The Maastricht Convergence Criteria and Monetary Regimes for the EMU Accession Countries

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Abstract

The goal of this paper is to study the ability of different monetary regimes to satisfy the Maastricht criteria. We perform our analysis in the framework of a two-sector small open economy DSGE model with nominal rigidities exposed to both domestic and external shocks. We analyze the regimes that reflect the policy choices observed in the EMU Accession countries, i.e. peg regime, managed float regime and flexible exchange rate regime with CPI inflation targeting.

There exists a significant trade-off between compliance with the CPI inflation criterion and the nominal interest rate criterion. The sensitivity analysis reveals that the probabability that some of the regimes will satisfy all the criteria increases with openness of the economy and also degree of substitution between traded goods. Moreover, provided that two previous conditions are satisfied, degree of exchange rate pass through determines which of the regimes can comply with the criteria. Low degree of pass through enables regimes with managed exchange rate to fulfill all the criteria while high degree of pass through implies that the CPI targeting regime satisfies all the criteria.

Keywords: monetary regimes, the Maastricht convergence criteria, EMU accession economies.

JEL classification: F41, E52.

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1 Introduction

A common objective and also an obligation of the new entrant countries to the European Union (EU) is the accession to the European Monetary Union (EMU).[1] Importantly, these economies share common characteristics such as a rapid productivity growth and vulnerability to external disturbances. Moreover, they are small and relatively open. At the same time their monetary policies are obliged to satisfy the Maastricht convergence criteria which stand for the prerequisites to enter the EMU. All the EMU accession countries should achieve a high and durable degree of price stability, which in quantitative terms is reflected in low inflation rates and low long-term interest rates. Additionally, nominal exchange rates of the EMU accession countries versus the euro should stay within normal fluctuation margins provided for by the Exchange Rate Mechanism of the European Monetary System.

Thus the choice of the monetary policy regime in these countries is crucial for their compliance with the Maastricht criteria. In reality we observe a heterogeneity in the choice of the regime among the EMU accession countries. Baltic countries (i.e. Estonia, Latvia and Lithuania) and also Bulgaria chose to peg to the euro. The Czech Republic, Hungary and Slovakia decided for the managed floating regime while Poland and Romania went for the flexible regime with CPI strict targeting. What is more, many EMU accession countries do not fulfill some of the Maastricht criteria. Bulgaria, Estonia, Hungary, Latvia, Lithuania, Romania and Slovakia fail to fulfill the CPI inflation criterion. Hungary and Romania violate the nominal interest rate criterion. Poland, Slovakia and Romania do not comply with the nominal exchange rate criterion.[2]

The goal of this paper is to study the ability of different monetary regimes to comply with the Maastricht criteria. To provide a proper framework for the analysis, we build a small open economy model with nominal rigidities and two production sectors: a nontraded and traded good sector. In this way, we want to take account of the empirical literature that emphasizes the role of sector productivity shocks in shaping inflation and real exchange rate dynamics in the EMU accession countries (see Mihaljek and Klau (2004)). At the same time, we follow the theoretical literature that argues that existence of the nontraded sector helps to explain international business cycle dynamics (Benigno and Thoenisen (2003) and Altissimo et al (2004)). We perform policy experiments by changing the monetary regimes and analyzing their implications on the compliance with the Maastricht criteria. The monetary regimes we study reflect current choices of the EMU accession countries, i.e. peg regime, managed float and flexible exchange rate regime with CPI inflation targeting.

The interaction between the Maastricht requirements and the monetary regimes has attracted the interest of academics. For example, Buiter and Grafe (2003) and Coricelli (2002)) call for adopting the peg regime in these countries as it enhances the credibility of the monetary policies and also strengthens links with the EU and EMU. Similarly, Ravenna (2005) finds that the gain from a credible adoption of the fixed regime can

[1] On the 1st of May 2004 10 Central and Eastern European countries, i.e. Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia, entered the European Union. Additionally, Bulgaria and Romania entered the EU on 1st of January 2007. Importantly all these countries are entitled to enter the EMU as it was stated in their accession agreement with the EU. Slovenia is the first country in this group that joined the European Monetary Union on January 1, 2007. Cyprus and Malta joined the EMU on January 1, 2008.

[2] See figures (2), (3), (4) in Appendix B.

outweigh the loss of monetary policy independence. At the same time, all these authors acknowledge that the peg regime can prevent from the compliance with the Maastricht CPI inflation criterion and suggest that this criterion should be revised. On the other hand, Devereux (2003) and Natalucci and Ravenna (2003) find that the monetary regime characterized by flexible inflation targeting with some weight on exchange rate stability should comply with the Maastricht criteria.

There are several caveats of the previous studies that this paper aims to eliminate. First of all, the studies concentrate mainly on the Balassa-Samuelson effect (Balassa (1964)) and therefore on the implications of only one type of shocks, i.e. traded productivity shocks, on the monetary regime choice. We analyze responses of the monetary regimes to both domestic supply and demand shocks and also external shocks. Moreover, the policy recommendations could be sensitive to structural differences among the EMU accession countries. We discuss thoroughly implications of openness, trade specialization pattern and also degree of exchange rate pass through on the choice of monetary regime that would satisfy the Maastricht criteria. Finally, most of the studies discuss the ability of different monetary regimes to satisfy the criteria in qualitative terms. We provide a quantitative framework that enables us to evaluate whether a given monetary regime can satisfy the Maastricht criteria.

Our results can be summarized as follows. There exists a significant trade-off between compliance with the CPI inflation criterion and the nominal interest rate criterion. Under the benchmark specification (which aims to reflect the Czech Republic economy) none of the regimes satisfies all the criteria. The sensitivity analysis reveals that the probability that some of the regimes will satisfy all the criteria increases with openness of the economy and also degree of substitution between traded goods. Moreover, provided that two previous conditions are satisfied, degree of exchange rate pass through determines which of the regimes can comply with the criteria. Specifically, low degree of pass through enables regimes with managed exchange rate to fulfill all the criteria while high degree of pass through implies that the CPI targeting regime satisfies all the criteria.

The paper is organized as follows. Section 2 reviews some stylized facts on the EMU accession countries based on the empirical literature. Section 3 describes the model and contrasts it with the existing theoretical literature. Section 4 and 5 focus on the determinants of the macroeconomic volatility in the long run and in the short run respectively. Section 6 presents comparison of the monetary regimes under the benchmark parameterization. Section 7 reports the sensitivity analysis results on the structural parameters and their impact on the monetary regime performance. Section 8 concludes indicating further research directions.

2 Stylized facts on the EMU accession economies

Our aim is to detect important characteristics of the EMU accession countries which affect the choice of the monetary regime in these countries. Importantly we study the determinants of macroeconomic volatility in these countries. Moreover we have a close look at some structural parameters which can be indicative for the choice of the monetary regime. Finally we analyze briefly economic performance of the EMU accession economies on the basis of their monetary regime choice.

All the EMU accession countries can be treated as small open economies. Their real GDP do not exceed 1% of the nominal GDP of the euro area (except for Poland for which the ratio amounts to 3%). However structure of these economies varies as far as share of nontraded sector and degree of openness are concerned.[3] In particular the ratio of imports in their nominal GDP ranges from 37% (for Poland) up to 83% (for Estonia). Importantly the euro area countries are the biggest trading partner of these countries with the share on average of 50% in their total trade.

As far as the stochastic environment of the EMU accession countries is concerned, Sueppel (2003) finds that these countries are characterized by higher growth and wider output fluctuations than the euro area and other EU countries.[4] Moreover he identifies that the degree of synchronization of their business cycles with the euro area is smaller and heterogenous than of the United Kingdom, Sweden and Denmark. This a consequence of the stabilization process taking place in these countries and reflected in the structural reforms, infrastructure improvements and a high productivity growth.

Having in mind the restrictions set on the monetary policy in the accession countries we find important to identify the main determinants of the real exchange rate dynamics which summarize pressures on the Maastricht variables, i.e.: inflation, nominal interest rate and nominal exchange rate.

Since all the EMU accession countries are characterized by a high productivity growth (especially in the tradable sector) many researchers test the hypothesis of the Balassa - Samuelson effect for these countries. According to the Balassa -Samuelson effect (Balassa (1964)) a country which experiences a higher productivity growth in the traded sector will face higher consumer prices and subsequently real exchange rate appreciation. An existence of the strong Balassa - Samuelson effect could endanger the attempts of keeping low inflation differential between these countries and the euro area. We can list the following empirical studies analyzing the Balassa-Samuelson effect in the EMU accession countries: Cipriani (2001), de Broeck and Slok (2001), Egert et al. (2002), Fisher (2002), Halpern and Wyplosz (2001), Coricelli and Jazbec (2001), Arratibel et al. (2002) and Mihaljek and Klau (2004). The main findings of these papers are rather diverse. The estimates indicate that the Balassa - Samuelson effect can explain from 0 - 3.5% per annum of the existing difference between inflation rates in the transition countries and the euro area.[5]

The original formulation of the Balassa - Samuelson theory totally neglects the role of the demand side of an economy in affecting the real exchange rate dynamics.[6] Some authors such as de Gregorio et el. (1994), de Broeck and Slok (2001), Cova (2004) and Astrov (2005) and Dufrenot et al. (2003) point out that in reality also demand side shocks can lead to real exchange rate appreciation and inflationary pressures. According to de Broeck and Slok (2001) observed growth of incomes in the EMU accession countries can increase the demand for nontradable goods and subsequently their price. Additionally since government expenditures fall

[3] Detailed data can be found in Appendix B.

[4] See figure (1) in Appendix B.

[5] These different results come from the varied methodologies used and also diverse treatment of the data: especially the share of nontradable goods in the economies and inclusion of the regulated prices in it. Moreover many studies neglected also a significant rise in productivity of nontradables and existence of the nontradable component in tradable goods.

[6] This is due to very restrictive assumptions such as homogeneity of traded goods, perfect competition in the traded good sector and perfect mobility of production factors.

predominantly on the nontraded goods they lead to a rise of price of nontradables. Moreover de Gregorio and Wolf (1994), Cova (2004) and Astrov (2005)[7] argue that demand shocks in the accession countries can lead to terms of trade improvements and through the income effect to real exchange rate appreciation and inflation. Astrov (2005) finds that real exchange rate in the EMU accession countries is affected positively by terms of trade (depreciation effect) and negatively by the share of government expenditures (appreciation effect) in the gross domestic product.[8] Additionally Dufrenot et al. (2003)[9] report that public finances and current account influence the real exchange rate dynamics. Their substantial deterioration is reflected in the real exchange rate depreciation.

The described demand side and supply side shocks constitute qualitatively for the common factors shaping the macroeconomic volatility in the EMU accession countries. Still there exist initial conditions, i.e. inflationary environment and structural parameters such as degree of openness and degree of exchange rate pass-through which make the countries to choose different monetary regimes.

Interestingly as far as the initial conditions are concerned Klyuev (2001) in his model of exchange rate regime choice in the EMU accession countries[10] finds the nonlinear relationship between the rate of inflation and the degree of exchange rate flexibility. The panel study indicates that a rise in inflation from a low level suggests introduction of more flexible exchange rate regimes while an increase in already high inflation is a sign to implement a rather fixed regime. The fixed regime present in the environment of considerable rigidities in both labour and goods market may lead to a decrease in the competitiveness of a country. That is why several Central and Eastern European countries (i.e. the Czech Republic, Hungary and Poland) have decided recently to introduce more flexible exchange rate arrangements.

Moreover the traditional Optimum Currency Area theory indicates that countries that are more open and therefore more vulnerable to nominal exchange rate movements should opt for the fixed regime. This can be somewhat explanatory for the case of Estonia which chose to peg and on the other pole for Poland which opted for the flexible regime.[11]

The degree of exchange rate pass through in an economy, i.e. the degree to which extent nominal exchange rate fluctuations feed into the domestic prices and affect the rate of inflation in the economy is especially crucial for small, open economies. According to Calvo and Reinhart (2002) and also empirical studies by Chaudry and Hakura (2002) and Devereux and Yetman (2003) exchange rate shocks in the emerging economies tend to feed into aggregate inflation at a much faster pace than in the industrialized economies. This fact influences the choice of monetary policy which should be used to adjust to external shocks. Moreover it raises the question of

[7] The authors argue that these demand shocks are reflected in an increased demand for the tradables due to quality improvements (consistent with a changing composition of the tradables in the EMU accession countries). In that way the Balassa - Samuelson effect can be replicated as long as the productivity increase consists in a quality improvement and a rise in the price of tradables.

[8] It is a panel regression study. The countries included in the sample are: Bulgaria, Croatia, Czech Republic, Hungary, Poland, Slovakia, Slovenia and Romania. The sample period for the study is 1990-2001. In this study one can also find the summary of some of the previous results.

[9] The authors of this study use the structural VAR and Behavioral Equilibrium Exchange Rate methodology. The study is is developed for 5 countries: the Czech Republic, Hungary, Poland, Slovakia and Slovenia.

[10] His study includes 13 Central and Eastern European economies: Albania, Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, LIthuania, Macedonia, Poland, Romania, Slovakia and Slovenia.

[11] see Table 1 in Appendix A.

how important the exchange rate adjustment should be in the chosen monetary rule.

Importantly the large pass through together with observed rigidities in the labour and goods market endanger the effectiveness of monetary policy and suggest implementation of strict exchange rate targeting. Additionally Coricelli and Jazbec (2004) in their study on the four EMU accession countries find that managed float policies aimed at accommodating the adverse shocks on the real exchange rate can actually induce the strong exchange rate pass-through.[12] That is why Slovenia and Hungary (opting for more fixed regimes) are reported to experience perfect pass-through while in case of the Czech Republic and Poland (opting for more flexible regimes) this degree is much smaller.

Summing up the EMU accession economies experience common driving forces affecting their macroeconomic volatility. Still they differ in some structural parameters and ultimate choices of the monetary regimes. The natural question which arises now how the choice of the monetary regime can influence the macroeconomic volatility of a country and compliance with the Maastricht criteria. A quick look at the data presented in the Appendix B indicates that countries following monetary regimes that entails some degree of the nominal exchange rate stabilisation are characterised by strong productivity growth but at the same time experience higher inflation rates, which can endanger compliance with the Maastricht criteria.

