

Monetary regime choice in the accession countries - a  
theoretical analysis  
**PRELIMINARY**

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**Abstract**

This paper studies the choice of the monetary regime in a small open economy with the special focus on the EMU accession countries. In the framework of a two - country DSGE model we conduct policy experiments consisting in analysing the effects of different monetary regimes (roughly representing the current choices of the accession countries) on the dynamics and volatility of an accession economy. We study carefully the real exchange rate determination in the long run and the short run as it summarises the pattern of the stabilisation of an accession economy in response to the shocks. Our benchmark analysis indicates that the managed float regime can attain the lowest consumption gap and at the same time guarantee the moderate changes in the nominal interest rate, nominal exchange rate and inflation. However parameters summarising its sensitivity to nominal exchange rate movements and inflation pressures depend on the underlying shocks. Additionally the sensitivity analysis indicates that the choice of the monetary regime may be dependent also on the specific structure of a small open economy. In particular a small share of nontradables, a high degree of openness and the high pass through may be advocates for the managed regimes frequently observed in the accession countries.

Keywords: monetary regime choice, real exchange rate dynamics, accession economies.

JEL classification: F41, E52.

# 1 Introduction

The common objective of the Central and Eastern European (CEE) countries and also South Eastern European (SEE) countries is the accession to the European Union (EU) and subsequently to the European Monetary Union (EMU).<sup>1</sup> Each of these countries has a different macroeconomic experience and faces a different stage of the stabilization process aimed at convergence towards the euro area. Despite the differences these economies share common characteristics such as a rapid productivity growth, infrastructure improvements and vulnerability to external disturbances. Additionally their monetary policies are obliged to satisfy the Maastricht convergence criteria which stand for the prerequisites to enter the EMU.<sup>2</sup>

These restrictions raise a question on the choice of the monetary regime in the accession countries which would facilitate their fast compliance. Some academics in the qualitative debates (e.g. Buiter and Grafe (2003) or Coricelli (2002)) call for adopting the peg regime in these countries as it enhances the credibility of the monetary policies<sup>3</sup> and also strengthens links with the EU and EMU. However in reality we still observe a heterogeneity in the choice of the regime among the accession countries. Bulgaria, Estonia and Lithuania and also Latvia<sup>4</sup> chose to peg to the euro. Interestingly majority of the accession countries, i.e. Croatia, the Czech Republic, Hungary, Romania, Slovakia and Slovenia<sup>5</sup> decided for the managed floating regime while Poland went for the flexible regime with CPI strict targeting.<sup>6</sup>

The goal of this paper is to study the implications of the different monetary regimes on the volatility of an accession economy - especially volatility of the variables summarizing the Maastricht criteria, i.e.: inflation rate, nominal interest rate and also nominal exchange rate. Moreover taking into account the structural differences between the accession countries we analyse whether and how structural parameters matter for the performance of the studied monetary regimes.

We build a two - country dynamic stochastic general equilibrium model which aims to illustrate the

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<sup>1</sup>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. At the moment Estonia, Lithuania and Slovenia (from 27th of June 2004), Latvia, Cyprus, Malta (from 2nd of May 2005) and Slovakia (26th of November 2005) participate in the Exchange Rate Mechanism II which constitutes for a preparatory step to enter the European Monetary Union. As far as the group of the South Eastern European countries is concerned, i.e. Bulgaria, Romania and Croatia, the first two are expected to join the European Union in 2007. The latter waits still for the opening of the negotiation process with the EU.

<sup>2</sup>These criteria constitute in: achieving the level of domestic inflation that does not exceed by more than 1.5% the average level of domestic inflation in the three lowest inflation countries of the euro area and also the long - term nominal interest that does not exceed by more than 2% above the average in the three lowest inflation countries of the euro area. What is more the countries are required to attain nominal exchange rate stability by limiting their nominal exchange rate movements around central parity against the euro within the band of  $\pm 15\%$ .

<sup>3</sup>The credibility aspects of the monetary regime choice in the CEE and SEE countries are adressed in the paper of Ravenna (2005).

<sup>4</sup>Bulgaria, Estonia and Lithuania opted for currency board with the euro as an anchor. Latvia pegged towards SDR (Special Drawing Rights) until January of 2005 when it switched for euro.

<sup>5</sup>Hungary follows the peg regime towards euro with the band of 15% around the central parity. The Czech Republic and Slovakia stress also the inflation targeting as the reference for the monetary policy.

<sup>6</sup>The official classification of the exchange rate regimes in the accession countries together with the Reinhart Rogoff classification and Yeyati classification can be found in Goldberg (2005).

structure of each of these economies and also its disturbances' environment. Importantly the chosen modelling strategy enables us to perform policy experiments consisting in changing the monetary regimes and analyzing its implications on the economies. The model describes a small open economy exposed to its internal disturbances (both demand and supply shocks) and also external ones coming from the large economy such as the euro area. Since the adjustment process to any of the shocks in a small open economy depends greatly on the real exchange rate dynamics we study in detail the main determinants of this variable in the long and short run. In our framework real exchange rate is a summary of the current and future decisions on the interest rate. The study of the determinants of the real exchange rate in the short run provides us with the meaningful platform for the monetary regimes comparison, i.e. the real interest rate developments. We also identify the key structural parameters, i.e. degree of openness, structure of the goods, elasticity of substitution between home and foreign goods, degree of exchange rate pass-through and price stickiness which affect the way a small open economy responds to the shocks. Finally we study whether performance of the alternative regimes can be altered by changing values of the structural parameters.

The paper is organized as follows. Section 2 reviews some stylized facts on the CEE and SEE 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 a comparison of the monetary regimes under the chosen calibration. Section 7 reports the sensitivity analysis results on the structural parameters and their impact on the monetary regime performance. Section 8 concludes indicating possible further research directions.

## 2 Stylized facts on the CEE and SEE economies

Our aim is to detect important characteristics of the CEE and SEE 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 CEE and SEE on the basis of their monetary regime choice.

All the CEE and SEE 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%). The ratio of imports in their nominal GDP ranges from 37% (for Poland) up to 83% (for Estonia). Moreover the euro area countries are the biggest trading partner of these countries with the share on average of 50% in their total trade.<sup>7</sup>

As far as the stochastic environment of the CEE and SEE countries is concerned, Sueppel (2003) finds that these countries are characterized by higher growth and wider output fluctuations than the

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<sup>7</sup>A detailed data on the structural characteristics of the accession countries as compared to the EU-15 can be found in the appendix.

euro area and other EU countries.<sup>8</sup> 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 the pressures on inflation, nominal interest rate and nominal exchange rate.

Since all the CEE and SEE 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. Assuming that the price of tradables is fixed internationally, a higher productivity growth in the traded sector will necessarily lead to an increase in the country wide wage and subsequently an increase in nontradable prices (due to higher labour costs). This mechanism will lead to a real exchange rate appreciation. Under the fixed exchange rate regime Balassa - Samuelson effect will result in higher CPI inflation and real exchange rate appreciation. Under the floating regime we can observe a combination of an increased CPI inflation in transition countries together with nominal exchange rate appreciation. This issue comes to be especially relevant in light of the future membership of the CEE and SEE countries in the EMU and their necessity to comply with the Maastricht criteria. 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 CEE and SEE 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.<sup>9</sup> These different results come from the varied methodologies used<sup>10</sup> and also diverse treatment of the data: especially the share of nontradable goods in the economies and inclusion of the regulated prices in it<sup>11</sup>. Moreover many studies neglected also a significant rise in productivity of nontradables and existence of the nontradable component in tradable goods.

The original formulation of the Balassa - Samuelson theory totally neglects the role of the demand

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<sup>8</sup>See graphs 1 and 2 in the section of data on the accession countries of the Appendix.

<sup>9</sup>See Mihaljek and Klau (2004) for the comparative analysis of the empirical studies on the Balassa - Samuelson effect in the CEE and SEE countries (Table 1).

<sup>10</sup>The methodologies used in the empirical studies range from simple OLS exercises to more advanced techniques such as: VAR and panel cointegration analyses.

<sup>11</sup>According to Mihaljek, Klau (2004) the common mistake in number of studies was to include in the nontradables the regulated prices (such as energy, transport). These kinds of goods can account up to 25% of GDP and since they are not governed by market - based pricing we cannot observe the Balassa - Samuelson effect on them.

side of an economy in affecting the real exchange rate dynamics. This is due to very restrictive assumptions such as the law of one price for tradables, perfect mobility of production factors and perfect competition. Some authors such as de Gregorio et al. (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 CEE and SEE countries can increase the demand for nontradable goods and subsequently their price. Additionally since government expenditures fall 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)<sup>12</sup> 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 CEE and SEE 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.<sup>13</sup> Additionally Dufrenot et al. (2003)<sup>14</sup> 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 CEE and SEE 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 CEE and SEE countries<sup>15</sup> 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

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<sup>12</sup>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 CEE and SEE 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.

<sup>13</sup>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.

<sup>14</sup>The authors of this study use the structural VAR and Behavioral Equilibrium Exchange Rate methodology. The study is developed for 5 countries: the Czech Republic, Hungary, Poland, Slovakia and Slovenia.

<sup>15</sup>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.

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.<sup>16</sup>

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

As far as the accession countries are concerned the majority of their imports is invoiced in euro. According to ECB reports on the international role of the euro (2002, 2004, 2005) and Goldberg (2005) in 2002 on average 58,5% of the accession countries imports were invoiced in euro.<sup>17</sup> 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 CEE 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. 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 CEE and SEE 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. A quick look at the summary of economic indicators presented in the section: data on the accession countries of the Appendix indicates that countries following an intermediate monetary regime perform the worst in terms of inflation stabilization. On the other hand the only country following the free floating strategy experiences the highest volatility in nominal exchange rate. Countries following peg regime are characterized by strong GDP growth and stable inflation.

### 3 The Model

We build a small scale model of an accession economy<sup>18</sup> with the aim to study how different monetary regimes perform in stabilizing such an economy in the stochastic environment. We present an accession

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<sup>16</sup>See the tables on the share of imports and exports in GDP and also share of nontradables in the total consumption for the accession countries compared with EU-15, presented in the section: data on the accession countries in the Appendix.

<sup>17</sup>In the EU-15 countries it was respectively 49,5%. (see Goldberg (2005)).

<sup>18</sup>By this term we mean any CEE and SEE economy.

economy as a small open economy interacting with the rest of the world economy - chosen to be the euro area. The model represents two economies of unequal size: a small open home economy and a foreign large and closed economy. In each country consumers can choose between nontraded goods, home traded goods and foreign traded goods. We introduce home bias meaning that consumers prefer to buy domestic traded goods rather than foreign imported goods.<sup>19</sup> Labour markets are perfectly competitive where labour is mobile between sectors in each country and immobile between countries. Goods markets are assumed to be monopolistically competitive. The price rigidities occur in all the sectors and moreover producers of traded goods are allowed to price discriminate across countries. Purchasing power parity does not hold for two reasons: existence of the nontraded goods and market power in the tradable goods sector. Importantly market power in the tradable good sector opens the role for terms of trade in stabilisation of the economy.<sup>20</sup> Moreover price discrimination in the tradable goods sector results in the imperfect exchange rate pass - through of nominal exchange rate into prices. Finally assets markets are complete in both countries.

Our model is constructed in the spirit of open - economy models introduced by Obstfeld and Rogoff (2000), who incorporated in stochastic models a non-traded good sector with sticky prices. Although our focus is on the small open economy our model composes of two countries and therefore it is close in its structure to the model of Benigno and Thoenisen (2003). The authors examine the real exchange rate fluctuations between United Kingdom and the euro area and analyze whether supply shocks in the traded good sector could explain the real exchange rate appreciation of the British pound in the nineties. Our setting is also similar to the model of a currency area presented in the paper of Altissimo et al. (2004). The authors focus their analysis on the determinants of inflation differentials in a currency area.

As far as the literature on monetary policy in the accession economies is concerned our model is closely related to Devereux (2003), Natalucci and Ravenna (2003) and Laxton and Pesenti (2003). The models of Devereux (2003) and Natalucci and Ravenna (2003) describe small open economies without a detailed structure of the rest of the world economy. Devereux (2003)<sup>21</sup> relaxes a number of assumptions present in our model: he allows for rigidities in labour market, incomplete asset structure and introduces two production factors: mobile labour and immobile capital. However the traded good sector is more restrictively set: it is assumed to be perfectly competitive with prices fixed internationally. Consumers can choose only between nontraded goods and import goods (with internationally fixed prices). The model of Natalucci and Ravenna (2003) differs from Devereux (2003) in a number of assumptions: importantly export goods can be consumed also internally and there is a limited substitutability between foreign and home traded goods, labour market is perfectly

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<sup>19</sup>This feature is common for the Central and Eastern European countries. The share of foreign imported consumption goods is very low amounting to 32% of the tradable consumption (see the section: data on the accession countries of the Appendix).

<sup>20</sup>According to Goldberg (2005) in 2003 differentiated products accounted for 62-83% of the accession country exports. Organized exchange traded goods (often priced in dollars) amounted to less than 8% of the total exports in these countries. Finally reference priced goods are between 15 to 30% of the accession country exports.

<sup>21</sup>The model used in this paper is based on Devereux, Lane (2003).

competitive. In both papers there is put a special attention on productivity shocks in the domestic traded good sector which lead to a real exchange rate appreciation and higher inflation (the Balassa - Samuelson effect). Subsequently the authors study how different monetary regimes perform in absorbing these shocks. Devereux (2003) finds out that flexible inflation targeting with some weight on exchange rate stability proves to be the best policy responding to two (specific to these countries) types of shocks: changing country risk - premia and productivity rises in domestic export sector.<sup>22</sup> This policy prevents from excessive inflation present under fixed regime and recession with reduction in employment appearing under CPI inflation targeting. Similarly according to Natalucci and Ravenna (2003) under a fixed or managed exchange rate regime productivity increases in tradable sector can lead to excessive inflation.

In addition the model of Laxton and Pesenti (2003) presents in a very rich structure a small accession economy and its interdependence relation with the big economy, the euro area. The authors focus their study on how different interest rate rules perform in stabilising variability of inflation and output of the small economy. Other papers which develop small open economy models with two sectors are Soto (2003) and Devereux, Lane and Xu (2004). The latter examines the importance of the exchange rate pass through in the choice of monetary regime when the economy is hit by terms of trade shocks and world interest rate shocks. Soto (2003) studies the implications of the existence of the rigidities in both traded and nontraded sector for the monetary policy choice in the small open economy.

As far as the structure of our model is concerned we include some realistic assumptions not present jointly in the previous papers on the accession economies, namely: a nonhomogeneous tradable sector, market power in both domestic sectors, home bias and imperfect pass through. Moreover on the contrary to the above listed papers in which only chosen shocks are discussed, we examine how the variability of the economy is affected by the set of the following internal and external (demand and supply side) shocks:

- supply: productivity shocks in traded and nontraded good sector both in the domestic economy and abroad,
- demand: government expenditure shocks in nontraded and trade good sector both in the domestic economy and abroad, changes in the distortionary taxes both in the domestic economy and abroad.

This analysis enables us to answer the question on the relative importance of each of the shocks in destabilizing the economy. Importantly we perform a policy experiment consisting in analyzing the effects of the chosen monetary regime on the way the accession economy responds to the shocks. In particular we study the implications of the four monetary regimes which can reflect roughly the choices in the CEE and SEE countries, i.e.:

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<sup>22</sup>However the author stresses that if one wants to incorporate into the discussion the role of liability dollarization and balance sheet effects then the fixed regime seems to be more appropriate.



- a fixed exchange rate regime (a strict peg to the currency of the big country, suitable for the description of e.g. Bulgaria, Latvia, Lithuania),
- a flexible exchange rate regime in which the monetary rule stabilises CPI inflation (e.g. Poland),
- a managed float exchange rate regime in which the monetary rule stabilises CPI inflation and nominal exchange rate (e.g. the Czech Republic, Hungary, Slovakia, Slovenia).

Moreover we analyze the role of the chosen structural parameters of the economy such as degree of openness, degree of elasticity of substitution between home and foreign goods, share of nontradables and degree of exchange rate pass-through in affecting volatility of the domestic economy under each of the studied regimes.

### 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 non-traded 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 non-traded goods. 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: non-traded, domestic traded and foreign traded goods. Foreign households are indexed with  $i^*$ .  $C_s^i$  represents consumption at period  $s$  of a consumer  $i$  and  $L_s^i$  stands for his labour supply. Each agent  $i$  maximizes the following utility function:<sup>23</sup>

$$\max E_t \left\{ \sum_{s=t}^{\infty} \beta^{s-t} [U(C_s^i) - V(L_s^i)] \right\} \quad (1)$$

where  $E_t$  denotes the expectation conditional on the information set at date  $t$ ,  $\beta$  is the intertemporal discount factor and  $0 < \beta < 1$ ,  $U(\cdot)$  stand for flows of utility from consumption and  $V(\cdot)$  represents flows of disutility from supplying labour.<sup>24</sup>  $C$  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 ( $C_{N,t}$ ):

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

<sup>23</sup>We assume specific functional forms of the consumption utility  $U(C_s^i)$ , and disutility from labour  $V(L_s^i)$ :  $U(C_s^i) \equiv \frac{(C_s^i)^{1-\rho}}{1-\rho}$ ,  $V(L_s^i) \equiv \varphi_l \frac{(L_s^i)^{1+\eta}}{1+\eta}$  with  $\rho$  ( $\rho > 0$ ) - the inverse of the intertemporal elasticity of substitution in consumption and  $\eta$  ( $\eta \geq 0$ ) - the inverse of the labour supply elasticity.

<sup>24</sup>In general we assume that  $U$  is twice differentiable, increasing and concave in  $C_t$  and  $V$  is twice differentiable, increasing and convex in  $L_t$ .

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

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

where  $\theta > 0$  is elasticity of substitution between home traded and foreign traded goods,  $\nu$  - home bias being the function of the relative size of the small economy with respect to the euro area and its degree of openness  $\lambda$  such that  $(1-\nu) = (1-n)\lambda$  and  $\lambda \in (0, 1]$ .<sup>25</sup> 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.

Similarly we can write the consumption aggregator for the big economy (the euro area):

$$C_t^* \equiv \left[ \mu^* \frac{1}{\phi^*} C_{N^*,t}^{\frac{\phi^*-1}{\phi^*}} + (1-\mu^*) \frac{1}{\phi^*} C_{T^*,t}^{\frac{\phi^*-1}{\phi^*}} \right]^{\frac{\phi^*}{\phi^*-1}} \quad (4)$$

$$C_{T^*,t} \equiv \left[ \nu^* \frac{1}{\theta^*} C_{t,H^*}^{\frac{\theta^*-1}{\theta^*}} + (1-\nu^*) \frac{1}{\theta^*} C_{t,F^*}^{\frac{\theta^*-1}{\theta^*}} \right]^{\frac{\theta^*}{\theta^*-1}} \quad (5)$$

where  $\nu^* = n\lambda$ .

