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Brázdik, František
2013

WORKING PAPER SERIES 2

2013

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2/2013

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Expected Regime Change: Transition Toward Nominal Exchange Rate Stability

František Brázdik*

Abstract

This work presents an extension of a small open economy DSGE model allowing the transition toward a monetary policy regime aimed at exchange rate stability to be described. The model is estimated using the Bayesian technique to fit the properties of the Czech economy. In the scenarios assessed, the monetary authority announces and changes its policy so that it is focused solely on stabilizing the nominal exchange rate after a specific transition period is over. Four representative forms of monetary policy are followed to evaluate their properties over the announced transition period. Welfare loss functions assessing macroeconomic stability are defined, allowing the implications of the transition period regime choice for macroeconomic stability to be assessed. As these experiments show, exchange rate stabilization over the transition period does not deliver the lowest welfare loss. Under the assumptions taken, the strict inflation-targeting regime is identified as the best-performing regime for short transition periods. However, it can be concluded that for longer transition periods the monetary policy regime should respond to changes in the exchange rate.

JEL Codes: E17, E31, E52, E58, E61, F02, F41.
Keywords: monetary policy change, new Keynesian models, small open economy.

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This research was supported by the Czech National Bank. The views expressed in this paper are those of the author and do not necessarily represent those of the Czech National Bank.
I am thankful to Dana Hajková and Michal Kejak for valuable comments and suggestions. I am also thankful to Michal Franta for his patience.

Nontechnical Summary

The motivation for this paper is to analyze whether the announcement of a monetary policy regime switch in a small open economy can lead to gradual changes in macroeconomic volatility with real effects. The paper assesses the behavior of a small open economy that announces a change in its monetary policy regime after a transition period. It is assumed that the sole objective of the new regime is to offset deviations in the nominal exchange rate. The announcement of the regime change also includes a specification of the length of the transition period and the transition period regime. Four types of regimes for the transition period are assessed: CPI inflation targeting, targeting of change in nominal exchange rate, the Taylor rule, and the Taylor rule with exchange rate targeting. These types reflect representative classes of regimes.

The small open economy model presented by Justiniano and Preston (2004) is used for the analysis. This model is characterized by the presence of Calvo-type nominal rigidities. I present an extension of the model to include a policy indicator which allows the effects of the announced regime change to be captured. Further, the parameters of the model are estimated by the Bayesian method using data describing the Czech economy.

The aim of this work is to analyze the stability of the small open economy over the transition period. Therefore, the variance of macroeconomic series and the evolution of the variance over the transition period are assessed.

The main finding is that the variance of the nominal interest rate increases dramatically as the regime switch gets closer. This increase is a consequence of active monetary policy, which toward the end of the transition period has to cope with rising inflation volatility originating from a change in the formation of inflation expectations. However, there are trade-offs in the evolution of variance over the regime and transition period. Therefore, loss functions are used to rank the regimes according to their performance.

The loss function analysis shows that the minimum welfare loss is delivered by focusing solely on CPI inflation over the transition period. This focus delivers the highest volatility in the exchange rate at the beginning of the transition as a result of the trade-off. The exchange rate is used to dampen the propagation of shocks over the transition period. However, when exchange rate stability is also considered, it can be concluded that changes in the nominal exchange rate should also be considered in the monetary policy rule for transition periods longer than eight periods.

1. Introduction

New members of the European Union agree to join the Economic and Monetary Union (EMU) in their accession treaty. To achieve this goal, countries with an independent monetary policy have to demonstrate their ability to fulfill stability requirements. Therefore, monetary union applicants are required to demonstrate macroeconomic stability in expectation that they will adopt the common currency over some transition period. The uncertainty about the properties of the economy during the accession period, when the formation of model agents' expectations is altered by expectations of regime change, motivates the following analysis.

The accession process raises the following questions. How will the outcome of monetary policy differ when expectations are driven by the future regime? Will macroeconomic stability increase over the transition period? How will the loss originating from expectations of a regime switch evolve?

To simplify this analysis, I focus on the behavior of a small open economy that will adopt a monetary policy regime which suppresses deviations in the nominal exchange rate.[1] In the experiments considered, the monetary authority also announces the time of the regime switch and chooses the transition period regime from a given set of regimes. The set of regimes examined include: strict inflation targeting, strict targeting of change in exchange rate, the standard Taylor rule, and a rule where inflation and the change in the exchange rate are targeted. The welfare optimality of the regimes used is not questioned. As in Cuche-Curti et al. (2008), I assume that conducting optimal monetary policy is limited by informational problems. Therefore, to avoid assuming policy-makers have unconstrained information capabilities, as optimal policy rules do, this analysis compares simple monetary policy regimes.

A small open economy model following Justiniano and Preston (2004) is employed. This model was also used in Brázdik (2011), where the announcement effects of an anticipated future change in monetary policy regime are analyzed. This model is characterized by the presence of Calvo-type nominal rigidities. This analysis, as opposed to Brázdik (2011), considers four representative forms of standard monetary policy regimes, in which the effects of the monetary policy regime choice on macroeconomic stability over the transition period are analyzed. Furthermore, future exchange rate targeting in the current paper is not as strong as in Brázdik (2011). This option gives rise to immediate real effects of the future regime change, unlike the effects in Brázdik (2011). Moreover, the estimated parameters are confronted with the calibrated parameters typically used in the literature, with model parameters estimated for the Czech economy. On top of that, the performance of the examined regimes based on loss functions is evaluated.

In this work, similarly as in Antal and Brázdik (2007), the behavior of the economy over the transition period between the announcement and implementation of the monetary policy regime change is modeled. The summary by Farmer et al. (2007) of models relying on Markov switching processes to account for regime change shows that these models are not able to account for the announced change. Therefore, my analysis does not rely on Markov switching processes. To cope with the announcement, the structure of the standard model is extended to include a buffer that allows the regime indicator to be stored. This structure allows the introduction of a

[1] The presented analysis is not designed to draw conclusions about the future single currency regime, due to a number of assumptions taken.

policy indicator that determines current and future monetary policy. The announced change in the policy regime is modeled by means of the flow of information shocks through the buffer.

The rest of the paper is organized as follows. Section 2 presents the model and gives a description of the regime switch modeling. In section 3, the estimation of the parameters is described. The basic characteristics and properties of the model are presented in section 4, where impulse response functions are discussed. Section 5 presents the results of variance computation, and section 6 concludes. All figures can be found in the Appendix.

2. Model

The basics of the model are taken from Justiniano and Preston (2004). The model consists of a small open economy (domestic) and the rest of the world (foreign). The domestic economy is characterized by the existence of habit formation and indexation of prices to inflation. The fundamental model is based on the work of Gali and Monacelli (2002) and Monacelli (2005), where the micro-foundations of the small open economy model are summarized and incomplete pass-through is discussed. The following sections provide derivations of the structural equations of the Justiniano and Preston (2004) model together with comments. The modification of monetary policy and the approach to modeling the transition period are described in a separate subsection.

2.1 Households

The small open economy under consideration is populated by a representative household that maximizes its lifetime utility function

$$E_t \sum_{t=0}^{\infty} \beta^t e^{g_t} \left[\frac{(C_t - H_t)^{1-\sigma}}{1-\sigma} - \frac{{N_t}^{1+\varphi}}{1+\varphi} \right], \tag{2.1}$$

where $\beta,\ 0 < \beta < 1,$ is the utility discount factor; σ and φ are the inverses of the elasticities of the inter-temporal substitution and labor supply, respectively; N_t is total labor effort; $g_t = \rho_g g_{t-1} + \varepsilon_t^g$ is a preference shock, and $\varepsilon_t^g \sim N(0, \sigma_g^2)$; C_t is the consumption of a composite good; $H_t = hC_{t-1}$ is the external habit taken as exogenous by the household as presented by Fuhrer (2000). The parameter h indexes the importance of habit formation. The household consumes a Dixit-Stiglitz composite of the home and foreign good:

$$C_t \;=\; [(1-\alpha)^{\frac{1}{\eta}} (C_t^H)^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} (C_t^F)^{\frac{\eta-1}{\eta}}]^{\frac{\eta}{\eta-1}}, \tag{2.2}$$

where α is the share of the imported good in domestic consumption and $\eta > 0$ is the intra-temporal elasticity of substitution between the domestic and foreign good.

Given the specification of the household's preferences, the minimization of expenditures for a given level of consumption C_t implies, as in Walsh (2003), the following aggregate domestic consumer price index (CPI):

$$P_t \;=\; [(1-\alpha)(P_t^H)^{1-\eta} + \alpha (P_t^F)^{1-\eta}]^{\frac{1}{1-\eta}}, \tag{2.3}$$

where P_t^H and P_t^F are the prices of the domestic and foreign Dixit-Stiglitz composite good used to produce the final composite good C_t.

In aggregate, the household maximizes lifetime utility according to the following budget constraint:

$$P_t C_t + Q_{t,t+1} D_{t+1} \quad \leq \quad D_t + W_t N_t + T_t, \tag{2.4}$$

where W_t is the nominal wage, D_{t+1} is the nominal pay-off received in the period $t+1$ acquired from the portfolio held at the end of the period t, and $Q_{t,t+1}$ is the value of the discount factor of this portfolio, T_t are transfers which include taxes/subsidies and profits collected from domestic firms and importers.

Given Dixit-Stiglitz aggregation, households optimally (cost minimization) allocate their aggregate expenditures on the foreign and domestic good according to the following demand functions:

$$\begin{aligned} C_t^H &= (1-\alpha)\left(\frac{P_t^H}{P_t}\right)^{-\eta} C_t \\ C_t^F &= \alpha \left(\frac{P_t^F}{P_t}\right)^{-\eta} C_t. \end{aligned} \tag{2.5}$$

The first-order necessary conditions imply the domestic Euler equation in the following form:

$$\lambda_t E_t[Q_{t,t+1}] \quad = \quad \beta E_t[\lambda_{t+1} \frac{P_t}{P_{t+1}}], \tag{2.6}$$

where λ_t is the Lagrange multiplier associated with the budget constraint. This equation is used in the following section to link the domestic and foreign economy.

2.2 International Arrangements

The real exchange rate is defined as the ratio of foreign prices in domestic currency to domestic prices $\hat{q}_t \equiv \hat{e}_t \frac{P_t^*}{P_t}$, where $\hat{e}_t$ is the nominal exchange rate (in terms of the domestic currency per unit of foreign currency), P_t^* is the foreign consumer price index, and P_t is the domestic consumer price index given by equation 2.3. An increase in $\hat{e}_t$ coincides with a depreciation of the domestic currency.[2] Further, I assume that $P_t^* = P_t^{F*}$ (P_t^{F*} is the price of the foreign good in foreign currency). Following Monacelli (2005), the law of one price gap in linearized form is given by $\Psi_t^F = \hat{e}_t \frac{P_t^*}{P_t^F}$. The law of one price gap represents the wedge between the foreign price of the foreign good P_t^{F*} and the price of the foreign good when sold on the domestic market P_t^F by importers (see (Lubik, 2005) for details). The law of one price (LOOP) holds when $\Psi_t^F = 1$; for $\Psi_t^F > 1$, importers realize losses due to increasing costs of imported goods; when $\Psi_t^F < 1$, importers enjoy profits.