3 The Model

We build a small scale model of an accession economy with the aim to study how different monetary regimes perform in stabilizing the Maastricht variables, i.e. inflation, nominal interest rate and nominal exchange rate in the stochastic environment. We present an EMU accession economy as a small open economy interacting with the rest of the world economy - proxied as the euro area. We model a small open economy as the limiting case of a two country model where the size of one of the countries is set to zero. In each of the economies there are two good sectors: nontraded and traded goods. We consider highly integrated two economies where asset markets are complete. The structure of labour markets is such that labour is mobile between sectors in each country and immobile between the countries. We assume existence of home bias in consumption which is a function of the relative size of an economy and its degree of openness.[13]

Purchasing power parity (PPP) is violated due to three reasons: existence of the nontraded sector, home bias in consumption and also local currency pricing in the traded good sector which violates law of one price. Moreover, in order to study a role of the monetary policy, we introduce monopolistic competition and price rigidities with staggered Calvo contracts in all the good sectors. However we abstract from any monetary frictions by assuming cashless limiting economies. Importantly existence of market power in the traded good sector opens up role for terms of trade in transmission of the shocks. Additionally, local currency pricing in the

[12] The reaction function of such a policy responds to disequilibria in the real exchange rate rather than deviations from the infaltion and/or nominal exchange rate target.

[13] This assumption enables us to consider a limit case of the zero size of the home economy and concentrate on the small open economy.

traded good sector induces the imperfect exchange rate pass - through into domestic prices.[14] The stochastic environment of the small open economy is characterized by asymmetric productivity shocks originating in both domestic sectors, preference shocks and foreign consumption shocks.

The model can be seen as an extension of a one-sector small open economy model of De Paoli (2004). Moreover, it is also similar in its structure to two-country models of Benigno and Thoenisen (2003) and Altissimo et al (2004).[15] As far as the literature on monetary policy in the EMU accession economies is concerned our model is closely related to Devereux (2003), Natalucci and Ravenna (2003). Importantly, their specification of the traded good sector (i.e. domestic firms are price takers) implies exogeneity of terms of trade.

3.1 Households

The world economy consists of a measure one of agents: $[0, n)$ belonging to the small country (home) and $[n, 1]$ belonging to the rest of the world - the euro area (foreign). There are two types of differentiated goods produced in each country: traded and nontraded goods. Home traded goods are indexed on the interval $[0, n)$ and foreign traded goods on the interval $[n, 1]$ respectively. The same applies to the nontraded goods. Since our focus is on the limiting case of a two-country model we show only equations of the home economy. Foreign variables are indexed with $*$.

Households are assumed to be infinitely lived and they behave according to the permanent income hypothesis. Moreover in each country they can choose between three types of goods: nontraded, domestic traded and foreign traded goods. C_t^i represents consumption at period t of a domestic consumer i and L_t^i stands for his labour supply. Each agent i maximizes the following utility function:[16]

$$\max E_{t_0} \left\{ \sum_{t=t_0}^{\infty} \beta^{t-t_0} \left[U\left(C_t^i, B_t\right) - V\left(L_t^i\right) \right] \right\} \tag{1}$$

where E_t denotes the expectation conditional on the information set at date t, β is the intertemporal discount factor and $0 < \beta < 1$, $U(\cdot)$ stands for flows of utility from consumption and $V(\cdot)$ represents flows of disutility from supplying labour.[17] C is a composite consumption index. We define consumers' preferences over the composite consumption index C_t of tradable goods ($C_{T,t}$) (domestically - produced and foreign ones) and nontradable goods ($C_{N,t}$):

$$C_t \equiv \left[\mu^{\frac{1}{\phi}} C_{N,t}^{\frac{\phi-1}{\phi}} + (1-\mu)^{\frac{1}{\phi}} C_{T,t}^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}} \tag{2}$$

[14] In Section 7 we discuss an alternative pricing of firms, i.e. producer currency pricing.

[15] In both papers the assumption regarding a two-sector structure of an economy plays a crucial role. Benigno and Thoenisen (2003) examine the real exchange rate fluctuations between United Kingdom and the euro area and analyze whether Balassa-Samuelson effect could explain the real exchange rate appreciation of the British pound in the nineties. Altissimo et al. (2004) focus their analysis on the determinants of inflation differentials in a currency area.

[16] In general we assume that U is twice differentiable, increasing and concave in C_t and V is twice differentiable, increasing and convex in L_t.

[17] We assume specific functional forms of the consumption utility $U\left(C_t^i\right)$, and disutility from labour $V\left(L_t^i\right)$: $U\left(C_t^i\right) \equiv \frac{B_t^{\rho}\left(C_t^i\right)^{1-\rho}}{1-\rho}$, $V\left(L_t^i\right) \equiv \varphi_l \frac{\left(L_t^i\right)^{1+\eta}}{1+\eta}$ with ρ ($\rho > 0$) - the inverse of the intertemporal elasticity of substitution in consumption and η ($\eta \geq 0$) - the inverse of the labour supply elasticity.

where $\phi > 0$ is the elasticity of substitution between traded and nontraded goods and $\mu \in [0,1]$ is the share of the nontraded goods in the overall consumption. The traded good consumption is a composite of the domestically - produced traded goods (C_H) and foreign produced traded goods (C_F):

$$C_{T,t} \equiv \left[\nu^{\frac{1}{\theta}} C_{H,t}^{\frac{\theta-1}{\theta}} + (1-\nu)^{\frac{1}{\theta}} C_{F,t}^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}} \tag{3}$$

where $\theta > 0$ is elasticity of substitution between home traded and foreign traded goods, ν - home bias being the function of the relative size of the small economy with respect to the foreign one and its degree of openness λ such that $(1-\nu) = (1-n)\lambda$ and $\lambda \in [0,1]$.[18] Let us notice that degree of openness is related to degree of home bias, i.e. the higher degree of openness the smaller degree of home bias. Finally, C_j (where $j = H, N$) is a consumption sub-index of the continuum of differentiated goods:

$$C_{j,t} \equiv \left[\left(\frac{1}{n}\right)^{\frac{1}{\sigma}} \int_0^n c_t(j)^{\frac{\sigma^j-1}{\sigma^j}} dj\right]^{\frac{\sigma}{\sigma-1}} \tag{4}$$

where $\sigma > 1$ represent elasticity of substitution between differentiated goods in each of the sectors. The consumption - based price indices expressed in the units of currency of the respective country are the following ones:

$$P_t \equiv \left[\mu P_{N,t}^{1-\phi} + (1-\mu) P_{T,t}^{1-\phi}\right]^{\frac{1}{1-\phi}} \tag{5}$$

$$P_{T,t} \equiv \left[\nu P_{H,t}^{1-\theta} + (1-\nu) P_{F,t}^{1-\theta}\right]^{\frac{1}{1-\theta}} \tag{6}$$

with

$$P_{j,t} \equiv \left[\left(\frac{1}{n}\right) \int_0^n p_t(j)^{1-\sigma} dj\right]^{\frac{1}{1-\sigma}}. \tag{7}$$

The existence of the nontraded goods, assumed home bias and also possibility of local currency pricing cause the deviations from purchasing power parity. So $P \neq SP^*$ (where S stands for the nominal exchange rate). The real exchange rate can be defined in the following manner: $RS = \frac{SP^*}{P}$. Moreover we define the terms of trade as $T = \frac{P_F}{P_H}$ and the domestic terms of trade as $T^d = \frac{P_N}{P_T}$.

In order to represent the small open economy limiting case we use the definition of ν and set $n \to 0$. From consumers' preferences we can derive total demand of the generic goods - n (home nontraded goods) and h

[18] This specification is based on De Paoli (2004).

(home traded goods):

$$y^d(n) = \left[\frac{p(n)}{P_N}\right]^{-\sigma} \left[\frac{P_N}{P}\right]^{-\phi} \mu C \tag{8}$$

$$y^d(h) = \left[\frac{p(h)}{P_H}\right]^{-\sigma} \left[\frac{P_H}{P_T}\right]^{-\theta} (1-\lambda)C_T + \left[\frac{p^*(h)}{P_H^*}\right]^{-\sigma} \left(\frac{P_H^*}{P_T^*}\right)^{-\theta} \lambda C_T^* \tag{9}$$

Households get disutility from supplying labour to all the firms present in each country. Each individual supplies labour to both sectors, i.e. traded and nontraded one:

$$L_t^i = L_t^{i,H} + L_t^{i,N}. \tag{10}$$

We assume that consumers have the access to a complete set of securities - contingent claims traded internationally. Each household faces the following budget constraint:

$$P_t C_t^i + E_t\{Q_{t,t+1} D_{t+1}\} \leq D_t + P_t TR_t^i + W_{H,t}^i L_{H,t}^i + W_{N,t}^i L_{N,t}^i + \frac{\int_0^n \Pi_{N,t}^i di}{n} + \frac{\int_0^n \Pi_{H,t}^i di}{n} \tag{11}$$

where at date t: D_{t+1} - nominal payoff of the portfolio held at the end of period (t), $Q_{t,t+1}$ - the stochastic discount factor for one-period ahead nominal payoffs relevant to the domestic household, $\Pi_{H,t}$ and $\Pi_{N,t}$ - nominal profits from the domestic firms and TR_t^i - nominal lump sum transfers from the domestic government to the household i. The similar budget constraint can be written for the foreign economy. Moreover in both countries consumers face no Ponzi game restriction. The short term interest rate (R_t) is defined as the price of the portfolio which delivers one unit of currency in each contingency that occurs next period:

$$R_t^{-1} = E_t\{Q_{t,t+1}\} \tag{12}$$

The maximization problem of any household consists in maximizing discounted stream of utility (1) subject to the budget constraint (11) in order to determine the optimal path of the consumption index, labour index and contingent claims at all times. The solution to the household decision problem gives a set of first order conditions.[19] Optimization of the portfolio holdings leads to the following Euler equations for the home and foreign economy:

$$U_C(C_t, B_t) = \beta E_t \left\{ U_C(C_{t+1}, B_{t+1}) Q_{t,t+1}^{-1} \frac{P_t}{P_{t+1}} \right\} \tag{13}$$

$$U_C(C_t^*) = \beta E_t \left\{ U_C(C_{t+1}^*) Q_{t,t+1}^{-1} \frac{S_t P_t^*}{S_{t+1} P_{t+1}^*} \right\} \tag{14}$$

There is a perfect sharing in this setting meaning that marginal rates of consumption in nominal terms are

[19] We suppress here subscript i as we assume that in equilibrium all the agents are identical. Therefore we represent optimality conditions for a representative agent.

equalized between countries in all states and at all times:

$$\frac{U_C(C^*_{t+1})}{U_C(C^*_t)}\frac{P_{t+1}}{P_t} = \frac{U_C(C_{t+1}, B_{t+1})}{U_C(C_t, B_t)}\frac{S_{t+1}P^*_{t+1}}{S_t P^*_t} \tag{15}$$

Moreover choosing appropriately the distribution of initial wealth we obtain that:

$$\frac{U_C(C_t, B_t)}{U_C(C^*_t)} = \upsilon\frac{P_t}{S_t P^*_t} \tag{16}$$

where $\upsilon > 0$ and depends on the initial wealth distribution. We have to point out here that although the assumption of complete markets conveniently simplifies the model it neglects a possibility of wealth effects as a result of the shocks.

The optimality condition for the labour supply is the following one:

$$\frac{W^k_t(i)}{P_t} = \frac{V_L(L^i_t)}{U_C(C^i_t, B_t)} \tag{17}$$

where $W^k(i)$ - nominal wage of the consumer i in the sector k ($k = H, N$). So the real wage is equal to the marginal rate of substitution between labour and consumption.[20]

3.2 Firms

All the firms are owned by consumers. Both traded and nontraded sectors are monopolistically competitive. Since firms use only labour as their output the production function for firm i in sector k ($k = H, N$) is the following one:

$$Y_{k,t}(i) = A^k_t L^k_t(i) \tag{18}$$

Subsequently the nominal marginal cost for the firm i in sector k is:

$$MC^k_t(i) = \frac{W^k_t(i)}{A^k_t}. \tag{19}$$

3.2.1 Nontraded sector

Prices are set according to Calvo pricing scheme. Each period a fraction of firms $(1 - \alpha_N)$ decides their price maximizing the future expected profits.

The maximization problem of any firm in the nontraded sector at time t is given by:

[20] Notice that wages are equalised between the sectors inside each of the economies due to perfect labour mobility and perfect competition in the labour market.

$$\max_{P_{N,t_0}(i)} E_{t_0} \sum_{t=t_0}^{\infty} (\alpha_N)^t Q_{t_0,t} \left[(1-\tau_N) P_{N,t_0}(i) - MC_t^N(i) \right] Y_{N,t_0:t}^d(i) \tag{20}$$

$$subject\ to\ Y_{N,t_0:t}^d(i) = \left(\frac{P_{N,t_0}(i)}{P_{N,t}} \right)^{-\sigma} Y_{N,t} \tag{21}$$

where $Y_{N,t_0:t}^d(i)$ - demand for the individual good produced by firm i at time t conditional on keeping the price $P_{N,t_0}(i)$ fixed at the level chosen at time t_0, MC_t^N - nominal marginal cost in the nontraded sector at time t, τ_N - revenue taxes in the nontraded sector.

Let us notice that in the flexible price equilibrium the optimal price in the nontraded sector is set at any time according to the following relation:

$$\frac{\widetilde{P}_{N,t}(i)}{P_t} = \mu_N MC_t^{N,r} \frac{P_t}{P_{N,t}} \tag{22}$$

where $\mu_N = \frac{\sigma}{(\sigma-1)(1-\tau_N)}$ and $MC_t^{N,r} = \frac{W_t^N(i)}{P_t A_t^N}$.

In the sticky price environment we obtain the following inflation equation:

$$\widehat{\pi}_{N,t} = k_N(-\widehat{A}_t^N + \widehat{\omega}_t - (1-b)\widehat{T}_t^d) + \beta E_t \widehat{\pi}_{N,t+1}, \tag{23}$$

where $k_N = \frac{(1-\alpha_N\beta)(1-\alpha_N)}{\alpha_N}$ and $b = \mu(\overline{T^d}\overline{p_T})^{1-\theta}$ - represents a share of nontraded goods in the consumption basket of the small open economy evaluated at the steady state.

According to equation (23) the sector inflation ($\widehat{\pi}_{N,t}$) depends on changes in the real marginal cost and the relative prices. Real marginal cost decreases due to productivity increases ($\widehat{A}_t^N$) and raises in result of higher real wages ($\widehat{\omega}_t$). Additionally a rise in the relative price of nontraded goods generates a substitution effect away from this sector and leads to deflationary pressures. The magnitude of this effect depends inversely on the share of nontraded goods in the domestic consumption basket.

