

Central European University
Department of Economics

**An Estimated DSGE Model For Turkey
With A Monetary Regime Change**

By
Samir Huseynov

Submitted to
Central European University
Department of Economics

In partial fulfillment of the requirements for the degree of Master of Economics

Supervisor: Katrin Rabitsch

**Budapest, Hungary
2010**

Contents

Abstract.....	iii
List of tables and figures.....	ii
1. Introduction.....	1
2. Derivation of the baseline model.....	6
2.1. Households.....	6
2.2. Inflation, the real exchange rate and terms of trade.....	9
2.3. International Risk Sharing Condition.....	11
2.4. Firms.....	13
2.5 Price setting behavior and incomplete path through.....	13
2.6. Equilibrium.....	17
3. The estimation methodology.....	21
3.1 Specification of the data and prior distribution.....	22
4. Results.....	23
4.1 Parameter estimation and posterior distribution.....	23
4.2. Variance decomposition and Impulse response.....	26
Conclusion.....	31
Reference.....	33
Appendix A.....	35
Appendix B.....	57

Abstract

Using of developments of the last decade in Bayesian estimation, I estimate a small open economy Dynamic Stochastic General Equilibrium (DSGE) model for Turkey. The thesis explicitly accounts for a monetary regime change from an exchange rate targeting to an explicit inflation targeting with a flexible exchange rate. In both regimes, I investigate the behavior of the monetary authority and the main driving forces of business cycles of key macro economy variables of the Turkish economy. My results can be summarized as follows. Monetary policy focused on the stabilizing of the nominal exchange rate in the exchange rate targeting regime. But, it is mainly concerned with the price stability in the inflation targeting regime. Monetary policy shocks were the main sources of the fluctuations under both regimes. However, the foreign output shock in the first regime and the real exchange rate shock in the second regime appeared as the additional sources of the fluctuations in the business cycles. The Central Bank of Turkey managed to neutralize inflationary shocks and achieved stability in output and consumption after the regime change.

Keywords: Turkey, Bayesian estimation, DSGE models, regime change

List of tables and figures

Table1: Business Cycle Facts for Turkey and ROW.....	38
Table2: Business Cycle Facts for Turkey and ROW.....	39
Table 3: Structural Parameters, Prior and Posterior Distributions-Exchange rate targeting.....	40
Table 4: Shocks, Prior and Posterior Distributions.....	41
Table 5: Structural Parameters, Prior and Posterior Distributions-Inflation targeting.....	42
Table 6: Shocks, Prior and Posterior Distributions-Inflation targeting.....	43
Table7: Variance Decomposition (in percent)-Exchange rate targeting.....	44
Table8: Variance Decomposition (in percent)-inflation targeting.....	45
Figure1: Observed Variables.....	46
Figure2: Priors and Posteriors of the Exchange Rate Targeting Regime.....	47
Figure3: Priors and Posteriors of the Inflation targeting Regime.....	48
Figure4: Impulse Responses to Productivity Shock.....	49
Figure5: Impulse Responses to Terms of Trade Shock.....	50
Figure6: Impulse Responses to Real Exchange Rate Shock.....	51
Figure7: Impulse Responses to Home Inflation Shock.....	52
Figure8: Impulse Responses to Imported Inflation Shock.....	53
Figure9: Impulse Responses to Nominal Interest Rate Shock.....	54
Figure10: Impulse Responses to Foreign Real Interest Rate Shock.....	55
Figure11: Impulse Responses to Foreign Output Shock.....	56

1. Introduction

Until 21 February 2001, the Turkish economy was "ruled" by a fixed exchange rate regime towards the USD. In this period Turkey had a very inflated economy. The main reasons of inflation and consequently economic crises were income-expenditure disbalances in the public sector. Lack of structural and financial reforms made the economy vulnerable to foreign shocks and resulted in several serious inflationary crises in 1988-1989, 1991, 1994 and 1998-1999. In 2000, IMF supported stabilization and disinflation program aimed at tying down inflation which reached a level of 80% and at establishing financial stability. An exchange rate based disinflation and monetary control mechanism set certain tasks for the Central Bank (CB), such as not violating net domestic asset position and avoiding sterilization. But, insufficient funding from ongoing privatization programs and inefficient structural reforms forced the government to continue borrowing at higher interest rates. This led to a loss of monetary policy credibility in both domestic and foreign markets which resulted in further loss of confidence in the ruling authority and an increase of the devaluation expectations. Thus, defending predetermined exchange rate parity was beyond the CB's scope and in February 2001 the Central Bank abandoned fixed parity and let the exchange rate float.

After the currency collapse, the monetary authority switched to a different monetary policy regime, which is a very typical for an emerging market economy which abandons fixed parity. As stated by Taylor (2000), in this case the best policy to stick to for an emerging economy is a flexible exchange rate, an inflation target and a monetary policy rule. As a result, Turkey opted to an inflation targeting regime with a floating exchange rate. The CB continued

using short-term interest rates as the main policy tool to reach its policy target in the second regime.

After one decade from starting the inflation targeting, it is time to analyze the relationships between the two monetary policy regimes and macroeconomic stability and evaluating the driving forces of the business cycles of the Turkish economy under both regimes.

Similar researches were done by many authors, especially on advanced economies. Curdia and Finocchiaro (2005) studied a monetary policy regime change in Sweden by employing Bayesian framework. They used modified and conventional Taylor rules as the monetary policy rules for the first and the second regimes respectively. I follow their method in defining monetary policy rules for the both regimes of the Turkish economy in this study which will be discussed later. Seminal paper of Smets and Wouters (2002) made Bayesian estimation one of main tools of quantitative macro analysis in the last decade. My thesis intensively uses their methods in an estimation stage. By using the latest developments in the Bayesian estimation Lubik and Schorfheide (2005) successfully analyzed economies of the U.S. and the Euro Area. They developed two-country model which was modified to a small open economy in this study. I am closely following derivation methods of Haider and Khan (2008) and Liu (2006) in converting Lubik and Schorfheide's (2005) two-country model to a small open economy model.

In this work, I estimate a small open economy Dynamic Stochastic General Equilibrium (DSGE) model on Turkish data with two goals. Namely, my first goal is to estimate monetary policy rules of the exchange rate targeting and the inflation targeting regimes and to clarify whether the Turkish data shows the monetary regime change which was announced by the CB. Furthermore, I aim at disclosing that which shocks triggered changes in the business cycles of the Turkish economy under both regimes, which is a good benchmark for similar analysis for

emerging economies. That is why, my work makes two important contributions to the existing literature. First, it estimates a small open economy DSGE model with explicit regime switching by Bayesian methods for the emerging market. The second contribution is that this study quantitatively assesses the behavior of Turkish economy under two different monetary regimes and can serve as a valuable benchmark for future analysis in a similar framework for both Turkey and other emerging economies. To the best of my knowledge, it is a pioneer study for Turkey.

To achieve my goal, I estimate a stochastic business cycle model with deviations from the law of one price (LOP) and Calvo type price setting. The study is enriched by including external habit formation in the utility function in order to capture inertia in consumption which was well documented by King and Rebelo (2000). These rigidities will help to simulate reality and get more trustful results.

Curbing inflation has been the overall target of monetary policy in Turkey since February 2001, but until regime switching price stability used to be one of main goals of CB, as Turkey possessed one of the most inflated economies of Middle East. At the end of 80s and at the beginning of 90s inflation rates fluctuated between 40% and 110% annually (Rivlin, 2003). After regime switching, "furious" response of CB to inflation made it possible to chain inflation down to one digit values. Following Curdia and Finocchiaro (2005) I define monetary policy rule for the first and second regime, as modified Taylor rule and "conventional" Taylor rule respectively. As previously stated, remarkable inflation history of Turkish economy validates using modified Taylor rule for the first regime. Modified Taylor rule can be described as an interest rate rule, whereat CB reacts to a change in the nominal exchange rate as well.

Eight structural shocks help the study to analyze economy's stability conditions: shocks

to productivity, monetary policy, terms of trade, exchange rate, foreign interest rate, foreign output, domestic inflation and imported inflation. Meanwhile, the paper employs eight time series: foreign real interest rate, foreign output, domestic output, domestic nominal interest rate, domestic inflation, imported inflation, real exchange rate and terms of trade.

In estimation part, I closely follow Smets and Wouters (2002), *id est* employing Bayesian techniques and other numerical methods, like Markov Chain Monte Carlo (MCMC), for finding posterior modes, driving forces of business cycles, variance decomposition and impulse response functions.

The estimated monetary policy rule reveals out the strong focus of the CB on exchange rate stabilization in the exchange rate targeting regime. In its term, it limited the monetary independence of the CB by reducing its ability to respond to domestic shocks and made the economy vulnerable to foreign shocks as well. It is clearly visible from the variance decomposition analysis, where the foreign output and the foreign monetary policy shocks are the main sources of the economic fluctuations with the monetary policy shock under the first regime. After the regime change, the CB set price stability as the main target and the real exchange rate appeared as one of the main sources of the economic volatility in the Turkish economy. From impulse response analysis one can easily detect that the responses of variables to the foreign shocks increased in the inflation targeting regime. So, under the inflation targeting regime the real exchange rate transmitted the foreign shocks into the economy more than it did under the exchange rate targeting regime.

Analyzing stylized facts (tables 1 and 2) discloses that after the regime switching the Turkish economy became less volatile in terms of a nominal interest rate, terms of trade and a domestic inflation, as the standard deviations of the mentioned indicators went down after

regime change. (from 27.08 to 5.26, from 4.46 to 2.28, from 43.82 to 7.51 respectively). Notable change in the volatility of the nominal interest rate and domestic inflation proves that the CB implemented very rigid interest rate smoothing and achieved its goal of reducing inflation. But it should be noted that the standard deviation of the real exchange rate approximately stayed unchanged and in the second regime it served as one of the main sources of the cyclical behaviors.

2. Derivation of the baseline model

In this section, I derive a small-scale open economy DSGE model for Turkey. I am closely following Haider and Khan (2008), Liu (2006), Gali and Monacelly (2005) and Lubik Schorfheide (2005) in derivation of the key blocks of the model. In order to make the paper self contained, I include the derivation of key equations, which were proposed by Gali and Monacelli (2005) in Appendix A. The model's structure was enriched by including external habit formation, Calvo type price setting and furthermore I assume symmetric preferences and symmetric technology and complete international asset markets. Nevertheless, my model is in high harmony with the above stated models, I employ two different monetary policy rules, for capturing the answer to main questions of my thesis, which were inspired by Curdia and Finocchiaro (2005).

2.1 Households

The model describes the economy which is inhabited by a representative household who maximizes her utility through the following equations:

$$E_0 \sum_{t=0}^{\infty} \beta^t \{U(C_t, H_t) - V(N_t)\} \quad (1)$$

$$U(C_t, H_t) = \frac{(C_t - H_t)^{1-\sigma}}{1-\sigma} \text{ and } V(N_t) = \frac{N_t^{1+\varphi}}{1+\varphi}$$

where $\beta_t \in (0,1)$, is intertemporal discount factor representing time preferences, $\sigma > 0$ is the inverse elasticity of intertemporal substitution in consumption and $\varphi > 1$ is the inverse elasticity of labor supply. N_t denotes hours worked. The model allows for external habit formation with

$H_t = hC_{t-1}, h \in (0,1)$. C_t is aggregate consumption index for foreign and domestic goods:

$$C_t = \left((1-\alpha)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}} \quad (2)$$

whereat $\alpha \in [0,1]$ is the import ratio and captures degree of openness and $\eta > 0$ is the elasticity of substitution between home and foreign produced goods. $C_{H,t}$ and $C_{F,t}$ are defined as following:

$$C_{H,t} = \left[\int_0^1 C_{H,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}} \text{ and } C_{F,t} = \left[\int_0^1 C_{F,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (3)$$

here $\varepsilon > 0$ is the elasticity of substitution between varieties. The household's budget constraint is given by the following equation:

$$\int_0^1 \{ P_{H,t}(i) C_{H,t}(i) + P_{F,t}(i) C_{F,t}(i) \} di + E_t \{ Q_{t,t+1} D_{t+1} \} \leq D_t + W_t N_t \quad (4)$$

for $t = 1, 2, \dots, \infty$, wherein $P_{H,t}(i)$ and $P_{F,t}(i)$ denote the prices of domestic and foreign good i respectively, $Q_{t,t+1}$ is stochastic discount rate, D_t is nominal payoff from a portfolio of asset bought at $t-1$ and W_t is the nominal wage.

From optimization problem, we can easily derive the following demand functions for $C_{H,t}$ and $C_{F,t}$ respectively:

$$C_{H,t}(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}} \right)^{-\varepsilon} C_{H,t} \text{ and } C_{F,t}(i) = \left(\frac{P_{F,t}(i)}{P_{F,t}} \right)^{-\varepsilon} C_{F,t} \quad (5)$$

where $P_{H,t}$ and $P_{F,t}$ is the price index of home and imported goods respectively. From symmetry assumption in preferences and technology we can get the allocation scheme of expenditures:

$$C_{H,t} = (1-\alpha) \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} C_t \text{ and } C_{F,t} = \alpha \left(\frac{P_{F,t}}{P_t} \right) C_t \quad (6)$$

where $P_t = \left\{ (1-\alpha)P_{H,t}^{1-\eta} + \alpha P_{F,t}^{1-\eta} \right\}^{\frac{1}{1-\eta}}$ is consumer price index (CPI). So, we can state total consumption expenditures for the domestic household by $P_{H,t}C_{H,t} + P_{F,t}C_{F,t} = P_t C_t$. It helps us to express budget constraint as:

$$P_t C_t + E_t \{ Q_{t,t+1} D_{t+1} \} \leq D_t + W_t N_t \quad (7)$$

Household's maximization problem yields the following first order conditions (FOCs):

$$(C_t - hC_{t-1})^{-\sigma} \frac{W_t}{P_t} = N_t^\varphi \quad (8)$$

$$\beta R_t E_t \left\{ \frac{P_t}{P_t} \left(\frac{C_{t+1} - hC_t}{C_t - hC_{t-1}} \right)^{-\sigma} \right\} = 1 \quad (9)$$

here $R_t = 1 / E_t Q_{t,t+1}$ is the gross nominal return on a riskfree one-period bond maturing in $t+1$.

