominal interest rate, after 5 years, has risen nearly all the way back to the steady state level. The corresponding foreign interest rate reverts more slowly. The difference between the two - which are expected to behave symmetrically in a fixed exchange rate regime - stems from the presence of an endogenous risk premium, described in eq. (31). We assume 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 countries.

If the central bank adopts the CPI inflation targeting rule previously described (with $\omega_{\pi^c} = 2$ and $\omega_e = 0$), the nominal exchange rate appreciates together with the real exchange rate. Figure 3 shows that CPI inflation drops, as both the tradable and the non-tradable inflation are lower. The real interest rate drops by much less than under the fixed exchange rate case. The increase in consumption and investment is therefore less pronounced.

Compare now the capital inflows generated by the reduction in the risk premium with the inflows linked to the B-S effect. Regardless of the exchange rate regime, after one year the productivity-driven inflows are about eight times larger. Moreover, while the inflows related to a lower risk premium reach a peak shortly afterwards, the inflows related to the B-S effect continue to grow, due to the "long-term" nature of the shock.

Is there evidence of a similar pattern in the Czech Republic? Figure 4 shows the composition of capital flows for the period 1994-2001. Net direct investment surged after 1997 and has been since the main component of capital flows. Net portfolio investment and other investment appear to be more volatile but much smaller. Net equity capital, the less volatile component of net direct investment, represents around eighty percent of the total.

6 Policy Choices and Compliance with EMU Admission Criteria

The previous section showed that monetary policy can influence the allocation of the real exchange rate appreciation due to the Balassa-Samuelson effect between CPI inflation and nominal exchange rate appreciation. Recent proposals to change the EMU admission criteria to accommodate the Balassa-Samuelson effect have focused on this trade-off.

Buiter and Grafe [4], for example, suggest re-defining the Maastricht inflation criterion in terms of a basket of tradable goods in order to take into account the Balassa-Samuelson-induced CPI differential. In our model the Law of One Price, eq. (23), implies that the (log-linear) tradable good inflation differential, $(\pi_T - \pi_T^*)$, is equal to the rate of depreciation of the nominal exchange rate, Δe_t. Any inflation criterion specified in terms of tradable good inflation is, in fact, an exchange rate criterion.

This debate neglects the fact that, in the presence of nominal rigidities, the choice of monetary policy affects the volatility of real variables in response to *all* the exogenous shocks driving the dynamics of the economy over the business cycle. In this section, we compare alternative simple Taylor rules by deriving the inflation/exchange rate and inflation/output gap variance trade-offs conditional on all domestic and foreign shocks.

We obtain three results. First, we offer a quantitative evaluation of how much the B-S effect reduces the probability of complying with the EMU accession requirements. Second, the B-S effect has important consequences for business cycle volatility. This, in turn, affects the choice of the optimizing policy maker and the constraints imposed on his choice by the Maastricht criteria. Third, we evaluate the consequences of modifying the EMU accession criteria for the policy choice of new EU member countries.

6.1 Parametrization of Exogenous Shocks

To calculate the variance trade-offs we need to make assumptions about the shocks that drive the dynamics of the economy and their forcing processes. Examples of dynamic stochastic general equilibrium models calibrated on Eastern European countries are scarce (Mahadeva and Smidkova [30]). Two issues arise that are specific to formerly-planned economies. First, the span of data available to calibrate the model is very short - these countries left the Soviet bloc after 1990, and some did not even exist before that date. Second, using data from the early 1990s is likely to lead to spurious results, since that is the time when these countries underwent a transition toward market economy institutions. The business cycle behavior, as measured since the early 1990s, is therefore unlikely to be representative of the future dynamics of these economies.

Given these caveats, we estimate the stochastic processes driving the model using post-1994 data, when possible. When this is not possible, we calibrate the shocks by evaluating the fit of the moments of the model's moments, as common in the Real Business Cycle literature.

Table 1 reports the standard deviations and autocorrelations of the exogenous shocks. The values for the tradable and non-tradable sector productivity are calibrated and are within reasonable bounds of the values used in RBC models. We assume that the entire government demand is for goods produced in the non-tradable sector. The policy rule implies a strong degree of interest rate smoothing, as found in most estimates of policy rules for OECD economies. The Central Bank is assumed to react to deviations of current inflation and exchange rate from their steady state values. All other exogenous shocks processes are estimated from the data.

Table 2 compares the second moments of the model with the values obtained from the data. A second column, for comparison purposes, shows averages for Japan, Germany, UK, three OECD open economies, over the post-Bretton Woods period. The model performs remarkably well in terms of volatilities while lacks in some dimensions in matching cross-correlations across variables in the economy. The volatility of real variables matches closely the Czech data. As expected, it is much harder to match sectoral volatilities. Contemporaneous correlation with domestic output is weaker in the model than in the data for the nominal and real exchange rate, and for net exports. This discrepancy may be explained by the fact that the real GDP in the model is evaluated at consumer rather than producer prices. Correlation between output and consumption, investment and inflation rate is instead very close to the data.

6.2 Policy Choices and Productivity Growth

The first issue we are interested in is whether trend productivity growth affects the inflation/exchange rate trade-off. The previous section has already shown that, depending on the degree of nominal exchange rate flexibility, either the inflation rate will be high or the nominal exchange rate appreciation will be large. We therefore expect a country experiencing the B-S effect to face a higher unconditional variance in either the inflation rate or the nominal exchange rate. Figure 5 confirms this intuition. The plot shows the quarterly inflation/nominal exchange rate variance trade-off given the log-linear policy rule:

$$i_t = \chi i_{t-1} + (1-\chi)[\omega_\pi \pi_t + \omega_e e_t] \tag{41}$$

for values of the feedback 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 very high volatility of the exchange rate while targeting aggressively the inflation rate. The interest-smoothing coefficient χ is set equal to 0.8. We allow for a high value of the inflation feedback coefficient $\omega_\pi = 3.5$ to prevent the weight of the exchange rate objective from driving monetary policy for all but the smallest values of ω_e. The dotted line plots the standard case - i.e., without the B-S shock. The solid line plots the variance trade-off under the assumptions that productivity growth in the tradable sector is higher by an average of 2.65 percent per annum over the 10 year period of the simulation and the steady state inflation rate is equal to the EU average.