The foreign economy is identical in preferences, therefore its optimality conditions are similar to the domestic optimality conditions. The foreign economy is considered to be large and the domestic good accounts for only a negligible fraction of its consumption. Therefore, the foreign composite consumption bundle can be simplified and only foreign-produced goods are considered in overall foreign consumption. Further, under the assumption of complete international

[2] The superscript * denotes "foreign" equivalents of domestic variables throughout this paper.

financial markets, arbitrage implies that the marginal utility of consumption in the foreign economy is proportional to that in the domestic economy. Using the domestic version of the Euler equation 2.6, the following condition is derived:

$$\beta E_t[\frac{\lambda_{t+1}}{\lambda_t}\frac{P_t}{P_{t+1}}] = \quad E_t[Q_{t,t+1}] \quad = \beta E_t[\frac{\lambda^*_{t+1}}{\lambda^*_t}\frac{P^*_t}{P^*_{t+1}}\frac{\hat{e}_{t+1}}{\hat{e}_t}]. \tag{2.7}$$

Defining the gross nominal return on the portfolio as $R_t^{-1} = E_t[Q_{t,t+1}]$, the risk-sharing condition (2.7) equation implies the following uncovered interest rate parity (UIP) condition:

$$E_t[Q_{t,t+1}(R_t - R^*_t(\frac{\hat{e}_{t+1}}{\hat{e}_t}))] \quad = \quad 0. \tag{2.8}$$

The uncovered interest rate parity places a restriction on the relative movement of the domestic and foreign interest rates and on the nominal exchange rate. However, the interest rate parity can be distorted by a risk premium shock. Therefore, as in Kollmann (2002), a shock that captures deviations from purchasing power parity and is not already explained endogenously through imperfect pass-through, such as a time-varying risk premium, is added into the log-linearized form of the model. Moreover, the risk premium is constant in the steady state and equation 2.8 collapses to the standard uncovered interest rate parity equation for the nominal exchange rate in the steady state.

Finally, the terms of trade are defined as the relative price of imports in terms of exports:

$$S_t \quad = \quad \frac{P^F_t}{P^H_t}. \tag{2.9}$$

Note that changes in the terms of trade may reflect future changes in the competitiveness of an economy. A depreciation of the exchange rate induces an increase in import prices and a deterioration in the terms of trade. However, the depreciated exchange rate restores the competitiveness of the economy, since demand for cheaper exports grows and import demand from domestic consumers decreases.

2.3 Firms

In this economy, the nominal rigidities that drive price adjustment arise due to monopolistic competition in the goods market. Suppose there is a continuum of domestic firms indexed by $i,\ 0 \leq i \leq 1$. A typical firm i in the home country produces a differentiated good with constant returns to scale according to the following production function:

$$Y_t(i) = A_t N_t(i),$$

where $N_t(i)$ is labor supplied by a household to firm i; A_t is a common stationary productivity process that follows $log(A_t) = a_t = \rho_a a_t + \varepsilon^a_t$, where $\varepsilon^a_t \sim N(0, \sigma^2_a)$ is an exogenous productivity shock common to all firms. The firm's index can be dropped, while in symmetric equilibrium all choices of the firms are identical. According to the production function, the representative firm faces real marginal costs $MC_t = \frac{W_t}{P_t A_t}$, where W_t is the nominal wage.

Here, the domestic inflation rate is defined as $\pi^H_t = log(P^H_t/P^H_{t-1})$. Firms producing a domestic good are monopolistically competitive with Calvo-style price setting using inflation indexation.

Further, only a fraction $(1-\theta^H)$ of firms are allowed to set their price $P_t^{H,new}$ optimally in the period considered. The remaining fraction θ^H, $0 \leq \theta^H < 1$, sets its price according to the following indexation rule:

$$log(P_t^H(i)) = log(P_{t-1}^H(i)) + \delta\pi_{t-1}^H,$$

where $0 \leq \delta < 1$ is the degree of indexation. Therefore, the aggregate price index evolves according to the following relation:

$$P_t^H \;=\; \left[(1-\theta^H)(P_t^{H,new})^{(1-\varepsilon)} + \theta^H \left(P_{t-1}^H \left(\frac{P_{t-1}^H}{P_{t-2}^H}\right)^{\delta}\right)^{(1-\varepsilon)}\right]^{1/(1-\varepsilon)}, \tag{2.10}$$

where $\varepsilon > 1$ is the elasticity of substitution between the varieties of goods produced by domestic firms. Firm i, setting its price in period t and following the indexation rule in all subsequent periods T, $T \geq t$, faces the following demand curve in period T:

$$y_T^H(i) = \left(\frac{P_t^{H,new}(i)}{P_T^H}\left(\frac{P_{T-1}^H}{P_{t-1}^H}\right)^{\delta}\right)^{-\varepsilon}(C_T^H + C_T^{H*}),$$

where C_t^H is domestic demand and C_t^{H*} is foreign demand for the composite domestic good. While firm i is maximizing its present value by maximizing the value of the real profit stream, the firm's price-setting problem in period t is to solve:

$$\max_{P_t^H(i)} \; E_t \sum_{T=t}^{\infty}(\theta^H)^{T-t}Q_{t,T}y_t^H(i)\left[P_t^{H,new}(i)\left(\frac{P_{T-1}^H}{P_{t-1}^H}\right)^{\delta} - P_T^H MC_T\right]$$

subject to the aforementioned demand curve. This implies the following first-order condition:

$$E_t \sum_{T=t}^{\infty}(\theta^H)^{T-t}Q_{t,T}y_t^H(i)\left[P_t^{H,new}(i)\left(\frac{P_{T-1}^H}{P_{t-1}^H}\right)^{\delta} - \frac{\varepsilon}{1-\varepsilon}P_T^H MC_T\right] = 0,$$

where MC_T are real marginal costs in the period of the price decision.

Similarly as in domestic goods production, the nominal rigidities in the foreign goods sector result from staggered price setting and monopolistic competition. Foreign goods retailers import foreign goods so that the law of one price holds "at the docks" and resell them in a monopolistically competitive market. To set their prices, importers also use Calvo pricing with indexation to past inflation of imported goods prices, which is defined as $\pi_t^F = log(P_t^F/P_{t-1}^F)$.

Again, only a fraction $(1-\theta^F)$ of importers are allowed to set their new price $P_t^{F,new}$ optimally in each period. The fraction θ^F, $0 \leq \theta^F < 1$, of importers just updates its price according to the following indexation rule:

$$log(P_t^F(i)) = log(P_{t-1}^F(i)) + \delta\pi_{t-1}^F,$$

where the same degree of indexation δ as for domestic producers is assumed. The foreign goods price index evolves according to the following relation:

$$P_t^F = \left[(1-\theta^F)(P_t^{F,new})^{(1-\varepsilon)} + \theta^F \left(P_{t-1}^F \left(\frac{P_{t-1}^F}{P_{t-2}^F} \right)^\delta \right)^{(1-\varepsilon)} \right]^{1/(1-\varepsilon)}.$$

Similarly, importer i, who sets its price in period t, faces the following demand curve in period T, $T \geq t$:

$$y_T^F(i) = \left(\frac{P_t^{F,new}(i)}{P_T^F} \left(\frac{P_{T-1}^F}{P_{t-1}^F} \right)^\delta \right)^{-\varepsilon} C_T^F, \tag{2.11}$$

as for the domestic good, where $\varepsilon > 1$ is a parameter describing the substitution between the varieties of foreign goods. Therefore, the importer's price-setting problem in period t is to maximize

$$E_t \sum_{T=t}^{\infty} (\theta^F)^{T-t} Q_{t,T} y_t^F(i) \left[P_t^{F,new}(i) \left(\frac{P_{T-1}^F}{P_{t-1}^F} \right)^\delta - \hat{e}_T P_T^F MC_T \right]$$

subject to the aforementioned demand equation (2.11). This implies the following first-order condition:

$$E_t \sum_{T=t}^{\infty} (\theta^F)^{T-t} Q_{t,T} y_t^F(i) \left[P_t^{F,new}(i) \left(\frac{P_{T-1}^F}{P_{t-1}^F} \right)^\delta - \frac{\varepsilon}{1-\varepsilon} \hat{e}_T P_T^F MC_T \right] = 0,$$

and the new optimal price $P_t^{F,new}(i)$ is the solution to this equation. The presence of nominal rigidities results in deviations from the law of one price in the short run, while a complete pass-through is reached in the long run, as presented in Monacelli (2005).

2.4 Equilibrium

Equilibrium requires that all markets clear. The goods market clearing condition in the domestic economy is given by the following equation:

$$Y_t^H = C_t^H + C_t^{H*}. \tag{2.12}$$

Under the assumption of a large foreign economy, market clearing in the foreign economy gives $Y_t^* = C_t^*$. Households, which are assumed to have identical initial wealth, make identical consumption and portfolio decisions. So, the following analysis considers a symmetric equilibrium in which domestic producers, importers, and foreign firms also behave identically. Therefore, the individual index can be dropped and the representative household, the representative firm, and the single good in each sector can be used for the model solution. In period t the representative domestic producers set common prices P_t^H. Importers also set a common price P_t^F, as do the foreign producers when setting P_t^*. Finally, as in Gali and Monacelli (2002) and Justiniano and Preston (2004), I assume that the government offsets distortions originating from monopolistic competition in the goods markets by a subsidy/transfer financed through a lump-sum tax T_t on the representative household.

2.5 Log-linearized Model

To analyze the behavior of the underlying model, an approximation around the non-stochastic steady state of the presented model is obtained as in Justiniano and Preston (2004). For any variable, lowercase letters denote the log-deviation from the steady state of their uppercase counterparts in the frictionless equilibrium. The non-stochastic steady state is characterized by setting all shocks to zero for all periods.

As in Justiniano and Preston (2004), a zero inflation steady state is assumed, so that $\pi_t = \frac{P_t}{P_{t-1}} = \frac{P_t^H}{P_{t-1}^H} = \frac{P_t^F}{P_{t-1}^F} = 1$, and for the steady state of the nominal interest rate $1 + i_t = \frac{1}{\beta}$.

Linearizing the domestic goods market clearing condition given by equation 2.12 together with a linearized version of the demand functions 2.5 implies

$$(1-\alpha)c_t = y_t - \alpha\eta(2-\alpha)s_t - \alpha\eta\psi_t^F - \alpha y_t^*, \tag{2.13}$$

where $\psi_t^F = (e_t + p_t^*) - p_t^F$ is a log-linear approximation of the law of one price, and $s_t = p_t^F - p_t^H$ is a log-linear approximation of the terms of trade given by equation 2.9. Time differencing of the terms of trade definition implies

$$\Delta s_t = \pi_t^F - \pi_t^H. \tag{2.14}$$

Using the log-linearized equations of the law of one price gap and the terms of trade, the following link between the terms of trade and the real exchange rate can be derived:

$$q_t = \psi_t^F + (1-\alpha)s_t. \tag{2.15}$$

The log-linear approximation to the optimality conditions of domestic firms for price setting, the law of motion for the domestic producer price, and the domestic price index given by equation 2.10 imply the following hybrid Philips curve:

$$\pi_t^H - \delta\pi_{t-1}^H = \frac{1-\theta^H}{\theta^H}(1-\theta^H\beta)mc_t + \beta E_t[(\pi_{t+1}^H - \delta\pi_t^H)], \tag{2.16}$$

where the marginal costs are

$$mc_t = \varphi y_t - (1+\varphi)a_t + \alpha s_t + \sigma(1-h)^{-1}(c_t - hc_{t-1}). \tag{2.17}$$

The log-linear form of the real marginal costs mc_t of the representative firm originates from the log-linearization of the aggregate production function and the household's optimality condition for labor choice.