Equation (8) and (9) express intratemporal optimality condition and Euler equation respectively. Log-linear approximation of equation (6) and FOCs yields:

$$c_{H,t} = -(1-\alpha)\{\eta(p_{H,t} - p_t) + c_t\} \quad (10)$$

$$c_{F,t} = -\alpha\{\eta(p_{F,t} - p_t) + c_t\} \quad (11)$$

$$w_t - p_t = \varphi n_t + \frac{\sigma}{1-h} \hat{c}_t \quad (12)$$

$$\hat{c}_t = E_t \hat{c}_{t+1} - \frac{1-h}{\sigma} (r_t - E_t \pi_{t+1}) \quad (13)$$

where lower case letters denote the logs of the respective variables, $\hat{c}_t = \frac{1}{1-h}(c_t - hc_{t-1})$, and $\pi_t = p_t - p_{t-1}$ is CPI inflation.

I assume that households in the rest of the world (ROW) have the same optimization problems with identical preferences and domestic economy has not any influence on the ROW. That is why, I also assume $C_t^* = C_{F,t}^*$ and $P_t^* = P_{F,t}^*$. So, equation (12) and (13) is true for the foreign economy as well. (with all variables taking a superscript (*))

2.2 Inflation, the real exchange rate and terms of trade

In this section I derive key open economy relationships between inflation, real exchange rate, terms of trade, international risk sharing and uncovered interest parity. As stated earlier, the model allows deviations from Law of one price (LOP). As Turkey has little bargaining power in international markets, LOP holds for export sector, *id est* for exported goods, prices are determined exogenously in the ROW. I assume due to competition in the world import markets,

prices of imported goods are equal to marginal costs at the wholesale level. But, because of rigidities in inefficient distribution network and monopolistic retailers, there is LOP gap in imported prices.

Terms of trade (TOT) is defined as $S_t = \frac{P_{F,t}}{P_{H,t}}$ (or in logs $s_t = p_{F,t} - p_{H,t}$). It can be easily

spotted that, an increase in TOT means an increase in competitiveness. Log-linearizing the CPI formula around steady state and substituting $p_{F,t}$ with $s_t + p_{H,t}$ yields:

$$\begin{aligned} p_t &= (1-\alpha)p_{H,t} + \alpha p_{F,t} \\ &= p_{H,t} + \alpha s_t \end{aligned} \quad (14)$$

First difference of equation (14) yields the following relationships:

$$\pi_t = \pi_{H,t} + \alpha \Delta s_t \quad (15)$$

$$\Delta s_t = \pi_{F,t} - \pi_{H,t} \quad (16)$$

From equation (15) and (16) we can state that, the difference between total and domestic inflation is proportional to change in TOT and this proportionality increases with degree of openness. Nominal exchange rate (ξ_t), is defined as a foreign currency per unit of a domestic currency. So, an increase of nominal exchange rate means an appreciation of the domestic currency. Next step is defining real exchange rate and LOP gap respectively:

$$\zeta_t = \frac{\xi_t P_t}{P_t^*} \quad (17)$$

$$\Psi_t = \frac{P_t^*}{\xi_t P_{F,t}} \quad (18)$$

where P_t^* is the foreign price index. Note that, if LOP holds, then $\Psi_t = 1$. Taking log of (18) and using the formula for TOT yields:

$$s_t = p_t^* - e_t - p_{H,t} - \psi_t \quad (19)$$

here e_t represents the log of nominal exchange rate. From substitution of (19) into (18) and with the help of (14) we can get:

$$q_t = e_t + p_t - p_t^* \quad (20)$$

$$= p_t - p_{H,t} - s_t - \psi_t$$

$$= -\psi_t - (1 - \alpha)s_t$$

$$\psi_t = -[q_t + (1 - \alpha)s_t]$$

where $q_t = \ln(\zeta_t)$. It can be stated without any doubt that, LOP gap is inversely proportionate to the real exchange rate and degree of international competitiveness.

2.3 International risk sharing and uncovered interest parity

I assume complete international financial markets in my model and I can go further by assuming perfect capital mobility as well. So, then the expected nominal return from riskless bonds, in home currency terms, must be the same as the expected domestic-currency return from foreign bonds. It can be expressed by $E_t Q_{t,t+1} = E_t (Q_{t,t+1}^* \frac{\xi_{t+1}}{\xi_t})$. This equality makes it possible to

equate Euler conditions of both domestic and foreign households:

$$\beta E_t \left\{ \frac{P_t}{P_{t+1}} \left(\frac{\hat{C}_{t+1}}{\hat{C}_t} \right)^{-\sigma} \right\} = \beta E_t \left\{ \frac{P_t^*}{P_{t+1}^*} \frac{\xi_{t+1}}{\xi_t} \left(\frac{\hat{C}_{t+1}^*}{\hat{C}_t^*} \right)^{-\sigma} \right\} \quad (21)$$

whereat $\hat{C}_t = C_t - hC_{t-1}$ and $\hat{C}_t^* = C_t^* - hC_{t-1}^*$. So, I assume the same habit formation parameter for households in the ROW as well. And the following relationship is inspired from previous developments:

$$C_t - hC_{t-1} = \vartheta (C_t^* - hC_{t-1}^*) \zeta_t^{-\frac{1}{\sigma}} \quad (22)$$

here, ϑ is constant parameter representing initial asset positions. Log-linearizing (22) around the steady state yields:

$$c_t - hc_{t-1} = (c_t^* - hc_{t-1}^*) - \frac{1-h}{\sigma} q_t \quad (23)$$

$$= (y_t^* - hy_{t-1}^*) - \frac{1-h}{\sigma} q_t$$

where I assume that $c_t^* = y_t^*$, and it is quite logical as domestic consumption of foreign goods is so negligible that it does not distort $c_t^* = y_t^*$. From the assumption of complete international financial markets I can easily derive the uncovered interest parity condition:

$$E_t \left(Q_{t,t+1} \left\{ R_t - R_t^* \frac{\xi_t}{\xi_{t+1}} \right\} \right) = 0 \quad (24)$$

Log-linearizing (24) around steady-state yields UIP condition for nominal exchange rate and it gives way to the expression for real exchange rate as well:

$$r_t - r_t^* = E_t \Delta e_{t+1} \quad (25)$$

$$E_t \Delta q_{t+1} = -(r_t - \pi_{t+1}) - (r_t^* - \pi_{t+1}^*) \quad (26)$$

2.4 Firms

Firms' side is comprised by a continuum of identical monopolistic firms and j^{th} firm produces a differentiated good, Y_j , using the following linear technology production function:

$$Y_t(j) = A_t N_t(j) \quad (27)$$

here technology ($a_t = \log(A_t)$) follows an AR(1) process, $a_t = \rho_a a_{t-1} + v_t^a$. We can state aggregate output as:

$$Y_t = \left[\int_0^1 Y_t(j)^{(1-\rho)} dj \right]^{-\frac{1}{1-\rho}} \quad (28)$$

Assumption of symmetric equilibrium across all j firms helps me to get log-linear form of production function as following:

$$y_t = a_t + n_t \quad (29)$$

Firms' real total cost can be expressed as $TC_t = \frac{W_t}{P_{H,t}} \frac{Y_t}{A_t}$ and log of real marginal cost is

stated as the following:

$$mc_t = w_t - p_{H,t} - a_t \quad (30)$$

2.5 Price setting behavior and incomplete pass-through

It is assumed that domestic monopolistic firms follow Calvo type price setting behavior,

id est in any period t , only $1-\theta_H$, where $\theta_H \in [0,1]$, fraction of firms set their prices optimally, while θ_H fraction is indexing prices to last period's inflation according to:

$$P_{H,t}^I(j) = P_{H,t-1}(j) \left(\frac{P_{H,t-1}}{P_{H,t-2}} \right)^{\theta_H} \quad (31)$$

It is also assumed that degree of past inflation indexation is the same as the probability of resetting prices and this ensures "verticality" of Phillips curve in the long run. Aggregate domestic price level evolves according to below stated formula, whereat $\bar{P}_{H,t}$ is the price level of an optimizing firm at each period:

$$P_{H,t} = \left\{ (1-\theta_H) \bar{P}_{H,t}^{1-\rho} + \theta_H \left[P_{H,t-1} \left(\frac{P_{H,t-1}}{P_{H,t-2}} \right)^{\theta_H} \right]^{1-\rho} \right\}^{\frac{1}{1-\rho}} \quad (32)$$

Or we can restate with the inflation:

$$\pi_{H,t} = (1-\theta_H)(\bar{p}_{H,t} - p_{H,t-1}) + \theta_H^2 \pi_{H,t-1} \quad (33)$$

While setting a new price, an optimizing firm is maximizing the following problem:

$$\max_{P_{H,t}} \sum_{k=0}^{\infty} (\theta_H)^k E_t \left\{ Q_{t,t+k} Y_{t+k} \left(\bar{P}_{H,t} - MC_{t+k}^n \right) \right\} \quad (34)$$

Subject to $Y_{t+k} \leq \left(\frac{\bar{P}_{H,t}}{P_{H,t+k}} \right)^{-\varepsilon} (C_{H,t+k} + C_{H,t+k}^*)$. Here MC_{t+k}^n is nominal marginal cost and

$\theta_H^k E_t Q_{t,t+k-1,t+k}$ is the effective stochastic discount rate. The FOC of the maximization problem can

be easily stated as the following:

$$\sum_{k=0}^{\infty} \theta_H^k E_t \left\{ Q_{t,t+k} Y_{t+k} \left(\bar{P}_{H,t} - \frac{\varepsilon}{\varepsilon-1} MC_{t+k}^n \right) \right\} = 0 \quad (35)$$

whereat $\frac{\varepsilon}{\varepsilon-1}$ is the real marginal cost under flexible prices. Let's substitute $Q_{t,t+k}$ with the expression which we can borrow from consumption Euler equation in (9):

$$\sum_{k=0}^{\infty} (\beta\theta_H)^k P_t C_t^\sigma E_t \left\{ P_{t+k}^{-1} C_{t+k}^{-\sigma} Y_{t+k} (\bar{P}_{H,t} - \frac{\varepsilon}{\varepsilon-1} MC_{t+k}^n) \right\} = 0 \quad (36)$$

We can take out $P_t C_t^\sigma$, as it is known at current period t and I can rearrange (36) as the following:

$$\sum_{k=0}^{\infty} (\beta\theta_H)^k E_t \left\{ P_{t+k}^{-1} C_{t+k}^{-\sigma} Y_{t+k} (\bar{P}_{H,t} - \frac{\varepsilon}{\varepsilon-1} MC_{t+k}^n) \right\} = 0 \quad (37)$$

Taking into the consideration that $MC_{t+k} = \frac{MC_{t+k}^n}{P_{H,t+k}}$ is the real marginal cost, we can express (37) as the following:

$$\sum_{k=0}^{\infty} (\beta\theta_H)^k E_t \left\{ C_{t+k}^{-\sigma} Y_{t+k} \frac{P_{H,t-1}}{P_{t+k}} \left(\frac{\bar{P}_{H,t}}{P_{H,t-1}} - \frac{\varepsilon}{\varepsilon-1} MC_{t+k}^n \frac{P_{H,t+k}}{P_{H,t-1}} \right) \right\} = 0 \quad (38)$$

and log-linearizing equation (38) yields:

$$\bar{p}_{H,t} = p_{H,t-1} + \sum_{k=0}^{\infty} (\beta\theta_H)^k \left\{ E_t \pi_{H,t+k} + (1 - \beta\theta_H) E_t mc_{t+k} \right\} \quad (39)$$

It literally means that firms follow future discounted sum of inflation and deviations of real marginal cost from its steady state in setting their prices. We can go further by rewriting (39) as the following and doing some "mathematical tricks":

$$\bar{p}_{H,t} = p_{H,t-1} + \pi_{H,t} + (1 - \beta\theta_H) mc_t + (\beta\theta_H) \sum_{k=0}^{\infty} (\beta\theta_H)^k \left\{ E_t \pi_{H,t+k+1} + (1 - \beta\theta_H) E_t mc_{t+k+1} \right\}$$

Here, I split up the summation into two parts, one for period t and other for from $t+1$ to ∞ . From now on, the last term in above stated equation can be expressed by using (39) as the following:

$$\bar{p}_{H,t} = p_{H,t-1} + \pi_{H,t} + (1 - \beta\theta_H)mc_t + \beta\theta_H(\bar{p}_{H,t+1} - p_{H,t})$$

and rearranging it yields NKPC equation:

$$\bar{p}_{H,t} - p_{H,t-1} = \beta\theta_H E_t \pi_{H,t+1} + \pi_{H,t} + (1 - \beta\theta_H)mc_t \quad (40)$$

and also rearranging (40) and substituting back to (33) yields domestic inflation equation:

$$\pi_{H,t} = \beta(1 - \theta_H)E_t \pi_{H,t+1} + \theta_H \pi_{H,t-1} + \lambda_H mc_t \quad (41)$$

here $\lambda_H = \frac{(1 - \beta\theta_H)(1 - \theta_H)}{\theta_H}$. If there is not any stickiness in the economy, *id est* $\theta_H = 0$, then

inflation process would be purely forward looking and it would make disinflationary policies costless.

Again, I refresh my assumption about LOP: LOP holds at the wholesale level for imports, but because of monopolistic retailers LOP fails at the retailers' level. Following Gali and Monacelli (2005) I can get equation of price setting for domestic importer retailers:

$$\bar{p}_{F,t} = p_{F,t-1} + \sum_{k=0}^{\infty} (\beta\theta_F)^k \{E_t \pi_{F,t+k} + (1 - \beta\theta_F)E_t \psi_{t+k}\} \quad (42)$$

here analogically, Calvo type pricing mechanism can also be assumed for importer retailers.

$\theta_F \in [0,1]$ is the fraction of importers who cannot set their prices optimally at every period. So, above equation states in plain English that in setting prices for imports, domestic retailers take into the consideration future path of import inflation and also LOP gap (ψ_t). Literally, LOP gap

is a deviation of domestic import prices from the world prices. Steps in derivation of (41) can be done for derivation of the equation for $\pi_{F,t}$ as well and I can get:

$$\pi_{F,t} = \beta(1-\theta_F)E_t\pi_{F,t+1} + \theta_F\pi_{F,t-1} + \lambda_F\psi_t \quad (43)$$

whereat $\lambda_F = \frac{(1-\beta\theta_F)(1-\theta_F)}{\theta_F}$. Log-linearizing CPI equation and taking the first difference

yields:

$$\pi_t = (1-\alpha)\pi_{H,t} + \alpha\pi_{F,t} \quad (44)$$

As firms tend to smooth their pricing decisions, in sticky-price models, this gives way to nominal rigidities, which would be dismissed under flexible price setting. In this framework, non-optimized prices serve as a source of cost to the economy. So, in this setup, CB tries to minimize deviations of marginal cost and the LOP gap from their steady state.