Since the shocks are normally distributed, we can compute the implied probability that a variable falls within a given interval as a function of the variance of the variable itself. The left-most vertical line corresponds to the variance of e_t that guarantees that the nominal exchange rate is within a ± 2.25 percent band in any quarter with a 95 percent probability [6]. Any policy rule that generates a lower variance of e_t - points along the dotted line to the left of the vertical probability boundary - keeps the exchange rate within the band with a probability equal or higher than 95 percent. ERM-II membership requires that the exchange rate stay within a ± 15 percent band around the central parity. However, to comply with the 'exchange rate stability' admission criterion EMU accession countries are expected to keep the exchange rate within a narrower ± 2.25 percent band for a period of two years[7]. The second vertical line has to its left all combinations of standard deviation (σ_e, σ_π) - attainable by a policy maker that follows the rule (41) - that satisfy the ERM-II requirement in any quarter with a 95 percent probability. Below the horizontal boundary line lay all points (σ_e, σ_π) that, with 86 percent probability, give a quarterly inflation rate differential with the EMU lower than 1 percent - a conservative target for a policy-maker trying to achieve a yearly inflation rate differential smaller than 1.5 percent[8].

For a policy maker adopting the rule defined in (41), the plots show that there exists a range of policies allowing the economy to comply with the EMU accession requirements with a high probability. However, in the presence of B-S effect, the variance trade-off shifts to the right and there is no policy allowing the economy to meet the ERM-II criterion and the Maastricht inflation criterion at the same probability level as in the standard case. Assume, in fact, that the policy maker aims at meeting the ERM-II criterion in any quarter with at least 95 percent probability. Then the 86 percent probability boundary shows that the combination (σ_e, σ_π) attainable by any such policy implies a probability of a quarterly CPI inflation in excess of 1 percent not lower than 14 percent[9]. Alternatively, any policy that

[6] The corresponding probability that the exchange rate is within the band in *all* quarters over the required period of two years will be lower, and can be derived as $\Pr(e_t \in [-2.5\%, +2.5\%]) * \Pr(e_{t+1} \in [-2.5\%, +2.5\%] | e_t \in [-2.5\%, +2.5\%]) * ...$up to $t+7$.

[7] Appreciation (but not depreciation) within the wider band was deemed acceptable for past entrants in the EMU. At this stage, which interpretation of the Maastricht Treaty will prevail remains an open question. See Kenen and Meade [27] for details.

[8] In building the inflation rate differential variable, we assume that tradable goods produced in the candidate country are a negligible fraction of the EMU consumption basket, as common in small open economy models (see Gali and Monacelli [25]), and set π^*_{EMU} equal to its steady state value. An alternative assumption is to set $\pi^*_{EMU} = \alpha \pi^*_F$ where α is the weight of tradable goods in the EMU CPI. For any value of α, the results reported are strenghtened.

[9] The probability level for the variance boundaries drawn on the picture will actually be lower 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

guarantees a higher ex-ante probability of meeting the inflation criterion implies that the probability of meeting the ERM-II criterion in any quarter is lower than 95 percent. Note also that, even in the absence of the B-S effect, no policy would allow the economy to meet the Maastricht inflation criterion and keep the exchange rate within the narrower ±2.25 percent band against the euro with a very high probability.

What are the implications of different monetary policies for the inflation/output gap trade-off? Figure 6 shows the inflation/output gap variance trade-off corresponding to the conditional policy frontiers shown in figure 5. A more flexible exchange rate is able to deliver both lower inflation *and* a lower output gap - measured as the distance between output and the flexible-price potential output. In the B-S case, the gain from exchange rate flexibility is even larger. Compare, for example, points *A*-*A*', *B*-*B*', and *C*-*C*'. The extra cost in terms of inflation and output gap volatility due to the B-S effect becomes larger as ω_e increases and the exchange rate volatility gets smaller. The probability boundaries - to the right of which are attainable combinations $(\sigma_{y_{gap}}, \sigma_\pi)$ that guarantee, with 95 percent probability, a given volatility of the exchange rate conditional on the Taylor rule - get further and further to the right relative to the standard case. Relative to the ±15 percent band, complying with the ±2.5 percent band increases output gap and inflation volatility by respectively 52% and 30% in the B-S case, but only by 35% and 22% in the standard case.

A ±15 percent band for the exchange rate offers a superior economic performance - under the assumption that an optimizing policy maker prefers regimes that minimize both output gap and inflation rate fluctuations. But we know from figure 5 that if the B-S effect is at work, any point in figure 6 to the right of the ±15 percent volatility boundary does not satisfy the Maastricht inflation criterion with a probability of at least 16 percent (conditional on the Taylor rule (41)).

Proposals to adapt the EMU requirements to the rapid productivity growth of new EU members suggest relaxing either the exchange rate stability requirement or the Maastricht inflation criterion (see Buiter and Grafe [4]). Figure 7 compares the inflation/output gap trade-off generated by two alternative families of policy rules. Either policy implies a violation of one of the nominal convergence criteria.

The solid line plots the variance trade-off for the Taylor rule (41) as a

inflation (exchange rate) will have a positive (negative) skew relative to the Gaussian, and more probability mass for positive (negative) values of the variable. The probability level is then only an upper bound in the Balassa-Samuelson case.

function of ω_e. We showed, in figure 5, that this rule violates the inflation criterion with a probability of at least 14%. Relaxing the inflation criterion allows the policy-maker to choose any point to the right of the probability boundary and still have a reasonable expectation to meet the exchange rate requirement. How does this result compare with relaxing the exchange rate criterion? A possible amendment to the EMU convergence criteria would be to set a target in terms of inflation rate and nominal exchange rate depreciation/appreciation. The dashed line draws the variance trade-off for an instrument rule formulated in terms of rate of change, rather than levels, of the nominal exchange rate:

$$i_t = \chi i_{t-1} + (1-\chi)[\omega_\pi \pi_t + \omega_e \Delta e_t] \tag{42}$$

for $\omega_\pi = [2.5, 3, 3.5]$. While any of these rules delivers a larger volatility in the exchange rate, establishing limits for the rate of nominal appreciation/depreciation would still rule out a number of non-virtuous monetary policies during the accession phase. It would offer countries a meaningful choice on how to allocate the trend appreciation of the real exchange rate between inflation and exchange rate movements.

Many points on these trade-off plots imply a lower volatility of both output gap and inflation relative to the outcome of the policy rule (41). Thus, within the family of policy rules examined, any modification that relaxes the exchange rate stability requirement delivers a better economic performance. For example, compare a rule that meets the ± 15 percent band requirement along the solid line with the exchange rate depreciation target rule for $\omega_\pi = 2.5$. Pegging the exchange rate requires at least a 28 percent increase in inflation volatility for given output gap volatility.

7 Conclusion

Integrating Central and Eastern European transition economies into the euro area presents a number of challenges. This paper examines the choice of exchange rate regime during the process of accession to the EMU. Using a dynamic stochastic general equilibrium model, we discuss the implications of the Balassa-Samuelson effect under alternative exchange rate regimes, analyze its impact on capital flows, and evaluate alternative policy rules in terms of the volatility of the economy over the business cycle.

