ROLE OF INVESTMENT SHOCKS IN EXPLAINING BUSINESS CYCLES IN TURKEY

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF SOCIAL SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
THE DEPARTMENT OF ECONOMICS

FEBRUARY 2012

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ABSTRACT

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February 2012, 87 pages

This thesis aims to understand the sources of business cycles observed in Turkish economy. In particular the thesis investigates the role of investment shocks in explaining fluctuations in output. For this purpose a small open economy DSGE model is estimated on Turkish data for 2002-2011 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.

Keywords: Open economy, Bayesian estimation, Business cycle

ÖZ

TÜRKİYE İŞ ÇEVRİMLERİNİN AÇIKLANMASINDA YATIRIM ŞOKLARININ ROLÜ

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Tez Yöneticisi: Doç. Dr. Ebru Voyvoda

Şubat 2012, 87 sayfa

Bu tez, Türkiye ekonomisinde gözlenen iş çevrimlerinin kaynaklarını araştırmayı amaçlamaktadır. Özellikle, üretimde gözlenen dalgalanmaları açıklamada yatırım şoklarının rolü incelenmektedir. Bu amaçla Türkiye için 2002-2011 dönemi verileri kullanılarak bir küçük açık ekonomi dinamik stokastik genel denge modeli, Bayesçil yöntemlerle tahmin edilmektedir. Varyans ayrıştırma analizleri, kalıcı teknoloji şoklarının Türkiye ekonomisinde gözlenen iş çevrimlerinin en önemli kaynağı olduğunu, yatırım şoklarının rolünün ise daha sınırlı olduğunu göstermektedir.

Anahtar Kelimeler: Açık Ekonomi, Bayesçil Tahmin, İş Çevrimleri

To My Family

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to my thesis supervisor Assoc. Prof. Dr. Ebru Voyvoda for her guidance and effort throughout this study. I would also like to thank the examining committee members for their valuable comments and critiques.

I owe special thanks to The Scientific and Technological Research Council of Turkey for the financial support they provided throughout my graduate study.

I would like to express genuine appreciation to Ali Rıza Yücel for his help, tolerance and motivation. Without his invaluable company, this thesis could not be completed. I also want to sincerely thank Harun Alp and Hande Küçük for their support and helpful suggestions.

Finally, I am deeply indebted to my family, especially my mother Yasemin Yüksel, for their unconditional love, care and encouragement throughout my entire life.

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CHAPTER 1

INTRODUCTION

Explaining business cycles has been central in the public and academic debates for long periods. Different methods have been used to understand fluctuations in aggregate variables. On the one hand, the question is approached from the perspective of general equilibrium models. Analyses based on general equilibrium theory have claimed a central role for exogenous movements in total factor productivity, i.e. neutral technology shocks (Kydland and Prescott, 1982, King and Rebelo, 1999). On the other hand, the empirical approach to account for the business cycle questioned the standard predictions of RBC model that productivity shocks are the main source of business cycles. Moreover as discussed in Gali (1999), response of hours to technology shocks is found to be hard to reconcile with data. This line of research pointed at other disturbances such as labor supply shocks and oil prices (Shapiro and Watson, 1988).

In the last two decades a new generation of micro-founded general equilibrium models enriched with various nominal and real frictions gained popularity in many fields of macroeconomic analysis, including business cycle analysis. The developments on theory and estimation techniques of the so-called New Keynesian models stimulated emergence of a new literature that examines business cycles from a structural perspective. This approach involves estimation of Dynamic Stochastic General Equilibrium (DSGE) models utilizing Bayesian techniques, focusing on the historical and variance decomposition of main macroeconomic variables to explain business cycles. Leading examples of this line of research are those examining developed economies in closed economy settings (Smets and Wouters, 2003 and Justiniano et al., 2010). However, besides a host of research in closed economy models, open economy literature has not been far behind in utilizing Bayesian techniques (Bergin, 2003, Dib, 2003, Del Negro et al., 2004, Adolfson et al., 2007).

This thesis aims to understand the main sources of output fluctuations in Turkish economy in the last ten years within a general equilibrium framework. In particular this thesis investigates the role of investment shocks in explaining business cycles, whose contribution to macroeconomic fluctuations has been found to be significant for developed economies (Justiniano et al., 2010, Smets and Wouters, 2007). Also the importance of investment shock relative to other supply shocks such as stationary and unit-root productivity shocks, which have been found to be important for emerging market economies (Aguiar and Gopinath, 2007 and Alp and Elekdağ, 2011) is investigated. Understanding sources of business cycles is important for both market participants and policy makers. Understanding the cyclical patterns is also crucial for predicting and avoiding recessions and for policy design. For instance if investment shock turns to be the most important driving force in the economy, a policy advice to decrease output volatility would be decreasing the volatility of investment shock. Since the investment shock is related to financing conditions than taking measures to maintain financial stability may help to decrease volatilities of both investment shock and economic activity. Therefore for policy design it is important to know sources of business cycles. To this end, I develop a medium-scale open economy DSGE model for Turkish economy and estimate it on quarterly data using Bayesian estimation techniques. The model is buffeted by fourteen orthogonal shocks, including permanent and stationary shocks to total factor productivity, an investment shock, domestic and import mark-up shocks and a shock to labor supply. Using data on fourteen macroeconomic variables including output, inflation, interest rate, the real exchange rate, imports, exports and foreign economy variables for 2002:2-2011:3 period, key model parameters are estimated. The estimated model is then used to address a number of key business cycle issues such as computing variance decomposition of the observed variables and identifying the historical evolution of underlying shocks that explain business cycles fluctuations.

The structural model used in this thesis generally follows the framework set by Smets and Wouters (2003, 2007) and specifically extends the closed economy DSGE model of Justiniano et al., (2010) by incorporating the open economy aspects. The open economy features are in line with Adolfson et al. (2007). The theoretical model also integrates a number of nominal and real frictions including sticky prices, sticky wages, variable capital utilization, capital and investment adjustment costs and habit persistence in consumption. There is incomplete exchange rate pass-through in the import sector due to nominal price rigidities (i.e., local currency price stickiness) whereas law of one price is assumed to hold in the export sector. Consistent with small open economy perspective, foreign inflation, output and interest rate are assumed to be exogenously given.

In particular, this thesis gives a special focus on the role of investment shocks in understanding Turkish business cycles. Following the seminal work by Justiniano et al. (2010), who find that a shock to the marginal efficiency of investment[1] (MEI) is the key driver of business cycles observed in U.S. economy, investment shocks started to be one of the much debated driving forces in understanding macroeconomic fluctuations. Prior to Greenwood et al. (1988), investment shocks were considered as unlikely candidates to generate business cycles in a general equilibrium environment. Justiniano et al. (2010) is the first study to attribute investment shocks a key role in a DSGE setting. Among the studies examining sources of business cycles (Smets and Wouters, 2003 and 2007; Adolfson et al., 2007), permanent technology shocks and mark-up shocks have been the most pronounced disturbances, whereas contributions of investment shocks were found to be non-negligible, but less important. Especially for developing economies, permanent technology shock was proposed to be the key driving force of

[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 thesis I use the terms "MEI shock" and "investment shock" interchangeably.

macroeconomic fluctuations (Aguiar and Gopinath, 2007; Medina and Soto, 2007 and Alp and Elekdağ, 2011).

Role of various technology shocks including stationary, unit-root and investment specific technology shock as a key source of business cycles is a debated issue in macroeconomic analysis (Sims, 2011, Ravn and Simonelli, 2008). In general most of the studies including Smets and Wouters (2003, 2007), Justiniano et al. (2010) show that the three technology shocks combine to explain bulk of the cyclical variation in output, where the stationary technology shock has the smallest contribution. Hence the literature seems to agree on the overall importance of technology shocks relative to non-technology shocks. However, the literature is far from a consensus on the relative role of investment and permanent technology shocks. This thesis fits in this lively part of the literature and tries to answer what role investment shocks play in generating business cycles in Turkish economy.

The estimation results and variance decomposition analyses show that unit-root technology, investment and exogenous spending shocks 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 of the technology shocks. 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. There also seems to be an important contribution by the exogenous spending shock. However in comparison to studies on developed economies (e.g. Smets and Wouters, 2003, Adolfson et al. 2007), there seems to be a limited role for the mark-up and stationary technology shocks. These results are consistent with the findings of Alp and Elekdağ (2011), which is, to the best of my knowledge, the only other study utilizing Bayesian methods for a small open economy DSGE model tailored for Turkish economy.

The main contribution of this thesis is its provision of an analysis of Turkish business cycles from the perspective of a fully articulated DSGE model. The Turkish case often enforces an environment of working with short time series if the utilized model does not account for structural break or policy switch since there is a policy change and a set of structural reforms in post 2001 period, which should be taken into account. 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. Moreover this thesis 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 remainder of the thesis is organized as follows. Chapter 2 gives a brief review of the related literature. In Chapter 3 the theoretical model is described. Chapter 4 contains a short description of the data and a review of Bayesian methods. In Chapter 5, I first discuss the choice of parameters to calibrate, and the prior distributions for the estimated parameters. Then, I report the estimation results and compare the empirical properties of the estimated DSGE model with the actual data to validate the model fit. In this Chapter, I also discuss the role of various shocks in explaining Turkish business cycles. Finally, Chapter 6 concludes.

CHAPTER 2

SYNOPSIS OF THE LITERATURE ON DSGE MODELING, BAYESIAN ESTIMATION AND INVESTMENT SHOCKS

This chapter presents a review of the literature that is relevant for this thesis in three parts. The first section provides a summary of the literature on DSGE modeling with a special focus on the part of the literature which examines the sources of business cycles. Section 2.2 reviews the empirical literature on the estimation of DSGE models by the use of Bayesian techniques. This section discusses briefly the main studies applying such methods and their findings[2]. Lastly, Section 2.3 summarizes the literature investigating investment shocks and their findings. This section also provides some inference on the meaning and propagation of shocks to marginal efficiency of investment which is the main addressed disturbance in this thesis.

2.1. Literature on DSGE Modeling

This section provides an overview of the literature on theory of DSGE modeling, the main reference framework for the analysis of economic fluctuations in modern macroeconomic theory. In principle, DSGE models can help to identify sources of fluctuations, answer questions about structural shifts, forecast and predict the effect of policy changes, and perform counterfactual experiments. As a result of the ability of DSGE models to address such policy-relevant questions, these models have also been used by many policy-making institutions as a modeling framework.

Understanding the methodology of DSGE modeling requires a review of the transition from traditional quantitative macroeconomic models towards the so-called New Keynesian (NK) framework. The traditional macro models consist of a set of

[2] A detailed description of the method is presented in Chapter 4.

ad-hoc equations mimicking the behavior of key aggregate macroeconomic variables instead of an optimization-based approach. Failure of these models to predict the stagflation observed during the 1970s led to weakening of their popularity. This breakdown in the performance of these macroeconometric models together with the rational expectations revolution inspired by the Lucas critique gave way to the emergence of real business cycle (RBC) theory introduced by Kydland and Prescott (1982)[3]. For the first time, this paper proposed a small and coherent dynamic model of the economy, built from first principles with optimizing agents, rational expectations, and market clearing, that could match stylized facts in the data at a remarkable degree. The RBC models consider business cycles as efficient responses of a frictionless economy to exogenous movements in total factor productivity. Although these models were criticized on many aspects (such as assumption of frictionless, perfectly competitive markets, inability to match data on movement of hours and wage), methods of RBC approach have still been employed and the general structure of the RBC models with its "optimizing agents in a general equilibrium setting" is preserved in DSGE models.

Emergence of the New Keynesian (NK) paradigm is considered as an attempt to provide micro-foundations for resuscitating basic Keynesian concepts such as market imperfections, the inefficiency of aggregate fluctuations and rationale for policy making, as opposed to the RBC approach. Hence most of the work in NK literature, including Calvo (1983), Bernanke et al. (1999), Clarida et al. (1999), aimed to provide microfoundations such as nominal and real rigidities, financial market imperfections, and to incorporate these into general equilibrium models. DSGE models were developed by feeding of these mechanisms into the stochastic neoclassical growth model of Kydland and Prescott (1982).

The literature on open economy DSGE models was engendered by the contribution of Obstfeld and Rogoff (1995). Closed economy setting in the early works of DSGE models had problems in matching some facts in the data. To overcome such

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[3] King and Rebelo (1999) provides a detailed review of RBC models.

problems, open economy models incorporated the possibility that international trade in final goods and financial assets affects the evolution of the domestic economy giving rise to richer dynamics. Prominent studies on this line are Gali and Monacelli (2002) and Monacelli (2003). The former develops a small open economy model (SOEM) incorporating many of the microfoundations appearing in the closed economy NK framework, summarized in Woodford (2003). Monacelli (2003) on the other hand allows for local currency pricing of traded goods and presents a mechanism for limited pass-through of exchange rate movements to consumer prices. The SOEM in Adolfson et al. (2007) incorporates all the features of closed economy models, summarized in Christiano et al. (2005), and adds up some open economy features such as consumption and investment of foreign goods, saving in foreign bonds and incomplete exchange rate pass-through to both import and export prices. Their work provides an elegant example that nests most of the developments in the literature.

To sum up, over the past 25 years DSGE models, with their coherent frameworks, have become increasingly popular in both academia and in non-academic circles. Policy makers have become increasingly interested in usefulness of DSGE models for policy analysis and forecasting. This type of modeling approach seems to continue to be the reference framework for macroeconomic analysis.