2.6 Equilibrium

Aggregate demand and output

Goods market clearing condition for the domestic economy requires that domestic output is weighted sum of domestic consumption and foreign consumption of domestic goods:

$$y_t = (1-\alpha)c_{H,t} + \alpha c_{H,t}^* \quad (45)$$

Log-linearizing of the equation (6) for home consumption of domestic goods and the

equation for foreign consumption of domestic goods- $C_{H,t}^* = (1-\alpha) \left(\frac{\xi_t P_{H,t}}{P_t^*} \right)^{-\eta} C_t^*$ yields:

$$\begin{aligned} c_{H,t} &= -\eta(p_{H,t} - p_t) + c_t \\ &= \alpha\eta s_t + c_t \end{aligned} \quad (46)$$

$$\begin{aligned} c_{H,t}^* &= -\eta(e_t + p_{H,t} - p_t^*) + c_t^* \\ &= -\eta(p_{H,t} - p_{F,t} - \psi_t) + c_t^* \\ &= \eta(s_t + \psi_t) + c_t^* \end{aligned} \quad (47)$$

(46) and (47) can be "decoded" as the following: in (46) an increase in terms of trade stimulates domestic buyers to substitute out foreign goods into domestic goods with magnitude which is proportionate to η and α . Similar argumentation is valid for foreign consumers as well in (47).

Simplification of (45) with the "light" of (46) and (47) yields goods market clearing condition for a small open economy:

$$y_t = (1-\alpha)c_t + \alpha c_t^* + (2-\alpha)\alpha\eta s_t + \alpha\eta\psi_t \quad (48)$$

It can be easily spotted that in case of autarky ($\alpha = 0$) $y_t = c_t$.

Marginal cost and inflation dynamics

Equation (30) states real marginal cost as $mc_t = w_t - p_{H,t} - a_t$. Log-linearized FOC condition in (12) and linearized production function in (29) make it possible to express real marginal cost as the following:

$$\begin{aligned} mc_t &= (w_t - p_t) + (p_t - p_{H,t}) - a_t \\ &= \frac{\sigma}{1-h} (c_t - hc_{t-1}) + \varphi n_t + \alpha s_t - a_t \\ &= \frac{\sigma}{1-h} (c_t - hc_{t-1}) + \varphi y_t + \alpha s_t - (1+\varphi)a_t \end{aligned} \quad (49)$$

So, marginal cost is increasing in domestic output and terms of trade and decreasing in level of labor productivity.

Monetary Policy

In order to make our model full-fledged we need to specify monetary policy reaction function for our small open economy. The aim of monetary policy in target zone is to provide the economy with "controlled" exchange rate and in the inflation target period to bind down inflation to one digit values. We use modified Taylor rule with extension of nominal exchange rate:

$$r_t = \rho_r r_{t-1} + (1 - \rho_r) [\phi_1 \pi_t + \phi_2 \Delta y_t + \phi_3 \Delta e_t] \quad (50)$$

here ρ_r is the degree of interest rate smoothing, ϕ_1, ϕ_2 and ϕ_3 are measuring responsiveness of CB to inflation, output growth and change in nominal exchange rate respectively. We use "speed

limit" policy rule proposed by Walsh (2003) instead of "traditional Taylor" rule, *id est* CB policy reacts to the rate of change in the output gap, rather than to its level. For the inflation target period we use the same equation, but without $\phi_3 \Delta e_t$ term:

$$r_t = \rho_r r_{t-1} + (1 - \rho_r) [\phi_1 \pi_t + \phi_2 \Delta y_t] \quad (51)$$

ROW

Rest of the world in our small open economy is characterized by two AR (1) exogenous equation:

$$y_t^* = \lambda_1 y_{t-1}^* + v_t^{y^*} \quad (52)$$

$$r_t^* - E_t \pi_{t+1}^* = \rho_{r^*} (r_{t-1}^* - \pi_t^*) + v_t^{r^*} \quad (53)$$

3. The Estimation Methodology

This paper uses recent advancements in Bayesian estimation and evaluation techniques for answering previously mentioned questions. Last decade is notorious for many developments in DSGE modeling and especially evaluating this kind of models through direct parameter estimates and data. In particular, the study's estimation is built around likelihood function which is derived from the DSGE model. In this context, linear-approximation methods help to develop state-space representation of the DSGE model which can be analyzed with the Kalman filter. Specification of a prior distribution and state-space representation lead to form posterior distribution. So, Bayesian estimation finds a parameter by maximizing the posterior, within the help of the prior and the likelihood which bases on the data. Let's denote the vector of estimated parameters with ω and the data with V . Then, according to Bayes theorem, the posterior density $p(\omega/V)$ can be found as the following:

$$p(\omega/V) = \frac{p(V/\omega)p(\omega)}{p(V)} \propto p(V/\omega)p(\omega) = L(\omega/V)p(\omega)$$

here $p(\omega)$ is the prior density of the parameter vector, $L(\omega/V)$ is likelihood, based on the data and $p(V) = \int p(V/\omega)p(\omega)d\omega$ can be named as unconditional data density which is independent of the estimated parameter vector. From the assumption of independently distributed priors we can get the logarithm of the posterior as the following:

$$\ln(p(\omega/V)) = \ln(L(\omega/V)) + \sum_{i=1}^N \ln(p(\omega_i))$$

The term of $\sum_{i=1}^N \ln(p(\omega_i))$ can be calculated from the prior distribution of the estimated

parameters.

While the estimation of the model for the first subsample we use 57 observations (1987Q1–2001Q1), but for the second subsample the number of observations is 35 (2001Q2–2009Q4). The log likelihood for the first subsample can be derived as the sum of the log likelihood of the exchange rate targeting period ($T_1 = 57$), using the state-space representation of the subsample and the for the second subsample as the sum of the log likelihood of the inflation targeting period ($T_2 = 35$) using state-space representation of the subsample. Non-monetary policy parameters are held constant for both subsamples.

After finding the mode of posterior, through approximation around the mode, a large sample of Markov-Chain Monte Carlo (MCMC) draws is generated. I use Metropolis-Hastings algorithm for proposal draws.

3.1 Specification of Data and Prior Distributions

Data set from 1987Q1 to 2009Q4 was retrieved from International Financial Statistics Browser (IFS) and from the CB of Turkey's CBRT Electronic Data Delivery System. The quarterly data seasonally adjusted, logged except real and nominal interest rates and HP filtered ($\lambda = 1600$). Detailed descriptions of the observed variables are given in Appendix C.

In choosing prior distributions I closely follow conventions of the main literature. For positive parameters I assume gamma distribution; for the parameters which vary between 0 and 1, I choose beta distribution; for shocks inverse gamma distribution and for the remaining parameters normal distribution are assumed. For the means and standard deviations of the priors I am guided by the results of previous studies on calibration and estimation of similar models for the similar emerging countries.

4 Results

4.1 Parameter Estimates and Posterior Distributions

The complete "picture" of parameter estimates is described through the tables- 3-6. The tables 3 and 4 comprise results for the exchange rate targeting regime which cover the period of 1987Q1-2001Q1. The results of inflation targeting regime, in the period of 2001Q2-2009Q4, are summarized in the tables 5 and 6. Priors, maximum likelihood estimation results and Bayesian estimation results are given in each table. I report the modes and standard errors of parameters and shocks from maximized posterior, which were derived from the diagonal elements of inverse Hessian matrix and also means and standard deviations of posterior distributions, which were generated by means of the Metropolis Hastings Markov-Chain Monte Carlo algorithm¹. While discussion of the results we will focus on the Bayesian estimation results, unless other results mentioned.

Posterior estimation results for the monetary policy function are in line with Turkey's historical reality. I find that in the exchange rate regime CB reacts to the change in nominal exchange rate more than other indicators. The value of the coefficient of the CB's responsiveness to the change in nominal exchange rate (φ_3) is equal to 2. However responsiveness coefficient to inflation (φ_1) and to the change in output (φ_2) are 1.49 and 0.25 respectively. This result coincides with the policy goal of the monetary authority. Among policy coefficients, the highest value of φ_3 overlaps with the purpose of the exchange rate targeting regime, which was providing stability in the exchange rate. High value of φ_1 is quite logical, as curbing down

¹The MCMC algorithm was run with 100000 draws with 6 Metropolis Hasting parallel chains

inflation was one of secondary goals of CB. Saatcioglu et al (2006) report that annual inflation was 85% in 1997. For the inflation target regime we got the values of 1.82 and 0.30 for φ_1 , φ_2 respectively. The increase in the value of φ_1 proves that after regime change CB became more aggressive towards inflation and it is in line with the reality. Furthermore, Comert and Yeldan (2008) find that after regime change CB put more effort on interest rate smoothing, but interest rate smoothing parameter (ρ_r) decreased from 0.50 to 0.18 in my estimations. So, my model does not capture this fact. Additionally, they found "CB persistently ignored (or had to ignore) the developments in output gap in designing its interest rate policy", which was reflected in low values of φ_2 in my estimation results (0.25 and 0.30 for the first and the second regimes respectively). Persistence parameters for exogenous processes, namely for technology and foreign real interest rate, increased after the regime switching (from 0.49 to 0.83 and from 0.36 to 0.49 respectively).

My results for utility parameter are mostly in line with conventional literature on similar studies for Turkey. For the exchange rate targeting regime, the value of the parameter is 0.91, but for the second regime, coefficient of relative risk aversion (CRRA) - σ is 0.99 (with the 0.90 and 0.79 standard errors respectively). It means, intertemporal elasticity of substitution (IES) - $1/\sigma$ is 1.10 and 1.01 respectively. Tasdemir (2006) estimates IES coefficient for Turkey for the period 1987-2005 with quarterly data and gets median value - 1.03 for the coefficient. The comparison of the results from two different regimes shows that IES did not change remarkably after regime switching.

Labor utility parameter- φ is 0.99 and 1.61 for the exchange rate targeting and inflation targeting regime respectively and it can be "translated" as 1.01 and 0.62 for wage elasticity - $1/\varphi$. It is quite logical for Turkey's reality, as from 2002, Turkey demonstrated substantial

economic growth with decreasing unemployment rate. So, it means one percent increase in wages triggers less labor supply in the second subsample than it was under the first subsample. From labor economics perspective it also means Turkey experienced an increase of minimum wage level for labor market participation, which shows development in welfare.

Habit parameters, with results of 0.87 and 0.99 for the first and the second regime respectively, indicates high consumption smoothing in Turkish economy. Furthermore, elasticity between domestic and imported goods in consumption did not change substantially (1.04 and 0.93 for the two subsequent regimes respectively). However, very high standard deviations of reported parameters show that in both regimes Turkey's economy was highly volatile.

Results for Calvo parameters indicate that Turkish economy has less price rigidity than its neighbors, more precisely than European Union. It coincides with results of Sahinoz *et al* (2008). They survey pricing behavior of 999 firms during the period of May-July (2005) and conclude that "degree of price stickiness is much lower in Turkey than in the Euro area". They also note that "the price reviews lies in the range of one to three times a year in Turkey and the median price change is once a year in the Euro area". The stickiness parameter for EU is 0.90 in Smets and Wouters (2002). Stickiness parameter for domestic firms θ_H , is 0.49 in the first regime and 0.74 in the second regime for Turkey. As, price stickiness is negatively correlated with inflation, it is quite understandable that stickiness parameter increased after regime switching, as inflation rate decreased as well. Furthermore, we also can conclude that as Turkey's economy has small price stickiness, it means that monetary "disbalances" have smaller and less persistent influences on the economy than in the Euro area. In impulse response analysis one can see that the monetary policy shock lasted 6 period units in the first regime, while in the second regime, it lasted 10 period units. It should also be noted that stickiness parameter of import

retailers, θ_F increased after regime change from 0.49 to 0.51.

Results of shocks parameters, presented in the tables 4 and 6, give very valuable insights into which shocks drive cyclical variations in our model. Under the exchange rate targeting regime, foreign output shock was the most powerful shock in Turkey's economy. But, after the regime change, its value decreased from 6.42 to 0.28. It should be noted that after the regime switching the values of the rest of the shock parameters increased, except the terms of trade shock.

4.2 Variance Decomposition and Impulse Responses

Table 7 and 8 represent variance decompositions of observed variables in the exchange rate and the inflation targeting regime respectively. It can easily be spotted that in the exchange rate targeting regime the business cycles of observed variables were mostly driven by the nominal interest rate (ν_r), foreign real interest rate (ν_{rst}) and foreign output (ν_{yst}) shocks. But, after regime switching the contribution of the foreign output shock became negligible, while real exchange rate shock (ν_q) became important in variations of the variables. So, it proves that the domestic and the foreign monetary policy shocks, *id est* the nominal interest rate and the foreign real interest rate shocks used to be and still are the important source of the volatility in Turkey's economy. It also should be noted that, after the regime switching the share of the domestic monetary policy shock in the volatility of the domestic and the CPI inflations decreased (from 53.37% to 42.98% and from 52.35% to 44.01% respectively). Appearance of the ν_q , after the regime change, as one of the main contributors in the variance of the variables shows that the shock to the real exchange rate is still important factor in the Turkish economy.

In the impulse response subsection I analyze results of Bayesian impulse response functions, *id est* the parameters are set to the estimation results, obtained from posterior distribution. Through figures 4 to 11 the consumption, the change in the nominal exchange rate, the marginal cost, the imported inflation, the domestic inflation, the CPI inflation, the LOP gap, the real exchange rate, the nominal interest rate, the terms of trade, the output, the foreign output and the foreign real interest rate were denoted by c , del_nom , mc , pif , pih , pit , psi_t , q , r , tot , y , y_{st} and r_{st} respectively. Here, an increase in the terms of trade means an increase in the competitiveness of the economy. An increase in the change in the nominal exchange rate means appreciation of the domestic currency. My findings from impulse response analysis can be summarized under four items. First, after the regime change the CB managed to reduce the impact of inflationary shocks to the economy. Second, In the second regime the CB achieved very smooth behavior in the output and the consumption. Third, after the regime change the influence of the real exchange rate shock to the Turkish economy increased. Fourth, in the inflation targeting regime the economy became more volatile when facing foreign shocks.