The main results can be summarized as follows. First, excess productivity growth relative to the EU generates a consumption boom, and a surge in imports and in the production of the non-traded good under both a fixed exchange rate and an inflation targeting regime. The increase in consumption is sustained by a large capital inflow, about eight times larger than the capital inflow associated with a 1% drop in the country risk premium.

Second, we show that, conditional on monetary policy being conducted according to a Taylor rule, sectoral productivity growth differentials shift the output gap/inflation variance trade-off and increase the cost of managing the exchange rate in terms of inflation or output gap volatility. The Balassa-Samuelson effect lowers considerably the probability of complying with the current EMU admission criteria.

Third, we show that policy rules that allow for more exchange rate flexibility than the current stability requirement lower the volatility of the economy in terms of both the inflation rate and the output gap. Alternative entry paths into the EMU proposed for new EU members, such as an easing of the Maastricht inflation rate criterion, do not take into account the implied cost in terms of larger business cycle volatility. Setting nominal admission criteria in terms of inflation and exchange rate depreciation rate lowers this cost and can still accommodate the Balassa-Samuelson effect.

This result deserves further investigation. Ideally, we would like to know which EMU admission criteria are consistent with nominal convergence without constraining prospective EMU members to welfare-dominated monetary regimes. However, answering this question requires the computation of optimal monetary policy frontiers and an appropriate utility-based quadratic loss function, which is beyond the scope of this paper.

Our analysis captures the costs resulting from business-cycle volatility under alternative, fully credible policy rules. However, some countries might benefit from the credibility gain of fixing their exchange rate or unilaterally adopting the euro before entry into the EMU. They might, in fact, lack the credibility to conduct monetary policy without an external anchor. In addition, some of the benefits from joining the currency area (such as increased trade or FDI, lower transaction costs and a reduction in the foreign interest rate premium) could be brought forward by fixing the exchange rate as soon as possible. These benefits might well outweigh the welfare cost highlighted in our analysis for countries that choose to manage the external value of their currency.

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7.1 Statistical Appendix

In what follows, 'IFS' refers to the IMF publication International Financial Statistics (2003), 'SC' refers to the OECD publication Statistical Compendium (2003), 'CRNA' refers to Czech Republic National Accounts (July 2003).

Exogenous variables follow first-order autoregressive processes. Except when otherwise indicated, autocorrelation coefficients ρ_i and innovation standard deviations σ_{ε_i} are estimated parameters, as reported in Table 1. Innovations ε_i are white noise random processes assumed to be mutually independent except in the case of the tradable and non-tradable sector productivities. Units are expressed in percent. Data are sampled at quarterly intervals.

The stochastic process for the government's demand of non-tradable good is estimated from:

$$G_t = \rho_G G_{t-1} + \varepsilon_{G,t}$$

where G_t is detrended (HP-filtered) seasonally-adjusted per capita government final consumption expenditure at 1995 constant prices (SC).

The behaviour of P_F^*, P_M^*, import prices of foreign consumption and intermediate goods, is described by:

$$P_{j,t}^* = \rho_{P_j^*} P_{j,t-1}^* + \varepsilon_{P_j^*} \qquad j = F, M$$

where P_j^* is detrended foreign price of good j. P_j^* is obtained from import commodity price indices (CRNA) converted in units of foreign currency (euro) using the Nominal Effective Exchange Rate (IFS). 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. Since in the model the share of foreign good F is much larger in investment than in consumption, we assume that P_F^* is an aggregate of capital and consumption good price indices. The weights for good M and F price indices are the 1997-2001 average Commodity Composition of Imports as reported in [26].

The behaviour of foreign tradable good inflation is described by:

$$\ln\left(\frac{P_{H,t}^*}{P_{H,t-1}^*}\right) = (1-\rho_{P_H^*})\pi_H^* + \rho_{P_H^*}\ln\left(\frac{P_{H,t-1}^*}{P_{H,t-2}^*}\right) + \varepsilon_{P_H^*}$$

where π_H^* is steady state foreign price inflation of the tradable good H, and P_H^* is the detrended foreign price. P_H^* is obtained from the aggregate export price index (CRNA) converted in units of foreign currency using the Nominal Effective Exchange Rate (IFS).

The stochastic process for the foreign interest rate is estimated from:

$$\tilde{\imath}_t^* = (1-\rho_{i^*})\tilde{\imath}^* + \rho_{i^*}^*\tilde{\imath}_{t-1} + \varepsilon_{i^*}$$

where $\tilde{\imath}^*$ is the steady state foreign nominal interest rate, and $\tilde{\imath}_t^*$ is the quarterly 3-months Euribor index (Reuter).

The model's moments in Table 2 are computed averaging six hundred 10-year long simulations. Data used in Table 2 are per capita and seasonally adjusted, where appropriate. Details are as follows: **Output**: GDP at 1995 constant prices (SC). Tradable good output is an aggregate of sectoral GDP for: Agriculture, Hunting, Forestry; Fishing; Mining and Quarrying; Manufacturing; Electricity, Gas, Water. Non-tradable good output is an aggregate of sectoral GDP for: Construction; Wholesale and Retail trade; Hotels and Restaurant; Transport; Services. **Consumption:** Household total consumption expenditure at 1995 constant prices (CRNA). **Investment**: Total gross capital formation at 1995 constant prices (CRNA). **Net Exports**: External balance of goods and services at 1995 constant prices (CRNA). **Nominal Interest Rate**: Three-months T-bill interest rate (IFS). **Nominal Exchange Rate**: Bilateral Koruny/Euro exchange rate, quarter average (IFS). **CPI Inflation Rate**: HICP-Harmonized Index of Consumer Prices (Eurostat). The tradable and non-tradable price index sectoral weights are computed by the Czech National Bank on Czech Statistical Office data. **Real Exchange Rate**: Ratio of tradable to non-tradable good price index built from sectoral HICP data (Eurostat). For comparison purposes Table 2 also reports the Real Effective Exchange Rate (IFS).

Czech Republic GDP composition: Data for 1997-2001, GDP by origin (IMF [26]). In the non-tradable sector we include the following categories: construction, wholesale and retail trade, restaurants and hotels, and services.

Czech Republic Import composition: Data for 1997-2001, Commodity Composition of Imports (IMF [26]). We classify "Machinery and transport equipment" as capital goods, corresponding to the share $(1-\gamma_{ih})$. We classify "Crude materials inedible, except fuels", "Minerals, fuels, lubrificants, and related materials", "Chemicals", "Manufactured goods", and 50 percent of "Miscellaneous manufactured articles" as intermediate goods, corresponding to the share $(1-\gamma_v)$. Finally, we classify the remaining categories as consumption, corresponding to $(1-\gamma_{ch})$. This implies that capital goods are less than 40 percent, intermediate inputs more than 50 percent, and consumption about 10 percent of imports.