Similarly, the optimality condition for the pricing problem of retailers results in the following Philips curve:

$$\pi_t^F - \delta\pi_{t-1}^F = \frac{1-\theta^F}{\theta^F}(1-\theta^F\beta)\psi_t^F + \beta E_t[(\pi_{t+1}^F - \delta\pi_t^F)]. \tag{2.18}$$

Following the arguments of Justiniano and Preston (2004) and the derivation by Gali and Monacelli (2002), the complete markets assumption together with condition 2.7 imply the following relation for the log-linear approximation of the Euler equation 2.6:

$$c_t - hc_{t-1} = y_t^* - hy_{t-1}^* + \sigma^{-1}(1-h)[\psi_t^F + (1-\alpha)s_t] + \sigma^{-1}(1-h)g_t. \tag{2.19}$$

The log-linear approximation of the uncovered interest rate parity equation 2.8 gives $i_t - i_t^* = E_t \Delta e_{t+1}$. As mentioned in the previous section, to capture the deviations from UIP, a risk premium shock ϵ_t is added into equation 2.8; $\epsilon_t = \rho_s \epsilon_{t-1} + \varepsilon_t^s$, where $\varepsilon_t^s \sim N(0, \sigma_s^2)$. Using the definition of the real exchange rate,

$$\Delta e_t \;=\; \Delta q_t + \pi_t - \pi_t^*, \tag{2.20}$$

the following equation is derived:

$$(i_t - E_t \pi_{t+1}) - (i_t^* - E_t \pi_{t+1}^*) = E_t \Delta q_{t+1} + \epsilon_t. \tag{2.21}$$

The risk premium shock ϵ_t is zero in the steady state, so the steady state equation 2.21 collapses to a standard uncovered interest rate parity equation. Also, note that positive (negative) values of Δe_t reflect domestic currency depreciation (appreciation).

Finally, the approximations of the CPI equation 2.3 and the change in the terms of trade 2.14 give the following relation:

$$\pi_t \;=\; \pi_t^H + \alpha \Delta s_t. \tag{2.22}$$

Since the goods produced in the home economy represent only a small fraction of the consumption of the foreign economy, I consider the large foreign economy to be exogenous to the domestic economy. Therefore, I assume that the paths of foreign variables $\pi_t^*,\ y_t^*$, and i_t^* are determined by the following VAR process:

$$\pi_t^* \;=\; \omega_\pi^\pi \pi_{t-1}^* + \omega_y^\pi y_{t-1}^* + \omega_i^\pi i_{t-1}^* + \varepsilon_t^\pi, \tag{2.23}$$

$$y_t^* \;=\; \omega_\pi^y \pi_{t-1}^* + \omega_y^y y_{t-1}^* + \omega_i^y i_{t-1}^* + \varepsilon_t^y, \tag{2.24}$$

$$i_t^* \;=\; \omega_\pi^i \pi_{t-1}^* + \omega_y^i y_{t-1}^* + \omega_i^i i_{t-1}^* + \varepsilon_t^i, \tag{2.25}$$

where $\varepsilon_t^\pi,\ \varepsilon_t^y$, and ε_t^i; $\varepsilon_t^y \sim N(0, \sigma_y^2)$, $\varepsilon_t^\pi \sim N(0, \sigma_\pi^2)$, and $\varepsilon_t^i \sim N(0, \sigma_i^2)$, represent independent structural shocks that drive the foreign economy.

The description of the model is closed by describing the behavior of the domestic monetary authority. As the Czech central bank reacts to forecasted inflation, I deviate from Justiniano and Preston (2004) in my analysis. As discussed by Carlstrom and Fuerst (2000), I assume that the monetary authority acts according to expected inflation rather than using the actual level of inflation. To keep my analysis simple, I assume that the monetary authority is forward looking only for one period ahead.

So, the monetary policy rule for the basic model takes the following form:

$$i_t \;=\; \rho_i i_{t-1} + \rho_\pi E_t[\pi_{t+1}] + \rho_y y_t + \rho_e \Delta e_t + \varepsilon_t^m, \tag{2.26}$$

where $0 \leq \rho_i < 1,\ \rho_\pi > 1,\ \rho_y > 0$, and $\rho_e \geq 0$ are weights describing the responses of the domestic monetary authority, and ε_t^m, $\varepsilon_t^m \sim N(0, \sigma_m^2)$ is the shock capturing errors arising from the description of monetary policy. By varying the choice of parameters $\rho_\pi,\ \rho_y$, and ρ_e in rule 2.26 various monetary policies can be described. These parameters are estimated to set up the basic model.

2.6 Monetary Policy Rule in Transition Period

The aim of this paper is to analyze macroeconomic stability during the transition, so in this section an extension of the basic model is presented.

The economy begins at time $t = 1$, when it is announced that the regime will change in period $T, T > 1$. To simplify this analysis, it is assumed that the monetary authority follows the same policy rule over all periods of the transition, $t \leq T$.

The monetary policy rule for the model of the transition period takes the following form:

$$\begin{aligned} i_t &= regime_t(\rho_i i_{t-1} + \rho_\pi E_t[\pi_{t+1}] + \rho_y y_t + \rho_e \Delta e_t + \varepsilon_t^m) + \\ &+ (1 - regime_t)\widehat{\rho_e}\Delta e_t, \end{aligned} \tag{2.27}$$

where $0 \leq \rho_i < 1$, $\rho_\pi > 1$, $\rho_y > 0$, and $\rho_e \geq 0$ are weights describing the responses of the domestic monetary authority, and ε_t^m, $\varepsilon_t^m \sim N(0, \sigma_m^2)$ is the shock capturing errors arising from the description of monetary policy. The active monetary policy regime is selected via the regime indicator. In the following experiment, when the change is announced in the first period, the indicator is defined as follows:

$$regime_t = \begin{cases} 1, & \text{if } t < T; \\ 0, & \text{if } t \geq T, \end{cases}$$

where T is the announced time of the regime change. By varying the values of the rule parameters ρ_π, ρ_y, and ρ_e in rule 2.27, various monetary policies can be defined for the transition period ($t < T$), e.g., inflation targeting or exchange rate targeting.

Together with the adoption of the new monetary policy rule, the exchange rate risk premium is also removed. To make this change foreseen in the model of transition, the AR(1) process for the risk premium shock ϵ_t in equation 2.21 will become $\varepsilon_t = \rho_s \varepsilon_{t-1} + regime_t \varepsilon_t^s, \varepsilon_t^s \sim N(0, \sigma_s^2)$, since $t > T$.

The introduction of the regime indicator transforms the problem of modeling an announced change into a problem of foreseen changes in the indicator. To model the announced changes in the indicator, as in Antal and Brázdik (2007) the state space of the model is extended to include an information buffer of length N, where $N > T$. This information buffer is capable of storing information for N periods ahead and takes the following form:

$$\begin{aligned} regime_t &= inf_{t,1} \\ inf_{t,1} &= inf_{t-1,2} + \nu_{t,1} \\ inf_{t,2} &= inf_{t-1,3} + \nu_{t,2} \\ &\vdots \\ inf_{t,N-1} &= inf_{t-1,N} + \nu_{t,N-1} \\ inf_{t,N} &= \nu_{t,N}, \end{aligned} \tag{2.28}$$

where $inf_{t,i}$, $i \in 1, \ldots, N$ are the new endogenous variables, and $\nu_{t,i}$, $i \in 1, \ldots, N$ are the announcement shocks, such that $\nu_{t,i}$ takes values 0 and 1 for all $i = 1, \ldots, N$ and $t > 0$. The initial condition for the buffer is $inf_{0,i} = 0$ and $\nu_{0,i} = 0$, $\forall i \in 1, \ldots, N$.

In the experiment, only perfectly credible announcements are considered. Therefore, I can think of $\nu_{t,i}$s as random variables with zero mean and zero variance. However, by varying the assumption about information shocks, it is possible to model the uncertainty about the monetary authority keeping its commitment to the announced policy rule switch. The higher is this uncertainty, the higher should be the value of the information shock variance used.

The announcement of the regime change at $t = 1$ is modeled by the realization of the information shocks $\nu_{t,i}$ $i \in 1, \ldots, N$ according to the following scheme:

$$\nu_{1,i} = \begin{cases} 1, & i \leq T; \\ 0, & i > T, \end{cases} \tag{2.29}$$

and $\nu_{t,i} = 0,\ \forall i$ and in all subsequent periods $t,\ 1 < t \leq T$. This realization of information shocks describes a one-time announcement of a policy rule switch in period T without any further changes of the transition length.

The model of the transition period consists of equations 2.13–2.25, the monetary policy rule (2.27), the information buffer given by equations 2.28, and definitions of the AR(1) processes for technology and preference shocks.

The model for the post-transition regime ($t \geq T$) is a modification of the basic model. In this model, the only monetary policy objective is to offset all the foreseen changes in the nominal exchange rate, so $\rho = \rho_\pi = \rho_y = 0$. This regime is characterized by $\widehat{\rho_e}$, which measures the offsetting of the change in the nominal exchange rate. Therefore, the post-transition monetary policy rule takes the following form:

$$i_t = \widehat{\rho^e} \Delta e_t. \tag{2.30}$$

To keep the level of exchange rate volatility reasonably low, I set $\widehat{\rho_e} = 1.25$. It is also assumed that there are no future shocks (for $t \geq T$) to the risk premium. So, the risk premium shock ϵ_t in equation 2.21 will become $\epsilon_t = \rho_s \epsilon_{t-1}$, where the initial condition depends on the transition period model.

The construction of the policy indicator $regime_t$ creates non-linearities in the monetary policy rule and risk premium process. Therefore, to solve and simulate the transition period model, second-order approximation is used. The model is solved by Dynare++.[3]

The solution of the transition period model given by equations 2.13–2.25 and equations 2.28 takes the following general form:

$$x_t = F(x_{t-1}, \varepsilon_t, \nu_t),\ 0 < t \leq T$$

where x_t is the vector of the model variables, $\varepsilon_t = \{\varepsilon_t^\pi, \varepsilon_t^y, \varepsilon_t^i, \varepsilon_t^a, \varepsilon_t^m, \varepsilon_t^g, \varepsilon_t^s\}$ is the vector of foreign and domestic structural shocks, $\nu_t = \{\nu_{t,1}, \ldots, \nu_{t,N}\}$ is the vector of information shocks, and $F(.)$ is the second-order polynomial. However, due to the independence of information and structural shocks after the evaluation of information shocks (the announcement of the transition), the system will be become linear. The evaluation takes the form given by scheme 2.29

[3] Dynare++, developed by Kameník (2007), is a standalone C++ version of Dynare. Dynare is a pre-processor and collection of Matlab routines introduced by Juillard (1996), Collard and Juillard (2001a), and Collard and Juillard (2001b).

and $\nu_{t,i} = 0, \forall i$ and for all subsequent periods $t,\ 1 < t \leq T$. Therefore, the transition period model with a given transition period length takes the following form:

$$x_t = A_t x_{t-1} + B\varepsilon_t,\ 0 \leq t \leq T \qquad (2.31)$$

where matrices $A_t,\ t = 0, \ldots, N$ and matrix B depend on the structural parameters of the model and the transition period length. Matrix B is time invariant, while the structural shocks are independent. However, for $t_1, t_2 > T$, I have $A_{t_1} = A_{t_2}$ because ν_t for $t > 1$ is a vector of zeros and after period T the information buffer is filled only with zeros.

The state-space solution conditional on evaluation of the information shocks is used to simulate the model and compute the covariance matrices Σ_t. To compute the covariance matrix Σ_t recursively the following formula is used:

$$\Sigma_t = A_t \Sigma_{t-1} A_t^T + BVar(\varepsilon_t)B^T,\ 0 < t \leq T \qquad (2.32)$$

where Σ_0 is the covariance matrix from the model estimated on data and $Var(\varepsilon_t)$ is the time-invariant covariance matrix of structural shocks. Further, to compute the evolution of variance after the change of regime, the following recursive formula for $t > T$ is used:

$$\Sigma_{t+1} = A^f \Sigma_t A^{f^T} + B^f Var(\varepsilon_t) B^{f^T},\ t > T \qquad (2.33)$$

where matrices A^f and B^f are taken from the solution of the model with the monetary policy rule given by equation (2.27) for $regime_t = 0$.