Finally  $C_j$  and  $C_{j^*}$  (where  $j = H, H^*, N$  and  $j^* = F, F^*, N^*$ ) are consumption sub-indices of the continuum of differentiated goods:

$$C_{j,t} \equiv \left[ \left( \frac{1}{n} \right)^{\frac{1}{\sigma^j}} \int_0^n c_t(j)^{\frac{\sigma^j-1}{\sigma^j}} dj \right]^{\frac{\sigma^j}{\sigma^j-1}}, C_{j^*,t} \equiv \left[ \left( \frac{1}{1-n} \right)^{\frac{1}{\sigma^{j^*}}} \int_n^1 c_t(j^*)^{\frac{\sigma^{j^*}-1}{\sigma^{j^*}}} dj^* \right]^{\frac{\sigma^{j^*}}{\sigma^{j^*}-1}} \quad (6)$$

where  $\sigma^j > 1$ ,  $\sigma^{j^*} > 1$  are elasticities of substitution between domestic goods in each country.<sup>26</sup>

The consumption - based price indices expressed in the units of currency of the respective country are the following ones:

$$P_t \equiv \left[ \mu P_{N,t}^{1-\phi} + (1-\mu) P_{T,t}^{1-\phi} \right]^{\frac{1}{1-\phi}} \quad (7)$$

$$P_{T,t} \equiv \left[ \nu P_{H,t}^{1-\theta} + (1-\nu) P_{F,t}^{1-\theta} \right]^{\frac{1}{1-\theta}} \quad (8)$$

<sup>25</sup>This specification is based on de Paoli (2004). Moreover we exclude the situation where  $\lambda = 0$  for which the economy is closed.

<sup>26</sup>We assume later for simplicity in our benchmark model that:  $\mu = \mu^*$ ,  $\phi = \phi^*$ ,  $\theta = \theta^*$  and  $\sigma^{j^*} = \sigma$  where  $j = N, H, H^*, N^*, F, F^*$ .

$$P_t^* \equiv \left[ \mu^* P_{N,t}^{*1-\phi^*} + (1-\mu^*) P_{T,t}^{*1-\phi^*} \right]^{\frac{1}{1-\phi^*}} \quad (9)$$

$$P_{T,t}^* \equiv \left[ \nu^* P_{H,t}^{*1-\theta^*} + (1-\nu^*) P_{F,t}^{*1-\theta^*} \right]^{\frac{1}{1-\theta^*}} \quad (10)$$

with

$$P_{j,t} \equiv \left[ \left( \frac{1}{n} \right) \int_0^n p_t(j)^{1-\sigma^j} dj \right]^{\frac{1}{1-\sigma^j}}, P_{j^*,t} \equiv \left[ \left( \frac{1}{1-n} \right) \int_n^1 p_t(j^*)^{1-\sigma^{j^*}} dj^* \right]^{\frac{1}{1-\sigma^{j^*}}} \quad (11)$$

Both the existence of the nontradable goods and assumed home bias cause the deviations from purchasing power parity. So  $P \neq SP^*$ . 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 ratio of nontradable to tradable goods' prices as  $T^d = \frac{P_N}{P_T}$ .

From consumers' preferences we can derive total demand of the generic goods -  $n$  (home nontradables),  $h$  (domestic tradables),  $f$  (foreign tradables):

$$y^d(n) = \left[ \frac{p(n)}{P_N} \right]^{-\sigma^N} \left\{ \left[ \frac{P_N}{P} \right]^{-\phi} \mu C + G_N \right\} \quad (12)$$

$$y^d(n^*) = \left[ \frac{p(n^*)}{P_N^*} \right]^{-\sigma^{N^*}} \left\{ \left[ \frac{P_N^*}{P^*} \right]^{-\phi^*} \mu^* C^* + G_N^* \right\} \quad (13)$$

$$y^d(h) = \left[ \frac{p(h)}{P_H} \right]^{-\sigma^H} \left\{ \left[ \frac{P_H}{P_T} \right]^{-\theta} \nu C_T + G_H \right\} + \quad (14)$$

$$+ \left[ \frac{p^*(h)}{P_H^*} \right]^{-\sigma^{H^*}} \left( \frac{P_H^*}{P_T^*} \right)^{-\theta^*} \frac{\nu^*(1-n)}{n} C_T^* \quad (15)$$

$$y^d(f) = \left[ \frac{p(f)}{P_F} \right]^{-\sigma^F} \left[ \frac{P_F}{P_T} \right]^{-\theta} \frac{(1-\nu)n}{1-n} C_T + \quad (16)$$

$$+ \left[ \frac{p^*(f)}{P_F^*} \right]^{-\sigma^{F^*}} \left\{ \left[ \frac{P_F^*}{P_T^*} \right]^{-\theta} (1-\nu^*) C_T^* + G_F^* \right\} \quad (17)$$

where  $G_N, G_N^*, G_H, G_F^*$  are the government expenditure shocks occurring both in nontraded and traded good sectors in each economy.

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:

$$L_s^i = L_s^{i,H} + L_s^{i,N} \quad (18)$$

$$L_s^{i*} = L_s^{i*,F} + L_s^{i*,N^*} \quad (19)$$

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

$$P_{T,s}C_{T,s}^i + P_{N,s}C_{N,s}^i + E_s\{Q_{s,s+1}D_{s+1}\} \leq D_s + P_s TR_s^i + W_{H,s}^i L_{H,s}^i + W_{N,s}^i L_{N,s}^i + \frac{\int_0^n \Pi_{N,s}^i di}{n} + \frac{\int_0^n \Pi_{H,s}^i di}{n} \quad (20)$$

where at date  $s$ :  $D_{s+1}$  - nominal payoff of the portfolio held at the end of period ( $s$ ),  $Q_{s,s+1}$  - the stochastic discount factor for one-period ahead nominal payoffs relevant to the domestic household,  $\Pi_{H,s}$  and  $\Pi_{N,s}$  - nominal profits from the domestic firms and  $TR_s^i$  - nominal lump sum transfers from the domestic government to the household  $i$ . The similar budget constraint can be written for the euro area. Moreover in both countries consumers face no Ponzi game restriction.

The short term interest rate is defined as the price of the portfolio which delivers one unit of currency in each contingency that occurs next period:

$$\frac{1}{1+i_s} = E_s\{Q_{s,s+1}\} \quad (21)$$

Both economies are cashless - limiting monetary ones (as in Woodford (2003)).

The maximization problem of any household consists in maximizing (1) to (20) 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. Optimization of the portfolio holdings leads to the following Euler equations for the accession country and the euro area:

$$U_C(C_t) = \beta E \left\{ U_C(C_{t+1}) Q_{t,t+1}^{-1} \frac{P_t}{P_{t+1}} \right\} \quad (22)$$

$$U_C(C_t^*) = \beta \left\{ U_C(C_{t+1}^*) Q_{t,t+1}^{-1} \frac{S_t P_t^*}{S_{t+1} P_{t+1}^*} \right\} \quad (23)$$

There is a perfect sharing in this setting meaning that marginal rates of consumption in nominal terms are equalized between countries in all states and at all times:

$$\frac{U_C(C_{t+1}^*)}{U_C(C_t^*)} \frac{P_{t+1}}{P_t} = \frac{U_C(C_{t+1})}{U_C(C_t)} \frac{S_{t+1} P_{t+1}^*}{S_t P_t^*} \quad (24)$$

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

$$\frac{U_C(C_t)}{U_C(C_t^*)} = v \frac{P_t}{S_t P_t^*} \quad (25)$$

where  $v > 0$  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 different shocks.

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

$$\frac{W_t^k(i)}{P_t} = \frac{V_L(L_t^i)}{U_C(C_t^i)} \quad (26)$$

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

## 3.2 Firms

All the firms are owned by the consumers. Both tradable and nontradable sectors are monopolistically competitive. As far as the traded goods are concerned (both domestic and foreign ones) we assume price discrimination between domestic market and a foreign one.

Since firms use only labour as their output the production function for firm  $i$  in  $k$  ( $k = H, F, N$ ) sector is the following one:

$$Y_{k,t}(i) = A_t^k L_t^k(i) \quad (27)$$

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

$$MC_t^k(i) = \frac{W_t^k(i)}{A_t^k} \quad (28)$$

We take the domestic economy as the representative one in which firms in nontraded and traded sector optimize prices.

### 3.2.1 Nontraded sector

Price is set according to Calvo pricing scheme. Each period a fraction of firms  $(1 - \alpha_N)$  decides their price maximizing the expected profits. The price law of motion is given by the following equation:

$$P_{N,t}^{1-\sigma^N} = \alpha_N (P_{N,t-1})^{1-\sigma^N} + (1 - \alpha_N) \tilde{P}_{N,t}^{1-\sigma^N}(i) \quad (29)$$

where  $\tilde{P}_{N,t}(i)$  is the price chosen as a result of the maximization problem. Loglinearization of (29) around the steady state gives the following relation:

$$\hat{q}_{N,t} = \frac{\alpha_N}{1 - \alpha_N} \pi_{N,t} \quad (30)$$

where  $\hat{q}_{N,t} = \ln \frac{\tilde{P}_{N,t}(i)}{P_{N,t}}$ . The maximization problem of any firm in the nontraded sector at time  $t$  is given by:

$$\max_{P_{N,t}(i)} E_t \sum_{s=0}^{\infty} (\alpha_N)^s Q_{t,t+s} [(1 - \tau_{t+s}) P_{N,t}(i) - MC_{t+s}^N(i)] Y_{N,t:t+s}^d(i) \quad (31)$$

$$\text{subject to } Y_{N,t:t+s}^d(i) = \left( \frac{P_{N,t}(i)}{P_{N,t+s}} \right)^{-\sigma^N} Y_{N,t+s} \quad (32)$$

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

The corresponding first order condition for the above maximization problem is:

$$\frac{\tilde{P}_{N,t}(i)}{P_{N,t}} = \frac{\sigma^N}{\sigma^N - 1} \frac{E_t \sum_{s=0}^{\infty} (\alpha_N \beta)^s (C_{t+s})^{-\rho} Y_{N,t+s} MC_{t+s}^{N,r}(i) \left( \frac{P_{N,t+s}}{P_{N,t}} \right)^{\sigma^N}}{E_t \sum_{s=0}^{\infty} (\alpha_N \beta)^s (C_{t+s})^{-\rho} (1 - \tau_{t+s}) \frac{P_{N,t+s}}{P_{t+s}} Y_{N,t+s} \left( \frac{P_{N,t+s}}{P_{N,t}} \right)^{\sigma^N - 1}} \quad (33)$$

where  $\tilde{P}_{N,t}(i)$  - the optimal price and  $MC_{t+s}^{N,r}(i) = \frac{W_{t+s}^N(i)}{P_{t+s} A_{t+s}^N} = \frac{\varphi_L L_{t+s}^\eta(i) C_{t+s}^\rho(i)}{A_{t+s}^N}$ .

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

$$\frac{\tilde{P}_{N,t}(i)}{P_{N,t}} = \frac{\sigma^N}{(\sigma^N - 1)(1 - \tau_t)} MC_t^{N,r} \frac{P_t}{P_{N,t}} \quad (34)$$

In the sticky price environment we obtain the nontraded inflation equation (as a result of the loglinearisation of (33) around the steady state defined in the appendix):

$$\hat{\pi}_{N,t} = k_N (-\hat{A}_t^N + \hat{\omega}_t + w \hat{\tau}_t - (1 - \mu) \hat{T}_t^d) + \beta E_t \hat{\pi}_{N,t+1} \quad (35)$$

where  $w = \frac{\bar{\tau}}{1 - \bar{\tau}}$ ,  $k_N = \frac{(1 - \alpha_N \beta)(1 - \alpha_N)}{\alpha_N}$  ( $\bar{\tau}$  is a steady state ratio of taxes in the aggregate output).

The equation (35) represents the new - Keynesian Phillips curve for the domestic nontraded sector. According to this equation the nontraded inflation is driven by changes in the real marginal cost which are represented by:  $(-\hat{A}_t^N + \hat{\omega}_t + w \hat{\tau}_t - (1 - \mu) \hat{T}_t^d)$ . Therefore we study the main determinants of the real marginal in this sector. Nontradable productivity shocks lead to a decline in the real marginal cost. Tax shocks and real wage increases result in the higher real marginal cost. Additionally a rise in the relative price of domestic nontradable goods to tradable goods generates a substitution effect away from the nontradable to tradable goods and decreases the real marginal cost. The magnitude of this effect depends inversely on the share of nontradables in the domestic consumption basket.

### 3.2.2 Traded sector

Traded goods' firms supply goods both to the home market and export to the rest of the world. Their pricing decision is based on the local currency pricing. Price is set according to Calvo pricing scheme. Each period a fraction of firms  $(1 - \alpha_H)$  decides the price maximising their expected profits subject to the demand schedule in a given market: foreign market and a domestic one (we can separate pricing decisions depending on the market as our production function is linear):

- domestic market

$$\max_{P_{H,t}(i)} E_t \sum_{s=0}^{\infty} (\alpha_H)^s Q_{t,t+s} [(1 - \tau_{t+s}) P_{H,t}(i) - MC_{t+s}^H(i)] Y_{H,t:t+s}^d(i) \quad (36)$$

$$\text{subject to } Y_{H,t:t+s}^d(i) = \left( \frac{P_{H,t}(i)}{P_{H,t+s}} \right)^{-\sigma^H} (C_{H,t+s} + G_{H,t+s}) \quad (37)$$

- foreign market

$$\max_{P_{H,t}^*(i)} E_t \sum_{s=0}^{\infty} (\alpha_H)^s Q_{t,t+s} [(1 - \tau_{t+s}) S_{t+s} P_{H,t}^*(i) - MC_{t+s}^H] Y_{H,t:t+s}^{*d}(i) \quad (38)$$

$$\text{subject to } Y_{H,t:t+s}^{*d}(i) = \left( \frac{P_{H,t}^*(i)}{P_{H,t+s}^*} \right)^{-\sigma^{*H}} Y_{H,t+s}^* \quad (39)$$

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

$$\frac{\tilde{P}_{H,t}}{P_t} = \frac{\sigma^H}{(\sigma^H - 1)(1 - \tau_t)} MC_t^{H,r} \quad (40)$$

$$\frac{\tilde{P}_{H,t}^*}{P_t^*} = \frac{\sigma^{*H}}{(\sigma^{*H} - 1)(1 - \tau_t)} MC_t^{H,r} \frac{1}{RS_t} \quad (41)$$

where  $MC_t^{H,r}(i) = \frac{W_t^H(i)}{P_t A_t^H}$ .

In the sticky price environment we obtain two sector inflation equations, i.e. home traded inflation  $\hat{\pi}_{H,t}$  and export traded inflation  $\hat{\pi}_{H,t}^*$  (after loglinearization around the steady state):

$$\hat{\pi}_{H,t} = k_H (-\hat{A}_t^H + \hat{\omega}_t + w\hat{\tau}_t + \mu\hat{T}_t^d + (1 - \nu)\hat{T}_t) + \beta E_t \hat{\pi}_{H,t+1} \quad (42)$$

$$\hat{\pi}_{H,t}^* = k_H^* (-\hat{A}_t^H + \hat{\omega}_t - \hat{RS}_t + w\hat{\tau}_t + (1 - \nu^*)\hat{T}_t^* + \mu^*\hat{T}_t^{*d}) + \beta E_t \hat{\pi}_{H,t+1}^* \quad (43)$$

where  $k_H = \frac{(1-\alpha_H\beta)(1-\alpha_H)}{\alpha_H}$ ,  $k_H^* = \frac{(1-\alpha_H\beta)(1-\alpha_H)}{\alpha_H}$ .

It is interesting to analyze the determinants of the real marginal costs for the domestic tradable good sector and for the export sector since they are the driving forces of the changes in the sector inflations. The real marginal cost in the domestic tradable good sector depends positively on the tax shocks and wage changes. Tradable productivity shocks decrease the real marginal cost. Moreover we observe also the effects of movements in the relative prices on the real marginal cost. Both a rise in the ratio of nontradable to tradable prices and a rise in terms of trade (the ratio of foreign tradable to home tradable prices) result in substitution effect towards home tradable prices making the real marginal cost increase. The magnitude of this change depends inversely on respective shares of home tradables in the aggregate and tradable consumption basket. As far as the export sector of home tradables is concerned we also notice that changes in the real exchange rate affect the real marginal cost. In particular when we observe a real exchange rate depreciation then through the expenditure switching effect there is an increase in output of tradables leading to a decrease in the real marginal cost.

Similarly we can derive the optimal prices for the both markets of the foreign traded good sector.

### 3.3 Monetary and fiscal policies

There exist governments in both economies which occupy with collecting revenue taxes and finance government expenditures in the domestic traded and nontraded sector. We allow for lump sum taxation which serves to balance the budget in each period:

$$\int_0^n \tau_t (P_{H,t}(i)Y_{H,t}(i) + P_{N,t}(i)Y_{N,t}(i)) di = \int_0^n (P_{H,t}(i)G_{H,t}(i) + P_{N,t}(i)G_{N,t}(i)) di + \int_0^n TR_t^j dj \quad (44)$$

$$\int_0^{1-n} \tau_t^* (P_{H,t}(i^*)Y_{H,t}(i^*) + P_{N,t}(i^*)Y_{N,t}(i^*)) di^* = \int_0^{1-n} (P_{H,t}(i^*)G_{H,t}(i^*) + P_{N,t}(i^*)G_{N,t}(i^*)) di^* + \int_0^{1-n} TR_t^{*j} dj^* \quad (45)$$

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 output subsidy in the steady state so that output in the flexible price equilibrium is efficient.<sup>27</sup>

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<sup>27</sup>We set the steady state ratio of taxes to be  $\bar{\tau} = -\frac{1}{\sigma-1}$ .



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

$$1 + \tilde{i}_{t+1} = \left( \frac{Y_t}{Y_t^n} \right)^{\mu_y} \left( \frac{\pi_t}{\bar{\pi}} \right)^{\mu_\pi} \left( \frac{S_t}{\bar{S}} \right)^{\mu_S} (1 + \bar{i}) \quad (46)$$

where  $\mu_y$ ,  $\mu_\pi$ ,  $\mu_S$  are the feedback coefficients to output gap ( $Y_t^n$  is the natural level of output obtained from equilibrium under flexible prices), 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),  $\bar{i}$  - the steady state value of the nominal interest rate. We also assume the interest rate smoothing:

$$(1 + i_{t+1}) = (1 + \tilde{i}_{t+1})^{1-\kappa} (1 + i_t)^\kappa \varepsilon_{t+1}^{mp} \quad (47)$$

where  $\kappa$  - the rate of interest rate smoothing,  $\varepsilon_{t+1}^{mp}$  - the monetary policy shock (exogenous). The loglinearised version of equation (46) around the steady state is the following:

$$\hat{R}_t = \mu_y(1 - \kappa)\hat{y}_t + \mu_\pi(1 - \kappa)\hat{\pi}_t + \mu_S(1 - \kappa)\hat{S}_t + \kappa\hat{R}_{t-1} + \hat{\varepsilon}_t^{mp} \quad (48)$$

where  $\hat{R}_t = \ln \frac{1+i_t}{1+\bar{i}}$ ,  $\hat{y}_t$  - output gap, i.e.  $\hat{y}_t = \ln \frac{Y_t}{Y_t^n}$ .

## 4 Macroeconomic volatility in the long run

As we already discussed, the catch up process of accession economies from the centrally planned economy to the market one can be characterized by a rapid productivity growth, much higher than in the euro area, and also by a strong rise in public investment reflected in infrastructure improvements. These two shocks both on the supply and demand side of the economy, together with external shocks occurring in the euro area, affect the variability of accession economies. Researchers especially point at the importance of productivity increases and their effect on accession economies. Indeed in papers of Devereux (2003) and Natalucci and Ravenna (2003) positive supply side shocks occurring especially in traded good sector in the accession countries lead to the Balassa - Samuelson effect. However this effect can be achieved if we impose quite a restrictive set of assumptions: mobility of labour and capital across sectors, mobility of capital internationally, constant returns to scale in the mobile factors, exogenous world interest rate, perfect competition in the goods' sector. Since we abandon some of these assumptions, i.e. mobility of capital and also perfect competition in the tradable sector, in our modelling framework we can expect that the Balassa - Samuelson effect will not be strong.

