Role of Investment Shocks in Explaining Business Cycles in Turkey

February 2013

Canan YÜKSEL
ROLE OF INVESTMENT SHOCKS IN EXPLAINING BUSINESS CYCLES IN TURKEY*

Canan Yüksel*

February 2013

Abstract

This paper aims to understand the role of investment shocks in explaining output fluctuations observed in Turkish economy. For this purpose a small open economy DSGE model is estimated on Turkish data for 2002:1-2012:2 period by Bayesian methods. Variance decomposition analysis shows that permanent technology shock is the key driving force of business cycles in Turkish economy and the role of investment shock is less spelled.

JEL Classification Numbers: E3; F4; C11.
Keywords: Open economy, Bayesian estimation, Business cycle.

*The views expressed herein are those of the author and do not necessarily represent the official views of the Central Bank of the Republic of Turkey.

Research and Monetary Policy Department, Central Bank of Turkey. Email: canan.yuksel@tcmb.gov.tr.
I thank Harun Alp, Mustafa Kılınç, Hande Küçük and Ebru Voyvoda, as well as the referee and the editor for their valuable comments and suggestions. I also thank seminar participants at 3rd International Conference of Turkish Economic Association.
1. Introduction

Explaining business cycles has been central in the public and academic debates for long periods as it is crucial to understand the cyclical patterns for both market participants and policy makers.

The question of business cycle analysis is approached both by empirical and theoretical methods. Following the developments on theory and estimation techniques of the New Keynesian models, a new literature that examines business cycles from a structural perspective has emerged. This approach involves estimation of Dynamic Stochastic General Equilibrium (DSGE) models by Bayesian techniques, focusing on the historical and variance decomposition of main macroeconomic variables to figure out the sources of business cycles. Leading examples of this line of research include Smets and Wouters (2003), Justiniano et al., (2010) and Adolfson et al., (2007) among others.

By using a similar methodology this paper aims to identify the role of investment shock in generating output fluctuations in Turkish economy, whose contribution to macroeconomic fluctuations has been found to be significant for developed economies. Investment shocks turned to be an important candidate to explain macroeconomic fluctuations following the seminal work of Justiniano et al. (2010), which shows that a shock to the marginal efficiency of investment\(^1\) (MEI) is the key driver of business cycles in the U.S. Prior to this study, contribution of investment shocks was found to be non-negligible, but less important whereas permanent technology shocks and mark-up shocks have been the most pronounced disturbances in explaining business cycles (Smets and Wouters, 2003 and 2007; Adolfson et al., 2007). Especially for developing economies, permanent technology shock has been proposed to be the key driving force of macroeconomic fluctuations (Aguiar and Gopinath, 2007, Medina and Soto, 2007 and Alp and Elekdag, 2011).

I try to answer what role investment shock plays in generating business cycles in Turkish economy compared to stationary and unit-root technology shocks, which have been found to be key sources of business cycles in emerging market economies. To this end, I develop a medium-scale open economy DSGE model for Turkish economy and estimate it on quarterly data using Bayesian method. The structural model used in this paper is framed in the New

\(^1\) This shock affects the yield of a foregone unit of consumption in terms of future capital input. The literature often refers to this shock as investment specific technology shock, since the shock is equivalent to a productivity shock specific to the capital goods producing sector in a simple two-sector economy (Greenwood et al. 1997). Throughout the paper I use the terms “MEI shock” and “investment shock” interchangeably.
Keynesian tradition following the framework set by Smets and Wouters (2003, 2007). The model contains a number of nominal and real frictions such as sticky prices, sticky wages, variable capital utilization, investment adjustment costs and habit persistence. The open economy features are in line with Adolfson et al. (2007). The model is buffeted by thirteen orthogonal shocks, including permanent and stationary shocks to total factor productivity and an investment shock. Using data on thirteen macroeconomic variables including output, inflation, interest rate, the real exchange rate, imports, exports and foreign economy variables for 2002:1-2012:2 period, key model parameters are estimated\(^2\). The estimated model is then used to address a number of key business cycle issues such as computing variance decomposition of the observed variables.

The main contribution of this paper is to provide an analysis of Turkish business cycles through the lens of a DSGE model and examine the contribution of investment shock in the observed output fluctuations in Turkish economy. Moreover this paper addresses a relevant question in the literature on the relative importance of technology shocks in generating business cycles, by incorporating stationary and unit root technology shocks and an investment specific technology shock into the model.

The estimation results and variance decomposition analyses show that unit-root and stationary technology shocks and investment shock account for a large share of output fluctuations in Turkish economy in the last ten years. In particular, the unit root technology shock seems to be the most important source of variation and the role of investment shock is less spelled. Such an outcome echoes the results of Aguiar and Gopinath (2007) which concludes that this kind of trend shock is an important determinant of business cycle fluctuations across emerging markets.

The remainder of the paper is organized as follows. Section 2 presents a quick review of the literature on investment shocks. Section 3 describes the theoretical model. Section 4 presents a short description of the data and the calibrated parameters along with the prior distributions for the estimated parameters. Then, it compares the empirical properties of the estimated DSGE model with the actual data to validate the model fit and reports the estimation results. Section 5 discusses the role of various shocks in explaining business cycles. Finally, Section 6 concludes.

---

\(^2\) The estimation period starts at 2002 when a set of structural reforms along with inflation targeting started in Turkey.
2. Literature on Investment Shocks

This section gives a brief review of the literature that discusses the role of shocks to marginal efficiency of investment (MEI) in macroeconomic fluctuations.

The MEI shock is either introduced as a shock to investment cost function as shown in (2.1) (Smets and Wouters, 2003) or as a source of exogenous variation in the efficiency with which the final good is transformed into physical capital as shown in (2.2) (JPT, 2010 and 2011). In the latter specification, MEI shock affects the yield of a foregone unit of consumption in terms of next period’s capital input.

\[ K_{t+1} = (1 - \delta)K_t + I_t[1 - S(Y_t/L_t/L_{t-1})] \]  
\[ \dot{K}_t = (1 - \delta)K_t + I_tY_t[1 - S(L_t/L_{t-1})] \]

Until late 1990’s, investment shocks have been considered as unlikely candidates to generate business cycles in standard neoclassical environments, because they fail to generate the co-movement of key macroeconomic variables. Consider a case where a positive shock to the MEI hits the economy leading to an increase in the rate of return on existing capital. This leads households to save more, consume less, but also to work harder. Since capital remains fixed in the short run, labor productivity and real wage are expected to fall. Hence a positive MEI shock creates a situation where working hours and output rise but consumption falls, which is not a recognizable business cycle fact. This premise can be understood better from the efficiency condition which has to hold in a frictionless closed economy:

\[ MRS(C, L) = MPL(L) \]

Note that marginal rate of substitution (MRS) between consumption and hours depends positively on its arguments, whereas marginal product of labor (MPL) is decreasing in hours worked. As Barro and King (1984) points out, any shock that rises hours, without shifting the marginal product of labor, leads the right hand side (RHS) of (2.3) to fall. For condition (2.3) to hold at the new equilibrium, consumption should be falling so that the left hand side (LHS) of (2.3) falls down as well. Indeed, this is the way how investment shock transmits into the economy and creates an opposite movement in consumption and hours. Therefore the earlier literature did not give much credit to MEI shocks as a driving force of business cycles.

Greenwood et al. (1988) was the first to suggest investment shocks as a viable alternative to neutral technology shocks in a general equilibrium framework. This paper investigated the role
of investment-specific technological change in generating postwar U.S. growth. In their model, there are two types of capital one of whose evolution is subject to a specific technology change. This paper concluded that investment specific technology (IST) change accounts for the major part of growth in the post-war U.S. In a later study Greenwood et al. (2000) strengthens the previous conclusion by showing that this form of technological change can explain about 30 percent of postwar U.S. output fluctuations. In another study examining U.S. economy by a structural VAR analysis, Fisher (2006) shows that investment shocks have a prominent role in business cycles and changes in the relative price of investment accounts for a large part of the fluctuations in output and hours. These studies were motivated by the observed fall in price of investment relative to consumption in the post-war U.S. and assume that the production of capital goods becomes increasingly efficient with the passage of time. They identified investment disturbances with the trend fall in relative price of investment.

With the increasing feasibility and popularity of Bayesian methods in macroeconomic analysis, the importance of investment shocks for business cycles is also analyzed by Bayesian estimation of DSGE models. Justiniano, Primiceri and Tambalotti (JPT) (2010, 2011) address this issue in a New Neoclassical Synthesis model of the US economy. They treat the investment shock as an unobservable process and identify it through its dynamic effects on the variables included in the estimation. They find that MEI shock, which determines the efficiency of newly produced investment goods, is the key driver of U.S. business cycles explaining more than 50 percent of the observed volatility in output. On contrary to the aforementioned problems related to MEI shocks in generating co-movement of key macroeconomic series, this paper shows that consumption, hours and output move in the same direction as a response to MEI shock. This finding owes to the newly introduced channels, which were absent in a standard neoclassical model. JPT (2010) highlights that the existence of nominal and real rigidities along with endogenous capital utilization and internal habit formation (in consumption) operate to make the transmission of investment shocks more conformable with the typical pattern of business cycles. These three features of the model break the equilibrium condition (2.3) and help generating movement of the main macroeconomic variables in same direction. First, internal habit formation limits the adjustments in consumption in response to a MEI shock and consumption becomes less likely to fall when a positive shock hits the economy. On the other hand, endogenous capital utilization works through MPL. In response to a positive MEI shock, utilization of existing
capital increases as new investment becomes more efficient. Higher capital utilization, in turn, implies an increase in the marginal product of labor affecting the RHS of (2.3). In addition, price and wage stickiness create a wedge between MPL and MRS such that equilibrium condition becomes:

$$\omega(L)MRS(C, L) = MPL(L)$$

(2.4)

In (2.4), $\omega(L)$ can be treated as the sum of price and wage mark-up. When this wedge is countercyclical, i.e. $\omega(L)$ is decreasing in hours, one can observe a rise in both consumption and hours in response to a positive MEI shock since the required fall in LHS now takes place through $\omega(L)$. JPT (2010) points that the existence of price and wage rigidities is the main channel that leads MEI shock to be the most important driving force of business cycles and concludes that the role of MEI shocks becomes negligible in a flexible price and wage economy.

The ultimate origin of MEI shocks is another debated issue in the literature. JPT (2011) points out that MEI shock can be treated as a proxy for the effectiveness of financial intermediation in channeling household savings into productive capital. This is based on the fact that transformation of investment goods into productive capital is closely related to financial conditions and access to credit plays an important role in this process. For instance JPT (2011) shows that the estimated series of MEI shock displays a strong negative relation with a spread measure (i.e. the spread between high-yield and AAA corporate bonds). Although absent in JPT (2010, 2011) and, also in this paper, introducing financial accelerator mechanism could motivate a similar propagation endogenously. In such a model, part of the new capital would be destroyed because of the agency cost ($\tau_t$) associated with monitoring costs and would constitute a drain on the capital formation process:

$$\tilde{K}_{t+1} = (1 - \delta)\tilde{K}_t + I_t[1 - \tau_t]$$

(2.5)

Equation (2.5) is quite comparable to (2.2). As JPT (2011) points out, this mechanism would be similar to a MEI shock in the sense that it also introduces a randomness and interruption in the capital formation process.