2.2. Literature on Bayesian estimation of DSGE models[4]

Regarding the application of Bayesian techniques, this thesis is related to the large literature using estimated micro-founded models to understand the main sources of business cycle fluctuations (Smets and Wouters, 2003, Adolfson et al., 2007, Justiniano et al., 2010). With the explosion of research using Bayesian methods, the formal estimation of DSGE models has become one of the cornerstones of modern macroeconomics. This section presents the evolution of the literature towards use of

[4]This section is based on An and Schorfheide (2006), Lubik and Schorfheide (2007) and Fernández-Villaverde (2009), as main references that present detailed reviews of Bayesian methods in macroeconomic analyses.

Bayesian techniques in DSGE analysis. Moreover, the findings of leading examples of the Bayesian DSGE literature, related to business cycle analysis, are presented in this subsection.

Although DSGE models provide a complete multivariate stochastic process representation for the data, for a long time they were in many cases rejected against less restrictive specifications such as vector autoregressions (VAR). That was because the quantitative evaluation of DSGE models was conducted without formal statistical methods and the models constituted a framework that is more restrictive than VARs. Subsequently with the improvement of the structural models and the amendment of some misspecified restrictions, more traditional econometric techniques have become applicable such as generalized method of moments (GMM) estimation of equilibrium relationships, minimum distance estimation based on the discrepancy among VAR and DSGE model impulse response functions, (Christiano et al., 2005). However, as discussed in An and Schorfheide (2007), the econometric analysis of DSGE models has to cope with several challenges, including potential model misspecification and identification problems[5]. In recent years, to address these challenges, methods that are built around a likelihood function derived from the model, such as a Bayesian framework, have been developed for empirical work with DSGE models.

Bayesian estimation of DSGE models has three main advantages. First, instead of an estimation based on equilibrium relationships, the Bayesian analysis is system-based and it fits the solved DSGE model to a vector of aggregate time series. Second, the estimation is based on the likelihood function generated by the DSGE model itself rather than, for instance, the discrepancy between DSGE model responses and VAR impulse responses. Third, the use of priors enables the researcher to include additional information which helps to sharpen inference and provides a useful device

[5] DSGE model misspecification can take many forms including omitted non-linearities, misspecified structural relationships, or misspecification due to wrongly-specified exogenous processes. The identification problems may arise due to omitting a relevant observation or from a case where probability model implies different values of parameters lead to same joint distribution for the observable variables (Lubik and Schorfheide, 2007).

for incorporating micro-level information in the estimation of aggregate time series model. Prior distributions can be used to incorporate additional information into the parameter estimation and to re-weight the likelihood function so that the peak appears in a region of the parameter space that is consistent with extraneous information. This helps especially when data do not include information that's needed for identification of parameters. For example, estimates of the discount factor should be consistent with the average magnitude of real interest rates, even if the estimation sample does not include observations on interest rates. Moreover, use of prior information in Bayesian analysis provides a further advantage to cope with identification problems. In such a case even a weakly informative prior helps to update the likelihood function in directions of the parameter space in which it is not flat. This way the prior can introduce curvature into the posterior density surface that facilitates numerical maximization. Hence, Bayesian analysis provides a powerful framework for DSGE model estimation and inference.

The literature on likelihood-based Bayesian estimation of DSGE models is generally based on the studies by Landon-Lane (1998), DeJong et al. (2000), Schorfheide (2000) and Otrok (2001). The abovementioned superiorities of Bayesian estimation methods and the improvement in computational tools stimulated the use of Bayesian techniques in formal estimation and evaluation of DSGE models. A prominent example towards such a target is Smets and Wouters (2003). This paper estimates a medium-scale closed economy DSGE model for Euro area for 1980:2-1999:4 period and finds that the productivity and wage mark-up shocks are the main driving forces of output in medium to long run. Smets and Wouters (2003) also concludes that investment specific technology shock accounts for a significant, but much less important fraction of output developments at business cycle frequency. In a similar model estimated for U.S. economy, covering the period 1966:1-2004:4, Smets and Wouters (2007) finds that the identified sources of business cycle fluctuations and the effects of various shocks are similar to their findings for Euro Area. In another study for U.S. economy using 1954:3-2004:4 data, Justiniano et al. (2010) proposes that shocks to marginal efficiency of investment (MEI) is the main source of business cycles and this shock can explain more than half of the volatility in output. Justiniano et al. (2011) arrives at a similar conclusion based on estimating a medium-scale DSGE model for the U.S. economy by using the additional information in relative investment prices. This paper introduces two different types of investment shocks: first is the MEI shock which hits the capital good producer sector affecting the production of installed capital from investment goods and is related to factors other than price movements. The second is the investment specific technology (IST) shock that hits the investment good producing sector. This shock affects the transformation of consumption into investment goods and is identified with the relative price of investment. In this setting, Justiniano et al. (2011) concludes that the MEI shock remains to be the main source of business cycles while the role of IST shocks is negligible. On the other hand, Christiano et al. (2010) suggests a negligible role for MEI shocks and proposes a different source of variation (the risk shock) that governs the investment returns. Estimating a closed economy model, enriched with financial frictions and a banking sector, they conclude that the main source of fluctuations in both U.S. and Euro area is the risk shock.

Besides such closed economy studies, the question of "what is the main source of macroeconomic fluctuations" is also discussed in the open economy context by using Bayesian estimation techniques. For example, Justiniano and Preston (2004) considers the situations of imperfect exchange rate pass-through. Similarly Lubik and Schorfheide (2007) examines whether the central banks respond to exchange rates in open economies such as Australia and Canada. The distinguishing study by Adolfson et al. (2007) analyzes an open economy model that includes variable capital utilization as well as numerous real and nominal frictions and examines sources of business cycles in Euro Area in 1970:1-2002:4 period. According to their results, technology and mark-up shocks (especially in the Philips curves for import and export goods) appear to be of importance.

For Turkey, Alp and Elekdağ (2011) estimates a SOEM with financial accelerator channel. They find that the unit-root and investment-specific technology shocks are the two prominent supply shocks in explaining output fluctuations, whereas mark-up and stationary technology shocks play a limited role as a source of economic fluctuations.

2.3. 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.

$$\bar{K}_{t+1} = (1-\delta)\bar{K}_t + I_t[1 - S(\boldsymbol{\Upsilon_t} I_t/I_{t-1})] \tag{2.1}$$

$$\bar{K}_{t+1} = (1-\delta)\bar{K}_t + I_t\boldsymbol{\Upsilon_t}[1 - S(I_t/I_{t-1})] \tag{2.2}$$

Until late 1990's, investment shocks have been considered as unlikely candidates to generate business cycles in standard neoclassical environments, because they cannot 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 moves in opposite direction and 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:

$$MRS(C,L) \equiv MPL(L) \tag{2.3}$$

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 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 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% 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. Moreover Canova et al. (2006) finds similar results. 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[6]. 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 a 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:

$$\omega(L)MRS(C,L) \equiv MPL(L) \tag{2.4}$$

[6] The question and the main techniques applied in this thesis are largely based upon JPT (2010).

In (2.4), *ω(L)* can be treated as the sum of price and wage mark-up. When this wedge is countercyclical, i.e. *ω(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 *ω(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.

JPT (2010) is the first to find such a high explanatory power of MEI shock in an estimated DSGE model. In a quite similar model Smets and Wouters (2007) finds a smaller contribution of MEI shocks to volatility of output. JPT (2010) concludes that the main reason for this divergence of the results of the two related papers is the difference in definitions of consumption and investment variables.

The ultimate origin of MEI shocks is another debated issue in this part of the literature. JPT (2011) points out that MEI shock can be treated as a proxy for the effectiveness of financial intermediation in channelling household savings into productive capital since the 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 thesis, 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 (τ_t) associated with monitoring costs and would constitute a drain on the capital formation process:

$$\overline{K}_{t+1} = (1-\delta)\overline{K}_t + I_t[1-\tau_t] \tag{2.5}$$

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. On the other hand, in a recent paper Chrisitano 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.

CHAPTER 3

THE OPEN ECONOMY DSGE MODEL

This chapter gives an overview of the model economy and presents the key equations in the theoretical model. 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 used in this thesis has also similarities with that of Alp and Elekdağ (2011) except the financial accelerator mechanism in the latter. On the contrary, there is no explicit role for financial intermediation in this thesis.

The model economy is populated by households, domestic firms, importing and exporting firms, a government, 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. The model allows the imported goods to enter the aggregate investment as well as aggregate consumption, considering the significantly high share of imports in total investment in Turkey. 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 model. 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 whereas government spending is assumed to be an exogenous AR(1) process. 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 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 and the government.

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:

$$H_t = \left[\int_0^1 h_{j,t}^{\frac{1}{\lambda_{w,t}}} \, dj \right]^{\lambda_{w,t}} \quad (3.1)$$

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

$$\lambda_{w,t} = (1 - \rho_{\lambda w})\lambda_w + \rho_w \lambda_{w,t-1} + \varepsilon_{\lambda w,t} \quad (3.2)$$

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:

$$Y_t = \left[\int_0^1 Y_{i,t}^{\frac{1}{\lambda_{d,t}}} \, di \right]^{\lambda_{d,t}} \quad (3.3)$$

Here, $\lambda_{d,t}$ represents the time-varying markup in the domestic economy, which follows an exogenous process:[7]

$$\lambda_{d,t} = (1 - \rho_{\lambda_d})\lambda_d + \rho_{\lambda_d} \lambda_{d,t-1} + \varepsilon_{\lambda d,t} \quad (3.4)$$

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 out of its optimization problem is given by (3.5):

$$\frac{Y_{i,t}}{Y_t} = \left(\frac{P_t}{P_{i,t}} \right)^{\frac{\lambda_{d,t}}{\lambda_{d,t} - 1}} \quad (3.5)$$

[7] Note that assuming that these markup shocks are white noise implies setting $\rho_{\lambda d} = 0$.

$$P_t = \left[\int_0^1 P_{i,t}^{\frac{1}{1-\lambda_{d,t}}} \, di \right]^{1-\lambda_{d,t}} \tag{3.6}$$

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

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

where $K_{i,t}$ and $H_{i,t}$ are the capital services and labor inputs used by firm *i*, respectively. ϕ 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 do 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. ϵ_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:

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

The stationary shock has the following representation:

$$\hat{\epsilon}_t = \rho_\epsilon \hat{\epsilon}_{t-1} + \varepsilon_{\epsilon,t} \tag{3.9}$$

To ease notation, throughout the thesis, a variable with a hat denotes the log-deviations from steady-state values.

Given $P_{i,t}$, the intermediate firm that is constrained to produce $Y_{i,t}$ faces the following cost minimization problem:

$$min\{W_t H_{i,t} + R_t^k K_{i,t} + \lambda_t P_{i,t}[Y_{i,t} - \epsilon_t K_{i,t}^{\alpha}(z_t H_{i,t})^{1-\alpha} + z_t \phi]\} \tag{3.9}$$

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 $H_{i,t}$..

The first order conditions for the optimization (3.10) with respect to *H* and *K* are:

$$W_t = (1-\alpha)\lambda_t P_{i,t}\epsilon_t z_t^{1-\alpha}(H_{i,t}^{-1}K_{i,t})^{\alpha} \tag{3.11}$$

$$R_t^k = \alpha\lambda_t P_{i,t}\epsilon_t z_t^{1-\alpha}(K_{i,t}^{-1}H_{i,t})^{1-\alpha} \tag{3.12}$$

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 ξ_d that intermediate firms cannot readjust price optimally but choose according to the indexation rule:

$$P_{t+1} = P_t\,\pi_t^{\kappa_d}\,(\pi_{t+1}^T)^{1-\kappa_d} \tag{3.13}$$

where π_t is the gross inflation rate $\pi_t = (P_t/\mathrm{P}_{t-1})$ and π^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 :

$$E_t\left\{\sum_{s=0}^{\infty}(\xi_d\beta)^s \nu_{t+s}\left[P_{new,t}\left(\prod_{k=1}^{s}\pi_{t+k-1}^{\kappa_d}\,(\pi_{t+k}^T)^{1-\kappa_d}\right)Y_{i,t+s} - MC_{i,t+s}(Y_{i,t+s}+z_{t+s}\phi)\right]\right\} \tag{3.14}$$

ν is 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:

$$P_t = \left[\xi_d\left(P_{t-1}\,\pi_{t-1}^{\kappa_d}\,(\pi_t^T)^{1-\kappa_d}\right)^{\frac{1}{1-\lambda_{d,t}}} + (1-\xi_d)\left(P_{new,t}\right)^{\frac{1}{1-\lambda_{d,t}}}\right]^{1-\lambda_{d,t}} \tag{3.15}$$

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

$$\hat{\pi}_t - \hat{\pi}_t^T = \frac{\beta}{1+\beta\kappa_d}(E_t\hat{\pi}_{t+1} - \rho_\pi\hat{\pi}_t^T) + \frac{\kappa_d}{1+\beta\kappa_d}(\hat{\pi}_{t-1} - \hat{\pi}_t^T) - \frac{\kappa_d\beta(1-\rho_\pi)}{1+\beta\kappa_d}\hat{\pi}_t^T + \frac{(1-\xi_d)(1-\beta\xi_d)}{\xi_d(1+\beta\kappa_d)}(\widehat{mc}_t + \hat{\lambda}_{d,t}) \tag{3.16}$$