We study first the long run characteristics of our model (the flexible price economy)<sup>28</sup> by putting a special attention on the real exchange rate dynamics. We solve the model by taking first

<sup>28</sup>The flexible price environment allows for an analytical solution and subsequently finding the determinants of fluctuations for each variable. Importantly the flexible price equilibrium can be considered as a kind of the long run equilibrium towards which the sticky price economy converges.

order approximation around the deterministic steady state where the shocks take constant values.<sup>29</sup> The solution of this log-linearised model will provide us with the representation of the variables as functions of the domestic and foreign shocks.

In particular combining log-linearised around the steady state domestic and Euler equations and international risk sharing condition ((22), (23), (25)) we obtain that the real exchange rate is a function of the current and future real interest rate differentials between home and foreign economy:

$$\widehat{RS}^n_t = \rho \widehat{C}^n_t{}^R = E_t \sum_{i=0}^{\infty} \left[ \widehat{RR}^{n*}_{t+i} - \widehat{RR}^n_{t+i} \right] \quad (49)$$

where  $\widehat{RR}^n_t, \widehat{RR}^{n*}_t$  - log-linearised deviations from the steady state of the domestic and foreign real interest rate in the flexible price model,  $\widehat{C}^n_t{}^R = \widehat{C}^n_t - \widehat{C}^{n*}_t$  - log-linearised deviations from the steady state of the consumption differences between two countries.<sup>30</sup> Subsequently the current and future real interest rate differentials are summarized by the current consumption differential between two countries which depends on the productivity shocks in both countries and changes in the terms of trade:

$$\widehat{C}^n_t{}^R = -\frac{\mu}{\rho} (\widehat{A}_t^{T,R} - \widehat{A}_t^{N,R}) + \frac{1 + \lambda(\mu - 1)}{\rho} \widehat{T}_t^n \quad (50)$$

where  $\widehat{A}_t^{T,R}, \widehat{A}_t^{N,R}$  - the relative productivity shocks. Similarly we can represent the real exchange rate as the function of the relative prices:

$$\widehat{RS}^n_t = -\mu \widehat{T}_t^{n,d,R} + (1 - \lambda) \widehat{T}_t^n \quad (51)$$

where  $\widehat{T}_t^{n,d,R} = \widehat{T}_t^{n,d} - \widehat{T}_t^{n,d*}$ . Subsequently the relative prices can be represented as functions of the set of the domestic and foreign shocks:

$$\widehat{T}_t^{n,d,R} = \widehat{A}_t^{T,R} - \widehat{A}_t^{N,R} - \lambda \widehat{T}_t^n \quad (52)$$

$$\begin{aligned} \chi \widehat{T}_t^n = & \frac{\eta}{2} (\widehat{g}_{N,t}^R + \widehat{g}_{T,t}^R) + w \widehat{\tau}_t^R + \frac{\eta}{2} (\phi(\mu(2 - \lambda) - 1) + \frac{\mu}{\rho}(-2 + \lambda) - \frac{2}{\eta} - 1) \widehat{A}_t^{T,R} + \\ & - \frac{\eta}{2} (\phi(2\mu - \mu\lambda - 1) + \frac{\mu}{\rho}(-2 + \lambda) + 1) \widehat{A}_t^{N,R} \end{aligned} \quad (53)$$

where  $\chi = \left( -1 - \frac{\eta}{2} \left( (2 - \lambda) \frac{1 - \lambda(1 - \mu)}{\rho} + \theta\lambda(2 - \lambda) - \phi\lambda(1 + \mu(\lambda - 2)) \right) \right)$ ;  $\widehat{g}_{N,t}^R, \widehat{g}_{T,t}^R, \widehat{\tau}_t^R$  - the relative government expenditure shocks and tax shocks.<sup>31</sup>

<sup>29</sup>For the purpose of the following derivation we assume that two countries are symmetric in their structural parameters except for the size. Moreover we assume that the government expenditures equal zero in the steady state.

<sup>30</sup>The superscript  $n$  stands for the flexible price economy variables.

<sup>31</sup> $\widehat{g}_{N,t}^R = \widehat{g}_{N,t} - \widehat{g}_{N,t}^*$ ,  $\widehat{g}_{T,t}^R = \widehat{g}_{H,t} - \widehat{g}_{F,t}^*$ ,  
 $\widehat{\tau}_t^R = \widehat{\tau}_t - \widehat{\tau}_t^*$ ,  $\widehat{A}_t^{T,R} = \widehat{A}_t^H - \widehat{A}_t^{F*}$ ,  $\widehat{A}_t^{N,R} = \widehat{A}_t^N - \widehat{A}_t^{N*}$

The equation (51) represents a useful platform to study the effects of the domestic tradable productivity shocks on the real exchange rate. When the domestic tradable productivity shock occurs we observe a rise in the ratio of domestic nontradable to tradable prices (domestic terms of trade). This effect leads to a real exchange rate appreciation. Moreover the higher the share of nontradables in the domestic economy this effect is stronger. However since home and foreign tradables in our model are assumed to be imperfect substitutes we can also observe movements in terms of trade in result of the domestic tradable productivity shock. As already studied by Benigno and Thoenisen (2003) higher productivity in the home tradable sector can actually lead to a lower price of home tradable goods in relation to foreign tradable goods which means worsening of terms of trade. The magnitude of the terms of trade movements depends inversely on the degree of substitution between home and foreign tradable goods. This effect leads to a real exchange rate depreciation. In addition it is stronger the smaller the degree of openness.<sup>32</sup>

Summing up in presence of the home tradable productivity shocks there are two opposing effects determining the real exchange rate adjustment. The final outcome depends on the degree of substitutability between home and foreign goods, share of nontradables and degree of openness. A recent empirical literature sheds some light on this uncertain effect of productivity shocks in the domestic tradable sector. In particular Arratibel et al. (2002)<sup>33</sup> report that inflation in the accession countries is negatively affected by labour productivity increases in the manufacturing sector<sup>34</sup>.

Notice that Devereux (2003) and Natalucci and Ravenna (2003) base their analyses on the assumption that home tradable prices are fixed internationally. This supposition is based on the argument that accession countries cannot affect their terms of trade. Subsequently terms of trade are treated exogenously and cannot act as transmitters or absorbers of the shocks. Prices of home tradable goods are not affected by domestic supply shocks. That is why in their framework we observe a real exchange rate appreciation and inflation as a result of the domestic tradable productivity shock.

Additionally the role of demand side shocks in the real exchange rate dynamics is absent in the papers of Devereux (2003) and Natalucci and Ravenna (2003). The flexible price equilibrium in our model illustrates the role of demand shocks occurring through the terms of trade movements (look at equations: (51), (52)). Interestingly (as analysed by Altissimo et al (2004)) there is no role for demand shocks in driving the dynamics of the real exchange rate once the home and foreign tradables are perfect substitutes, i.e.  $\theta \rightarrow \infty$ . In particular equation on the real exchange rate dynamics (51)

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<sup>32</sup>Notice that for the flexible price economy (with a symmetric steady state) if we assume that there is no home bias, i.e.  $\lambda = 1$ , then for a sufficiently high elasticity of substitution between home and foreign tradable goods, i.e.  $\theta > 1$  the productivity increases in the domestic tradable sector will always lead to domestic inflation and real exchange rate appreciation.

<sup>33</sup>Arratibel et al (2002) perform an panel study on determinants of dual inflation (in tradable and nontradable goods) in the following transition countries: Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. 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 rates, GDP, euro area GDP growth and terms of trade.

<sup>34</sup>In many empirical studies the sectoral productivity increases are proxied by labour productivity increases.

becomes:

$$\widehat{RS}_t^R = -\mu(\widehat{A}_t^{T,R} - \widehat{A}_t^{N,R}) \quad (54)$$

The equation (54) represents the Balassa - Samuelson effect in its original form. Since terms of trade do not move in result of the shocks real exchange rate and inflation movements are associated only with supply shocks. From the international risk sharing condition we obtain that consumption is also driven only by supply shocks:

$$\widehat{C}_t^R = -\frac{\mu}{\rho}(\widehat{A}_t^{T,R} - \widehat{A}_t^{N,R}) \quad (55)$$

As already discussed in Froot and Rogoff (1996) the demand shocks will affect only quantities of tradables and nontradables produced (a country' s consumption basket) and the aggregate output will not change:

$$\widehat{Y}_{N,t}^R = (-\phi(1 - \mu) - \frac{\mu}{\rho})(\widehat{A}_t^{T,R} - \widehat{A}_t^{N,R}) + d_G \widehat{g}_{N,t}^R \quad (56)$$

$$\widehat{Y}_{T,t}^R = -d_G \widehat{g}_{N,t}^R - 2\frac{w}{\eta} \widehat{\tau}_t^R + (\phi(1 - \mu) + \frac{\mu}{\rho} + \frac{2}{\eta} + 1)\widehat{A}_t^{T,R} + (\phi(\mu - 1) - \frac{\mu}{\rho} + 1)\widehat{A}_t^{N,R} \quad (57)$$

where  $\widehat{Y}_{N,t}^R = \widehat{Y}_{N,t} - \widehat{Y}_{N,t}^*$ ,  $\widehat{Y}_{T,t}^R = \widehat{Y}_{H,t} - \widehat{Y}_{F,t}^*$ ,  $\widehat{g}_{N,t}^R = \widehat{g}_{N,t} - \widehat{g}_{N,t}^*$ ,  $\widehat{\tau}_t^R = \widehat{\tau}_t - \widehat{\tau}_t^*$  and <sup>35</sup>

Summing up the real exchange rate and 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 and inflation respond to the shocks. These are: the degree of substitutability between home and foreign tradables, share of nontradables in aggregate consumption and degree of openness of the domestic economy.

## 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. Similarly to the flexible price environment the real exchange rate is a function of the current and future real interest rate differentials between both countries (see (22, 23), (25)):

$$\widehat{RS}_t = E_t \sum_{i=0}^{\infty} \left[ \left( \widehat{R}_{t+i}^* - \widehat{\pi}_{t+i+1}^* \right) - \left( \widehat{R}_{t+i} - \widehat{\pi}_{t+i+1} \right) \right] \quad (58)$$

The main difference between this equation and the one in the flexible price economy (49) consists

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<sup>35</sup>Notice that tax shocks will also affect the real wage, i.e.:  $\widehat{\omega}_t^R = (1 - \mu)\widehat{A}_t^{T,R} + \mu\widehat{A}_t^{N,R} - w\widehat{\tau}_t^R$ .

in the fact that in the flexible price economy the real interest rates are the functions of the shocks while in the sticky price environment they are formed by the chosen monetary regime.

Notice that 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. Observe that we can write the log - linearized (around the efficient steady state) Euler condition in terms of consumption gaps:

$$\widehat{Cgap}_t = \widehat{Cgap}_{t+1} - \frac{1}{\rho} \left( \widehat{R}_t - \widehat{\pi}_{t+i+1} - \widehat{RR}^n_t \right) \quad (59)$$

where:  $\widehat{Cgap}_t = \widehat{C}_t - \widehat{C}^n_t$ ,  $\widehat{C}^n_t$  - natural rate of consumption, i.e. the equilibrium consumption in the flexible price economy,  $\widehat{RR}^n_t$  - the natural real interest rate, i.e. the equilibrium interest rate in the flexible price economy. Interestingly performing infinite recursions on (59) we obtain that the current consumption gap differential is determined by current and future real interest rate gap differentials the sticky and flexible price environment:

$$\widehat{Cgap}_t = -E_t \sum_{i=0}^{\infty} \frac{1}{\rho} \left[ \left( \widehat{R}_{t+i} - \widehat{\pi}_{t+i+1} \right) - \widehat{RR}^n_{t+i} \right] \quad (60)$$

Additionally by combining equations (58) and (59) current real exchange rate can be represented as:

$$\widehat{RS}_t = E_t \sum_{i=0}^{\infty} \left[ \widehat{RR}^n_{t+i} - \widehat{RR}^n_{t+i} \right] + \rho \left( \widehat{Cgap}_t - \widehat{Cgap}_t^* \right) \quad (61)$$

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

Precisely if the real interest rates were above the natural ones in the domestic economy then this would have an additional appreciation effect on the current real exchange rate which can be 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 can be associated with inflation or/and nominal depreciation of the currency.

## 6 Monetary regimes comparison

In order to perform the simulation exercise aimed at comparison of the monetary regimes we follow a standardized parametrization. Let us note that for this benchmark case we set the majority

of parameters to be the same in both economies. In the section regarding the sensitivity analysis we will discuss the impact of some of the structural parameters on the monetary regimes comparison.

Importantly we set the size of the small country,  $n$ , to 1%. The degree of openness of the small country,  $\lambda$ , is assumed to be 0.5 which implies that the imported consumption constitutes for around 50% of the tradable consumption.<sup>36</sup> The steady state ratio of government expenditures to sector output is assumed to be 10% following the supposition of Natalucci and Ravenna (2003). As we already said earlier we set the steady state tax ratio to a value that offsets the monopolistic distortions in the flexible price equilibrium.

The discount factor,  $\beta$ , 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,  $\rho$ , is set to 2. As in Laxton and Pesenti (2003) we assume that inverse of labour supply elasticity is equal to 2.5. The elasticity of substitution between tradable and nontradable consumption,  $\phi$ , is set to 0.5 as in Stockman and Tesar (1995) and the elasticity of substitution between home and foreign tradables,  $\theta$ , is assumed to be 1.5 following Backus et al (1995). The elasticity of substitution for goods within a sector,  $\sigma$ , is assumed to be 7.88 as in Rotemberg and Woodford (1997) which implies a 15% markup. Probability of not changing the price,  $\alpha$ , for all the sectors in both economies is set to 0.85. This parameter is taken from Smets and Wouters (2003) who calibrate their model to the euro area data and Natalucci and Ravenna (2003)<sup>37</sup> who choose this value for the CEE countries. Lastly the share of nontradables in the aggregate consumption,  $\mu$ , is assumed to be 0.5. This value is in line with Benigno and Thoenisen (2003) for the euro area and Natalucci and Ravenna (2003) for the CEE countries.

As far as the monetary policy is concerned the different monetary regimes are distinguished by the specific values assigned to the feedback coefficients in the monetary rule (see (48)). In particular:

- a fixed exchange rate regime (a strict peg to the currency of the big country) is described as the monetary rule with  $\mu_y = 0$ ,  $\mu_\pi = 0$ ,  $\mu_S \rightarrow \infty$ ,
- a flexible exchange rate regime in which the monetary rule stabilises CPI inflation is described as the monetary rule with  $\mu_y = 0$ ,  $\mu_\pi \rightarrow \infty$ ,  $\mu_S = 0$ ,
- 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  $\mu_y = 0$ ,  $\mu_\pi = 2$ ,  $\mu_S = 0.025$ .<sup>38</sup>

In addition the monetary rule is characterised by the interest rate smoothing, namely  $\kappa = 0.8$ . Let us remark that the foreign economy follows the Taylor rule with the feedback coefficients:  $\mu_y = 0.2$ ,

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<sup>36</sup>The value of this parameter is chosen in a fairly arbitrary way but later in the sensitivity analysis we discuss the implications of the changing value of this parameter on the performance of the monetary regimes. Still this value is consistent with Natalucci and Ravenna (2003).

<sup>37</sup>They argue that the existence of a high share of regulated prices in the CEE and SEE countries justifies such a high value of price stickiness.

<sup>38</sup>The specific values of the feedback coefficients are taken from Natalucci and Ravenna (2003).

$\mu_\pi = 2$ ,  $\mu_S = 0$  which is in line with the empirical findings of Smets and Wouters (2003) for the euro area.<sup>39</sup>

We impose some simplifying assumptions on the nature of the shocks. All the shocks except for monetary policy shocks follow an AR(1) process with the standard deviation of 1% and autocorrelation coefficient 0.9, they are not correlated with each other. Monetary policy shocks are white noise shocks with the standard deviation of 1%.<sup>40</sup>

Based on the theoretical discussion in the previous sections we decide to analyze performance of the monetary regimes in response to the foreign and domestic shocks by observing the evolution of consumption gap which summarises the stabilization pattern of each of the regimes and also the three variables constituting for the Maastricht convergence criteria, i.e.: nominal interest, aggregate inflation and nominal exchange rate.

## 6.1 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 under all the regimes considered and also the flexible price economy. Next we identify the sources of differences in the response of each of the regimes by analyzing behaviour of the consumption gap (see 61).

### 6.1.1 Domestic supply shocks

First we examine the effects of domestic productivity shocks in both sectors (see Figure 1 in the appendix). Both productivity shocks result in the real exchange rate depreciation under all the regimes and the flexible price economy. 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.

Importantly the magnitude of the real exchange rate depreciation differs for the two shocks analyzed. This can be easily understood by observing the changes in relative prices.(see 51). Productivity shocks in the nontradable sector lead to a decline in the ratio of nontradable to tradable prices and a rise in terms of trade. Both changes have a depreciation effect on the real exchange rate. On the other hand productivity shocks in the tradable 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 (59), (61)). Since the productivity shocks entail deflationary pressures

<sup>39</sup>Smets and Wouters (2003) estimate that  $\mu_y = 0.14$ ,  $\mu_\pi = 1.65$  with the interest rate smoothing parameter  $\kappa = 0.95$ .

<sup>40</sup>Natalucci and Ravenna (2003) assume that productivity shocks in the small country are perfectly correlated. Moreover their standard deviations are 2% for the tradable good productivity and 1,8% for the nontradable good productivity. The autocorrelation is assumed to be 0.85. Moreover they estimate based on the Czech Republic data that the government spending on nontradable goods follows an AR(1) process with the standard deviation of 2.42% and autocorrelation of 0.7. The monetary policy shock is assumed to be a white noise with the standard deviation of 0.6%.

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 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.<sup>41</sup> 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. The managed float is characterized by the intermediate responses: we observe both deflation and some fluctuations of the nominal exchange rate: depreciation followed by a small appreciation.<sup>42</sup>

Interestingly comparison of the consumption gaps among the regimes reveals that productivity shocks occurring in the tradable sector require more stabilization of the nominal exchange rate. On the other hand productivity shocks originating in the nontradable sector require more stabilization of the aggregate inflation. (see Table 1 in the Appendix)<sup>43</sup>

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. These opposite results are due to the fact that in our setting the domestic supply shocks lead to the real exchange rate depreciation and deflationary pressures.

### 6.1.2 Domestic demand shocks

Now we analyze the response of the economy to the government expenditure shocks in both sectors and also tax shock (see Figure 3 in the appendix). The government expenditure shocks lead to the crowding out effect resulting in the domestic aggregate consumption decline. Natural rate of interest increases which effects in the real exchange rate appreciation. An additional government demand in one of the sectors increases the sector output and subsequently leads to a rise in real wages and higher real marginal cost. Tax shocks directly increase the real marginal cost leading to a lower domestic aggregate output and consumption. As a result under all the domestic demand shocks terms of trade improve and the ratio of nontradable to tradable prices increases.

We identify the differences between the alternative regimes by examining the behavior of the

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<sup>41</sup>Benigno and Benigno (2004) study in detail the nominal exchange rate determination under the interest rate rules. They find that the 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.

<sup>42</sup>As discussed in Benigno and Benigno (2004) productivity shocks under the flexible exchange rate regimes lead to a rise in terms of trade and the depreciation of the nominal exchange rate followed by the appreciation. The magnitude of both effects depends on the aggressiveness of the monetary rule towards inflation. In the limiting case - under CPI targeting we observe only a short run effect. Similarly under the managed exchange rate regimes we observe a deflation followed by a small inflation. The magnitude of the effects depend on the aggressiveness of the regime towards the exchange rate.