In the literature, Bayesian methods are considered an attractive tool for the estimation of a model's parameters, especially in open economy modeling. The recent examples include Smets and Wouters (2003), which estimates a Eurozone model; Lubik and Schorfheide (2005), which analyzes the behavior of the monetary authority and identification problems; and Ireland (2004). Studies such asMusil and Vašíček (2006) use Bayesian techniques to estimate a simple model of the Czech economy.

According to the aforementioned studies, Bayesian methods are preferred because the use of priors makes the estimation results more stable. Due to the short span of the Czech data sample, information from previous studies in the form of priors on parameter estimates is used. This allows informative rather than flat priors to be used.

Model M and its associated parameters Θ can be estimated using the method outlined by An and Schorfheide (2007). In the Bayesian context, given a prior $p(\Theta)$ and a sample of data Y, the posterior density of the model parameters Θ is evaluated, and it is proportional to the likelihood of the data multiplied by the prior $p(\Theta)$:

$$p(\Theta|Y, M) \propto L(\Theta|Y, M)p(\Theta), \qquad (2.34)$$

where the goal of the Bayesian estimation is to describe the posterior distribution of the parameters, that is, to identify the distribution of the parameters given the data Y.

The Bayesian estimation procedure consists of the following three steps. In the first step, the model is extended to include a measurement block that links the model variables to the data.

The extended model is solved. In the second step, the fact that the solution of the model is in the form of a state space model is exploited. This allows us to compute the likelihood function of the underlying model by means of the Kalman filter conditional on the observed data and parameter priors. The objective is to maximize the value of the likelihood as a function of the model parameters. The second step results in maximum-likelihood estimates of the model parameters. The objective of these estimation steps is to get the parameter values for the model.

In the third step, the likelihood function conditional on the parameter estimates is combined with the prior distribution of the parameters to obtain the posterior density function. Here, the modes of the posterior distributions are identified using the maximum-likelihood estimates from the second step. The posterior distributions are estimated using the Markov Chain Monte Carlo (MCMC) method. In this estimation of the posterior distribution, an implementation of the Metropolis-Hastings (MH) algorithm is used as an MCMC algorithm. The objective of computing the posterior distributions is to evaluate the sensitivity of the results to the choice of priors and optimization algorithm settings.

2.7 Estimation

The parameters of the model are estimated using data on the Czech Republic. The data sample covers the period of the inflation-targeting regime from its introduction in 1998 through to the third quarter of 2007. Over this period, the Czech National Bank undertook to pursue an inflation-targeting monetary policy. A policy change occurred in the period under consideration – a switch from core inflation targeting to CPI targeting. However, this is considered a minor change and is assumed not create breaks in the parameter estimation. Due to the fact that de-trended series are used, we can also abstract from the effects of a decreasing inflation target. A detailed description of the data and the transformations used is given in the A.1.

The basic form of the model is used for the estimation. This model consists of equations 2.13–2.25, the simple monetary policy rule (2.26), and the definitions of the AR(1) processes for shocks. No information buffer or regime indicators are present in the estimated model.

The domestic block of the underlying model is estimated using de-trended data on output growth, inflation, the nominal interest rate, the terms of trade, and the real exchange rate. The foreign block is described by the de-trended series of effective output, inflation, and the nominal interest rate. The effective series are constructed from the series of the main trade partners of the Czech Republic. These series are weighted using the export-based weights of the trade partners.

The model variables are expressed in percentage deviations from the steady state. The data series are related to the model variables via a block of measurement equations. In these equations, the model variables are linked with the observed data using the measurement error. The block of measurement equations and the characteristics of the measurement errors are summarized in A.2.

The choice of parameter priors is derived mostly from previous studies (e.g., (Lubik and Schorfheide, 2003), (Justiniano and Preston, 2004), (Musil and Vašíček, 2006)) and is guided by several considerations. The choice of prior distributions reflects the restrictions on the parameters, such as non-negative deviations and interval constraints. Therefore, for parameters constrained to the interval $\langle 0, 1 \rangle$, the beta distribution is used. The prior distributions for the standard deviations of shocks have been set to inverse gamma. Similarly, for parameters taking positive values, the gamma distribution is used. The standard deviations of the priors also reflect beliefs and confidence in the values of the parameters. There are few studies estimating DSGE models of the Czech Republic. Therefore, loose priors rather than tighter ones are used. Tables A1 and A2 provide an overview of the choice of priors. Also, it is assumed (strict prior) that $\beta = 0.99$, which implies an annual interest rate of about 4% in the steady state.

To construct the joint probabilistic distribution, it is assumed that the priors are independent of each other. This simplifies the use of the MCMC algorithm. The Dynare toolbox is used to estimate the model. Given the data and priors, 300,000 draws are generated for each of the five Markov chains using the MH algorithm. While acceptance rates of between 20% and 40% are considered reasonable for distribution sampling, the scaling parameter for the jumping distribution in the MH algorithm is set to deliver an average acceptance rate of 0.32.

2.8 Estimation Results

The estimation results are summarized in Tables A1 and A2 in A.3. The reported results show that there is no straightforward relation between the priors motivated by previous studies and the posterior estimates supported by the data. The analysis of the posterior distributions, together with the posterior density for values around the computed mode for each estimated parameter, did not indicate the presence of computational problems.

The parameter α is estimated to be 0.38, close to the estimate by Natalucci and Ravenna (2003). Moreover, it can be believed that this value reflects the characteristics of the Czech Republic and evidence from openness measures based on the ratios of imports and exports to domestic product. This value can be considered consistent with the value of 1.01 for foreign-home goods substitution η because it indicates that for households, foreign and domestic goods are Cobb-Douglas substitutes.

The value of 0.11 for the inverse elasticity of intertemporal substitution σ implies low relative risk aversion and high elasticity of intertemporal substitution. The high value of elasticity indicates that consumption responds strongly even to small changes in the interest rate. The high value of habit persistence (0.72) indicates that households are also concerned about their level of consumption. When a change in consumption occurs, households try to maintain the new level of consumption. Also, the high value of the inverse elasticity of labor substitution, $\varphi = 3.36$, implies significant non-elasticity of the labor supply. This may be a reflection of the low volatility of hours worked as shown by statistics for the Czech labor market, especially at the beginning of the period under consideration.

According to the estimation results, the interest rate smoothing ρ_i takes an only slightly higher value than the prior used. The reactions to inflation and output gap deviations take values of 1.48 and 0.43, respectively. These values of ρ_π and ρ_y reveal that keeping future inflation at the level of the inflation target is preferred more than 3.4 times more than closing the output gap. Moreover, the low value of the reaction to the deviation of the nominal exchange rate ρ_e is consistent with the inflation-targeting policy of the Czech National Bank.

The priors for the price stickiness parameters θ's are chosen based on Lubik and Schorfheide (2005) and reflect the evidence on U.S. prices. The prior value of price indexation is set to 0.5, although there are studies where the indexation value is set to unity. The estimation results show that a high fraction of domestic firms optimize their prices every quarter (the estimate of θ_H takes the value 0.13) . By contrast, importers optimize their prices less often, so the average contract length is approximately 3 months [1/(1-0.68)]. The high value of inflation means that the goods price is updated for a large fraction of the price level change. Therefore, the estimated value of 0.63 for the inflation indexation δ, which is almost twice as high as the values reported by Justiniano and Preston (2004), is consistent with a low frequency of price optimization.

High persistence of technological, risk premium, and taste shocks is assumed, so the priors are set to 0.85. However, the estimates show that the most persistent shock is the preference shock, with a value of 0.95 for ρ_g. The estimated value of 0.81 for the persistence of a technological shock is higher than the value of 0.7 used by Justiniano and Preston (2004).

For the foreign block, the autocorrelation of foreign shocks is assumed to be 0.7, as used by Natalucci and Ravenna (2003). However, the estimation results show low persistence in the foreign block for inflation and the nominal interest rate series, so these are closer to the estimates by Justiniano and Preston (2004). Only the output series reveal a higher persistence than assumed.

The priors and estimates of the standard deviation of structural shocks are summarized in Table A2. These results show that the preference shock ε_t^g is the most volatile. The high volatility of the preference shock is consistent with the high persistence of consumption, which accounts for a significant fraction of gross domestic product. However, this does not mean that the preference shock is the main driving force of the variables of interest. Using variance decomposition, it can be identified that the preference shock generates only 9% of inflation, 5% of output growth, and 7% of nominal interest rate variance. Due to the high value of openness, the risk premium is responsible for 42% of the CPI inflation variance. Each of the foreign shocks (foreign inflation, output, and the interest rate) is responsible for approximately 3% of the domestic inflation variance.

Table 2.1: Moments Summary

	Data		Model	
Variable	Std. dev.	Corr.	Std. dev.	Corr.
Output growth	1.05	1.00	3.04	1.00
Nominal interest rate	1.38	-0.53	1.84	-0.26
CPI inflation	3.14	-0.12	4.02	-0.15
Change in nominal ex. rate	8.37	0.17	8.54	0.02
Real ex. rate	3.48	0.17	6.79	-0.03
Foreign output gap	0.81	0.02	0.67	0.00
Foreign inflation	0.66	0.21	0.76	-0.01
Foreign nom. int. rate	0.65	-0.03	0.60	0.00

To evaluate the empirical properties of the generic model, Table 2.1 compares the moments of the time series used for the estimation with the moments of the variables of the estimated model. Using this comparison, it can be concluded that the estimated model over-estimates the volatility of output and the real exchange rate.

Finally, to evaluate the amount of information included in the observed series, comparison of the prior and posterior distributions is used. This comparison helps us to gain insight into the extent to which the data provide information about the estimated parameters. According to the figures presented in Table A3, it can be concluded that the observed data contain a portion of information that leads to an update of the priors used.

3. Impulse Response Analysis

In this section, the impulse responses for the estimated model and for the model of the transition period (the model with the monetary policy rule 2.27) are compared. The goal of this comparison is to point up differences that are induced by adding information on the regime indicator in the model that allows for it. Figures B1–B3 compare the impulse response functions to a 1% shock to the following four models: the estimated model (solid red line) and the models of regime switch in 4 (dash-dotted magenta line), 8 (dashed blue line), and 40 (dotted black line) periods.

Figure B1 depicts the responses to the supply shock ε_t^a. As expected for the case of a supply shock, output increases and inflation decreases. Via the uncovered interest rate parity relation, the decrease in domestic inflation is accompanied by a currency appreciation (since the inflation and interest rate of the foreign economy do not react to domestic shocks). The monetary authority reacts by lowering interest rates. Due to the appreciation and the fact that importers do not update their prices immediately for a lower input cost, the law-of-one-price (LOOP) gap reaches negative values, indicating importers' profits. These profits are returned to households and used to finance a subsequent increase in consumption. The presence of habit formation also supports the observed hump-shaped consumption profile, because households gradually adjust their consumption profile. However, the update of imported goods prices, with slowing appreciation and real depreciation, restrains the rise in demand for foreign goods. As inflation in the imported goods sector rises, the steady state is established. Due to the imported price rigidity and appreciation in the case of a late regime switch (in 8 or 40 periods), exporters face losses. For a late regime switch, the monetary policy response is expansionary as a result of a slower return of the currency appreciation to its steady state.

The main difference in the responses between the regime switch model and the independent monetary policy model lies in the extent of the deviation from the steady state. Due to the expected regime switch, the monetary authority reacts with a more expansionary policy to establish the steady state of change in the nominal exchange rate. As expected, the monetary policy response is followed by a larger consumption increase than in the independent policy model.