3.2.2 Traded sector

As far as the traded goods are concerned we assume a possibility of price discrimination between domestic market and a foreign one. We study two alternative pricing decisions: local currency pricing (LCP) and producer currency pricing (PCP). The first one implies delayed pass-through while the second one implies perfect exchange pass-through. As a benchmark scenario we choose LCP pricing. In Section 7 we discuss thoroughly implications of higher pass-through and PCP on performance of alternative monetary regimes.

Under LCP firms in the traded good sector decide their prices maximising the expected profits subject to the demand schedule in a given market, i.e. domestic or foreign one:[21]

[21] We can separate pricing decisions depending on the market since our production function is linear.

- domestic market

$$\max_{P_{H,t_0}(i)} E_{t_0} \sum_{t=t_0}^{\infty} (\alpha_H)^s Q_{t_0,t} \left[(1-\tau_H) P_{H,t_0}(i) - MC_t^H(i) \right] Y_{H,t_0:t}^d(i) \tag{24}$$

$$subject\ to\ Y_{H,t_0:t}^d(i) = \left(\frac{P_{H,t_0}(i)}{P_{H,t}} \right)^{-\sigma} C_{H,t}; \tag{25}$$

- foreign market

$$\max_{P^*_{H,t_0}(i)} E_t \sum_{s=0}^{\infty} (\alpha_H)^s Q_{t_0,t} \left[(1-\tau_H) S_t P^*_{H,t_0}(i) - MC_t^H \right] Y_{H,t_0:t}^{*d}(i) \tag{26}$$

$$subject\ to\ Y_{H,t_0:t}^{*d}(i) = \left(\frac{P^*_{H,t_0}(i)}{P^*_{H,t}} \right)^{-\sigma} Y^*_{H,t}. \tag{27}$$

where $Y_{H,t_0:t}^d(i)$, $Y_{H,t_0:t}^{*d}(i)$ - demands for the individual good produced by firm i at time t in the domestic and export home traded sector conditional on keeping, respectively, the prices $P_{H,t_0}(i)$ and $P^*_{H,t_0}(i)$ fixed at the level chosen at time t_0, MC_t^H - nominal marginal cost in the home traded sector at time t, τ_H - revenue taxes in the home traded sector.

When prices are flexible the optimal prices in the home traded sector, i.e. the internal price $\widetilde{P}_{H,t}$ and export price $\widetilde{P}^*_{H,t}$ are set at any time according to the following relations:

$$\frac{\widetilde{P}_{H,t}(i)}{P_t} = \mu_H MC_t^{H,r} \frac{P_t}{P_{H,t}}, \tag{28}$$

$$\frac{\widetilde{P}^*_{H,t}(i)}{P^*_t} = \mu_H MC_t^{H,r} \frac{1}{RS_t} \frac{P^*_t}{P^*_{H,t}} \tag{29}$$

where $\mu_H = \frac{\sigma}{(\sigma-1)(1-\tau_H)}$ and $MC_t^{H,r} = \frac{W_t^H(i)}{P_t A_t^H}$.

In the sticky price environment we obtain two sector inflation equations for goods in the traded sector, i.e. home traded inflation $\widehat{\pi}_{H,t}$ and export traded inflation $\widehat{\pi}^*_{H,t}$:

$$\widehat{\pi}_{H,t} = k_H(-\widehat{A}_t^H + \widehat{\omega}_t + b\widehat{T}_t^d + a\widehat{T}_t) + \beta E_t \widehat{\pi}_{H,t+1} \tag{30}$$

$$\widehat{\pi}^*_{H,t} = k^*_H(-\widehat{A}_t^H + \widehat{\omega}_t - \widehat{RS}_t + \widehat{T}_t^* + b^* \widehat{T}_t^{*d}) + \beta E_t \widehat{\pi}^*_{H,t+1} \tag{31}$$

where $k_H = \frac{(1-\alpha_H\beta)(1-\alpha_H)}{\alpha_H}$, $k^*_H = \frac{(1-\alpha_H\beta)(1-\alpha_H)}{\alpha_H}$, and a, b, a^*, b^* are the steady state ratios.

As in the coase of nontraded sector, sector inflation is driven by changes in the real marginal cost and relative prices. As far as the export sector is concerned, inflation dynamics are also affected by real exchange rate changes, e.g. real exchange rate depreciation leads to deflationary pressures in this sector.

Similarly, we can derive the optimal prices for the both markets of the foreign traded good sector. As a result, we obtain the following inflation equation for the import sector of our small open economy:

$$\widehat{\pi}_{F,t} = k_F(-\widehat{A}_t^{*F} + \widehat{\omega}_t^* + \widehat{RS}_t - (1-a)\widehat{T}_t + b\widehat{T}_t^d) + \beta E_t \widehat{\pi}_{F,t+1}. \tag{32}$$

Under PCP inflation in the import and export sector of the small open economy is driven entirely by domestic inflation of a given sector and nominal exchange rate movements ($\Delta\widehat{S}_t = \widehat{S}_t - \widehat{S}_{t-1}$), i.e. inflation in the export sector: $\widehat{\pi}^*_{H,t} = \widehat{\pi}_{H,t} - \Delta\widehat{S}_t$, inflation in the import sector: $\widehat{\pi}_{F,t} = \widehat{\pi}^*_{F,t} + \Delta\widehat{S}_t$.

3.3 Monetary and fiscal policies

The government in this small open economy occupies with collecting revenue taxes which are later redistributed to households in the form of lump sum transfers in such a way that each period there is a balanced budget:

$$\int_0^n \tau_t \left(P_{H,t}(i)Y_{H,t}(i) + P_{N,t}(i)Y_{N,t}(i)\right) di = \int_0^n TR_t^j dj \tag{33}$$

The existence of price stickiness and also other rigidities in the model such as deviations from PPP provide a role for the monetary policy. The distortion caused by monopolistic competition is offset by setting the appropriate output subsidies for each of the domestic sectors in the steady state so that output in the flexible price equilibrium is efficient.[22]

The monetary authority uses a short-term interest rate as its instrument. The general form of the interest rate feedback rule is the following one:

$$\widetilde{R}_t = \left(\frac{\pi_{t-1}}{\bar{\pi}}\right)^{\mu_\pi} \left(\frac{S_{t-1}}{\bar{S}}\right)^{\mu_S} \overline{R} \tag{34}$$

where μ_π, μ_S are the feedback coefficients to CPI inflation around a target rate $\bar{\pi}$ ($\bar{\pi}$ is the steady state value of CPI inflation), nominal exchange rate around a target level of $\bar{S}$ ($\bar{S}$ is the steady state value of the nominal exchange rate), $\overline{R}$ - the steady state value of the nominal interest rate. We also assume the interest rate smoothing:

$$R_t = \widetilde{R}_t^{1-\kappa} R_{t-1}^{\kappa} \varepsilon_t^{mp} \tag{35}$$

where κ - the rate of interest rate smoothing, ε_t^{mp} - the monetary policy shock (exogenous).

The loglinearised (around the steady state) version of equation (34) is the following:

$$\widehat{R}_t = \mu_\pi(1-\kappa)\widehat{\pi}_t + \mu_S(1-\kappa)\widehat{S}_t + \kappa\widehat{R}_{t-1} + \widehat{\varepsilon}_t^{mp} \tag{36}$$

where $\widehat{R}_t = \ln \frac{R_t}{\overline{R}}$.

[22] See Appendix A for derivation of the efficient steady state. As in Rotemberg and Woodford (1998) we assume that the average level of output is optimal and independent of monetary policy.

This form of the feedback rule allows us to study different regimes chosen by the EMU accession countries.[23] We follow here approach presented by Natalucci and Ravenna (2003). In particular the flexible exchange rate regime with the CPI targeting is characterised by a strong feedback coefficient to fluctuations in the aggregate inflation ($\mu_\pi \to \infty$). On the other side the fixed regime is characterised by a strong feedback coefficient to fluctuations in the nominal exchange rate ($\mu_S \to \infty$).[24] The managed float involves both nonzero feedback coefficients to fluctuations in the nominal exchange rate and inflation.

4 Macroeconomic volatility in the long run

This section analyzes the long run effects of the stochastic shocks in the presented small open economy environment. We solve the model by taking first order approximation around the steady state in the flexible price environment. Importantly the flexible price environment can be considered as the long run equilibrium towards which the sticky price equilibrium converges. Subsequently the solution of the model will provide us with the representation of the variables as functions of the stochastic shocks.

We focus on the real exchange rate dynamics as it can give us insight on the dynamics of the Maastricht variables in the sticky price environment.

From the supply relations in the flexible price environment ((22)) and the definition of the real exchange rate we can obtain the following relations between relative prices:

$$\widehat{T_t^{d,n}} = \widehat{A}_t^H - \widehat{A}_t^N - a\widehat{T_t^n}, \tag{37}$$

$$\widehat{RS_t^n} = -b\widehat{T_t^{d,n}} + (1-a)\widehat{T_t^n}. \tag{38}$$

where $\widehat{T_t^{d,n}}$, $\widehat{T_t^n}$, $\widehat{RS_t^n}$ - fluctuations (around the steady) of domestic terms of trade, terms of trade and real exchange rate in the flexible price environment.

As a consequence the real exchange rate can be represented as a function of the productivity shocks and terms of trade:

$$\widehat{RS_t^n} = -b\widehat{A}_t^H + b\widehat{A}_t^N + (1-a(1-b))\widehat{T_t^n} \tag{39}$$

The above equation indicates that real exchange rate depends positively on the productivity shocks occurring in the domestic nontraded sector and negatively on the productivity shocks occurring in the domestic traded sector. However also terms of trade have to be taken into account when analyzing the overall effect of the stochastic shocks on the real exchange rate dynamics.

[23] The monetary rule used for parameterization has a slightly more general form as it involves also response coefficient to aggregate output fluctuations (see Section 6).

[24] Notice that combining the Euler conditions for both economies and risk sharing condition we obtain an uncovered interest rate parity condition that directly links changes in the nominal exchange rate to nominal interest rates in both countries: $\Delta\widehat{S}_{t+1} = \widehat{R}_t - \widehat{R}_t^*$. Therefore in the case of the domestic shocks under the peg regime the nominal interest rate does not react.

The assumption of imperfect substitution and the existence of market power in the domestic traded sector appears to be crucial when analysing the validity of the Balassa Samuelson hypothesis and its inflationary impact on the EMU accession countries. In our framework when productivity shock in the domestic traded sector occurs we observe a rise in the ratio of domestic terms of trade through a unified labour market channel and increased real wages in the whole economy. Moreover the higher the share of nontraded goods the higher this appreciation effect on the real exchange rate. However since the home and foreign traded goods are imperfect substitutes we observe a lower price of the home traded goods in relation to the foreign ones. This worsens the terms of trade and has a depreciation effect on the real exchange rate.[25] This effect is stronger the smaller the degree of openness, the higher share of nontraded goods and a smaller degree of substitutability between home and foreign traded goods. So overall effect of the home traded productivity shocks on the real exchange rate is not certain.[26]

Importantly productivity shocks in the home nontraded sector lead to real exchange rate depreciation due to a decline in the domestic terms of trade accompanied by a rise in terms of trade. Morever domestic demand shocks result in real exchange rate appreciation through its positive effect on the domestic terms of trade and negative effect on terms of trade. Domestic demand shocks lead to a higher relative price of home goods which results in a decline of terms of trade.

These conslusions are in contrast with Devereux (2003) and Natalucci and Ravenna (2003) who base their analyses on the assumption that home traded prices are fixed internationally. This suposition is based on the argument that accession countries cannot affect their terms of trade. As a result terms of trade are treated exogenously and cannot act as transmitters and absorbers of shocks. That is why in their framework we observe a strong real exchange appreciation in presence of the home traded productivity shocks (see (39) when $\widehat{T_t^n}$ - exogenous). It is important to note that in such a framework there is no role for demand shocks as real exchange rate dynamics are determined entirely by productivity shocks in both domestic sectors.

Summing up the real exchange rate and therefore inflation movements can be a result of both demand and supply side shocks. In our analysis we identify a set of the crucial structural parameters which influence the way real exchange rate responds to the shocks. These are: share of nontraded goods in the aggregate consumption, degree of openness and degree of substitutability between home and foreign traded goods.

5 Macroeconomic volatility in the short run

In the short run when prices are sticky the real exchange rate adjustment to the new steady state depends on the chosen monetary rule, i.e. behaviour of the nominal interest rate. Combining international risk sharing

[25] as in Benigno and Thoenisen (2003) and Altissimo et al (2004).

[26] A recent empirical literature sheds some light on this uncertain effect of home tradable productivity shocks. In particular Arratibel et al. (2002) report that inflation in the EMU accession countries is negatively affected by labour productivity increases in the manufacturing sector (in many empirical studies the sectorial productivity is proxied by labour productivity). This finding is based on the panel study on determinants of dual inflation (in tradable and nontradable goods) in the chosen EMU accession countries. The regression equation (with inflation as the dependent variable) is based on the hybrid new Phillips curve equation with some other explanatory variables such as: exchange rate regime, productivity growths, liberalisation index, oil prices, government deficit ratios, unemployment ratios, GDP, euro area GDP growth and terms of trade.

condition and Euler condition we obtain that the real exchange rate is a function of the current and future real interest rate differentials between the small domestic economy and the foreign one (see (13), (14), (16)):

$$\widehat{RS}_t = E_t \sum_{i=0}^{\infty} \left[\left(\widehat{R}^*_{t+i} - \widehat{\pi}^*_{t+i+1} \right) - \left(\widehat{R}_{t+i} - \widehat{\pi}_{t+i+1} \right) \right] \tag{40}$$

However on the contrary to the flexible price environment where the real interest rates are functions of the shocks the real interest rates are formed by the chosen monetary rule.