<sup>43</sup>This is due to the fact that natural rate of interest decreases much more under the domestic nontradable productivity shock than under the domestic tradable productivity shock.



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 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 features intermediate responses and is characterized by the smallest consumption gap. (see Table 2 in the Appendix)

Notice 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 in Devereux (2003) and Natalucci and Ravenna (2003) for the domestic tradable productivity shocks.

### 6.1.3 Foreign shocks

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 a decrease in the foreign consumption and an increase in the foreign real interest rate.<sup>44</sup> A change in the foreign consumption leads to a change of the same sign in the domestic aggregate consumption. 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.<sup>45</sup> As a result the domestic natural rate of interest changes to a lesser extent than the foreign one.

Importantly the peg regime totally accommodates all the foreign shocks by setting the same nominal interest as the foreign one which leads to a high volatility in the domestic variables (see Figure 7 in the appendix). This means that we observe a significant deflation and a positive consumption gap in result of the foreign supply shocks and inflation together with a negative consumption gap in result of the foreign demand shocks. The flexible exchange rate regimes choose a different 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 in result of the foreign supply shocks and a positive consumption gap in the case of the foreign demand shocks.

Interestingly comparison of the consumption gaps reveals that a total stabilization of the nominal exchange rate guarantees the smallest consumption gap for almost all the foreign shocks. However

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<sup>44</sup>The mechanisms of the effects of the foreign shocks on the foreign variables are equivalent to the ones explained in the previous subsections.

<sup>45</sup>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.

the smallest consumption gap for the peg regime is achieved at the expense of the highest volatility of inflation and nominal interest rate (see Table 2 in the Appendix). Only in the case of the foreign nontradable productivity shock flexible exchange rate regimes attain a smaller consumption gap.<sup>46</sup> Note that these results crucially depend on the monetary policy chosen by the big economy. In our parameter setting we observe a negative foreign consumption gap for the supply shocks and a positive one for the demand shocks. If the foreign economy was replicating the flexible price allocation<sup>47</sup> than changes in the domestic real interest rate induced by the peg regime would be too aggressive. Finally choosing appropriately the parameters of the managed float regime it is possible to achieve a low consumption gap together with a moderate change in the nominal interest rate, inflation and the nominal exchange rate.

#### 6.1.4 Monetary shocks

The nature of response to the foreign or domestic monetary shocks depends on the chosen monetary regime (see Figure 6 and 12 in the appendix). As far as the domestic monetary shock is concerned the domestic economy is only affected under the managed float (it comes from the definition of the regimes). An unexpected rise in the nominal interest rate leads to the overall recession together with a real exchange rate depreciation and deflation.

In the case of the foreign monetary shocks the domestic economy is affected the most under the peg regime. Since the peg regime follows the foreign monetary policy this shock leads to the recession together with deflation but no change in the real exchange rate. Other regimes reduce the nominal interest rate only slightly in order to prevent deflationary pressures coming from the import sector. Importantly the real exchange rate appreciation observed under these regimes makes the domestic economy worse off leading to a recession but at a smaller scale than under the peg regime. The smallest volatility of nominal interest rate is observed for the managed float regime however it happens at the expense of the high nominal exchange rate fluctuations and a considerable deflation. (see Table 2 in the Appendix)

#### 6.1.5 An overall evaluation of the monetary regimes performance

The differences in the way the monetary regimes respond to the shocks lie in the importance they attach to inflation and nominal exchange rate changes. As far as the domestic shocks are concerned the deflationary pressures produce a positive consumption gap under the flexible regimes and a negative consumption gap under the peg regime. On the other hand inflationary pressures result in a negative consumption gap under the flexible regimes and a positive one under the peg. In the case of foreign

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<sup>46</sup>The change in terms of trade is much smaller for the foreign nontradable productivity shock which results in a smaller domestic natural rate of interest. On the other hand the nominal interest rate change induced by the peg regime does not differ for the two foreign supply shocks. This is due to the fact that the big country is closed and therefore responds in a similar manner to any sector specific productivity shock (price stickiness is assumed to be equal in the sectors).

<sup>47</sup>by setting a higher coefficient to the changes in inflation.

shocks the results are opposite. Note that under the domestic shocks we distinguish clear differences between the different flexible regimes and the peg regime. Under the foreign shocks responses of the flexible regimes do not differ much between each other but altogether they are significantly different from the peg regime.

For all the shocks considered managed float regime can attain the lowest consumption gap and at the same time guarantee the moderate changes in the nominal interest rate, nominal exchange rate and inflation. However parameters summarizing its sensitivity to nominal exchange rate movements and inflation pressures depend on the underlying shocks. In particular in the case of domestic shocks a low consumption gap is achieved by setting an aggressive response to the inflation changes (except for the tradable productivity shocks). Foreign shocks require a more aggressive response to the nominal exchange rate movements (except for the nontradable productivity shocks).

Next we study whether our findings can be subject to the chosen set of the structural parameters describing the small domestic economy.

## 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 nontradables, 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.

We study how changing values of the mentioned above structural parameters affect the standard deviations and also impulse responses of the domestic variables. Moreover we examine whether these changes affect the way regimes respond to the shocks. We assume from now on that the monetary regimes are occupied only with the stabilization of domestic economy in response to the real side disturbances and do not undertake surprise actions (the foreign and domestic monetary shocks are set to be zero). Thanks to it we can investigate how a monetary regime can affect the volatility of the domestic variables in presence of the changing structural parameters.

### 7.1 Share of nontradables

Share of nontradables gives us the insight on how open the economy is: a high share of nontradables indicates a relatively closed economy and a small share of nontradables describes a more open economy.<sup>48</sup> An increasing share of nontradables affects the magnitude of the movements in the flexible price equilibrium real exchange rate (see 51).

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<sup>48</sup>One has to also take into account a degree of home bias in order to conclude on the openness of an economy.

In the case of the domestic nontradable productivity shocks and domestic demand shocks the real exchange rate changes are higher. Subsequently there is observed a much higher volatility of inflation and/or nominal exchange rate. This in turn leads to stronger changes in the nominal interest rate for the CPI targeting regime and to a lesser extent under the managed float regime. As the share of nontradables increases the consumption gaps for all the regimes rise, the highest increase is reported for the peg regime.

On the other hand real exchange rate movements originating from the domestic tradable productivity shocks get weaker with a higher share of nontradables. As a result volatility of both domestic inflation and nominal interest rate declines for all the regimes. Finally consumption gap decreases substantially for the peg regime.

In the case of the foreign shocks a higher share of nontradables induces higher changes in the real exchange rate which lead to an increasing difference between domestic and foreign natural real interest rate.<sup>49</sup> The peg regime is characterized by a higher volatility of domestic inflation and also a higher consumption gap. On the other hand volatility of the nominal interest rate declines under the CPI targeting regime and also the managed regime.<sup>50</sup> However we observe an increasing volatility of the nominal exchange rate for these regimes.

## 7.2 Degree of openness

Degree of openness is described by the share of imports in the domestic tradable consumption. It also explains the importance of terms of trade movements in the real exchange rate determination (see 51). What is more the higher degree of openness the higher share of imports in the aggregate consumption and a stronger interdependence between nominal exchange rate movements and the inflationary pressures.

In particular an increasing degree of openness leads to smaller real exchange rate movements in the long run. In the case of the domestic shocks this means that changes in the natural rate of interest decrease with a higher degree of openness. So the inflationary or deflationary pressures induced by a domestic shock are smaller. This implies that the managed exchange rate regimes can guarantee at the same time a stabilization of inflation and nominal exchange rate regime which yields a smaller consumption gap (except for the domestic nontradable productivity shock). On the other hand the CPI targeting regime is characterized by an increasing consumption gap due to the nominal exchange rate fluctuations.

As far as the foreign shocks are concerned a smaller real exchange rate movement in the flexible price equilibrium means that the domestic and foreign natural real interest rates do not differ much

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<sup>49</sup>This result can be understood by an analysis of the equation (51). In particular in the case of the foreign demand shocks foreign ratio of nontradable to tradable prices and also terms of trade rise while the domestic ratio of nontradable to tradable prices decreases. Subsequently a higher share of nontradables in the domestic economy leads to a higher real exchange rate depreciation. Note that the foreign demand shocks lead to a decrease in the foreign aggregate consumption and a rise in the foreign natural rate of interest. However with the increasing share of nontradables the perfect risk sharing condition implies that the domestic economy will decrease to much lesser extent than the foreign one. Finally the difference between the domestic and foreign natural rate of interest widens as the share of nontradables increases.

<sup>50</sup>This is due to a shrinking import sector and therefore smaller pressures on the aggregate inflation.

(it follows from the perfect risk sharing condition (124)). That is why if the big closed economy replicates the flexible price economy allocation then the consumption gap for the peg regime will be decreasing. However at the same time volatility of the nominal interest is going to rise for this regime. On the other hand the CPI targeting regime and the managed float regime responding to changes in inflation and letting for the fluctuations in the nominal exchange rate will be characterized by higher consumption gaps (except for the foreign nontradable productivity shocks).

### 7.3 Degree of substitution between home and foreign tradable goods

Degree of substitution between home and foreign tradables plays an important role in shaping the real exchange rate dynamics through the changes in relative prices. The higher the degree of substitution between home and foreign tradables the smaller the volatility of terms of trade. This in turn will influence changes in the real exchange rate in the flexible price equilibrium and therefore changes in the natural rate of interest.

As far as the domestic nontradable productivity shocks and domestic demand shocks are concerned a higher degree of substitution will lead to smaller changes in the real exchange rate. As a result we observe a smaller volatility of inflation and the nominal interest rate (except for the CPI targeting regime where additional movements in the nominal exchange rate keep the nominal interest rate volatility on the same level). Subsequently consumption gap for the peg regime and the managed regime is going to decrease. On the other hand in the case of the domestic tradable productivity shocks real exchange rate changes increase with a (considerably) higher degree of substitution between home and foreign tradables. As the home and foreign tradables become better substitutes we actually observe inflationary pressures (but of a smaller magnitude than the benchmark deflation). Volatility of the nominal interest rate reduces for the managed regime. On the other hand the CPI targeting regime experiences a higher volatility of the nominal interest which is strengthened by the nominal exchange rate fluctuations. Finally consumption gaps for the peg regime and the managed regime increase considerably.

In the case of the foreign shocks we follow the same reasoning as in the previous sections. In particular for the foreign nontradable productivity shocks we observe smaller real exchange rate movements in the flexible price equilibrium. This implies that provided that the response of the big closed economy aims to replicate the flexible price equilibrium the consumption gap for the peg regime will decrease with a higher degree of substitution. On the other hand the CPI targeting regime and the managed regime will be characterized by a higher consumption gap as nominal interest rate induced by these regimes is smaller than the one of the peg regime. In the case of the foreign tradable productivity shocks and foreign demand shocks a higher degree of substitution induces higher real exchange rate movements. So the consumption gaps for the peg regime and the managed regime will be higher. Moreover volatility of the nominal interest will rise for the managed regime and the CPI targeting regime.

## 7.4 Exchange rate pass through

Our benchmark model assumes that there is a delayed pass through reflected in the local currency pricing (LCP). This delayed pass through allows for the large real exchange movements to stabilize the economy in response to the foreign shocks. Thanks to it the more flexible regimes do better in stabilizing the domestic variables such as consumption, output and inflation than the fixed regime. In our simulation exercise we compare the performance of the different monetary regimes in our benchmark scenario with the environment of the producer currency pricing (PCP) which assumes the fast pass through (see Figures 1a, 3a, 7a in the appendix).

As far as the domestic shocks are concerned we observe that in the immediate pass through environment CPI targeting involves a change in the nominal interest rate of the opposite sign than in the benchmark case. This happens due to the fact that nominal exchange rate depreciation present with deflationary pressures (or nominal exchange rate appreciation present with inflationary pressures) leads to inflation in the import sector.<sup>51</sup> The more open economy is, i.e. the share of nontradables is small and the degree of openness is high, the more important these inflationary pressures in the import sector are for the aggregate changes in inflation. As a result consumption gaps are similar for all the regimes. On the other hand volatility of the nominal exchange rate is smaller. When the domestic economy is hit by the foreign shocks the immediate pass through also induces strong movements in the nominal interest rate under the CPI targeting regime. As a result the consumption gap under the peg regime and the CPI targeting regime get similar. On the other hand the managed float is characterized by smaller but more persistent movements in the nominal interest rate.

Summing up under PCP the flexible regimes by preventing inflationary or deflationary pressures originating from the nominal exchange rate fluctuations succeed in reducing the real exchange rate movements. But on the other hand they destabilize the domestic variables such as consumption and output to extent similar as under the peg regime. These results confirm the findings of Lane, Devereux and Xu (2004) who identify that in presence of the fast pass - through a small open economy faces a trade - off between stabilizing inflation and output while responding to the foreign shocks.

## 7.5 The sensitivity analysis and the monetary regime evaluation

The sensitivity analysis that we perform on the structural parameters of a small open economy indicates that the choice of the regime is dependent on the specific structure of a small open economy and also its stochastic environment. Here we summarize our findings having in mind that our point of reference in the regimes evaluation is the flexible price economy and the induced volatility of the chosen domestic variables.

All the long - run parameters analyzed affect a degree of the real exchange rate movements in the flexible price equilibrium. In the case of the domestic shocks these movements summarize inflationary or deflationary pressures present in the domestic economy. On the other hand in the case of the

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<sup>51</sup>Under PCP inflation in the import sector is given by the following log - linearised equation:  $\hat{\pi}_{F,t} = \hat{\pi}_{F,t}^* + \widehat{\Delta S}_t$ .

foreign shocks these movements describe a difference between domestic natural rate of interest and the foreign natural rate of interest. Subsequently the higher real exchange rate movements present in the flexible price economy lead to a decrease in the consumption gap of the flexible regimes and an increase in the consumption gap of the peg regime. The higher real exchange rate movements in the flexible price economy are associated generally with the higher volatility of the nominal interest rate and inflation.<sup>52</sup>

Based on this discussion we can summarize that the managed regimes attain small consumption gaps for the economies with a high degree of openness, a small share of nontradables (when hit by all the types of the shocks analyzed except for the domestic tradable productivity shocks) and a high degree of substitution between home and foreign tradables (when hit by the foreign and domestic nontradable productivity shocks or the domestic demand shocks). Additionally in the short run we find that a speed with which nominal exchange rate movements feed into the import prices creates a trade - off between stabilization of the real exchange rate and the domestic variables (i.e. consumption gap) for the flexible regimes.

Let us briefly relate these findings with the nature of the CEE and SEE countries. Researchers indicate that still the share of nontradables in these countries is considerably lower than in other developed economies, e.g. euro area.<sup>53</sup> On the other the home bias is reported to be very strong in the consumption goods.<sup>54</sup> Interestingly an examination of the data presented in the appendix reveals that the countries which decided to peg are characterized by the highest degree of openness. Finally the pass through is reported to be rather high in the accession economies as it is reflected in the high share of euro in the import invoicing patterns. This could be an answer to why the predominant number of the CEE and SEE countries follow the regimes which stabilize the nominal exchange rate.

## 8 Conclusions

This paper studies the choice of the monetary regime in the SEE and CEE countries. We identify some common characteristics of these countries regarding both a structure of the economy and its stochastic environment which can influence the choice of the monetary regime. Then we build a two - country dynamic stochastic general equilibrium model representing a small open economy - one of the SEE and CEE 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 foreign and domestic shocks. The studied monetary regimes roughly aim to reflect the monetary choices already made in the CEE and SEE countries: the fixed regime,

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<sup>52</sup>However in the case of the foreign shocks smaller real exchange rate movements lead to stronger nominal interest rate movements under the peg regime.

<sup>53</sup>See the tables with detailed data on the share of nontradables in the accession countries and the EU-15 in the Appendix.

<sup>54</sup>See the detailed data on the share of the foreign tradable consumption in the tradable consumption for the accession countries and the EU-15 presented in the Appendix.

the managed float and the CPI targeting regime.

We perform the theoretical analysis of the macroeconomic volatility of a small open economy in the long and short run. We attach great importance to the real exchange rate determination as it summarizes the pattern of the stabilization of a small open economy in response to the shocks. Moreover we build up a useful platform for the monetary regime comparison by contrasting the monetary regime choices on the real interest rates with the natural rate of interest. The study of consumption gaps (defined as the differences in current consumption with consumption under flexible price economy) in response to the shocks gives us useful insights about the nature of each of the monetary regimes studied. Additionally we identify structural parameters of a small open economy: a share of nontraded sector, degree of openness, degree of substitution between home and foreign tradable goods, degree of price stickiness and also degree of exchange rate pass through which affect the way a small open economy responds to the shocks.

Our benchmark analysis reveals that the differences in the way the monetary regimes respond to the shocks origin from the importance they attach to inflation and nominal exchange rate changes. In particular the deflationary pressures produce a positive consumption gap under the flexible regimes and a negative consumption gap under the peg regime. The inflationary pressures lead to the opposite results. Importantly the managed float regime can attain the lowest consumption gap and at the same time guarantee the moderate changes in the nominal interest rate, nominal exchange rate and inflation. However parameters summarizing its sensitivity to nominal exchange rate movements and inflation pressures depend on the underlying shocks. Additionally the sensitivity analysis indicates that the choice of the monetary regime may be dependent also on the specific structure of a small open economy. In particular a small share of nontradables, a high degree of openness and the high pass through may be advocates for the managed regimes frequently observed in the CEE and SEE countries.

The above analysis on the performance of the monetary regimes is based on their comparison with the outcomes of the efficient flexible price economy. The welfare analysis together with the welfare ranking of the alternative monetary regimes is the obvious extension of our study. In particular it would be interesting to check whether the optimal monetary policy (derived from the optimal objective function) satisfies the Maastricht convergence criteria which fulfillment is the condition to enter the European Monetary Union and therefore constitutes a challenge for the monetary policies in these countries.

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## 9 Appendix

### 9.1 Steady state characterisation

We define a symmetric, deterministic steady state with zero inflation rate. There are no productivity shocks ( $A^H = A^N = A^{*F} = A^{*N} = 1$ ). Other shocks: government expenditure shocks and tax shocks are assumed to take constant values. In particular  $\overline{G}_H = \overline{G}_N = G$ ,  $\overline{G}_F^* = \overline{G}_N^* = G^*$ ,  $\overline{\tau} = \tau$ ,  $\overline{\tau}^* = \tau^*$ .

Moreover discount factors are:

$$Q_{t,t+s} = Q_{t,t+s}^* = \beta^s \quad (62)$$

Demands for tradable and nontradable goods (12):

- domestic goods

$$\overline{Y}_N = \overline{C}_N + \overline{G}_N \quad (63)$$

$$\overline{Y}_H = \nu \overline{C}_T + \frac{\nu^*(1-n)}{n} \overline{C}_T^* + \overline{G}_H \quad (64)$$

$$\overline{Y}_H = \overline{C}_H + \overline{C}_H^* + \overline{G}_H \quad (65)$$

where:  $\overline{C}_H = \nu \overline{C}_T$ ,  $\overline{C}_N = \mu \overline{C}$ ,  $\overline{C}_T = (1 - \mu) \overline{C}$ ,  $\overline{C}_H^* = \frac{\nu^*(1-n)}{n} \overline{C}_T^*$ .