Figure B2 presents the response to the domestic demand shock ε_t^g. This shock initiates an increase in domestic inflation and output as expected in the case of a demand shock. In reaction to the subsequent inflation increase, the domestic currency appreciates in the initial period. Because of the initial currency appreciation, importers reduce the prices of their goods and imported inflation decreases. Foreign goods become cheaper and the expected switch to foreign goods translates into higher foreign goods prices. The international price of a foreign good does not change because the foreign economy is large and does not react to the domestic demand. In the case of the no-regime-switch model, the import price decrease is larger than in the case of a regime change, and this makes households increase their demand for foreign goods. This results from the reaction of the monetary authority, which has to prevent the extensive appreciation and initially runs an expansionary policy in the case of a regime switch. Due to output rigidities, the increase in output follows with a lag. In response to the inflation and output increase, the domestic monetary authority raises the interest rate. Due to the long duration of contracts in the import sector, the LOOP gap is negative (importers enjoy profits), especially in the case of the no-regime-switch model.

Figure B3 depicts the responses to the foreign demand shock ε_t^y. An increase in foreign output leads to an increase in demand for domestic goods and domestic inflation, so domestic output rises in response to this shock. The inflation increase leads to currency depreciation in the case of the model without a regime switch. Because of high rigidity in foreign demand and the gradual adjustment of a household's consumption profile, a hump-shaped decrease in the consumption response is observed.

For the foreign output shock, the main differences in the responses occur in the initial period. In the model with an announced regime switch, the nominal exchange rate appreciates and inflation decreases, as an increase in foreign inflation is expected. This makes foreign goods cheaper relative to domestic goods. Therefore, households are also able to increase their consumption of domestic goods and the increase in demand drives an increase in output. The growth of output leads to an increase in the marginal cost of production and a rise in inflation. Therefore, the domestic monetary authority has to increase nominal interest rates in the case of an early regime switch. In contrast, for a late change of regime, growth of output and consumption are supported with an expansionary policy. In this case, the system returns to the steady state before the regime switch is effective, so no reaction from the monetary authority is needed to eliminate the change in the nominal exchange rate. Notice that for models with a late change of regime, inflation, consumption, and output are more volatile than in the case of no regime switch.

4. Macroeconomic Stability

In the previous section, differences in impulse responses induced by the announcement of a change in monetary policy regime were assessed. The differences lie mostly in the extent of the responses, while the shape of the responses does not differ much across the regimes under consideration. Therefore, the subsequent analysis focuses on the volatilities of the key macroeconomic variables (inflation, output gap, and exchange rate change) under the alternative monetary policy regimes described by rules 2.26 and 2.27.

Assessment of macroeconomic stability is used as the standard approach in the early literature on monetary policy evaluations. The main advantage of this approach is its independence of the utility–loss function specification. However, it can still offer interesting comparisons, as presented by Cuche-Curti et al. (2008) and Collard and Dellas (2002).

As mentioned in the introductory section, this analysis is restricted to four parameterizations of the general rules 2.26 and 2.27 in the model that allows for the announcement of a change in monetary policy regime. The following four representative regimes are assessed: strict CPI inflation targeting (SIT); strict change in exchange rate targeting (SET); the standard Taylor rule (STR); and a rule where inflation and change in the exchange rate are targeted (STRET).

Table 4.1 summarizes the calibration of the monetary policy rules 2.26 and 2.27 for the aforementioned regimes. To set up the rest of the structural parameters, the values estimated in the previous section are used.

First, to initialize the recursive computation of the variances over the transition period, the model without the possibility of a regime switch is used. Table 4.2 shows the resulting standard

Table 4.1: Regime Definitions

Regime	Parameters			
SIT	$\rho_i = 0.6$	$\rho^{\pi} = 2.0$	$\rho^{y} = 0.0$	$\rho^{e} = 0.0$
SET	$\rho_i = 0.6$	$\rho^{\pi} = 0.0$	$\rho^{y} = 0.0$	$\rho^{e} = 1.0$
STR	$\rho_i = 0.6$	$\rho^{\pi} = 1.5$	$\rho^{y} = 0.5$	$\rho^{e} = 0.0$
STRET	$\rho_i = 0.6$	$\rho^{\pi} = 1.5$	$\rho^{y} = 0.0$	$\rho^{e} = 0.1$

deviations (in percentage points at quarterly frequency) of the variables of interest in the four aforementioned regimes. The last column of Table 4.2 shows the standard deviations after the adoption of the new monetary policy regime 2.30 (post-transition regime).

Table 4.2: Standard Deviations: Model without Regime Switch

Variable	SIT	SET	STR	STRET	Post-transition
Output	1.04	1.06	1.00	1.04	1.06
Nominal int. rate	0.82	0.95	0.83	0.85	1.01
Real ex. rate	4.19	4.10	4.19	4.16	4.19
Terms of trade	6.74	6.69	6.94	6.73	6.84
CPI inflation	1.98	1.31	2.23	1.81	1.41
Domestic inflation	2.83	1.98	3.17	2.60	1.99
Imported inflation	1.22	0.53	1.37	1.08	0.87
LOOP gap	2.63	0.94	2.80	2.27	0.78
Marginal costs	0.79	0.48	0.87	0.71	0.43
Δe	2.87	0.86	3.04	2.45	0.81

The standard deviations presented in Table 4.2 reflect the nature of the regimes used. Low volatility of change in the nominal exchange rate is delivered by the SET and post-transition regimes, where the monetary policy rule focuses on offsetting these changes. This is reflected by higher volatility of the nominal interest rate and output. Surprisingly, the strict IT regime is not able to deliver the lowest value of inflation volatility. However, the high volatility of Δe and inflation signal that the SIT regime exhibits a trade-off between these volatilities and the nominal interest rate.

The aim of this analysis is to establish the volatility of the macroeconomic variables over the transition from the initial regime to the post-transition regime. To compute the variance of the variables over the transition between the regime switch announcement and the actual regime switch, information shocks are evaluated.

Figure C1 shows the development of the standard deviations for the regimes summarized in Table 4.1 in the case of a transition that is 8 periods long. In this figure, period 1 is the initial period, and the values refer to the standard deviations in the model without a regime change. Period 2 is the first period of transition and is followed by 8 periods of transition. So, period 9 is the last period of transition, and the post-transition regime is employed starting from period 10. In all the figures showing the variance, the black dotted line represents the SIT regime, the magenta solid line the SET regime, the red dash-dotted line the STR regime, and the blue dashed line the STRET regime.

The evolution of the standard deviations, shown in Figure C1, confirms that by construction, inflation-targeting regimes deliver low volatility of CPI inflation over the transition. These regimes also deliver low variance for the domestic component of inflation and, in the late periods of transition, for the foreign inflation component, too. This is consistent with the observed trade-off between inflation and nominal exchange rate volatility.

These computations show that the nominal interest rate volatility peaks in the last period of the transition for all of the regimes considered. This peak is consistent with the foreseen deviations in the changes of the nominal exchange rate and with the reaction of the monetary authority, which tries to eliminate them before the regime switch. It is also consistent with a hike in the volatility of change in the nominal exchange rate in the late periods of the transition regime.

Due to the volatility trade-offs between variables, a simple comparison of volatilities does not straightforwardly identify the regime that delivers the lowest welfare loss. Therefore, a ranking of the representative monetary policy regimes under consideration is created in order to find the best-performing one. For simplicity of analysis, as in Santacreu (2005), the traditional form of the loss function is used:

$$L_t = \tau Var(\pi_t) + (1-\tau)Var(y_t) + \frac{\tau}{4}Var(\Delta i_t), \tag{4.35}$$

where $\tau \in \langle 0, 1\rangle$ is the weight on inflation stabilization. To compute the loss function, $\tau = 0.77$ to reflect the ratio of inflation to output stabilization in the estimated monetary policy rule. In this assessment, the loss function is evaluated for various transition period lengths.

The evolution of the instantaneous loss function values given by 4.35 for the aforementioned regimes is plotted in Figure C2. In these plots, the first period plotted is the first period of the transition regime. These plots suggest that the SIT regime delivers the lowest loss values at the end of the transition regime. The highest loss is delivered by the SET regime.

However, the form of the loss function, as mentioned by Santacreu (2005), does not reflect the changes in the volatility of the exchange rate. Therefore, the following alternative form of the loss function is used:

$$L_t^a = \tau Var(\pi_t) + (1-\tau)Var(y_t) + \frac{\tau}{4}Var(\Delta i_t) + \frac{\tau}{4}Var(\Delta e_t). \tag{4.36}$$

The evolution of L_t^a is presented in Figure C3. These plots show that focusing on exchange rate stabilization affects the ordering of the regimes under consideration.

To identify the best-performing regime over the transition period, the sums of the instantaneous losses discounted by a factor of β are computed over the 40 periods for the aforementioned loss functions. The overall welfare losses for a given transition period length are presented in Figures C2 and C3.

For the form given by equation 4.35, the SIT regime is identified as the best-performing regime (delivering the lowest values of welfare loss) for all lengths of the transition period. When the alternative form of loss function with a non-zero weight on exchange rate targeting is used, the choice of the optimal regime depends on the transition period length. For a transition period shorter than 8 periods, the SIT regime is the best-performing regime. For transition periods longer than 8 periods the STRET regime is the optimal regime.

Figure C5 shows the initial change in standard deviations as the percentage change in the standard deviation in comparison with the standard deviation in the model without the possibility of a regime switch. In this figure, the initial change is a function of the number of periods to the regime switch. As can be observed, a short period of transition leads to a substantial increase in the volatility of imported inflation and the nominal interest rate. This can be explained by the strong monetary policy reaction needed to suppress deviations over the short term.

The extent of the initial changes in the standard deviations of all the variables does not vary much for transition periods that are more than 12 periods long. Therefore, it is assumed that further extension of the transition period does not affect the ranking. This assumption can be justified by looking at the impulse response functions (Figures B1–B3), which show that there are significant deviations from the steady state after 12 periods only for a very persistent shock.

Figure C5 also reveals that the output volatility is almost unaffected by the choice of transition length and the change originates from the transition to a model with the possibility of regime switch. This is consistent with small differences in output volatility across the regimes analyzed. Therefore, the changes in output volatility are not the main force driving the loss function ranking.

Further, the variance of the terms of trade is used to rank the regimes examined. The use of this criterion is based on the conclusion by Gali and Monacelli (2005) that the critical element for distinguishing a simple rule relative to the optimal policy is the excess smoothness of the terms of trade. They note that the terms of trade are more stable under an exchange rate peg than under any other policy regime. This feature is a consequence of the inability of sticky prices to compensate for the elimination of change in the nominal exchange rate. Gali and Monacelli (2005) show that the higher the terms of trade volatility, the lower the volatility of inflation and the output gap across the regimes considered. This means that the higher the volatility of the terms of trade, the higher the resulting welfare score.

In this case, the regimes are compared against the strict IT regime, which is identified as the best performing according to the traditional loss function form. In Figure C4, the variances of the terms of trade are plotted in the form of differences from the variance in the SIT regime. Here, a positive value indicates an excess of volatility over the SIT regime. It can be observed that the strict ET regime delivers the largest amount of terms of trade volatility. According to the conclusion by Gali and Monacelli (2005), this implies the highest welfare score should be achieved for the SET regime. These results are contrary to the aforementioned results of the loss function evaluation.

4.1 Variance Decomposition

Finally, to assess the forces that drive the business cycles under the pre-transition and post-transition regimes, the differences in variance decomposition for the variables of interest are reported in Table 4.3. The reported differences are computed as the difference in the shock contribution (in percent) between the post-transition regime and pre-transition regime (estimated model), where positive values mean an excess of the contribution in the post-transition regime.