The current and future decisions on the real interest rates are reflected in the current consumption. In order to understand the effects of each of the monetary regimes on the stabilization of the domestic variables it is useful to introduce a new variable: the consumption gap defined as the difference between the current consumption in the sticky price environment and the consumption under the flexible price environment. We can write the log - linearized (around the efficient steady state) Euler condition in terms of consumption gaps:

$$\widehat{Cgap}_t = \widehat{Cgap}_{t+1} - \frac{1}{\rho} \left(\widehat{R}_t - \widehat{\pi}_{t+i+1} - \widehat{RR}^n_t \right) \tag{41}$$

where: $\widehat{Cgap}_t = \widehat{C}_t - \widehat{C}^n_t$, $\widehat{C}^n_t -$ natural rate of consumption, i.e. consumption in the flexible price equilibrium, $\widehat{RR}^n_t -$ the natural real interest rate, i.e. the real interest rate in the flexible price equilibrium. Performing infinite recursions on (41) we obtain that the current consumption gap differential is determined by current and future real interest rate gap differentials in the sticky and flexible price environment:

$$\widehat{Cgap}_t = -E_t \sum_{i=0}^{\infty} \frac{1}{\rho} \left[\left(\widehat{R}_{t+i} - \widehat{\pi}_{t+i+1} \right) - \widehat{RR}^n_{t+i} \right] \tag{42}$$

Additionally by combining equations (40) and (41) current real exchange rate can be represented as:

$$\widehat{RS}_t = E_t \sum_{i=0}^{\infty} \left[\widehat{RR}^n_{t+i}{}^* - \widehat{RR}^n_{t+i} \right] + \rho \left(\widehat{Cgap}_t - \widehat{Cgap}_t^* \right) \tag{43}$$

The above relation gives us very useful insights concerning the nature of any monetary rule studied as compared to the flexible price equilibrium where the monetary rule cannot affect the economy.

If the real interest rates were above the natural ones in the domestic economy then this would have an additional appreciation effect on the real exchange rate, which is associated with deflation or/and nominal appreciation of the currency. On the other hand if the real interest rates were below the natural ones in the domestic economy this would lead to an additional depreciation effect on the current real exchange rate, which is associated with inflation or/and nominal depreciation of the currency.

6 Monetary regimes comparison

6.1 Parameterization

We follow the previous literature on the EMU accession economies (i.e. Laxton and Pesenti (2003), Natalucci and Ravenna (2003)) we calibrate the model to match moments of the variables for the Czech Republic economy.

The degree of openness of the small open economy , λ, is assumed to be 0.4 which implies that the imported consumption constitutes for around 40% of the tradable consumption. The share of nontradables in the aggregate consumption, μ, is assumed to be 0.42. These values are in accordance with the corresponding weights in CPI index for the Czech Republic over the period 2000-2005 (see Table 1 in Appendix B). Moreover, the share of nontradable consumption in the foreign aggregate consumption (μ^*) is assumed to be 0.6, consistent with the value chosen by Benigno and Thoenisen (2003) for the euro area economy.

The discount factor, β, equals 0.99 implying the annual interest rate of around 4 percent. Following Stockman and Tesar (1995) we assume that inverse of intertemporal elasticity of substitution, ρ, is set to 2. As in Laxton and Pesenti (2003) we assume that inverse of labour supply elasticity, η, is equal to 4. The elasticity of substitution between tradable and nontradable consumption, ϕ, is set to 0.5 as in Stockman and Tesar (1995) and the elasticity of substitution between home and foreign tradables, θ, is assumed to be 1.5 following Backus et al (1995). The elasticity of substitution between differentiated goods, σ, is equal 10, which together with the revenue tax of 0.1[27] implies a markup of 1.23[28].

The degree of price rigidity in the nontraded sector, α_N, is chosen to be 0.85. The degree of price rigidity in the tradable sectors, α_H and α_F, are slightly smaller and equal 0.8. These values are a bit higher than the values reported in the micro and macro studies for the euro area countries.[29] At the same time, they are in accordance with Smets and Wouters (2003) who calibrate their model to the euro area data and Natalucci and Ravenna (2003)[30] who choose these values for the EMU accession countries.

The shock processes are assumed to follow autoregressive processes AR(1). The parameters of the shocks are chosen to match the historical moments of the variables (see Table 2 in Appendix A). Following Natalucci and Ravenna (2003) and Laxton and Pesenti (2003), the productivity shocks in both domestic sectors are characterised by a strong persistence parameter equal to 0.85. Standard deviations of productvity shocks are set to 1.6% (nontraded sector) and 1.8% (traded sector).These values are consistent in magnitude with values chosen by Natalucci and Ravenna (2003), i.e. 1.8% (nontraded sector) and 2% (traded sector). Additionally, we assume that productivity shocks are strongly correlated, their correlation coefficient is set to 0.7.[31] Other

[27] This value represents the average share of Taxes less Subsidies in the Gross Domestic Product at 1995 constant prices in the Czech Republic for the years 1995-2006 (source: Eurostat).

[28] Martins et al. (1996) estimate the average markup for manufacturing sectors at around 1.2 in most OECD countries over the period 1980-1992. Some studies (Morrison (1994), Domowitz et al (1988)) suggest that the plausible estimates range between 1.2 and 1.7.

[29] Stahl (2004) estimates that the average duration between price adjustment in the manufacturing sector is 9 months (i.e. degree of price rigidity is 0.67). On the other hand, Gali et al (2001) and Benigno and Lopez-Salido (2003) estimate the aggregate supply relations for the European countries and find that overall degree of price rigidity for these countries to be 0.78.

[30] They argue that the existence of a high share of regulated prices in the EMU accession countries justifies such a high value of price stickiness.

[31] Empirical evidence suggests that sector productivity shocks are strongly correlated (see e.g. Backus et al (1992)).

shocks are independent of each other. Parameters defining the preference shock are, 0.72% (standard deviation) and 0.95 (persistence parameter).[32] Parameters of the foreign consumption shock are estimated using quarterly data on aggregate consumption in the euro area over the period 1990-2005 (source: Eurostat). The standard deviation of the foreign consumption shock is equal to 0.23% and its persistence parameter is 0.85.

In order to match the historical moments of the Czech Republic economy, we parameterize the monetary policy rule, i.e. the nominal interest rate follows the rule described by: $\widehat{R}_t = 0.9\widehat{R}_{t-1} + 0.1(\widehat{\pi}_t + 0.2\widehat{Y}_t + 0.3\widehat{S}_t) + \widehat{\varepsilon}_{R,t}$, where $\widehat{\varepsilon}_{R,t}$ is the monetary policy innovation with a standard deviation) 0.4%. In Table 3 (in the Appendix B) we present comparison of the model moments with the historical moments.

Finally, for the purpose of our analysis regarding performance of the monetary regimes, we specify each of the regimes by assigning specific values of the feedback coefficients in the monetary rule (see (36)). In particular:

- a fixed exchange rate regime (a strict peg to the currency of the foreign economy) is described as the monetary rule with $\mu_\pi = 0$, $\mu_S \to \infty$,
- a flexible exchange rate regime in which the monetary rule stabilises CPI inflation is described as the monetary rule with $\mu_\pi \to \infty$, $\mu_S = 0$,
- a managed float exchange rate regime in which the monetary rule stabilises CPI inflation and nominal exchange rate is described as the monetary rule with $\mu_\pi = 2$, $\mu_S = 0.025$ and the smoothing parameter $\kappa = 0.9$.[33]

6.2 Impulse responses to the domestic and foreign shocks

We study how the small domestic economy responds to the domestic and foreign shocks. First we identify the common patterns of responses of the key domestic variables that are present in the flexible price environment and under all the considered regimes. Next we identify the sources of differences in the response of each of the regimes by analyzing behaviour of the consumption gap (see (43)). Finally we evaluate the monetary regimes taking as a point of reference their ability to comply with the Maastricht criteria.

6.2.1 Domestic supply shocks

We examine the effects of domestic productivity shocks in both sectors (see Figure (5) and (6) in Appendix B). Both productivity shocks result in the real exchange rate depreciation in the flexible price environment and also under all the regimes. An imperfect substitution between all types of goods leads to a decline in domestic prices and the real exchange depreciation. Moreover we observe a decline in the natural real interest rate which is associated with the increase in the domestic aggregate consumption. Subsequently the expenditure switching effect leads to an increase in the domestic aggregate output.

[32] These values are similar to the values chosen by Laxton and Pesenti (2003), 0.4% (standard deviation) and 0.7 (persistence parameter).

[33] The specific values of the feedback coefficients are taken from Natalucci and Ravenna (2003) and represent estimates of Taylor rules for the OECD countries.

Importantly the magnitude of the real exchange rate depreciation differs for the two shocks analyzed. This can be understood by observing the changes in relative prices (see (38)). Productivity shocks in the nontraded sector lead to a decline in the domestic terms of trade and a rise in international terms of trade. Both changes have a depreciation effect on the real exchange rate. On the other hand productivity shocks in the traded productivity sector result in a rise of both types of relative prices with the opposing effects on the real exchange rate.

The differences in response of the economy under the alternative regimes are summarized by the consumption gap (see equations (41), (43)). Since the productivity shocks entail deflationary pressures the magnitude of a change in the nominal interest will depend on the importance which is attached to inflation changes in each of the alternative monetary rules and also to the fluctuations in the nominal exchange rate. Not surprisingly CPI targeting results in the strongest decline of the nominal interest rate and a positive consumption gap. On the other hand the peg regime, not able to use the nominal interest rate to stabilize the economy, is characterized by the strongest deflation followed later by inflation and a negative consumption gap.

The stabilization under CPI targeting regime involves a high response of the nominal interest rate and a nonstationary depreciation of the nominal exchange rate.[34] On the other hand peg regime guarantees stabilization of the nominal exchange rate but at the expense of deflation and a fall in real wage. Importantly complete stabilisation of the nominal exchange rate guarantees the stationarity of aggregate price level which is reflected in the pattern of aggregate inflation: first it declines and then it rises after several quarters. The managed float is characterized by the intermediate responses: the smoothed character of the Taylor rule and moderate response coefficients towards inflation and nominal exchange rate result in the muted hump - shaped response of the nominal interest rate. Consistent with the findings of Benigno and Benigno (2004) we observe depreciation followed by appreciation under this regime. Similarly we also report deflation (of the magnitude similar to the peg regime) followed by small inflation. The magnitudes of these short run effects depend on respectively response coefficient towards inflation and response coefficient towards nominal exchange rate. Finally persistence of deflation under this regime depends on the smoothing parameter.

Notice that these results are on the contrary to the findings of Devereux (2003) and Natalucci and Ravenna (2003) who report that CPI inflation targeting leads to excessive recession when responding to domestic supply shocks in the tradable sector. The main difference in results originates from the assumption on the endogeneity of terms of trade.

6.2.2 Domestic demand shocks

Now we analyze the response of the domestic economy to the government expenditure shocks in the nontraded sector (see Figure (7) in Appendix B). The domestic preference shock leads to a direct increase in domestic consumption. Natural rate of interest rate increases resulting in the real exchange rate appreciation. An additional domestic demand boosts production in both domestic sectors and subsequently leads to a rise in real

[34] This finding is consistent with the study of Benigno and Benigno (2004), i.e. nonstationary behaviour of the nominal exchange rate can be generated by the real shocks drawn from the stationary distribution in the flexible exchange rate regimes.

wages and higher real marginal cost. Domestic goods become relatively more expensive which is reflected in improved terms of trade and also a rise in domestic terms of trade.

We identify the differences between the alternative regimes by examining the behavior of the consumption gap. Note that domestic demand shocks lead to inflationary pressures and the real exchange rate appreciation. The CPI targeting is characterized by the highest increase in the nominal interest as this regime aims at stabilizing inflation. This response results in a negative consumption gap and a higher real exchange rate appreciation leading to a smaller expansion in the economy. On the other hand the peg regime allowing for inflation (which is later balanced by a small deflation so that aggregate price level is stationary) and also the highest rise in real wage reports a positive consumption gap resulting in a smaller real exchange rate appreciation and a boom in the economy. The managed float regime is characterised by moderate change in the nominal interest rate which stabilises partially nominal exchange rate (depreciation followed by appreciation) and inflation (followed by deflation). However the change in inflation under this regime is of the same magnitude as under the peg regime.

It is worth pointing out that since in our setting the domestic demand shocks lead to the real exchange rate appreciation and inflation we face the same evaluation of the regimes as Devereux (2003) and Natalucci and Ravenna (2003) for the domestic traded productivity shocks.

6.2.3 Foreign shocks

Importantly the peg regime accomodates all the foreign shocks by setting the nominal interest rate that guarantees stability of the nominal exchange rate.

The general pattern of response of the domestic economy to the foreign shocks depends on the way foreign aggregate consumption and also foreign real interest rate are affected. In particular foreign supply shocks lead to an increase in the foreign consumption and decline in the foreign real interest rate. Foreign demand shocks result in an increase in the foreign consumption and an increase in the foreign real interest rate.[35] A change in the foreign consumption leads to a change of the same sign in the domestic aggregate consumption (through the risk sharing condition (16)) At the same time we also observe a change in the real exchange rate (induced by a change in the foreign real interest rate) which affects adversely aggregate output through the expenditure switching effect. [36] Subsequently, the domestic natural rate of interest changes to a lesser extent than the foreign one.

In our experiment foreign consumption increase is associated with a decrease in the foreing real interest rate. Importantly, peg regime is characterised by a decline in the nominal interest rate which guarantees stability of the nominal exchange rate (see Figure (8) in the Appendix B). As a result, we observe a significant inflation and a positive consumption gap.

The remaining regimes allowing for some degree of the nominal exchange rate flexibility choose a different

[35] The mechanisms of the effects of the foreign shocks on the foreign variables are similar to the ones explained in the previous subsections.

[36] The strength of the expenditure switching effect depends on the structural parameters, i.e. elasticity of demand between home and foreign tradables and also the domestic monetary policy.

response in the domestic nominal interest as both of them, to a different extent, are concerned with the inflationary pressures which arise through the changes in inflation of the import sector and real exchange rate movements. That is why their responses are muted in comparison to the flexible price economy and lead to a negative consumption gap.

6.2.4 An overall evaluation of the monetary regimes performance

Till now, we have analysed how monetary regimes respond to domestic and foreign shocks. But how these different responses affect ability of monetary regimes to comply with the Maastricht criteria? In order to answer this question we reformulate the Maastricht criteria in two important dimensions.[37] First, we state the Maastricht criteria in quarterly terms. Second, we reformulate the upper bounds on levels into the upper bounds on variances of the Maastricht variables. The upper bounds on variances are calculated in such a way that compliance with the reformulated criterion gives 95% probability that the original criterion on levels is satisfied.[38] Subsequently, a criterion will be satisfied (violated) when the variance of the respective Maastricht variable is lower (higher) than the upper bound.