- foreign goods

$$\overline{Y}_N^* = \overline{C}_N^* + \overline{G}_N^* \quad (66)$$

$$\overline{Y}_F^* = \frac{(1-\nu)n}{1-n} \overline{C}_T + (1-\nu^*) \overline{C}_T^* + \overline{G}_F^* \quad (67)$$

$$\overline{Y}_F^* = \overline{C}_F + \overline{C}_F^* + \overline{G}_F^* \quad (68)$$

where:  $\overline{C}_F = \frac{(1-\nu)n}{1-n} \overline{C}_T$ ,  $\overline{C}_F^* = (1-\nu^*) \overline{C}_T^*$ .

We define the following steady state ratios:

$$d_{CN} = \frac{\bar{C}_N}{\bar{Y}_N} \quad (69)$$

$$d_{GN} = \frac{\bar{G}_N}{\bar{Y}_N} \quad (70)$$

$$d_{GH} = \frac{\bar{G}_H}{\bar{Y}_H} \quad (71)$$

$$d_{CT} = \nu \frac{\bar{C}_T}{\bar{Y}_H} \quad (72)$$

$$\frac{\nu^*(1-n)}{n} \frac{\bar{C}_T^*}{\bar{Y}_H} = 1 - d_{CT} - d_{GH} \quad (73)$$

$$d_{CN}^* = \frac{\bar{C}_N^*}{\bar{Y}_N^*} \quad (74)$$

$$d_{GN}^* = \frac{\bar{G}_N^*}{\bar{Y}_N^*} \quad (75)$$

$$d_{GF}^* = \frac{\bar{G}_F^*}{\bar{Y}_F^*} \quad (76)$$

$$d_{CT}^* = (1 - \nu^*) \frac{\bar{C}_T^*}{\bar{Y}_F^*} \quad (77)$$

$$\frac{(1-\nu)n}{1-n} \frac{\bar{C}_T}{\bar{Y}_F} = 1 - d_{CT}^* - d_{GF}^* \quad (78)$$

Labour supply optimality conditions (coming from (26)) are the following ones:

$$\bar{C}^{-\rho} \frac{\bar{W}^H}{\bar{P}} = \varphi_l(\bar{L})^\eta \quad (79)$$

$$\bar{C}^{-\rho} \frac{\bar{W}^N}{\bar{P}} = \varphi_l(\bar{L})^\eta \quad (80)$$

The previous equations determine that wages are equalised in tradable and nontradable sector:

$$\bar{W}^H = \bar{W}^N \quad (81)$$

First order conditions of the domestic and foreign firms (coming from (34), (40), (41)) are the

following:

$$\bar{p}_N = \bar{P}_N = \frac{\sigma}{(\sigma-1)(1-\bar{\tau})} \frac{\bar{W}^N}{\bar{A}^N} \quad (82)$$

$$\bar{p}_H = \bar{S}\bar{p}_H^* = \bar{P}_H = \frac{\sigma}{(\sigma-1)(1-\bar{\tau})} \frac{\bar{W}^H}{\bar{A}^H} \quad (83)$$

$$\bar{p}_N^* = \bar{P}_N^* = \frac{\sigma}{(\sigma-1)(1-\bar{\tau}^*)} \frac{\bar{W}^{*N}}{\bar{A}^{*N}} \quad (84)$$

$$\bar{p}_F^* = \frac{\bar{p}_F^*}{\bar{S}} = \bar{P}_F^* = \frac{\sigma}{(\sigma-1)(1-\bar{\tau}^*)} \frac{\bar{W}^{*F}}{\bar{A}^{*F}} \quad (85)$$

Since wages are equalised in tradable and nontradable sector we obtain that:  $\bar{P}_N = \bar{P}_H, \bar{P}_N^* = \bar{P}_F^*$ . Additionally we normalize home and foreign prices such that  $\bar{P}_H = \bar{P}_F$ .

So we obtain that real exchange rate is equal to 1:

$$\bar{R}\bar{S} = 1 \quad (86)$$

Moreover from the production function (27)we obtain that:

$$\bar{Y} = \bar{Y}_H + \bar{Y}_N \quad (87)$$

$$\bar{Y}_H = \bar{A}_H \bar{L}_H \quad (88)$$

$$\bar{Y}_N = \bar{A}_N \bar{L}_N \quad (89)$$

$$\bar{L} = \bar{L}_H + \bar{L}_N \quad (90)$$

Substituting into labour supply optimality conditions production, demand equations, consumption identities and first order conditions of firms we obtain the following two relations for the domestic economy and foreign economy respectively:

$$\bar{C}^{-\rho} \frac{\bar{P}_H}{\bar{P}} \bar{A}_H \frac{(\sigma-1)(1-\bar{\tau})}{\sigma} = \varphi_l \left( \mu \bar{C} + \nu(1-\mu)\bar{C} + \frac{\nu^*(1-n)}{n}(1-\mu^*)\bar{C}^* \right)^\eta \quad (91)$$

$$\bar{C}^{*- \rho} \frac{\bar{P}_F^*}{\bar{P}^*} \bar{A}_F^* \frac{(\sigma-1)(1-\bar{\tau}^*)}{\sigma} = \varphi_l \left( \mu^* \bar{C}^* + (1-\nu^*)(1-\mu^*)\bar{C}^* + \frac{(1-\nu)n}{1-n}(1-\mu)\bar{C} \right)^\eta \quad (92)$$

This system of two nonlinear equations determines total domestic and foreign consumption. In our simulation exercises we follow a numerical procedure to solve this system of two equations with two unknowns.

## 9.2 Log - linearisation around the steady state

We approximate the model around the above defined steady state. We present the loglinearised equations for the flexible price economy and also for the sticky price economy.

### 9.2.1 The flexible price economy

**Supply** Nontraded sector:

$$(1 - \mu)\widehat{T}_t^d = -\widehat{A}_t^N + \widehat{\omega}_t + w\widehat{\tau}_t \quad (93)$$

$$(1 - \mu^*)\widehat{T}_t^{*d} = -\widehat{A}_t^{*N} + \widehat{\omega}_t^* + w^*\widehat{\tau}_t^* \quad (94)$$

Traded goods:

- internal consumption:

$$-\mu\widehat{T}_t^d - (1 - \nu)\widehat{T}_t = -\widehat{A}_t^H + \widehat{\omega}_t + w\widehat{\tau}_t \quad (95)$$

$$\nu^*\widehat{T}_t^* - \mu^*\widehat{T}_t^{*d} = -\widehat{A}_t^{*F} + \widehat{\omega}_t^* + w^*\widehat{\tau}_t^* \quad (96)$$

- exporting goods:

$$\widehat{R}S_t - (1 - \nu^*)\widehat{T}_t^* - \mu^*\widehat{T}_t^{*d} = -\widehat{A}_t^H + \widehat{\omega}_t + w\widehat{\tau}_t \quad (97)$$

$$-\mu\widehat{T}_t^d + \nu\widehat{T}_t - \widehat{R}S_t = -\widehat{A}_t^{*F} + \widehat{\omega}_t^* + w^*\widehat{\tau}_t^* \quad (98)$$

Labour supply:

$$-\rho\widehat{C}_t + \widehat{\omega}_t - \eta\left(\frac{\overline{Y}_N}{\overline{Y}}\widehat{Y}_{N,t} + \frac{\overline{Y}_H}{\overline{Y}}\widehat{Y}_{H,t} - \frac{\overline{Y}_H}{\overline{Y}}\widehat{A}_t^H - \frac{\overline{Y}_N}{\overline{Y}}\widehat{A}_t^N\right) = 0 \quad (99)$$

$$-\rho\widehat{C}_t^* + \widehat{\omega}_t^* - \eta\left(\frac{\overline{Y}_N^*}{\overline{Y}^*}\widehat{Y}_{N,t}^* + \frac{\overline{Y}_F^*}{\overline{Y}^*}\widehat{Y}_{F,t}^* - \frac{\overline{Y}_F^*}{\overline{Y}^*}\widehat{A}_t^{*F} - \frac{\overline{Y}_N^*}{\overline{Y}^*}\widehat{A}_t^{*N}\right) = 0 \quad (100)$$

**Demand** Nontraded consumption:

$$\widehat{Y}_{N,t} = d_{CN}(\widehat{C}_t - \phi(1 - \mu)\widehat{T}_t^d) + d_{GN}\widehat{g}_{N,t} \quad (101)$$

$$\widehat{Y}_{N,t}^* = d_{CN}^*(\widehat{C}_t^* - \phi^*(1 - \mu^*)\widehat{T}_t^{*d}) + d_{GN}^*\widehat{g}_{N,t}^* \quad (102)$$

Traded consumption:

$$\begin{aligned} \widehat{Y}_{H,t} = \theta d_{CT}(1 - \nu)\widehat{T}_t + d_{CT}(\widehat{C}_t + \phi\mu\widehat{T}_t^d) + \theta^*(1 - d_{CT} - d_{GH})((1 - \nu^*)\widehat{T}_t^*) + \\ (1 - d_{CT} - d_{GH})(\widehat{C}_t^* + \phi\mu\widehat{T}_t^{*d}) + d_{GH}\widehat{g}_{H,t} \end{aligned} \quad (103)$$

$$\widehat{Y}_{F,t}^* = -\theta(1 - d_{CT}^* - d_{GF}^*)\nu\widehat{T}_t + (1 - d_{CT}^* - d_{GF}^*)(\widehat{C}_t + \phi\mu\widehat{T}_t^d) - \theta^*d_{CT}^*\nu^*\widehat{T}_t^* + d_{CT}^*(\widehat{C}_t^* + \phi^*\mu^*\widehat{T}_t^{*d}) + d_{GF}^*\widehat{g}_{F,t}^* \quad (104)$$

Resource constraint:

$$\widehat{Y}_t = \frac{\overline{Y}_N}{\overline{Y}}\widehat{Y}_{N,t} + \frac{\overline{Y}_H}{\overline{Y}}\widehat{Y}_{H,t} + \frac{\overline{Y}_N}{\overline{Y}}\widehat{T}_t^d + \frac{\overline{Y}_N}{\overline{Y}}(1 - \nu)\widehat{T}_t \quad (105)$$

$$\widehat{Y}_t^* = \frac{\overline{Y}_N^*}{\overline{Y}^*}\widehat{Y}_{N,t}^* + \frac{\overline{Y}_F^*}{\overline{Y}^*}\widehat{Y}_{F,t}^* + \frac{\overline{Y}_N^*}{\overline{Y}^*}\widehat{T}_t^{*d} - \frac{\overline{Y}_N^*}{\overline{Y}^*}\nu^*\widehat{T}_t^* \quad (106)$$

Risk sharing:

$$\widehat{C}_t^* = \widehat{C}_t - \frac{1}{\rho}\widehat{RS}_t \quad (107)$$

Euler conditions:

$$\widehat{RR}_t = \rho(\widehat{C}_{t+1} - \widehat{C}_t) \quad (108)$$

$$\widehat{RR}_t^* = \rho(\widehat{C}_{t+1}^* - \widehat{C}_t^*) \quad (109)$$

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

## 9.2.2 The sticky price economy

**Supply** Nontraded sector:

$$\widehat{\pi}_{N,t} = k_N(-\widehat{A}_t^N + \widehat{\omega}_t + w\widehat{\tau}_t - (1 - \mu)\widehat{T}_t^d) + \beta E_t \widehat{\pi}_{N,t+1} \quad (110)$$

$$\widehat{\pi}_{N,t}^* = k_N^*(-\widehat{A}_t^{*N} + \widehat{\omega}_t^* + w^*\widehat{\tau}_t^* - (1 - \mu^*)\widehat{T}_t^{*d}) + \beta E_t \widehat{\pi}_{N,t+1}^* \quad (111)$$

Traded goods:

- internal consumption:

$$\widehat{\pi}_{H,t} = k_H(-\widehat{A}_t^H + \widehat{\omega}_t + w\widehat{\tau}_t + \mu\widehat{T}_t^d + (1 - \nu)\widehat{T}_t) + \beta (E_t \widehat{\pi}_{H,t+1} - \gamma_H \widehat{\pi}_{H,t}) \quad (112)$$

$$\widehat{\pi}_{F,t}^* = k_F^*(-\widehat{A}_t^{*F} + \widehat{\omega}_t^* + w^*\widehat{\tau}_t^* - \nu^*\widehat{T}_t^* + \mu^*\widehat{T}_t^{*d}) + \beta E_t \widehat{\pi}_{F,t+1}^* \quad (113)$$

- exporting goods:

$$\widehat{\pi}_{H,t}^* = k_H(-\widehat{A}_t^H + \widehat{\omega}_t - \widehat{R}S_t + w\widehat{\tau}_t + (1 - \nu^*)\widehat{T}_t^* + \mu^*\widehat{T}_t^{*d}) + \beta E_t \pi_{H,t+1}^* \quad (114)$$

$$\widehat{\pi}_{F,t} = k_F(-\widehat{A}_t^{*F} + \widehat{\omega}_t^* + \widehat{R}S_t + w^*\widehat{\tau}_t^* - \nu\widehat{T}_t + \mu\widehat{T}_t^d) + \beta E_t \pi_{F,t+1} \quad (115)$$

Labour supply:

$$-\rho\widehat{C}_t + \widehat{\omega}_t - \eta\left(\frac{\overline{Y}_N}{\overline{Y}}\widehat{Y}_{N,t} + \frac{\overline{Y}_H}{\overline{Y}}\widehat{Y}_{H,t} - \frac{\overline{Y}_H}{\overline{Y}}\widehat{A}_t^H - \frac{\overline{Y}_N}{\overline{Y}}\widehat{A}_t^N\right) = 0 \quad (116)$$

$$-\rho\widehat{C}_t^* + \widehat{\omega}_t^* - \eta\left(\frac{\overline{Y}_N^*}{\overline{Y}^*}\widehat{Y}_{N,t}^* + \frac{\overline{Y}_F^*}{\overline{Y}^*}\widehat{Y}_{F,t}^* - \frac{\overline{Y}_F^*}{\overline{Y}^*}\widehat{A}_t^{*F} - \frac{\overline{Y}_N^*}{\overline{Y}^*}\widehat{A}_t^{*N}\right) = 0 \quad (117)$$

**Demand** Nontraded consumption:

$$\widehat{Y}_{N,t} = d_{CN}(\widehat{C}_t - \phi(1 - \mu)\widehat{T}_t^d) + d_{GN}\widehat{g}_{N,t} \quad (118)$$

$$\widehat{Y}_{N,t}^* = d_{CN}^*(\widehat{C}_t^* - \phi^*(1 - \mu^*)\widehat{T}_t^{d*}) + d_{GN}^*\widehat{g}_{N,t}^* \quad (119)$$

Traded consumption:

$$\begin{aligned} \widehat{Y}_{H,t} = & \theta d_{CT}(1 - \nu)\widehat{T}_t + d_{CT}(\widehat{C}_t + \phi\mu\widehat{T}_t^d) + \theta^*(1 - d_{CT} - d_{GH})(1 - \nu^*)\widehat{T}_t^* + \\ & (1 - d_{CT} - d_{GH})(\widehat{C}_t^* + \phi^*\mu^*\widehat{T}_t^{d*}) + d_{GH}\widehat{g}_{H,t} \end{aligned} \quad (120)$$



$$\widehat{Y}_{F,t}^* = -\theta(1-d_{CT}^*-d_{GF}^*)\nu\widehat{T}_t + (1-d_{CT}^*-d_{GF}^*)(\widehat{C}_t + \phi\mu\widehat{T}_t^d) - \theta^*d_{CT}^*\nu^*\widehat{T}_t^* + d_{CT}^*(\widehat{C}_t^* + \phi^*\mu^*\widehat{T}_t^{*d}) + d_{GF}^*\widehat{g}_{F,t}^* \quad (121)$$

Resource constraint:

$$\widehat{Y}_t = \frac{\overline{Y}_N}{\overline{Y}}\widehat{Y}_{N,t} + \frac{\overline{Y}_H}{\overline{Y}}\widehat{Y}_{H,t} + \frac{\overline{Y}_N}{\overline{Y}}\widehat{T}_t^d + \frac{\overline{Y}_N}{\overline{Y}}(1-\nu)\widehat{T}_t \quad (122)$$

$$\widehat{Y}_t^* = \frac{\overline{Y}_N^*}{\overline{Y}^*}\widehat{Y}_{N,t}^* + \frac{\overline{Y}_F^*}{\overline{Y}^*}\widehat{Y}_{F,t}^* + \frac{\overline{Y}_N^*}{\overline{Y}^*}\widehat{T}_t^{d*} - \frac{\overline{Y}_N^*}{\overline{Y}^*}\nu^*\widehat{T}_t^* \quad (123)$$

Risk sharing:

$$\widehat{C}_t^* = \widehat{C}_t - \frac{1}{\rho}\widehat{RS}_t \quad (124)$$

Euler conditions:

$$\rho E_t \widehat{C}_{t+1} = \rho \widehat{C}_t + \widehat{R}_t - \widehat{\pi}_{t+1} \quad (125)$$

$$\rho E_t \widehat{C}_{t+1}^* = \rho \widehat{C}_t^* + \widehat{R}_t^* - \widehat{\pi}_{t+1}^* \quad (126)$$

Monetary rules:

$$\widehat{R}_t = \mu_y(1-\kappa)\widehat{y}_t + \mu_\pi(1-\kappa)\widehat{\pi}_t + \mu_S(1-\kappa)\widehat{S}_t + \kappa\widehat{R}_{t-1} + \widehat{\varepsilon}_t^{mp} \quad (127)$$

$$\widehat{R}_t^* = \mu_{\pi_N}^*(1-\kappa^*)\widehat{\pi}_{N,t}^* + \mu_\pi^*(1-\kappa^*)\widehat{\pi}_t^* + \mu_y^*(1-\kappa^*)\widehat{Y}_t^* + \kappa^*\widehat{R}_{t-1}^* + \widehat{\varepsilon}_t^{*mp} \quad (128)$$

## Prices

$$\widehat{\pi}_t = \mu\widehat{\pi}_{N,t} + (1-\mu)\nu\widehat{\pi}_{H,t} + (1-\mu)(1-\nu)\widehat{\pi}_{F,t} \quad (129)$$

$$\widehat{\pi}_t^* = \mu^*\widehat{\pi}_{N,t}^* + (1-\mu^*)\nu^*\widehat{\pi}_{H,t}^* + (1-\mu^*)(1-\nu^*)\widehat{\pi}_{F,t}^* \quad (130)$$

$$\widehat{T}_t^d - \widehat{T}_{t-1}^d = -\nu\widehat{\pi}_{H,t} - (1-\nu)\widehat{\pi}_{F,t} + \widehat{\pi}_{N,t} \quad (131)$$

$$\widehat{T}_t^{*d} - \widehat{T}_{t-1}^{*d} = -\nu^*\widehat{\pi}_{H,t}^* - (1-\nu^*)\widehat{\pi}_{F,t}^* + \widehat{\pi}_{N,t}^* \quad (132)$$

$$\widehat{T}_t - \widehat{T}_{t-1} = \widehat{\pi}_{F,t} - \widehat{\pi}_{H,t} \quad (133)$$

$$\widehat{T}_t^* - \widehat{T}_{t-1}^* = \widehat{\pi}_{F,t}^* - \widehat{\pi}_{H,t}^* \quad (134)$$