Figure 4 captures the positive technology shock (a) to Turkey's economy and impulse responses of other macro variables to the shock. Under the inflation targeting regime (1) technology shock is more persistent than under the exchange rate targeting regime (2). According to conventional theory it should boost consumption and output up and we witness the increase in both variables. But in the first regime the increase is substantial. In contrast, we see very little change in the second regime. All variables respond to the shock more in the inflation targeting regime than in the exchange rate targeting regime. So, technology shock causes more volatility in the second regime. That is why, the severe response of the monetary authority to the shock in the second regime is quite understandable. Furthermore, according to my baseline

model the marginal cost should go up. One can see that the mentioned variable follow model's prediction in the inflation targeting regime, but it demonstrates inverse path in the exchange rate targeting regime. It should be noted that there are negligible increases in the output and consumption. So, the increase in the mc should mostly be driven by the terms of trade. However, one can see a decrease in the first three periods in the terms of trade. Then why do I have a substantial increase in the marginal cost in the first three periods? I propose the following explanation. The hint is hidden in the prices. We had to have a decrease in the domestic prices because of more production, but we see an increase. It seems that the establishment of the distribution networks was very costly in initial periods. But, after some periods established distribution networks caused the decrease in the domestic prices and consequently in the domestic inflation. This scenario can be proven with the upward behavior of terms of trade after the third period, as it means a decrease in the domestic prices.

Figure 5 reflects impulse responses of the key macro economic variables when the positive terms of trade shock is observed in the Turkish economy. The positive shock in the terms of trade means increase in the competitiveness of the economy through an increase in the prices of imported goods and a decrease in the prices of imported goods. In the exchange rate targeting regime the shock causes huge volatility in the economy, but in contrast very negligible changes in the inflation targeting regime. It can be concluded that, as in the second regime price control has been done by the CB very decisively, so the terms of trade shock generated very small changes in the economy. We observe upward and downward behavior in the domestic and imported inflation respectively, but according to my model it should be vice verse. Furthermore, marginal cost should decrease, but it also follows inverse path. Perhaps, an increase of prices of imported intermediate goods causes the marginal cost to increase and it eventually ends up with

the domestic inflation. As, I do not have intermediate goods sector in my model, my model does not capture prices changes caused by intermediate goods.

Impulse response of the real variables, more precisely consumption and output to the real exchange rate shock is more in the exchange rate targeting regime than the inflation targeting regime, which can be seen from figure 6. Other variables follow similar paths under both regimes, but their responses are more under the second regime, except terms of trade and domestic inflation. Switching to the flexible exchange rate made the Turkish economy more volatile when facing the real exchange rate shock. So, it again shows that changing the fixed exchange rate for the flexible exchange rate left the economy more prone to fluctuations generated by the real exchange rate shocks.

Figure 8 depicts the 2% percent import inflation shock and the relative responses of the variables. The model in this study "requires" that, when the mentioned shock hits the economy, the terms of trade and the domestic output should go up and we can see the increase in the variables under both regimes. From figure 7 we can realize that when domestic inflation shock hits the economy, consumption and output decrease and it is in line with theory. It should also be mentioned that, in the exchange rate targeting regime, the response of the variables mostly are more than in the inflation targeting regime during both shocks. It documents that in the first regime, the economy was more volatile and more prone to damages from inflationary shocks. Also, it documents that the CB managed to neutralize inflationary shocks in the second regime.

Figure 9 depicts the monetary policy shock and the response of the other variables to it. All results are in line with my model and with the conventional RBC models, except output. The increase in the nominal interest rate conventionally discourages output, but the result in the figure 9 contradicts with it. The increase is remarkable in the exchange rate targeting regime.

However it is negligible in the inflation targeting regime. It can easily be spotted that after the regime change the impact of monetary policy on the economy, especially on the real variables decreased.

Figure 10 and 11 show impulse responses of the variables to the foreign real interest rate and foreign output shocks respectively. It can be concluded that the reaction of output and the consumption is less in the second regime. However, the paths of other variables show that in inflation targeting regime the Turkish economy is much more volatile when facing foreign shocks.

Conclusion

In my thesis, I estimate a small open economy model on Turkish data by using Bayesian techniques. An important contribution of my thesis is to account for the monetary policy regime change from an exchange rate targeting to an explicit inflation targeting, which occurred in 2001 after the currency collapse in Turkey, and to assess quantitatively the performance of the monetary policy under both regimes. My thesis additionally provides a very useful guideline on the main driving forces of the Turkish economy in the exchange rate targeting and in the inflation targeting regimes. The paper closely analyzes the main shocks and their contributions in the business cycles of the key macro economic variables. The thesis can serve as a valuable benchmark to future researches on an emerging economy. To my best knowledge it is a pioneer study on Turkish economy.

My estimations prove that under the first regime the CB mainly concerned with the exchange rate and under the second regime it mainly focused on the price stability. But, the monetary authority persistently ignored the changes in output gap.

Results of parameter estimates show that after the regime switching the Turkish economy became more rigid, but it is still less rigid than advanced economies. That is why, monetary policy is less persistent in the Turkish economy. Furthermore, under the exchange rate targeting regime the foreign output was one of the main sources of the volatility and this result overlaps with the variance decomposition analysis.

Variance decomposition analysis reveals out that in the exchange rate regime business cycles of the key macro economic variables were driven by the foreign output, the domestic and the foreign monetary policy shocks. However, in the inflation targeting regime the main sources

of the economic volatility were the real exchange rate, domestic and monetary policy shocks. So, under both regimes monetary policy shocks were triggers of the fluctuations in the Turkish economy. Furthermore, the flexible exchange rate in the second regime allowed the real exchange rate shock to appear as the additional source of the economic volatility.

Findings from the impulse response analysis can be summarized as follows. The technology shock generated more volatility in the inflation targeting regime and the CB reacted more severely to the technology shock. Strict price control in the second regime helped the monetary authority to neutralize inflationary shocks and the terms of trade shock. But, the flexible exchange rate made the economy economically more vulnerable when facing the real exchange rate shock. Additionally, under the inflation targeting regime the economy became more volatile during the foreign shocks. After the regime switching the CB achieved very smooth behavior in the output and the consumption.

In future researches, it would be interesting to include capital and capital related rigidities and to have intermediate goods sector in the model part. With the help of suggested advancements, the model can simulate the Turkish economy in a better way.

Reference

Frank Smets, Raf Wouters. 2002. “An Estimated Stochastic Dynamic General Equilibrium Model of the Euro Area”. European Central Bank, Working Paper, No.171

Vasco Curdia, Daria Finocchiaro. 2005. “An Estimated DSGE Model For Sweden With A Monetary Regime Change”. Stockholm University, Seminar Paper, No. 740

Haider Adnan, Khan Safdar Ullah. 2008. “A Small Open Economy DSGE Model For Pakistan”. State Bank of Pakistan, MPRA paper, No. 12997

Philip Liu. 2006. “A Small New Keynesian Model Of The New Zealand Economy”. Reserve Bank of New Zealand, Discussion Paper, No. 03

Thomas Lubik, Frank Schorfheide. 2005. “A Bayesian Look at New Open Economy Macroeconomics”. NBER (National Bureau of Economic Research) Macroeconomics Annual, pp. 313-366.

John B. Taylor. 2000. “Using Monetary Policy Rules in Emerging Market Economies”.

Bank of Mexico, Conference Paper.

Robert G. King, Sergio T. Rebelo. 2000. “Resuscitating Real Business Cycles”. NBER, Working Paper, No. 7534.

Paul Rivlin. 2003. “Two Middle Eastern Inflations: Israel and Turkey 1980-2001”. British Journal of Middle Eastern Studies, Vol. 30, No. 2. Pp 211-235.

Jordi Gali, Tomasso Monacelli. 2005. “Monetary Policy and Exchange Rate Volatility in a Small Open Economy”. Review of Economic Studies (2005) 72, 707–734.

Walsh, C. (2003): "Speed limit policies: the output gap and optimal monetary policy", American Economic Review, 93, 1, pp. 265-278.

Sahinöz Saygin, Bedriye Saraçoğlu. 2008. “Price Setting Behavior In Turkish Industries : Evidence From Survey Data”. Turkish Economic Association Discussion Paper, No 03.

Hasan Cömert, A. Erinc Yeldan. 2008. “Interest Rate Smoothing and Macroeconomic Instability under Post-Capital Account Liberalization Turkey”. University of Massachusetts Amherst. Working Paper, No. 173.

Cem Saatçioğlu, H. Levent Korap. 2006. “Determinants of Turkish Inflation”. Turkish Economic Association Discussion Paper, No 07.

Appendix A

Consumption demand functions

Here, I am deriving demand functions in (5) from expenditure minimization problem as the following:

$$\min_{C_{H,t}(i), C_{F,t}(i)} \int_0^1 \{P_{H,t}(i)C_{H,t}(i) + P_{F,t}(i)C_{F,t}(i)\} di$$

$$s.t. C_{H,t} = \left(\int_0^1 C_{H,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}}$$

$$C_{F,t} = \left(\int_0^1 C_{F,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}}$$

$$L = \int_0^1 \{P_{H,t}(i)C_{H,t}(i) + P_{F,t}(i)C_{F,t}(i)\} di + \lambda \left(C_{H,t} - \left(\int_0^1 C_{H,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}} \right) + \mu \left(C_{F,t} - \left(\int_0^1 C_{F,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}} \right)$$

F.O.C.

$$C_{H,t}(i) - P_{H,t}(i) - \lambda \frac{\varepsilon}{\varepsilon-1} \left(\int_0^1 C_{H,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}-1} \frac{\varepsilon-1}{\varepsilon} C_{H,t}(i)^{\frac{\varepsilon-1}{\varepsilon}-1} = 0$$

$$P_{H,t}(i) = \lambda C_{H,t}^{\frac{1}{\varepsilon}} C_{H,t}(i)^{-\frac{1}{\varepsilon}}$$

$$P_{H,t}(i)^{1-\varepsilon} = \lambda^{1-\varepsilon} C_{H,t}^{\frac{1-\varepsilon}{\varepsilon}} C_{H,t}(i)^{-\frac{1-\varepsilon}{\varepsilon}} \quad (*)$$

$$\int_0^1 P_{H,t}(i)^{1-\varepsilon} = \lambda^{1-\varepsilon} C_{H,t}^{\frac{1-\varepsilon}{\varepsilon}} \int_0^1 C_{H,t}(i)^{-\frac{1-\varepsilon}{\varepsilon}}$$

$$\left[\int_0^1 P_{H,t}(i)^{1-\varepsilon} \right]^{\frac{\varepsilon}{\varepsilon-1}} = \lambda^{-\varepsilon} C_{H,t}^{-1} \left[\int_0^1 C_{H,t}(i)^{-\frac{1-\varepsilon}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}}$$

$$\left[\int_0^1 P_{H,t}(i)^{1-\varepsilon} \right]^{\frac{\varepsilon}{\varepsilon-1}} = \lambda^{-\varepsilon}$$

$$\left[\int_0^1 P_{H,t}(i)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} = \lambda = P_{H,t}$$

Substitute λ back to (*)

$$P_{H,t}(i)^{1-\varepsilon} = P_{H,t}^{1-\varepsilon} C_{H,t}^{\frac{1-\varepsilon}{\varepsilon}} C_{H,t}(i)^{-\frac{1-\varepsilon}{\varepsilon}}$$

$$P_{H,t}(i) = P_{H,t} C_{H,t}^{\frac{1}{\varepsilon}} C_{H,t}(i)^{-\frac{1}{\varepsilon}}$$

$$C_{H,t}(i) = \left[\frac{P_{H,t}(i)}{P_{H,t}} \right]^{-\varepsilon} C_{H,t}$$

By following above described steps, it is straightforward to derive demand equation for $C_{F,t}(i)$ as well.

Household's F.O.Cs.

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\left\{ \frac{(C_t - H_t)^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \right\} + \lambda_t \left[P_t C_t + E_t \{ Q_{t,t+1} D_{t+1} \} - D_t - W_t N_t \right] \right]$$

$$C_t (C_t - H_t)^{-\sigma} = -\lambda_t P_t$$

$$N_t - N_t^\varphi = \lambda_t W_t$$

Merging above expressed two F.O.Cs yields:

$$(C_t - H_t)^{-\sigma} \frac{W_t}{P_t} = N_t^\varphi$$

$$D_{t+1} \beta^t \lambda_t E_t Q_{t,t+1} = \beta^{t+1} \lambda_{t+1}$$

$$1 = \beta \frac{\lambda_{t+1}}{\lambda_t} \frac{1}{Q_{t,t+1}}$$

Substituting λ_t and λ_{t+1} with expression which can be obtained from F.O.C. w.r.t. C_t yields Euler:

$$1 = \beta R_t E_t \left\{ \frac{P_t}{P_{t+1}} \left(\frac{C_{t+1} - H_{t+1}}{C_t - H_t} \right)^{-\sigma} \right\}$$

F.O.C. of the optimizing firm

The optimizing firm maximizes the following problem:

$$\max_{\bar{P}_{H,t}} \sum_{k=0}^{\infty} (\theta_H)^k E_t \left\{ \mathcal{Q}_{t,t+k} Y_{t+k} \left(\bar{P}_{H,t} - MC_{t+k}^n \right) \right\}$$

$$\text{subject to } Y_{t+k} \leq \left(\frac{\bar{P}_{H,t}}{\bar{P}_{H,t+k}} \right)^{-\varepsilon} (C_{H,t+k} + C_{H,t+k}^*)$$

Our Lagrangian can be stated as the following:

$$L = \sum_{k=0}^{\infty} (\theta_H)^k E_t \left\{ \mathcal{Q}_{t,t+k} \left(\frac{\bar{P}_{H,t}}{\bar{P}_{H,t+k}} \right)^{1-\varepsilon} (C_{H,t+k} + C_{H,t+k}^*) - \frac{W_{t+k}}{A_t} \left(\frac{\bar{P}_{H,t}}{\bar{P}_{H,t+k}} \right)^{-\varepsilon} (C_{H,t+k} + C_{H,t+k}^*) \right\}$$

$$\boxed{\bar{P}_{H,t}}$$

$$\sum_{k=0}^{\infty} (\theta_H)^k E_t \left\{ \mathcal{Q}_{t,t+k} (1-e) \left(\frac{\bar{P}_{H,t}}{\bar{P}_{H,t+k}} \right)^{-e} (C_{H,t+k} + C_{H,t+k}^*) + e \frac{W_{t+k}}{A_t} \left(\frac{\bar{P}_{H,t}}{\bar{P}_{H,t+k}} \right)^{-e-1} (C_{H,t+k} + C_{H,t+k}^*) \right\} = 0$$

$$\sum_{k=0}^{\infty} (\theta_H)^k E_t \left\{ \mathcal{Q}_{t,t+k} (1-\varepsilon) Y_{t+k} + \varepsilon \frac{Y_{t+k} W_{t+k}}{A_t \bar{P}_{H,t}} \right\} = 0$$

$$\sum_{k=0}^{\infty} (\theta_H)^k E_t \left\{ \mathcal{Q}_{t,t+k} Y_{t+k} \left(\bar{P}_{H,t} - \frac{\varepsilon}{\varepsilon-1} MC_{t+k}^n \right) \right\} = 0$$