To capture the link between MEI shock and financial sector, JPT (2011) presents an additional version of their baseline model which is estimated by adding spread data among observables. In that version MEI shocks still explain an important, but lower, part (around 40 percent) of
output fluctuations compared to the baseline model. Christiano et al. (2010) investigates the sources of business cycles in a DSGE model enriched with financial factors and introduces a shock to risk, which emanates from the financial sector. They show that this risk shock turns out to be the most important source of fluctuations and it crowds out some of the role of the MEI shocks. This fact also hints a close relation between the MEI shocks and financial conditions in the economy.

3. The Open Economy DSGE Model

This paper builds on a tradition of small open economy DSGE models popularized by Gali and Monacelli (2005) among others. It is a small open economy DSGE model quite similar to the one developed in Adolfson, Laséen, Linde and Villani –ALLV- (2007) and shares its basic closed economy features with many recent new Keynesian models, including the models of Christiano et al. (2005), Smets and Wouters (2003) and Justiniano et al. (2010). The model incorporates several open economy features, as well as a number of nominal and real frictions such as sticky prices, sticky wages, variable capital utilization, capital and investment adjustment costs and internal habit persistence that are proved to be important for the empirical fit of the models.

The model economy is populated by households, domestic firms, importing and exporting firms, a central bank and an exogenous foreign economy. The households consume a basket of domestically produced goods and imported goods, which are supplied by importing firms. Considering the significantly high share of imports in total investment in Turkey, the model allows the imported goods to enter the aggregate investment as well as aggregate consumption. Households can save in domestic and/or foreign bonds. The choice between domestic and foreign bonds balances into an arbitrage condition (i.e., an uncovered interest rate parity condition) which is a key equation of this model. Households rent capital to the domestic firms and decide how much to invest in their stock of capital given the investment adjustment costs. The model introduces wage stickiness through an indexation variant of the Calvo (1983) model.

Domestic production is exposed to a stationary and a stochastic unit root technology growth. The domestic and importing firms produce differentiated goods and set prices a la Calvo (1983). By including nominal rigidities in the importing sector, the model allows for short-run incomplete exchange rate pass-through to import prices. On the other hand, following Gertler
et al. (2007), I assume that foreign demand for the home tradable good (i.e. the demand for home country exports) is exogenously given and the law of one price holds for the exporting sector.

Monetary policy is approximated with a Taylor-type interest rate rule. Adopting a small open economy perspective, the foreign economy is taken to be exogenous. Accordingly the foreign inflation, output and interest rate are assumed to be given by exogenous autoregressive (AR(1)) processes. The following section provides the optimization problems of the different firms and the households, and describes the behavior of the central bank.

3.1. Firms

There are three categories of firms operating in this economy: domestic, importing and exporting firms. The intermediate domestic firms produce a differentiated good, using capital and labor inputs, which they sell to a final good producer who transforms a continuum of these intermediate goods into a homogenous final good. The importing firms, in turn, buy a homogenous good in the world market, and sell it to the domestic households after transforming into a differentiated import good. The exporting firms buy the domestic final good and sell it in the world market.

3.1.1. Domestic Firms

There are three types of domestic firms. First type is the employment agencies. They operate competitively and combine the specialized labor of each household $j$ into a homogenous labor input $H$ and sell to the intermediate goods producers:

$$H_t = \left[ \int_0^1 h_{j,t}^\lambda w, t d j \right]^\lambda w, t$$  \hspace{1cm} (3.1)

where $\lambda_{w,t}$ represents the desired markup of wages over household's marginal rate of substitution. It follows an exogenous process:

$$\lambda_{w,t} = (1 - \rho_{\lambda w}) \lambda_{w} + \rho_{w} \lambda_{w,t-1} + \varepsilon_{\lambda w,t}$$  \hspace{1cm} (3.2)

The intermediate goods producers buy $H$ from employment agencies and rent capital from households to produce an intermediate good $Y_{i,t}$. There is a continuum of these intermediate firms, each of which is a monopoly supplier of its own good. Final good firms transform the intermediate product into a homogenous final good, which is used by the households for
consumption and investment. Final good producers combine a continuum of intermediate goods $Y_{i,t}$ and produce $Y_t$:

$$Y_t = \left[ \frac{1}{0} \int Y_{i,t}^{\lambda_{d,t}} dt \right]^{1-\lambda_{d,t}} \quad (3.3)$$

Here, $\lambda_{d,t}$ represents the time-varying markup in the domestic economy, which follows an exogenous process $\lambda_{d,t} = (1 - \rho_{\lambda_d})\lambda_d + \rho_{\lambda_d}\lambda_{d,t-1} + \varepsilon_{\lambda_d,t} \quad (3.4)$.

Final good producer takes its output price, $P_t$, and its input prices $P_{i,t}$ as given. The relation between these prices is given by (3.6). The corresponding demand function of the final good firm is given by (3.5):

$$\frac{Y_{i,t}}{Y_t} = \left( \frac{P_t}{P_{i,t}} \right)^{\lambda_{d,t}} \quad (3.5)$$

$$P_t = \left[ \frac{1}{0} \int p_{i,t}^{1-\lambda_{d,t}} dt \right]^{1-\lambda_{d,t}} \quad (3.6)$$

The production function of the intermediate firm $i$ is given by:

$$Y_{i,t} = \varepsilon_t K_{i,t}^\alpha (z_t H_{i,t})^{1-\alpha} - z_t \phi \quad (3.7)$$

where $K_{i,t}$ and $H_{i,t}$ are the capital services and labor inputs used by firm $i$, respectively. $\phi$ is a fixed cost of production. This parameter is chosen such that zero profit condition holds at steady state. Moreover it is assumed to grow at the same rate as output does in steady state. Otherwise, the fixed cost would become irrelevant and profits would tend to be systematically positive as a result of monopoly power of the firms. $\varepsilon_t$ is a covariance stationary technology shock and $z_t$ is a permanent technology shock. Level of permanent technology is non-stationary and its growth rate, $\mu_{z,t} = \log (z_t / z_{t-1})$ follows an AR(1) process:

$$\mu_{z,t} = (1 - \rho_{\mu_z})\mu_z + \rho_{\mu_z}\mu_{z,t-1} + \varepsilon_{z,t} \quad (3.8)$$

The stationary shock has the following representation $^4$:

$$\hat{\varepsilon}_t = \rho_{\varepsilon}\hat{\varepsilon}_{t-1} + \varepsilon_{\varepsilon,t} \quad (3.9)$$

$^3$Note that assuming that these markup shocks are white noise implies setting $\rho_{\lambda_d} = 0$.

$^4$To ease notation, throughout the paper, a variable with a hat denotes the log-deviations from steady-state values.
Given $P_{t,t}$, the intermediate firm that is constrained to produce $Y_{t,t}$ faces the following cost minimization problem:

$$\min \left\{ W_t H_{t,t} + R_t^k K_{t,t} + \lambda_t P_{t,t} \left[ Y_{t,t} - e_t K_{t,t} (z_t H_{t,t})^{1-\alpha} + z_t \phi \right] \right\}$$

(3.9)

$R^k$ is the gross nominal rental rate per unit of capital services and $W_t$ is the nominal wage rate per unit of labor $H_{t,t}$.

The first order conditions for the optimization (3.9) with respect to $H$ and $K$ are:

$$W_t = (1 - \alpha) \lambda_t P_{t,t} e_t z_t (H_{t,t}^{-1} K_{t,t})^{1-\alpha}$$

(3.10)

$$R_t^k = a \lambda_t P_{t,t} e_t z_t (K_{t,t}^{-1} H_{t,t})^{1-\alpha}$$

(3.11)

The price rigidity is introduced a la Calvo (1983). The intermediate firms are allowed to change their price only when they receive a random price change signal. Every period there is a random probability $\xi_d$ that intermediate firms cannot readjust price optimally but choose according to the indexation rule:

$$P_{t+1} = P_t \pi_t^{\kappa_d} (\bar{\pi}_t^{T})^{1-\kappa_d}$$

(3.12)

where $\pi_t$ is the gross inflation rate $\pi_t = (P_t / P_{t-1})$ and $\bar{\pi}_t^{T}$ is the inflation target. With probability $(1 - \xi_d)$, the firm can choose its price optimally by maximizing the present discounted value of future profits as follows:

$$E_t \left\{ \sum_{s=0}^{\infty} (\xi_d R)^s \nu_{t+s} \left[ P_{new,t} \left( \prod_{k=1}^{s} \pi_{t+k-1}^{\kappa_d} (\bar{\pi}_t^{T})^{1-\kappa_d} \right) Y_{t,t+s} - MC_{t,t+s} (Y_{t,t+s} + z_{t+s} \phi) \right] \right\}$$

(3.13)

vis the household's marginal utility of income and existence of that in the price setting makes profits conditional on utility. $P_{new}$ is the re-optimized price and $MC$ is the firm's nominal marginal cost. Consequently, the average price in period $t$ is:

$$P_t = \left[ \xi_d (P_{t-1} \pi_{t-1}^{\kappa_d} (\bar{\pi}_t^{T})^{1-\kappa_d})^{1/\lambda_d} + (1 - \xi_d) (P_{new,t}^{1/\lambda_d}) \right]^{1-\lambda_d}$$

(3.14)

Log-linearizing this condition gives the domestic price Philips curve:

$$\hat{P}_t - \hat{P}_t^{T} = \frac{\beta}{1 + \beta \kappa_d} (E_t \hat{P}_{t+1} - \rho \hat{P}_t^{T}) + \frac{\kappa_d}{1 + \beta \kappa_d} (\hat{P}_{t-1} - \hat{P}_t^{T})$$

$$- \frac{\kappa_d \beta (1 - \rho \pi)}{1 + \beta \kappa_d} \hat{P}_{t+1}^{T} + \frac{(1 - \xi_d)(1 - \beta \xi_d)}{\xi_d (1 + \beta \kappa_d)} (\hat{m}_t + \hat{\lambda}_{d,t})$$

(3.15)
3.1.2. Importing Firms

The importing firms buy a homogenous good in the world market at price \( P^* \) and transform it into a differentiated good under brand naming. There is a continuum of importing firms which sell their differentiated goods to the households. The model allows for incomplete exchange rate pass-through to import prices by the assumption of local currency price stickiness. Price setting process of importing firms is similar to that of intermediate goods producers. Each importing firm can re-optimize its price in any period with a random probability \( (1 - \zeta_m) \). Importing firms cannot reset their price optimally with probability \( \zeta_m \) but choose according to the indexation rule:

\[
P^m_{t+1} = p^m_t (\pi^m_t)^{\kappa_m} (\pi^T_{t+1})^{1-\kappa_m} \tag{3.16}
\]

\( \pi^m_t = (P^m_t / P^m_{t-1}) \) is the import price inflation. The importing firm \( i \) who sells \( M_i \) amount of imported goods, maximizes the following discounted profits:

\[
E_t \left( \sum_{s=0}^{\infty} (\xi m \beta)^s v_{t+s} \left[ P_{new,t}^m M_{i,t+s} (\pi^m_t \cdots \pi^m_{t+s-1})^{\kappa_m} (\pi^T_{t+1} \cdots \pi^T_{t+s})^{1-\kappa_m} - S_{t+s} p^m_{t+s} (M_{i,t+s} + z_{t+s} \Phi^m) \right] \right)
\tag{3.17}
\]