In Table 1 we present variances of the Maastricht variables under alternative monetary regimes. We find that none of the regimes satisfies all the Maastricht criteria. While the nominal exchange rate criterion is satisfied by all the regimes there exists a trade-off between compliance with nominal interest rate criterion and CPI inflation criterion. Not suprisingly, CPI targeting regime fails to satisfy the nominal interest rate criterion. On the other hand, peg regime fails to satisfy the CPI inflation criterion. The above trade-off is well reflected in variances induced by the managed float regime. Under this regime, variance of the nominal interest rate almost hits the upper bound of the criterion. But still it is not enough to guarantee stabilization of the CPI inflation rate in accordance with the Maastricht criterion.

Which of the regimes performs the best with respect to Maastricht criteria? Overall, managed float guarantees moderate variances of all Maastricht variables. Interestingly, this regime also induces the smallest variance of the consumption gap (as shown in Table 1 below). This indicates that both from the points of view of compliance with the Maastricht criteria and at the same time efficiency monetary regime in the EMU Accession countries should allow for some flexibility in stabilization of CPI inflation and the nominal exchange rate.[39]

[37] This reformulation methodology of the Maastricht criteria is explained in the Appendix A. Lipinska (2008a) provides a thorough discussion regarding this reformulation.

[38] A similar approach of reformulating the criteria was undertaken by Natalucci and Ravenna (2007).

[39] This result is similar to Devereux (2003) and Natalucci and Ravenna (2003).

Table 1: Variances of the Maastricht variables and consumption gap under alternative regimes (LCP)				
	CPI inflation	nominal interest rate	nominal exchange rate	consumption gap
CPI targeting	0	0.60	21.03	0.35
managed float	0.15	0.06	6.10	0.20
peg regime	0.27	0.02	0	0.63
bound	0.04	0.06	58.57	-
note: Variances and bounds are multiplied by 100^2 (in $(\%)^2$)				

7 Sensitivity analysis

The theoretical analysis of the real exchange rate determination in the long and short run enabled us to identify the structural parameters that can affect the responses of the small domestic economy to different shocks. In the long run perspective we discussed that a share of nontraded goods, a degree of openness and also a degree of substitution between home and foreign goods affect the magnitude of a change in the real exchange rate. Additionally in the short run a degree of exchange rate pass through in the domestic economy can alter the performance of the small domestic economy.

7.1 The long run analysis - openness of economy

Share of nontradables and degree of openness (defined as the share of imports in the tradable consumption) give us the insight on how open the economy is: a high share of nontradables together with small degree of openness indicate a relatively closed economy and a small share of nontradables together with a high degree of openness describe a more open economy. Changes in the degree of openness, share of nontradables and also degree of substitution between home and foreign goods affect the magnitude of the movements in the flexible price equilibrium real exchange rate (see equation (38)). Importantly the more open economy is the stronger interdependence between nominal exchange rate movements and the inflationary pressures. The higher the degree of substitutability between home and foreign goods the smaller movements in the terms of trade and traded inflation. Figures (9), (10), (11) in Appendix B present variances of the Maastricht variables and also consumption gap as functions of the share of nontraded consumption, degree of openness and degree of substitution between home and foreign goods.

We find that the ability of the monetary regimes to comply with the Maastricht criteria depends in a substantial way on openness of domestic economy and the degree of subsitutability of traded goods. Importantly, managed float regime and peg regime can satisfy the CPI inflation criterion provided that share of nontradables is small and/or degre of openness is high and/or home and foreign goods and good substitutes. On the other hand, CPI targeting regime does not satisfy nominal interest rate criterion no matter how open the economy is.[40] Finally, nominal exchange rate criterion is always satisifed by all the regimes. Not surprisingly, variance

[40] Variance of the nominal interest rate under this regime remains above the upper bound for all the parameter configurations

of the nominal exchange rate decreases for the CPI targeting and managed float regime with the more open economy and the higher degree of substitutability of traded goods.

Additionally, we control on how close different regimes are with respect to the flexible price equilibrium by studying variance of consumption gap. It appears that the more open economy is managed float and peg regime not only are characterised by an increased ability to satisfy the Maastricht criteria but also they are closer to the efficient flexible price equilibrium.

7.2 The short run analysis- exchange rate pass through

Our benchmark model assumes that there is a delayed pass through reflected in the local currency pricing (LCP). Importantly, the delayed pass-through diminishes the expenditure switching role of the nominal exchange rate. That is why, the managed exchange rate regimes outperform[41] the flexible exchange rate regimes in such an environment (Devereux and Engel (2003)). On the other hand, when exchange rate pass-through is high then nominal exchange rate movements enable necessary relative price adjustments in the environment where prices are sticky and the country faces real country-specific shocks (Friedman (1953)). Having these results in mind, we study how the assumption of instead high-pass through affects the relative performance of monetary regimes, i.e. the ability of alternative monetary regimes to comply with the Maastricht criteria. We compare local currency pricing environment with producer currency pricing (PCP).

In Table 2 we present variances of the Maastricht variables under alternative regimes. First of all, none of the regimes satisfies all the criteria. Interestingly, variances of the Maastricht variables under the CPI targeting and the managed regime are smaller than under LCP.[42] The high pass-through of the nominal exchange rate under PCP enables fast relative price adjustment under these regimes. Thanks to this, both the nominal exchange rate and nominal interest rate are characterised by a smaller variance than under LCP.[43] Note that, in accordance with the discussion above, CPI targeting regime is characterised by the smallest variance of the consumption gap.

Table 2: Variances of the Maastricht variables and consumption gap under alternative regimes (PCP)

	CPI inflation	nominal interest rate	nominal exchange rate	consumption gap
CPI targeting	0	0.15	8.97	0.27
managed float	0.09	0.05	5.51	0.35
peg regime	0.27	0.02	0	0.63
bound	0.04	0.06	58.57	-
note: Variances and bounds are multiplied by 100^2 (in $(\%)^2$)				

(μ, λ, θ).

[41] are characterised by higher welfare.

[42] Figure (13) in Appendix B presents variances of the Maastricht variables and also the consumption gap as a function of price stickiness in the import sector.

[43] Compare figures (5) and (12) that represent impulse responses to the domestic productivity shock in the nontraded sector under LCP and PCP respectively.

Finally, we control whether these results are dependent on how open the domestic economy is. In Figures (14) and (15) in Appendix B we present variances of the Maastricht variables and consumption gap as a function of the share of nontraded consumption and degree of openness. Interestingly, CPI targeting regime can satisfy all the criteria provided that the degree of openness of the economy is high. This is due to the fact that variance of the nominal interest rate under CPI targeting regime diminishes with both higher degree of openness and smaller share of nontradables (on the contrary to the LCP case). Moreover, this regime is also the closest to the efficient flexible price equilibrium as it implies the smallest variance of the consumption gap. This result is robust to all the parameter specification of the share of nontraded consumption and degree of openness.

8 Conclusions

This paper studies the ability of different monetary regimes in the EMU Accession countries to satisfy with the Maastricht criteria regarding the CPI inflation, nominal interest rate and nominal exchange rate. We identify some common characteristics of these countries regarding both a structure of the economy and its stochastic environment which can influence the current choices of the monetary regimes in these countries and also their performance. Then we build a two - country dynamic stochastic general equilibrium model representing a small open economy - one of the EMU accession countries and a big country - the euro area. This framework enables us to conduct policy experiments consisting in analyzing the effects of different monetary regimes on the way a small open economy responds to the set of domestic and foreign shocks. The studied monetary regimes roughly aim to reflect the monetary choices already made in the EMU accession countries: the fixed regime, the managed float and the CPI targeting regime.

The analysis suggests that ability of regimes to satisfy the Maastricht criteria depends on openness of an economy and substitutability of home and foreign goods. At the same time, degree of exchange rate pass through plays an important role. as it affects to a great extent variances of the Maastricht variables. Importantly, there exists a trade-off between satisfying the nominal interest rate and inflation criterion. We find that for many parameter specifications there is no regime which complies with all the Maastricht criteria. Higher degree of openness and strong substitutability of traded goods enables some of the regimes to comply with the criteria. However the ultimate choice of the regime which satisfies all the criteria depends on exchange rate-pass through. That can imply that the design of the regime that would satisfy all the Maastricht criteria is a of more complex nature. Moreover, we obtain for some parameterizations that if the regime satisfies all the criteria it is also characterized by the smallest consumption gap. That can imply that in this situation there is no trade-off between fullfillment of the Maastricht criteria and desirability of the efficient outcome. However in order to answer these two issues properly, a proper welfare analysis together with the derivation of the optimal policy constrained by the Maastricht criteria is needed. We cover these topics in Chapter 2.

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A Derivation of the model

A.1 Efficient steady state characterisation

We define a deterministic steady state with zero inflation rate. There are no productivity shocks ($A^H = A^N = 1$). Other domestic shock: preference shock is assumed to take constant values ($B = \overline{B}$). In order to eliminate rigidities present as a result of the monopolistic competition in both domestic sectors we impose optimal subsidies (τ_N, τ_H) which values constitute for the solution of the social planner.

The social planner chooses subsidies (τ_N, τ_H) in order to maximise welfare of the domestic consumers subject to the aggregate constraints of the economy:

$$\max(U(\overline{C}, \overline{B}) - V(\overline{L})) \tag{A.1}$$

$$s.t. \tag{A.2}$$

$$\overline{C} = \overline{RS}^{\frac{1}{\rho}} \overline{C}^* \tag{A.3}$$

$$1 = \mu \overline{p}_N^{1-\phi} + (1-\mu)\overline{p}_T^{1-\phi} \tag{A.4}$$

$$\overline{p}_T^{1-\theta} = (1-\lambda)\overline{p}_H^{1-\theta} + \lambda \overline{p}_F^{*1-\theta} \overline{RS}^{1-\theta} \tag{A.5}$$

$$\overline{Y_N} = \mu \overline{p}_N^{-\phi} \overline{C} \tag{A.6}$$

$$\overline{Y_H} = (1-\mu)(1-\lambda)\overline{p}_H^{-\theta} \overline{p}_T^{\theta-\phi} \overline{C} + \lambda(1-\mu)\overline{p}_H^{-\theta} \overline{RS}^{\theta} \overline{p}_F^{*\theta-\phi} \overline{C}^* \tag{A.7}$$

Foreign variables: $\overline{p}_F^*$ and $\overline{C}^*$ are derived from the similar social planner's problem for the rest of the world assuming that such an economy is a closed one.

A.2 Log - linearisation around the efficient steady state

We approximate the model around the above defined steady state. We present the loglinearised equations for the flexible price equilibrium and the sticky price equilibrium of the small open economy. Our set of shocks is composed of the domestic supply shocks: $A_{N,t}$, $A_{H,t}$, domestic demand shock: B_t and foreign shocks: C_t^*. We assume that $\widehat{\pi}_t^*$, $\widehat{\pi}_{F,t}^*$ and also $\widehat{T}_t^{d,*}$are zero (i.e. the rest of the world economy follows price stability policy).

A.2.1 The flexible price equilibrium - small open economy

Supply Nontraded sector:

$$(1-b)\widehat{T}_t^d = -\widehat{A}_t^N + \widehat{\omega}_t \tag{A.8}$$

where $b = \mu(\overline{T^d}\overline{p_T})^{1-\theta}$.

Domestic traded goods:

- internal consumption:

$$-b\widehat{T}_t^d - a\widehat{T}_t = -\widehat{A}_t^H + \widehat{\omega}_t \tag{A.9}$$

where $a = \lambda(\frac{\overline{RS}\overline{p}_F^*}{\overline{p}_T})^{1-\theta}$.

Domestic labour supply:

$$-\rho\widehat{C_t} + \widehat{\omega}_t - \eta(\frac{\overline{Y}_N}{\overline{Y}}\widehat{Y}_{N,t} + \frac{\overline{Y}_H}{\overline{Y}}\widehat{Y}_{H,t} - \frac{\overline{Y_H}}{\overline{Y}}\widehat{A}_t^H - \frac{\overline{Y_N}}{\overline{Y}}\widehat{A}_t^N) = 0 \tag{A.10}$$

Demand Nontraded consumption:

$$\widehat{Y}_{N,t} = \widehat{C_t} - \phi(1-b)\widehat{T}_t^d \tag{A.11}$$

Domestic traded consumption:

$$\widehat{Y}_{H,t} = \theta d_{CT} a\widehat{T}_t + d_{CT}(\widehat{C}_t + \phi b\widehat{T}_t^d) + \theta(1-d_{CT})\widehat{T}_t + (1-d_{CT})\widehat{C}_t^* \tag{A.12}$$

where $d_{CT} = \frac{\overline{p}_H^{-\theta}\overline{p}_T^{\theta-\phi}(1-\lambda)(1-\mu)\overline{C}}{\overline{Y}_H}$.

Aggregate output definition:

$$\widehat{Y}_t = dyn(\widehat{Y}_{N,t} + (1-b)\widehat{T}_t^d) + dyh(\widehat{Y}_{H,t} - b\widehat{T}_t^d - a\widehat{T}_t) \tag{A.13}$$

where $dyn = \frac{\overline{p_N}\overline{Y_N}}{\overline{Y}}$; $dyh = \frac{\overline{p_H}\overline{Y_H}}{\overline{Y}}$.

Risk sharing:

$$\widehat{C}_t^* = \widehat{C}_t - \frac{1}{\rho}\widehat{RS}_t - \widehat{B}_t \tag{A.14}$$

Euler condition:

$$\widehat{RR}_t = \rho(\widehat{C}_{t+1} - \widehat{C}_t) - \rho(\widehat{B}_{t+1} - \widehat{B}_t) \tag{A.15}$$

where $\widehat{RR}_t = \widehat{R}_t - \widehat{\pi}_{t+1}$.