Tables

Table1 :Business Cycle Facts for Turkey and US (proxy of the ROW)
standard deviation, HP-filtered data

Turkey	entire sample (1987Q1-2009Q4)	exch. rate targ. (1987Q1-2001Q1)	infl. rate targ. (2001Q2-2009Q4)
output	3.84	3.53	4.28
nominal interest rate	21.50	27.08	5.26
terms of trade	3.77	4.46	2.28
real xchange rate	8.85	8.78	8.82
domestic inflation	34.69	43.82	7.51
imported inflation	3.99	3.34	4.92
ROW			
output	1.06	1.15	0.99
real interest rate	1.18	1.08	1.31

Table2 :Business Cycle Facts for Turkey and US (proxy of the ROW)
corr with output, HP-filtered data

Turkey	entire sample (1987Q1-2009Q4)	Turkey-exch. rate targ. (1987Q1-2001Q1)	Turkey-infl. rate targ. (2001Q2- 2009Q4)
output	1.00	1.00	1.00
nominal interest rate	-0.21	-0.26	-0.27
terms of trade	-0.39	-0.49	-0.26
real exchange rate	0.62	0.59	0.64
domestic inflation	-0.16	-0.17	-0.041
imported inflation ROW	0.14	-0.37	0.60
output	1.00	1.00	1.00
real interest rate	0.68	0.63	0.73
correlations (Turkish with the ROW)			
	entire sample	exc. rate targ. reg	Inf. rate targ. reg.
output	0.31	-0.05	0.71
real interes trate	0.17	-0.16	0.50

Table 3: Structural Parameters, Prior and Posterior Distributions-Exchange rate targeting

Parameter		domain	density	Prior Distribution		Maximized Posterior		Bayesian Estimation	
				mean	st.err.	mode	st.err.	mean	st.dev.
Habit. param.	h	$[0,1)$	<i>Beta</i>	0.7	0.20	0.70	0.02	0.87	0.84
Cons. utility	σ	\mathbf{R}^+	<i>Normal</i>	1.00	0.25	1.00	0.00	0.91	0.90
Elast.of sub.	η	\mathbf{R}^+	<i>Gamma</i>	1.00	0.30	1.00	0.00	1.04	1.03
Labor utility	φ	\mathbf{R}^+	<i>Gamma</i>	1.00	0.30	1.00	0.00	0.99	0.98
Calvo prices	θ_H	$[0,1)$	<i>Beta</i>	0.50	0.25	0.50	0.00	0.49	0.49
Calvo prices *	θ_F	$[0,1)$	<i>Beta</i>	0.50	0.25	0.50	0.00	0.49	0.49
Taylor rule	φ_1	\mathbf{R}^+	<i>Gamma</i>	1.50	0.25	1.50	0.00	1.49	1.49
Taylor rule	φ_2	\mathbf{R}^+	<i>Gamma</i>	0.25	0.10	0.25	0.00	0.25	0.25
Taylor rule	φ_3	\mathbf{R}^+	<i>Gamma</i>	2.00	1.10	2.00	0.00	2.00	2.00
Taylor rule	ρ_r	$[0,1)$	<i>Beta</i>	0.50	0.20	0.50	0.00	0.50	0.50
persist. param.	ρ_{r^*}	$[0,1)$	<i>Beta</i>	0.50	0.20	0.50	0.19	0.36	0.00
persist. param.	ρ_a	$[0,1)$	<i>Beta</i>	0.50	0.20	0.50	0.00	0.49	0.49
persist. param.	λ_1	$[0,1)$	<i>Beta</i>	0.50	0.20	0.50	0.01	0.56	0.47

Table 4: Shocks, Prior and Posterior Distributions - Exchange rate targeting regime

Shocks		domain	density	Prior	st.err.	Maximized		Bayesian	
				Distribution mean		Posterior	st.err.	Estimation mean	st.dev.
Technology	ν^a	\mathbf{R}^+	<i>InvGamma</i>	2	∞	2.00	0.04	1.77	1.76
Foreign output	ν^{y^*}	\mathbf{R}^+	<i>InvGamma</i>	2	∞	2.00	1.45	6.42	1.57
Foreign real interest	ν^{r^*}	\mathbf{R}^+	<i>InvGamma</i>	2	∞	2.00	0.31	1.18	0.89
Domestic inflation	$\nu^{\pi_{H,t}}$	\mathbf{R}^+	<i>InvGamma</i>	2	∞	2.00	0.01	2.03	2.03
Imported inflation	$\nu^{\pi_{F,t}}$	\mathbf{R}^+	<i>InvGamma</i>	2	∞	2.00	0.65	1.14	0.34
Nominal interest rate	ν^r	\mathbf{R}^+	<i>InvGamma</i>	2	∞	2.00	0.01	2.05	2.01
Real exchange rate	ν^q	\mathbf{R}^+	<i>InvGamma</i>	2	∞	2.00	0.01	2.00	1.99
Terms of trade	ν^s	\mathbf{R}^+	<i>InvGamma</i>	2	∞	2.00	0.99	1.69	2.05

Table 5: Structural Parameters, Prior and Posterior Distributions-Inflation targeting regime

Parameter		domain	density	Prior Distribution		Maximized Posterior		Bayesian Estimation	
				mean	st.err.	mode	st.err.	mean	st.dev.
Habit. param.	h	$[0,1)$	<i>Beta</i>	0.7	0.20	0.77	0.19	0.99	0.99
Cons. utility	σ	\mathbf{R}^+	<i>Normal</i>	1.00	0.25	0.99	0.08	0.99	0.79
Elast.of sub.	η	\mathbf{R}^+	<i>Gamma</i>	1.00	0.30	0.97	0.50	0.93	1.11
Labor utility	φ	\mathbf{R}^+	<i>Gamma</i>	1.00	0.30	0.98	0.79	1.61	1.66
Calvo prices	θ_H	$[0,1)$	<i>Beta</i>	0.50	0.25	0.73	0.13	0.74	0.73
Calvo prices *	θ_F	$[0,1)$	<i>Beta</i>	0.50	0.25	0.51	0.01	0.51	0.51
Taylor rule	φ_1	\mathbf{R}^+	<i>Gamma</i>	1.50	0.25	1.71	0.40	1.82	1.82
Taylor rule	φ_2	\mathbf{R}^+	<i>Gamma</i>	0.25	0.10	0.16	0.13	0.30	0.29
Taylor rule	ρ_r	$[0,1)$	<i>Beta</i>	0.50	0.20	0.18	0.00	0.18	0.18
persist. param.	ρ_{r^*}	$[0,1)$	<i>Beta</i>	0.50	0.20	0.49	0.04	0.49	0.51
persist. param.	ρ_a	$[0,1)$	<i>Beta</i>	0.50	0.20	0.83	0.00	0.83	0.83
persist. param.	λ_1	$[0,1)$	<i>Beta</i>	0.50	0.20	0.50	0.13	0.38	0.34

Table 6: Shocks, Prior and Posterior Distributions-Inflation targeting regime

Shocks		domain	density	Prior Distribution		Maximized Posterior		Bayesian Estimation	
				mean	st.err.	mode	st.err.	mean	st.dev.
Technology	ν^a	\mathbf{R}^+	<i>InvGamma</i>	2	∞	2.03	1.23	1.99	1.75
Foreign output	ν^{y^*}	\mathbf{R}^+	<i>InvGamma</i>	2	∞	2.00	1.87	0.28	0.24
Foreign real interest rate	ν^{r^*}	\mathbf{R}^+	<i>InvGamma</i>	2	∞	2.00	0.27	2.11	1.92
Domestic inflation	$\nu^{\pi_{H,t}}$	\mathbf{R}^+	<i>InvGamma</i>	2	∞	2.04	2.26	2.43	2.93
Imported inflation	$\nu^{\pi_{F,t}}$	\mathbf{R}^+	<i>InvGamma</i>	2	∞	2.00	71.26	1.24	1.09
Nominal interest rate	ν^r	\mathbf{R}^+	<i>InvGamma</i>	2	∞	1.98	0.19	2.30	1.94
Real exchange rate	ν^q	\mathbf{R}^+	<i>InvGamma</i>	2	∞	2.00	0.08	2.35	2.50
Terms of trade	ν^s	\mathbf{R}^+	<i>InvGamma</i>	2	∞	2.00	0.45	0.44	0.40

Table7: Variance Decomposition (in percent)-Exchange rate targeting

	<i>nu_a</i>	<i>nu_tot</i>	<i>nu_q</i>	<i>nu_pih</i>	<i>nu_pif</i>	<i>nu_r</i>	<i>nu_rst</i>	<i>nu_yst</i>
<i>a</i>	100	0	0	0	0	0	0	0
<i>c</i>	4.33	0.12	13.12	1.28	3.42	47.81	28.5	16.79
<i>del_nom</i>	1.44	0.21	9.31	1.11	1.84	25.74	57.86	24.27
<i>mc</i>	2.67	0.13	9.37	5.44	0.79	49.35	19.61	13.91
<i>pif</i>	0.4	7.15	17.43	0.73	27.94	7.47	39.01	24.76
<i>pih</i>	1.65	0.25	8.88	1.78	1.43	53.37	28.84	20.28
<i>pit</i>	1.52	0.03	5.43	1.17	0.81	52.35	34.48	25.15
<i>psi_t</i>	0.15	8.07	25.72	0.14	51.31	2.03	12.11	3.88
<i>q</i>	0.94	0.08	19.03	0.64	1.16	47.62	29.48	14.17
<i>r</i>	0.96	0.14	6.23	0.74	1.23	17.22	71.77	49.34
<i>rst</i>	0	0	0	0	0	0	100	0
<i>tot</i>	0.95	0.63	13.98	0.63	5.65	47.9	29.32	16.56
<i>y</i>	4.53	0.71	17.13	2.13	2.7	42.96	27.4	12.54
<i>y_st</i>	0	0	0	0	0	0	0	0

Table8: Variance Decomposition (in percent)-inflation rate targeting

	<i>nu_a</i>	<i>nu_tot</i>	<i>nu_q</i>	<i>nu_pih</i>	<i>nu_pif</i>	<i>nu_r</i>	<i>nu_rst</i>	<i>nu_yst</i>
<i>a</i>	100	0	0	0	0	0	0	0
<i>c</i>	0.51	0.01	18.78	0.14	0.45	41.23	38.11	0.78
<i>mc</i>	0.02	0.01	18.49	0.34	0.26	42.86	35.58	2.45
<i>pif</i>	0.01	1.61	13.67	0.01	6.14	40.51	37.87	0.17
<i>pih</i>	0.06	0.05	13.64	0.08	0.26	42.98	37.70	1.24
<i>pit</i>	0.05	0	15.76	0.08	0.01	44.01	38.90	1.18
<i>psi_t</i>	0.03	3.45	31.11	0.02	22.86	22.94	18.64	0.95
<i>q</i>	0.11	0	23.81	0.05	0	38.65	36.85	0.52
<i>r</i>	0.02	0.01	17.27	0.01	0.02	26.70	55.36	0.62
<i>rst</i>	0	0	0	0	0	0	100	0
<i>tot</i>	0.11	0.18	19.17	0.05	1.16	40.32	38.63	0.38
<i>y</i>	4.83	0.35	22.25	1.59	0.54	34.69	34.77	0.98
<i>yst</i>	0	0	0	0	0	0	0	100

Figure.