Table 1: Exogenous Shocks Parameters

VARIABLE	STD DEV %	AUTOCORR
Tradable Good Productivity*	2	0.85
Non-tradable Good Productivity*	1.8	0.85
Government Non-tradable Good Demand	2.42	0.7
Foreign Tradable Good Inflation	1.49	0.25
Foreign Import Price (consumption good)	1.78	0.71
Foreign Import Price (intermediate good)	3.57	0.85
Foreign Interest Rate	0.25	0.9
Domestic Interest Rate Innovations*	0.6	na

Note: * indicates parameters which could not be estimated from the data. For details on estimation of all other parameters see the Statistical Appendix. The Tradable and Non-tradable sector productivity shocks are assumed to have correlation equal to one. The policy rule is calibrated to i(t)=0.9*[i(t-1)] + 0.1*[pai(t)+0.2*y(t)+0.3e(t)]

Table 2: Model Simulation Moments

Statistics	Simulation		Czech Republic	G-3 (1973-1994)
Standard Deviation %				
Output	1.53	(0.30)	1.74	1.52
Non-Tradable Sector	2.72	(0.44)	1.55	
Tradable Sector	2.87	(0.51)	2.25	
Consumption	2.28	(0.37)	2.29	1.45
Investment			6.86	5.55
Non-Tradable Sector	5.99	(0.98)		
Tradable Sector	3.36	(0.55)		
Net Exports	2.5	(0.39)	1.74	
Nominal Interest Rate	0.48	(0.08)	0.47	0.46
Nominal Exchange Rate	2.79	(0.49)	3.04	9.13
Real Exchange Rate	2.48	(0.46)	2.75	
CPI-based Real Exchange Rate			3.19	8.89
CPI Inflation Rate	1.1	(0.12)	1.08	
Non-Tradable Sector	0.79	(0.13)	2.61	
Tradable Sector	2.4	(0.28)	0.99	
Contemporaneous correlation with domestic output				
Consumption	0.69	(0.13)	0.7	0.69
Investment			0.81	0.8
Non-Tradable Sector	0.61	(0.16)		
Tradable Sector	0.7	(0.12)		
Net Exports	-0.05	(0.23)	-0.56	
Nominal Interest Rate	-0.33	(0.23)	0.06	0.14
Nominal Exchange Rate	0.09	(0.26)	-0.52	-0.07
Real Exchange Rate	0.16	(0.24)	0.66	
CPI-based Real Exchange Rate			0.07	-0.01
CPI Inflation Rate	0.34	(0.16)	0.12	

Note: Standard deviation of simulation estimates is in brackets. All series are logged (with the exception of interest and inflation rates) and Hodrick-Prescott filtered. The net export variable is the Hodick-Prescott filtered ratio to real output. Rates of change are quarterly. Data sample for Czech Republic is 1994:1 - 2003:1. Tradable and non-tradable output data sample is 1998:1 - 2003:1. G-3 columns shows arithmetic averages of statistics across Japan, Germany, UK as reported in Kollmann (2001). See appendix for full details on data.

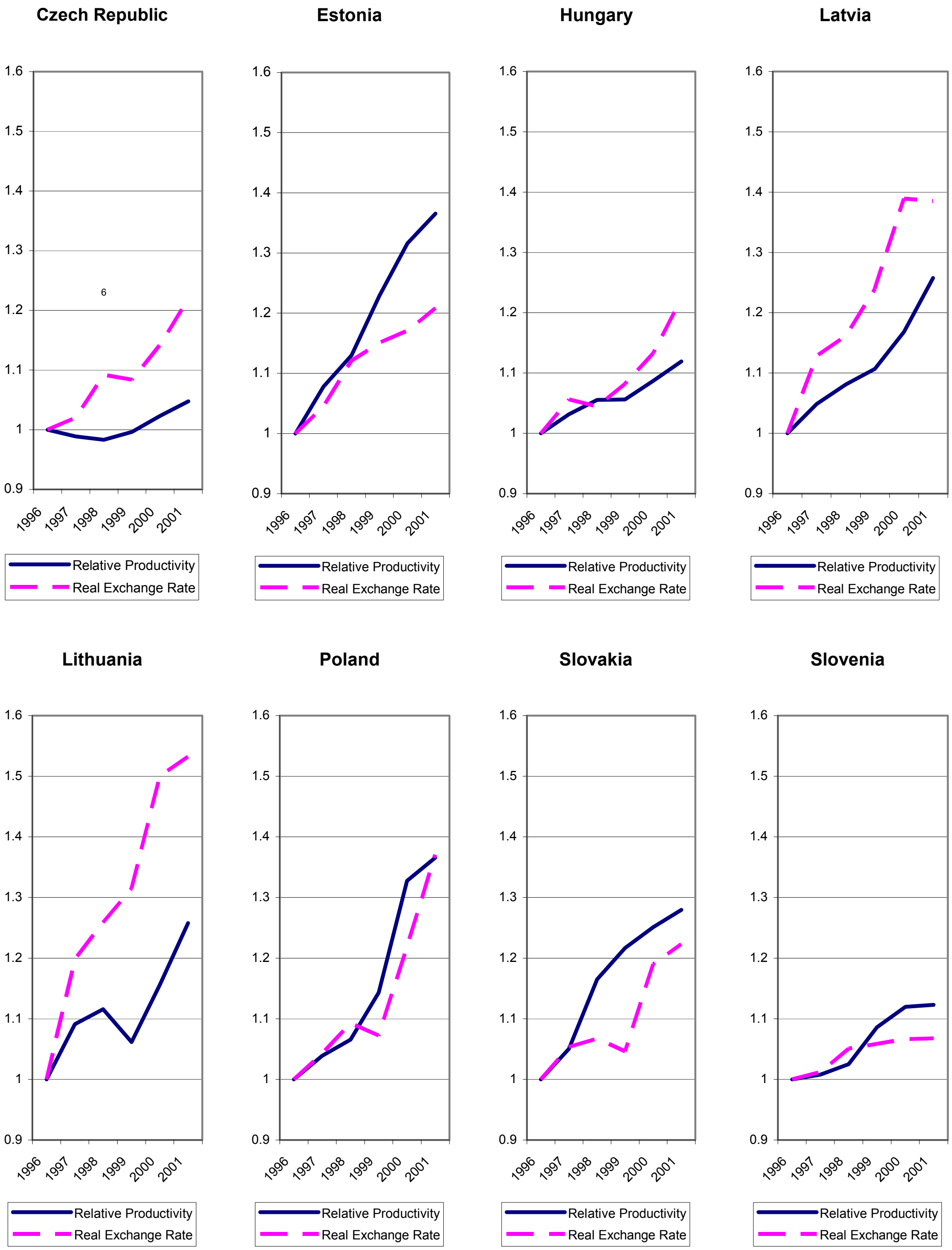

Figure 1: Solid: ratio of GDP per worker in the accession country to GDP per worker in the Euro area. Dashed: real exchange rate against the Euro (ratio of the domestic Harmonized CPI to the EU Monetary Union CPI evaluated in domestic currency). Source: IMF-IFS, Eurostat, Haver.