Definition of the real exchange rate:

$$\widehat{RS}_t = -b\widehat{T_t^d} + (1-a)\widehat{T}_t \tag{A.16}$$

A.2.2 The sticky price equilibrium

Supply Nontraded sector:

$$\widehat{\pi}_{N,t} = k_N(-\widehat{A}_t^N + \widehat{\omega}_t - (1-b)\widehat{T}_t^d) + \beta E_t\widehat{\pi}_{N,t+1} \tag{A.17}$$

Domestic traded goods:

- internal consumption:

$$\widehat{\pi}_{H,t} = k_H(-\widehat{A}_t^H + \widehat{\omega}_t + b\widehat{T}_t^d + a\widehat{T}_t) + \beta E_t \widehat{\pi}_{H,t+1} \tag{A.18}$$

- export consumption:

$$\widehat{\pi}_{H,t}^* = k_H^*(-\widehat{A}_t^H + \widehat{\omega}_t - \widehat{RS}_t + \widehat{T}_t^*) + \beta E_t \widehat{\pi}_{H,t+1}^* \tag{A.19}$$

Foreign traded goods:

$$\widehat{\pi}_{F,t} = k_F(-\widehat{A}_t^{*F} + \widehat{\omega}_t^* + \widehat{RS}_t - (1-a)\widehat{T}_t + b\widehat{T}_t^d) + \beta E_t \widehat{\pi}_{F,t+1} \tag{A.20}$$

Labour supply:

$$-\rho\widehat{C_t} + \widehat{\omega}_t - \eta(\frac{\overline{Y}_N}{\overline{Y}}\widehat{Y}_{N,t} + \frac{\overline{Y}_H}{\overline{Y}}\widehat{Y}_{H,t} - \frac{\overline{Y_H}}{\overline{Y}}\widehat{A}_t^H - \frac{\overline{Y_N}}{\overline{Y}}\widehat{A}_t^N) = 0 \tag{A.21}$$

Demand Nontraded consumption:

$$\widehat{Y}_{N,t} = \widehat{C_t} - \phi(1-b)\widehat{T}_t^d \tag{A.22}$$

Traded consumption:

$$\widehat{Y}_{H,t} = \theta d_{CT} a\widehat{T}_t + d_{CT}(\widehat{C}_t + \phi b\widehat{T}_t^d) + \theta(1-d_{CT})\widehat{T}_t^* + (1-d_{CT})\widehat{C}_t^* \tag{A.23}$$

where $d_{CT} = \frac{\overline{p}_H^{-\theta}\overline{p}_T^{\theta-\phi}(1-\lambda)(1-\mu)\overline{C}}{\overline{Y}_H}$.

Resource constraint:

$$\widehat{Y}_t = dyn(\widehat{Y}_{N,t} + (1-b)\widehat{T}_t^d) + dyh(\widehat{Y}_{H,t} - b\widehat{T}_t^d - a\widehat{T}_t) \tag{A.24}$$

where $dyn = \frac{\overline{p_N}\overline{Y_N}}{\overline{Y}}$; $dyh = \frac{\overline{p_H}\overline{Y_H}}{\overline{Y}}$.

Risk sharing:

$$\widehat{C}_t^* = \widehat{C}_t - \frac{1}{\rho}\widehat{RS}_t - \widehat{B}_t \tag{A.25}$$

Euler condition:

$$\rho E_t(\widehat{C}_{t+1} - \widehat{B}_{t+1}) = \rho(\widehat{C}_t - \widehat{B}_t) + \widehat{R}_t - E_t\widehat{\pi}_{t+1} \tag{A.26}$$

Monetary rule:

$$\widehat{R}_t = \mu_\pi(1-\kappa)\widehat{\pi}_t + \mu_S(1-\kappa)\widehat{S}_t + \kappa\widehat{R}_{t-1} + \widehat{\varepsilon}_t^{mp} \tag{A.27}$$

Prices

$$\widehat{\pi}_t = \widehat{\pi}_{H,t} + b(\widehat{T}_t^d - \widehat{T}_{t-1}^d) + a(\widehat{T}_t - \widehat{T}_{t-1}) \tag{A.28}$$

$$\widehat{T}_t^d - \widehat{T}_{t-1}^d = -\widehat{\pi}_{T,t} + \widehat{\pi}_{N,t} \tag{A.29}$$

$$\widehat{T}_t - \widehat{T}_{t-1} = \widehat{\pi}_{F,t} - \widehat{\pi}_{H,t} \tag{A.30}$$

$$\widehat{T}_t^* - \widehat{T}_{t-1}^* = \widehat{\pi}_{F,t}^* - \widehat{\pi}_{H,t}^* \tag{A.31}$$

$$\Delta\widehat{RS}_t = \Delta\widehat{S}_t + (\widehat{\pi}_t^* - \widehat{\pi}_t) \tag{A.32}$$

$$\Delta\widehat{S}_t = \widehat{S}_t - \widehat{S}_{t-1} \tag{A.33}$$

$$\Delta\widehat{RS}_t = \widehat{RS}_t - \widehat{RS}_{t-1} \tag{A.34}$$

A.3 Parameterization

We present values of the structural parameters and also values of the stochastic parameters chosen in the numerical exercise.

Table B.1: Structural parameters		
The parameter definition	value of the parameter	
inverse of the intertemporal elasticity of substitution	ρ	2
inverse of the labour supply elasticity	η	4
discount factor	β	0.99
intratemporal elasticity between variety of the goods	σ	10
elasticity of substitution between home and foreign tradables	θ	1.5
elasticity of substitution between tradables and nontradables	ϕ	0.5
share of nontradables	μ	0.42
degree of openness	λ	0.4
price rigidity in the nontradable sector	α_N	0.85
price rigidity in the tradable sectors	$\alpha_H, \alpha_H^*, \alpha_F$	0.8
steady state share of taxes in the nontradable sector	τ_N	0.1
steady state share of taxes in the tradable sector	τ_H	0.1
share of nontradables in the foreign economy	μ^*	0.6

Table B.2: Stochastic environment		
shocks	autoregressive parameter	standard deviation (in %)
nontradable productivity (A_N)	0.85	1.6
tradable productivity (A_H)	0.85	1.8
preference (B)	0.95	0.72
foreign consumption (C^*)	0.85	0.23
$corr(\widehat{A}_{N,t}, \widehat{A}_{H,t}) = 0.7$ where $corr$ - correlation coefficient		

Note: The policy rule is calibrated following Natalucci and Ravenna (2003): $\widehat{R}_t = 0.9\widehat{R}_{t-1} + 0.1(\widehat{\pi}_t + 0.2\widehat{Y}_t + 0.3\widehat{S}_t) + \widehat{\varepsilon}_{R,t}$, where $SD(\widehat{\varepsilon}_{R,t}) = 0.45$.

Table B.3: Matching the moments				
Statistics	My framework		Natalucci and Ravenna (2003)	
Standard deviation in %	Model	Historical	Model	Historical
Output:	1.74	1.68	1.53	1.74
nontraded sector	1.76	1.56	2.72	1.55
traded sector	3.68	4.32	2.87	2.25
Consumption	1.79	1.93	2.28	2.29
Nominal interest rate	0.52	0.52	0.48	0.47
Nominal exchange rate	2.60	2.59	2.79	3.04
Real exchange rate	3.19	3.62	2.48	2.75
CPI inflation rate:	0.56	0.91	1.1	1.08
nontraded sector	0.61	0.97	0.79	2.61
traded sector	0.94	0.74	2.4	0.99

Note: For comparison purposes the table shows also the results of the paper by Natalucci and Ravenna (2003). The model moments are theoretical.

As far as the historical statistics are concerned our data sample for the Czech Republic is 1995:1 - 2006:2 (Natalucci and Ravenna (2003) database is 1994:1 - 2003:1). CPI inflation rate in the traded and nontraded sector data sample is 2000:1 - 2006:2. All series are logged (except for interest and inflation rates) and Hodrick - Prescott filtered. Rates of change are quarterly.

All data were collected from the Eurostat webpage (the data in Natalucci and Ravenna (2003) were collected from the OECD publication Statistical Compendium (2003) and the Czech Republic National Accounts (July 2003)). Data are seasonally adjusted where appropriate. We present the detailed data series. Output: Gross value added (GVA) at 1995 constant prices in national currency. Traded output is an aggregate of sectoral GVA for: Agriculture; Hunting; Forestry and Fishing; Total industry (excluding construction). Nontraded output is an aggregate of sectoral GVA for: Wholesale and retail trade, repair of motor vehicles, motorcycles and personal household goods; Hotels and restaurants; Transport, storage and communication; Financial intermediation, real estate, renting and business activities. Consumption: Final consumption expenditure of households at 1995 constant prices in national currency. Nominal interest rate: three months T - bill interest rate. Nominal exchange rate: Bilateral Koruny/euro exchange rate (quarterly average). Real exchange rate: CPI based real effective exchange rate (6 trading partners, quarterly average). CPI inflation rate: Harmonised Index of Consumer Prices (HICP). CPI inflation rate in the nontraded sector: HICP - Services. CPI inflation in the traded sector: HICP - Goods.

Table B.4: Variance decomposition of the Maastricht variables under the benchmark rule				
	shocks:			
variables:	A_N	A_H	B	C^*
CPI inflation	70%	3%	26%	0.5%
nominal interest rate	58%	3%	24%	15%
nominal exchange rate	32%	1.5%	27%	40%

A.4 Reinterpretation of the Maastricht convergence criteria

First, we summarize the Maastricht criteria by the following inequalities:

- CPI aggregate inflation criterion

$$\pi_t^A - \pi_t^{A,*} \leq B_\pi, \tag{A.35}$$

where $B_\pi = 1.5\%$, π_t^A is annual CPI aggregate inflation in the domestic economy, $\pi_t^{A,*}$ is the average of the annual CPI aggregate inflations in the three lowest inflation countries of the European Union.

- nominal interest rate criterion

$$R_t^L - R_t^{L,A*} \leq C_R \tag{A.36}$$

where $C_R = 2\%$, R_t^L is the annul interest rate for ten-year government bond in the domestic economy, $R_t^{L,A*}$ is the average of the annual interest rates for ten-year government bonds in the three countries of the European Union with the lowest inflation rates.

- nominal exchange rate criterion

$$(1 - D_S)S \leq S_t \leq (1 + D_S)S, \tag{A.37}$$

As explained in the main text, we restate the criteria in the quarterly terms. That means, that the bounds B_π and C_R have to be adjusted, i.e. $B_\pi = \sqrt[4]{1,015} - 1$ and

$C_R = \sqrt[4]{1,02} - 1$. Assuming that shocks are normally distributed we can reformulate the original Maastricht criteria into the criteria which set upper bounds on variances of the Maastricht variables:

$$k * SD(\widehat{\pi}_t) \leq B_\pi, \tag{A.38}$$

$$k * SD(\widehat{R}_t) \leq C_R, \tag{A.39}$$

$$k * SD(\widehat{S}_t) \leq D_S. \tag{A.40}$$

where SD – standard deviation. Parameter $k = 1.96$ guarantees that compliance with the reformulated criteria gives 95% of probability that the original criteria are satisfied.

B Tables and figures

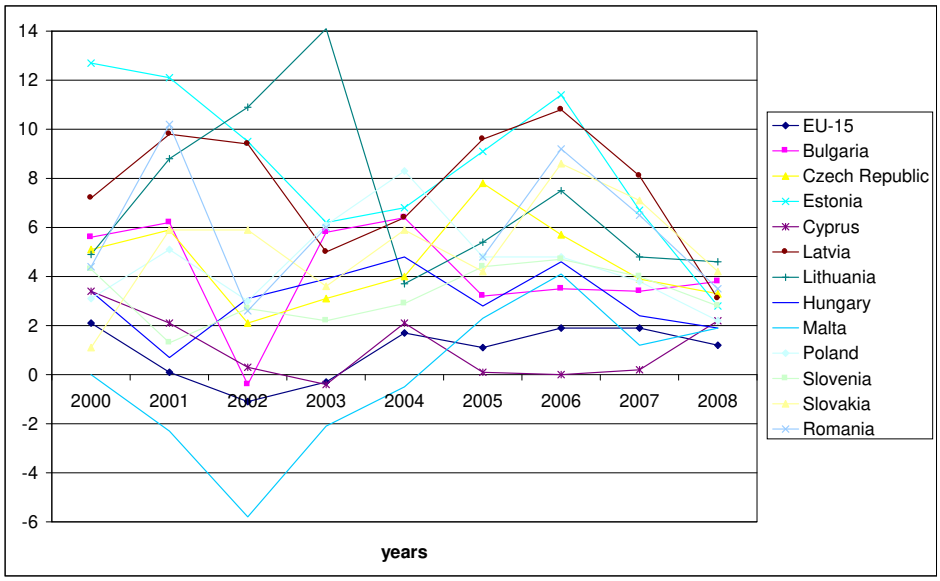

Figure 1: Total annual labour productivity growth in the EMU Accession countries and EU-15 (annual rates in %) for the period 2000-2008. Values fro 2007 and 2008 are forecasts.

Structure of the EMU accession economies				
			degree of openness	
countries	**monetary regime**	**share of nontradables in consumption (average 2000 - 2005)**	**share of imports in GDP (at current prices, average 2000-2007)**	**share of foreign traded consumption in the traded consumption (average 2000 - 2004)**
Czech Republic	managed float	42%	68%	36%
Estonia	peg	39%	86%	48%
Hungary	managed float	44%	71%	30%
Latvia	peg	37%	55%	35%
Lithuania	peg	33%	58%	23%
Poland	CPI targeting	37%	35%	13%
Slovenia	managed float	49%	59%	36%
Slovakia	managed float	41%	78%	34%
	average	**40%**	**64%**	**32%**

Note: We provide two alternative measures of the degree of openness since in our model openness is measured as the share of foreign traded consumption in the traded consumption.