Figure 1: Business cycles of the observed variables

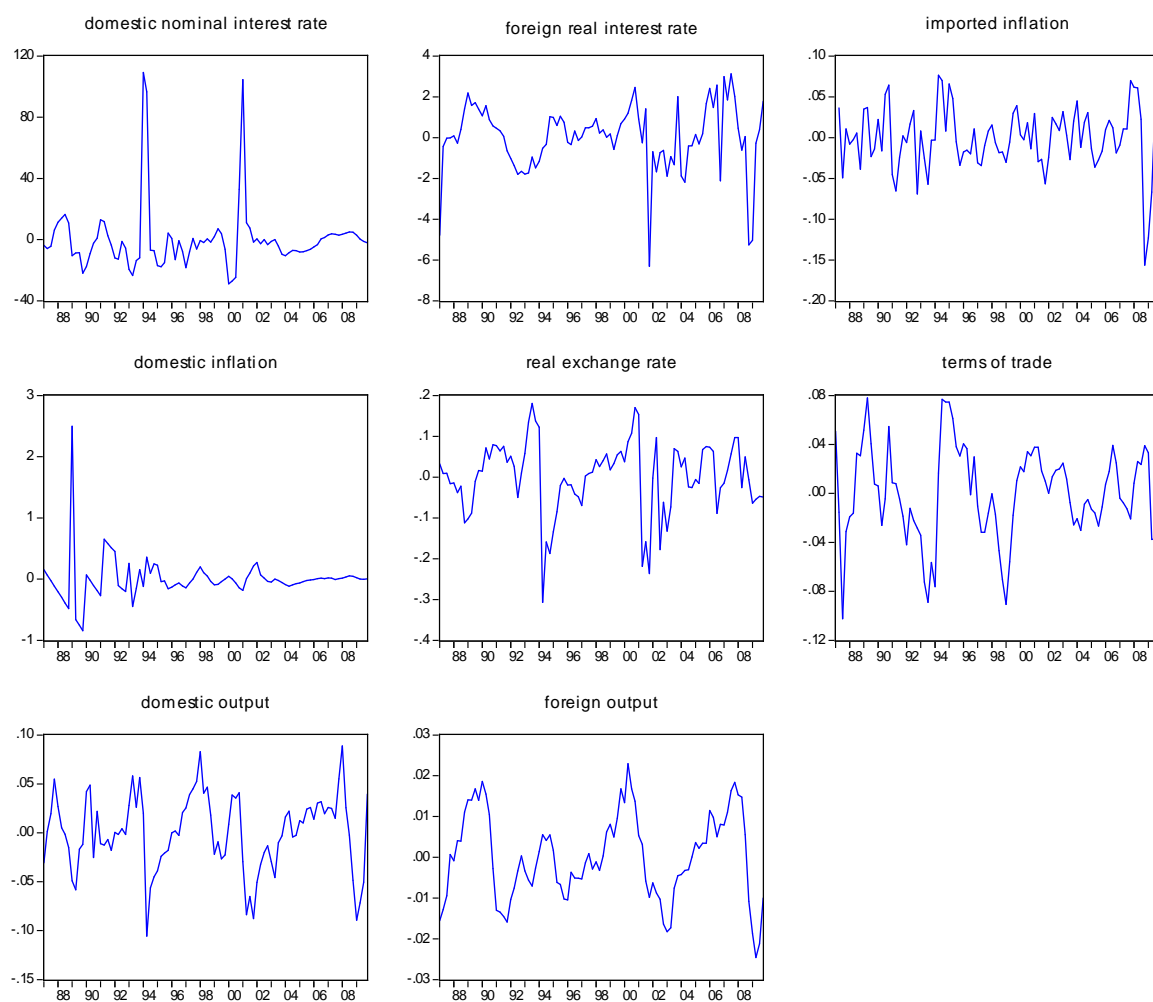


Figure 2: Priors and posteriors of the exchange rate targeting regime

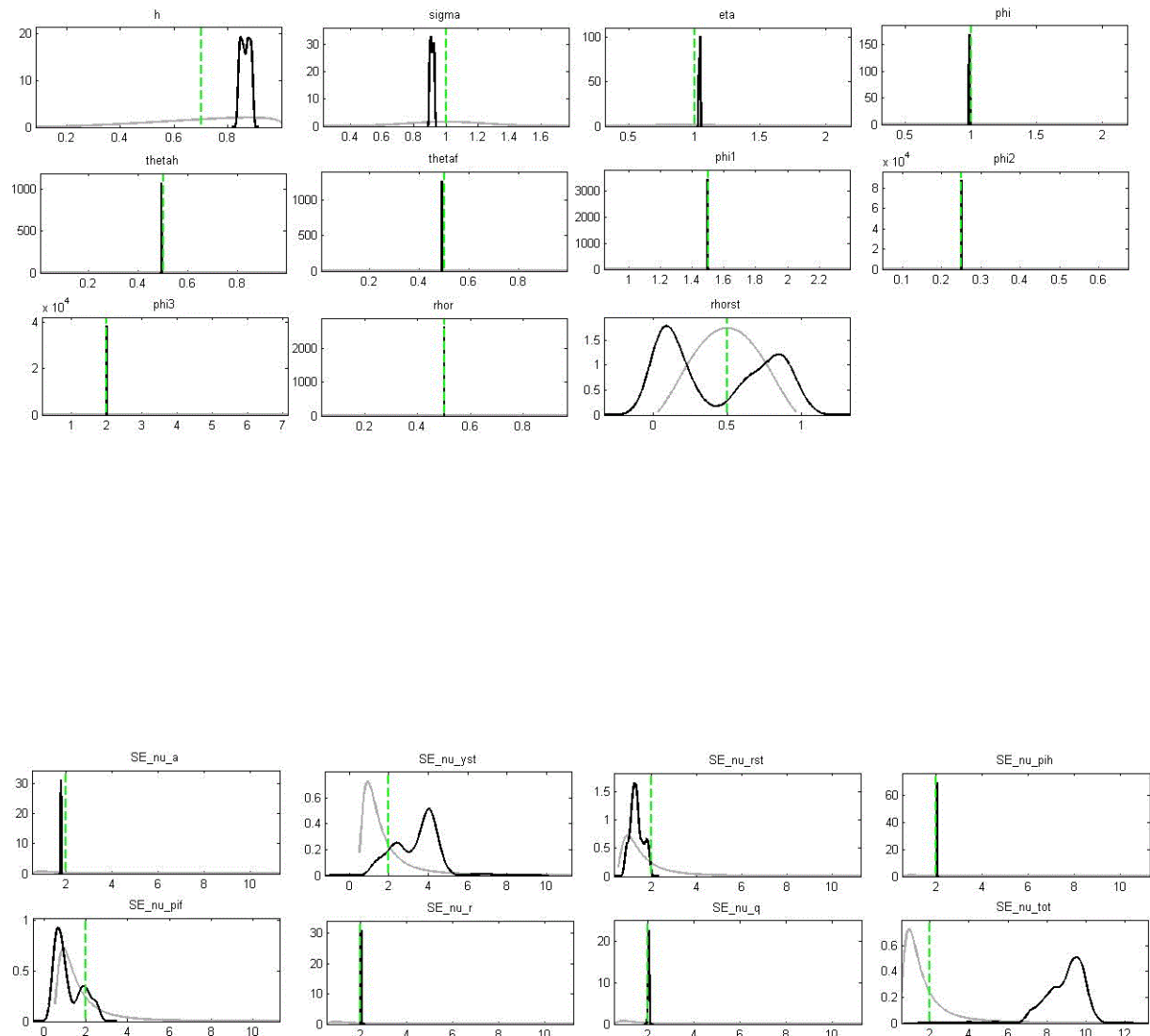


Figure 3: Priors and posteriors of the inflation targeting regime

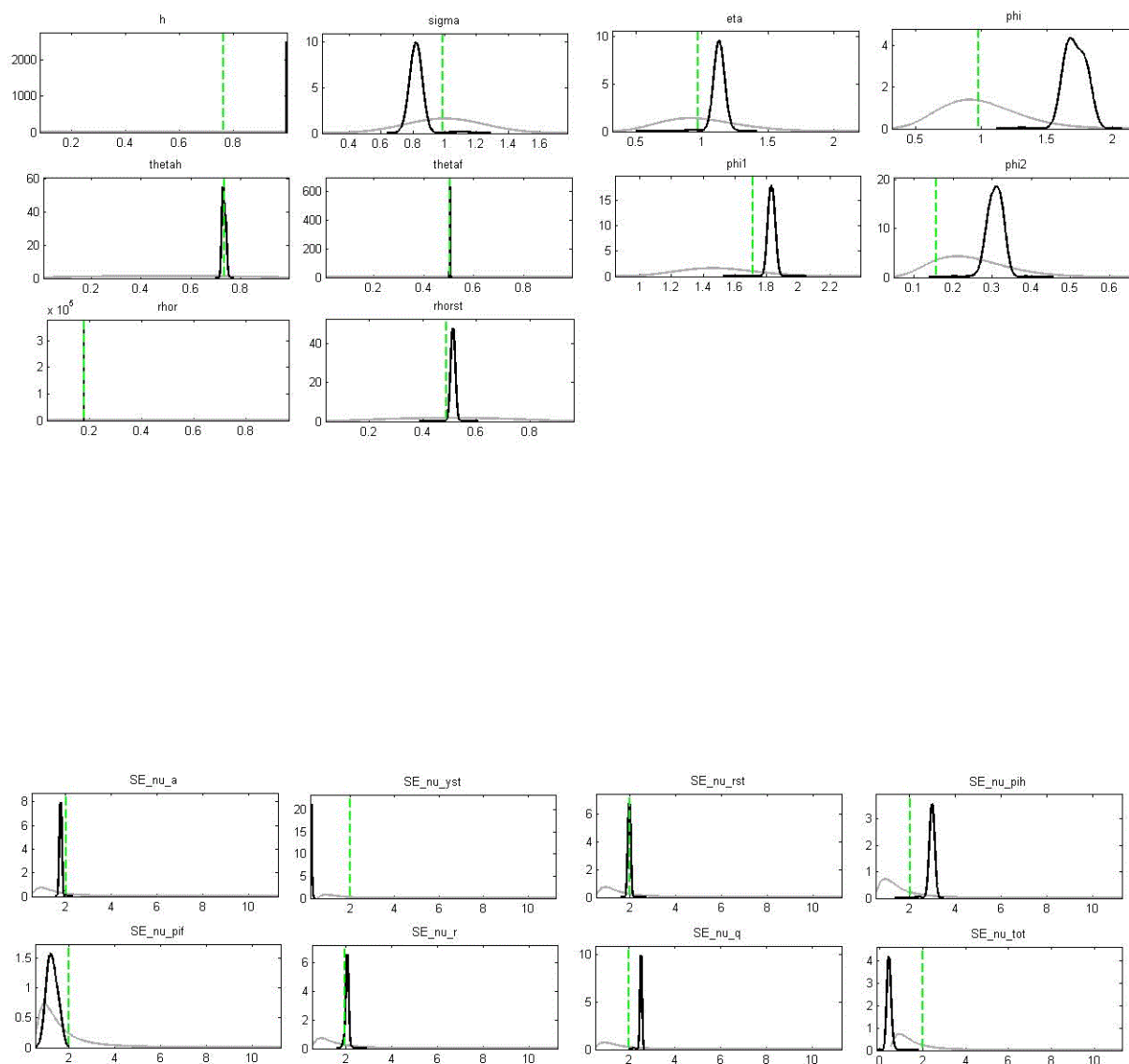


Figure 4: Impulse responses to the technology shock

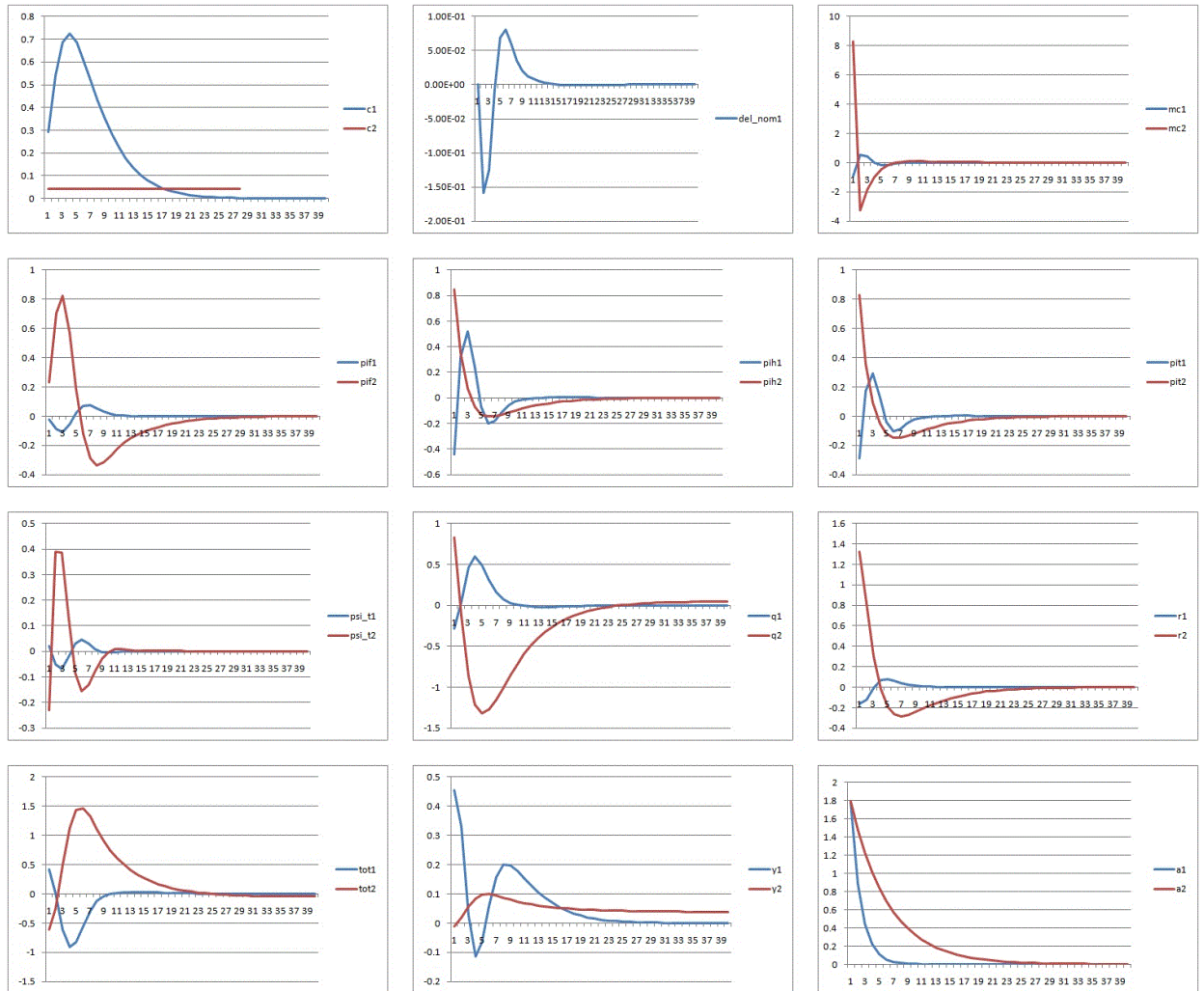


Figure 5: Impulse responses to the terms of trade shock

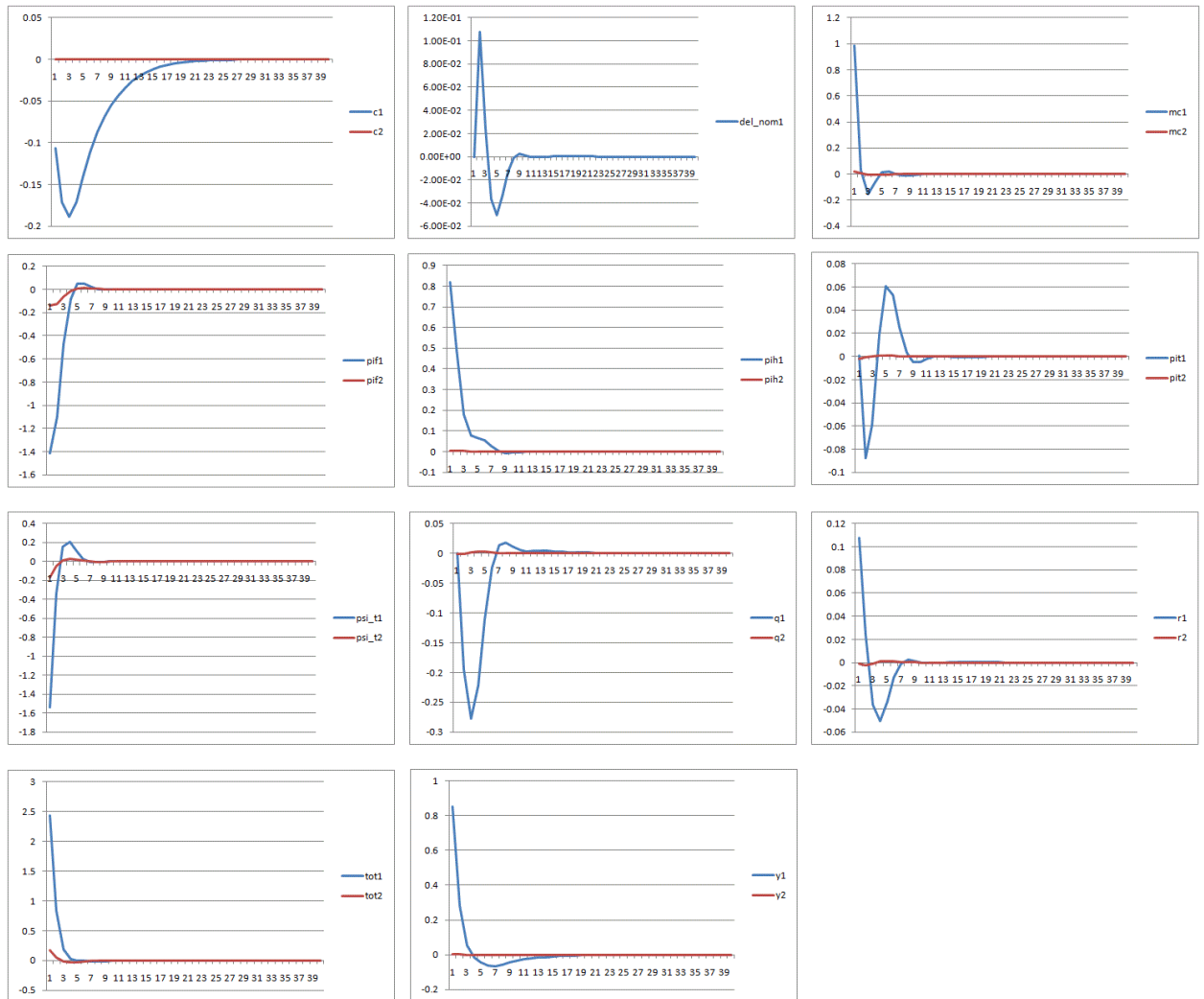


Figure 6: Impulse responses to the real exchange rate shock

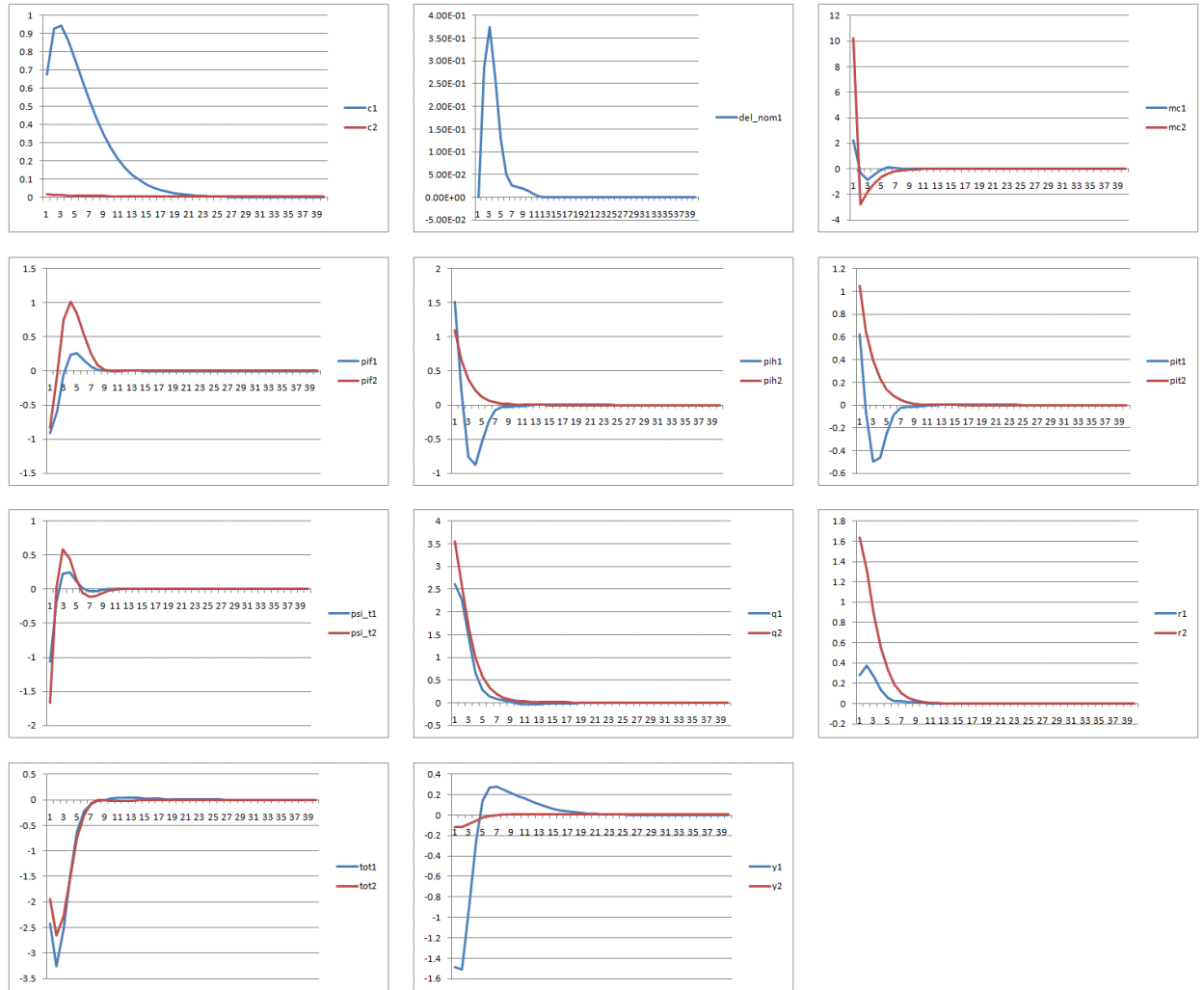


Figure 7: Impulse responses to the domestic inflation shock

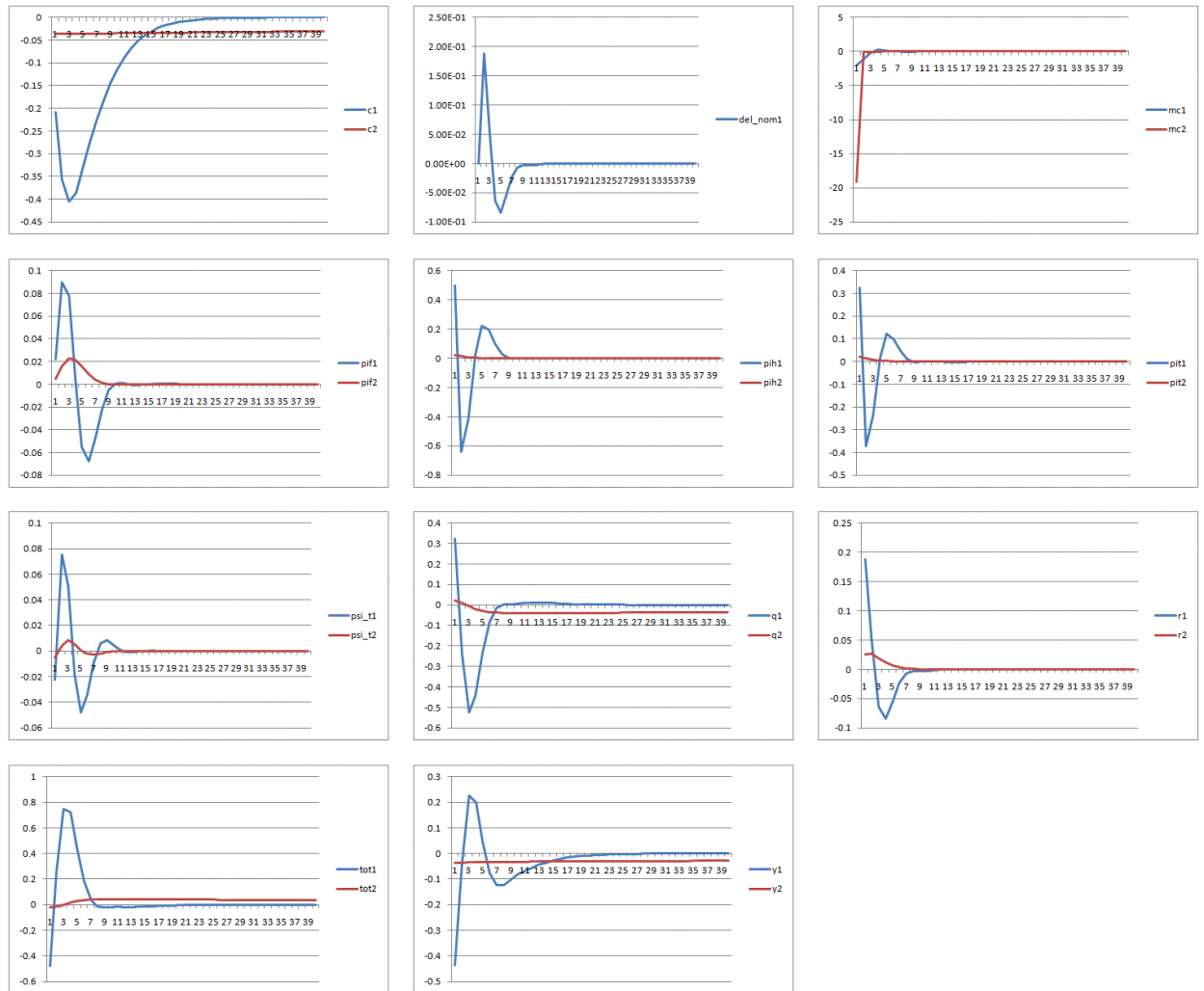


Figure 8: Impulse responses of the imported inflation shock

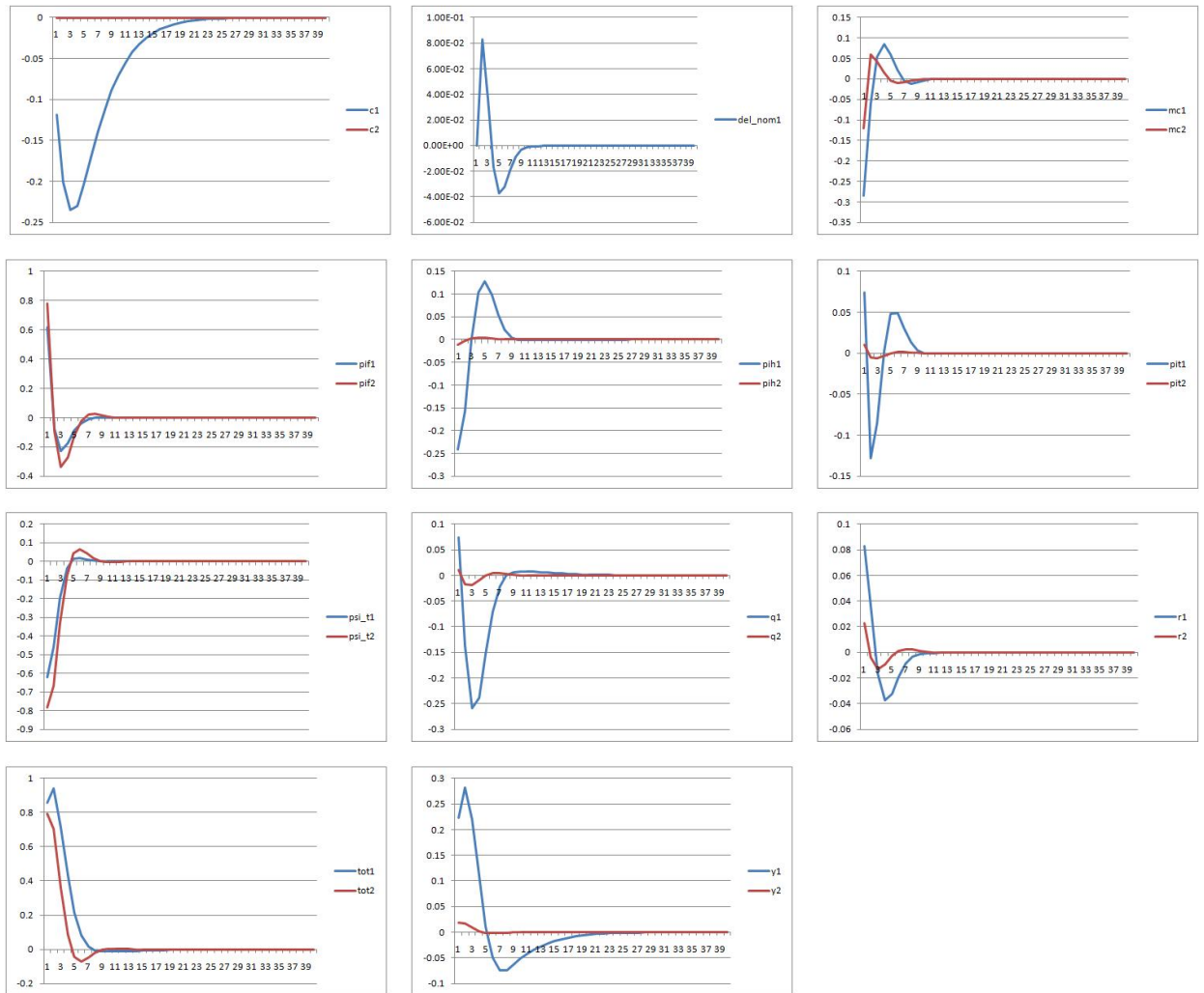


Figure 9: impulse responses to the nominal interest rate shock

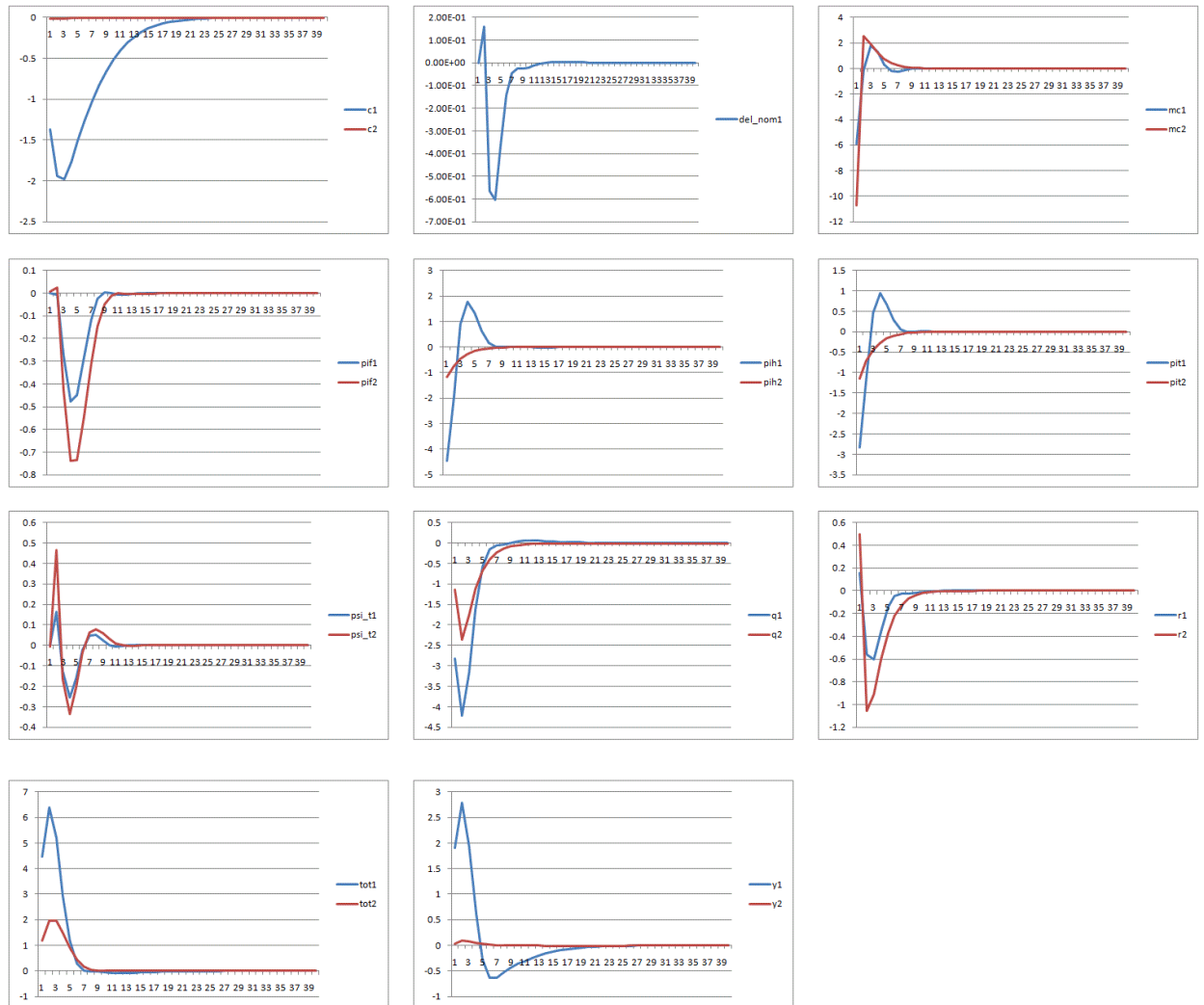


Figure 10: Impulse responses to the foreign real interest rate shock

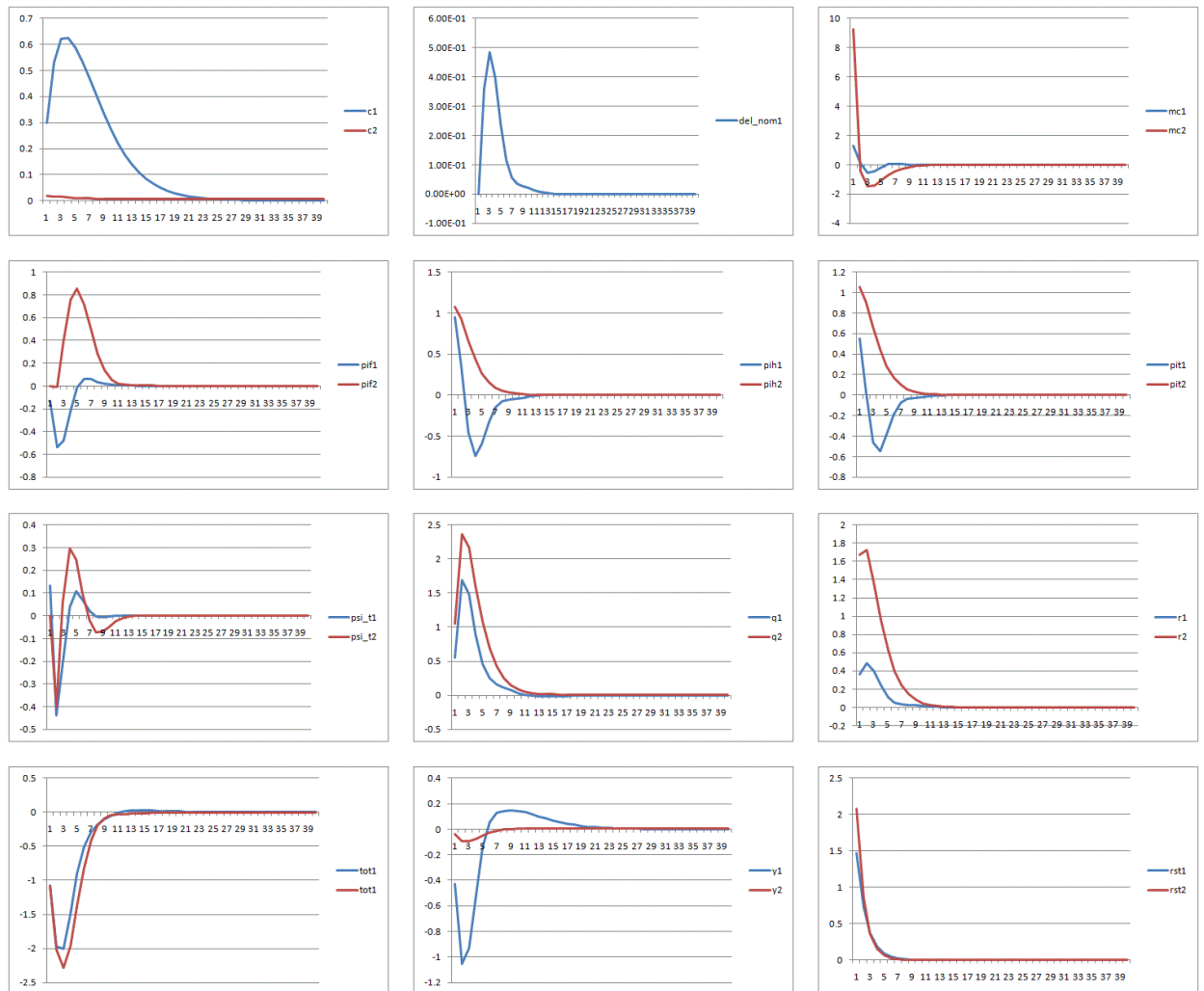
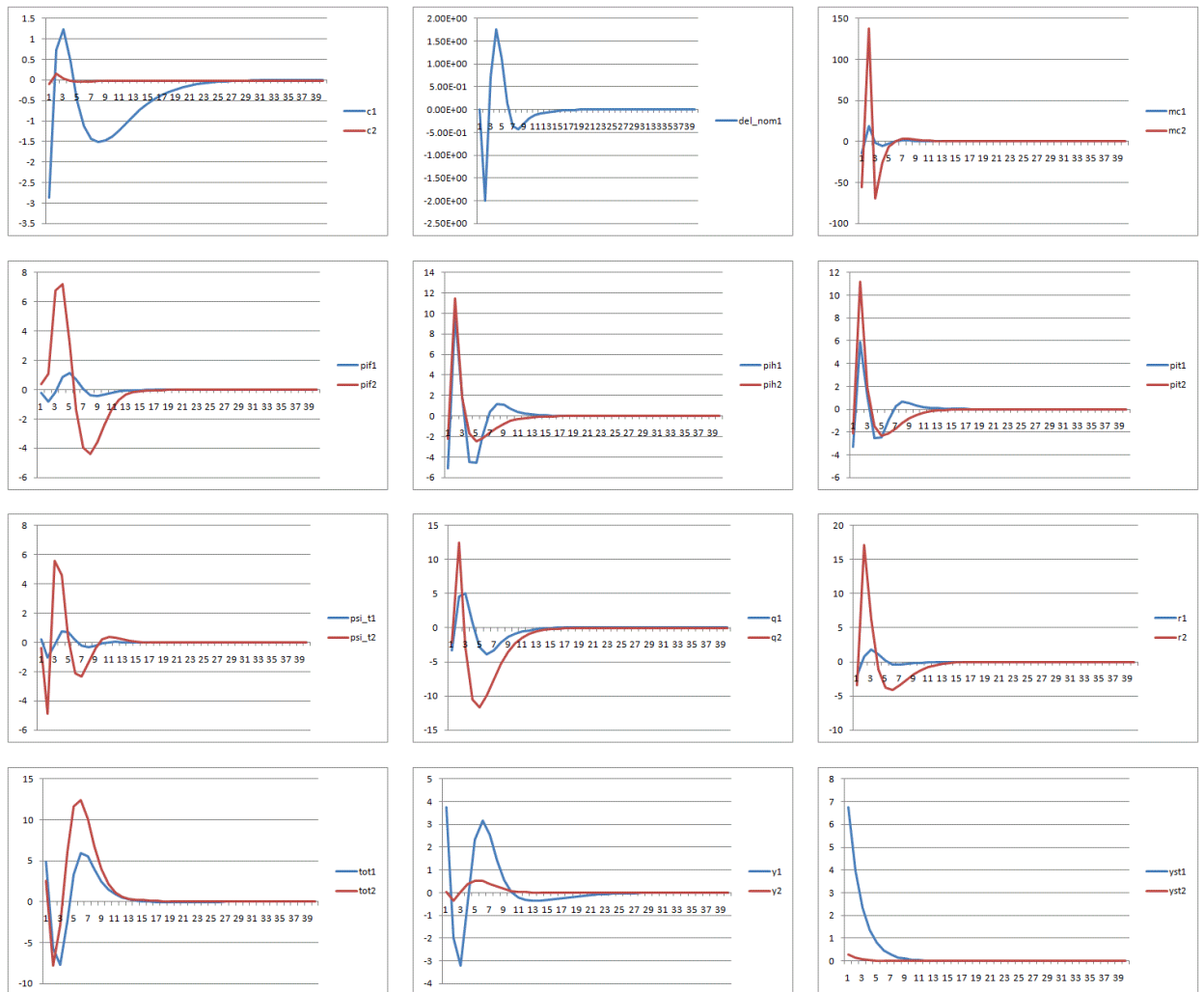


Figure 11: Impulse responses to the foreign output shock



Appendix B

Data Description