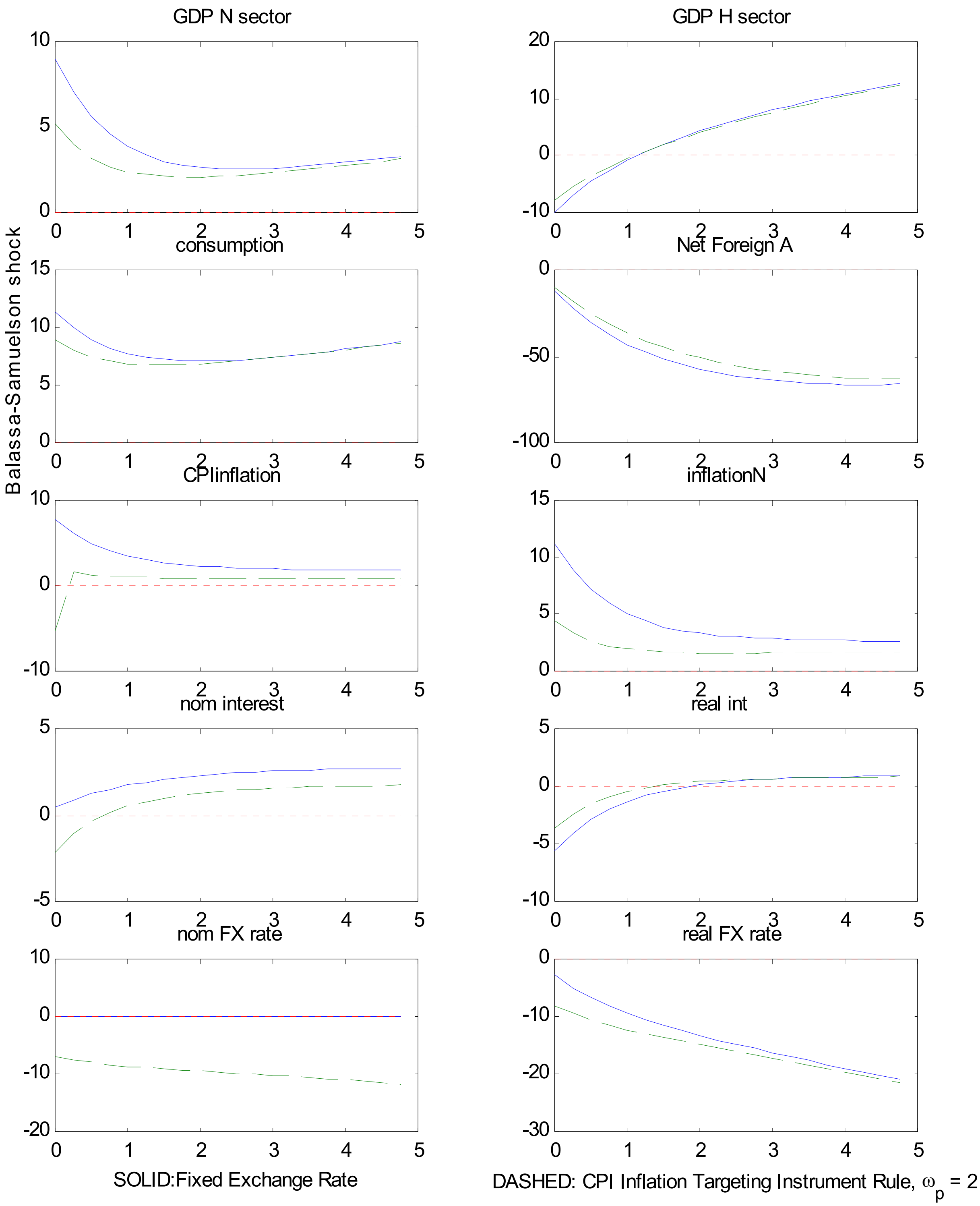

Figure 2: Impulse Response Function to a persistent tradable-sector productivity growth shock. Productivity grows by 30% over a 10-year period. Taylor rule coefficient: $\omega_\pi = 2$. Time measured in years.