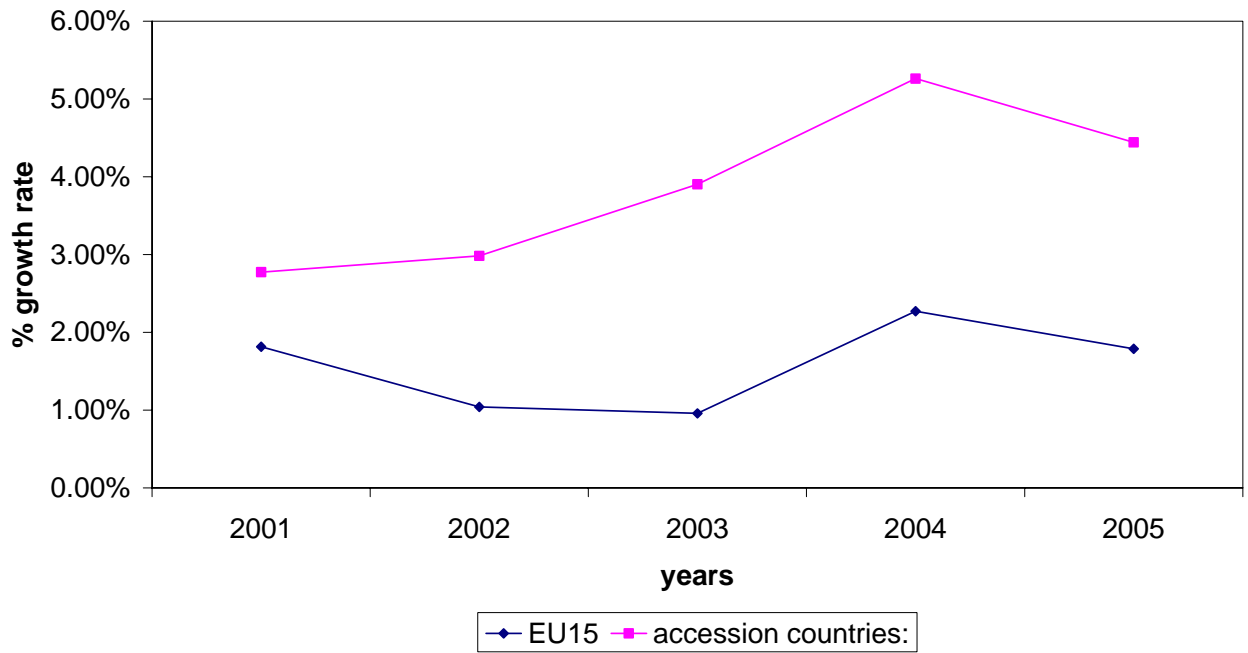
$$\Delta \widehat{RS}_t = \Delta \widehat{S}_t + (\widehat{\pi}_t^* - \widehat{\pi}_t) \quad (135)$$

$$\Delta \widehat{S}_t = \widehat{S}_t - \widehat{S}_{t-1} \quad (136)$$

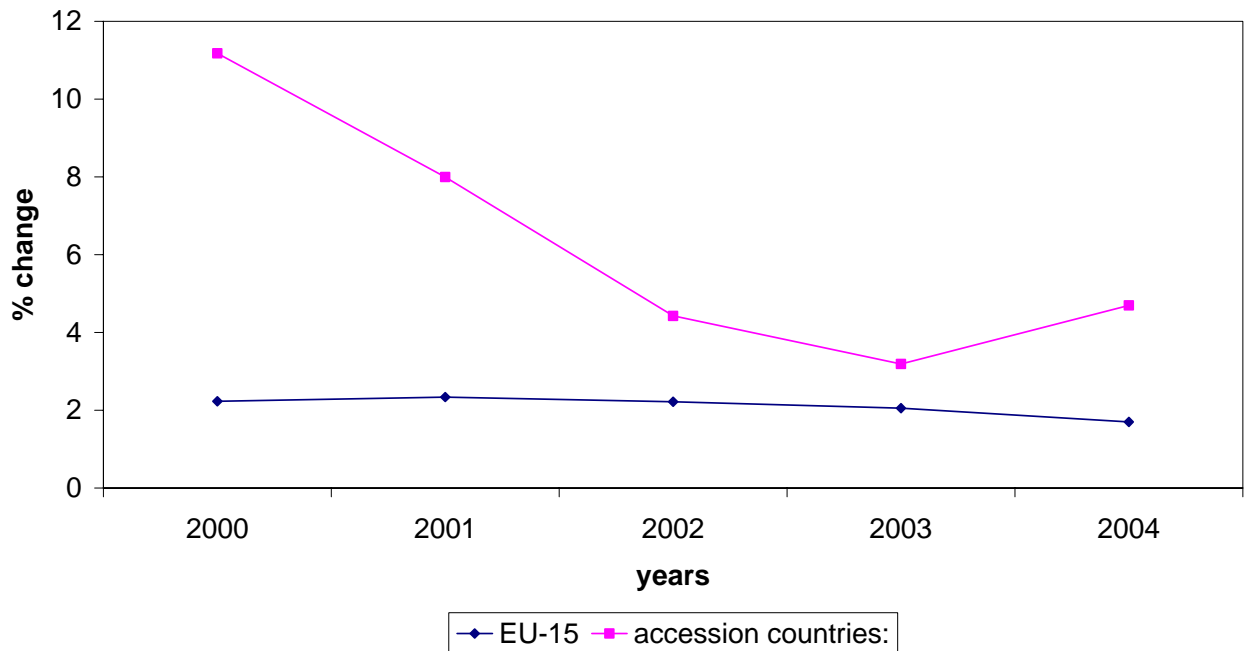
$$\Delta \widehat{RS}_t = \widehat{RS}_t - \widehat{RS}_{t-1} \quad (137)$$

## 10 Tables and graphs

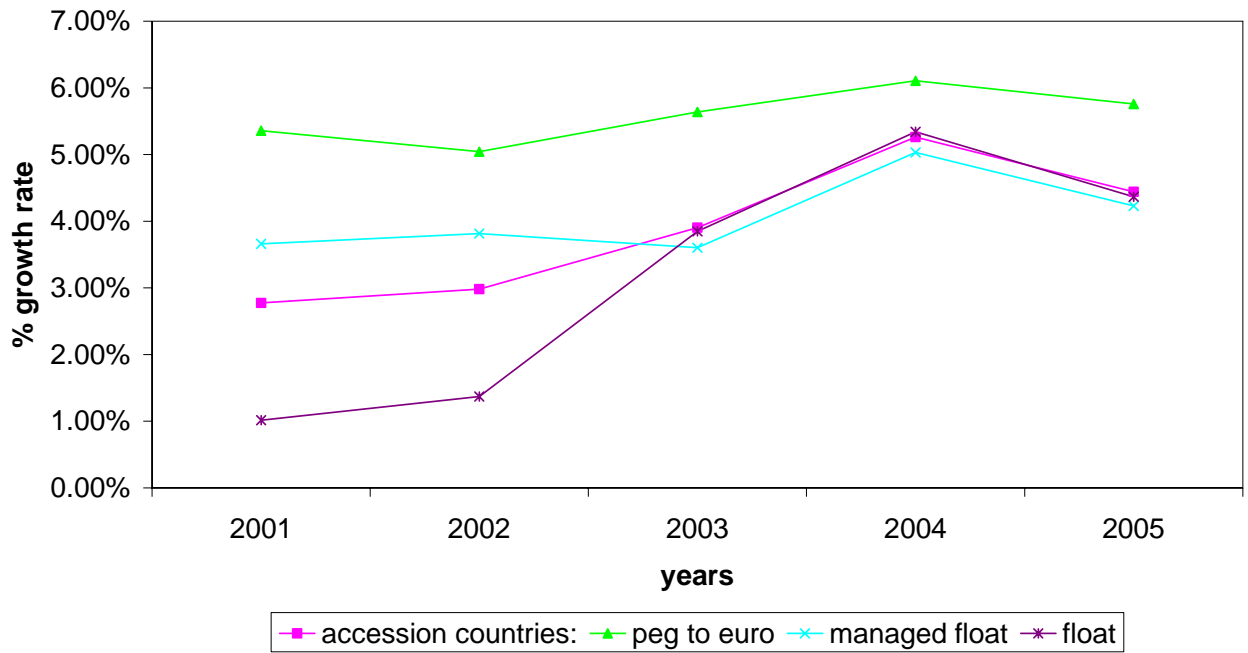
**Figure A: GDP growth in the EU-15 and in the accession countries (at constant prices, annual changes)**



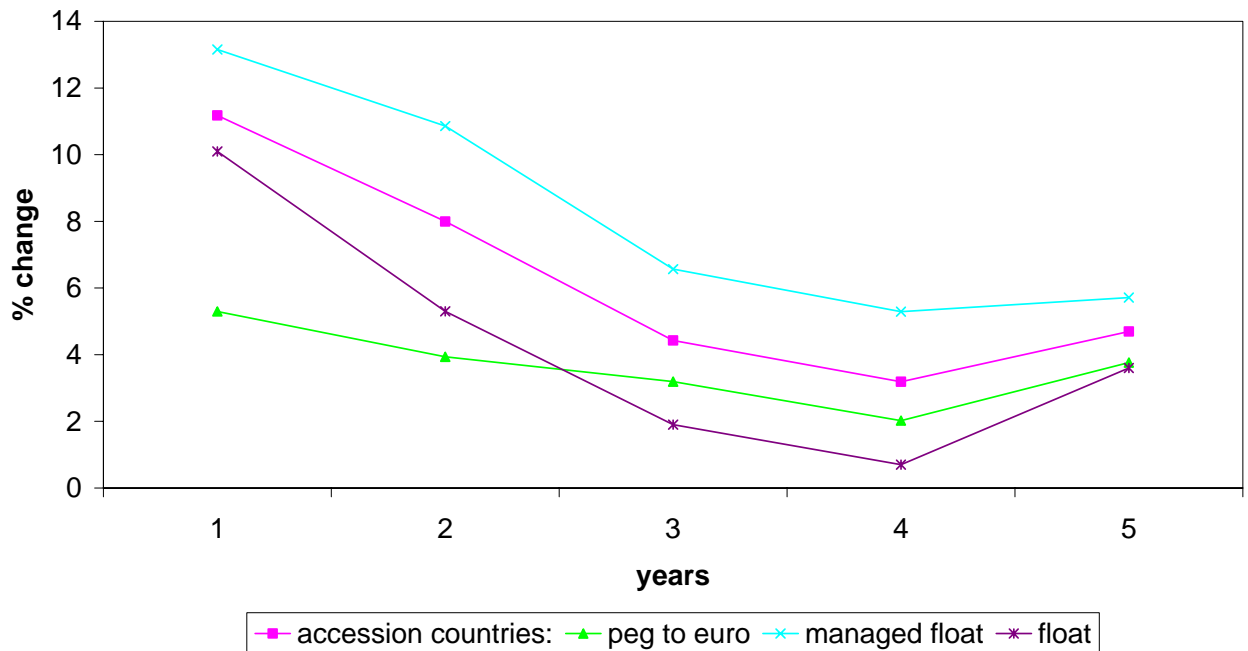
**Figure B: CPI inflation in the EU-15 and the accession countries (annual changes, weighted by constant GDP)**



**Figure A1: GDP growth in the accession countries (at constant prices, annual changes)**



**Figure B1: CPI inflation in the EU-15 and the accession countries (annual changes, weighted by constant GDP)**



<b>Share of the nontradable consumption in the total consumption (average for 2000-2005)</b>				<b>Share of the foreign imported tradable consumption in the tradable consumption (average for 2000-2004)</b>			
<b>European Union</b>		<b>Accession countries</b>		<b>European Union</b>		<b>Accession countries</b>	
<b>Austria</b>	54%	<b>Bulgaria</b>	29%	<b>Austria</b>	37%	<b>Bulgaria</b>	13%
<b>Belgium</b>	49%	<b>Croatia</b>	37%	<b>Belgium</b>	69%	<b>Croatia</b>	14%
<b>Denmark</b>	47%	<b>Cyprus</b>	55%	<b>Denmark</b>	44%	<b>Cyprus</b>	57%
<b>Finland</b>	51%	<b>Czech Republic</b>	42%	<b>Finland</b>	22%	<b>Czech Republic</b>	36%
<b>France</b>	52%	<b>Estonia</b>	39%	<b>France</b>	22%	<b>Estonia</b>	48%
<b>Germany</b>	48%	<b>Hungary</b>	44%	<b>Germany</b>	22%	<b>Hungary</b>	30%
<b>Greece</b>	47%	<b>Latvia</b>	37%	<b>Greece</b>	23%	<b>Latvia</b>	35%
<b>Ireland</b>	57%	<b>Lithuania</b>	33%	<b>Ireland</b>	79%	<b>Lithuania</b>	23%
<b>Italy</b>	49%	<b>Malta</b>	54%	<b>Italy</b>	17%	<b>Malta</b>	68%
<b>Netherlands</b>	49%	<b>Poland</b>	37%	<b>Netherlands</b>	43%	<b>Poland</b>	13%
<b>Portugal</b>	53%	<b>Romania</b>	23%	<b>Portugal</b>	30%	<b>Romania</b>	9%
<b>Spain</b>	48%	<b>Slovenia</b>	49%	<b>Spain</b>	21%	<b>Slovenia</b>	36%
<b>Sweden</b>	48%	<b>Slovakia</b>	41%	<b>Sweden</b>	32%	<b>Slovakia</b>	34%
<b>United Kingdom</b>	59%			<b>United Kingdom</b>	27%		
<b>average</b>	<b>51%</b>		<b>40%</b>	<b>average</b>	<b>35%</b>		<b>32%</b>

Source (all the graphs and the table): Eurostat and the Croatian Statistical Office

Table 2: Volatility of the consumption gap, nominal interest rate, nominal exchange rate and aggregate inflation induced by each type of the shocks (benchmark case) under different monetary regimes

volatility (in %) induced by 1% shock to:		BENCHMARK CASE											
		CPI targeting				Managed float				Fixed regime			
		Cgap	R	S	$\pi$	Cgap	R	S	$\pi$	Cgap	R	S	$\pi$
domestic shocks	nontradable productivity	0.141	0.226	nonstationary	0.000	0.264	0.111	0.736	0.119	0.459	0.000	0.000	0.148
	tradable productivity	0.334	0.217		0.000	0.035	0.072	0.395	0.080	0.117	0.001	0.000	0.093
	nontradable government expenditure	0.034	0.031		0.000	0.019	0.013	0.080	0.014	0.041	0.000	0.000	0.017
	tradable government expenditure	0.034	0.031		0.000	0.019	0.013	0.080	0.014	0.041	0.000	0.000	0.017
	tax	0.017	0.016		0.000	0.010	0.007	0.041	0.007	0.021	0.000	0.000	0.009
	monetary	0.001	0.001		0.000	1.808	1.129	0.348	4.855	0.000	0.000	0.000	0.000
foreign shocks	nontradable productivity	0.042	0.025	nonstationary	0.000	0.034	0.097	0.640	0.070	0.121	0.167	0.000	0.092
	tradable productivity	0.303	0.055		0.000	0.233	0.104	0.683	0.044	0.040	0.193	0.000	0.084
	nontradable government expenditure	0.023	0.005		0.000	0.017	0.014	0.083	0.008	0.011	0.026	0.000	0.012
	tradable government expenditure	0.023	0.005		0.000	0.017	0.014	0.083	0.008	0.011	0.026	0.000	0.012
	tax	0.000	0.005		0.000	0.030	0.014	0.214	0.019	0.083	0.001	0.000	0.032
	monetary	0.602	0.355		0.000	0.229	0.110	4.219	0.282	1.823	1.012	0.000	0.541

Figure 1: Impulse responses to the domestic nontradable productivity shock: local currency pricing

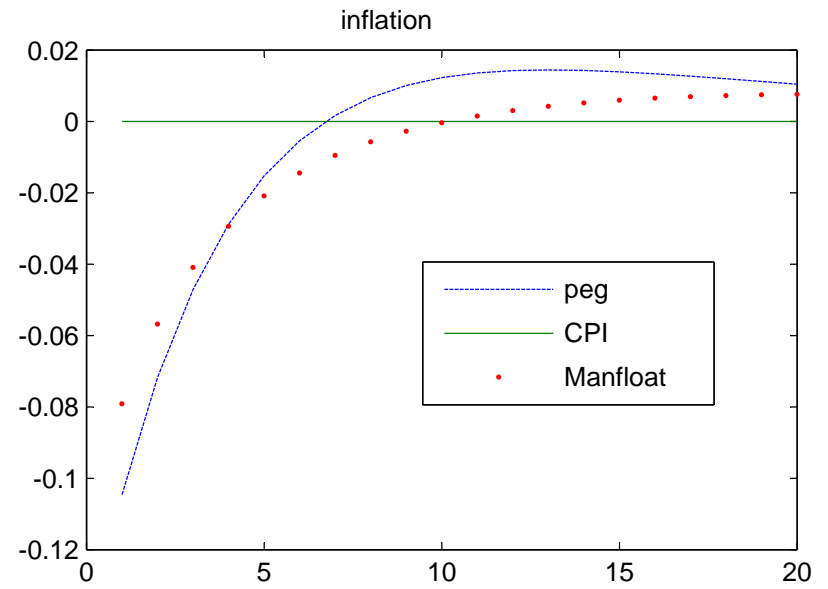
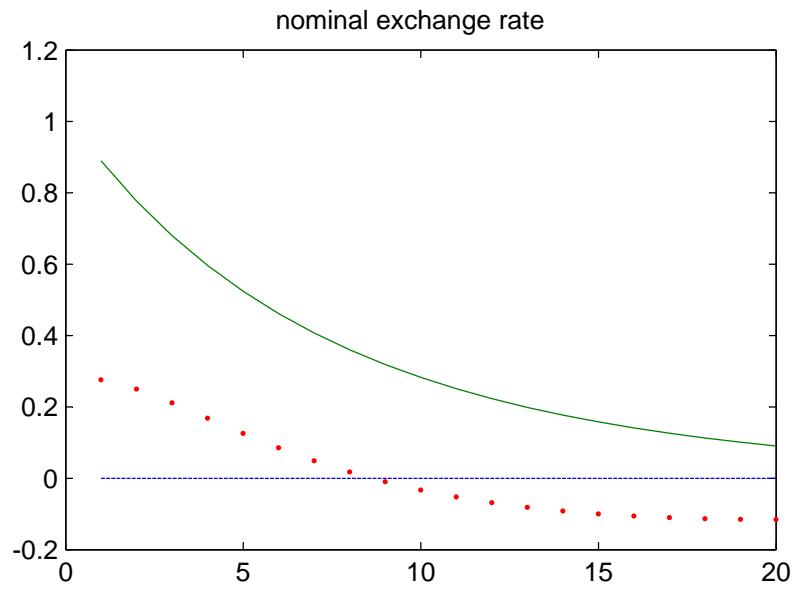
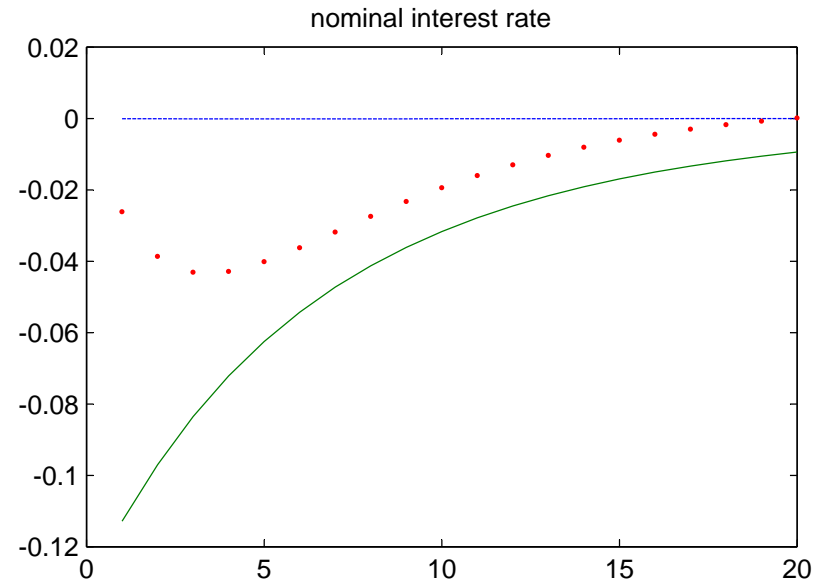
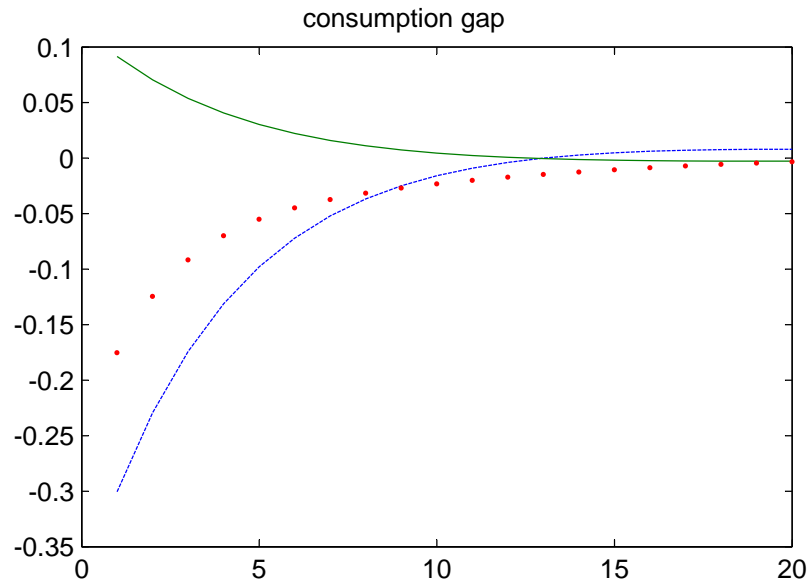