The negative changes in the contributions of the monetary policy shock and risk premium shock originate from the design of the experiment, as these shocks are eliminated in the post-transition model. The preference shock ε^g becomes the dominant source of macroeconomic volatility under the post-transition regime. So, offsetting the nominal exchange rate changes makes the

Table 4.3: Variance Decomposition: Difference Between Post-Transition and Pre-Transition

	Shocks						
Variable	ε^a	ε^m	ε^g	ε^s	ε^π	ε^y	ε^i
Δe_t	-3.8	-11.3	-64.8	-17.9	5.0	78.2	14.6
i_t	-10.4	-2.2	-6.7	-73.1	4.1	75.4	12.9
mc_t	-12.3	-29.1	91.6	-44.4	0.5	-3.5	-2.9
π_t	-15.2	-26.6	82.7	-43.3	1.6	2.7	-2.0
pi_t^F	-9.8	-9.7	-61.2	-17.7	14.3	78.0	6.0
pi_t^H	-11.2	-22.3	70.1	-35.5	1.0	-0.2	-1.9
ψ_t^F	-3.6	-11.0	-66.5	-17.6	63.9	14.4	20.4
y_t	2.3	-1.2	0.8	-1.9	0.1	-0.1	-0.1

Czech Republic significantly more vulnerable to the domestic preference shock, which acts as a demand shock in the estimated model.

As the exchange rate becomes less volatile, the foreign shock becomes an important source of macroeconomic volatility. The source of volatility in the LOOP gap ψ_t^F moves from the domestic preference shock toward mostly a foreign inflation shock, indicating that profits of importers are fully dependent on the foreign economy under the post-transition regime. Similarly, as the role of the interest rate is to prevent exchange rate movements, more than 90% of its volatility originates in the foreign economy. These changes reflect the structural change in the economy when the monetary authority focuses on exchange rate stability.

5. Conclusions

The motivation for this paper is to analyze whether the announcement of a monetary policy regime switch in a small open economy can lead to gradual changes in macroeconomic volatility with real effects. Therefore, the presented model was designed to describe the behavior of the economy when the change in monetary policy regime is expected. This analysis focuses on the behavior over the period of transition toward an exchange rate stability regime.

The parameters of the model without the possibility of regime switch are estimated by the Bayesian method using data on the Czech Republic. The estimated values of the parameters are consistent with the experience of the Czech economy.

Further, the estimated model is extended to include an information buffer. This extension leads to a non-linear model capable of capturing the announced monetary policy regime. The extended model is solved using second-order approximation. The announcement of the regime switch is simulated by realization of the information shocks and this makes the considered model linear.

For this analysis, impulse response functions are computed under different (easily implementable) monetary policy regimes in order to identify the differences in the behavior of the economy in the event of an announced regime switch. Then ad-hoc loss functions are computed in order to rank these regimes.

Analysis of conditional volatility allows us to identify changes in macroeconomic volatility over the transition period. When the regimes are ranked according to excess volatility, the regime targeting exchange rate changes is identified as the best performing. When the loss function approach is used, the regime strictly targeting CPI inflation is identified as the best performing. Not surprisingly, the changes in macroeconomic volatility are more profound for a short transition period. It turns out that as soon as the future regime shift is announced, the volatility of the variables increases immediately. This translates to low volatility afterwards, more than compensating for the initial jump in volatilities.

The findings reported above have interesting implications for the conduct of monetary policy in the transition regime. First, pursuing a regime of exchange rate stability over the transition period delivers a higher welfare loss when the preferences of the monetary authority still favor stability of domestic inflation and output. However, the regime with a strict focus on inflation delivers the best performance in terms of welfare loss. Second, the relative importance of domestic shocks for macroeconomic volatility is reduced, as foreign shocks become very important. Third, extending the length of the transition beyond 8 periods does not deliver significant changes in the welfare rankings.

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Appendix A. Estimation

A.1 Data Description

All the data in the estimation are from the Czech National Bank database. The series are seasonally adjusted. All the observed series are measured at quarterly frequency. The series are in logs, so they can be interpreted as percentage deviations from steady-state levels,

- Domestic output growth (ΔGDP_t) is the HP de-trended annualized logarithm of real GDP growth.
- Domestic CPI inflation deviation (PI_t) is the HP de-trended annualized quarterly growth rate of the logarithm of the consumer price index (CPI).
- Nominal interest rate (RS_t) is the HP de-trended annualized quarterly value of the 3-month PRIBOR.
- Change in the nominal exchange rate (ΔE_t) is the HP de-trended quarterly value of the nominal CZK–euro exchange rate.
- Real exchange rate (Q_t) is the HP de-trended quarterly value of the real exchange rate.
- Foreign output gap (GDP_t^*) is the real GDI gap for the effective Eurozone created using the weights of export values and de-trended by the Kalman filter.
- Foreign real interest rate (RS_t^*) is the HP de-trended annualized quarterly value of the 3-month EURIBOR.
- Foreign inflation (PI_t^*) is the HP de-trended annualized quarterly growth rate in the log of the consumer price index for the effective Eurozone (export weights).

All series used for the estimation cover the period from the first quarter of 1998 to the second quarter of 2007.

A.2 Measurement Block

For the estimation, the following measurement block is used to relate model variables to observed time series data:

$$\begin{aligned}
\Delta GDP_t &= 4*(y_t - y_{t-1} + \varepsilon_t^a - \varepsilon_{t-1}^a) + \varepsilon_t^{GDP} \\
PI_t &= 4*\pi_t + \varepsilon_t^{PI} \\
RS_t &= 4*i_t + \varepsilon_t^{RS} \\
\Delta E_t &= 4*e + \varepsilon_t^{\Delta E} \\
Q_t &= q_t + \varepsilon_t^{Q} \\
PI_t^* &= 4*pi^* + \varepsilon_t^{PI^*} \\
RS_t^* &= 4*i^* + \varepsilon_t^{RS^*} \\
GDP_t^* &= y^* + \varepsilon_t^{GDP^*},
\end{aligned}$$

where $\varepsilon_t^{PI}, \varepsilon_t^{RS}, \varepsilon_t^{\Delta E}, \varepsilon_t^{Q}, \varepsilon_t^{PI^*}, \varepsilon_t^{RS^*}, \varepsilon_t^{GDP^*}$ are independent normally distributed with zero mean. For the estimation, the standard deviations of the measurement errors take the following values: 0.5, 0.3, 2.0, 1.0, 0.1, 0.1, 0.1 (in the given order).

A.3 Priors and Posteriors

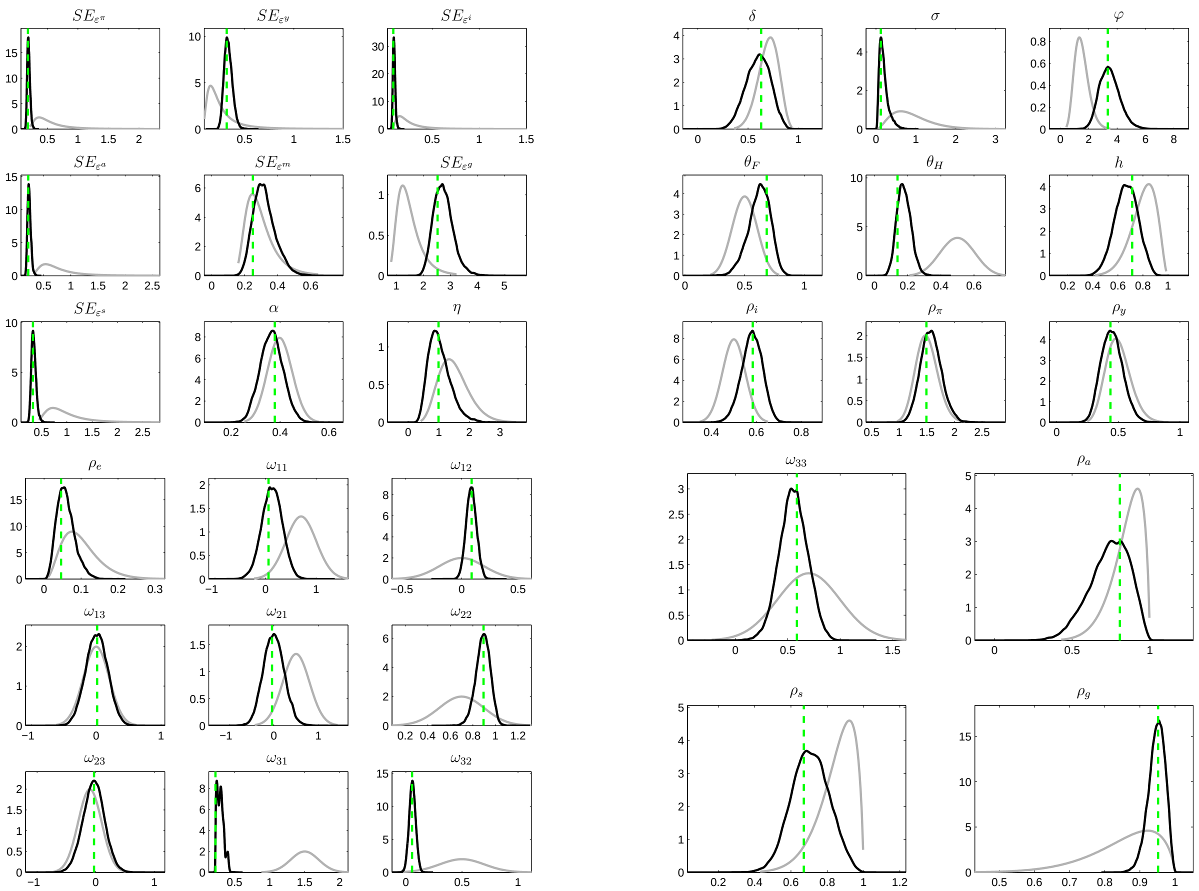
Table A1: Estimation Summary: Priors and Posterior Estimates

			Prior		Posterior	
Variable	Description	Distr.	Mean	s.d.	Mode	s.d.
β	Discount factor		0.99			
α	Degree of openness	Beta	0.40	0.05	0.38	0.04
η	Elasticity of F-H substitution	Gamma	1.50	0.50	1.01	0.36
δ	Degree of price indexation	Beta	0.70	0.10	0.63	0.15
σ	Inverse elasticity of substitution	Gamma	0.90	0.50	0.11	0.07
φ	Inverse elasticity of labor supply	Gamma	1.50	0.50	3.36	0.79
θ_F	Calvo pricing – foreign	Beta	0.50	0.10	0.68	0.08
θ_H	Calvo pricing – domestic	Beta	0.50	0.10	0.13	0.04
h	Degree of habit formation	Beta	0.80	0.10	0.72	0.10
ρ_i	Interest rate smoothing	Beta	0.50	0.05	0.58	0.05
ρ_π	Response to inflation	Gamma	1.50	0.20	1.48	0.19
ρ_y	Response to output gap	Gamma	0.50	0.10	0.43	0.08
ρ_e	Response to ex. rate change	Gamma	0.10	0.05	0.04	0.02
ω^{π}_{π}	Foreign VAR	Normal	0.70	0.30	0.07	0.27
ω^{π}_{y}	Foreign VAR	Normal	0.00	0.20	0.08	0.04
ω^{π}_{i}	Foreign VAR	Normal	0.00	0.20	0.01	0.18
ω^{y}_{π}	Foreign VAR	Normal	0.50	0.30	-0.03	0.25
ω^{y}_{y}	Foreign VAR	Normal	0.70	0.20	0.89	0.08
ω^{π}_{i}	Foreign VAR	Normal	-0.10	0.20	-0.02	0.19
ω^{i}_{π}	Foreign VAR	Normal	1.50	0.20	0.22	0.03
ω^{i}_{y}	Foreign VAR	Normal	0.50	0.20	0.05	0.02
ω^{i}_{i}	Foreign VAR	Normal	0.70	0.30	0.58	0.12
ρ_a	Technology – VAR(1)	Beta	0.85	0.10	0.81	0.13
ρ_s	Ex. rate risk – VAR(1)	Beta	0.85	0.10	0.67	0.11
ρ_g	Taste shock – VAR(1)	Beta	0.85	0.10	0.95	0.05

Table A2: Estimation Summary: Standard Deviation of Structural Shocks

			Prior		Posterior	
Variable	Description	Distribution	Mean	s.d.	Mode	s.d.
ε^{π}	Foreign shock variance	$Gamma^{-1}$	0.60	0.50	0.18	0.02
ε^{y}	Foreign shock variance	$Gamma^{-1}$	0.30	0.50	0.31	0.04
ε^{i}	Foreign shock variance	$Gamma^{-1}$	0.30	0.50	0.08	0.01
ε^{a}	Domestic shock variance	$Gamma^{-1}$	0.80	0.50	0.21	0.02
ε^{m}	Domestic shock variance	$Gamma^{-1}$	0.30	0.10	0.25	0.07
ε^{g}	Domestic shock variance	$Gamma^{-1}$	1.50	0.50	2.53	0.39
ε^{s}	Domestic shock variance	$Gamma^{-1}$	1.00	0.50	0.32	0.04

Table A3: Prior (Grey Line) and Posterior (Black Line) Distributions



Appendix B. Impulse Response Functions

Here, the following impulse responses are shown: the estimated model (solid red line) and the model of regime switch in 4 periods (dash-dotted magenta line); 8 periods (dashed blue line); and 40 periods (dotted black line).