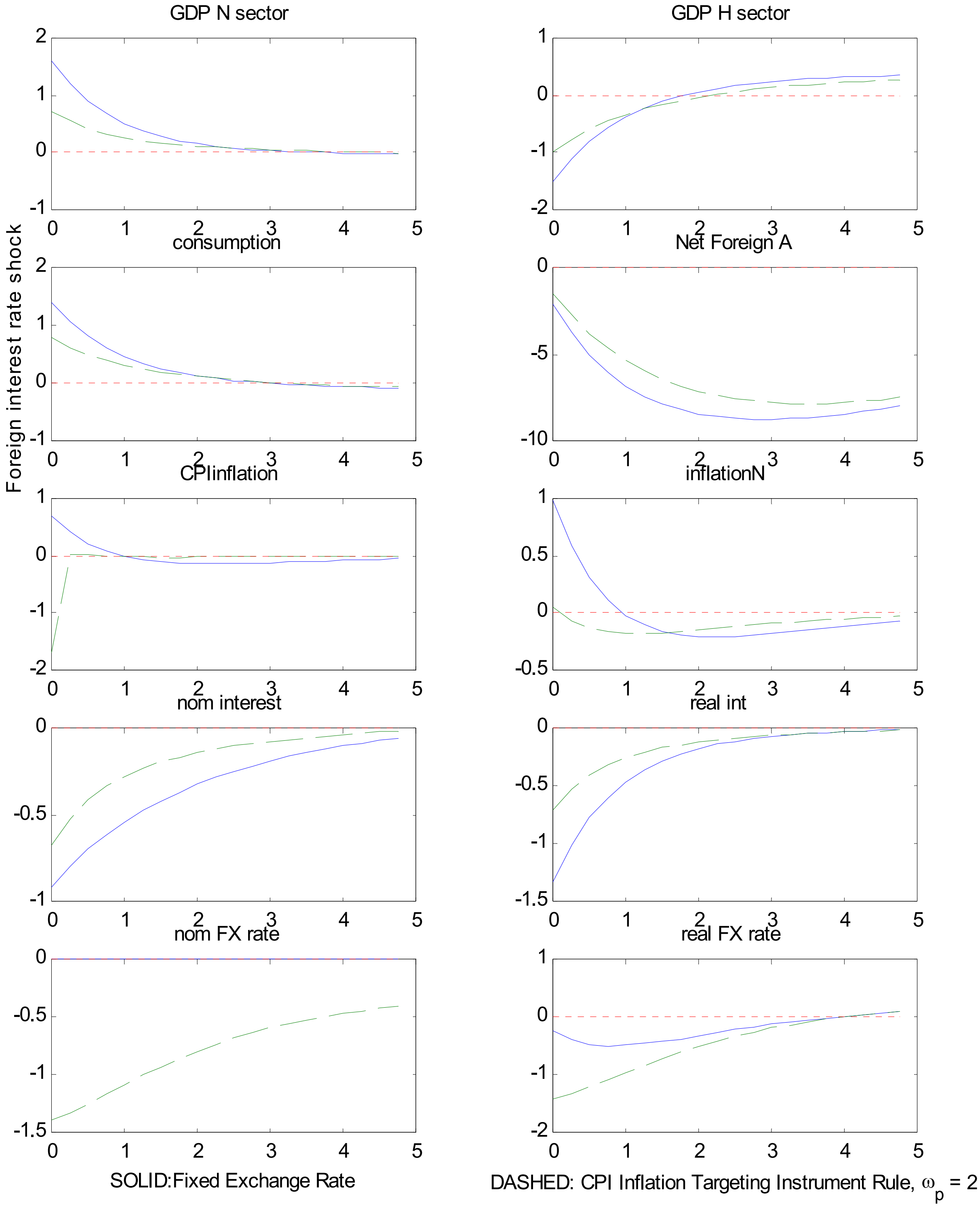

Figure 3: Impulse Response Function to 1% drop in the annualized foreign risk premium. The shock follows and AR(1) process with AR coefficients of 0.95. Time measured in years.

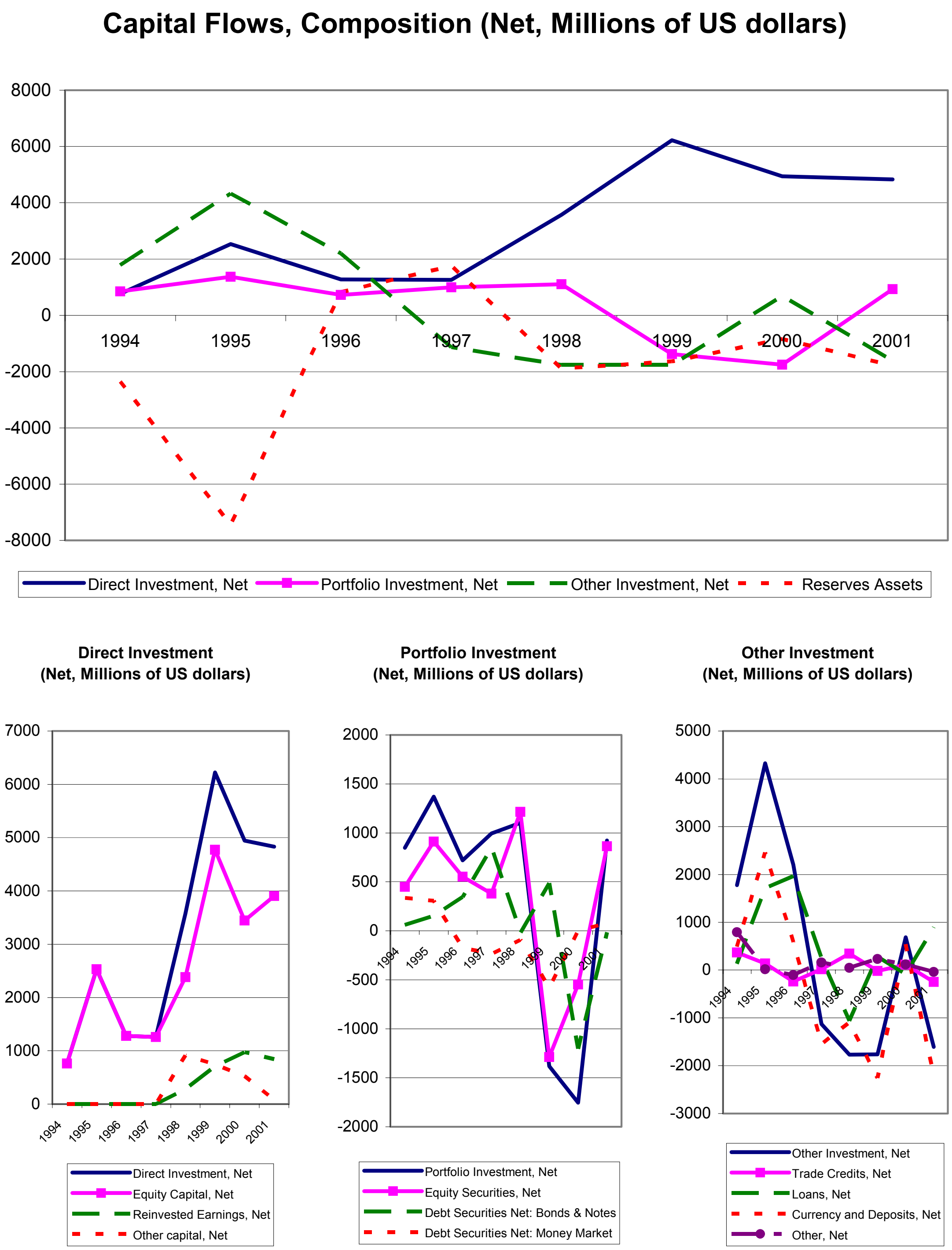

Figure 4: Czech Republic, Composition of Capital Flows. Source: IMF, Balance of Payments Statistics Yearbook 2002, 1994-2001.