\( \Phi^m \) is the fixed cost of the imported good firm and it is introduced to make import profits zero in steady state. The final import good is a CES aggregate of a continuum of \( i \) differentiated imported goods as follows:

\[
M_t = \left[ \int_0^1 (M_{i,t})^{\frac{1}{\lambda_{m,t}}} \, dt \right]^{\lambda_{m,t}} \tag{3.18}
\]

The cost minimization problem implies that each importer faces an isoelastic demand for her product given by (3.19):

\[
M_{i,t} = \left( \frac{P_{i,t}^m}{p_t^m} \right)^{-\frac{\lambda_{m,t}}{\lambda_{m,t} - 1}} M_t \tag{3.19}
\]

\[
P_t^m = \left[ \int_0^1 \left( \frac{p_{i,t}^m}{p_t^m} \right)^{\frac{1}{\lambda_{m,t} - 1}} \, dt \right]^{1-\frac{1}{\lambda_{m,t}}} \tag{3.20}
\]
where \( p_{i,t}^m \) is the price of the importing firm \( i \) and \( P_t^m \) is the corresponding price of the composite final imported good. \( \lambda_{m,t} \) is a stochastic process determining the time-varying markup for importing good firms. It is assumed to follow:

\[
\lambda_{m,t} = (1 - \rho_{\lambda m}) \lambda_m + \rho_{\lambda m} \lambda_{m,t-1} + \varepsilon_{\lambda m,t}
\]  

Aggregate import price is given by:

\[
P_t^m = \left[ \xi_m (P_{t-1}^m)^{\kappa_m} (\pi_t^m)^{1-\kappa_m} \right]^{1/1-\lambda_{m,t}} + (1 - \xi_m) \left( P_{new,t}^m \right)^{1/1-\lambda_{m,t}}
\]  

Log-linearizing the pricing equations will give the Philips curve for the imported good:

\[
\hat{r}_{t}^m - \hat{\pi}_{t}^m = \frac{\beta}{1 + \beta \kappa_m} (E_t \hat{r}_{t+1}^m - \rho_n \hat{\pi}_t) + \frac{\kappa_m}{1 + \beta \kappa_m} (\hat{\pi}_{t-1}^m - \hat{\pi}_t) - \frac{\kappa_m \beta (1 - \rho_n)}{1 + \beta \kappa_m} \hat{\pi}_t
\]

\[
+ \frac{(1 - \xi_m)(1 - \beta \xi_m)}{\xi_m(1 + \beta \kappa_m)} (\hat{mc}_{t}^m + \lambda_{m,t})
\]  

where, \( \hat{mc}_{t}^m = (\hat{p}_t^* + \hat{s}_t - \hat{p}_t^m) \) and \( S \) is the nominal exchange rate.

The mark-up shocks are observationally equivalent to shocks to the elasticity of substitution among imported goods with an opposite sign (i.e. a positive substitution elasticity shock is a negative mark-up shock). Such mark-up shocks can thus either originate in variations of importing firms’ price setting behavior or households’ willingness to substitute between different goods (Adolfson et al., 2007).

### 3.1.3. Exporting Firms

The exporting firms sell the final domestic good to the foreign households. The model allows for perfect exchange rate pass-through in export prices and assumes exporters do not have pricing power. The price and the foreign demand for domestic tradable good are given by:

\[
\tilde{r}_t = \left( \frac{P_t}{\delta_t} \right)^{\eta_f} Y_t^f
\]

\[
P_t^x = \frac{P_t}{S_t}
\]

### 3.2. Households

There is a continuum of households, indexed by \( j \in (0,1) \). They consume foreign and domestic goods and save in domestic and foreign bonds. Households own the physical capital, choose the utilization rate \( (u_t) \) and investment level \( (I_t) \). Households can increase their capital stock by investing in additional physical capital or by directly increasing the utilization rate of the
existing capital. The assumption of complete domestic financial markets in this economy allows the model to preserve the representative agent framework.

The representative household attains utility from consumption and leisure. The utility of a representative household is given by:

$$U = \sum_{t=0}^{\infty} \beta^t \left[ \xi_t \ln(C_t) - b c_{t-1} - \xi_t^h A_t \right]$$

(3.26)

In Equation (3.26), $\xi_t^c$ and $\xi_t^h$ are preference shocks and $b$ is the internal habit persistence parameter. $A_t$ is calibrated to match steady state level of hours. The preference shocks evolve according to:

$$\xi_t^c = \rho \xi_{t-1}^c + \epsilon_t^c$$

(3.27)

$$\xi_t^h = \rho \xi_{t-1}^h + \epsilon_t^h$$

(3.28)

Households consume a basket of imported ($C^m$) and domestically produced consumption goods ($C^d$). The aggregate consumption is given as a CES aggregate of these:

$$C_t = \left[ (1 - \omega_c)(C_t^d)^{\eta_c} + \omega_c(C_t^m)^{\eta_c} \right]^{\eta_c/(\eta_c+1)}$$

(3.29)

where $\omega_c$ is the share of imports in consumption and $\eta_c$ is the elasticity of substitution between domestic and imported consumption goods. Consumption demand and consumer price index (CPI) are given by:

$$C_t^d = (1 - \omega_c) \left( \frac{P_t^d}{P_t^c} \right)^{-\eta_c} C_t$$

(3.30)

$$C_t^m = \omega_c \left( \frac{P_t^m}{P_t^c} \right)^{-\eta_c} C_t$$

(3.31)

$$P_t^c = [(1 - \omega_c)(P_t^d)^{1-\eta_c} + \omega_c(P_t^m)^{1-\eta_c}]^{\eta_c/(\eta_c+1)}$$

(3.32)

Similarly aggregate investment is a CES aggregate of imported ($I^m$) and domestically produced goods ($I^d$):

$$I_t = \left[ (1 - \omega_i)(I_t^d)^{\eta_i} + \omega_i(I_t^m)^{\eta_i} \right]^{\eta_i/(\eta_i+1)}$$

(3.33)

where $\omega_i$ is the share of imports in investment, and $\eta_i$ is the elasticity of substitution between domestic and imported investment goods. Investment demand functions and aggregate investment price are given by:
Note that the prices of domestically produced consumption and investment goods are assumed to be same and equal to \( P_t \).

The law of motion for the physical capital stock is given by (3.37):

\[
\tilde{K}_{t+1} = (1 - \delta)\tilde{K}_t + I_t[Y_t(1 - S(l_t/l_{t-1})) + \Delta_t]
\]  

(3.37)

The variable, \( \Delta_t \), reflects that households have access to a market where they can purchase new, installed physical capital \( \tilde{K}_{t+1} \). In this market, households wishing to sell \( \tilde{K}_{t+1} \) are the only suppliers, while households wishing to buy \( \tilde{K}_{t+1} \) are the only buyers. This variable is introduced to define the price of capital, \( P_{k',t} \), and in equilibrium \( \Delta_t = 0 \) (ALLV, 2007) since all households are identical (See Christiano et al., 2005 for further details). \( \delta \) is the depreciation rate. The term in square brackets reflects the presence of costs of adjusting the flow of investment. Following Christiano et al. (2005), adjustment costs are placed on the change of investment. I assume that \( S \) and its derivative are zero along a steady state growth path for the economy: \( S = S' = 0 \) and \( S'' > 0 \). The second derivative of this function in the steady state, \( S'' \), is a parameter that will be estimated. \( Y_t \) represents shock to the marginal efficiency of investment which affects the transformation of investment into physical capital. Time series representation of \( \bar{Y}_t = (Y_t - 1)/1 \) is given by (3.38):

\[
\bar{Y}_t = \rho_t \bar{Y}_{t-1} + \varepsilon_{yt}
\]  

(3.38)

Budget constraint of a representative household in nominal terms is:

\[
P_t^C C_{jt} + p_t^l I_{jt} + B_{jt+1} + S_t B_{jt+1}^l
= B_{jt} R_{t-1} + R_{t-1}^* \phi \left( \frac{A_{t-1}}{\bar{z}_{t-1}}, \phi_{t-1} \right) S_t B_{jt}^l + \Pi_t + W_{jt} h_{jt}
+ R_t^k u_{jt} R_{jt} - P_t \left( a(u_{jt}) K_{jt} + P_{k',t} \Delta_t \right)
\]

\[
A_t = \frac{S_t B_{jt+1}^l}{P_t}
\]  

(3.39)

(3.40)

---

Lucca (2005) shows that this formulation of the adjustment cost function is equivalent to a generalization of the time to build assumption.
where $B$ and $B^*$ are nominal bonds denominated in domestic and foreign currency, respectively. $R_0$ is the gross nominal interest rate, $\Pi_t$ is the profit of the household as owner of the firms. Gross rental rate of capital is given by $R_t^k$ and risk-adjusted gross interest rate of foreign bonds is $R_t^*-\phi_t'\phi_t-\phi'_{t-1}$ where $A_t$ is the real aggregate net foreign asset position of the domestic economy. $\phi(\cdot,\cdot)$ is a risk premium on foreign bond holdings which is assumed to be strictly decreasing in $A_t$. The risk-premium is introduced in order to ensure a well-defined steady-state in the model (Schmitt-Grohe and Uribe, 2003). The function $\phi(\cdot,\cdot)$ captures imperfect integration in the international financial markets. If the domestic economy as a whole is a net lender ($B^*<0$), domestic households are charged a premium on the foreign interest rate. If the domestic economy is a net lender ($B^*>0$), households receive a lower remuneration on their savings. $\phi$ is a shock to the risk premium.

As the owners of physical capital stock, households choose the capital utilization rate, $u_t$ and pay the capital adjustment cost $P_t a(u_t)$. It denotes the cost of setting the utilization rate to $u_t$ in terms of consumption good. For the functional form of the utilization cost function, the general assumptions are maintained. In steady state $a(1)=0$, $u=1$ and $a'=r^k$. In production process, effective capital $K_t$ is used which is transformed from physical capital $\bar{K}_t$:

$$K_t = u_t \bar{K}_t$$  \hspace{1cm} (3.41)

Households solve the following maximization problem and choose $\{c_{j,t}, b_{j,t+1}, \bar{K}_{j,t+1}, l_{j,t}, u_{j,t}, B_{j,t+1}^*, h_{j,t}, \Delta_t\}$:

$$\begin{align*}
\sum_{t=0}^{\infty} \beta^t \left[ \xi_t \ln (c_{j,t} - bc_{j,t-1}) - \xi_t^k A_t \frac{h_{j,t}^{1+\sigma_t}}{1+\sigma_t} \\
+ \nu_t \left[ R_{t-1} b_j + R_{t-1}^* \phi_t \phi_{t-1} \right] S_{t} B_{j,t}^* + \Pi_t + W_{j,t} h_{j,t} \\
+ R_{t}^k u_{j,t} \bar{K}_{j,t} - p_t (a(u_{j,t}) \bar{K}_{j,t} + p_{k,t}^* \Delta_t) - p_t^* C_{j,t} - p_t^* l_{j,t} - B_{j,t+1}^* \\
- S_t B_{j,t+1}^* + \omega_t \left[ (1-\delta) \bar{K}_{j,t} + l_{j,t} Y_t \left[ 1 - S \left( \frac{1}{l_{t-1}^*} \right) \right] + \Delta_t - \bar{K}_{j,t+1} \right] \right] 
\end{align*}$$  \hspace{1cm} (3.42)