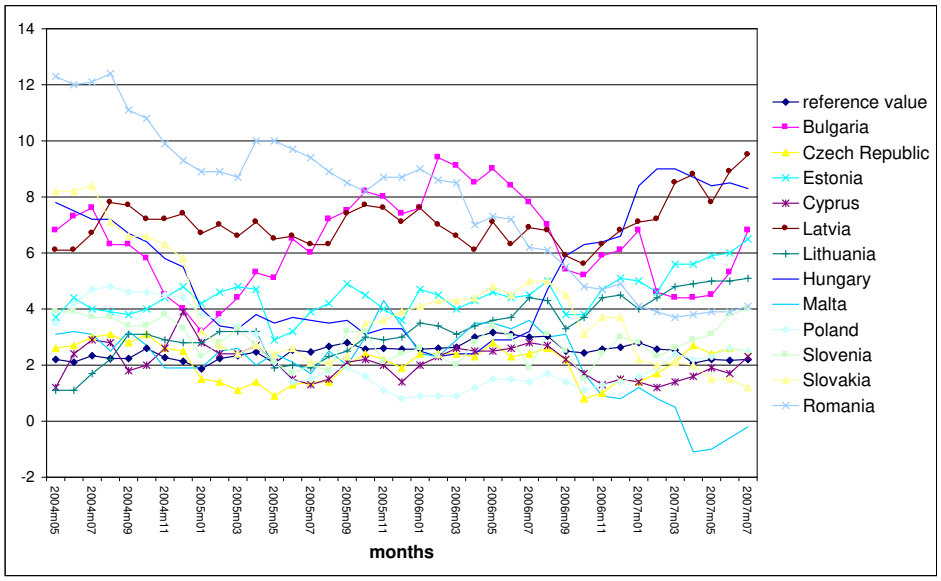

Figure 2: CPI inflation rates in the EMU accession countries since their accession to the EU (annual rates in %)

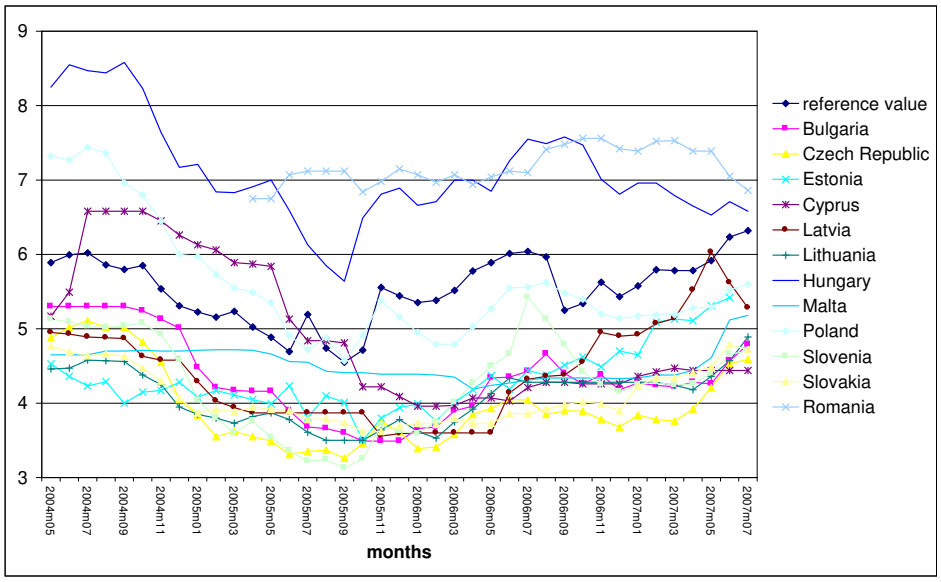

Figure 3: EMU convergence criterion bond yields for the EMU Accession countries since their accession to the EU (annual rates in %)

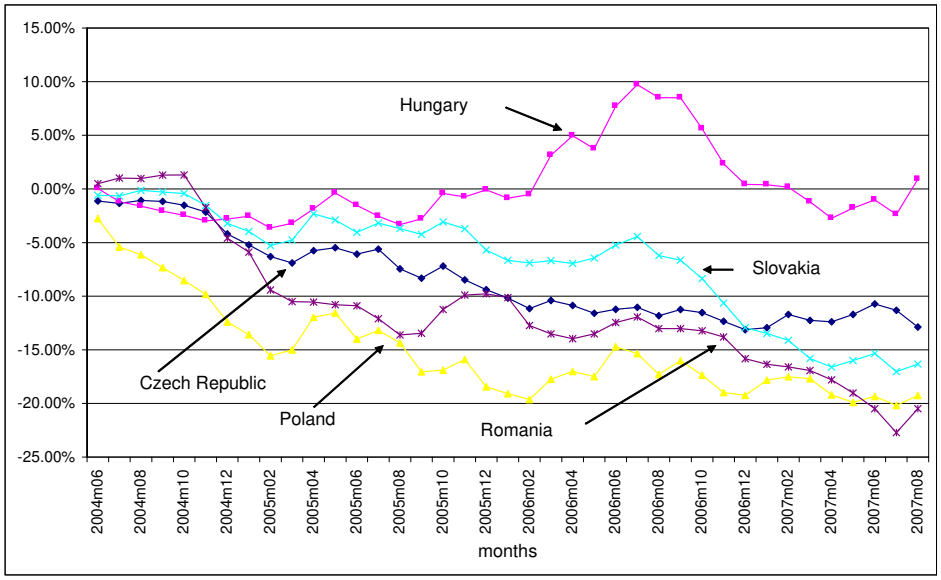

Figure 4: Nominal exchange rate fluctuations vs. euro of the EMU accession countries since the accession to the EU (average monthly changes since the EU accession date)

B.1 Impulse responses

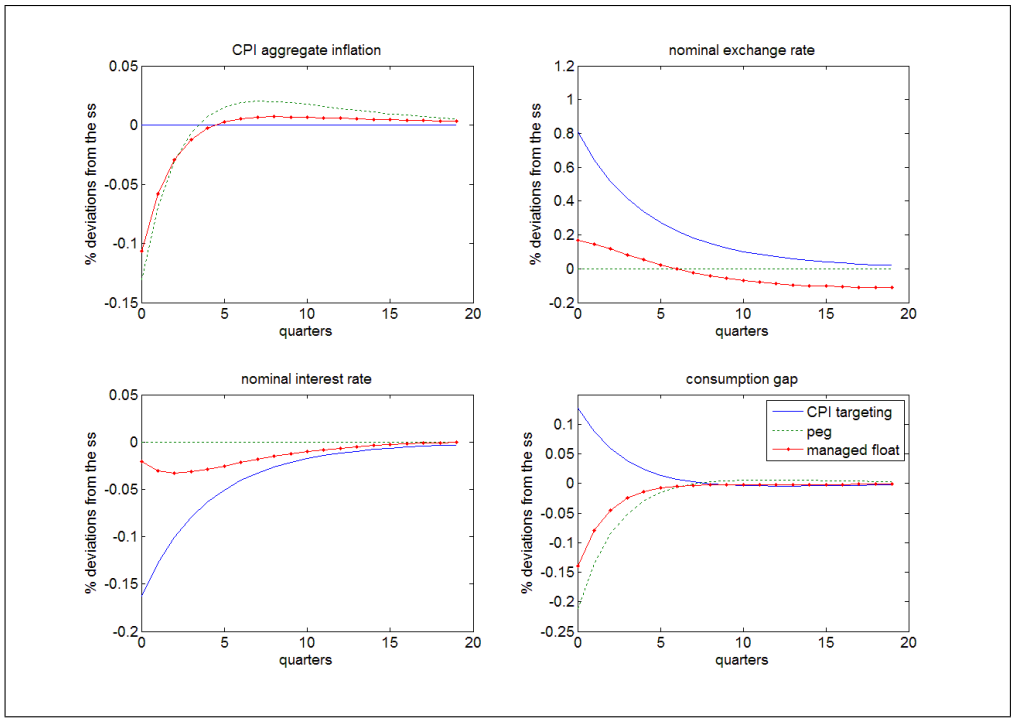

Figure 5: Impulse responses of the Maastricht variables and the consumption to the domestic nontradable productivity shock (LCP)

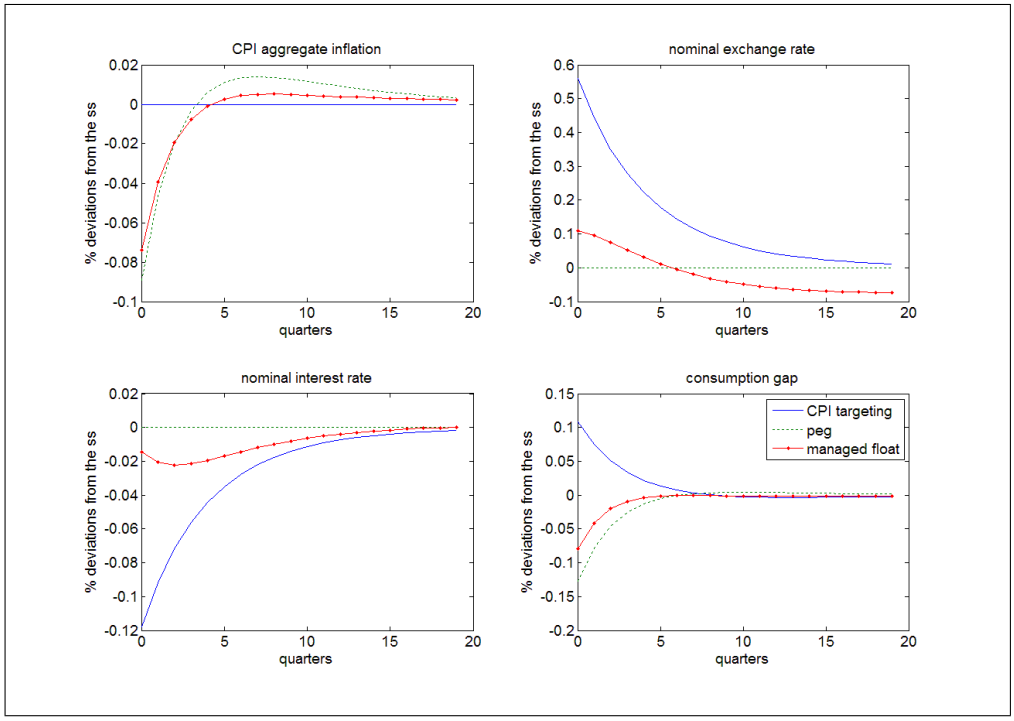

Figure 6: Impulse responses of the Maastricht variables and the consumption to the domestic tradable productivity shock (LCP)

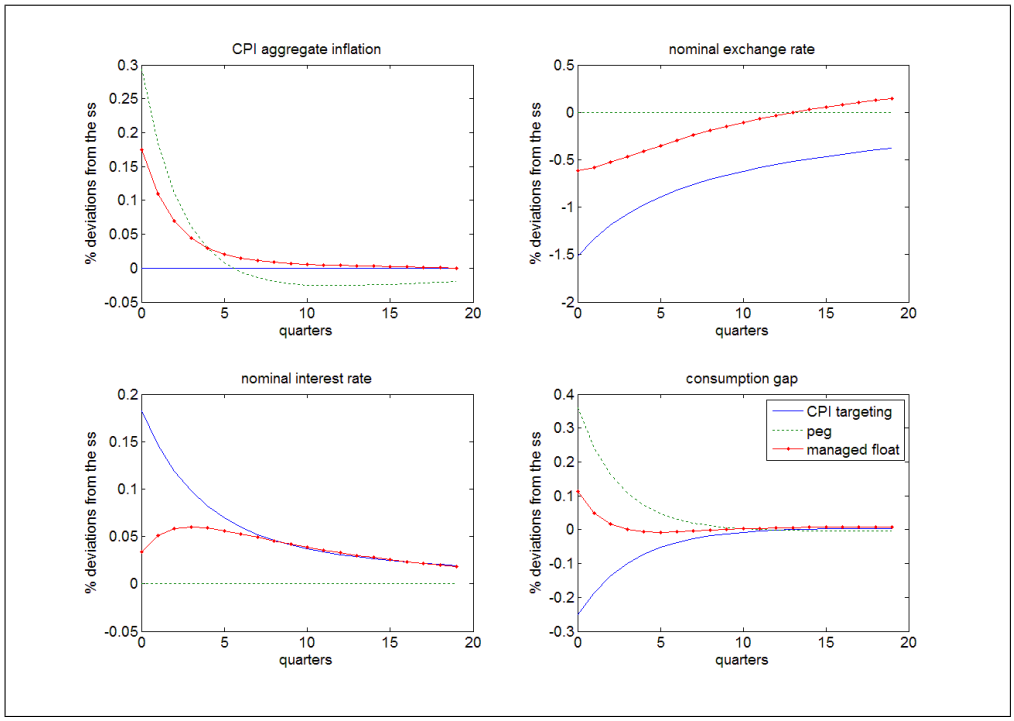

Figure 7: Impulse responses of the Maastricht variables and the consumption gap to the domestic preference shock (LCP)

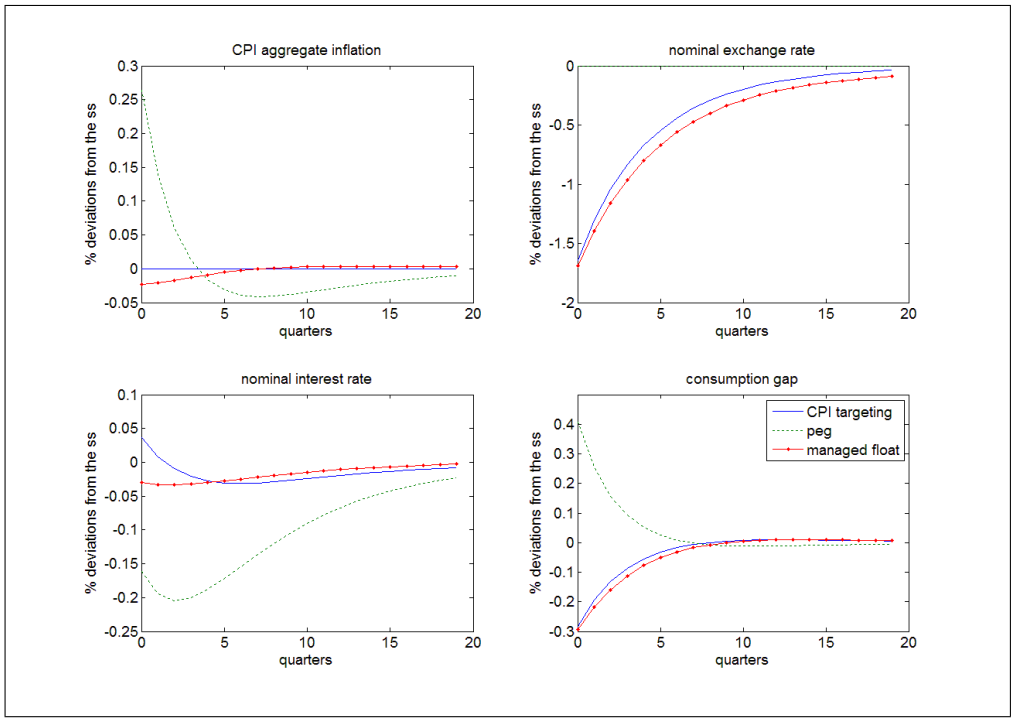

Figure 8: Impulse responses of the Maastricht variables and the consumption gap to the foreign consumption shock