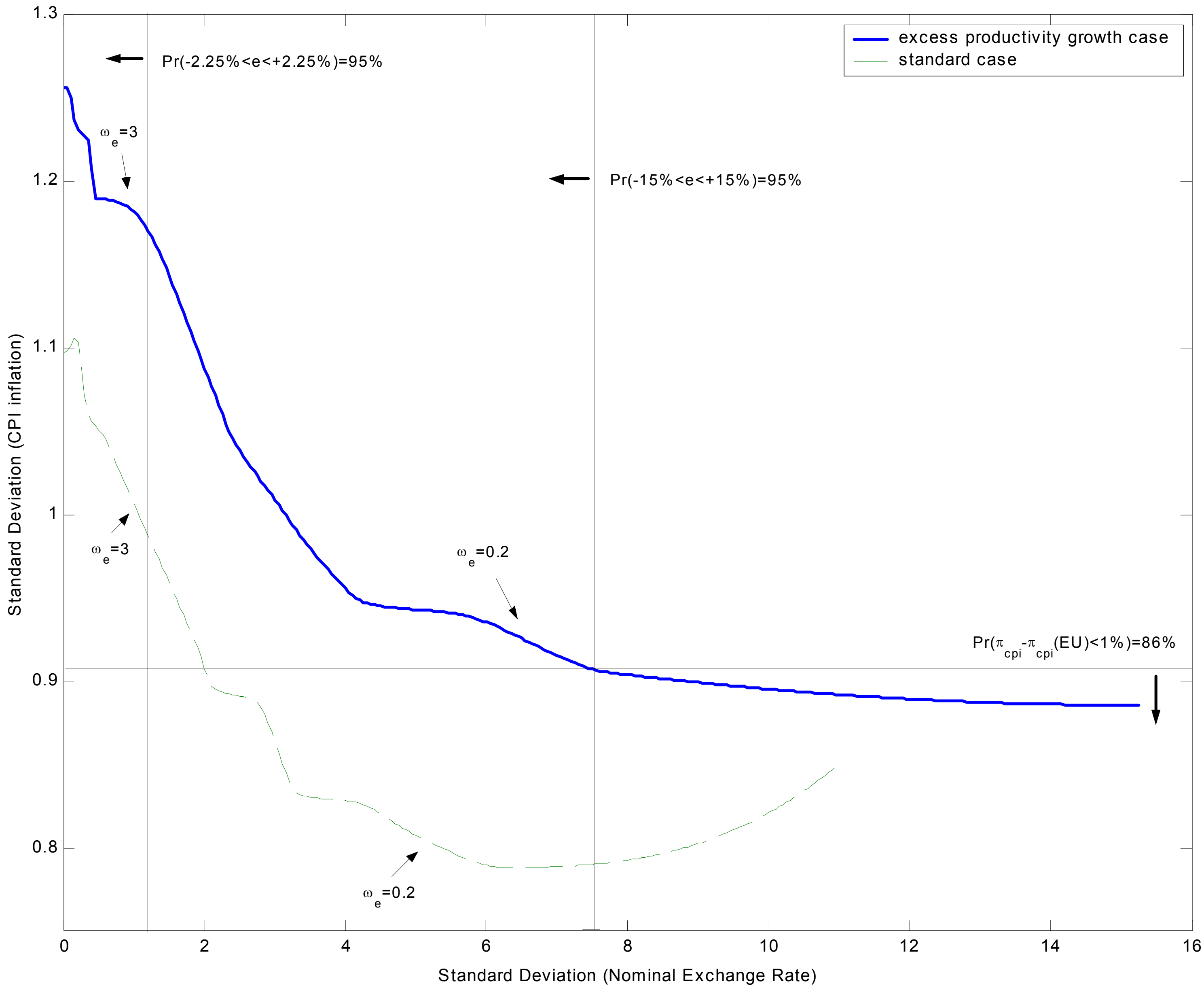

Figure 5: Inflation/exchange rate Volatility Trade-off for policy rule $i_t = \chi i_{t-1} + (1-\chi)[\omega_\pi \pi_t + \omega_e e_t]$ for $\omega_e \in [700, 0.01]$. Solid: tradable-sector productivity grows on average by 2.65% per year (30% over a 10-year period). Dashed: tradable-sector productivity follows AR(1) process. All exogenous shocks parameters are in Table 1. Probability boundaries (solid vertical and horizontal lines) are computed for the Standard case. Points to the left or below the $\alpha-$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.