There is unit-root technology in the model, so the solution requires stationarizing the model with the technology level such that all real variables are divided by $z_t$ and the multipliers are multiplied by $z_t$. The stationarized variables are written in small letters (as shown in (3.71)), for any real variable $X$, $x_t\equiv X_t/z_t$. Moreover, there exists unit-root in the price level and some of the variables (e.g. aggregate nominal wage, rental rate of capital) contain a nominal trend as well. To remove this nominal trend, those variables are divided by the price level.
The first order conditions for the household’s optimization problem are as follows:

\[ \frac{\zeta_t^c}{c_{t-1} - \beta c_{t+1}} - \beta b \frac{\zeta_{x,t+1}}{c_{t+1} \mu_{x,t+1} - \beta c_{t+1}} - \psi_{x,t} \frac{P_t^c}{P_t} = 0 \]  \hspace{1cm} (3.43)

w.r.t. \( b_{x,t+1} \):

\[ -\psi_{x,t} + \frac{\psi_{x,t+1} R_t}{\mu_{x,t+1} \Pi_{t+1}} = 0 \]  \hspace{1cm} (3.44)

w.r.t. \( k_{x,t+1} \):

\[ -\psi_{x,t} P_{t} k_{x,t+1}^r + \beta \frac{\psi_{x,t+1}}{\mu_{x,t+1}} \left[ (1 - \delta) P_{t} k_{x,t+1}^r + r_{t+1} k_{x,t+1}^r - (\delta^2) \right] = 0 \]  \hspace{1cm} (3.45)

w.r.t. \( \Delta_t \):

\[ -\frac{\psi_{x,t}}{\zeta_t} P_{t} k_{x,t}^r + \omega_t = 0 \]  \hspace{1cm} (3.46)

w.r.t. \( i_t \):

\[ -\psi_{x,t} \frac{P_t^i}{P_t} + \psi_{x,t} P_{k,t}^i \left[ 1 - S_t \left( \frac{i_t \mu_{x,t}}{i_{t-1}} - \frac{i_t \mu_{x,t}}{i_{t-1}} \right) \right] - \beta P_{k,t+1}^i \mu_{x,t+1} Y_t \left( \frac{(i_{t+1} \mu_{x,t+1})}{i_t} \right) S'' \left( \frac{(i_{t+1} \mu_{x,t+1})}{i_t} \right) = 0 \]  \hspace{1cm} (3.47)

w.r.t. \( u_t \):

\[ \psi_{x,t} \left( r_{t+1}^k - a(u_t) \right) = 0 \]  \hspace{1cm} (3.48)

w.r.t. \( b_{x,t}^* \):

\[ -\psi_{x,t} S_t + \frac{\psi_{x,t+1} R_t^i}{\mu_{x,t+1} \Pi_{t+1}} \left( \phi(a, \bar{a}, \bar{\phi}) \right) S_{t+1} = 0 \]  \hspace{1cm} (3.49)

Note that \( \Psi_t \) is the stationarized multiplier and \( P_{k,t}^i \) is the relative price of capital.

The risk premium on foreign bonds is assumed to have the following functional form:

\[ \phi(a, \bar{a}, \bar{\phi}) = \exp \left( \bar{\phi}_t (a_t - \bar{a}) + \bar{\phi}_t \right) \]  \hspace{1cm} (3.50)

By combining the households’ first order conditions for domestic and foreign bond holdings, after log-linearization one can obtain the following uncovered interest rate parity condition:

\[ \bar{R}_t - \bar{R}_t = E_t \Delta S_{t+1} - \bar{\phi}_t \bar{a}_t + \bar{\phi}_t \]  \hspace{1cm} (3.51)

Since it’s assumed that there is imperfect integration in the international financial markets, the net foreign asset position enters the interest rate parity condition.

### 3.2.1. Wage Setting

Another critical decision taken by households is the wage rate. Each household \( j \) is the sole supplier of a specialized labor \( h_{j,t} \). The demand for labor that an individual household faces is given by (3.52):

\[ h_{j,t} = \frac{W_{j,t}^h}{W_t} \frac{\lambda_{w,t}}{\lambda_{w,t}} H_t \]  \hspace{1cm} (3.52)
The model incorporates real rigidities and allows for wage stickiness. Every period with \( \xi_w \) probability, households cannot set their wage optimally but index it to last period’s CPI inflation rate and the current inflation target, adding a technology growth factor to their wage:

\[
W_{j,t+1} = \mu_{z,t+1} W_{j,t}(\pi^w)(\pi^w_{t+1})^{1-\xi_w}
\] (3.53)

Remaining \((1 - \xi_w)\) fraction of the households set their wage optimally by maximizing

\[
E_t \sum_{\tau=0}^{\infty} (\xi_w \beta)^\tau \left[ -\xi_w \pi_{t+\tau} + h_{t+\tau} \left( \pi^w_{t+\tau} \right)^{1-\xi_w} \right] + h_j u_{t+\tau} (\pi \pi_{t+\tau} - \pi_{t+\tau}^{\pi})^{1-\xi_w} \mu_{z,t+1} \mu_{z,t+\tau} W_{new,j,t}
\] (3.54)

The log-linearized real wage equation is given by:

\[
\hat{\mu}_t \eta_1 + \tilde{\mu}_{t-1} \eta_0 + \hat{\mu}_{t+1} \eta_2 + \eta_3 (\hat{\pi}^d - \hat{\pi}^c) + \eta_3 (\hat{\pi}^d_{t+1} - \rho_h \hat{\pi}^c_t) + \eta_2 (\hat{\pi}^c_{t+1} - \hat{\pi}^c_t) + \eta_9 \hat{\pi}^c_t + \eta_0 (\hat{\pi}^c_t - \rho_h \hat{\pi}^c_t) + \eta_7 \hat{\pi}^c_{t+1} + \eta_\beta \eta_{t+1} = 0
\] (3.55)

3.3. The Central Bank

Monetary policy follows the following instrument rule (in log-linear form):

\[
\hat{R}_t = \rho_R \hat{R}_{t-1} + (1 - \rho_R) (\hat{\pi}^c_t - \rho_n \hat{\pi}^c_{t-1} + r_n \hat{\pi}^c_{t-1} - \hat{\pi}^c_t) + r_y \hat{y}_{t-1} + r_y \hat{y}_{t-1} + r_y \hat{y}_{t-1}
\] (3.56)

where \( \hat{R}_t \) is the short-term interest rate, \( \hat{\pi}^c_t \) is the CPI inflation rate and \( \hat{y}_t \) is the output gap. The output gap is measured as the deviation from the trend value of output in the economy as in ALLV (2007), different from Smets and Wouters (2003) or Justiniano, Primiceri and Tambalotti (JPT) (2010) which measure output gaps as the deviation from the flexible price level.

\( \hat{x}_t \) is the log-linearized real exchange rate, which is given by (3.57):

\[
\hat{x}_t = \hat{x}_t + \hat{\pi}_t - \hat{\pi}_t^c
\] (3.57)

\( \hat{\pi}_t^c \) is the model-consistent measure of the CPI inflation rate index:

\[
\hat{\pi}_t^c = \left[ (1 - \omega_c) \left( \frac{P_t}{P_{t-1}} \right)^{1-\eta_c} \hat{\pi}_t^c + \omega_c \left( \frac{P_{t-1}}{P_t} \right)^{1-\eta_c} \hat{\pi}_t^m \right]
\] (3.58)

\( \hat{\pi}_t^m \) is the time-varying inflation target which can be referred as an inflation target shock.
\[ \hat{\pi}_t^* = \rho \hat{\pi}_{t-1}^* + \epsilon_{\pi_t} \] (3.59)

### 3.4. Foreign Economy

The foreign inflation, output and interest rate are exogenously described by the following equations:

\[ \hat{\pi}_t^* = \rho \hat{\pi}_{t-1}^* + \epsilon_{\pi_t} \] (3.60)
\[ y_t^* = \rho y_{t-1}^* + \epsilon_{y_t} \] (3.61)
\[ R_t^* = \rho R_{t-1}^* + \epsilon_{R_t} \] (3.62)

### 3.5. Market Clearing Conditions

To close the model, equilibrium in good market requires that the production of the final good be equal to the sum of total spending and the capital utilization adjustment cost:

\[ C_t^d + I_t^d + X_t + a(u_t)\bar{K}_t \leq \epsilon_t K_t^a(z_t \bar{H}_{t\bar{z}})^{1-a} - z_t \phi \] (3.63)

In stationary form the resource constraint is:

\[ (1 - \omega_c) \left( \frac{p^e_t}{p_t} \right)^{\eta_c} c_t + (1 - \omega_l) \left( \frac{p^i_t}{p_t} \right)^{\eta_l} i_t + g_t + \left( \frac{p^s_t}{p_t} \right)^{-\eta_f} y_t^* \leq \epsilon_t k_t^{\alpha} \left( \frac{1}{\mu_{z,t}} \right) (H_t)^{1-a} - \phi - a(u_t) \frac{\bar{k}_t}{\mu_{z,t}} \] (3.64)

Foreign bond market clears such that net foreign assets evolve according to:

\[ S_t B_t^* = S_t P_t^e \bar{X}_t - S_t P_t^i (C_t^m + I_t^m) + R_t^* \phi (a_{t-1}, \bar{\phi}_{t-1}) S_t B_t^* \] (3.65)

### 3.6. Relative Prices

Various stationary relative prices enter the model. First is defined in terms of the imported good which is the relative prices between domestically produced goods and imported goods perceived by domestic agents.

\[ \gamma_t^{m,d} = \frac{P_t^m}{P_t} \] (3.66)

In addition, the following relative prices are important for households when determining their consumption and investment baskets:

\[ \gamma_t^{c,d} = \frac{P_t^c}{P_t} \] (3.67)
The relative price between the domestically produced goods (home exports) and the foreign goods governs the export demand:

\[ y_{t}^{ld} = \frac{p_{t}^{i}}{p_{t}} \quad (3.68) \]

Consequently marginal cost function for the importing firm can be written as:

\[ m_{c_{t}}^{m} = \frac{S_{t}p_{t}^{*}}{p_{t}^{m}} = \frac{1}{\gamma_{t}^{m,a}_{t}}y_{t}^{t,x,*} \quad (3.70) \]

### 3.7. Model Solution

In the model, consumption, investment, capital, real wages and output fluctuate around a stochastic balanced growth path, since the level of technology \( z_t \) has a unit root. Because of the permanent technology shock and the unit-root in the price level, a number of variables are non-stationary as they contain a nominal and real stochastic trend. Therefore, the solution involves the following steps. First, to render stationarity of all variables, one needs to divide all quantities with the trend level of technology \( z_t \) and multiply the Lagrangian multiplier with it. \( K_t \) and \( R_t \) are stationarized with \( z_{t-1} \) whereas the other real variables with \( z_t \). Following Adolfson et al. (2007) the variables are stationarized in the following way:

\[ c_{t} \equiv \frac{C_{t}}{z_{t}}, r_{t}^{k} \equiv \frac{R_{t}^{k}}{P_{t}}, \tilde{w}_{t} \equiv \frac{W_{t}}{P_{t}z_{t}}, k_{t+1} \equiv \frac{K_{t+1}}{z_{t}}, \tilde{r}_{t+1} \equiv \frac{R_{t+1}}{z_{t}}, y_{t}^{*} \equiv \frac{Y_{t}^{*}}{z_{t}} \quad (3.71) \]

This way, the model is written in terms of stationary variables. Second, the non-stochastic steady state of the transformed model is computed and the model is log-linearly approximated around this steady state. By linearly approximating the model, a state-space representation is obtained so that the DSGE model can be analyzed with the utilization of the Kalman filter. The model is completed by defining a set of measurement equations that relate the endogenous variables of the model to a set of observables.