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 $(1-\xi_m)$. Importing firms cannot reset their price optimally with probability ξ_m but choose according to the indexation rule:

$$P_{t+1}^m = P_t^m(\pi_t^m)^{\kappa_m}(\pi_{t+1}^T)^{1-\kappa_m} \tag{3.17}$$

$\pi_t^m = (P_t^m/P_{t-1}^m)$ is the import price inflation. The importing firm i who sells M_i amount of imported goods, maximizes the following discounted profits:

$$E_t\left\{\sum_{s=0}^{\infty}(\xi_m\beta)^s \nu_{t+s}\left[P_{new,t}^m M_{i,t+s}(\pi_t^m \dots \pi_{t+s-1}^m)^{\kappa_m}(\pi_{t+1}^T \dots \pi_{t+s}^T)^{1-\kappa_m} - S_{t+s}P_{t+s}^*\left(M_{i,t+s} + z_{t+s}\phi^m\right)\right]\right\} \tag{3.18}$$

Φ^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:

$$M_t = \left[\int_0^1 \left(M_{i,t} \right)^{\frac{1}{\lambda_{m,t}}} di \right]^{\lambda_{m,t}} \tag{3.19}$$

The cost minimization problem implies that each importer faces an isoelastic demand for her product given by (3.20):

$$M_{i,t} = \left(\frac{P_{i,t}^m}{P_t^m} \right)^{\frac{-\lambda_{m,t}}{\lambda_{m,t}-1}} M_t \tag{3.20}$$

$$P_t^m = \left[\int_0^1 \left(P_{i,t}^m \right)^{\frac{1}{1-\lambda_{m,t}}} di \right]^{1-\lambda_{m,t}} \tag{3.21}$$

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:

$$\lambda_{m,t} = (1 - \rho_{\lambda_m})\lambda_m + \rho_{\lambda_m}\lambda_{m,t-1} + \varepsilon_{\lambda_{m,t}} \tag{3.22}$$

Aggregate import price is be given by:

$$\begin{aligned} P_t^m = \Big[& \xi_m \left(P_{t-1}^m (\pi_{t-1}^m)^{\kappa_m} \, (\pi_t^T)^{1-\kappa_m} \right)^{\frac{1}{1-\lambda_{m,t}}} \\ & + (1-\xi_m)\left(P_{new,t}^m \right)^{\frac{1}{1-\lambda_{m,t}}} \Big]^{1-\lambda_{m,t}} \end{aligned} \tag{3.23}$$

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

$$\begin{aligned} \hat{\pi}_t^m - \hat{\pi}_t^T = & \frac{\beta}{1+\beta\kappa_m} (E_t \hat{\pi}_{t+1}^m - \rho_\pi \hat{\pi}_t^T) + \frac{\kappa_m}{1+\beta\kappa_m} (\hat{\pi}_{t-1}^m - \hat{\pi}_t^T) \\ & - \frac{\kappa_m \beta (1-\rho_\pi)}{1+\beta\kappa_m} \hat{\pi}_t^T \\ & + \frac{(1-\xi_m)(1-\beta\xi_m)}{\xi_m(1+\beta\kappa_m)} \left(\widehat{mc}_t^m + \hat{\lambda}_{m,t} \right) \end{aligned} \tag{3.24}$$

where, $\widehat{mc}_t^m = \left(\hat{P}_t^* + \hat{s}_t - \hat{P}_t^m\right)$ 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 markup 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., 2005).

3.1.3. Exporting Firms

The exporting firms sell the final domestic good to the households in the foreign market. 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:

$$\check{X}_t = \left(\frac{P_t^x}{P_t^*}\right)^{-\eta_f} Y_t^* \tag{3.25}$$

$$P_t^x = P_t / S_t \tag{3.26}$$

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). As such, 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:

$$E_0^j \sum_{t=0}^{\infty} \beta^t \left[\varsigma_t^c ln\left(C_{j,t} - bC_{j,t-1}\right) - \varsigma_t^h A_L \frac{h_{j,t}^{1+\sigma_L}}{1+\sigma_L}\right] \tag{3.27}$$

In Equation (3.27), ς_t^c and ς_t^h are preference shocks and b is the internal habit persistence parameter. A_L is calibrated to match steady state level of hours. The preference shocks evolve according to:

$$\hat{\varsigma}_t^c = \rho_{\varsigma^c}\hat{\varsigma}_{t-1}^c + \varepsilon_{\varsigma_t^c} \tag{3.28}$$

$$\hat{\varsigma}_t^h = \rho_{\varsigma^h}\hat{\varsigma}_{t-1}^h + \varepsilon_{\varsigma_t^h} \tag{3.29}$$

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:

$$C_t = \left[(1-\omega_c)^{\frac{1}{\eta_c}} (C_t^d)^{\frac{\eta_c-1}{\eta_c}} + (\omega_c)^{\frac{1}{\eta_c}} (C_t^m)^{\frac{\eta_c-1}{\eta_c}}\right]^{\frac{\eta_c}{\eta_c-1}} \tag{3.30}$$

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

$$C_t^d = (1-\omega_c)\left(\frac{P_t}{P_t^c}\right)^{-\eta_c} C_t \tag{3.31}$$

$$C_t^m = \omega_c\left(\frac{P_t^m}{P_t^c}\right)^{-\eta_c} C_t \tag{3.32}$$

$$P_t^c = [(1-\omega_c)\,(P_t)^{1-\eta_c} + \omega_c\,(P_t^m)^{1-\eta_c}]^{\frac{1}{1-\eta_c}} \tag{3.33}$$

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

$$I_t = \left[(1-\omega_i)^{\frac{1}{\eta_i}} (I_t^d)^{\frac{\eta_i-1}{\eta_i}} + (\omega_i)^{\frac{1}{\eta_i}} (I_t^m)^{\frac{\eta_i-1}{\eta_i}}\right]^{\frac{\eta_i}{\eta_i-1}} \tag{3.34}$$

where ω_i is the share of imports in investment, and η_i is the elasticity of substitution between domestic and imported investment goods. Investment demand functions and aggregate investment price are given by:

$$I_t^d = (1-\omega_i)\left(\frac{P_t}{P_t^i}\right)^{-\eta_i} I_t \quad (3.35)$$

$$I_t^m = \omega_i \left(\frac{P_t^m}{P_t^i}\right)^{-\eta_i} I_t \quad (3.36)$$

$$P_t^i = [(1-\omega_i)\,(P_t)^{1-\eta_i} + \omega_i\,(P_t^m)^{1-\eta_i}]^{\frac{1}{1-\eta_i}} \quad (3.37)$$

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

$$\bar{K}_{t+1} = (1-\delta)\bar{K}_t + I_t \Upsilon_t [1 - S(I_t/I_{t-1})] + \Delta_t \quad (3.38)$$

The variable, Δ_t, reflects that households have access to a market where they can purchase new, installed physical capital $\bar{K}_{t+1}$. In this market, households wishing to sell $\bar{K}_{t+1}$ are the only suppliers, while households wishing to buy $\bar{K}_{t+1}$are the only source of demand. Since all households are identical, in equilibrium $\Delta_t = 0$. This variable is introduced to define the price of capital, $P_{k',t}$ (See Christiano et al., 2005 for further details). δ is the depreciation rate. The term in square brackets reflects the presence of costs of adjusting the flow of investment. As argued in Christiano et al., (2005), to enable the model to account for the hump-shaped response of investment to a monetary policy shock, 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 $S''>0$[8]. The second derivative of this function in steady state, S'', is a parameter that will be estimated. Υ_t represents a shock to marginal efficiency

[8] Lucca (2005) shows that this formulation of the adjustment cost function is equivalent to a generalization of the time to build assumption.

of investment which affects the transformation of investment into physical capital. Time series representation of $\hat{\Upsilon}_t = (\Upsilon_t - 1)/1$ is given by

$$\hat{\Upsilon}_t = \rho_{\Upsilon}\hat{\Upsilon}_{t-1} + \varepsilon_{\Upsilon,t} \tag{3.39}$$

Budget constraint of a representative household in nominal terms is:

$$\begin{aligned} P_t^c C_{j,t} &+ P_t^i I_{j,t} + T_t + B_{j,t+1} + S_t B_{j,t+1}^* \\ &= B_{j,t} R_{t-1} + R_{t-1}^* \phi\left(\frac{A_{t-1}}{z_{t-1}}, \tilde{\phi}_{t-1}\right) S_t B_{j,t}^* + \Pi_t \\ &+ W_{j,t} h_{j,t} + R_t^k u_{j,t} \bar{K}_{j,t} - P_t\big(a(u_{j,t})\bar{K}_{j,t} + P_{k',t}\Delta_t\big) \end{aligned} \tag{3.40}$$

$$A_t = \frac{S_t B_{t+1}^*}{P_t} \tag{3.41}$$

where T_t is lump-sum taxes, B and B^* are nominal bonds denominated in domestic and foreign currency, respectively. R_t is the gross nominal interest rate, Π_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 $R_{t-1}^* \phi\left(\frac{A_{t-1}}{z_{t-1}}, \tilde{\phi}_{t-1}\right)$ where A_t is the real aggregate net foreign asset position of the domestic economy and $\phi(.,.)$ 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 $\phi(.,.)$ captures imperfect integration in the international financial markets. If the domestic economy as a whole is a net borrower ($B^*<0$), 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. $\tilde{\phi}$ is a shock to the risk premium.

As the owners of physical capital stock, households choose capital utilization rate, u_t and pay the capital adjustment cost $P_t a(u_t)$. It denotes the cost, in terms of consumption good, of setting the utilization rate to u_t. 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, K_t is used which is transformed from physical capital $\overline{K}_t$ according to

$$K_t = u_t\overline{K}_t \tag{3.42}$$

Households solve the following maximization problem and choose $\{C_{j,t}, B_{j,t+1}, \overline{K}_{j,t+1}, I_{j,t}, u_{j,t}, B^*_{j,t+1}, h_{j,t}, \Delta_t\}$:

$$\begin{aligned}\sum_{t=0}^{\infty}\beta^t\Bigg\{&\varsigma_t^c ln\left(C_{j,t} - bC_{j,t-1}\right) - \varsigma_t^h A_L\frac{h_{j,t}^{1+\sigma_L}}{1+\sigma_L} \\ &+ \nu_t\Bigg[R_{t-1}B_{j,t} + R^*_{t-1}\phi\left(\frac{A_{t-1}}{z_{t-1}}, \tilde{\phi}_{t-1}\right)S_tB^*_{j,t} + \Pi_t + W_{j,t}h_{j,t} \\ &+ R_t^k u_{j,t}\overline{K}_{j,t} - P_t\left(a\left(u_{j,t}\right)\overline{K}_{j,t} + P_{k',t}\Delta_t\right) - P_t^c C_{j,t} - P_t^i I_{j,t} \\ &- T_t - B_{j,t+1} - S_tB^*_{j,t+1}\Bigg] \\ &+ \omega_t\left[(1-\delta)\overline{K}_{j,t} + I_{j,t}\Upsilon_t\left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] + \Delta_t - \overline{K}_{j,t+1}\right]\Bigg\}\end{aligned} \tag{3.43}$$

There is unit-root technology in the model, so the solution requires stationarizing the variables 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 (3.73), for any real variable X, $x_t=X_t/z_t$). 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:

w.r.t. c_t:

$$\frac{\varsigma_t^c}{c_t - bc_{t-1}/\mu_{z,t}} - \beta b\frac{\varsigma_{t+1}^c}{c_{t+1}\mu_{z,t+1} - bc_t} - \psi_{z,t}\frac{P_t^c}{P_t} = 0 \tag{3.44}$$

w.r.t. b_{t+1}:

$$-\psi_{z,t} + \frac{\psi_{z,t+1}}{\mu_{z,t+1}}\frac{R_t}{\Pi_{t+1}} = 0 \tag{3.45}$$

w.r.t. k_{t+1}:

$$-\psi_{z,t}P_{k't} + \beta\frac{\psi_{z,t+1}}{\mu_{z,t+1}}\left[(1-\delta)P_{k't+1} + r_{t+1}^k u_{t+1} - a(u_{t+1})\right] = 0 \tag{3.46}$$

w.r.t. Δ_t

$$-\frac{\psi_{z,t}}{z_t} P_{k't} + \omega_t = 0 \quad (3.47)$$

w.r.t. i_t:

$$-\psi_{z,t}\frac{P_t^i}{P_t} + \psi_{z,t}P_{k't}\Upsilon_t\left[1 - S\left(\frac{i_t\mu_{z,t}}{i_{t-1}}\right) - \frac{i_t\mu_{z,t}}{i_{t-1}}S'\left(\frac{i_t\mu_{z,t}}{i_{t-1}}\right)\right] + \beta P_{k't+1}\frac{\psi_{z,t+1}}{\mu_{z,t+1}}\Upsilon_{t+1}\left[\left(\frac{i_{t+1}\mu_{z,t+1}}{i_t}\right)^2 S''\left(\frac{i_{t+1}\mu_{z,t+1}}{i_t}\right)\right] = 0 \quad (3.48)$$

w.r.t. u_t:

$$\psi_{z,t}\left(r_t^k - a'(u_t)\right) = 0 \quad (3.49)$$

w.r.t. b^*:

$$-\psi_{z,t}S_t + \frac{\psi_{z,t+1}}{\mu_{z,t+1}\Pi_{t+1}}R_t^*\phi(a_t,\tilde{\phi}_t)S_{t+1} = 0 \quad (3.50)$$

Note that Ψ_z is the stationarized multiplier and $P_{k'}$ is the relative price of capital.