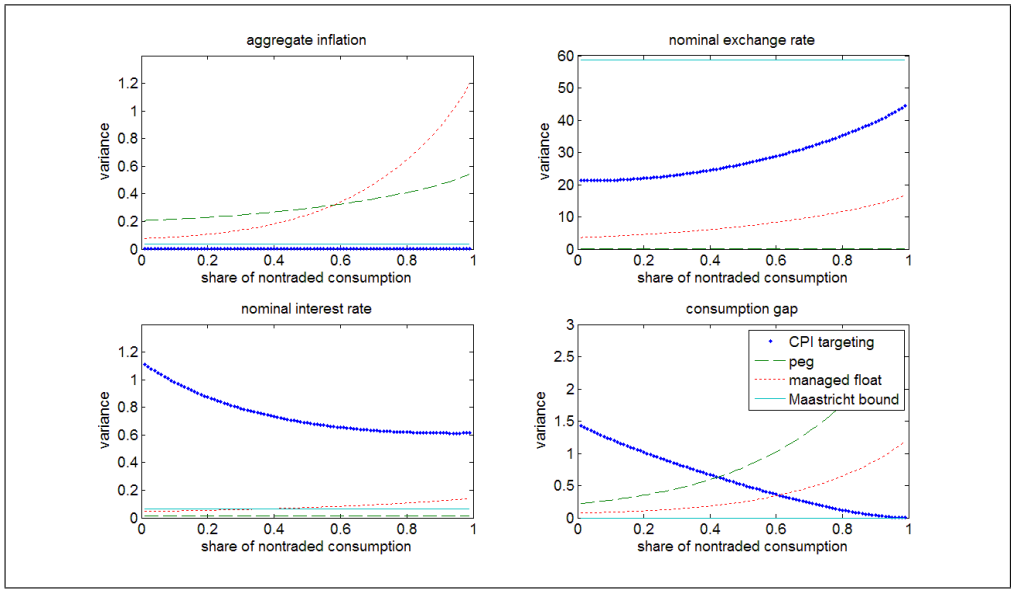

Figure 9: Variances of the Maastricht variables and the consumption gap as a function of the share of nontraded consumption (LCP)

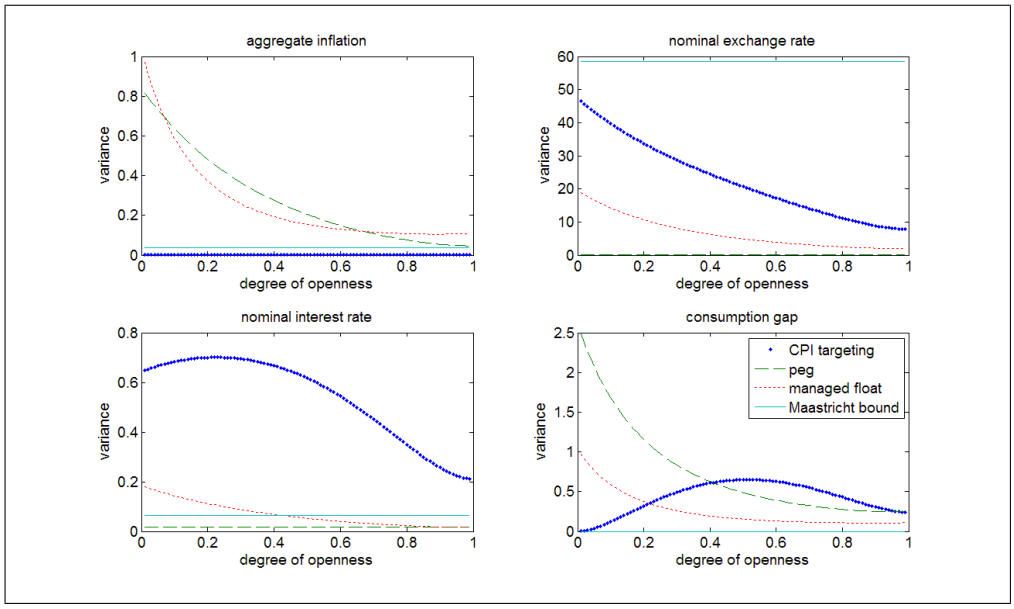

Figure 10: Variances of the Maastricht variables and the consumption gap as a function of the degree of openness (LCP)

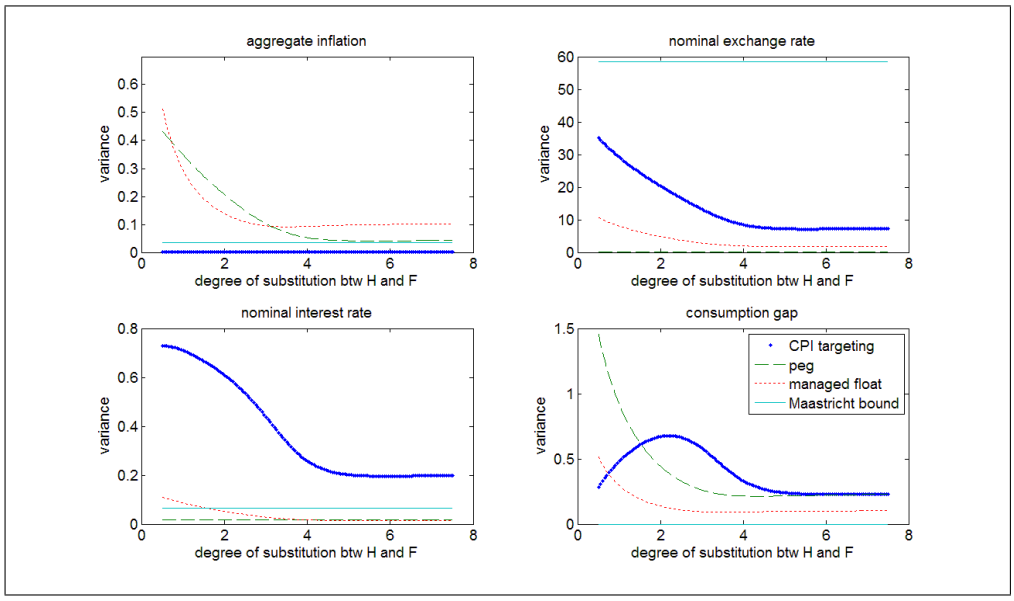

Figure 11: Variances of the Maastricht variables and the consumption gap as a function of the degree of substitutability between home and foreign goods (LCP)

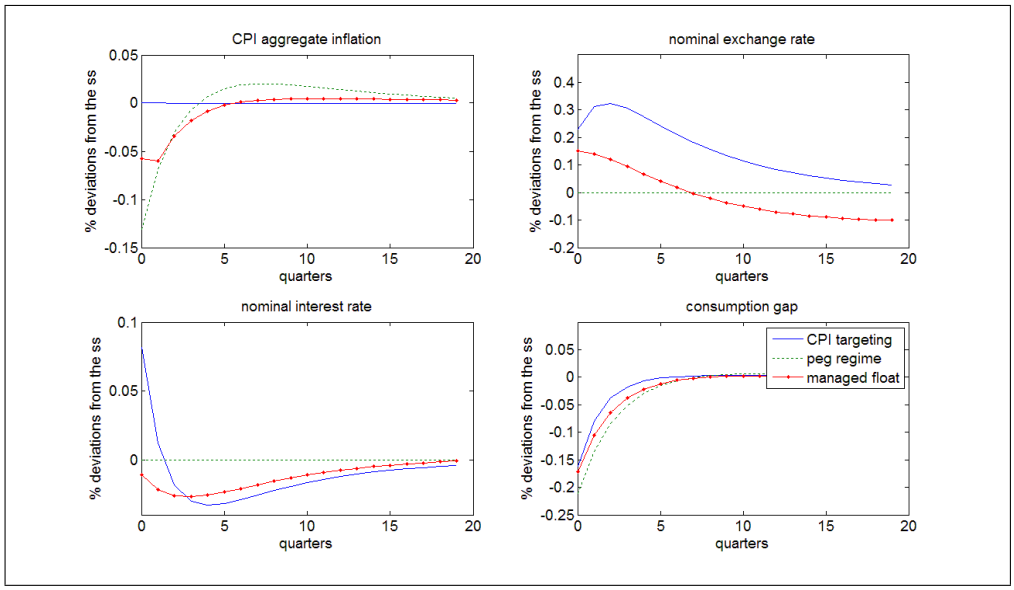

Figure 12: Impulse responses of the Maastricht variables and the consumption gap to the domestic nontradable productivity shock (PCP)

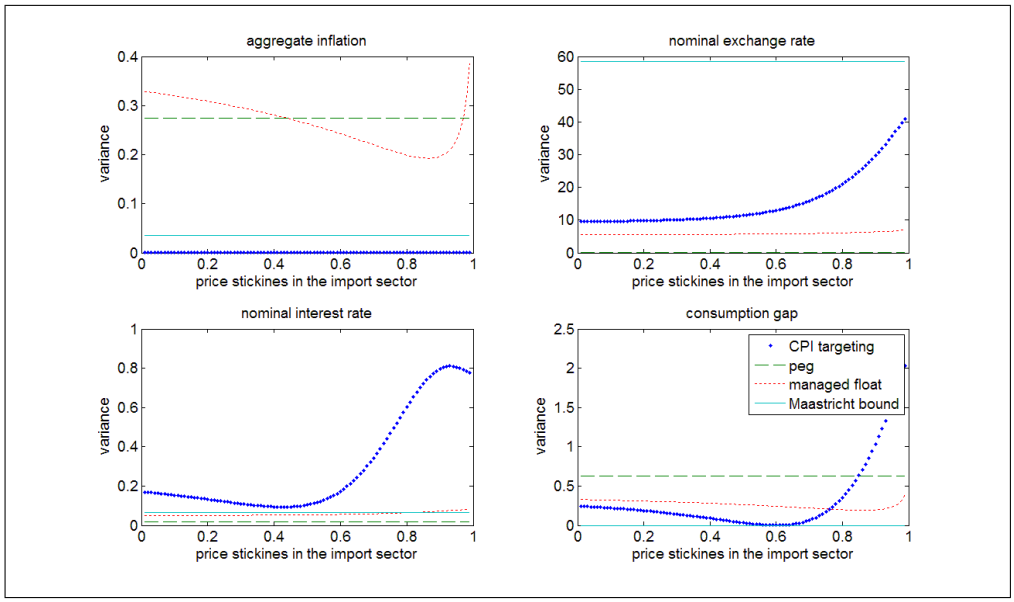

Figure 13: Variances of the Maastricht variables and the consumption gap as a function of the degree of price stickiness in the import sector (LCP)

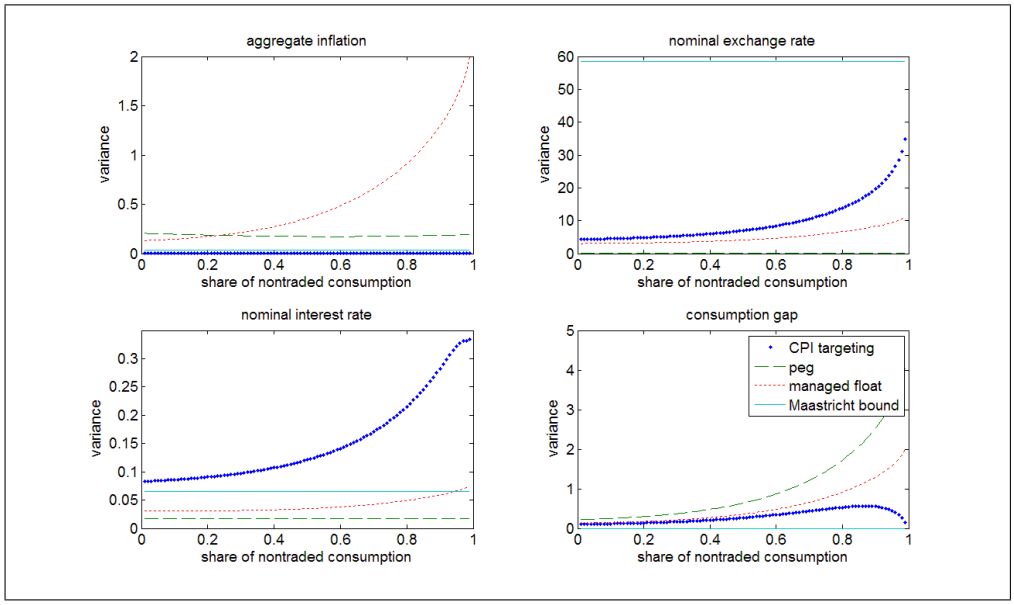

Figure 14: Variances of the Maastricht variables and the consumption gap as a function of the share of nontraded consumption (PCP)

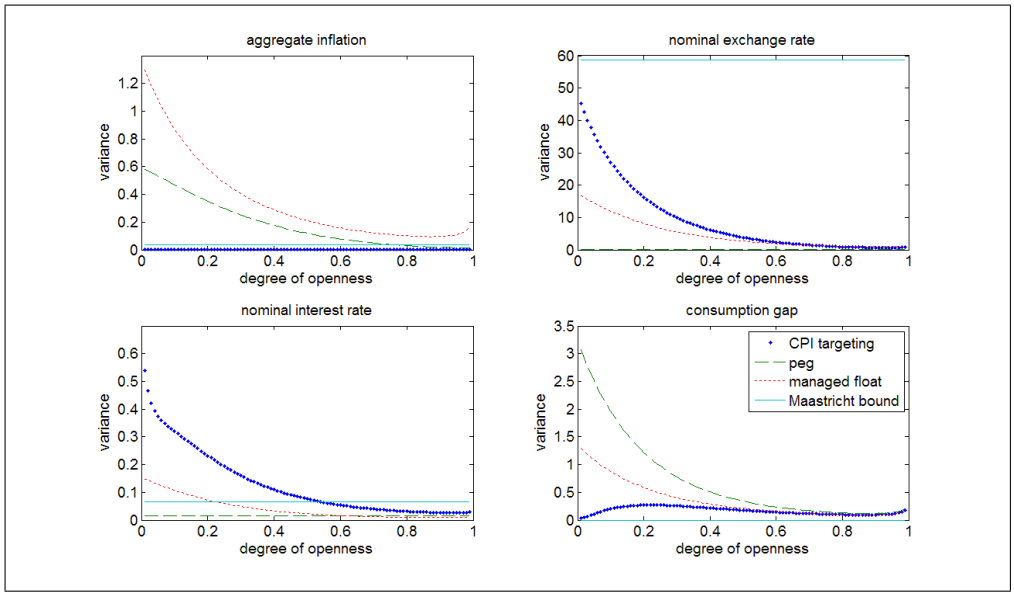

Figure 15: Variances of the Maastricht variables and the consumption gap as a function of the degree of openness (PCP)