---

6 The domestic and foreign variables stationarized with same level of technology. By doing so, it’s aimed to avoid adding the asymmetric technology shock since variables in the used data set cannot pin down this shock and this may lead to under-identification problem.

7 See Appendix A for the linear system of equations.
4. Data and Estimation: A Bayesian Approach

4.1. Data

There exist thirteen exogenous shocks in the model economy. The estimation is done with thirteen observable variables so that there exist as many observed variables as shocks to avoid stochastic singularity and identification problems. In line with the existing literature, the following key macroeconomic data series are tried to be matched: the growth rates of Gross Domestic Product (GDP), consumption, investment, imports, exports, foreign GDP, and the real exchange rate as well as the levels of the domestic policy and foreign interest rates; the inflation rates of domestic GDP deflator, core consumer price and import prices together with foreign consumer price indices. Regarding the foreign variables, euro area GDP is used for foreign output since it is Turkey’s largest trading partner. For interest rate and inflation rate, U.S. data is used (Table 3.1). To make these variables stationary I use first differences and derive the state space representation for the following vector of observed variables.

\[
\tilde{Y}_t = \begin{bmatrix}
\Delta ln Y_t, \Delta ln C_t, \Delta ln I_t, \Delta ln M_t, \Delta ln X_t, \Delta ln Y^*_t \\
\pi_t, \pi_t^{core}, \pi_t^{imp}, r_t, r_t^*, ren_t
\end{bmatrix}
\]  

(4.0)

To align the data with the model-based definitions, standard transformations are applied. For example, all interest rates are divided by four so that the periodic rates are consistent with the quarterly time series. In addition, in order to make observable variables consistent with the corresponding model variables, the data are demeaned by removing their sample mean, with the exception of inflation and interest rates, which are demeaned by subtracting their steady-state values.

The baseline estimation covers the period 2002:1-2012:2. I choose to start the estimation from 2002 to capture the episode when the Central Bank of Turkey began to implement an inflation targeting regime (initially implicitly, and explicitly starting in 2006). This way, I exclude the periods where regime changes and structural breaks were observed to avoid spurious inference.

---

8 Stochastic singularity is the problem of having a case when number of shocks is less than that of the observables. Similarly having less number of observable variables than that of the shocks is not desired since this leads to weak identification of the shocks.

9 The growth rates are measured as quarterly logarithmic difference of the mentioned series. See Table 3.1 for details.
4.2 Estimation

The method followed for the solution and estimation of the model discussed in the third section briefly involves two steps: first the model is solved and written in state-space form. Solving the model means writing the whole system in terms of lagged variables and current shocks. The coefficients in a DSGE model are structural and are often complicated functions of underlying preferences and technology. Therefore there is a high degree of nonlinearity in solution of the model with respect to the parameters. Hence solving the model requires linearization around a well-defined steady state. As a second step, the log-linear system is estimated by Bayesian techniques. The Turkish case often enforces an environment of working with short time series unless the utilized model accounts for structural break or policy switch due to the major policy change and a set of structural reforms observed in post 2001 crisis period. Estimating the model by Bayesian methods enables one to take the advantage of using prior information which is valuable while working with short data samples. The Bayesian methodology is a full information approach to jointly estimate the parameters of a DSGE model (Lubik and Schorfheide, 2007). The estimation is based on the likelihood function generated by the solution of the log-linear version of the model. The reduced form of the model is given by the following state-space form:

\[
x_t = G(\theta)x_{t-1} + M(\theta)\epsilon_t \\
y_t = H(\theta)x_t
\]

(4.1) (4.2)

Here \(x_t\) is the vector of endogenous variables written as log deviations from the corresponding steady state values, \(\epsilon_t\) is the vector of structural shocks and \(\theta\) is the vector of parameters. Equation (4.1) is the state/transition equation which describes the evolution of model’s endogenous variables. Equation (4.2) is the observation equation where \(y_t\) represents the set of observable variables.

4.2.1. Calibrated parameters

As is common in the literature, a selected set of parameters are kept fixed from the start of the estimation\(^\text{10}\). Most of these parameters can be directly related to the steady-state values of the state variables and are chosen to pin down key steady state ratios, while the remaining parameters are borrowed from the related literature. Table 4.1 reports the calibrated parameters.

\(^{10}\) This can be considered as giving infinitely strict priors.
The discount factor $\beta$, is calibrated to be 0.9928, which implies an annual riskless real interest rate of approximately three percent, close to many other studies in the literature (Alp and Elekdag, 2011). The depreciation rate $\delta$, is set equal to 0.035 per quarter, which indicates an annual depreciation on capital equal to 14 percent. Similarly, $\alpha$ is set to 0.4, which roughly implies a 60 percent steady-state share of labor income in total output. To match the sample average of the import-output ratio and the ratios of domestic consumption (and investment) over imported consumption (and investment), the parameters representing the share of imports in consumption ($\omega_c$) and investment ($\omega_i$) are set to 0.25 and 0.23, respectively. This calibration ensures that the shares of steady-state investment and consumption in total output are roughly 0.2 and 0.7, which corresponds to the average ratios observed over the estimation period. The constant in the labor disutility function $A_L$ is set to 7, implying that the agents devote around 30 percent of their time to work in steady state. Following Christiano et al. (2005) and Alp and Elekdag (2011), the labor supply elasticity $\sigma_L$ is set to 1. In addition, the parameters that capture the steady state mark-up rates in wage setting and price setting (for domestically produced goods and for imported goods) are calibrated since these parameters are weakly identified by the variables included in the data set. Consistent with Alp and Elekdag (2011), the steady state price and wage mark-ups are chosen to be 15 percent, which lies in the 10 to 20 percent range utilized in many other studies. The remaining parameters including various elasticities of substitution are based on Alp and Elekdag (2011) and are also summarized in Table 4.1.

The remaining 37 parameters, which mostly pertain to the nominal and real frictions in the model, the monetary policy stance, as well as the exogenous shock processes, are estimated.

4.2.2. Prior distributions of the estimated parameters

Table 4.2 shows the assumptions for the prior distribution of the estimated parameters. The location of the prior distribution of the estimated parameters corresponds to a large extent to those in Alp and Elekdag (2011).

General principles guiding the prior distributions are as follows: For all parameters bounded between 0 and 1, the beta distribution is assumed. This consequently applies to the nominal stickiness parameters $\xi$, the indexation parameters $\kappa$, and the persistence parameters of the shock processes $\rho$. For all the shocks, the prior mean of the autoregressive coefficient is set to 0.8. For parameters assumed to be positive, such as the standard deviations of the shocks $\sigma$,
the inverse gamma distribution is proposed. For the unbounded parameters, the normal distribution is assumed. This applies for instance to capital utilization cost \((\sigma_a)\) and investment adjustment cost parameters \((S'')\).

In Bayesian analysis of DSGE models, it is challenging to formulate beliefs about the parameters that govern the law of motion of latent exogenous shock processes. Therefore, to let the data determine the size of the shocks as freely as possible, the degree of freedom for these parameters are set to 2 as in ALLV (2007). While determining the mean of the shock volatilities, the prior means of the mark-up shocks in domestic and import goods are set to 0.05. This choice is based on the fact that Turkey is a small economy and is expected to be subject to large mark-up shocks (ALLV, 2008). Moreover, considering the low volatility in foreign variables, for the size of the foreign shocks I choose a smaller value of 0.01. For all other shocks, prior means are set to 0.03 in line with Alp and Elekdağ (2011).

4.2.3. Posterior distributions of the estimated parameters

The estimation results are reported in Table 4.2. It shows the means along with the 5\(^{th}\) and 95\(^{th}\) percentiles of the posterior distribution of the estimated parameters obtained through the Metropolis-Hastings sampling algorithm. The results are based on a total of 300,000 draws and two independent chains, and the Brooks and Gelman (1998) convergence criteria are achieved. The parameter draws are converted into variance decompositions to obtain the results presented in Table 4.3.

Additional information on the estimation results is presented in Figure 4.1a through Figure 4.1c, which plot the prior and the posterior distributions for the estimated parameters. A direct comparison of priors and posteriors can provide valuable insights about the extent to which data provide information about the parameters of interest. These figures provide a visual summary indicating that the data are quite informative regarding most of the estimated parameters. But since hours and wage data are absent, prior and posterior distributions of the parameters regarding wage stickiness and wage indexation are quite similar.

The Calvo parameter for domestic goods is found around 0.92 which is higher than the value found in Alp and Elekdağ (2011), but close to ALLV (2008). But as Özmen and Sevinç (2011) points out price stickiness in Turkey is time and state dependent and there is great heterogeneity across groups, which makes comparison of the findings of different studies difficult. The degree of wage stickiness parameter is around 0.75, implying wages are
adjusted every 4 quarters, on average. The degree of stickiness in import sector is lower than that of domestically produced goods which is consistent with the findings of ALLV (2008) suggesting import good prices are less sticky than domestic good prices. The indexation parameters (i.e. the $\kappa$’s) are around 0.4 which implies the Philips curve has significant backward looking components. Regarding the history of high inflation periods in Turkey, importance of backward looking behavior is meaningful. These indexation parameter values are higher than those found in ALLV (2008), suggesting that the estimated Phillips curves for Sweden are relatively more forward-looking. The results indicate that the unconditional variance of the markup shocks in the import sector is considerably higher than in the domestic sector.

Comparison of estimated policy rules turns to be challenging since various studies focus on different specifications. The specification in this paper is similar to that of ALLV (2007). The interest rate smoothing parameter, which is found to be 0.68, is in line with many other studies. As for the responsiveness of inflation deviation from target, the estimated value of 1.39 is close to the values of 1.5 and 1.6 found by Alp and Elekdağ (2011) and ALLV (2007), respectively. The responsiveness to the real exchange rate depreciation is smaller echoing the findings of Alp and Elekdağ (2011). The responsiveness of policy rates to the output gap takes on a lower value of 0.04. However this value should not be misleading. Although the interest rate rule coefficient implies a small systematic response of policy rate to output gap, it is known that Central Bank of Turkey responded to the large output drops during the crisis through discretion ary departures from the rule. Hence the importance given to output gap deviations may not be properly captured with these parameters ($r_y$ and $r_{dy}$).

Turning to exogenous shocks, I start off by discussing persistence parameters. The estimated persistence parameters lie within the range of 0.475 for the unit-root technology shock, and 0.935 for the foreign interest rate shock. A caveat should be made here. As will be discussed in the model fit section, the model does not perform persuasively enough at fitting the foreign variables; hence these parameter values should be interpreted with highest caution.

The posterior mean of the persistence parameter in the unit-root technology process is estimated to be 0.475. In addition, the persistence coefficient for the stationary technology shock is estimated to be around 0.816. These values compare quite favorably to the estimates in Alp and Elekdağ (2011). As for standard deviations, the variability of the preference, risk premium and import mark-up shocks are noteworthy.
4.2.4. Model Fit

Model evaluation is an important part of the empirical work that is based on DSGE modeling. Figure 4.2 reports the model’s one-sided Kalman filter estimates of the observed variables along with the actual variables. Such a comparison is informative in terms of assessing the fit of the model.