Figure B1: IRF Comparison – Response to Technology Shock ε^a

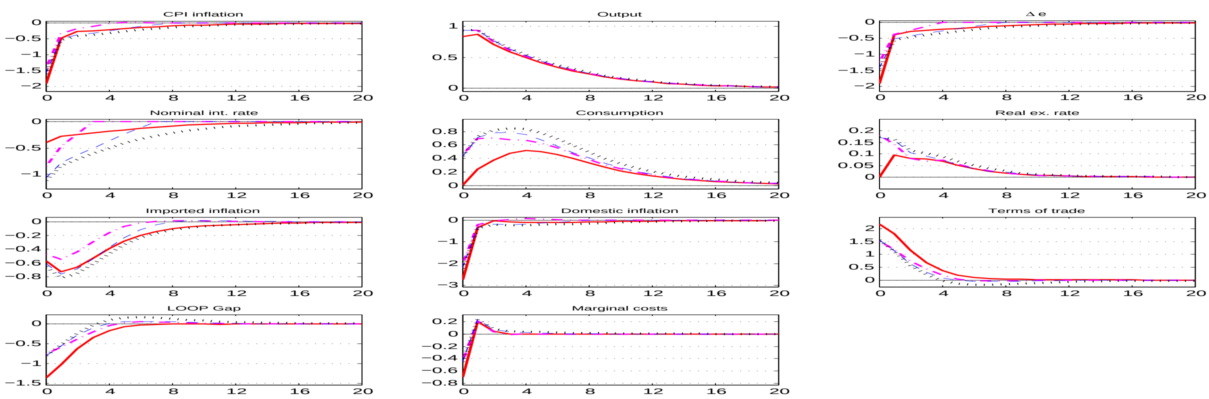


Figure B2: IRF Comparison – Response to Preference Shock ε^g

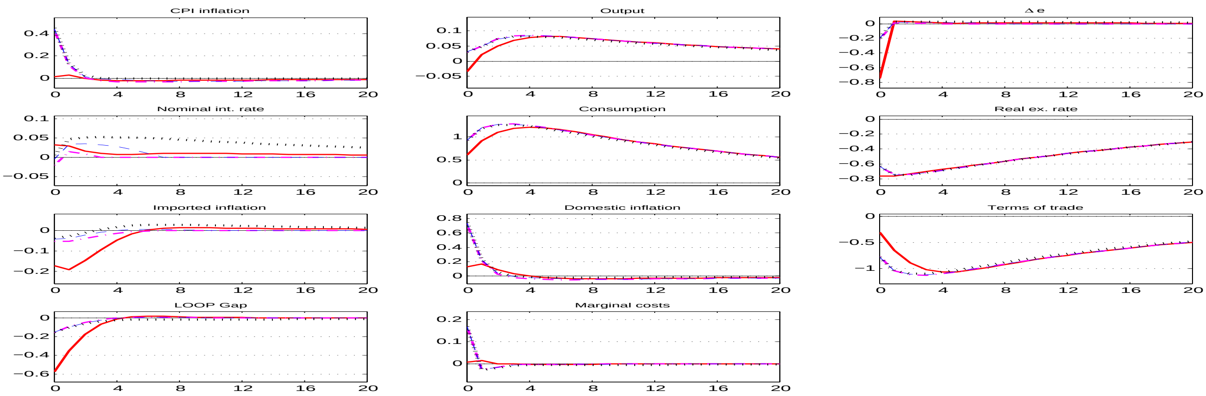
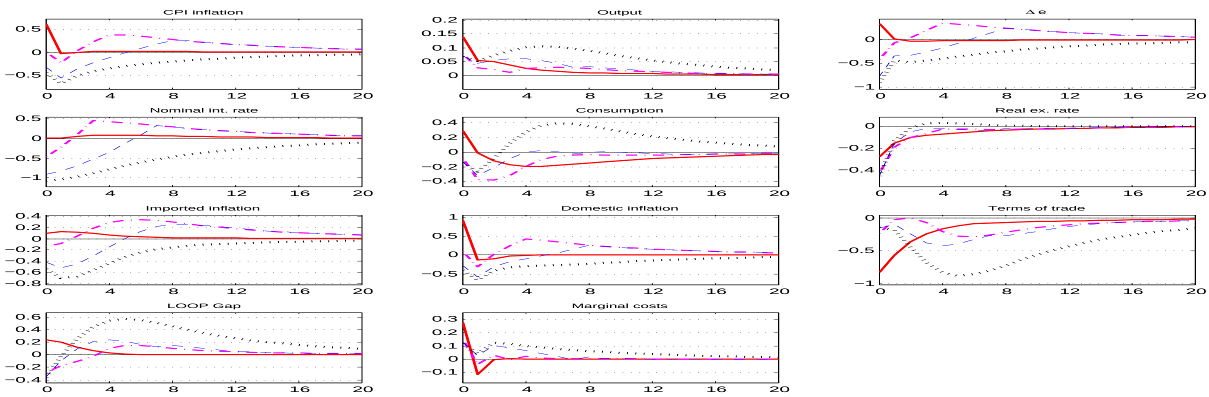


Figure B3: IRF Comparison – Response to Foreign Output ε^y



Appendix C. Conditional Standard Deviations

Here, the following plots are shown for the variance and loss function: the black dotted line represents the SIT regime, the magenta solid line the SET regime, the red dash-dotted line the STR regime, and the blue dashed line the STRET regime.

Figure C1: Conditional Standard Deviations: Comparison, 8 Periods of Transition

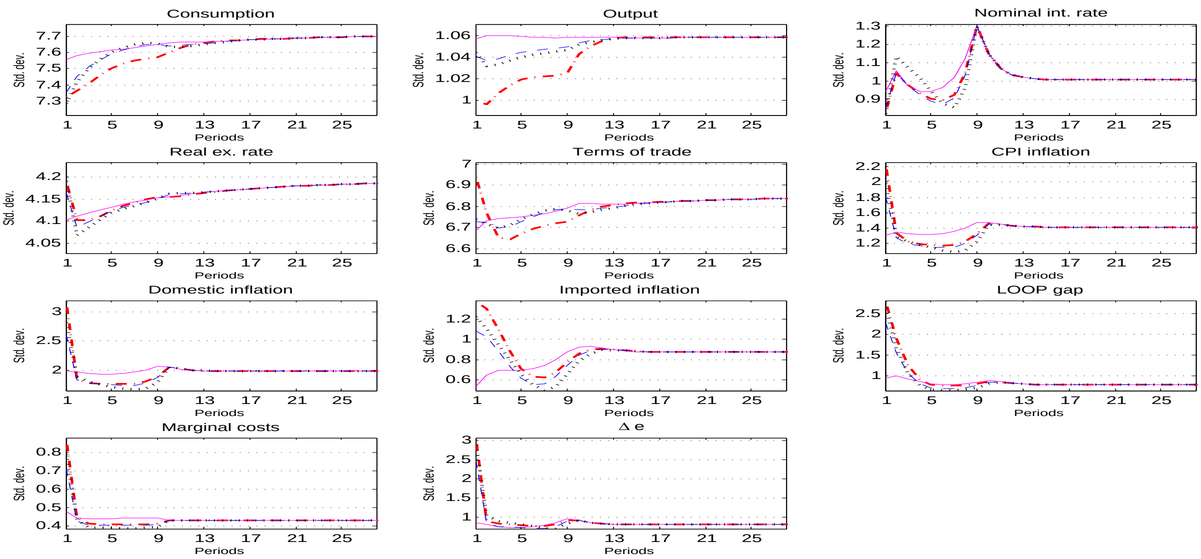


Table C1: Transition Length Sensitivity

Period length	Regime type			
	SIT	SET	STR	STRET
2	60.77	62.04	61.45	61.27
4	59.35	61.53	60.25	59.99
6	58.51	61.09	59.39	59.05
8	57.96	60.67	58.65	58.27
10	57.56	60.25	57.98	57.58
12	57.26	59.84	57.33	56.93

Table C2: Transition Length Sensitivity: Alternative Form

Period length	Regime type			
	SIT	SET	STR	STRET
2	127.85	131.46	129.83	129.24
4	125.29	129.66	127.54	126.25
6	124.92	128.22	126.53	124.51
8	125.83	126.89	126.05	123.41
10	127.44	125.60	125.83	122.65
12	129.40	124.31	125.73	122.07