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

$$\phi(a_t,\tilde{\phi}_t) = exp(\tilde{\phi}_a(a_t - \bar{a}) + \tilde{\phi}_t) \quad (3.51)$$

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:

$$\hat{R}_t - \hat{R}_t^* = E_t\Delta\hat{S}_{t+1} - \tilde{\phi}_a\hat{a}_t + \tilde{\phi}_t \quad (3.52)$$

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_{jt}. The demand for labor that an individual household faces is determined by

$$h_{j,t} = \left[\frac{W_{j,t}}{W_t}\right]^{\frac{\lambda_{w,t}}{1-\lambda_{w,t}}} H_t \tag{3.53}$$

The model incorporates real rigidities and allows for wage stickiness. Every period with ξ_w probability, households cannot set their wage optimally but index it to last period's CPI inflation rate π_t^c, the current inflation target π_{t+1}^T, an adds a technology growth factor to their wage:

$$W_{j,t+1} = \mu_{z,t+1} W_{j,t} (\pi_t^c)^{\kappa_w} (\pi_{t+1}^T)^{1-\kappa_w} \tag{3.54}$$

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

$$E_t \sum_{t=0}^{\infty} (\xi_w \beta)^s \begin{bmatrix} -\varsigma_{t+s}^h A_L \dfrac{h_{j,t+s}^{1+\sigma_L}}{1+\sigma_L} \\ +h_{j,t+s} \upsilon_{t+s} (\pi_t^c \dots \pi_{t+s-1}^c)^{\kappa_w} \\ (\pi_{t+1}^T \dots \pi_{t+s}^T)^{1-\kappa_w} (\mu_{z,t+1} \dots \mu_{z,t+s}) W_{new j,t} \end{bmatrix} \tag{3.55}$$

The log-linearized real wage equation is given by:

$$\begin{aligned} \widehat{w}_t \eta_1 + \widehat{w}_{t-1} \eta_0 + \widehat{w}_{t+1} \eta_2 + \eta_3 (\hat{\pi}_t^d - \hat{\pi}_t^T) + \eta_3 (\hat{\pi}_{t+1}^d - \rho_\pi \hat{\pi}_t^T) \\ + \eta_5 (\hat{\pi}_{t-1}^c - \hat{\pi}_t^T) + \eta_6 (\hat{\pi}_t^c - \rho_\pi \hat{\pi}_t^T) + \eta_7 \hat{\psi}_{z,t}^T \\ + \eta_8 \widehat{H}_t + \eta_{11} \hat{\zeta}_t^h = 0 \end{aligned} \tag{3.56}$$

3.3. The Government

The model assumes that government expenditures are given exogenously as an AR(1) process:

$$g_t = \rho_g g_{t-1} + \varepsilon_{g,t} \tag{3.57}$$

3.4. The Central Bank

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

$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1-\rho_R)\big(\hat{\pi}_t^T + r_\pi(\hat{\pi}_{t-1}^c - \hat{\pi}_t^T) + r_y \hat{y}_{t-1} + r_x \hat{x}_{t-1}\big) + r_{\Delta\pi}\Delta\hat{\pi}_t^c + r_{\Delta y}\Delta\hat{y}_t + \varepsilon_{R,t} \tag{3.58}$$

where $\hat{R}_t$ is the short-term interest rate, $\hat{\pi}_t^c$ 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), and thus not as the deviation from the flexible price level as in Smets and Wouters (2003) or JPT (2010).

$\hat{x}_t$ is the log-linearized real exchange rate, which is given by

$$\hat{x}_t = \hat{S}_t + \hat{P}_t^* - \hat{P}_t^c \tag{3.59}$$

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

$$\hat{\pi}_t^c = \left[(1-\omega_c)\left(\frac{P_t}{P_t^c}\right)^{1-\eta_c}\hat{\pi}_t^d + \omega_c\left(\frac{P_t^m}{P_t^c}\right)^{1-\eta_c}\hat{\pi}_t^m\right] \tag{3.60}$$

$\hat{\pi}_t^T$ is the time-varying inflation target which can be referred as inflation target shock:

$$\hat{\pi}_t^T = \rho_\pi \hat{\pi}_{t-1}^T + \varepsilon_{\hat{\pi}_t^T} \tag{3.61}$$

3.5. Foreign Economy

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

$$\hat{\pi}_t^* = \rho_{\pi*}\hat{\pi}_{t-1}^* + \varepsilon_{\pi*,t} \tag{3.62}$$

$$y_t^* = \rho_{y*} y_{t-1}^* + \varepsilon_{y*,t} \tag{3.63}$$

$$R_t^* = \rho_{R*} R_{t-1}^* + \varepsilon_{R*,t} \tag{3.64}$$

3.6. 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:

$$C_t^d + I_t^d + G_t + \check{X}_t + a(u_t)\bar{K}_t \leq \epsilon_t K_{i,t}^{\alpha} (z_t H_{i,t})^{1-\alpha} - z_t \phi \tag{3.65}$$

In stationary form the resource constraint is:

$$\begin{aligned}(1-\omega_c)\left(\frac{P_t^c}{P_t}\right)^{\eta_c} c_t + (1-\omega_i)\left(\frac{P_t^i}{P_t}\right)^{\eta_i} i_t + g_t + \left(\frac{P_t^x}{P_t^*}\right)^{-\eta_f} y_t^* \\ \leq \epsilon_t k_t^{\alpha}\left(\frac{1}{\mu_{z,t}}\right)^{\alpha} (H_t)^{1-\alpha} - \phi - a(u_t)\frac{\bar{k}_t}{\mu_{z,t}}\end{aligned} \tag{3.66}$$

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

$$S_t B_{t+1}^* = S_t P_t^x \check{X}_t - S_t P_t^* (C_t^m + I_t^m) + R_{t-1}^* \phi(a_{t-1}, \tilde{\phi}_{t-1}) S_t B_t^* \tag{3.67}$$

3.7. Relative Prices

Various stationary relative prices enter the model. First is defined in terms of the imported good. That is, the relative prices between domestically produced goods and imported goods perceived by the domestic agents. Contrary to ALLV (2007) model, there is only one domestic relative price since the domestic agents face same price on the imported consumption goods and the imported investment goods:

$$\gamma_t^{m,d} = \frac{P_t^m}{P_t} \tag{3.68}$$

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

$$\gamma_t^{c,d} = \frac{P_t^c}{P_t} \tag{3.69}$$

$$\gamma_t^{i,d} = \frac{P_t^i}{P_t} \tag{3.70}$$

The relative price between the domestically produced goods (home exports) and the foreign goods governs the export demand:

$$\gamma_t^{x,*} = \frac{P_t^x}{P_t^*} \tag{3.71}$$

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

$$mc_t^m = \frac{S_t P_t^*}{P_t^m} = \frac{1}{\gamma_t^{m,d} \gamma_t^{x,*}} \tag{3.72}$$

3.8. 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 $\overline{K}_t$ are stationarized with z_{t-1} whereas the other real variables with z_t. Following Adolfson et al. (2005) the variables are stationarized in the following way[9]:

$$c_t \equiv \frac{C_t}{z_t}, r_t^k \equiv \frac{R_t^k}{P_t}, \bar{w}_t \equiv \frac{W_t}{P_t z_t}, k_{t+1} \equiv \frac{K_{t+1}}{z_t}, \bar{k}_{t+1} \equiv \frac{\bar{K}_{t+1}}{z_t}, y_t^* \equiv \frac{Y_t^*}{z_t} \tag{3.73}$$

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[10]. 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. That's why linear approximation methods are very popular in the context of likelihood-based DSGE model estimation. The model is completed by defining a set of measurement equations that relate the endogenous variables of the model to a set of observables.

[9] 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 our data set cannot pin down this shock and this may lead to under-identification problem.

[10] See Appendix A for the linear system of equations.

CHAPTER 4

DATA AND METHOD

The DSGE model in this thesis is estimated for Turkish economy with Bayesian econometric techniques. This chapter presents a review of Bayesian estimation techniques and presents a description of the data used in the estimation process.

4.1. Data

There exist fourteen exogenous shocks in the model economy. The estimation is done with fourteen observable variables so that there exist as many observed variables as shocks to avoid stochastic singularity and identification problems[11].

In line with the existing literature, the following key macroeconomic data series are tried to match: 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 (the H-index defined by TURKSTAT) and import and export prices together with foreign consumer price indices. Regarding the foreign variables, for real GDP, Euro area GDP is used since the Euro area is Turkey's largest trading partner. For interest rate, and inflation rate, U.S. data are used.

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

[11] 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.

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 2002:2-2011:3. Although the data set could be extended up to 1987, I chose to start the estimation from 2002 to capture the episode when the Central Bank of Turkey (CBRT) began to implement an inflation targeting regime (initially implicitly, and explicitly starting in 2006). This way, I tried to avoid spurious inference by excluding the periods where regime changes and structural breaks were observed.

4.2. Method

The method followed for the solution and estimation of the model discussed in Chapter 3 briefly involves two steps: first the model is solved and written in state-space form. Then the log-linear system is estimated by Bayesian techniques.

Solving the model means writing the whole system in terms of lagged variables and current shocks. The coefficients in the 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 reduced form of the model is given by the following state-space form:

$$x_t = G(\theta)x_{t-1} + M(\theta)\varepsilon_t \tag{4.1}$$

$$y_t = H(\theta)x_t \tag{4.2}$$

Here x_t is the vector of endogenous variables written as log deviations from the corresponding steady state values, ε_t is the vector of structural shocks and θ 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.

Advantage of working with a log-linear model is that it allows one to simulate the dynamic response of the model variables to exogenous shocks and calculate descriptive statistics for all the variables in the model. Moreover, once written in linear state-space form, there are various ways of estimating or calibrating the parameters of a DSGE model. Geweke (1999) distinguishes between the weak and the strong econometric interpretation of DSGE models. The weak interpretation is built upon calibration and matching data moments or more generally aims to minimize the distance between empirical and theoretical impulse response functions. In this approach, the parameters of a DSGE model are calibrated in such a way that selected theoretical moments given by the model match as closely as possible those observed in the data.

The strong econometric interpretation on the other hand, attempts to provide a full characterization of the observed data series. Following Sargent (1989), a number of authors have estimated the structural parameters of DSGE models using classical maximum likelihood method. As discussed in detail by Smets and Wouters (2003), the classical maximum likelihood methods involve using the Kalman filter to form the likelihood function after writing the model in its state-space form and the parameters are estimated by maximizing the likelihood function. Alternatively within this strong interpretation, a Bayesian approach can be followed to estimate and evaluate DSGE models by combining the likelihood function with prior distributions for the parameters of the model, to form the posterior density function. Leading examples of such a Bayesian approach are Otrok (2001), Fernandez-Villaverde and Rubio-Ramirez (2004), and Schorfheide (2000), Smets and Wouters (2003).

Following the literature, this thesis uses Bayesian estimation techniques for estimating the developed DSGE model with the aim of analyzing the sources of business cycle movements in Turkey. This approach is chosen to include additional information to the estimation process by using prior information over the structural parameters so that the highly nonlinear optimization algorithm becomes more stable. This is particularly valuable when only relatively small samples of data are available (Smets and Wouters, 2003), as is the case with Turkish time series.

To implement rules resulting from agents' optimization problems, there is need to determine objects including mean or variance of the parameters -$E(\theta)$ or $Var(\theta)$. In particular in Bayesian analysis, the interest is to obtain the entire distribution of θ conditional on the available data, $p(\theta | Y)$. The existence of $p(\theta | Y)$ reflects the basic assumption of Bayesian approach that parameters are random variables with a probability distribution, whereas classical econometric analysis treats parameters as fixed, but unknown quantities.

The likelihood function of the observed data series, $p(Y | \theta)$, is evaluated with the Kalman filter. Bayesian approach involves combining this likelihood function, with prior distributions for the structural parameters of the model, θ. The prior distribution $p(\theta)$ describes the available information prior to observing the data and summarizes information from other datasets not included in the estimation sample or economic theory. The observed data, Y, is then used to update the prior, via Bayes theorem, to the posterior distribution of the model's parameters, $p(\theta | Y)$. Hence one can think of Bayesian inference as an update of beliefs (Primiceri, 2011). The posterior is proportional to the product of the likelihood and the prior:

$$p(\theta|y) \propto p(y|\theta)p(\theta) \tag{4.3}$$

The posterior is then optimized with respect to the model parameters either directly or through Monte-Carlo Markov-Chain (MCMC) sampling methods[12]. The objective of MCMC methods is describing the distribution of the posterior by taking draws from it. In general, the Metropolis–Hastings algorithm, which is a MCMC method, is used for obtaining a sequence of random samples from a probability distribution for

[12] Before posterior simulation, the posterior is maximized numerically with respect to θ, to find the maximum for initializing MCMC.

which direct sampling is difficult. This sequence is then used to approximate the posterior distribution. Main aim of Metropolis-Hasting algorithm is to sample from the region with highest probability but also to visit the parameter space as much as possible. The procedure assumes an initial draw from the posterior and as a first step a candidate value is drawn. Then kernel of posterior is computed at the initial point and at the draw. If the jump is uphill, draw is always accepted. If it is downhill, the draw is kept with some nonzero probability. Then the procedure is repeated from the first step. To monitor the convergence to an invariant distribution, best thing is to run multiple chains starting from disperse initial conditions (Primiceri, 2011). The advantage of MCMC algorithm is that MCMC approximating density changes as iterations progress so that if mistakes are made at some point, they are not carried to the next iteration.