As is evident from Figure 4.2, the in-sample fit of the model is satisfactory. However, the model is not good at capturing exports and other foreign variables. In this paper, the foreign variables are modeled as exogenous AR(1) processes. Such a specification does not incorporate the fact that these foreign variables (i.e. foreign demand and foreign interest rate) are highly correlated with each other. An alternative to this modeling approach would be modeling the foreign economy as a VAR model as in ALLV (2007), because the assumed structure does not capture the evolution of foreign economy as properly. As a consequence, the model falls somewhat short in capturing the export dynamics, which is closely related to the modeling assumptions of the foreign economy. This in turn weakens the fit of output to some extent. However, as is clear in Figure 4.2, the model is quite good in capturing main components of output including consumption, investment and imports.

5. Shocks and Business Cycles:

5.1. Variance Decomposition and the Role of Shocks

The driving forces of fluctuations are determined by looking at the variance decomposition of the main macroeconomic variables implied by the estimated model. To make a formal assessment of the contribution of each shock to the fluctuations of the endogenous observable variables, Table 4.3 reports the variance decompositions.

Looking at the shocks and variables, two results stand out. First, unit-root technology shock of the model serves as the leading source of the output fluctuations in Turkish economy. Second, the investment shock is the second important disturbance accounting for 13 percent of the fluctuations in output (Table 4.3).

The “unit root technology” row of Table 4.3 makes clear that unit-root technology shocks account for 57 percent of the fluctuations in output, 17 percent of those in consumption and around 36 percent of those in investment. Also Figure 5.1 shows that unit-root technology

11However, since the main question of this paper does not focus on foreign variables (or related shocks), this does not constitute a serious problem.
shock accounts for the bulk of the fluctuations in output. On the basis of this outcome, one can conclude that unit-root technology shock of the model serves as the leading source of the Turkish business cycles. This finding is consistent with Aguiar and Gopinath (2007) which argues that emerging markets are characterized by volatile trend growth rates and shocks to the trend growth constitute the primary source of fluctuations in emerging markets. Motivated by the observed frequent policy regime switches in emerging markets, Aguiar and Gopinath (2007) argues that these economies are subject to substantial volatility in the trend growth rate relative to developed markets. The unit-root technology shock could therefore be considered as associated with changes in government policy, including changes in monetary, fiscal and trade policies because dramatic changes in productivity are observed following reforms and the undoing of reforms. Consequently, shocks to trend growth are the primary source of fluctuations in these economies rather than transitory fluctuations around a stable trend. Moreover the observed predominance of permanent shocks relative to transitory shocks for emerging markets explains differences in key features of their business cycles stylized facts. The literature provides evidence that if growth shocks dominate transitory income shocks, the economy resembles a typical emerging market with its volatile consumption process and countercyclical current account. It is well-shown that trend shocks increase the ability of the models to capture some data facts specific to emerging market economies such as countercyclicality of net exports and higher volatility of consumption compared to output (Aguiar and Gopinath, 2007, Arslan, et al. 2012). Being an emerging market economy subject to policy changes, one can observe similar business cycle stylized facts in Turkish economy. As shown in Alp et al. (2012), volatility of consumption relative to GDP is quite high and net exports show a countercyclical pattern in Turkey. Moreover Alp et al. (2012) also shows that business cycle properties of some key macroeconomic variables change in pre- and post-2001 period due to a change in monetary policy and a set of structural reforms which points to importance of structural changes in Turkish economy. Therefore finding unit-root technology shock, which affects the trend growth rate, as the leading source of macroeconomic fluctuations in Turkish economy is in line with the suggestions of the literature.

Compared to unit-root technology shock, investment shock has a relatively minor role in explaining output fluctuations in Turkey. This finding is consistent with the impulse response

12See Alp et al. (2012) for a detailed survey of Turkish economy business cycle stylized facts.
analysis. As evident in Figure 5.2, investment shock leads output and consumption to move in opposite directions which reminds the critique of Barro and King (1984). Given the strongly positive correlation of output and consumption over the business cycle in Turkey (Alp et al., 2012), one should expect that a shock should generate comovement of consumption and output if it is important in explaining business cycles in Turkish economy. This implies that investment shocks, which lead consumption and output to move in opposite directions, cannot play a leading role in the output fluctuations in Turkey as given by the variance decomposition analysis.

One thing to mention at this point is that the way variables are measured could affect the estimation results. Especially measuring consumption and investment can affect the estimated role of investment shocks. JPT (2010) argues that the main reason why their findings about the role of investment shocks in business cycles differ from Smets and Wouters (2003) lies in the difference in measurement of investment and consumption series. In JPT (2010), investment series includes durable consumption and change in inventories whereas Smets and Wouters (2003) does not include durable consumption in investment. Similarly the consumption data used in this paper includes purchases of consumer durables because there is no separate series for durable and non-durable consumption in the officially released national income data. If investment series included durable consumption, the estimation results could change leading to a higher role for investment shocks.

Another outcome that needs to be focused is the leading role of preference shocks in explaining consumption path. The preference shock is an intertemporal disturbance, which perturbs the agents’ intertemporal first order conditions. This can be considered as a shock to the stochastic discount factor, which captures exogenous fluctuations in preferences, as well as unmodelled distortions in consumption choices. The leading role of this shock in explaining consumption is a symptom of the well-known failure of standard consumption Euler equations to capture the empirical relationship between consumption and interest rates, as argued in Primiceri et al. (2005). Intuitively, large exogenous variations in the stochastic discount factor are necessary to repair the poor performance of the standard Euler equation. Therefore, a large taste shock $\zeta$ is necessary to reconcile the interest rates with the growth

\[ \text{There was a methodological change in calculation of the published GDP series in 2007. In the official data that starts from 1998, only aggregate consumption series is released whereas up to 2007 durable and non-durable consumption series used to be published. In this paper the new series for GDP and its components are used since the old series are available up to 2007:3.} \]
rate of consumption. Especially in case of Turkey where the volatility of consumption is quite high (even as high as that of output), there is need for a large preference shock to explain the observed consumption volatility. That’s why the estimation results indicate such a big role for preference shocks.

Finally, comparing the findings of this paper with the results of other estimated models of the Turkish economy is also informative. To the best of my knowledge, Alp and Elekdağ (2011) is the only study that estimates a DSGE model for Turkey with Bayesian estimation methods for a similar sample period. Their model incorporates a richer set-up with financial accelerator mechanism. Throughout the estimation, I use this study as a benchmark while determining priors and analyzing estimation results. Turning to the business cycle implications, Alp and Elekdağ (2011) does not provide the variance decomposition of output but presents its historical decomposition to understand the contributions of the structural shocks to output growth. They find that two prominent supply shocks are the unit-root and investment-specific technology shocks, but emphasize that the unit root technology shock seems to be the most effective supply shock in output growth echoing the findings of this paper. Similar to this paper, they find limited role for the cost push (markup) shocks.

6. Conclusion

Understanding sources of business cycles has been central in the public and academic debates for long periods. For different countries, different sources emerge to be important. In emerging market economies unit-root technology shock is found to be the driving force of macroeconomic fluctuations whereas for developed economies in addition to such productivity shocks, investment and mark-up shocks are found to matter. Inspired by this line of research, this paper investigates sources of output fluctuations in Turkish economy and examines the role of investment shocks which had been found to be an important source of business cycles in developed countries. To this end, it conducts a test for the role of various shocks by looking at variance decomposition results obtained by estimating a small open economy DSGE model by Bayesian methods.

The results show that investment shock explains 13 percent of the output movements observed in Turkish economy in 2002:1-2012:2 period. The unit root technology shock is the leading source of output fluctuations as it accounts for more than half of the macroeconomic
fluctuations. This finding indicates the importance of permanent shocks such as policy changes and structural reforms in Turkish economy.

There are a number of dimensions in which the model can be improved. First, the foreign economy is assumed to be exogenously determined and all foreign variables are assumed to follow an AR (1) process. The weakness of the model to capture movement of foreign economy variables observed in the data indicates the need of a more structural modeling of foreign economy as is done in Adolfson et al. (2007). Second, in this paper there is no explicit role for fiscal policy. Enriching the fiscal part of the model would be interesting as it would allow studying the interaction between monetary and fiscal policy in an empirical model. Third, the model does not include a well-developed financial sector. Including a banking sector and financial accelerator channel can generate interesting dynamics in the economy and affect the empirical performance of the model.
References


Appendix

A. The log-linearized model

In this part of the Appendix, the log-linearized equations in the model are presented.

The domestic Phillips curve and the log-linearized marginal costs are given by:

\[
\hat{\pi}_t - \hat{\pi}_T = \frac{\beta}{1 + \beta \kappa_d} (E_t \hat{\pi}_{t+1} - \rho \pi \hat{\pi}_T) + \frac{\kappa_d}{1 + \beta \kappa_d} (\hat{\pi}_{t-1} - \hat{\pi}_T)
\]

\[- \frac{\kappa_d \beta (1 - \rho) \pi}{1 + \beta \kappa_d} \hat{\pi}_T + \frac{(1 - \xi_d) (1 - \beta \xi_d)}{\xi_d (1 + \beta \kappa_d)} (\hat{mc}_t + \dot{\lambda}_{d,t}) \]

\[
m\hat{c}_t = \alpha r^k + (1 - \alpha) \hat{\omega}_t - \hat{\epsilon}_t \]  

\[
r^k = \mu_{x,t} + \hat{\omega}_t + \hat{R}_t - \hat{k}_t \]  

The Phillips curves for the imported good is:

\[
\hat{\pi}^m_t - \hat{\pi}^T = \frac{\beta}{1 + \beta \kappa_m} (E_t \hat{\pi}^m_{t+1} - \rho \pi \hat{\pi}^T) + \frac{\kappa_m}{1 + \beta \kappa_m} (\hat{\pi}^m_{t-1} - \hat{\pi}^T)
\]

\[- \frac{\kappa_m \beta (1 - \rho \pi) \pi}{1 + \beta \kappa_m} \hat{\pi}^T + \frac{(1 - \xi_m) (1 - \beta \xi_m)}{\xi_m (1 + \beta \kappa_m)} (\hat{mc}^m_t + \dot{\lambda}_{m,t}) \]

\[
m\hat{c}^m_t = (\hat{R}_t + \hat{s}_t - \hat{\pi}^m_t) \]  

The log-linearized real wage equation can be written

\[
\hat{w}_t \eta_1 + \hat{\omega}_{t-1} \eta_2 + \hat{w}_{t+1} \eta_2 + \hat{\omega}_{t+1} \eta_2 + \eta_3 (\hat{\pi}^d_t - \hat{\pi}^T) + \eta_4 (\hat{\pi}^d_{t+1} - \rho \pi \hat{\pi}^T) + \eta_5 (\hat{\pi}^d_{t-1} - \hat{\pi}^T) + \eta_6 (\hat{\pi}^d_t - \rho \pi \hat{\pi}^T) + \eta_7 \hat{\omega}_{t+1} + \eta_8 \hat{\omega}_t + \eta_9 \hat{\omega}^* = 0 \]  