Figure C2: Loss Functions

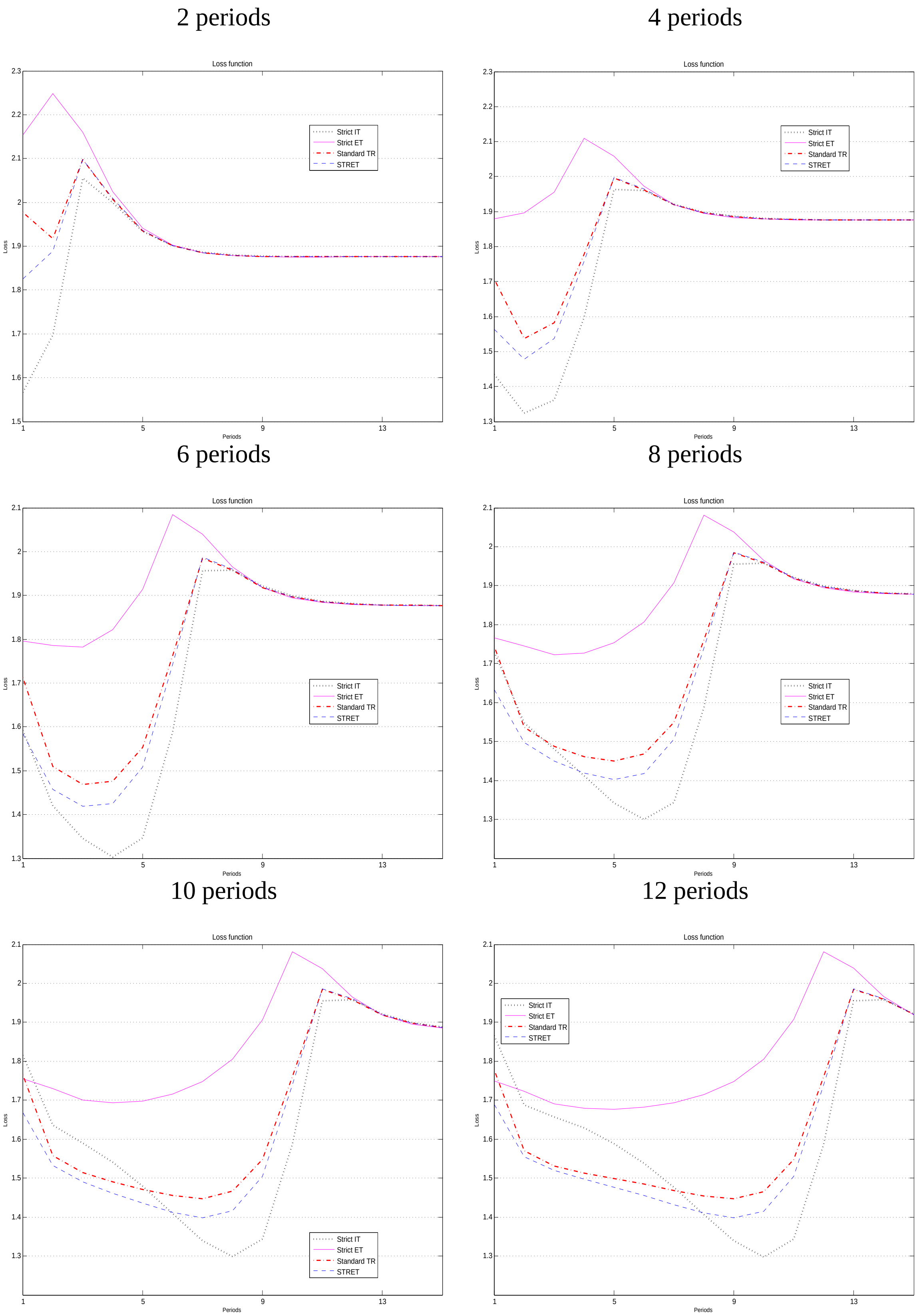


Figure C3: Loss Functions: Alternative Form

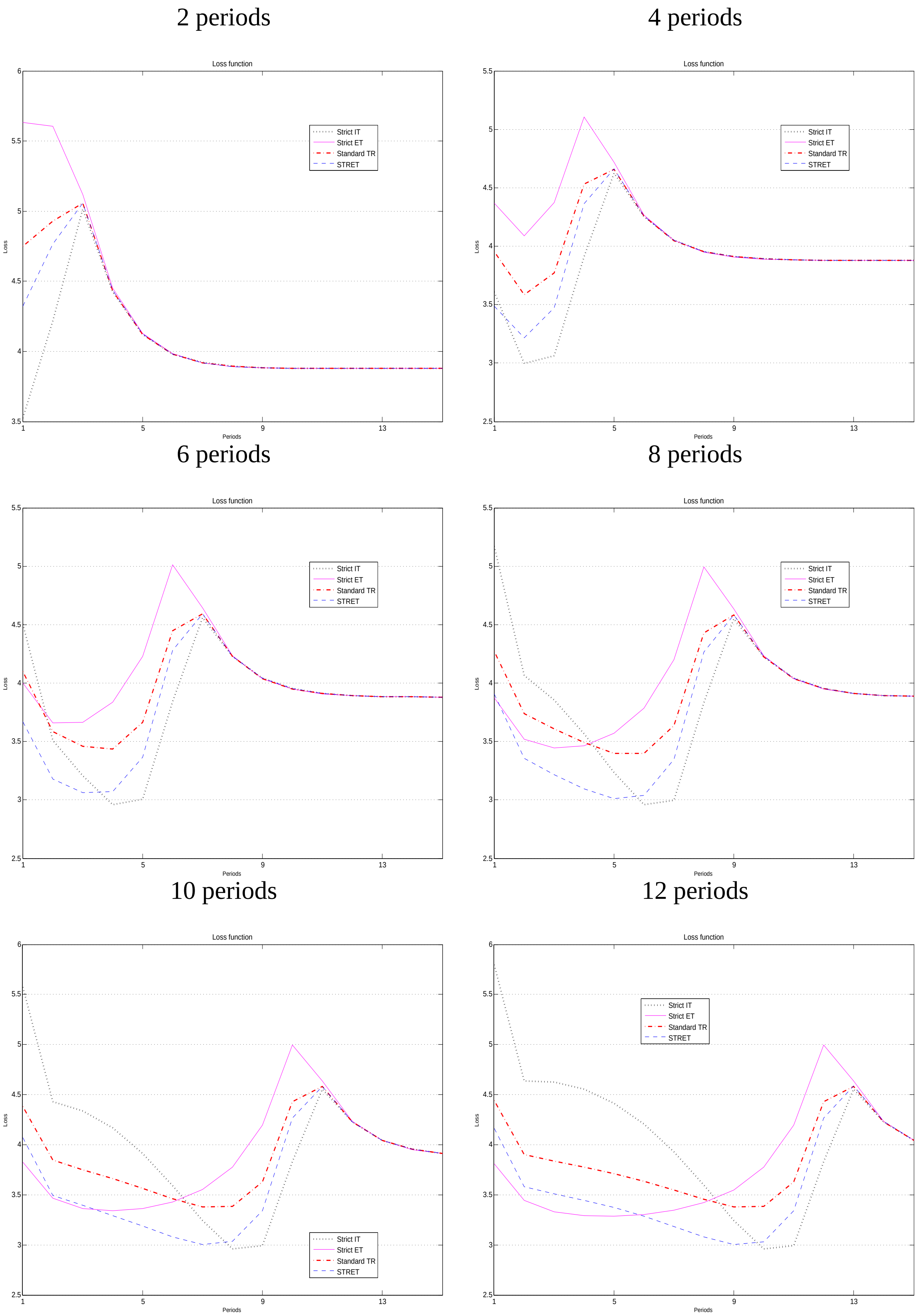
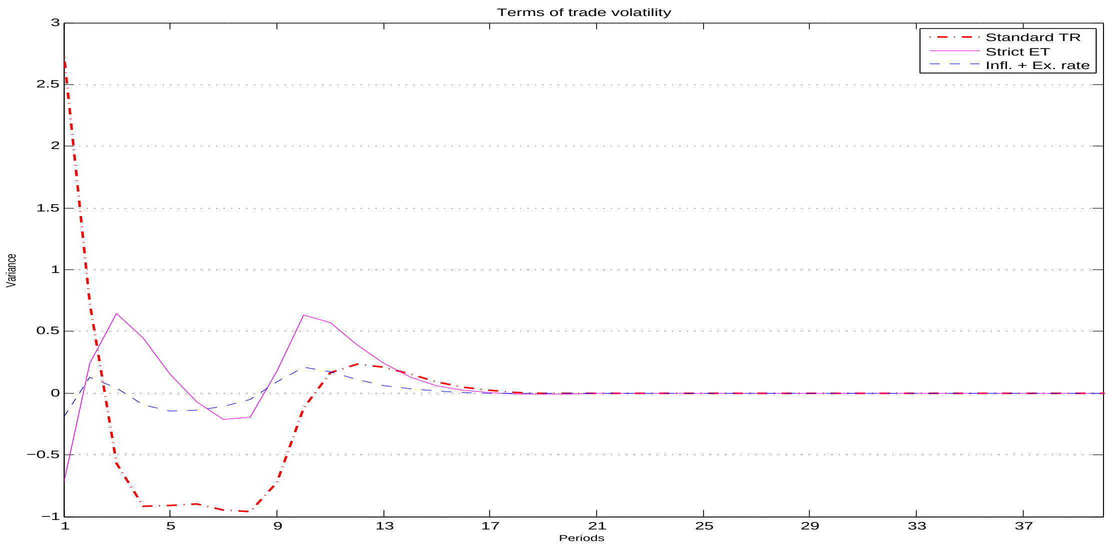


Figure C4: Terms Of Trade Variance: Difference from Strict IT



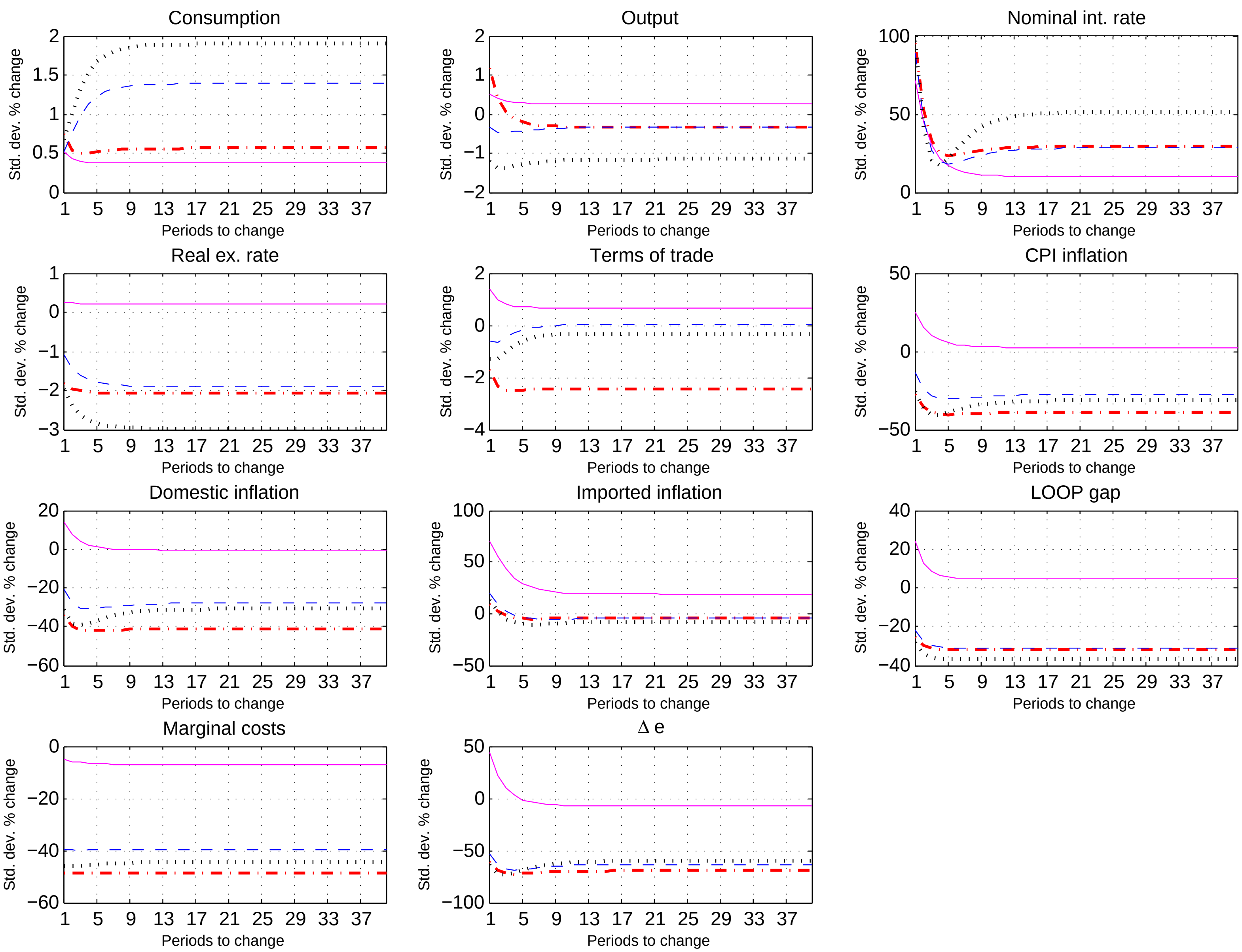


Figure C5: Initial Std. Deviation Change: Transition Period Length

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ISSN 1803-7070