Figure 3: Impulse responses to the domestic nontradable government expenditure shock: local currency pricing

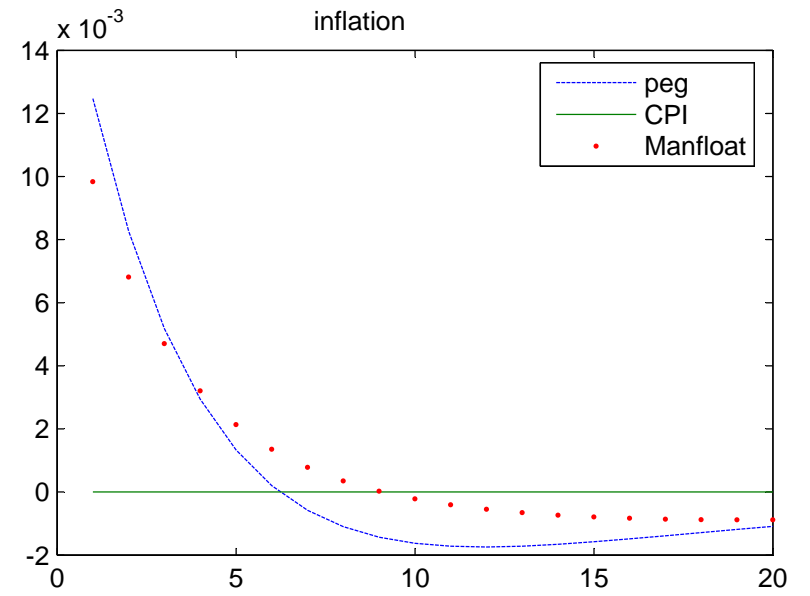
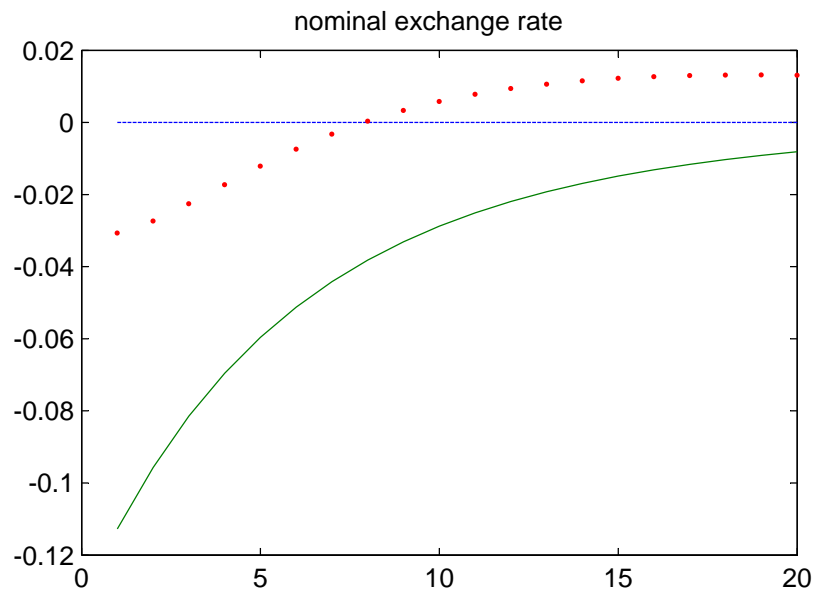
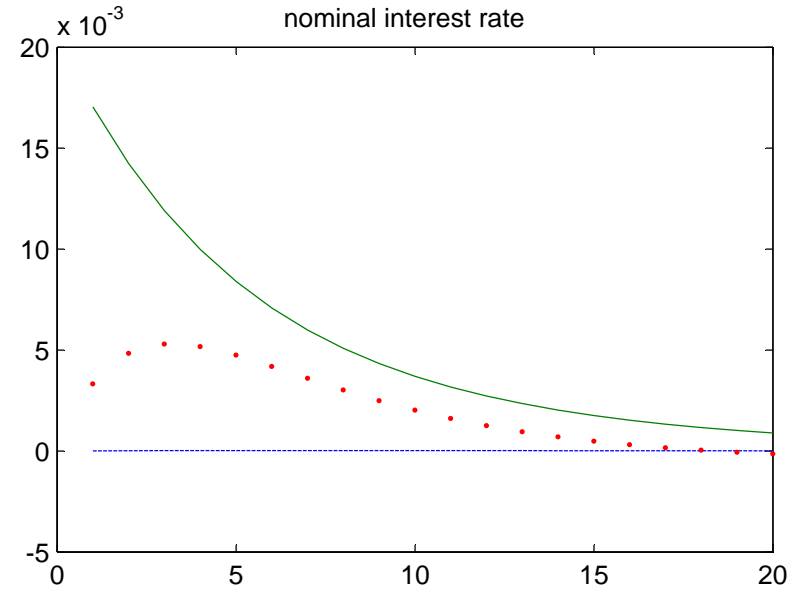
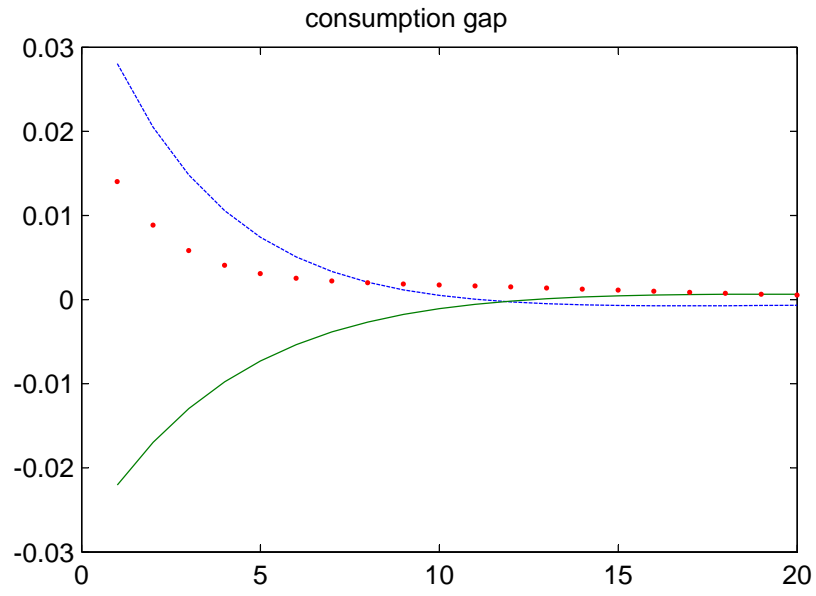




Figure 7: Impulse responses to the foreign nontradable productivity shock: local currency pricing

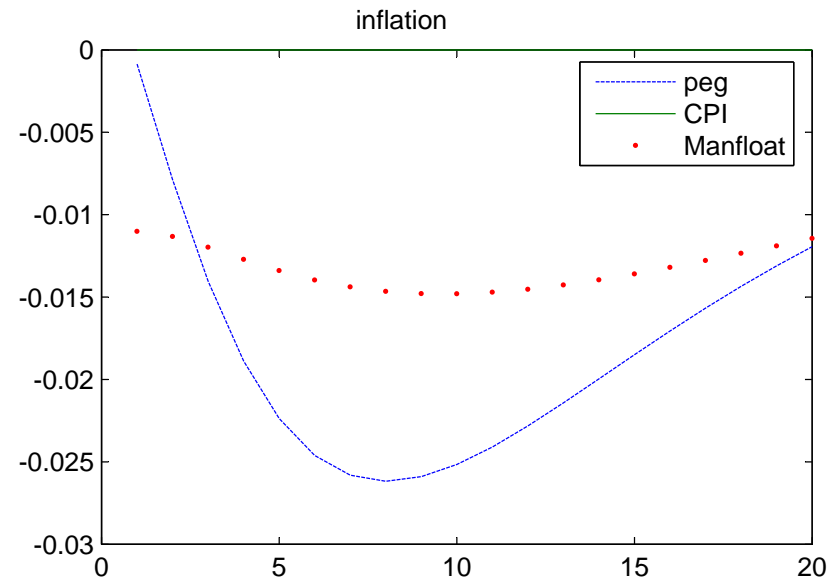
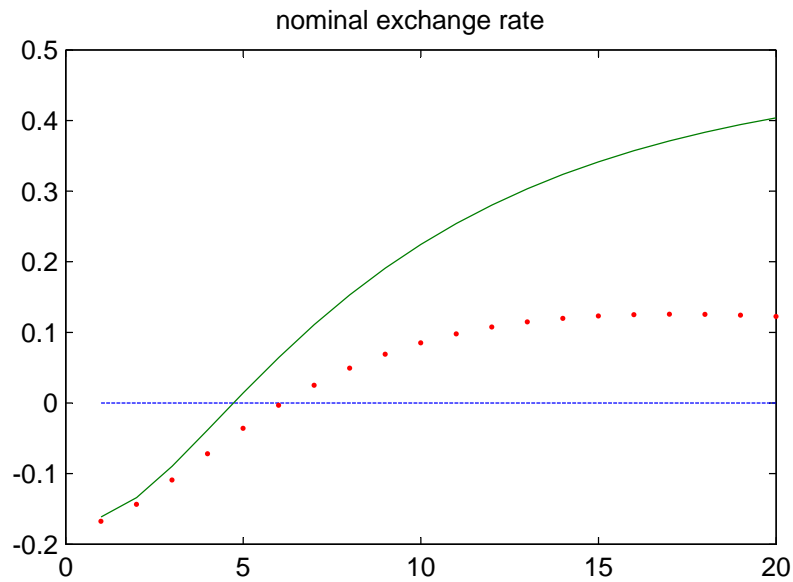
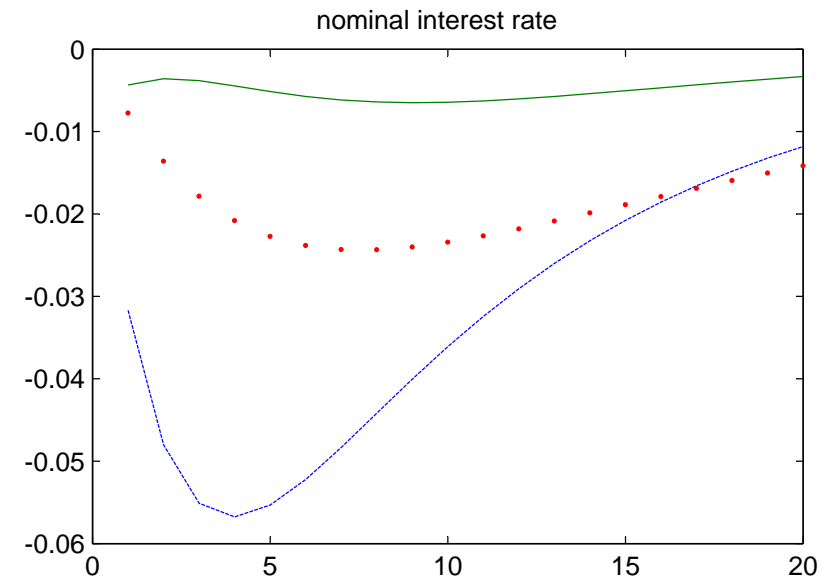
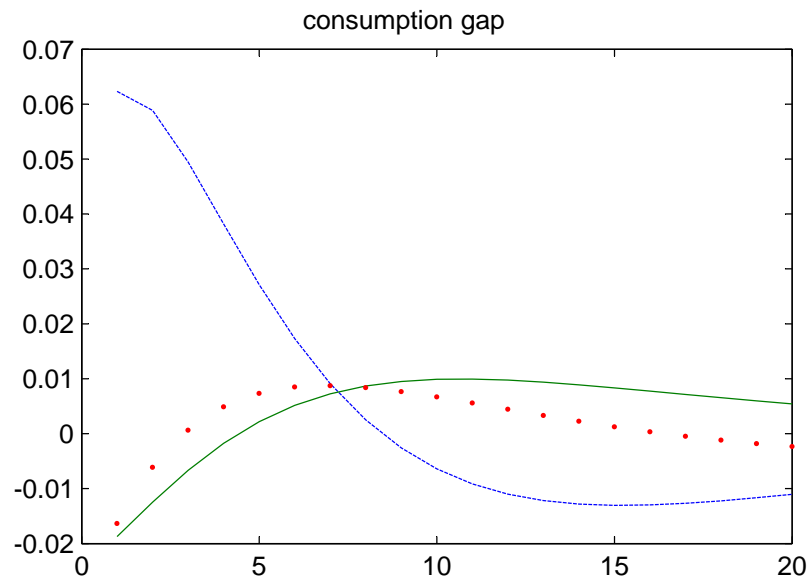


Figure 6: Impulse responses to the domestic monetary shock: local currency pricing

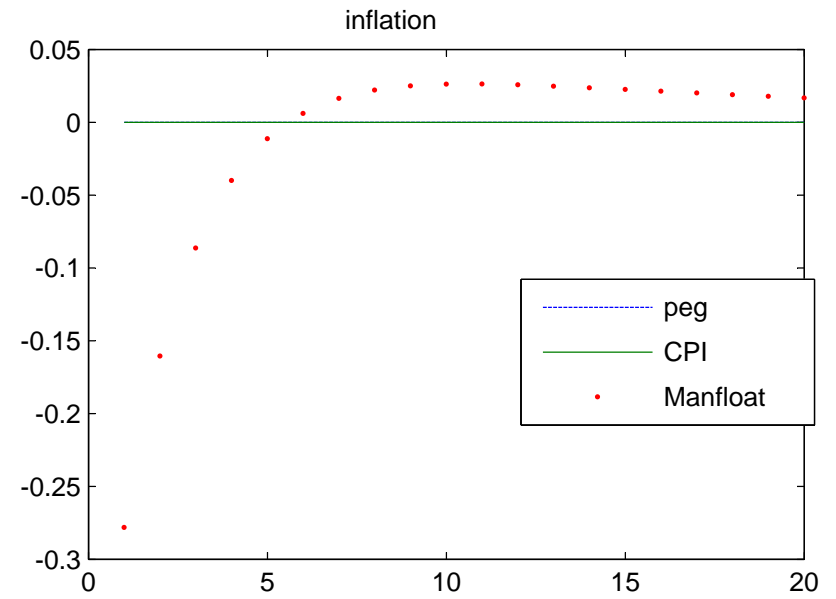
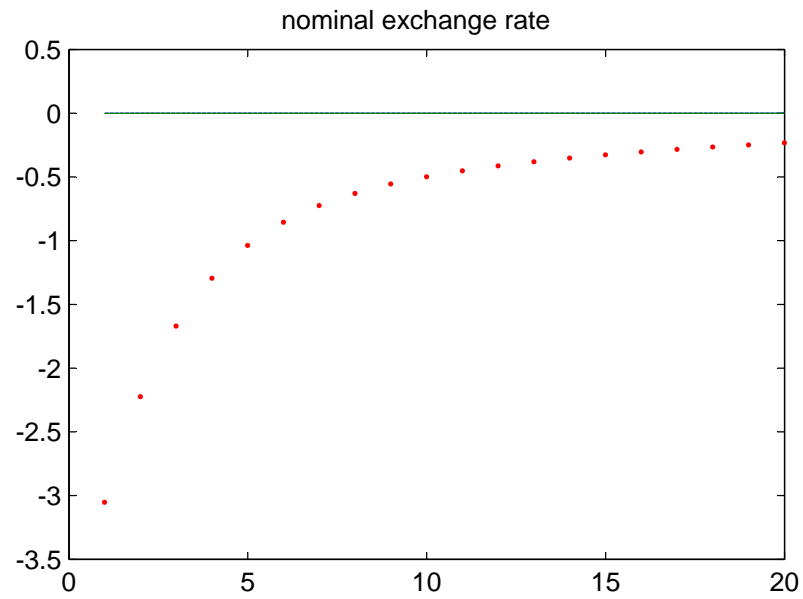
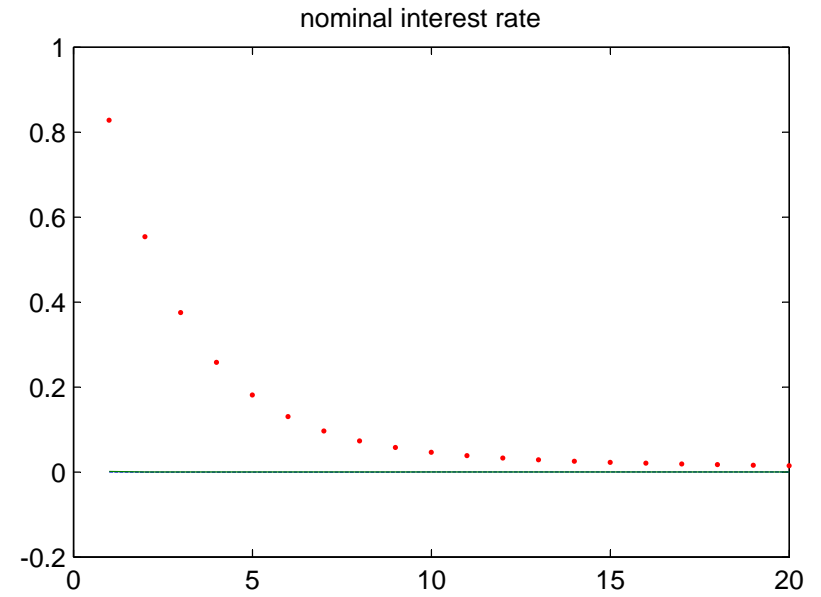
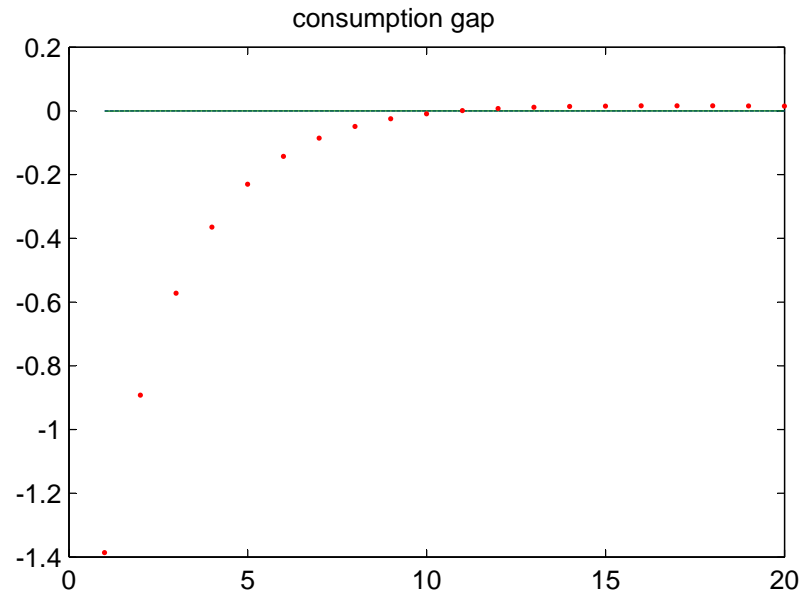


Figure 12: Impulse responses to the foreign monetary shock: local currency pricing

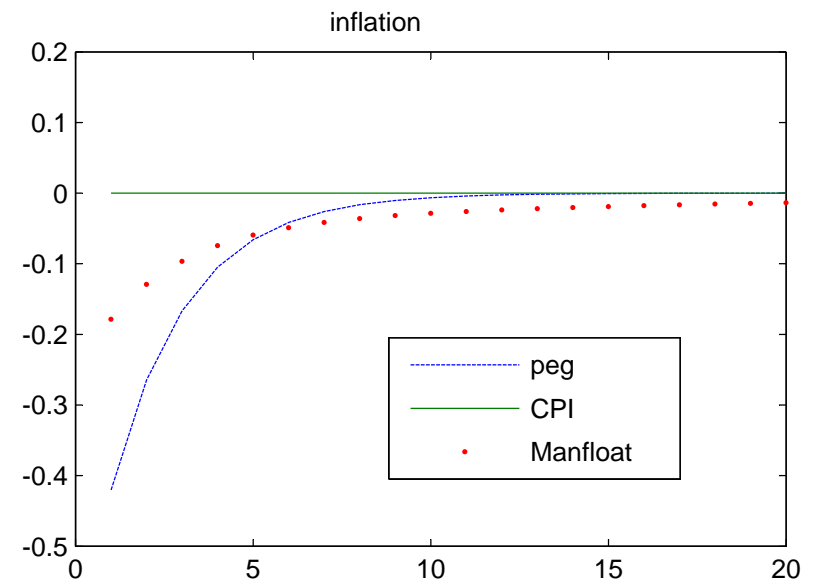
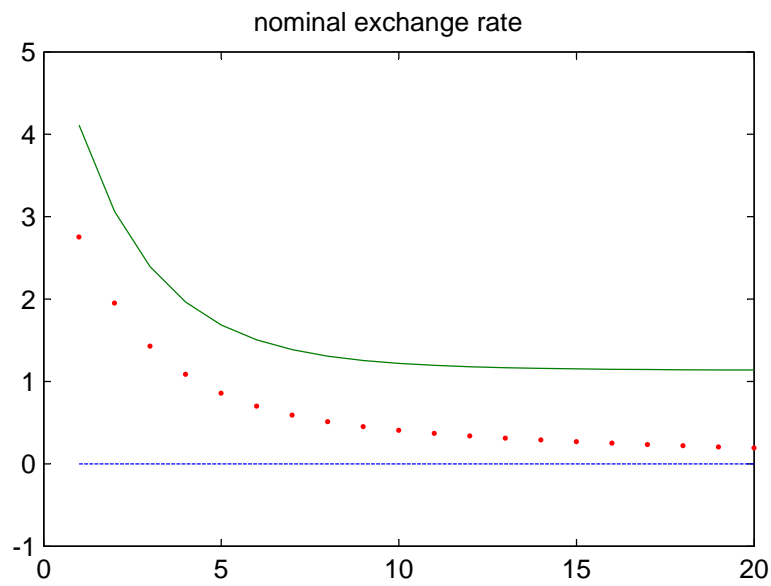
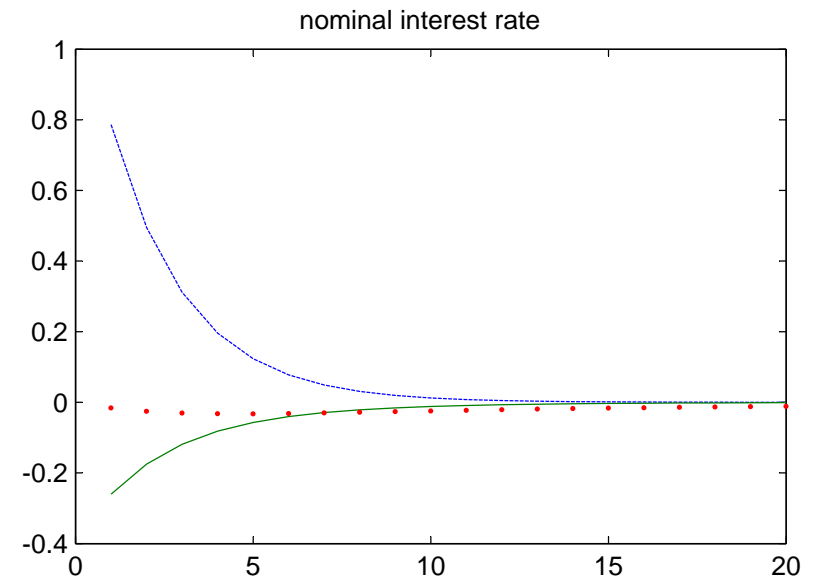
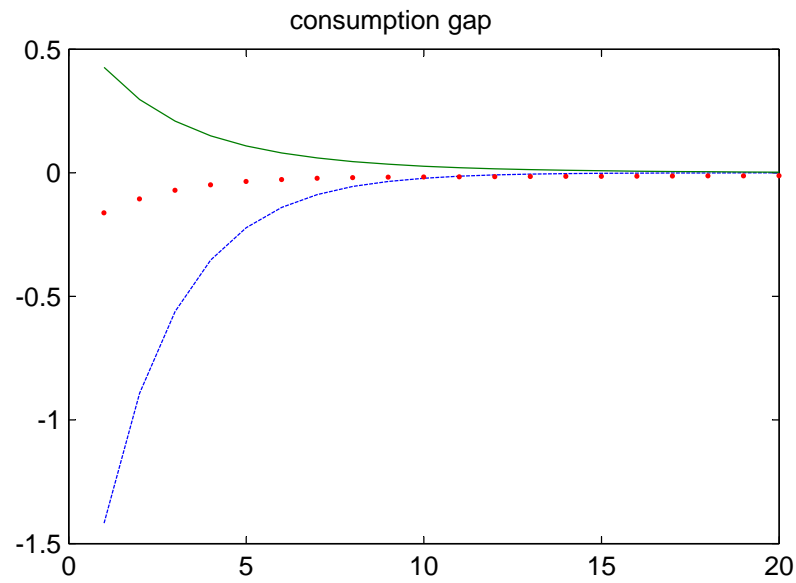


Figure 1a: Impulse responses to the domestic nontradable productivity shock: producer currency pricing

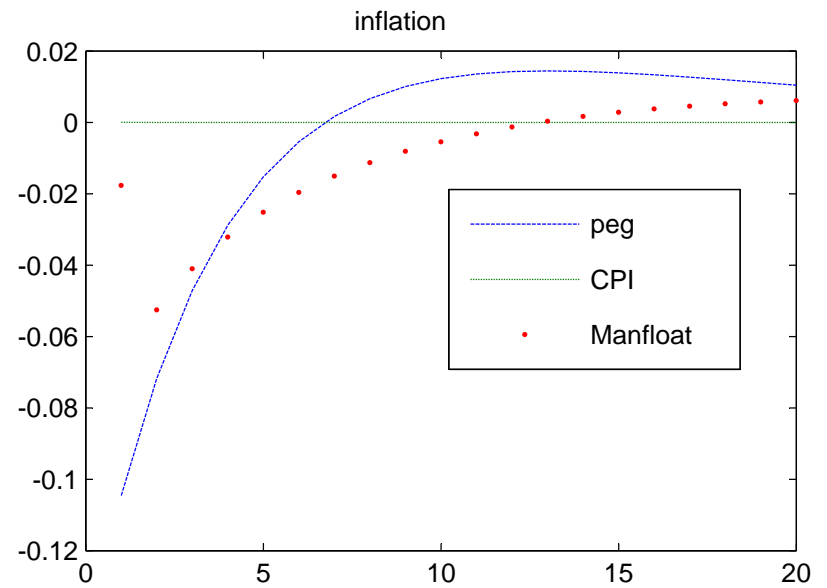
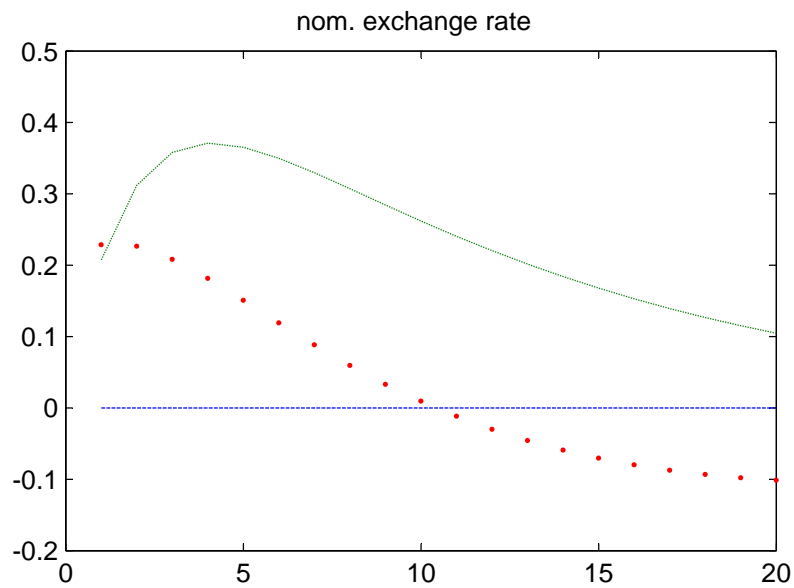
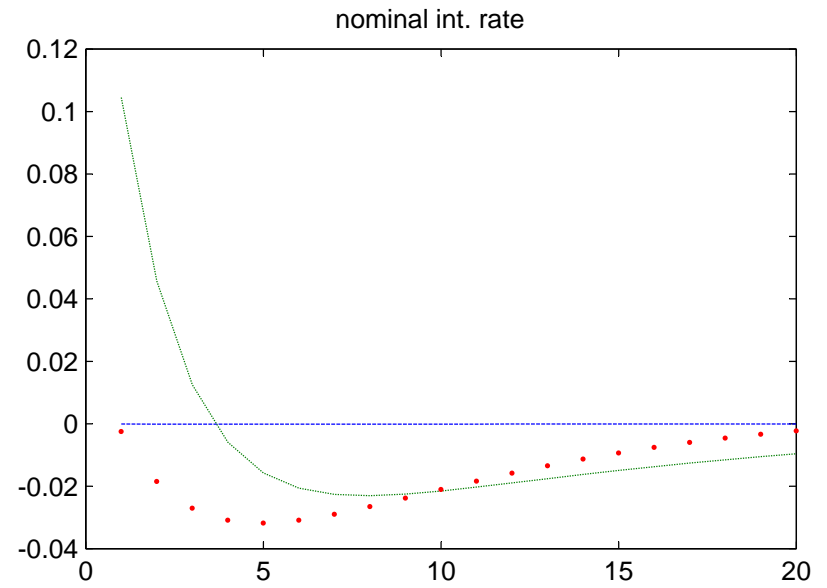
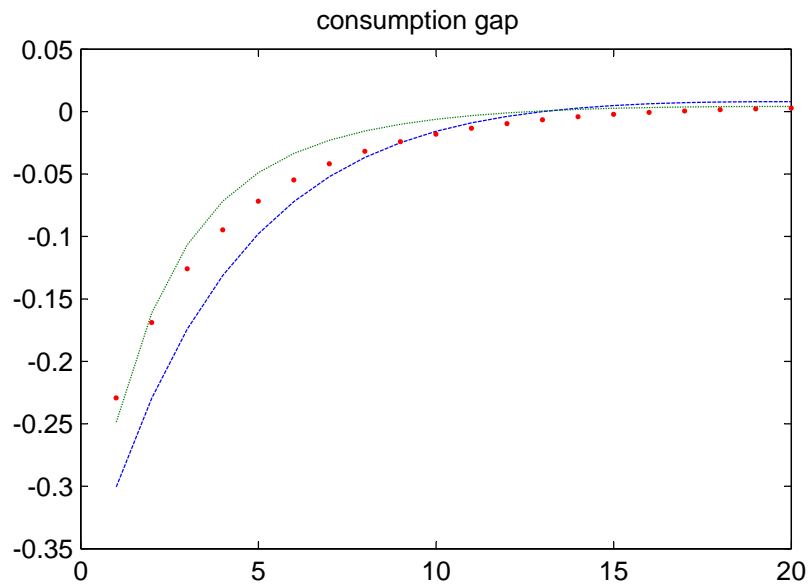


Figure 3a: Impulse responses to the domestic nontradable government expenditure shock: producer currency pricing

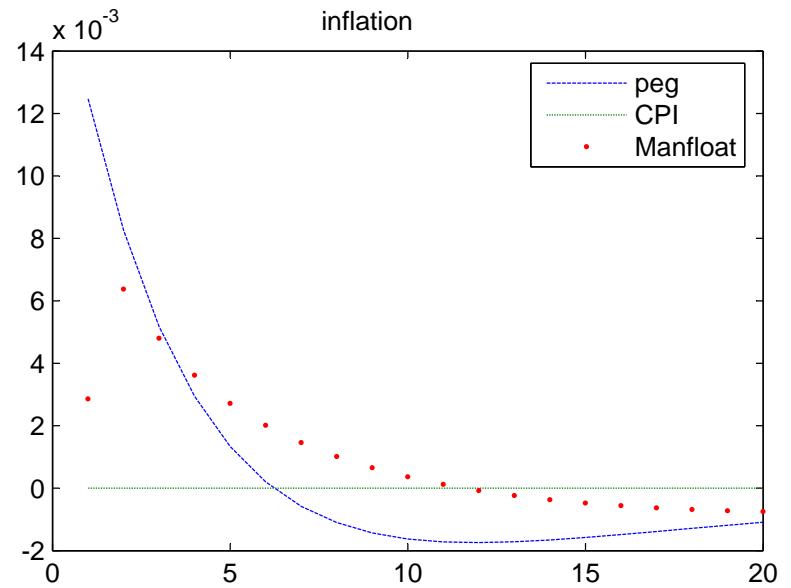
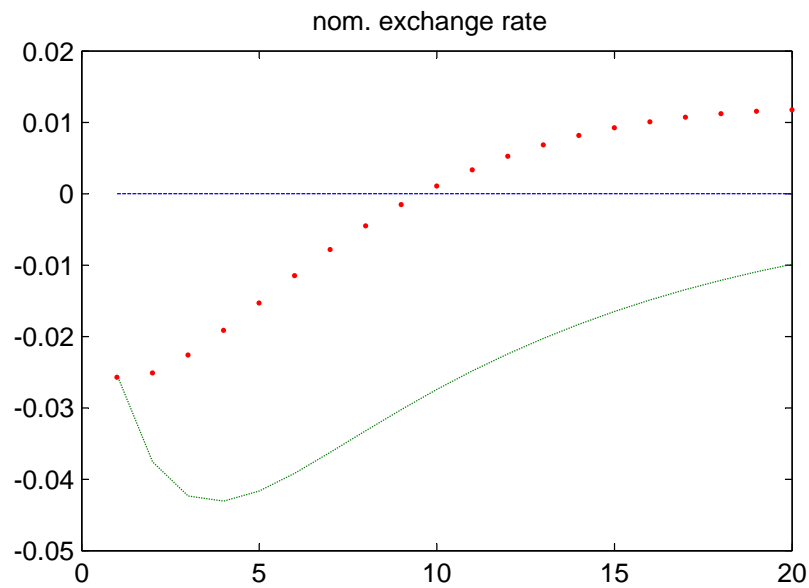
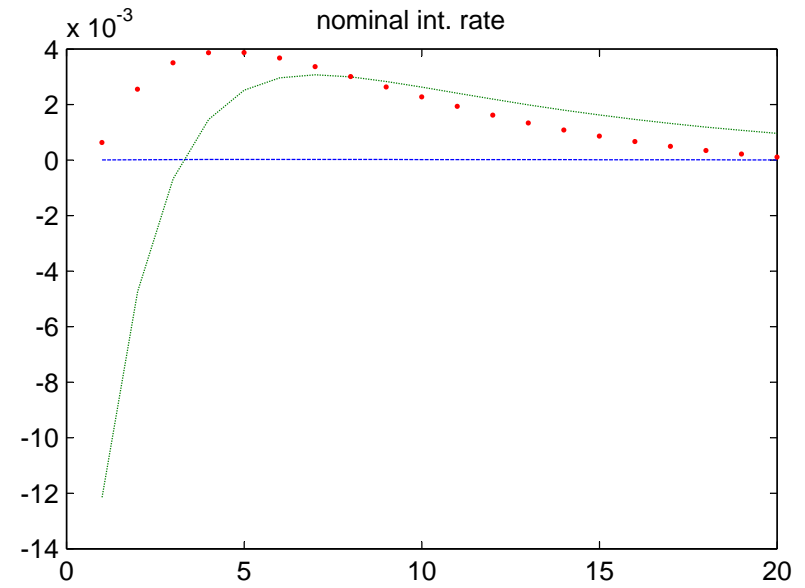
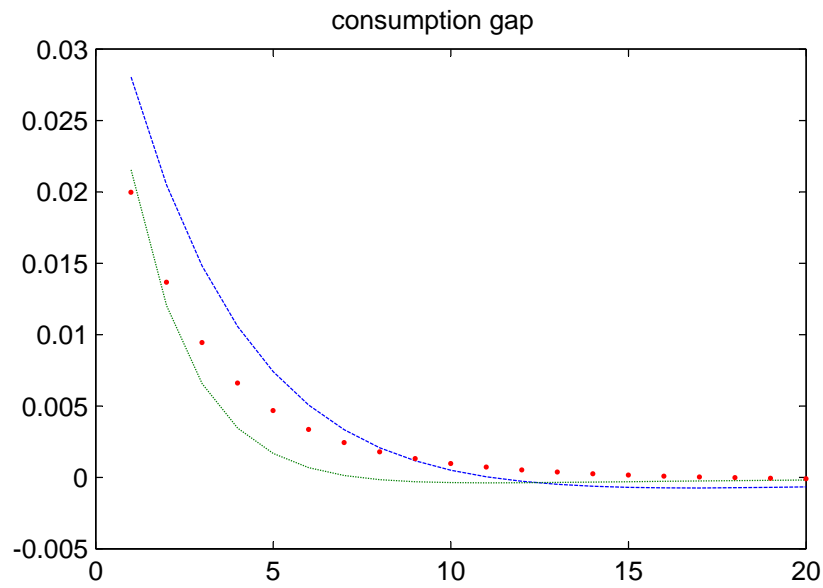


Figure 7a: Impulse responses to the foreign nontradable productivity shock: producer currency pricing