Investment equation is given by

\[
P_{l_t}^l \hat{y}^d_t - \hat{y}^d_t - \mu_2 S^d \left[ (\hat{i}_t - \hat{i}_{t-1}) - \beta (\hat{i}_{t+1} - \hat{i}_t) + \mu_{xl} \right] - \beta \hat{\mu}_{xl} + \hat{\epsilon}_t = 0 \]  

The log-linearized UIP condition is given by

\[
\bar{R}_t - \bar{R}_t^* = E_t \Delta \hat{S}_{t+1} - \hat{\phi}_a \hat{a}_t + \hat{\phi}_t \]  

The aggregate resource constraint is given by
\begin{align}
(1 - \omega_c)(y^{c,d})^e c \frac{c}{y} (\hat{c}_t + \eta_c \hat{c}_t^d) + (1 - \omega_d)(y^{i,d})^n \frac{i}{y} (\hat{i}_t + \eta_i \hat{i}_t^d) \\
+ \frac{x}{y} (\gamma_t^* - \eta_f \hat{\gamma}_t^\epsilon) \\
= \lambda_d \left( (\hat{\epsilon}_t + \alpha \hat{\kappa}_t - \alpha \hat{\mu}_x t) + (1 - \alpha) \hat{H}_t \right) - r^k \frac{1}{\mu_z} \left( \hat{k}_t - \hat{\kappa}_t \right) \\
\end{align} \tag{A8}

Evolution of capital stock gives
\begin{align}
\hat{\kappa}_{t+1} = \frac{(1 - \delta)}{\mu_z} \hat{\mu}_{z, t} + (\hat{\gamma}_t + \hat{\lambda}_t) \left( 1 - \frac{(1 - \delta)}{\mu_z} \right) \\
\end{align} \tag{A9}

In the model, there are the following log-linearized relative prices
\begin{align}
\hat{\phi}_t^{m,d} &= \hat{\phi}_t^{m,d} + \hat{\phi}_t^m - \hat{\phi}_t^d \\
\hat{\phi}_t^{\epsilon^*} &= \hat{\phi}_t^{\epsilon^*} + \hat{\phi}_t^\epsilon - \hat{\phi}_t^{\epsilon^*} \\
\end{align} \tag{A10}

The log-linearized interest rate rule is given by (A12)
\begin{align}
\hat{R}_t &= \rho_R \hat{R}_{t-1} + (1 - \rho_R)(\hat{\sigma}_t^\epsilon + r_n \hat{R}_{t-1} - \hat{R}_t^\epsilon) + r_y \hat{Y}_{t-1} \\
&\quad + r_x \hat{x}_{t-1} + r_d \hat{\Delta}_t^\epsilon + r_d \hat{\Delta}_t^y + \epsilon_{R,t} \\
\hat{\sigma}_t^\epsilon &= \left( (1 - \omega_c)(y^{c,d})^e c \frac{c}{y} (\hat{c}_t + \eta_c \hat{c}_t^d) + (1 - \omega_d)(y^{i,d})^n \frac{i}{y} (\hat{i}_t + \eta_i \hat{i}_t^d) \right) \hat{\phi}_t^m \\
\hat{x}_t &= \hat{\phi}_t^{\epsilon^*} - \omega_c (y^{c,m})^{1 - \eta_c} \hat{\phi}_t^{m,d} \\
\end{align} \tag{A13}
### B. Tables and Graphs

#### Table 3.1 Data

<table>
<thead>
<tr>
<th>Data</th>
<th>Source</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real GDP growth ($\Delta \ln Y_t$)</td>
<td>TurkStat</td>
<td>Expenditure based, at 1998 prices</td>
</tr>
<tr>
<td>Real consumption growth ($\Delta \ln C_t$)</td>
<td>TurkStat</td>
<td>Private consumption, at 1998 prices</td>
</tr>
<tr>
<td>Real investment growth ($\Delta \ln I_t$)</td>
<td>TurkStat</td>
<td>Private investment, at 1998 prices</td>
</tr>
<tr>
<td>Real imports growth ($\Delta \ln M_t$)</td>
<td>TurkStat</td>
<td>Total imports, at 1998 prices</td>
</tr>
<tr>
<td>Real exports growth ($\Delta \ln X_t$)</td>
<td>TurkStat</td>
<td>Total exports, at 1998 prices</td>
</tr>
<tr>
<td>Inflation $(\pi_t)$</td>
<td>TurkStat</td>
<td>GDP deflator</td>
</tr>
<tr>
<td>Core inflation $(\pi_t^{\text{core}})$</td>
<td>TurkStat</td>
<td>H-index*</td>
</tr>
<tr>
<td>Real exchange rate $(rer_t)$</td>
<td>BIS</td>
<td>BIS effective exchange rate indices</td>
</tr>
<tr>
<td>Interest rate $(r_t)$</td>
<td>Bloomberg</td>
<td>3-month bond rate**</td>
</tr>
<tr>
<td>Import price inflation $(\pi_t^{\text{imp}})$</td>
<td>TurkStat</td>
<td>Import unit value index</td>
</tr>
<tr>
<td>Foreign output ($\Delta \ln Y_t^*$)</td>
<td>Eurostat</td>
<td>Euro area GDP</td>
</tr>
<tr>
<td>Foreign inflation $(\pi_t^*$)</td>
<td>FED</td>
<td>U.S. inflation rate</td>
</tr>
<tr>
<td>Foreign interest rate $(r_t^*$)</td>
<td>FED</td>
<td>U.S. FED Funds rate</td>
</tr>
</tbody>
</table>

As a first step, all variables are seasonally adjusted. Then interest rates are kept in level forms and divided by 400 to make annual rates consistent with quarterly data. For the other variables, I calculate quarterly growth by taking log-difference. Then all variables except inflation and interest rates are demeaned by subtracting their sample means, while interest and inflation rates are written as deviations from corresponding steady state values.

*Excludes unprocessed food, energy, alcoholic beverages, tobacco products and gold.
**For interest rate I prefer to use a short term bond rate which is a summary of all policy actions taken by Central Bank of Turkey who began to use multiple tools including interest rate corridor, required reserve ratios, reserve option facility in addition to the one week repo rate. I should note that the results do not change significantly when I use overnight rate or one-week repo rate instead of short term bond rate.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Calibrated Value</th>
<th>Targeted Variable*</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>Discount factor</td>
<td>0.9928</td>
<td>3% annual riskless real interest rate</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Capital share in production</td>
<td>0.4</td>
<td>60% steady-state share of labor income in total output</td>
</tr>
<tr>
<td>$\eta_c$</td>
<td>Consumption intra-temporal elasticity of substitution</td>
<td>1$^a$</td>
<td>Gertler, et al (2007)</td>
</tr>
<tr>
<td>$\eta_i$</td>
<td>Investment intra-temporal elasticity of substitution</td>
<td>0.25$^a$</td>
<td>Gertler, et al (2007)</td>
</tr>
<tr>
<td>$\sigma_i$</td>
<td>Labor supply elasticity</td>
<td>1</td>
<td>Alp and Elekdağ (2011)</td>
</tr>
<tr>
<td>$\phi_\alpha$</td>
<td>Elasticity of country risk premium with respect to net foreign debt</td>
<td>0.01</td>
<td>Alp and Elekdağ (2011)</td>
</tr>
<tr>
<td>$\omega_i$</td>
<td>Share of imported goods in investment</td>
<td>0.23</td>
<td>20% sample average of investment to GDP ratio</td>
</tr>
<tr>
<td>$\omega_c$</td>
<td>Share of imported goods in consumption</td>
<td>0.25</td>
<td>70% sample average of consumption to GDP ratio</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Depreciation rate</td>
<td>0.035</td>
<td>14% annual depreciation on capital</td>
</tr>
<tr>
<td>$\lambda_w$</td>
<td>Steady state mark-up rate for wages</td>
<td>1.15</td>
<td>15% steady state wage mark up</td>
</tr>
<tr>
<td>$\lambda_m$</td>
<td>Steady state mark-up rate for imports</td>
<td>1.15</td>
<td>15% steady state import price mark up</td>
</tr>
<tr>
<td>$\lambda_d$</td>
<td>Steady state mark-up rate for domestically produced goods</td>
<td>1.15</td>
<td>15% steady state mark up on domestic good prices</td>
</tr>
</tbody>
</table>

* The values of calibrated parameters are chosen to match some steady state ratios when the calibrated parameter has a direct correspondence in the data. The remaining calibrated parameters (including $\eta_c, \eta_i, \phi_\alpha, \sigma_i$) are taken from the literature.

$^a$In Turkey consumption goods are thought to have a higher degree of substitution than intermediate or investment goods, hence the intratemporal elasticity of substitution for the consumption composite, $\eta_c$, is set at a higher rate (i.e. at unity) than the intratemporal elasticity of substitution for the investment composite, $\eta_i$, (i.e. at 0.25).
Table 4.2 Prior and Posterior Distributions