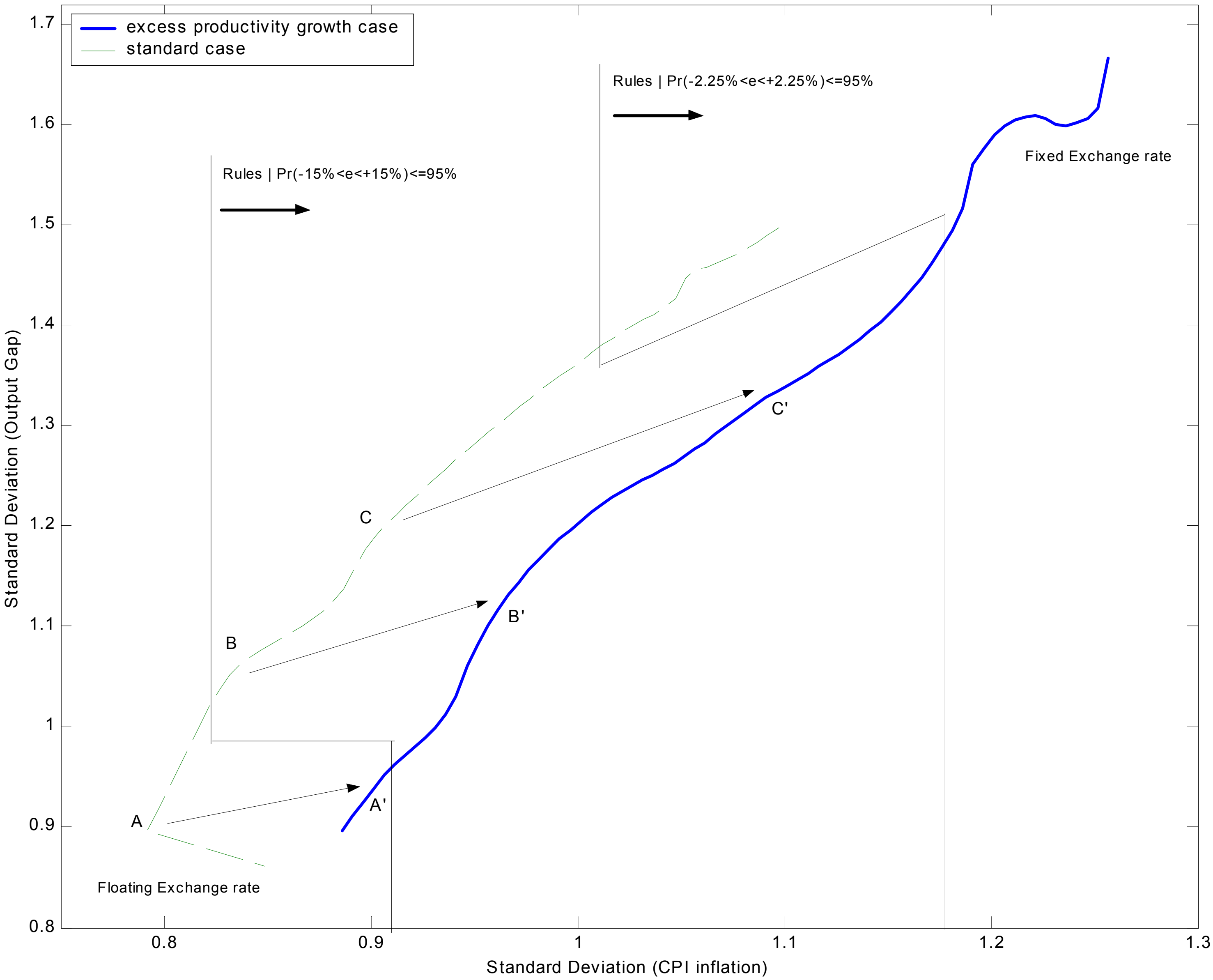

Figure 6: Inflation/output gap Volatility Trade-off for policy rule $i_t = \chi i_{t-1} + (1-\chi)[\omega_\pi \pi_t + \omega_e e_t]$ for $\omega_e \in [700, 0.01]$. Solid: tradable-sector productivity grows on average by 2.65% per year (30% over a 10-year period). Dashed: tradable-sector productivity follows AR(1) process. All exogenous shocks parameters are in Table 1. Points $(\sigma_{y-gap}, \sigma_\pi)$ to the right of the solid vertical lines occur for policy rules such that the nominal exchange rate fluctuation in every quarter is within a 30% (5%) band with 95% probability. These rules correspond to points to the left of the probability boundaries in Fig. 6. Point A, A'; B, B'; C, C' are plot for values of $\omega_e = [0.1,\ 0.4,\ 1]$.

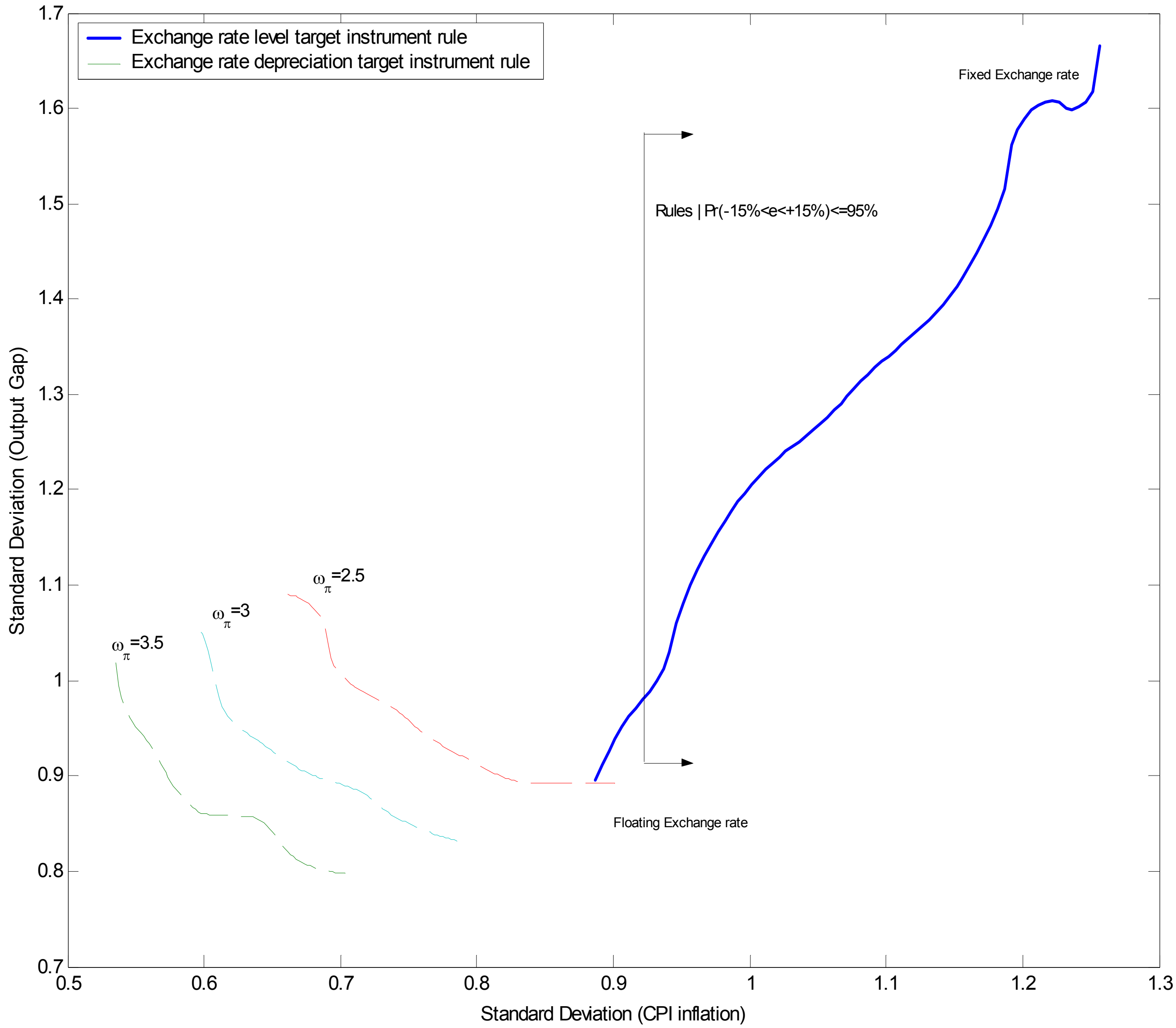

Figure 7: Inflation/output gap Volatility Trade-off. Solid line: policy rule $i_t = \chi i_{t-1} + (1-\chi)[\omega_\pi \pi_t + \omega_e e_t]$, $\omega_e \in [700, 0.01]$. Dashed line: policy rule $i_t = \chi i_{t-1} + (1-\chi)[\omega_\pi \pi_t + \omega_e \Delta e_t]$ for $\omega_e \in [1, 0.01]$. Both lines are drawn for the case of tradable-sector productivity growing on average by 2.65% per year (30% over a 10-year period).Other exogenous shock parameters are as in Table 1. Points $(\sigma_{y-gap}, \sigma_\pi)$ to the right of the vertical line occur for policy rules such that the nominal exchange rate fluctuation in every quarter is within a 30% band with 95% probability. These rules correspond to points to the left of the probability boundaries in Fig. 6.