In summary, Bayesian inference starts out from a prior distribution that describes the available information prior to observing the data. The observed data is used to update the prior to the posterior distribution of the model's parameters, which combines the prior information on the parameters with the likelihood of the data. Then, mode of the posterior distribution is estimated by maximizing the log posterior function. In a second step, the Metropolis-Hastings algorithm is used by generating draws to get a complete picture of the posterior distribution and to evaluate the marginal likelihood of the model[13].

[13] Chib and Greenberg (1995) provide details of Metropolis-Hastings algorithm and Schorfheide (2000) present further details about Bayesian estimation.

CHAPTER 5

ESTIMATION

This chapter presents the main results in terms of parameter estimates, impulse responses and business cycle variance decomposition[14]. Moreover a discussion of how these results fit in the literature is given by comparing parameter estimates across studies. It is important to note that although such comparison is potentially useful, two critical issues should be kept in mind. First, various studies consider distinct countries and sample periods and the structural features of the economies investigated are different. For example, estimation sample of this thesis includes the periods of the recent global financial crisis, while most other studies (except Alp and Elekdağ, 2011) do not. Second, while most of the models build upon a common core, important differences between models specifications still remain. In sum, modeling, sample period, and data differences should be recognized when comparing posterior estimates across various studies.

Section 5.1 discusses which parameters are calibrated and presents the prior and posterior values of the estimated parameters. Section 5.2 discusses the empirical fit of the model and presents an evaluation of the model in terms of data fit. The variance decomposition results are presented in section 5.3. In this section I will discuss which shocks are found to be important for business cycle fluctuations in Turkey. Based on the variance decomposition results, the most relevant shocks are discussed in detail in Section 5.4 giving a brief intuition for how they propagate in the economy. Since unit-root and investment-specific technology shocks turn out to govern most business cycle fluctuations, Section 5.5 focuses on technology shocks

[14] To carry out the numerical procedure, the software called Dynare is used in this thesis. Dynare is a collection of Matlab and GNU Octave routines (freely available http://www.dynare.org) which basically solve, simulate and estimate the models with forward looking variables.

discussing which of the technology shocks are found likely to matter for business cycles in the related literature with a particular focus on emerging market economies.

5.1. Model Parameters

In this thesis a combination of calibration and estimation strategy is followed as is common in the literature. A selected set of parameters are kept fixed from the start of the estimation[15]. 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 5.1 reports the calibrated parameters.

The discount factor, β, is calibrated to be 0.9928, which implies an annual steady-state real interest rate around 3 percent. The depreciation rate, δ, is set equal to 0.035 per quarter, which indicates an annual depreciation on capital equal to 14 percent. Similarly, α is set to 0.40, 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 (ω_c) and investment (ω_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 (steady state) government expenditure-output ratio is set equal to its sample mean of 0.1. 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 Elekdağ (2011), the labor supply elasticity σ_L is set to 1. In addition, the parameters capturing the markup 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

[15] This can be considered as giving infinitely strict priors.

variables included in the data set. Consistent with Alp and Elekdağ (2011), the steady state price and wage markups 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 Elekdağ (2011) and are also summarized in Table 5.1.

The remaining 39 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. Table 5.2 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 Elekdağ (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 ξ, the indexation parameters κ, the habit persistence b, and the persistence parameters of the shock processes ρ. 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 σ, the inverse gamma distribution is proposed. For the unbounded parameters, the normal distribution is assumed. This applies for instance to capital utilization cost (σ_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 Adolfson, Laséen, Linde and Villani (2007), (ALLV, hereafter). 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 chose a smaller value of 0.01. For all other shocks prior means are set to 0.03 in line with Alp and Elekdağ (2011).

The results are reported in Table 5.2. The Table shows the means along with the 5th and 95th 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 5.3. Additional information on the estimation results is presented in Figure 5.1a through Figure 5.1d, 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.

The Calvo parameter for domestic goods is found around 0.66 which implies domestic prices are adjusted on average every 3 quarters. The degree of domestic price stickiness is higher than the value found in Alp and Elekdağ (2011) and lower than 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 higher than that of domestically produced goods which is consistent with the findings of Alp and Elekdağ (2011). But the ALLV (2008) finds a reverse order suggesting import good prices are less sticky than domestic good prices. The indexation parameters (i.e. the κ's) are around 0.5 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, as expected. 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 thesis is similar to that of ALLV (2007). The interest rate smoothing parameter, which is found to be 0.7, is in line with many other studies. As for the responsiveness of inflation deviation from target, the estimated value of 1.42 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 0.08. 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 discretionary 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 0.3 for the foreign inflation shock, and 0.93 for the foreign interest rate shock. A caveat should be made here. As will be discussed in 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 mode of the persistence parameter in the unit-root technology process is estimated to be 0.55. In addition, the persistence coefficient for the stationary technology shock is estimated to be around 0.77. These values compare quite favorably to the estimates in Alp and Elekdağ (2011). As for standard deviations, the foreign interest rate shock is the least volatile, whereas the variability of the preference, exogenous spending and import mark-up shocks are noteworthy. It may also be useful to point out that as in other studies (Alp and Elekdağ, 2011, ALLV, 2007), the unit-root technology shock is more volatile than the stationary technology shock. As will be discussed in further detail in Section 5.3, in terms of driving the business cycle, it's expected to see that the unit-root technology shocks plays a much more prominent role. This finding is consistent with the theoretical predictions of Aguiar and Gopinath (2007) which emphasizes the fact that shocks to trend growth are the primary source of fluctuations in developing countries rather than transitory fluctuations around a stable trend.

5.2. Model Fit

Model evaluation is an important part of the empirical work that is based on DSGE modeling. Figure 5.2 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 5.2, the in-sample fit of the model is satisfactory. However, the model is not good at capturing exports and other foreign variables. In this thesis, 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 the modeling approach here 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[16]. 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 a certain extent. As is clear in Figure 5.2, the model is quite good in capturing main components of output including consumption, investment and imports.

[16] However, since the main question of this thesis does not focus on foreign variables (or related shocks), this does not constitute a serious problem.

5.3. Shocks and Business Cycles

This section analyzes the driving forces of fluctuations 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 5.3 reports the variance decompositions.

The "unit root technology" row of Table 5.3 makes clear that unit-root technology shocks account for 60 percent of the fluctuations in output, almost 35 percent of those in consumption and around 47 percent of those in investment; these are by far the largest shares. Also Figure 5.3 shows that unit-root technology 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 trend growth constitute the primary source of fluctuations in emerging markets.

The model in this thesis has two productivity processes, a transitory shock around the trend growth rate of productivity ($\mathcal{E}_t$) and a stochastic trend growth rate (z_t). The intuition for the model's dynamics is as follows. A positive shock to stationary technology makes agents increase their consumption and investment spending as they observe the economy entering a period of high growth. However, a positive disturbance to unit-root technology implies a boost to current output, but an even larger boost to future output. This implies that consumption responds more than income, reducing savings. 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. Conversely, an economy with a relatively stable growth process will be dominated by standard, transitory productivity shocks (Aguiar and Gopinath, 2007).

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 markets 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. 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, Akkoyun et al. 2011). 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[17]. Therefore finding unit-root technology shocks, which affect the trend growth rate, as the leading source of macroeconomic fluctuations in Turkish economy is in line with the suggestions of the literature.

Looking at the other shocks and variables, two results stand out. First, the investment shock appears to be fairly important. Together with the exogenous spending shock they stand as the next set of important shocks in explaining output fluctuations. Shocks to marginal efficiency of investment (MEI) are important in explaining output fluctuations. Investment is one of the most volatile components of output

[17] See Alp et al. (2012) for a detailed survey of Turkish economy business cycle stylized facts.

(volatility of investment relative to output is around 3) in Turkey. Explaining such a volatile variable requires a high role for the shock that is closely related to investment. Moreover, this shock is also closely related to financing conditions. As suggested in Chrisitano et al. (2010) and Justiniano et al. (2011), investment shocks might proxy for more fundamental disturbances to the intermediation ability of the financial system since access to credit and financial intermediation are important determinants of investment. Regarding the high volatility in financing conditions in Turkey (mainly due to the close relation of domestic credit to the highly volatile variables such as risk premium and capital flows) investment shock is naturally expected to play an important role in Turkish business cycles. However, the MEI shock is found to contribute less than expected and it accounts only for 10 percent of the fluctuations in output. Compared to the findings of JPT (2010), the role of investment shocks in explaining business cycles turns out to be less spelled. As discussed in JPT (2010), part of this conclusion may be related to the measurement of the observable variables. JPT (2010) argues that main reason why the studies that find less significant role of investment shocks in business cycles, is the difference in measurement of investment and consumption series[18]. In JPT (2010), investment series includes durable consumption and change in inventories. However, in Turkish data, there is no explicit time series for durable and non-durable consumption. Hence consumption series used in the estimation includes purchases of consumer durables in consumption, whereas JPT (2010) includes durable consumption in investment. This increases (decreases) the volatility of investment (of consumption) in JPT data set, compared to a case where durable consumption is included in consumption. Since Turkish data do not allow for such a differentiation, the way variables are measured may be resulting in a less volatile investment series than it should be. Although investment is a highly volatile component of GDP in Turkey, it may be the case that including durable consumption in investment may help to have a higher role for investment shocks as such inclusion would add up to the existing volatility

[18] Smets and Wouters (2003), for instance is one study that reports a lower effect for investment shocks in business cycles.

of investment. For model dynamics relative volatility of the variables does also matter. Such measurement of investment would add up to the volatility of investment relative to that of GDP as well. Hence, a higher volatility of investment might be necessary to have a higher role for investment shocks since the Turkish real GDP series is also volatile. As Guerron-Quintana (2010) points out the estimation results are quite sensitive to the used data. Another reason why investment shocks turn to play a minor role can be related to the impulse response analysis. As evident in Figure 5.5, investment shock leads output and consumption to move in opposite directions. Although model incorporates all the mechanisms that are proposed to be important for transmission of investment shocks, the estimated model does not generate the comovement of output and consumption. Given the strongly positive correlation of output and consumption over the business cycle in Turkey (Alp et al., 2012, this implies that investment shocks cannot play a leading role in the business cycles as given by the variance decomposition analysis.

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 b_t is necessary to reconcile the interest rates with the growth rate of consumption. Especially in case of Turkey where the volatility of consumption is quite high (even as high as that of output, as discussed in Alp et al., 2012), 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.

5.4 Model dynamics and shock identification

The variance decomposition analysis identifies that permanent technology and investment shocks explain bulk of the variation in output observed in Turkey. Therefore, the results of this thesis suggest that to understand business cycles in Turkish economy, one must understand permanent technology shocks and investment shocks, since these shocks are the largest contributors to fluctuations in several key macroeconomic variables. This section provides some intuition for how this identification is achieved, by studying the impulse responses of several key variables to some of the shocks. In particular, I focus on the two shocks that are responsible for the bulk of fluctuations according to estimation results: the investment shock and the unit-root technology shock. Figures 5.4 and 5.5 report the impulse responses to these shocks.

Figure 5.4 reports the impulse responses to unit root technology shock. Following a positive impulse, output, consumption and investment all rise. The reaction in investment is contemporaneous and roughly proportional to that in output, but larger. Real wages are also procyclical. The response of hours is very similar to that of output.

Figure 5.5 reports the impulse responses to investment shock. As evident in Figure 5.5, investment shocks trigger procyclical movements in all key macroeconomic variables. Following a positive impulse, output, hours and investment all rise. But the movement of consumption reminds the Barro-King (1984) critique. It shows a drop and remains flat, and rises after a long time. Finally, inflation and the nominal interest rate, both rise in response to a positive investment shock. The investment shock leads to a situation where output and investment moves in opposite directions and cannot create the comovement of consumption and output. In terms of comovement, the Barro-King (1984) critique applies.

5.5 Discussion: The role of technology and investment shocks

A central question in macroeconomics concerns the role of technology shocks in driving business cycle fluctuations. The evidence generated by the literature does not speak with a single voice and conclusions do vary. The first line of research (the early RBC literature) argues that technology shocks are the primary drivers of business cycles. A second line of literature pioneered by Gali (1999) questions the view of technological change as a central force behind cyclical fluctuations and concludes that technology shocks are largely irrelevant. Finally a relatively recent line of research including much of the estimated DSGE literature arrives at conclusions somewhere in between these two extremes (Fisher, 2006, and Smets and Wouters, 2007).

In this section I will discuss how the main findings of this thesis fit in this part of the literature, which discusses the relative importance of technology and non-technology shocks. While doing this, I will focus on role of three different technology shocks: First is the covariance stationary technology shock which does not affect long-run trend of productivity. The second is the permanent (or unit root) technology shock which does matter for long-run productivity level. The third is the investment shock which is either specified as a shock that affects transformation of consumption goods into investment goods (i.e. the investment-specific technology shock popularized by Greenwood et al., 1988) or as a shock that affects the transformation of investment goods into effective capital stock (i.e. the marginal efficiency of investment shock).

Neutral technology shocks are classified into two: First type is a transitory technology shock that can potentially capture a variety of driving forces behind output and labor input fluctuations that would not be expected to have permanent effects on labor productivity. This is the benchmark supply shock which has been attributed a central role in the RBC literature as an important source of business cycle fluctuations. Second is a particular type of shock to trend growth, which has a permanent impact on labor productivity. This shock is also referred to as a unit-root technology shock. Pioneered by Aguiar and Gopinath (2007), this type of trend shock is considered as a key determinant of business cycle fluctuations across emerging markets.