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Type</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Mean</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calvo wages</td>
<td>$\xi_w$</td>
<td>Beta</td>
<td>0.75</td>
<td>0.10</td>
<td>0.749</td>
<td>0.591 - 0.912</td>
</tr>
<tr>
<td>Calvo domestic prices</td>
<td>$\xi_d$</td>
<td>Beta</td>
<td>0.75</td>
<td>0.10</td>
<td>0.920</td>
<td>0.893 - 0.948</td>
</tr>
<tr>
<td>Calvo import prices</td>
<td>$\xi_m$</td>
<td>Beta</td>
<td>0.75</td>
<td>0.10</td>
<td>0.798</td>
<td>0.744 - 0.853</td>
</tr>
<tr>
<td>Indexation wages</td>
<td>$\kappa_w$</td>
<td>Beta</td>
<td>0.50</td>
<td>0.10</td>
<td>0.497</td>
<td>0.338 - 0.668</td>
</tr>
<tr>
<td>Indexation prices</td>
<td>$\kappa_d$</td>
<td>Beta</td>
<td>0.50</td>
<td>0.10</td>
<td>0.299</td>
<td>0.237 - 0.362</td>
</tr>
<tr>
<td>Investment adj cost</td>
<td>$\delta$</td>
<td>Normal</td>
<td>5.00</td>
<td>1.00</td>
<td>5.457</td>
<td>3.965 - 6.885</td>
</tr>
<tr>
<td>Capital adj. cost</td>
<td>$\sigma_a$</td>
<td>Normal</td>
<td>0.05</td>
<td>0.50</td>
<td>1.084</td>
<td>0.57 - 1.600</td>
</tr>
<tr>
<td>Export demand elasticity</td>
<td>$\eta_f$</td>
<td>Normal</td>
<td>1.00</td>
<td>0.20</td>
<td>1.192</td>
<td>0.945 - 1.446</td>
</tr>
<tr>
<td>Shock persistence</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit root tech.</td>
<td>$\rho_{\mu.x}$</td>
<td>Beta</td>
<td>0.80</td>
<td>0.10</td>
<td>0.475</td>
<td>0.381 - 0.566</td>
</tr>
<tr>
<td>Stationary tech.</td>
<td>$\rho_{\mu.x}$</td>
<td>Beta</td>
<td>0.80</td>
<td>0.10</td>
<td>0.816</td>
<td>0.743 - 0.891</td>
</tr>
<tr>
<td>Investment</td>
<td>$\rho_{\mu.Y}$</td>
<td>Beta</td>
<td>0.80</td>
<td>0.10</td>
<td>0.914</td>
<td>0.871 - 0.963</td>
</tr>
<tr>
<td>Preference</td>
<td>$\rho_{\zeta.c}$</td>
<td>Beta</td>
<td>0.80</td>
<td>0.10</td>
<td>0.868</td>
<td>0.787 - 0.955</td>
</tr>
<tr>
<td>Labor supply</td>
<td>$\rho_{\zeta.h}$</td>
<td>Beta</td>
<td>0.80</td>
<td>0.10</td>
<td>0.800</td>
<td>0.648 - 0.957</td>
</tr>
<tr>
<td>Risk premium</td>
<td>$\rho_{\phi}$</td>
<td>Beta</td>
<td>0.80</td>
<td>0.10</td>
<td>0.900</td>
<td>0.860 - 0.943</td>
</tr>
<tr>
<td>Inflation target</td>
<td>$\rho_{\pi}$</td>
<td>Beta</td>
<td>0.80</td>
<td>0.10</td>
<td>0.618</td>
<td>0.472 - 0.771</td>
</tr>
<tr>
<td>Foreign interest rate</td>
<td>$\rho_{\gamma.*}$</td>
<td>Beta</td>
<td>0.80</td>
<td>0.10</td>
<td>0.935</td>
<td>0.897 - 0.977</td>
</tr>
<tr>
<td>Foreign demand</td>
<td>$\rho_{\gamma.*}$</td>
<td>Beta</td>
<td>0.80</td>
<td>0.10</td>
<td>0.812</td>
<td>0.703 - 0.927</td>
</tr>
<tr>
<td>Foreign inflation</td>
<td>$\rho_{\pi.*}$</td>
<td>Beta</td>
<td>0.80</td>
<td>0.10</td>
<td>0.859</td>
<td>0.768 - 0.957</td>
</tr>
<tr>
<td>Monetary policy rule</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoothing parameter</td>
<td>$\rho_R$</td>
<td>Beta</td>
<td>0.70</td>
<td>0.05</td>
<td>0.679</td>
<td>0.621 - 0.736</td>
</tr>
<tr>
<td>Inflation response</td>
<td>$r_\pi$</td>
<td>Normal</td>
<td>1.40</td>
<td>0.05</td>
<td>1.393</td>
<td>1.315 - 1.473</td>
</tr>
<tr>
<td>Diff. inflation response</td>
<td>$r_{\Delta \pi}$</td>
<td>Normal</td>
<td>0.125</td>
<td>0.05</td>
<td>0.125</td>
<td>0.050 - 0.199</td>
</tr>
<tr>
<td>Exchange rate response</td>
<td>$r_x$</td>
<td>Normal</td>
<td>0.00</td>
<td>0.05</td>
<td>0.019</td>
<td>-0.020 - 0.056</td>
</tr>
<tr>
<td>Output response</td>
<td>$r_y$</td>
<td>Normal</td>
<td>0.125</td>
<td>0.05</td>
<td>0.035</td>
<td>0.014 - 0.057</td>
</tr>
<tr>
<td>Diff. output response</td>
<td>$r_{\Delta y}$</td>
<td>Normal</td>
<td>0.05</td>
<td>0.05</td>
<td>0.035</td>
<td>0.012 - 0.059</td>
</tr>
</tbody>
</table>
Table 4.2 Prior and Posterior Distributions (continued)

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Type</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Mean</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shock volatility</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit root technology</td>
<td>$\sigma_{u,z}$</td>
<td>Inverse gamma</td>
<td>0.03</td>
<td>2.00</td>
<td>0.071</td>
<td>0.058 - 0.083</td>
</tr>
<tr>
<td>Stationary technology</td>
<td>$\sigma_{u,z}$</td>
<td>Inverse gamma</td>
<td>0.03</td>
<td>2.00</td>
<td>0.085</td>
<td>0.063 - 0.106</td>
</tr>
<tr>
<td>Marginal efficiency of investment</td>
<td>$\sigma_\gamma$</td>
<td>Inverse gamma</td>
<td>0.03</td>
<td>2.00</td>
<td>0.122</td>
<td>0.088 - 0.155</td>
</tr>
<tr>
<td>Preference</td>
<td>$\varepsilon_{\xi,\gamma}$</td>
<td>Inverse gamma</td>
<td>0.03</td>
<td>2.00</td>
<td>0.414</td>
<td>0.328 - 0.494</td>
</tr>
<tr>
<td>Labor supply</td>
<td>$\varepsilon_{\xi,\gamma}$</td>
<td>Inverse gamma</td>
<td>0.03</td>
<td>2.00</td>
<td>0.025</td>
<td>0.007 - 0.050</td>
</tr>
<tr>
<td>Risk premium</td>
<td>$\varepsilon_\phi$</td>
<td>Inverse gamma</td>
<td>0.03</td>
<td>2.00</td>
<td>0.008</td>
<td>0.005 - 0.001</td>
</tr>
<tr>
<td>Monetary policy</td>
<td>$\varepsilon_R$</td>
<td>Inverse gamma</td>
<td>0.03</td>
<td>2.00</td>
<td>0.006</td>
<td>0.005 - 0.008</td>
</tr>
<tr>
<td>Inflation target</td>
<td>$\varepsilon_{\pi,T}$</td>
<td>Inverse gamma</td>
<td>0.03</td>
<td>2.00</td>
<td>0.020</td>
<td>0.015 - 0.026</td>
</tr>
<tr>
<td>Domestic mark-up</td>
<td>$\varepsilon_{\lambda,\mu}$</td>
<td>Inverse gamma</td>
<td>0.05</td>
<td>2.00</td>
<td>0.043</td>
<td>0.012 - 0.078</td>
</tr>
<tr>
<td>Import mark-up</td>
<td>$\varepsilon_{\lambda,m}$</td>
<td>Inverse gamma</td>
<td>0.05</td>
<td>2.00</td>
<td>0.963</td>
<td>0.504 - 1.430</td>
</tr>
<tr>
<td>Foreign demand</td>
<td>$\varepsilon_{\gamma,x}$</td>
<td>Inverse gamma</td>
<td>0.01</td>
<td>2.00</td>
<td>0.077</td>
<td>0.063 - 0.091</td>
</tr>
<tr>
<td>Foreign interest rate</td>
<td>$\varepsilon_{R,x}$</td>
<td>Inverse gamma</td>
<td>0.01</td>
<td>2.00</td>
<td>0.002</td>
<td>0.001 - 0.002</td>
</tr>
<tr>
<td>Foreign inflation</td>
<td>$\varepsilon_{\pi,x}$</td>
<td>Inverse gamma</td>
<td>0.01</td>
<td>2.00</td>
<td>0.002</td>
<td>0.002 - 0.002</td>
</tr>
</tbody>
</table>

Table 4.3 Posterior variance decomposition in the model

<table>
<thead>
<tr>
<th>Shock/ Series</th>
<th>Output</th>
<th>Consumption</th>
<th>Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stationary technology</td>
<td>10.96</td>
<td>0.08</td>
<td>1.07</td>
</tr>
<tr>
<td>Unit root technology</td>
<td>57.61</td>
<td>17.06</td>
<td>36.53</td>
</tr>
<tr>
<td>Preference</td>
<td>6.56</td>
<td>82.04</td>
<td>13.22</td>
</tr>
<tr>
<td>Labor supply</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Domestic mark-up</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Import mark-up</td>
<td>0.13</td>
<td>0.01</td>
<td>0.28</td>
</tr>
<tr>
<td>Risk premium</td>
<td>2.87</td>
<td>0.02</td>
<td>0.93</td>
</tr>
<tr>
<td>Marginal efficiency of investment</td>
<td>13.10</td>
<td>0.71</td>
<td>45.20</td>
</tr>
<tr>
<td>Monetary policy</td>
<td>1.03</td>
<td>0.00</td>
<td>0.25</td>
</tr>
<tr>
<td>Foreign inflation</td>
<td>0.12</td>
<td>0.00</td>
<td>0.02</td>
</tr>
<tr>
<td>Foreign demand</td>
<td>4.69</td>
<td>0.03</td>
<td>0.38</td>
</tr>
<tr>
<td>Foreign interest rate</td>
<td>0.26</td>
<td>0.00</td>
<td>0.16</td>
</tr>
<tr>
<td>Inflation target</td>
<td>2.85</td>
<td>0.03</td>
<td>1.96</td>
</tr>
</tbody>
</table>
Figure 4.1a Prior and posterior distributions (Parameters)

Figure 4.1b Prior and posterior distributions (Monetary policy parameters)
Figure 4.1c Prior and posterior distributions (Shock processes parameter)
Figure 4.2 Data and one-sided predicted values from the model
Figure 5.1 Historical decomposition of output

Figure 5.2 Impulse Responses to Investment Shock
Central Bank of the Republic of Turkey
Recent Working Papers
The complete list of Working Paper series can be found at Bank’s website
(http://www.tcmb.gov.tr).

Systemic Risk Analysis of Turkish Financial Institutions with Systemic Expected Shortfall
(Irem Talaslı Working Paper No. 13/11, February 2013)

Household Expectations and Household Consumption Expenditures: The Case of Turkey
(Evren Ceritoğlu Working Paper No. 13/10, February 2013)

Oil Price Uncertainty in a Small Open Economy

Consumer Tendency Survey Based Inflation Expectations
(Ece Oral Working Paper No. 13/08, February 2013)

A Literature Overview of the Central Bank’s Knowledge Transparency
(M. Haluk Güler Working Paper No. 13/07, February 2013)

The Turkish Approach to Capital Flow Volatility

Market-Based Measurement of Expectations on Short-Term Rates in Turkey
(Ibrahim Burak Kanlı Working Paper No. 13/05, February 2013)

Yurtiçi Tasarruflar ve Bireysel Emeklilik Sistemi: Türkiye’deki Uygulamaya İlişkin Bir Değerlendirme
(Özgür Özel, Cihan Yağış Çalışma Tebliği No. 13/04, Şubat 2013)

Reserve Options Mechanism and FX Volatility
(Arif Oduncu, Yasin Akçelik, Ergun Ermişoğlu Working Paper No. 13/03, February 2013)

Stock Return Comovement and Systemic Risk in the Turkish Banking System
(Mahir Binici, Bülent Köksal, Cüneyt Orman Working Paper No. 13/02, February 2013)

Import Surveillance and Over Invoicing of Imports in Turkey
(Zelal Aktaş, Altan Aldan Working Paper No. 13/01, January 2013)

Nowcasting Turkish GDP Growth
(Hüseyin Çağrı Akkoyun, Mahmut Günay Working Paper No. 12/33, December 2012)

Rezerv Opsiyonu Mekanizması ve Optimal Rezerv Opsiyonu Katsaylarının Hesaplanması
(Doruk Küçüksaraç, Özgür Özel Çalışma Tebliği No. 12/32, Kasım 2012)

Finansal Krizlerin Belirleyicileri Olarak Hızlı Kredi Genişlemeleri ve Cari İşlemler Açığı
(Aytül Ganoğlu Çalışma Tebliği No. 12/31, Kasım 2012)

On the Sources and Consequences of Oil Price Shocks: The Role of Storage
(Deren Ünalmuş, İbrahim Ünalmuş, Derya Filiz Unsal Working Paper No. 12/30, November 2012)

Mitigating Turkey's Trilemma Tradeoffs

Capital Regulation, Monetary Policy and Financial Stability