- Domestic output (y_t) is the quarterly GDP per capita of Turkey.
- Overall domestic inflation or CPI inflation (π_t) is annual growth rates in the CPI of Turkey.
- Imported inflation ($\pi_{F,t}$) is annual growth rates in the unit value of import index of Turkey.
- Real exchange rate (q_t) is the CPI based real effective exchange rate of Turkey.
- Nominal interest rate (r_t) is the short term money market rate of Turkey.
- Terms of trade (s_t) is the ratio of the unit value of import index and the unit value of export index of Turkey.
- Foreign output (y_t^*) is the annual growth rate of in US real GDP per capita.
- Foreign real interest rate ($\bar{r}_t^* = r_t^* - \pi_t^*$) is real interest rate of US.

The linearized model

1. LOP gap:

$$\psi_t = -[q_t + (1 - \alpha)s_t]$$

2. TOT with the shock:

$$\Delta s_t = \pi_{F,t} - \pi_{H,t} + v_t^s$$

3. Uncovered interest parity condition with a risk premium shock:

$$E_t \Delta q_{t+1} = -(r_t - \pi_{t+1}) - (r_t^* - \pi_{t+1}^*) + v_t^q$$

4. Domestic inflation with the shock:

$$\pi_{H,t} = \beta(1 - \theta_H)E_t \pi_{H,t+1} + \theta_H \pi_{H,t-1} + \lambda_H mc_t + v_t^{\pi_H}$$

5. Import inflation with the shock:

$$\pi_{F,t} = \beta(1 - \theta_F)E_t \pi_{F,t+1} + \theta_F \pi_{F,t-1} + \lambda_F \psi_t + v_t^{\pi_F}$$

6. Overall inflation or CPI inflation:

$$\pi_t = (1-\alpha)\pi_{H,t} + \alpha\pi_{F,t}$$

7. Marginal cost of a firm:

$$\frac{\sigma}{1-h}(c_t - hc_{t-1}) + \varphi y_t + \alpha s_t - (1+\varphi)a_t$$

8. Euler equation:

$$c_t - hc_{t-1} = E_t(c_{t+1} - hc_t) - \frac{1-h}{\sigma}(r_t - E_t\pi_{t+1})$$

9. International risk sharing condition:

$$c_t - hc_{t-1} = (y_t^* - hy_{t-1}^*) - \frac{1-h}{\sigma}q_t$$

10. Goods market clearing condition:

$$y_t = (1-\alpha)c_t + \alpha c_t^* + (2-\alpha)\alpha\eta s_t + \alpha\eta\psi_t$$

11. Monetary policy reaction functions:

For the exchange rate targeting regime

$$r_t = \rho_r r_{t-1} + (1-\rho_r)[\phi_1\pi_t + \phi_2\Delta y_t + \phi_3\Delta e_t] + v_t^r$$

For the inflation rate targeting regime:

$$r_t = \rho_r r_{t-1} + (1-\rho_r)[\phi_1\pi_t + \phi_2\Delta y_t] + v_t^r$$

12. Change in the nominal exchange rate:

$$r_{t-1} - r_{t-1}^* = E_t\Delta e_t$$

13. Exogenous processes:

$$y_t^* = \lambda_1 y_{t-1}^* + v_t^{y^*}$$

$$r_t^* - E_t \pi_{t+1}^* = \rho_{r^*} (r_{t-1}^* - \pi_t^*) + v_t^{r^*}$$

$$a_t = \rho_a a_{t-1} + v_t^a$$