Stationary and permanent technology shocks affect the aggregate production level whereas the third technology shock (i.e. investment shock) affects only transformation of investment goods. However, the channels these technology shocks affect the economy are similar. A positive shock to either of these leads to a rise in productivity and in output. But owing to the permanent nature of the shock, unit-root technology shock affects the long-run trend of productivity and its transmission is stronger. All real variables are affected strongly by the unit-root technology shock (Table 5.3). The effect of the stationary technology (ST) shock on output appears to be weaker compared to its unit-root counterpart. Moreover the fact that hours falls in response to a positive stationary technology shock is found to be problematic (Gali, 1999). Therefore as consistent with the findings in the literature, I find a negligible role for ST shock in explaining output fluctuations in Turkey. For example ALLV (2005), finds that at small frequencies (20 quarters) unit root technology shock explains 25 percent of the variations in output whereas the role of ST shock is limited (4 percent). In JPT (2010) ST shock is not even considered in the model and the unit-root technology shock is assumed to be the sole source of neutral technology shock which explains 25 percent of the U.S. output fluctuations at business cycle frequencies. One can conclude that the findings in the literature agree regarding the negligible explanatory role of ST shocks in business cycles. Rather, a lively debated issue in the literature is the relative role of unit-root technology and investment shocks in explaining output fluctuations.

The identification of investment specific technology shock, which hits the transformation of investment goods into capital goods, is an important part of the discussion. Some existing studies try to identify this shock by equating it to the relative price of investment (e.g. Altig et al., 2005). JPT (2011) argues that in addition to this identification, the investment shock has another source related to marginal efficiency of investment (MEI) which is not related to relative prices.

Therefore they point out that two sources of investment shock should be distinguished. But as is done in this thesis, most other studies, including Smets and Wouters (2007), ALLV (2007) and JPT (2010), treat the two disturbances as a unique unobservable shock[19]. Specified in this way, I find that main driving force of business cycles in Turkey is the unit-root shock whereas contribution of investment shock is also significant, but limited. Regarding the relative importance of unit-root technology and investment shocks, this finding is different from JPT (2010), which concludes MEI shock explains around 50 percent of output fluctuations. In an open economy setting, ALLV (2007) finds that in explaining output variations, unit-root technology shock has a higher explanatory role (25 percent) than that of investment shock (12 percent) which is quite comparable to the findings of this thesis. Similarly, Alp and Elekdağ (2011) finds that unit root technology shock is the most important supply shock in terms of output growth contributions in Turkey which is consistent with the findings of this thesis. Therefore, modeling the economy as an open economy seems to affect the importance of MEI shock.

One could also compare the results of this thesis with that of similar studies on developing small open economies. It is important to discuss how and why the importance of the three types of technology shocks, as sources of business cycles in developing economies, changes compared to the developed economies.

Emerging market economies have different business cycle stylized facts summarized by countercyclical net exports and highly volatile consumption. These features contrast with developed economies and constitute a unique case of emerging markets. Trying to capture these unique patterns in a dynamic stochastic small open economy model, Aguiar and Gopinath (2007) highlights the fact that these economies are subject to substantial volatility in the trend growth rate relative to developed markets and concludes shocks to trend growth are the primary source of

[19] Investment disturbance in this thesis refers to MEI shock. Such specification is still appropriate as Justiniano et al. (2011) finds that, contribution of IST shock identified with relative price of investment, is negligible whereas MEI shock remains to play a key role in U.S. business cycles as previously shown in Justiniano et al. (2010).

fluctuations in developing countries rather than transitory fluctuations around a stable trend. The findings of the studies examining sources of business cycles in developing economies within a DSGE setting are in line with the suggestions in Aguiar and Gopinath (2007). For instance Medina and Soto (2007) finds that unit root technology and investment shocks explain around 50 percent of output variations in Chile. Moreover there are various studies which show that modeling emerging market economies as an economy subject to trend shocks helps to better capture the data facts of these countries[20].

The above-mentioned findings of the literature suggest that although relative contributions are different, unit-root technology and investment shocks play a key role in business cycles. Moreover these two shocks create a similar movement in endogenous variables except consumption (Figures 5.4 and 5.5). Comparing the cumulative effects of the three types of technology shocks may give a better picture regarding the role of technology in explaining business cycles. JPT (2010) finds the total effect of technology (unit-root technology and MEI shocks) in variations of U.S. output as 70 percent. I find that technology shocks (unit-root technology, ST and MEI shocks) explain around 75 percent of the output fluctuations. Adding an asymmetric technology shock ALLV (2007) concludes that technology shocks explain around half of output fluctuations in Euro area. Such a comparison shows that the results of this thesis regarding the high role of technology shocks are consistent with the literature.

Finally, comparing the findings of this thesis 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 of Alp and Elekdağ

[20] See Akkoyun et al. (2011) and Arslan et al. (2012).

(2011), they do not provide the variance decomposition but presents 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. Although they find investment shocks to be important, they emphasize that the unit root technology shock seems to be the most effective supply shock in output growth echoing the findings of this thesis. Similar to this thesis, they find limited role for the cost push (markup) and stationary technology shocks.

Turning to data may give some clue about why role of investment shocks in explaining business cycles in Turkey are found to be limited in this thesis compared to findings for U.S. (JPT, 2010 and 2011). Figure 5.6 shows the relative price of investment together with GDP, consumption and investment price deflator. Figure 5.7 shows relative price of investment in U.S. as given in JPT (2011). In this thesis investment shock can be considered as a combination of investment specific technology shock, which is identified through relative price of investment and marginal efficiency of investment shock, which is related to financing conditions (JPT, 2011). Hence this figure can give some idea about the total role of investment shocks (JPT, 2011).

As evident from Figure 5.6, investment price deflator stays below GDP deflator for the whole sample and relative price of investment shows a downward pattern. But relative investment price seems to oscillate within 0.8- 1.1 range rather than showing a clear downturn as observed in U.S (Figure 5.7). Since part of the investment shock is related to the inverse of relative investment price, one would expect to see a more clear downward pattern if investment shocks were dominant in the sample period. Hence this figure does not give much hint about importance of investment shock in Turkey as is found in U.S.

CHAPTER 6

CONCLUSION

Understanding sources of business cycles has been has been central in the public and academic debates for long periods. For different countries, different sources emerge to be important for explaining output fluctuations. In emerging market economies unit-root technology shocks are 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 thesis investigates sources of output fluctuations and conducts a test for the role of various shocks in Turkish economy by looking at variance decomposition results obtained by estimating a small open economy DSGE model by Bayesian methods. Employing this method not only allows the data speak but also enables to take the advantage of using prior information about the economy which is valuable while working with short data samples.

The results show that unit root technology, investment and exogenous spending shocks explain around 75 percent of output fluctuations in Turkish economy for the period 2002:2-2011:3. The unit root technology shock appears to be the key driving force of business cycles as this shock accounts for more than half of the macroeconomic fluctuations. The result that unit-root technology shock, which affects trend growth rate, is the key driver of business cycles indicates the importance of permanent shocks such as policy changes and structural reforms in Turkish economy.

This thesis uses state-of-art modeling and estimation techniques, which are proven to be useful in the literature. However, 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 Adoolfson et al. (2007). Second, the treatment of fiscal policy in the model is very simplistic. 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.

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APPENDIX

A. The log-linearized model

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

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

$$\hat{\pi}_t - \hat{\pi}_t^T = \frac{\beta}{1+\beta\kappa_d}(E_t\hat{\pi}_{t+1} - \rho_\pi\hat{\pi}_t^T) + \frac{\kappa_d}{1+\beta\kappa_d}(\hat{\pi}_{t-1}^m - \hat{\pi}_t^T) - \frac{\kappa_d\beta(1-\rho_\pi)}{1+\beta\kappa_d}\hat{\pi}_t^T + \frac{(1-\xi_d)(1-\beta\xi_d)}{\xi_d(1+\beta\kappa_d)}\left(\widehat{mc}_t + \hat{\lambda}_{d,t}\right) \tag{A1}$$

$$\widehat{mc}_t = \alpha r_t^k + (1-\alpha)\hat{\bar{w}}_t - \hat{\epsilon}_t \tag{A2}$$

$$r_t^k = \hat{\mu}_{z,t} + \hat{\bar{w}}_t + \hat{H}_t - \hat{k}_t \tag{A3}$$

The Phillips curves for the imported good is:

$$\hat{\pi}_t^m - \hat{\pi}_t^T = \frac{\beta}{1+\beta\kappa_m}(E_t\hat{\pi}_{t+1}^m - \rho_\pi\hat{\pi}_t^T) + \frac{\kappa_m}{1+\beta m}(\hat{\pi}_{t-1}^m - \hat{\pi}_t^T) - \frac{\kappa_m\beta(1-\rho_\pi)}{1+\beta\kappa_m}\hat{\pi}_t^T + \frac{(1-\xi_m)(1-\beta\xi_m)}{\xi_m(1+\beta\kappa_m)}\left(\widehat{mc}_t^m + \hat{\lambda}_{m,t}\right) \tag{A4}$$

$$\widehat{mc}_t^m = \left(\hat{P}_t^* + \hat{s}_t - \hat{P}_t^m\right)$$

The log-linearized real wage equation can be written

$$\hat{\bar{w}}_t\eta_1 + \hat{\bar{w}}_{t-1}\eta_0 + \hat{\bar{w}}_{t+1}\eta_2 + \eta_3(\hat{\pi}_t^d - \hat{\pi}_t^T) + \eta_4(\hat{\pi}_{t+1}^d - \rho_\pi\hat{\pi}_t^T) + \eta_5(\hat{\pi}_{t-1}^c - \hat{\pi}_t^T) + \eta_6(\hat{\pi}_t^c - \rho_\pi\hat{\pi}_t^T) + \eta_7\hat{\psi}_{z,t}^T + \eta_8\hat{H}_t + \eta_{11}\hat{\zeta}_t^h = 0 \tag{A5}$$

Investment equation is given by

$$P_{k'\,t} + \hat{\Upsilon}_t - \hat{\gamma}_t^{i,d} - \mu_z^2 S''\left[(\hat{\imath}_t - \hat{\imath}_{t-1}) - \beta(\hat{\imath}_{t+1} - \hat{\imath}_t) + \hat{\mu}_{z,t}\right] - \beta\hat{\mu}_{z,t+1} = 0 \tag{A6}$$

The log-linearized UIP condition is given by

$$\hat{R}_t - \hat{R}_t^* = E_t \Delta \hat{S}_{t+1} - \tilde{\phi}_a \hat{a}_t + \hat{\tilde{\phi}}_t \quad \text{(A7)}$$

The aggregate resource constraint is given by

$$\begin{aligned}(1-\omega_c)\,(\gamma^{c,d})^{\eta_c}\frac{c}{y}(\hat{c}_t + \eta_c \hat{\gamma}_t^{c,d}) + (1-\omega_i)(\gamma^{i,d})^{\eta_i}\,\frac{i}{y}(\hat{\imath}_t + \eta_i \hat{\gamma}_t^{i,d}) \\ + \frac{g}{y}\hat{g}_t + \frac{x}{y}\left(y_t^* - \eta_f \hat{\gamma}_t^{x,*}\right) \\ = \lambda_d\left(\left(\hat{\epsilon}_t + \alpha \hat{k}_t - \alpha \hat{\mu}_{z,t}\right) + (1-\alpha)\hat{H}_t\right) \\ - r^k \frac{\bar{k}}{y}\frac{1}{\mu_z}\left(\hat{k}_t - \hat{\bar{k}}_t\right)\end{aligned} \quad \text{(A8)}$$

Evolution of capital stock gives

$$\hat{\bar{k}}_{t+1} = \frac{(1-\delta)}{\mu_z}\hat{\mu}_{z,t} + \left(\hat{\Upsilon}_t + \hat{\imath}_t\right)\left(1 - \frac{(1-\delta)}{\mu_z}\right) \quad \text{(A9)}$$

In the model, there are the following log-linearized relative prices

$$\hat{\gamma}_t^{m,d} = \hat{\gamma}_{t-1}^{m,d} + \hat{\pi}_t^m - \hat{\pi}_t^d \quad \text{(A10)}$$

$$\hat{\gamma}_t^{x,*} = \hat{\gamma}_{t-1}^{x,*} + \hat{\pi}_t^x - \hat{\pi}_t^* \quad \text{(A11)}$$

The log-linearized interest rate rule is given by (A12)

$$\begin{aligned}\hat{R}_t = \rho_R \hat{R}_{t-1} + (1-\rho_R)\big(\hat{\pi}_t^T + r_\pi(\hat{\pi}_{t-1}^c - \hat{\pi}_t^T) + r_y \hat{y}_{t-1} \\ + r_x \hat{x}_{t-1}\big) + r_{\Delta\pi}\Delta\hat{\pi}_t^c + r_{\Delta y}\Delta\hat{y}_t + \varepsilon_{R,t}\end{aligned} \quad \text{(A12)}$$

$$\hat{\pi}_t^c = \left((1-\omega_c)\,(\gamma^{c,d})^{\eta_c}\right)\hat{\pi}_t^d\,\left(\omega_c\,(\gamma^{m,c})^{(1-\eta_c)}\right)\hat{\pi}_t^m \quad \text{(A13)}$$

$$\hat{x}_t = -\hat{\gamma}_t^{x,*} - \omega_c\,(\gamma^{c,m})^{-(1-\eta_c)}\hat{\gamma}_t^{m,d} \quad \text{(A14)}$$

B. Tables and Graphs

Table 5.1 Calibrated Parameters

Parameter	Description	Value
β	Discount factor	0.9928
α	Capital share in production	0.4
η_c	Substitution elasticity (C^d and C^m)	1
η_i	Substitution elasticity (I^d and I^m)	0.25
g	G/Y ratio	0.1
σ_l	Labor supply elasticity	1
ϕ_a	Elasticity of country risk premium with respect to net foreign debt	0.01
ω_i	Imported investment share	0.23
ω_c	Imported consumption share	0.25
δ	Depreciation rate	0.035
λ_w	Steady state mark-up rate for wages	1.15
λ_m	Steady state mark-up rate for imports	1.15
λ_d	Steady state mark-up rate for domestically produced goods	1.15

Table 5.2 Prior and Posterior Distributions

	Prior				Posterior		
Description	**Parameter**	**Type**	**Mean**	**Standard Deviation**	**Mean**	**Confidence Interval**	
Calvo wages	ξ_w	Beta	0.75	0.10	0.746	0.585	0.914
Calvo domestic prices	ξ_d	Beta	0.75	0.10	0.669	0.549	0.801
Calvo import prices	ξ_m	Beta	0.75	0.10	0.738	0.649	0.812
Indexation wages	κ_w	Beta	0.5	0.10	0.501	0.337	0.669
Indexation prices	κ_d	Beta	0.5	0.10	0.495	0.333	0.658
Investment adj cost	$\tilde{S}$	Normal	5	1.00	4.962	3.405	6.486
Capital adj. cost	σ_a	Normal	0.05	0.50	1.190	0.637	1.715
Export demand elasticity	η_f	Normal	1	0.20	0.897	0.668	1.120
Habit formation	b	Beta	0.7	0.10	0.881	0.806	0.968
Shock persistence							
Unit root tech.	$\rho_{\mu,z}$	Beta	0.8	0.10	0.549	0.456	0.648
Stationary tech.	$\rho_{\mu,\varepsilon}$	Beta	0.8	0.10	0.768	0.610	0.917
Investment	$\rho_{\mu,\Upsilon}$	Beta	0.8	0.10	0.904	0.846	0.965
Preference	$\rho_{\zeta,c}$	Beta	0.8	0.10	0.691	0.494	0.952
Labor supply	$\rho_{\zeta,h}$	Beta	0.8	0.10	0.791	0.631	0.954
Risk premium	ρ_{ϕ}	Beta	0.8	0.10	0.868	0.814	0.929
Inflation target	$\rho_{\bar{\pi}}$	Beta	0.8	0.10	0.791	0.649	0.941
Foreign interest rate	ρ_{R*}	Beta	0.8	0.10	0.928	0.883	0.973
Foreign demand	ρ_{y*}	Beta	0.8	0.10	0.887	0.804	0.973
Foreign inflation	$\rho_{\pi*}$	Beta	0.8	0.10	0.271	0.188	0.360
Monetary policy rule							
Smoothing parameter	ρ_R	Beta	0.7	0.10	0.706	0.646	0.766
Inflation response	r_π	Normal	1.4	0.10	1.422	1.343	1.497
Diff. inflation response	$r_{\Delta\pi}$	Normal	0.12	0.05	0.144	0.070	0.221
Exchange rate response	r_x	Normal	0.0	0.05	-0.046	-0.083	-0.009
Output response	r_y	Normal	0.12	0.05	0.076	0.028	0.120
Diff. output response	$r_{\Delta y}$	Normal	0.05	0.05	0.034	0.004	0.062

Table 5.2 Prior and Posterior Distributions (continued)

	Prior				Posterior		
Description	**Parameter**	**Type**	**Mean**	**Standard Deviation**	**Mean**	**Confidence Interval**	
Shock volatility							
Unit root technology	$\sigma_{\mu,z}$	Inverse gamma	0.03	2.00	0.066	0.055	0.080
Stationary technology	$\sigma_{\mu,\varepsilon}$	Inverse gamma	0.03	2.00	0.025	0.009	0.041
Marginal efficiency of investment	σ_{Υ}	Inverse gamma	0.03	2.00	0.131	0.089	0.174
Preference	$\varepsilon_{\zeta,c}$	Inverse gamma	0.03	2.00	0.362	0.158	0.545
Labor supply	$\varepsilon_{\zeta,h}$	Inverse gamma	0.03	2.00	0.034	0.006	0.074
Risk premium	ε_{ϕ}	Inverse gamma	0.03	2.00	0.011	0.007	0.015
Monetary policy	ε_{R}	Inverse gamma	0.03	2.00	0.006	0.005	0.007
Inflation target	ε_{π^T}	Inverse gamma	0.03	2.00	0.011	0.007	0.016
Domestic mark-up	$\varepsilon_{\lambda,d}$	Inverse gamma	0.05	2.00	0.065	0.012	0.148
Import mark-up	$\varepsilon_{\lambda,m}$	Inverse gamma	0.05	2.00	0.539	0.245	0.808
Exogenous spending	$\varepsilon_{\lambda,d}$	Inverse gamma	0.03	2.00	0.215	0.172	0.258
Foreign demand	ε_{y*}	Inverse gamma	0.01	2.00	0.092	0.073	0.111
Foreign interest rate	ε_{R*}	Inverse gamma	0.01	2.00	0.002	0.001	0.002
Foreign inflation	$\varepsilon_{\pi*}$	Inverse gamma	0.01	2.00	0.065	0.054	0.077

Table 5.3 Posterior variance decomposition in the model

Shock/ Series	Output	Consumption	Investment
Stationary technology	1.78	0.02	1.2
Unit root technology	**62.62**	**34.53**	**47.64**
Preference	4.97	**63.61**	3.87
Labor supply	0.03	0.00	0.03
Domestic mark-up	0.32	0.00	0.03
Import mark-up	0.03	0.01	0.44
Risk premium	4.30	0.02	1.32
Marginal efficiency of investment	**10.22**	1.59	**43.6**
Monetary policy	0.78	0.00	0.17
Foreign inflation	1.00	0.00	0.00
Foreign demand	1.66	0.19	0.94
Foreign interest rate	0.29	0.00	0.16
Exogenous spending	**11.64**	0.02	0.51
Inflation target	0.34	0.00	0.09

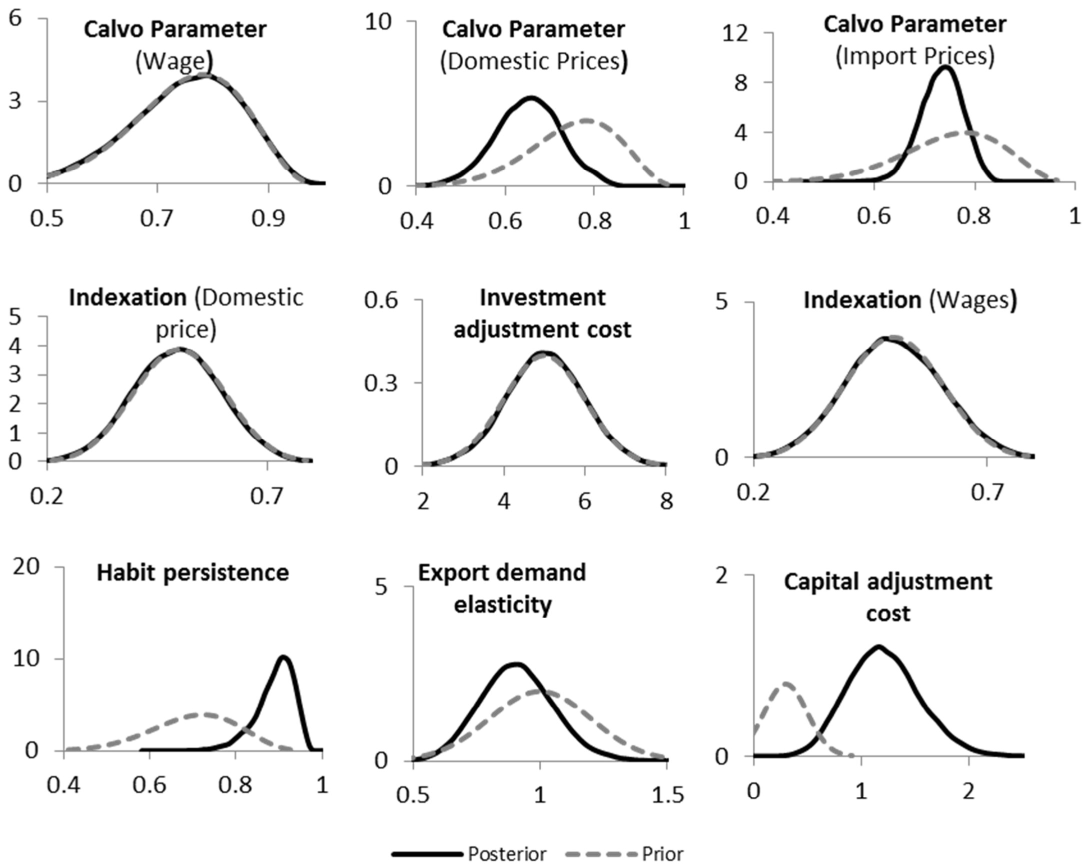

Figure 5.1a Prior and posterior distributions (Parameters**)**

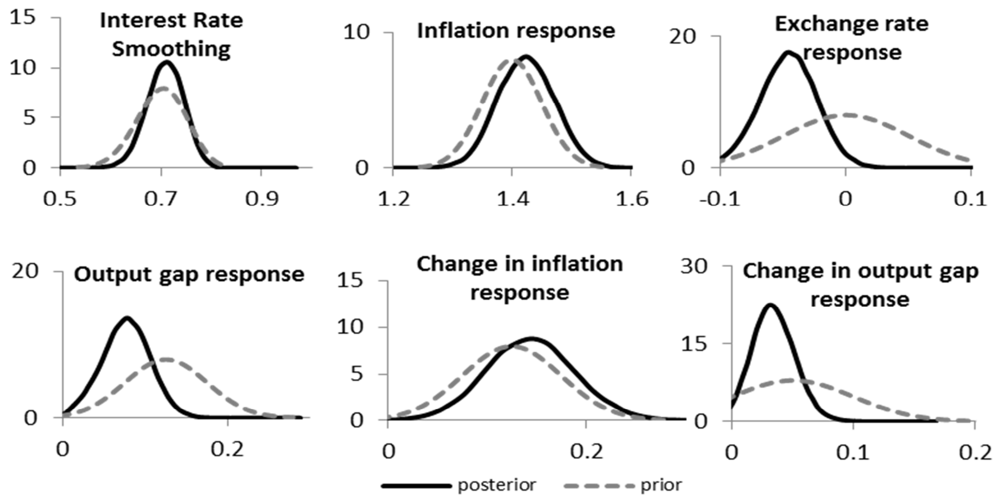

Figure 5.1b Prior and posterior distributions (Monetary policy parameters)

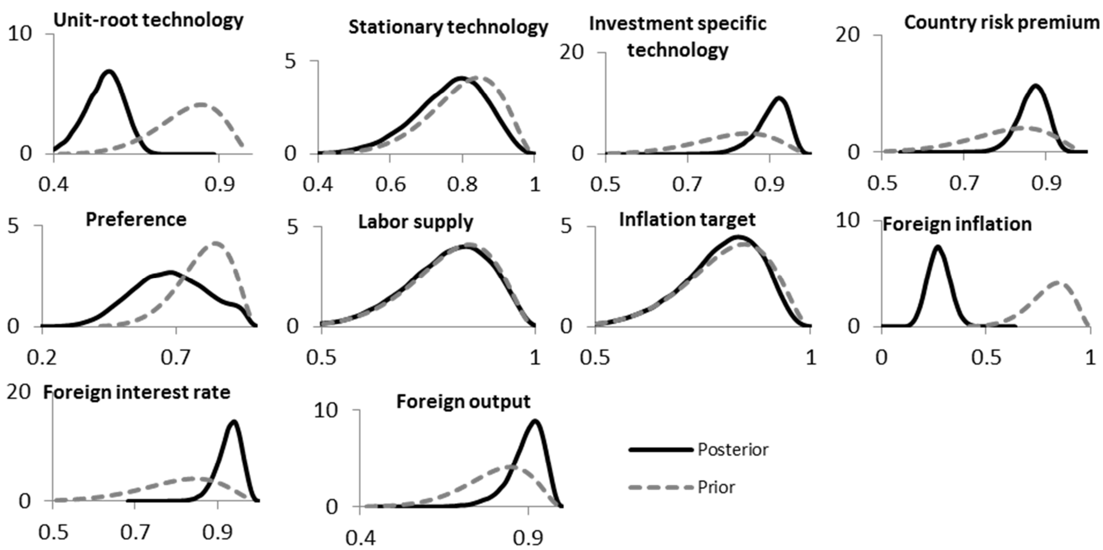

Figure 5.1c Prior and posterior distributions (Shock processes parameter)

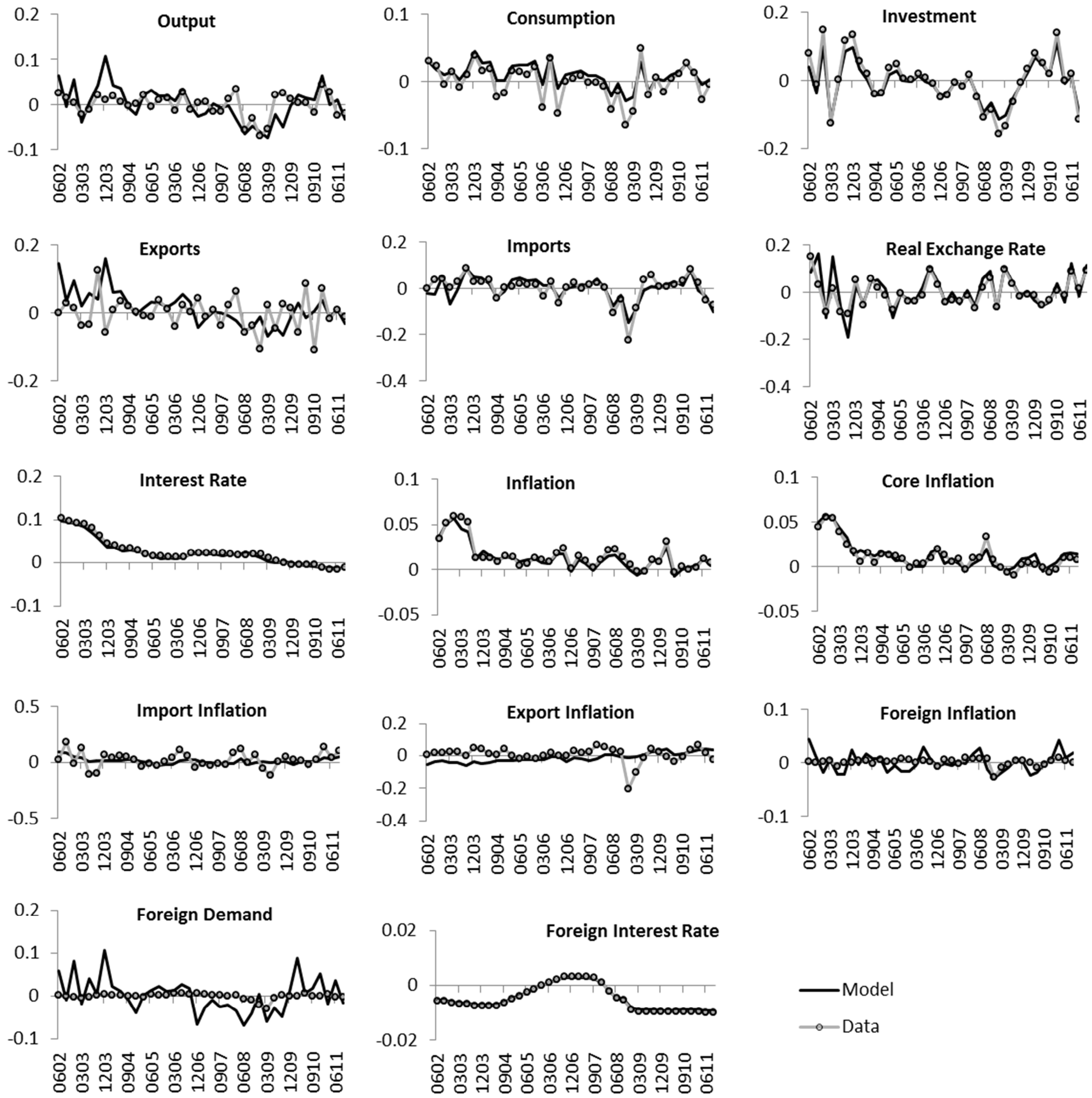

Figure 5.2 Data and one-sided predicted values from the model

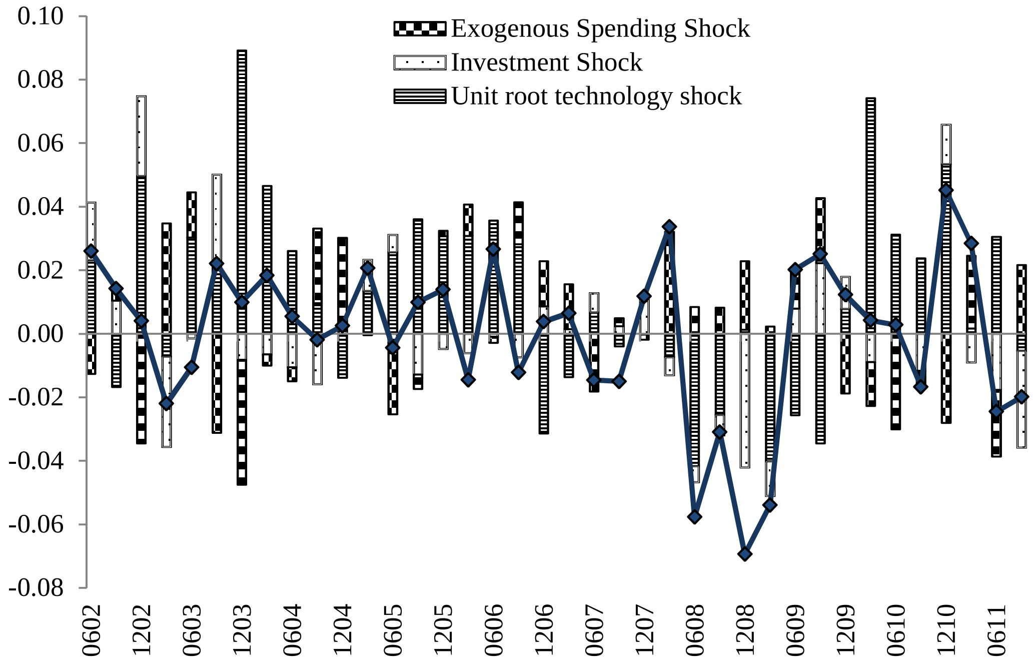

Figure 5.3 Historical decomposition of output

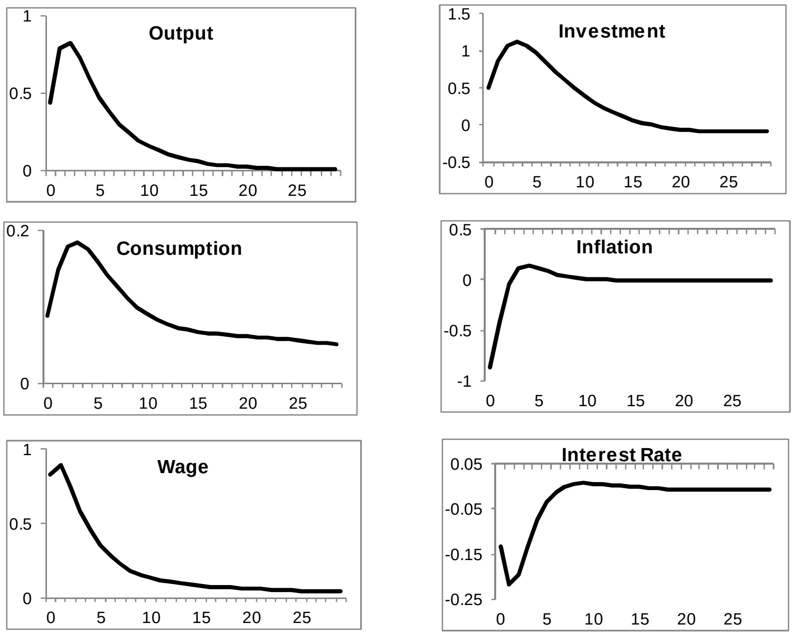

Figure 5.4 Impulse response to a unit-root technology shock

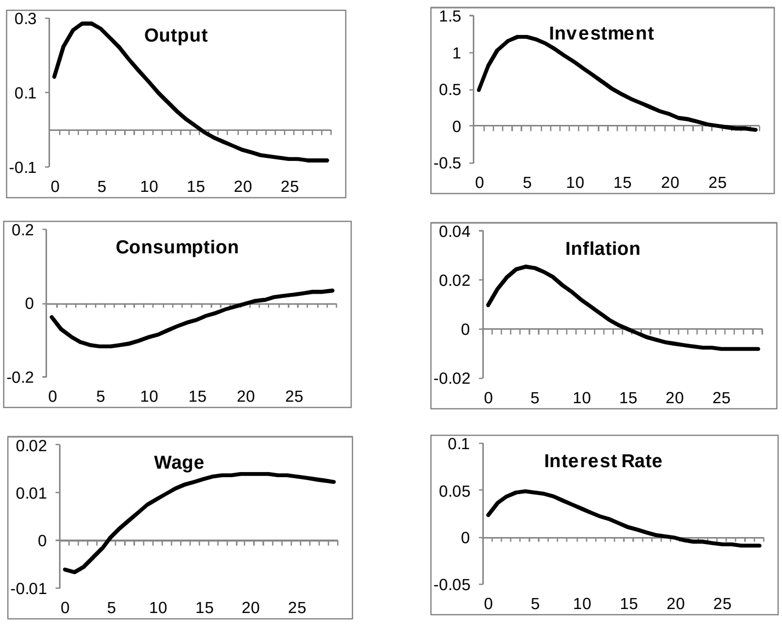

Figure 5.5 Impulse response to an investment shock

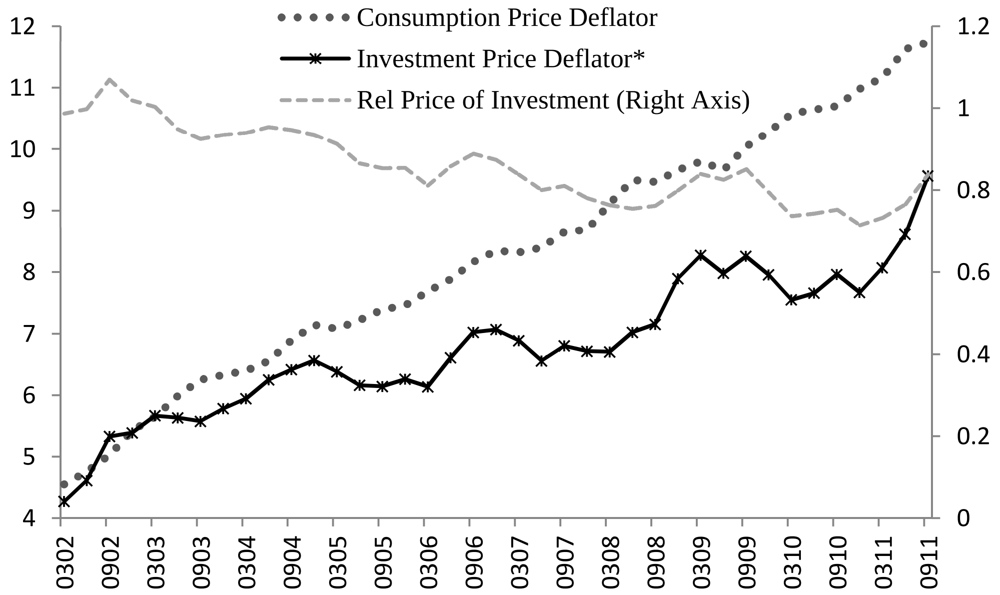

Figure 5.6 Relative price of investment in Turkey
*Investment price deflator/consumption deflator. Source: TURSTAT and author's calculations.

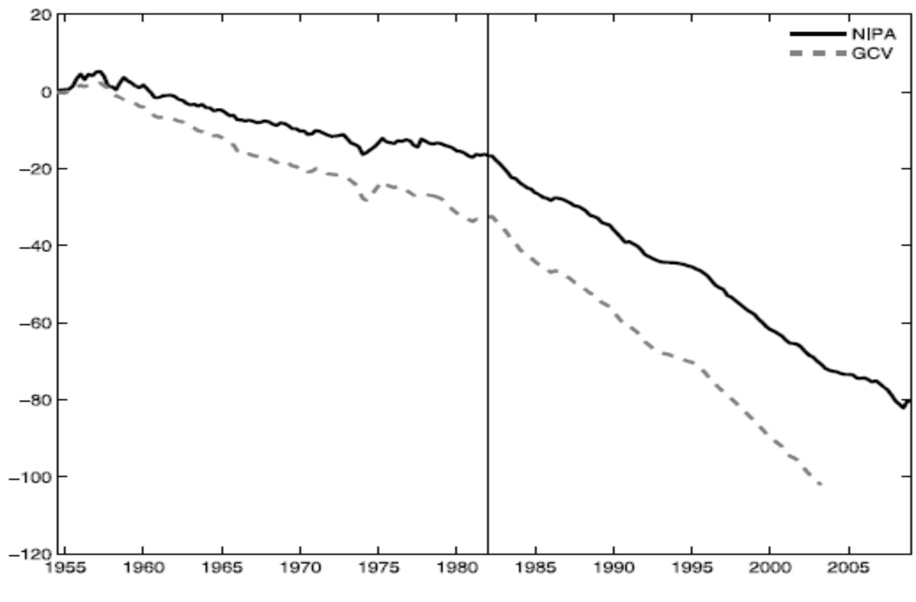

Figure 5.7 Relative price of investment in U.S.
Source: Justiniano et al. (2011), Alternative measures of the relative price of investment

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YAZARIN

Soyadı : Yüksel
Adı : Canan
Bölümü : İktisat

TEZİN ADI (İngilizce) : Role of Investment Shocks in Explaining Business Cycles in Turkey

TEZİN TÜRÜ : Yüksek Lisans ☒ Doktora ☐

1. Tezimin tamamından kaynak gösterilmek şartıyla fotokopi alınabilir. ☐

2. Tezimin içindekiler sayfası, özet, indeks sayfalarından ve/veya bir bölümünden kaynak gösterilmek şartıyla fotokopi alınabilir. ☐

3. Tezimden bir (1) yıl süreyle fotokopi alınamaz. ☒

TEZİN KÜTÜPHANEYE TESLİM TARİHİ: