THREE ESSAYS ON TECHNOLOGY, TRADE, AND BUSINESS CYCLE: A DYNAMIC ECONOMETRIC APPROACH

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PLAGIARISM

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ABSTRACT

In this thesis, we tried to shed light on the implementation of forward-looking and counter-cyclical macroeconomic policies by examining technology and international trade mechanisms based on macroeconomic models. The thesis includes three independent chapters on PMG-ARDL and GMM econometric modeling on technology and international trade and estimating and evaluating a small open economy and middle open economy DSGE modeling as well as an introduction.

In the second part of this study, we examined in detail the transfer of technology in terms of both developed and developing countries. In this direction, we have developed a "technology transfer index" including the volume of trade and industrial production of 32 developed and developing countries. We analyzed the relationships between technology transfer and per capita national income in the short and long-term using the ARDL model, which allows the use of non-stationary time series together, and System GMM methodologies, which overcome the endogeneity problem of independent variables.

In the third part of the study, we extensively investigated the dynamic and stochastic general equilibrium models, which have recently been used by many central banks in terms of analysis and planning of monetary and interest rate policies. Within the framework of this study, we modelled the Turkish Economy between 2003 - 2020 of which Turkish Central Bank began to implement inflation stabilization policy. In the model, we used the new Keynesian rigidities along with the Bayesian approach. We also included modified uncovered interest rate parity and terms of trade shocks in our model in addition to the rigidities used in conventional open general equilibrium models, and we found that these additions improved our model in terms of maximum log-likelihood. In this study, we also examined the decomposition of the open economy shocks on macroeconomic variable volatilities.

In the fourth and final part of our study, we used middle open economy DSGE model for the same period. In addition, we used important components of the new Keynesian synthesis, such as wage and price stickiness, incomplete exchange rate pass-through, imports and exports of investment and consumption goods. Although the actual data volatilities are below the values which are obtained from model simulations, convergence is achieved. In terms of maximum log-likelihood the results are in the range of literature studies.

As a result of our studies, we have determined that all countries are benefiting from technology transfer and there is a long-term relationship between technology transfer and the economic growth per capita. On the other hand, small open economy dynamic stochastic general equilibrium model simulation results are close to Turkish macroeconomic variable data set. However, high volatility of macroeconomic variables results abnormal standard deviations with the medium open economy dynamic stochastic general equilibrium model simulations. Both small and medium open economy general equilibrium models, however there are still some parts to be improved, are great tools to be used in optimal monetary policy analysis for Turkish economy.

Key words: Technology, International Trade, PMG- ARDL, System-GMM, DSGE modelling, Small open economy DSGE models, Medium open economy DSGE models

ÖZET

Bu tezde, makroekonomik modellere dayalı teknoloji ve uluslararası ticaret mekanizmalarını inceleyerek ileriye dönük ve ters döngüsel makroekonomik politikaların uygulanmasına ışık tutmaya çalıştık. Tez, teknoloji ve uluslararası ticaret üzerine PMG-ARDL ve GMM ekonometrik modelleme ve küçük bir açık ekonomi ve orta açık ekonomi DSGE modellemesini tahmin etme ve değerlendirme üzerine üç bağımsız bölüm ve bir giriş içermektedir.

Bu çalışmanın ikinci bölümünde, teknolojinin transferini hem gelişmiş ülkeler, hemde gelişmekte olan ülkeler nazarında detaylıca inceledik. Bu doğrultuda, gelişmiş ve gelişmekte olan 32 ülkenin en yoğun ticari ilişkilerinin olduğu ülkeler ile yaptıkları ticaretin hacmini ve endüstriyel üretimlerini dahil ederek 'teknoloji transfer indeksi' oluşturduk. Tekonoloji transferinin kısa ve uzun vadede kişi başı milli gelir ile aralarındaki ilişkileri, durağan olmayan zaman serilerini bir arada kullanmaya olanak sağlayan ARDL modeli ve Enstrümental değişkenler kullanarak bağımsız değişkenlerin içsellik sorununun üstesinden gelen System GMM metedolojilerini kullanarak inceledik.

Çalışmanın üçüncü bölümünde son dönemde bir çok Merkez bankası tarafından para ve faiz politikalarının analiz ve planlanması yönünden sıklıkla kullanılmaya başlayan dinamik ve stokastik genel denge modellerini kapsamlıca araştırdık. Bu çalışmamızda Türkiye'nin 2001 finansal krizi sonrasında Türkiye Cumhuriyet Merkez Bankası tarafından uygulanmaya başlayan enflasyonu stabil hale getirme programı çerçevesinde 2003 – 2020 arası dönemini, küçük ölçek açık ekonomi modeli çerçevesinde modelledik. Modelimizde Bayesçi yaklaşım ile birlikte yeni keynesçi rijitliklerinide kullandık. Ayrıca, klasik açık genel denge modellerinde kullanılan rijitliklere ilaveten modelimize modifiye edilmiş garantisiz faiz oranı paritesi ve ulusal ticaret şoklarını dahil ettik ve bu ilavalerin modelimizi ardıl maksimum

logaritmik olabilirlik açısından geliştirdiğini tespit ettik. Bu çalışmamızda ayrıca açık ekonomi şoklarının makroekonomik değişkenler üzerindeki ayrışmalarını inceledik.

Çalışmamızın dördüncü ve son bölümünde, orta ölçek açık ekonomi modeli ile ikinci bölümde kullandığımız aynı zaman aralığını kullanarak veri ve şok sayısını arttırarak Türkiye ekonomisini modelledik. Ayrıca, bu modelde küçük açık ekonomi modelindeki rijitliklere ilaveten ücret ve fiyat yapışkanlığı, tamamlanmamış döviz kuru geçişkenliği, yatırım ve tüketim ürünleri ithalatı ve ihracatı gibi yeni keynesçi sentezinin önemli bileşenlerini kullandık. Gerçek veri volatilerinin, model simülasyonu ile elde edilen değerlerin altında kalmasına rağmen orta ölçek dinamik stokastik genel denge modeli ile yakınsama sağlanmış ve ardıl maksimum logaritmik olabilirlik açısından kabul edilebilir sonuçlara ulaşılmıştır.

Yaptığımız çalışmalar sonucunda tüm ülkelerin teknoloji transferinden faydalandığını ve teknoloji transferi ile kişi başına ekonomik büyüme arasında uzun vadeli bir ilişki olduğunu tespit ettik. Öte yandan, küçük açık ekonomi dinamik stokastik genel denge modeli simülasyon sonuçları, Türk makroekonomik değişken veri setine yakındır. Bununla birlikte, makroekonomik değişkenlerin yüksek oynaklığı, orta açık ekonomi dinamik stokastik genel denge modeli simülasyonlarında anormal standart sapmalara neden olmaktadır. Hem küçük hem de orta ölçekli açık ekonomi genel denge modelleri, iyileştirilmesi gereken bazı kısımlar mevcut olsada, Türkiye ekonomisi için optimal para politikası analizinde kullanılması mümkün olan harika araçlardır.

Anahtar kelimeler: Teknoloji, Uluslararası Ticaret, PMG-ARDL, Sistem GMM, DSGE modellemesi, Küçük ölçek Açık Ekonomi Modeli, Orta ölçek Açık Ekonomi Modeli

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Chapter 1

Introduction

1. The Context

Despite global cooperation, technological alteration and technological transformation between countries have increased fabulously, the world economy has entered a slowdown process during the last three decades. This slowdown is totally attributed to the economic dynamics in high-income countries. (Popović, 2018) Some economists associate the reasons for this slowdown in the developed world with the secular stagnation theory put forward by the American economist Alvin Hansen in 1938. (Hansen, 1939) This theory was put forward towards the end of the period called the Great Depression. Because, according to Alvin Hansen, technological innovations that formed the basis of economic growth had decreased, new regions were not discovered and there were important problems in the demographic structure. Therefore, Alvin Hansen thought that this period of deeply troubled depression would last for a long time, so he tried to attract the attention of economic agents on this issue. However, contrary to expectations, the period of depression end and a new period of development began soon after the Second World War. Alvin Hansen was wrong. While technological development and transformation in developed countries after the Second World War carried the growth rates of the developed world upwards, many developing countries benefited from this situation. Economic development is not only closely related to international capital and product flows but also related to information and technology flows. (UNCTAD, 2014) Hence, understanding international technology movements is a crucial subject to explore in explaining economic growth variances.

In this context, we discussed international trade and technology transfer in Chapter Two. Following Mankiw, Romer, & Weil (1992) and Caselli, Esquivel, & Lefort (1996) and constructing an international trade based international technology transfer index, we investigated the relationship between technology transfer and economic growth. First, we constructed a balanced panel data including 32 countries from 1993 to 2017. We used the autoregressive distributed lag model (ARDL) with pooled mean group estimator (PMG) which is developed by Pesaran, Pesaran, Shin, & Smith (1999). The PMG ARDL model is immensely popular to estimate panel data estimators. On the other side, PMG ARDL model allows to estimate short and long run effects, simultaneously and PMG ARDL model is also valid for different order of stationarity. Then, we assessed the relationship between international technology transfer, human capital, government spending and economic growth following Arellano and Bond (1991) and Bond, Hoeffler, and Temple (2001).

After the study in the second chapter, in the third chapter, we examined technology and international trade in the Turkish economy, which is among the developing economies. The Turkish economy adopted inflation stabilization program immediately after the 2001 financial crisis. We assessed 2003 – 2020 period by using a Small Open Economy Dynamic Stochastic General Equilibrium (SOE DSGE) model with a Bayesian framework. DSGE models have increased in popularity among macroeconomic models recently. DSGE models are used by many central banks as a powerful tool for general evaluation and policy decisions as well as forecasting. These models have managed to overcome Lucas' criticism[1]. The general equilibrium models are based on the real business cycle model developed by Kydland and Prescott (1982). New Keynesian synthesis[2] DSGE models include nominal rigidities such as

[1] According to Lucas, the relationships between economic variables observed in historical data or predicted by macroeconomic models are not reliable for economic policymaking. Because economic agents adjust their expectations and behaviors rationally according to the effects of economic policies. Therefore, it is not appropriate to use basic macro-econometric models to evaluate the consequences of policy changes. (Lucas 1976)

[2] Please see seminal papers Smets and Wouters (2003) and Smets and Wouters (2008)

habit formation, price and wage rigidities, and Calvo[3] staggering price setting. We mainly followed Justiniano and Preston (2010) to construct Small Open Economy DSGE Model which includes several rigidities and exogeneous shocks. Unlike Justiniano and Preston (2010), we added terms of trade shocks and changed the uncovered interest rate parity condition to evaluate the last two decades of the Turkish Economy. The model assumes a perfectly competitive market in which households buy consumption goods from domestic producers and importers, receive wages for labor services, own capital and lease it to firms, domestic producers produce consumption goods and sell these products in the domestic and foreign markets, and importers buy consumption goods from foreign market and sell them to domestic households. Households are free to invest in domestic and foreign bonds. On the other side, households are the owners of the firms so they are paid dividends. Central Bank is the decision maker of the interest rates. In the model we applied several domestic and foreign shocks. Domestic shocks are technology, cost push, risk premium, preferences, terms of trade, and monetary shocks. Foreign shocks are foreign output growth, foreign inflation, and foreign interest rate shocks. In addition, we investigated in detail the efficacy of the new Keynesian approach rigidities by estimating different versions of the model.

In Chapter Four, we dealt with the expanded version of the open economy model in Chapter Three. In the Small open economy model constructed in Chapter three, capital, investments, different version of technology shocks, and markup shocks are excluded. In Chapter four, we strictly followed the Middle Open Economy model developed by Adolfson et al. (2007) and Christiano, Eichenbaum, and Evans (2005). Middle open economy model includes several New Keynesian synthesis rigidities such as sticky prices and wages, capital adjustment costs, and habit formation. In the model, households make decisions to maximize the utility from

[3] According to the Calvo pricing model, there is a fixed probability that a firm will be able to reoptimize its price regardless of the time that has passed since the last optimization. (Calvo 1983)

consumption, leisure, and cash balances. As a monopoly provider of differentiated labor services, households are subject to wage stickiness. Households can invest in domestic and foreign bonds. As in the small open economy model, households rent capital to domestic firms. Unlike the small open economy model, they make decisions on how much to invest in a capital stock based on capital adjustment costs. There are three type of domestic firms. The first type firm hire labor and sell to intermediate good producer after a transformation to a homogeneous input good. The second type of firm buy labor input from the first type firm and rent capital. This firm produces an intermediate goods and sell it to the third type domestic firm. The third type domestic firm is a final good producer who transforms intermediate inputs to a final good and sell in the market to households. Final good producers produce consumption final goods and investment final goods. There are also consumption goods and investment goods importers in the economy. As in the small open economy model, there are exporters in the economy who sell products to overseas households. All domestic firms determine their prices subject to the Calvo model. We followed Sheen and Wang (2016) to construct monetary policy formation. Four different technology shock are processed in the model. Permanent technology shocks, temporary technology shocks, investment specific technology shocks, and asymmetric technology shocks. However, markup shocks are also included in the model for firms.

We simulated both the small open economy model and the medium open economy model according to the parameters estimated by the models. We analyzed the fit of the models by comparing the second moments of the real data with the simulated data. Then, we examined in detail the impact of shocks on macroeconomic variables. First of all, we put forward the impulse response functions for each shock. Then, we examined which shocks are effective on the fluctuations of macroeconomic variables through both variance decompositions and historical decompositions.

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Chapter 2

International Technology Transfer, Human Capital and Economic Growth: A Panel Data Analysis

Abstract

The aim of this research is to examine the relationship between international technology transfer (ITT), human capital, government spending and economic growth in a balanced panel data of 32 countries around the globe for the period 1993 – 2017. First, we employed Pooled Mean Group Autoregressive Distributed Lag method to investigate co-integration and causality relationships between imported & exported technology and economic growth. Second, we applied two-step first difference and two-step system GMM estimates for robust inferences. By applying ARDL-PMG model, our findings reveal that technology transfer fosters economic growth. Empirical findings of the GMM estimations suggest that technology transfer and human capital matter for economic growth of the modern economies.

Keywords: International technology spillover, Economic growth, Panel data, PMG-ARDL, GMM

1. Introduction

ITT, as characterized by the development of the international trade, has been studied in relation to economic growth over the last century. ITT can be defined as "the flow of technical knowledge or technology between organizations". (Bozeman 2000) International trade, foreign direct investment, licensing and labor movement are the most prominent channels for technology transfer. (Hoekman, Maskus, and Saggi 2005) Technology transfer has increased substantially as result of increased global cooperation and international trade. However, despite global cooperation has increased fabulously, developed economies have entered a slowdown process during the several decades. In particular, it has been a decade after 2008, but the developed world is struggling with weak recovery which is considered by economists as a sign of long-term stagnation in developed world. Slowdown in developed world wafted U.S. economy to a trade obstruction, U.S. – China trade war, which occupied world agenda for a long time. One of the major issue of the U.S. to start a trade war to China in 2018 was the accusation of the plagiarization of U.S. made technological products by Chinese companies. (Liu and Woo 2018) Recently, ITT has been considered to cause an indirect loss of income for developed economies, while providing great opportunities for emerging middle-income economies which have high absorption capacities. In this context, we examined the effects of ITT on economies which is induced by international trade and industrial production.

The issue of ITT and its impact on economic growth covers a wide area in the literature. This paper examines the effects of ITT between nations upon their economic growth based on a data from 1993 to 2017 and 32 countries[4]. The aim of this paper is twofold. First is to

[4] The sample countries used in our study were both estimated for the entire sample and additionally divided into two main groups and estimated separately. Group A countries considered as high-income countries and

contribute to the growth literature by investigating the short run and long run relationship and causality analysis between ITT induced by imports & exports and economic growth by estimating a PMG-ARDL model. Second is to illustrate the response of economic growth to a change in ITT by first-differenced GMM and System GMM estimation techniques.

This article proceeds as follows. In section 2, we concentrated on the debate of the impact of international technology transfer on economic growth. Section 3 consists of data and methodology. Section 4 discusses the empirical results. Section 5 consists of conclusions. Finally, we tried to explain our guiding ideas about future studies in section 6.

2. Literature Review

ITT and its impact on economic growth covers a wide area in the literature. Although technology is predominantly transferred between companies or institutions, it makes a significant contribution not only to developing countries, but also to developed countries indirectly when evaluated in an international framework. Technology receivers benefit from maximizing real income and accessing the world's scientific and technical capacity, while technology senders benefit from increased exports, currency savings, unemployment reduction, and local research and development. (Reddy and Zhao 1990) ITT can be achieved through direct foreign investments, international trade, licensing, technology partnerships, worker relocations and non-legal operations (imitation, reverse engineering, etc.). (Hoekman, Maskus, and Saggi 2005)

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technology senders. Group B countries considered as middle-income countries and technology receivers. Group A countries are Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Singapore, Spain, Sweden, U.K. and U.S. Group B countries are Argentina, Brazil, Chile, China, Czech Republic, Iceland, Ireland, India, Indonesia, Mexico, New Zealand, Poland, Portugal, Romania, South Africa and Turkey.

The relationship between ITT and economic growth has been one of the most exciting issues, theoretically and empirically in literature. The significant roles of ITT, that is, technological changes in social lives are extensively discussed in both the neoclassical and endogenous growth models. Until the 1990s, the technology variable was added to growth models as an exogenous variable. In the beginning of 90s economists started to add technology as an endogenous variable into the growth models. Nobel laureate Paul Romer established his model by centering the technological change. In the model, it is stated that total human capital and integration with world trade, thus the development of global trade, accelerated technological change and economic growth. (Romer 1990) On the other hand, the world is experiencing a period of communication in which information becomes easier to spread. And cheap, easy and fast. Since this cheapness and convenience allows technology transfer, societies that have not completed the industrialization process have opportunity to benefit more from the technology developed by the communities that have completed this process. (Grossman and Helpman 1990)

Bozeman emphasized the efficiency of technology transfer. (Bozeman 2000) The efficiency of technology transfer is related to the capacity to absorb technology for receivers. Accumulated human capital, the quality of institutions and the conditions of international trade are the most important components of technology absorption capacity. (Henry, Kneller, and Milner 2009)

As a result of the econometric analysis which includes 55 developed countries, performed by Seck, to measure the effects of ITT, especially in developing countries, it is stated that the benefit obtained by technology diffusion is not homogeneous. (Seck 2012) Ferraro examined the effect of economic uncertainty on technology diffusion and concluded that as the volatility in per capita growth increased, technology adaptation time increased and low growth rates were obtained. (Ferraro 2017)

3. Data and Methodology

3.1 Data

In this research[5] we used a strongly balanced panel of annual data for 32 countries over the period 1993 – 2017. Our sample mainly obtained from Penn World Table version 9.1 database. (Feenstra, Inklaar, and Timmer 2015) Growth variable Ln(y) represents the growth rate of logarithm real GDP per capita (constant 2011 US$). We used population level variable Ln(p) in the PMG-ARDL model. Further, Ln(I/GDP) represents the log of gross capital formation used as a proxy for the average share of real investment was not available. We measured Ln(n+g+δ) as the sum of the annual rate of growth of the population, the annual average depreciation rate of capital stock and the technological growth of Labor. We assumed the technological growth of Labor is 0.02. Variable Ln(g) is the log annual share of governmental consumption to GDP. We motivated human capital index Ln(h) which is based on the average years of schooling and the rate of return for primary, secondary and tertiary education, into the model. Variables Ln(x) and Ln(m) represents the author estimations which will be discussed below. Table 1 reports the descriptive statistics for all variables used in estimations.

On the other hand, we distinguished the countries into two groups. Our aim of this categorization is twofold. First, as stated by many economists, the main reason for the slowdown in the global economy, it is suggested that it stems from the slow growth rates in the developed world. Second, it is generally accepted that the developed countries are known as they are technology provider and developer. In this way, the separation of countries into

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[5] Basically, we applied the estimation procedure built up by Solow (1956), Swan (1956), and Mankiw, Romer and Weil (1992) as discussed in Appendix.

groups could obtain us to understand the relationship between international technology transfer and growth rates.

Table 1 : Summary Statistics

Variable Description – Entire Sample	Obs.	Mean	Std. Dev.	Min.	Max.
Ln(y) – Real GDP per capita	800	10.10	0.70	7.61	11.33
Ln(p) – Population	800	17.20	1.72	12.47	21.06
Ln(I/GDP) – Investment to GDP ratio	800	3.18	0.24	2.45	4.24
Ln(n+g+δ)	800	1.90	0.14	1.51	2.25
Ln(h) – Human capital Index	800	1.06	0.19	0.44	1.38
Ln(g) – Governmental Spending to GDP	800	2.80	0.24	2.11	3.53
Ln(m) – Technology Transfer index (import)	800	27.16	0.49	25.98	28.64
Ln(x) – Technology Transfer index (export)	800	27.17	0.48	26.10	28.53

Variable Description – A Group countries	Obs.	Mean	Std. Dev.	Min.	Max.
Ln(y) – Real GDP per capita	800	10.59	0.24	10.05	11.33
Ln(p) – Population	800	17.02	1.26	15.00	19.59
Ln(I/GDP) – Investment to GDP ratio	800	3.25	0.18	2.83	4.24
Ln(n+g+δ)	800	1.86	0.11	1.67	2.24
Ln(h) – Human capital Index	800	1.18	0.10	0.80	1.38
Ln(g) – Governmental Spending to GDP	800	2.77	0.19	2.20	3.16
Ln(m) – Technology Transfer index (import)	800	27.10	0.47	26.39	28.63
Ln(x) – Technology Transfer index (export)	800	27.14	0.45	26.35	28.49

Variable Description – B Group countries	Obs.	Mean	Std. Dev.	Min.	Max.
Ln(y) – Real GDP per capita	800	9.62	0.67	7.61	11.21
Ln(p) – Population	800	17.38	2.08	12.47	21.06
Ln(I/GDP) – Investment to GDP ratio	800	3.12	0.27	2.45	4.00
Ln(n+g+δ)	800	1.93	0.15	1.51	2.25
Ln(h) – Human capital Index	800	0.95	0.19	0.44	1.29
Ln(g) – Governmental Spending to GDP	800	2.83	0.28	2.11	3.53
Ln(m) – Technology Transfer index (import)	800	27.22	0.51	25.98	28.64
Ln(x) – Technology Transfer index (export)	800	27.21	0.51	26.10	28.53

Note: Authors estimations

Since it is not possible to quantify the ITT numerically, we developed the ITT index by adding countries' industrial production and their linkage effects on each other. Developed countries benefit from the labor force of developing countries to produce new technologies. This situation also plays an important role in the increase of intermediate goods trade between countries. In addition, the commercial integration established by the countries in terms of firms, is an important constituent element of the technology spillover. We assumed and quantified the ITT induced by imports and exports which is specified as follows;

$$Ln(m)_{i,t} = Ln\left[\sum_{j=1}^{10} \frac{(\tau_{j,t\to i,t})\, Q_{j,t}^{m}}{\sum IM_{i,t}}\right] \tag{2.1}$$

$$Ln(x)_{i,t} = Ln\left[\sum_{j=1}^{10} \frac{(\varphi_{i,t\to j,t})\, Q_{j,t}^{m}}{\sum EX_{i,t}}\right] \tag{2.2}$$

$(\varphi_{j,t\to i,t})$ denotes the export volume of country j to country i, at time t, $(\tau_{j,t\to i,t})$ denotes the import volume of country j from country i, at time t, $Q_{j,t}^{m}$ denotes the total Industrial Production of country j at time t, $\sum EX_{i,t}$ denotes the total export volume of country i to the World at time t and $\sum IM_{i,t}$ denotes the total import volume of country i from the World at time t. The subscript i denotes selected countries, and the subscript j denotes the first 10 countries ranked from the largest volume to the smallest volume.

Figure 1 (imports) and Figure 2 (exports) shows the time series graphs for the individual country estimation results of the indexes. To interpret the Figure 1, it is possible to say most of the countries have increases during the 25 years period while just China index is decreased from its initial level. For Figure 2, it is again the same result, which indicates that most countries have important increases. But at the end of 2017 China, Iceland and Turkey almost the same level compared to the initial level. Generally, the results show that the industrial linkage between countries increased remarkably during the last three decades. In one respect, the technological transfer between countries is increasing in parallel with their globalization.

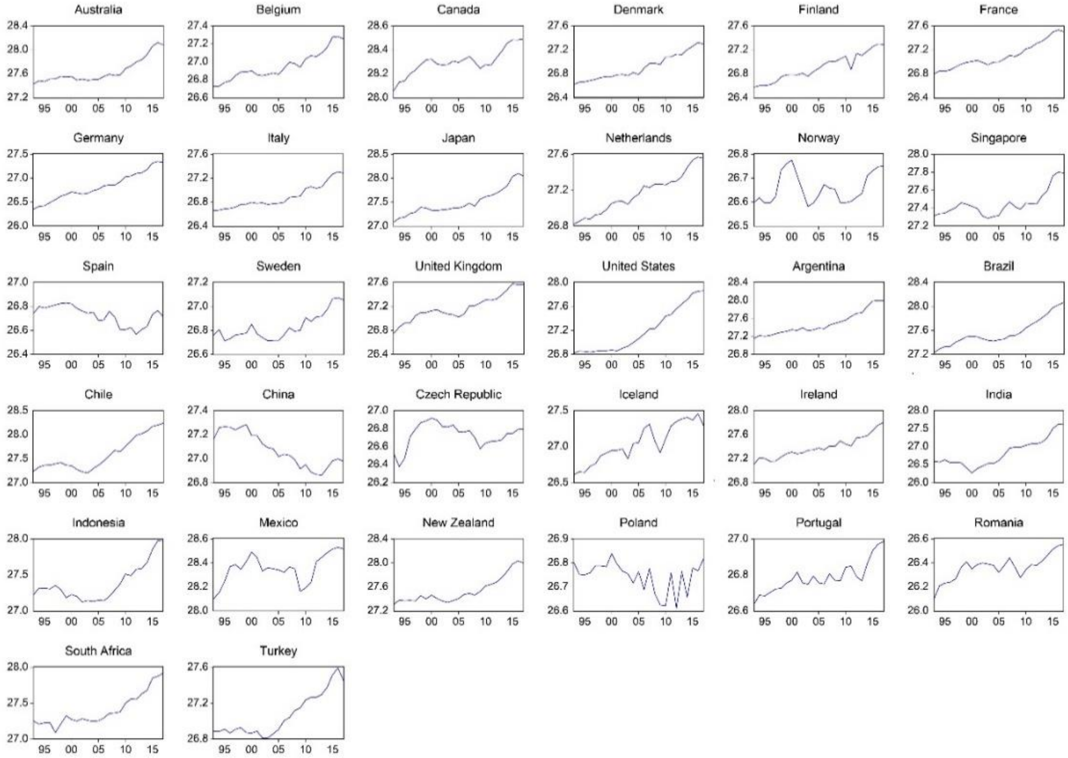

Figure 1: Ln(m) for individual countries

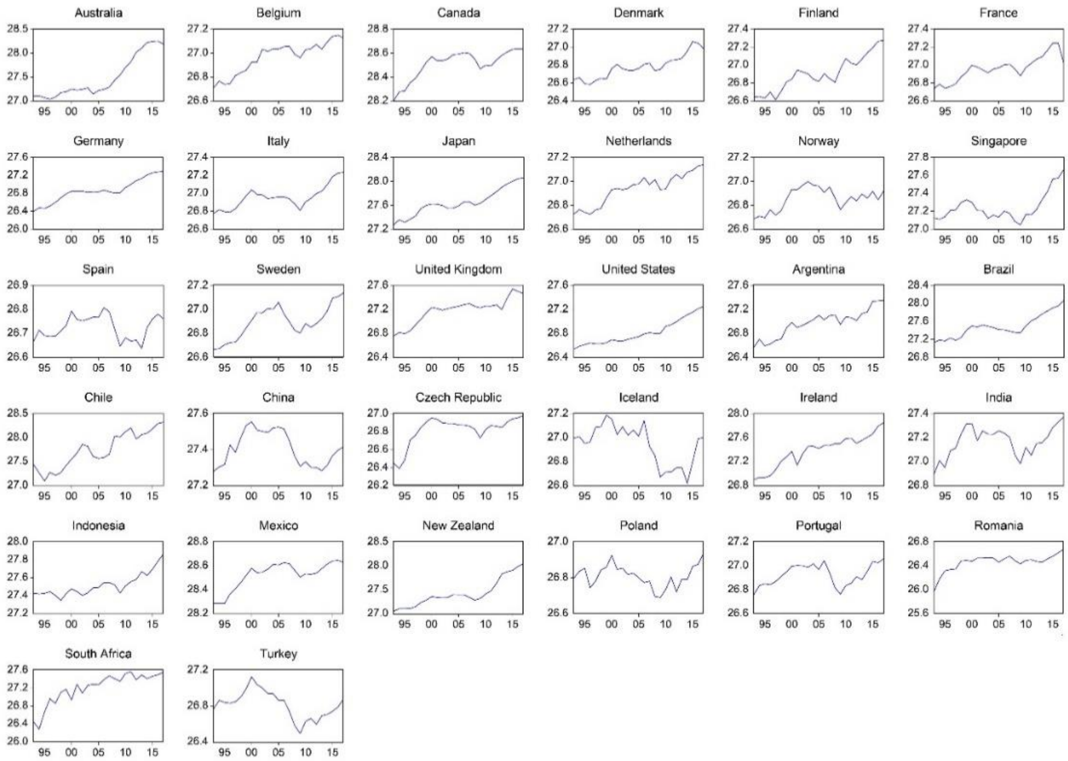

Figure 2 : Ln(x) for individual countries

3.2 Pooled mean group – Autoregressive distributed Lag model

In this study, we firstly applied pooled mean group estimation methodology which is the advanced and newest, proposed by Pesaran et al. to investigate the long run relationship between exports and imports induced ITT index, population levels and real GPD per capita. (Pesaran, Shin, & Smith, 1999) The PMG estimation approach is used to estimate dynamic heterogeneous panels by considering long run equilibrium relations. This estimation technique allows to use I(0) and I(1) variables together. On the other hand, by this technique, cointegration vector is estimated based on the error correction format. Let the ARDL(p,q,q,q) dynamic model is specified as follows;

$$y_{i,t} = \sum_{j=1}^{p} \lambda_{ij} y_{i,t-j} + \sum_{j=0}^{q} \delta'_{i,j} x_{i,t-j} + \mu_i + \varepsilon_{i,t} \qquad (2.3)$$

where the number of cross-country units i = 1,2,…,N, from 1 to N; the number of the period t = 1,2,…,T. $y_{i,t}$ is the real GDP per capita and $x_{i,t}$ is a kx1 vector of explanatory variables (imports induced ITT index, exports induced ITT index and population level), $\delta'_{i,j}$ is the kx1 vector of coefficients, λ_{ij} are the scalars, μ_i is the cross country specific effect and the $\varepsilon_{i,t}$ is the error term.

For the convenience of eq. (1), we can parameterize as follows;

$$\Delta y_{i,t} = \emptyset \Delta y_{i,t-1} + \beta'_i x_{i,t} + \sum_{j=1}^{p-1} \lambda'_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta'_{i,j} \Delta x_{i,t-j} + \mu_i + \varepsilon_{i,t} \qquad (2.4)$$

where $\emptyset_i = -\left(1 - \sum_{j=1}^{p} \lambda_{ij}\right)$; $\beta_i = \sum_{j=0}^{q} \delta_{ij}$; $\lambda'_{ij} = -\sum_{m=j+1}^{p} \lambda_{im,j}$; j=1,…,p-1 and $\delta'_{\mathrm{I,j}} = -\sum_{m=j+1}^{q} \delta_{\mathrm{im}}$, j=1,…,q-1

In the model, $\emptyset_i$ is error correction parameter, λ_{ij} is scalars, δ_{ij} is kx1 vector of coefficients and q is optimal lag length for independent variables. The parameter $\emptyset_i$ is also known as speed of adjustment term. There would be a long run relationship between variables if the estimation result of this parameter is negative and significant.

3.3 Difference -GMM and System-GMM

Generalized method of moments estimation methodology is the most used estimation method for the dynamic models which include lagged dependent variable. In this technique, instrumental variables are used to solve endogeneity problem of the independent variables. There are two types of GMM estimation method. First one is the difference-GMM estimators pioneered by Holtz-Eakin, Newey, & Rosen (1988) and Arellano & Bond (1991). Difference-GMM estimation technique instrument matrix includes the lagged values of differenced independent variables. Dynamic model is specified as follows; (Das 2016)

$$y_{i,t} = \alpha + \beta_1 y_{i,t-1} + \beta'[x]_{i,t} + \varphi_i + \varepsilon_{i,t} \qquad (2.5)$$

where the number of cross-country units i = 1,2,…,N, from 1 to N; the number of the period t = 1,2,…,T. $y_{i,t}$ is the real GDP per capita and $x_{i,t}$ represent the set of explanatory variables. φ_i is the unobserved country specific effects and the $\varepsilon_{i,t}$ is the error term. In order to eliminate the country specific effects we can formulate as follows;

$$y_{i,t} - y_{i,t-1} = \alpha + \beta_1\left(y_{i,t-1} - y_{i,t-2}\right) + \beta'\left[x_{i,t} - x_{i,t-1}\right]_{i,t} + (\varepsilon_{i,t} - \varepsilon_{i,t-1}) \qquad (2.6)$$

Second GMM estimation technique is the system-GMM estimator that is developed by Arellano & Bover (1995) Blundell & Bond (1998) and Bond, Hoeffler, & Temple (2001). According to these papers, difference-GMM does not perform well because of the weakness of the instruments. System-GMM estimator additionally uses the lagged value of independent variables as instrumental variables. By doing so, instrumental variables would be more strengthen within the Solow-Swan growth framework.

Table 2 : Panel Unit Root Test

Variables for ALL		Ln(y)	Ln(p)	Ln(I/GDP)	Ln(n+g+δ)	Ln(h)	Ln(g)	Ln(m)	Ln(x)
Levin, Lin and Chu (LLC)	Level	-6.30***	-5.06***	-1.91**	-3.04***	0.29	-4.68***	-0.18	5.88
Im, Pesaran and Shin (IPS)	Level	-1.33*	-0.94	-3.22***	-2.14***	4.90	-2.65***	1.44	8.81
ADF-Fisher Chi-Square	Level	100.59***	117.47***	104.14***	97.25***	48.90	96.84***	67.71	25.25
PP-Fisher Chi-Square	Level	117.02***	174.49***	82.93*	34.75	221.37***	46.71	55.49	25.20
Levin, Lin and Chu (LLC)	Diff.	-13.37***	2.23	-17.52***	-1.24	-3.64***	-10.19***	-15.41***	-16.75***
Im, Pesaran and Shin (IPS)	Diff.	-11.34***	-0.67	-16.89***	-6.28***	-3.11***	-10.86***	-15.47***	-16.93***
ADF-Fisher Chi-Square	Diff.	244.56***	99.84***	378.21***	155.97***	107.55***	233.33***	340.44***	373.44***
PP-Fisher Chi-Square	Diff.	282.31**	77.35	426.64***	85.86**	79.28*	283.84***	372.79***	395.52***
CD (Pesaran)		98.95***	75.21***	12.84***	32.87***	95.51***	17.10***	63.76***	66.23***
		I(0)	I(0)	I(0)	I(0)	I(1)	I(0)	I(1)	I(1)
Variables for A Countries		Ln(y)	Ln(p)	Ln(I/GDP)	Ln(n+g+δ)	Ln(h)	Ln(g)	Ln(m)	Ln(x)
Levin, Lin and Chu (LLC)	Level	-9.68***	-2.62***	-1.36*	-3.34***	-1.70**	-2.54***	0.74	3.24
Im, Pesaran and Shin (IPS)	Level	-4.40***	0.24	-1.46*	-3.15***	1.33	-1.05	2.18	5.78
ADF-Fisher Chi-Square	Level	81.75***	56.88***	39.79	69.70***	34.02	33.39	21.63	12.94
PP-Fisher Chi-Square	Level	98.43***	75.43***	37.29	17.27	158.67***	20.17	18.49	6.26
Levin, Lin and Chu (LLC)	Diff.	-8.86***	2.19	-14.40***	-1.01	-0.99	-7.80***	-9.35***	-11.31***
Im, Pesaran and Shin (IPS)	Diff.	-7.82***	-2.24**	-12.80***	-4.07***	-0.43	-7.91***	-10.15***	-11.58***
ADF-Fisher Chi-Square	Diff.	118.82***	71.60***	200.73***	68.93***	25.23	120.56***	158.25***	181.74***
PP-Fisher Chi-Square	Diff.	156.27***	17.24	214.96***	28.74	25.45	172.92***	159.38***	188.35***
CD (Pesaran)		50.61***	46.36***	10.91***	26.77***	45.82***	31.24***	40.58***	38.46***
		I(0)	I(0)	I(1)	I(0)	I(0)	I(1)	I(1)	I(1)
Variables for B Countries		Ln(y)	Ln(p)	Ln(I/GDP)	Ln(n+g+δ)	Ln(h)	Ln(g)	Ln(m)	Ln(x)
Levin, Lin and Chu (LLC)	Level	-1.22	-4.54***	-1.35*	-0.11	1.49	-3.79***	-1.31*	5.23
Im, Pesaran and Shin (IPS)	Level	2.48	-1.62*	-3.07***	0.14	5.59	-2.69***	-0.14	6.68
ADF-Fisher Chi-Square	Level	18.84	60.59***	64.36***	27.54	14.87	63.45***	46.08*	12.31
PP-Fisher Chi-Square	Level	18.59	99.05***	45.64*	17.47	62.70***	26.54	36.99	18.94
Levin, Lin and Chu (LLC)	Diff.	-10.13***	0.75	-10.16***	-0.74	-4.14***	-6.69***	-12.38***	-12.34***
Im, Pesaran and Shin (IPS)	Diff.	-8.21***	1.28	-11.12***	-4.82***	-4.74***	-7.45***	-11.73***	-12.37***
ADF-Fisher Chi-Square	Diff.	125.73***	28.24	177.48***	87.05***	82.31***	112.77***	182.18***	191.70***
PP-Fisher Chi-Square	Diff.	126.03***	60.12***	211.68***	57.12***	53.82***	111.02***	213.42***	207.17***
CD (Pesaran)		48.74***	27.72***	8.71***	9.15***	47.68***	0.84	24.36***	26.21***
		I(1)	I(0)	I(0)	I(1)	I(1)	I(0)	I(1)	I(1)

Note: Authors estimation. *** significant at 1%, ** significant at 5 % and * significant at 10%.

4. Empirical Results

In an econometric analysis stationarity is important to examine whether there is or not spurious correlation in terms of regression analysis to investigate the relationship between them. In this context, we used Levin, Lin and Chu (LLC), Im, Pesaran and Shin (IPS), Augmented Dickey Fuller (ADF) – Fischer Chi-Square and Philips and Perron – Fischer Chi-Square Tests. Table 2 shows the results of unit root tests for all (32 countries) and A Category and B Category, separately.

Results show that the new estimated export and import based ITT index variables are I(1) and other variables I(0) for all countries included panel data. For A category countries panel data unit root tests show that government consumption rate, investment rate and the new index variables are I(1) and other variables are I(0). But for the B category countries GDP per capita is I(1) instead of investment rate variable in category A panel data. Except this difference the other variables are at same integration level compared to the A category panel data. These results show that all the variables we have are I(0) and I(1).

The main problem during our estimation would be the cross-country dependencies. Normally, there should not be cross-country dependency during the PMG-ARDL and GMM estimations. But in the real world where the linkage is at the highest level between countries, it could not be possible to have independency in cross-countries.

4.1 Pooled mean group mean estimations

Table 3 represents the results of PMG-ARDL estimation of the exports and imports based ITT index, population level and the GDP per capita growth rates with long-run and short-run coefficients. We followed Pesaran et al. (1999) PMG-ARDL model. The convergence parameter is the adjustment between short-run and long-run, and it is expected to be negative and significant. The adjustment coefficient is (- 0.031) negative and significant for the entire sample estimation, (- 0.134) negative and significant for A Category countries' estimation and (- 0.008) negative but not significant for the B Category countries' estimation.

Long-run estimations indicate that imports induced ITT index has positive and significant impact on GDP per capita growth rates. It is not possible to say the same interpretation for exports induced ITT index because the impact is positive but not significant. Population level has negative and significant impact on the GDP per capita growth rates in the long run. For the A Category countries, imports induced ITT index has negative and significant impact on GDP per capita growth rates. Impact of the exports induced ITT is positive and significant. Population level has positive but not significant effect on GDP per capita growth rates. Exports and imports induced ITT indexes have positive and significant impact for B Category countries. Population level has negative and significant impact on the GDP per capita growth rates.

Table 3 : Pooled mean group estimation

	Period 1993-2017	Period 1993-2017	Period 1993-2017
	Entire Sample	A Group	B Group
Dependent Variable	Diff.Ln($y_{i,t}$)	Diff.Ln($y_{i,t}$)	Diff.Ln($y_{i,t}$)
Long Term			
Ln(m)	0.931***	-0.184***	2.385***
	(0.172)	(0.058)	(0.816)
Ln(x)	0.165	0.588***	0.765**
	(0.132)	(0.068)	(0.302)
Ln(p)	-4.243***	0.196	-4.805**
	(0.782)	(0.215)	(2.383)
Short Term			
Cointeq01	-0.031***	-0.134***	-0.08
	(0.012)	(0.019)	(0.012)
Diff.Ln(m)	-0.006	0.053***	-0.016
	(0.025)	(0.023)	(0.042)
Diff.Ln(x)	0.115***	0.061*	0.124***
	(0.029)	(0.033)	(0.047)
Diff.Ln(p)	1.441	-1.122	0.719
	(1.270)	(1.110)	(1.553)
Intercept	1.486**	-0.475***	-0.187*
	(0.626)	(0.067)	(0.109)
Mean dependent var	0.022	0.015	0.029
S.E of regression	0.026	0.017	0.030
Sum squared resid	0.415	0.089	0.293
Log Likelihood	2003.733	1121.773	914.126
S.D. dependent var	0.031	0.021	0.037
Observations	768	384	384

Note: The values in the parantheses are the associated standard errors. (***), (**) and (*) denotes statistical significance at 1%, 5% and 10%, respectevely.

4.2 System-GMM and First-Difference GMM estimations

Table 4 is the result from GMM estimations. At first sight, results show that the estimators signs are compatible with the results of Mankiw et al. and Caselli et al. (Mankiw, Romer, and Weil 1992a) (Caselli, Esquivel, and Lefort 1996) Lagged value of real GDP per capita have negative sign for the entire sample results and the investment to GDP ratio and population growth have the opposite sign. This is also compatible with the A category countries' estimation results. But if we look at the B category countries we can see that the investment to GDP ratio and population growth have the same positive sign which is not compatible with Mankiw et al. and Caselli et al. Entire sample results which is estimated by two-step System-GMM show that all other explanatory variables are statistically significant. But we can't say the same for the two-step Dif-GMM estimation results and the OLS (Ordinary Least Squares) estimation results. Human Capital and exports induced ITT index have positive and statistically significant impact on real GDP per capita growth rates for the entire sample. Government spending ratio and the imports induced ITT index has negative and statistically significant impact on real GDP per capita growth rates for the entire sample. A category and B category results have low statistically significant estimation results. This show that, decreasing the number of cross-countries impact the estimation negatively. Human capital has positive but statistically insignificant impact on real GDP per capita growth rates for A category and B category countries. For the A category countries, exports induced ITT index has positive and statistically significant impact and imports induced ITT index has negative and statistically insignificant impact on real GDP per capita growth rates. Interestingly, For the B category countries, exports induced ITT index and imports induced ITT index have positive and statistically significant impact on real GDP per capita growth rates. Here, it is possible to say that both import and export based ITT have positive impacts especially in terms of developing countries. For A category and B category countries, Government spending ratio have a negative impact on the growth rates. For the entire sample our convergence rate estimation is not low as Mankiw et al. and is not high as Caselli et al. estimations.

System-GMM results of the entire sample show that restricted convergence rate is 6,8 %. If we look at in the basis of A category and B category, unrestricted convergence rate is high. Probably, this is because the number of countries used in the estimation is not sufficient.

Table 4 : GMM Estimation Results

	Period 1993-2017			Period 1993-2017			Period 1993-2017		
	Entire Sample			A Group			B Group		
Dependent	Diff.Ln($y_{i,t}$)			Diff.Ln($y_{i,t}$)			Diff.Ln($y_{i,t}$)		
	OLS	**Dif-GMM**	**System-GMM**	**OLS**	**Dif-GMM**	**System-GMM**	**OLS**	**Dif-GMM**	**System-GMM**
Intercept	0.330***	-1.233***	-0.183*	0.197***	-1.390*	-0.351	0.398***	-1.928	-0.257
	(0.094)	(0.121)	(0.098)	(0.098)	(0.814)	(0.499)	(0.117)	-1.361	-2.368
Ln($y_{i,t-1}$)	-0.057***	-0.105***	-0.065***	0.015***	-0.112***	-0.096***	-0.021***	-0.303***	-0.253
	(0.004)	(0.016)	(0.015)	(0.006)	(0.058)	(0.019)	(0.004)	(0.127)	(0.119)
Ln(I/GDP)	0.047***	0.127***	0.126***	0.019**	0.104***	0.070***	0.050***	0.138***	0.131***
	(0.005)	(0.008)	(0.007)	(0.008)	(0.024)	(0.026)	(0.007)	(0.033)	(0.034)
Ln(n+g+δ)	-0.031***	-0.123***	-0.150***	-0.011	-0.124	-0.105	0.012	0.238	0.065
	(0.011)	(0.017)	(0.029)	(0.015)	(0.134)	(0.097)	(0.014)	(0.304)	(0.275)
Ln(h)	0.035**	0.088*	0.152***	-0.006	0.092	0.172	0.055***	0.439	0.547
	(0.014)	(0.046)	(0.047)	(0.014)	(0.224)	(0.192)	(0.014)	(0.351)	(0.494)
Ln(m)	0.004	0.007	-0.024***	0.004	-0.050	-0.030	-0.006	0.090**	0.059
	(0.005)	(0.007)	(0.007)	(0.006)	(0.034)	(0.028)	(0.007)	(0.038)	(0.042)
Ln(x)	-0.007	0.076***	0.054***	-0.002	0.144***	0.077**	0.007	0.044	0.005
	(0.005)	(0.008)	(0.006)	(0.005)	(0.024)	(0.034)	(0.007)	(0.033)	(0.052)
Ln(g)	-0.028***	-0.079***	-0.081***	-0.033***	-0.066**	-0.056*	-0.019***	-0.035	-0.037
	(0.005)	(0.007)	(0.006)	(0.005)	(0.029)	(0.030)	(0007)	(0.064)	(0.058)
Implied λ	0.028***	0.109***	0.068***	0.017***	0.118***	0.098***	0.062***	0.362***	0.290***
	(0.003)	(0.009)	(0.005)	(0.002)	(0.006)	(0.004)	(0.005)	(0.027)	(0.017)
Instruments		30	53		30	53		30	53
Sargan Test		28.47	30.367		12.848	13.333		9.158	9.047
AR(1) A-B Test		0.003	0.003		0.009	0.006		0.131	0.061
AR(2) A-B Test		0.022	0.014		0.074	0.053		0.508	0.28
Observations	768	736	768	384	368	384	384	368	384
Countries	32	32	32	16	16	16	16	16	16

Note: The values in the parantheses are the associated standard errors. (***), (**) and (*) denotes statistical significance at 1%, 5% and 10%, respectevely.

For the test of the validity of the results, we applied Sargan and Arellano-Bond serial correlation tests. For the entire sample, Sargan test results show that the null hypothesis is not rejected. This show that the instrumental variables and error term are not correlated. Arellano-Bond AR(2) test show that errors in the first difference regression do not exhibit second order serial correlation. Sargan test for A category and B category countries are valid. But for the Arellano-Bond test show there is second order serial correlation with errors for A category countries. This test is valid for B category countries.

5. Conclusion

Technology transfer between countries not only creates new business areas between both technology sending and receiving countries, but also involves economic and social gains in many different aspects for both sides. In order not to lose these gains, countries need more cooperation than separation or trade wars.

The results of our study show that technology transfer has long-term and strong effects on the economic growth of countries. As developed countries export technology and developing countries import technology, they can reach their desired growth rates. We could not get a clear conclusion as to whether technology transfer is a threat to the developed world. However, it is clear it offers opportunities for developing countries. Some countries in the developing world are successful in strengthening their human capital and institutions by receiving technology. This causes them to be successful in achieving higher growth rates.

6. Further Research

In this study, we could not reach a large number of countries due to lack of data on country basis. Industrial production of countries import and export data between them can be obtained more extensively in the future. In addition, performing this study on an intermediate goods basis may be helpful in understanding the subject in more detail.

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Appendix

Basically, we applied the estimation procedure built up by Solow (1956), Swan (1956), and Mankiw, Romer and Weil (1992). Let us briefly review the Solow-Swan model and the contribution of Mankiw et al.

$$Y(t) = K(t)^{\alpha}\big(A(t)L(t)\big)^{1-\alpha} \qquad 0 < \alpha < 1 \tag{2.7}$$

Where Y(t) is output at time t, K(t) is physical capital at time t, L(t) is Labor at time t and A(t) is technology level.

$$L(t) = L(0)e^{nt} \tag{2.8}$$

$$A(t) = A(0)e^{gt} \tag{2.9}$$

Model assumes Labor and Technology level grow exogenously at a rate of n and g, respectively. $\big(A(t)L(t)\big)$, Labor and Technology level show the effective units of labor. This variable grows at a rate of (n+g). If we divide Y and K with effective unit of labor, we get y=Y/AL and k=K/AL. So, y is the amount of output per effective unit of labor and k is the amount of physical capital per effective unit of labor. Model predicts k converges to its own steady-state value which the level differs for each country. Main prediction of the model is that Marginal Product of Physical Capital is very large when the initial level of physical capital is small and Marginal Product of Physical Capital is very small when the initial level of physical capital is large.[6] According to the model growth of physical capital per effective unit of labor depends on the difference between the friction of the saving in the output and the growth rate of effective unit of labor and the depreciation of physical capital.

[6] Inada conditions; $\lim_{x_i \to +\infty}(\partial f(x)/\partial x_i) = 0$ and $\lim_{x_i \to 0}(\partial f(x)/\partial x_i) = +\infty$

$$\dot{k}(t) = sk(t)^{\alpha} - (n + g + \delta)k(t) \qquad (2.10)$$

where $\dot{k}(t)$ is the growth rate of physical capital per effective unit of labor, s is the saving rate and δ is the depreciation rate of physical capital. This formula predicts growth rate of physical capital depends positively on saving rate and negatively on growth rate of effective unit of labor and depreciation rate of physical capital.

$$k^* = \frac{s^{\frac{1}{1}-\alpha}}{(n + g + \delta)^{\frac{1}{1}-\alpha}} \qquad (2.11)$$

k^* is the steady-state value of the model. Adapting this equation into the production function and take logs for both sides we get:

$$Ln(y) = LnA(0) + gt + \frac{\alpha}{1-\alpha}Ln(s) - \frac{\alpha}{1-\alpha}Ln(n + g + \delta) \qquad (2.12)$$

Mankiw et al. made an important contribution to the Solow growth model by adding Human Capital into the production function which is mostly called augmented Solow-Swan growth model. (Mankiw, Romer, and Weil 1992b). Let the production function be,

$$Y(t) = K(t)^{\alpha}H(t)^{\beta}\big(A(t)L(t)\big)^{1-\alpha-\beta} \qquad (2.12)$$

where $\mathrm{Y}(t)$ is flow of output produced at time t, $K(t)$ represents the durable physical inputs at time t, $L(t)$ is the labor input associated with the human body at time t, and $\mathrm{H}(t)$ is the Human Capital which captures the schooling level of the population at time t. Growth rate of physical capital and human capital will be as follows,

$$\dot{k}(t) = s_k k(t)^{\alpha} - (n + g + \delta)k(t) \qquad (2.13)$$

$$\dot{s}\big(t\big) = s_h h(t)^{\beta} - (n + g + \delta)h\big(t\big) \qquad (2.14)$$

where y=Y/AL, k=K/AL and h=H/AL. Steady state values for k* and h* will be as follows;

$$k^* = \left(\frac{s_k{}^{1-\beta} s_h{}^{\beta}}{(n+g+\delta)}\right)^{\frac{1}{(1-\alpha-\beta)}} \tag{2.15}$$

$$h^* = \left(\frac{s_k{}^{\alpha} s_h{}^{1-\alpha}}{(n+g+\delta)}\right)^{\frac{1}{(1-\alpha-\beta)}} \tag{2.16}$$

k* and h* are the steady-state values of the model. Adapting these into the production function and take logs for both sides we get;

$$\begin{aligned} Ln(y_{i,t}) = a + \frac{\alpha}{1-\alpha-\beta} Ln(s_{k,i,t}) + \frac{\alpha}{1-\alpha-\beta} Ln(s_{h,i,t}) \\ - \frac{\alpha+\beta}{1-\alpha-\beta} Ln(n_{i,t} + g_{i,t} + \delta_{i,t}) + \varepsilon_{i,t} \end{aligned} \tag{2.17}$$

Speed of convergence in the augmented Solow-Swan growth model; Neoclassical growth models predict (within the assumption of diminishing returns) that economies reach different steady state values. Speed of convergence provide us approximately how fast economies reach their steady state values. The speed of convergence, λ, defined as follows,

$$\frac{d\,\mathrm{Ln}(y(t))}{dt} = \lambda\left[(y^*) \ - \mathrm{Ln}(y(t))\right] \tag{2.18}$$

where, $\lambda=(n+g+\delta)(1\text{-}\alpha\text{-}\beta)$ and y^* is steady state value of GDP per capita per effective unit of labor. Unrestricted version may be written as follows;

$$\mathrm{Ln}(y(t)) = \left(1 - e^{-\lambda t}\right)(y^*) \ + e^{-\lambda t}\,\mathrm{Ln}(y(0)) \tag{2.19}$$

where y(0) is the initial date of income. Finally, subtracting y(0) from both sides and reduced form becomes,

$$
\begin{aligned}
Ln(y_{i,t}) - Ln(y_{i,t-\varphi}) & \\
&= a - (1 - e^{-\lambda t}) Ln(y_{i,t-\varphi}) \\
&+ (1 - e^{-\lambda t}) \frac{\alpha}{1 - \alpha - \beta} Ln(s_{k,i,t}) \\
&+ (1 - e^{-\lambda t}) \frac{\alpha}{1 - \alpha - \beta} Ln(s_{h,i,t}) \\
&- (1 - e^{-\lambda t}) \frac{\alpha + \beta}{1 - \alpha - \beta} Ln(n_{i,t} + g_{i,t} + \delta_{i,t}) + \varepsilon_{i,t}
\end{aligned}
\tag{2.20}
$$

In this study we followed standard practice with the same view with Caselli et al (1996). In the regression analysis the rate of growth of real GDP per capita instead of growth of real GDP per effective unit of labor. We assumed investment rate is constant for every one-year period which means φ is 1 year in our study.

Chapter 3

The Adjustment to Internal and External Shocks in a Small Open-New Keynesian Economy: Evidence from Turkey

Abstract

Turkish economy is suffering from sudden, persistent and highly volatile shocks in its economic conjuncture. Accordingly, we estimate a small open-New Keynesian DSGE model with domestic and foreign shocks, price stickiness and habit consumption for Turkey between 2003Q2 - 2020Q1. Following Justiniano and Preston (2010), the core objective of this study is to investigate whether an estimated small open economy DSGE model provides a realistic behaviour about the structure of Turkish economy. We have two different dimensions from Justiniano and Preston (2010) by adding modified uncovered interest rate parity parameter and terms of trade shock. The estimation results show that new Keynesian rigidities such as price indexation and the exchange rate sensitivity in Taylor Rule did not improve the model. Habir formation, MUIP and terms of trade shock included benchmark model fits the real data best. On the other hand, model is successful to match inflation and short-term interest rates in terms of second moment comparisons. 85 % of consumption volatility is explained by preference shocks. Variance of output is influenced by 19 % technology shocks and 69 % preference shocks. According to the posterior estimations of the benchmark model Turkish Central Bank was not sensitive to exchange rate changes as expected.

Keywords: word; New-Keynesian economics, open economy DSGE models, price rigidities, Bayesian Approach

1. Introduction

Turkish economy is suffering from sudden, persistent and highly volatile shocks in its economic conjuncture. In this study, we evaluated the Turkish economy within the New Keynesian approach small-open economy DSGE model for the last two decades just after the Central Bank of the Republic of Turkey (TCB) has been adopted inflation targeting regime. Following Justiniano and Preston (2010), the benchmark model is consisted with habit consumption, price indexation, Calvo price setting, modified uncovered interest rate parity and exchange rate augmented Taylor rule.

No consensus has been reached in the literature on the source of fluctuations in macroeconomic variables. (Justiniano, Primiceri, and Tambalotti 2010) The New Keynesian models which is composed with price and/or wage staggering, Euler equation and Taylor rule as well as financial frictions, became very important in monetary policy and welfare debates. (Blanchard and Galí 2007) Academic world is still working to develop DSGE models which are the leading tool for making assessments of macroeconomic changes in an open and transparent manner. (Christiano, Eichenbaum, and Trabandt 2018) DSGE models have gained increasing prominence not only in academic circles, but also in policymaking institutions. For example, these models have also became part of many central banks ' forecasting and policy analysis toolbox. On the other hand, post-Great Recession setting surely provided an important real-time test of their predictive accuracy. (Cai et al. 2018) (Edge and Gürkaynak 2010) DSGE models do considerably better forecasts than both the vector autoregression models and Bayesian vector autoregression models. (Smets and Wouters 2007) The fact that modern DSGE models overcome Lucas' famous criticism provides a significant advantage over other macroeconomic models. (Lucas 1976)

The central banks of developing economies have two important dimensions compared to the central banks of developed countries to stabilize the economy. First, in addition to domestic supply and demand shocks, emerging economies are subject to various external shocks. Second, they have to weigh the exchange rate in addition to output and inflation. (Liu 2010)

Following the influential papers of Gali and Monacelli (2005) and Justiniano and Preston (2010), the benchmark model includes preferences shocks (ε_g), risk premium shocks (ε_p), costs-push shocks (ε_{cp}), monetary policy shocks (ε_m) technology shocks (ε_a) and terms of trade shocks (ε_{tot}) on the domestic side and foreign output shocks (ε_{y^*}), foreign inflation shocks (ε_{π^*}) and foreign interest rates shocks (ε_{r^*}) on the foreign side. The benchmark model do not only includes new Keynesian synthesis formations but also MUIP parameter and terms of trade shock. These are embedded to the model which are not included in the original paper Justiniano and Preston (2010). However, we evaluated the different features and specifications of the small open economy model with the Bayesian estimation technique. For example, we ran the model neglecting habit formation to be able to understand the efficiency of the new Keynesian parameter in the benchmark model. Estimation results show that new Keynesian parameters did not improve the model in terms of model fit to real data. But, adding MUIP and terms of trade shock relatively improved the data.

In general, identifiability of structural parameters of the New Keynesian open economy models are problematic compared to the closed economy models. (Beltran and Draper 2008) Even detecting high correlations between some structural parameters, identifiability of the parameters we used in the benchmark model are quite good according to the prior and posterior distributions figure comparisons.

Evaluating the variance and historical decompositions in the benchmark model we reached important conclusions. Consumption is highly effected by preference shocks. Output growth of Turkish economy is mostly influenced by demand side shocks. This shows us that the Turkish economy, which is in a desirable position in terms of domestic demand, has a high potential to achieve significant growth rates by increasing its productivity. In the benchmark model, the strongest shock influencing interest rates are preference shocks and risk premium shocks. For this reason, as a country targeting low interest rates, the Turkish economy should continue to keep the country's risk premium at the lowest possible levels. The most influential shock effecting inflation is monetary policy shock.

There is a vast literature on estimating models using small open economy DSGE models with Bayesian approach. Linardi (2016) estimated a small open economy DSGE model for Brazilian economy and found that the best fitting model to the economy is the model without price indexation parameter. Haider and Khan (2008) examined the effects of high inflation on domestic demand and the effects of exchange rate volatility on inflation, stating that the small open economy model they developed showed real behaviour for the Pakistan economy. Bäurle and Menz (2008) examined whether the Swiss central bank's nominal exchange rate sensitivity was optimal. Kamber et al. (2016) used a model covering adaptive inflation expectations for the small open economy DSGE model and compared to the baseline model. They found addition of adaptive inflation expectations improved the model’s fit to the New Zealand economic data.

This chapter organised as follows. In section 2 the structure of the model is presented. Section 3 outlines the log-linearized model and Section 4 outlines estimation methodology and the data set used in estimation. Main results and the variance and historical decompositions of the macroeconomic variables discussed in section 5. Conclude remarks of the small open economy DSGE model estimated are interpreted in section 6.

2. Structure of the Model

Following Gali and Monacelli (2005), Monacelli (2005) and Justiniano and Preston (2010), we derive a small open economy DSGE model for Turkey, allowing for habit formation, indexation of prices, Calvo price setting and incomplete markets which has been widely used for the analysis of fiscal and monetary policies by the central banks of emerging markets. Figure 3 depicts the main agents of the small open economy model and their interactions.

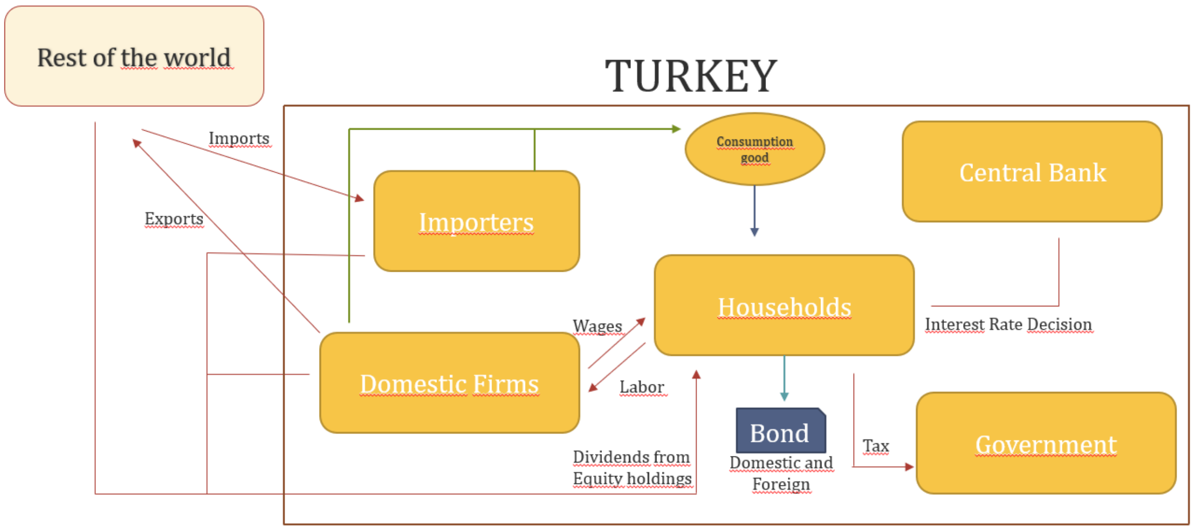

Figure 3 : Economic Schema of Small Open Economy Model

In the model, households consume only consumption goods from domestical producers and importers which import consumption goods from the rest of the world. Households rent labor to domestic producers, so they earn wages and they make decisions how much to work. Households are paid dividends as they are the owners of the domestic and/or foreign firms. On the other side, households can save in domestic and/or foreign bonds and they do not hold cash. Households pay tax to the government. It should be noted that consumption preferences of the households are subject to habit formation.

In the model there are two type of firms: domestic producers and importers. Domestic producers produce consumption goods with only labor inputs. They sell their products in domestic and foreign markets so they are free to export their products. Each domestic producer produce differentiated goods and they determine their prices subject to Calvo model and an indexation to past and future expected inflation. Importers buy consumption goods from foreign market and sell them to households. They determine their prices considering Calvo model, past and future expected inflation. Interest rate decisions are taken by the central bank.

2.1 Households

The economy consists of identical and infinitely lived agents indexed by $q \in (0,1)$, who derive utility from consuming consumption goods and disutility from supplying labor services to firms. Households lifetime utility is given by:

$$E_t \sum_{s=0}^{\infty} \beta^s \Psi_{g,t} \left[\frac{1}{1-\sigma_c} \left(C_{t+s}(q) - hC_{t+s-1}(q) \right)^{1-\sigma_c} - \left(\frac{1}{1+\sigma_l} L_{t+s}(q)^{1+\sigma_l} \right) \right] \quad (3.1)$$

where $\beta^s \in (0,1)$ is the intertemporal discount factor, household q consume C_t, and works in hourly basis L_t. We allow h as habits in consumption. The inverse elasticity of intertemporal substitution is given by $\sigma_c > 0$, and the inverse elasticity of labour supply is given by $\sigma_l > 0$. $\Psi_{g,t}$ is the preference shock which is assumed to evolve according to the following AR (1) specifications:

$$\Psi_{g,t} = \rho_g \Psi_{g,t-1} + \varepsilon_{g,t} \text{ and } \varepsilon_{g,t} \sim i.i.d\, N\,(0, \sigma_g) \quad (3.2)$$

Let's define C as a composite consumption index, given by the CES function:

$$C_t = \left[(1-\varrho)^{\frac{1}{\tau}} C_{H,t}{}^{\frac{\tau-1}{\tau}} + \varrho^{\frac{1}{\tau}} C_{F,t}{}^{\frac{\tau-1}{\tau}} \right]^{\frac{\tau}{\tau-1}} \quad (3.3)$$

where $C_{H,t}$ and $C_{F,t}$ are Dixit-Stiglitz aggregates of domestic and foreign produced goods respectively given by:

$$C_{H,t} = \left[\int_0^1 C_{H,t}(q)^{\frac{\vartheta-1}{\vartheta}}\, dq\right]^{\frac{\vartheta}{\vartheta-1}} \quad and \quad C_{F,t} = \left[\int_0^1 C_{F,t}(q)^{\frac{\vartheta-1}{\vartheta}}\, dq\right]^{\frac{\vartheta}{\vartheta-1}} \tag{3.4}$$

where $\varrho \in [0,1]$ is the share of foreign goods, and $\tau > 0$ and $\vartheta > 0$ are the elasticity of substitution between domestic and foreign goods and the elasticity of substitution across goods within each category, respectively.

Optimization problems of the households yields demand functions for each category of consumption goods:

$$C_{H,t}(q) = (1-\varrho)\left(\frac{P_{H,t}(q)}{P_{H,t}}\right)^{-\vartheta} C_{H,t} \quad and \quad C_{F,t}(q) = \varrho\left(\frac{P_{F,t}(q)}{P_{F,t}}\right)^{-\vartheta} C_{F,t} \tag{3.5}$$

where $P_{H,t} = \left[\int_0^1 P_{H,t}(q)^{1-\vartheta}\, dq\right]^{\frac{1}{1-\vartheta}}$ and $P_{F,t} = \left[\int_0^1 P_{F,t}(q)^{1-\vartheta}\, dq\right]^{\frac{1}{1-\vartheta}}$ are the aggregate price levels for the domestic economy and foreign economy, respectively. The Consumer Price Index (CPI) can be written as:

$$P_t = \left[(1-\varrho){P_{H,t}}^{1-\tau} + \varrho {P_{F,t}}^{1-\tau}\right]^{\frac{1}{1-\tau}} \tag{3.6}$$

we assumed all households have identical initial wealth and they earn equal fraction of the firm profits. As a result of optimality conditions, each household faces with same budget constraint which can be written as:

$$\begin{aligned} C_t(q) + \frac{D_t(q)}{P_t} + \frac{\check{e}_t B_t(q)}{P_t} \\ = \left(1+R_{t-1}^h\right)\frac{D_{t-1}(q)}{P_t} + \left(1+R_{t-1}^f\right)(\check{e}_t)\frac{B_{t-1}(q)}{P_t}(\Theta_t) \\ + \frac{W_t(q)L_t(q)}{P_t} + \frac{Div_t^h(q)}{P_t} + \frac{Div_t^f(q)}{P_t} + \frac{T_t(q)}{P_t} \end{aligned} \tag{3.7}$$

where P_t is consumer price index, D_t is the household's holding of one-period domestic bonds with corresponding interest rate, R_t^h, B_t is the household's holding of one-period foreign bonds with corresponding interest rate, R_t^f. ě$_t$ is the nominal exchange rate which is the domestic price of foreign currency. The households earn nominal wages from labour supply, W_t, and they earn Div_t^h and Div_t^h profits from equity holdings of the domestic and imported goods firms, respectively. T_t, is the lump-sum taxes and transfers. Households allocate their savings among domestic and foreign bonds. We assumed households purchase foreign bonds adjusted to a country risk premium and financial markets are not perfectly integrated. This yields an inverse proportionality between bond prices and corresponding interest rates. (Beningo 2009). Country risk premium is defined as follows:

$$\Theta_t\left(\Lambda_t, \check{e}_{t,} \Psi_{p,t}\right) = \exp\left(-\Theta_a \Lambda_t - \Phi_e\left(\frac{E_t \check{e}_{t+1}}{\check{e}_t}\frac{\check{e}_t}{\check{e}_{t-1}} - \frac{\pi}{\pi^*}\right) + \Psi_{p,t}\right) \tag{3.8}$$

Θ_t is the country risk premium which is also interpretable as the debt-elastic interest rate risk premium. According to Schmitt-Grohé and Uribe (2003), the inclusion of debt-elastic interest rate risk premium is crucial for the small open economy models.

$\Lambda_t = \frac{\check{e}_t B_t}{\hat{Y} P_t}$ is the real quantity of outstanding net foreign debt which is proportional to the nominal exchange rate and foreign bond holdings and reversely proportional to the steady-state output and domestic price level. $\Psi_{p,t}$ is the country risk premium shock which is assumed to follow AR (1) process:

$$\Psi_{p,t} = \rho_p \Psi_{p,t-1} + \varepsilon_{p,t} \quad and \quad \varepsilon_{p,t} \sim i.i.d\, N\,(0,\sigma_p) \tag{3.9}$$

On the other hand, the negative sign on the expected change of the nominal exchange rate could be evaluated as the willingness by households to accept a lower return on their foreign bond holdings. The households could expect the future nominal exchange rate to exceed the inflation differential between domestic and foreign inflation rates which we assumed they are identical.

2.2 Domestic Firms

There is a continuum of monopolistically competitive domestic firms which of each produces a differentiated good with a linear technology, indexed by $i \in (0,1)$. Each firm i uses labour as a single input. Aggregate production function is given by:

$$Y_{H,t} = \left[\int_0^1 Y_{H,t}(i)^{\frac{\vartheta-1}{\vartheta}} di\right]^{\frac{\vartheta}{\vartheta-1}} \tag{3.10}$$

where $Y_{H,t}(i) = \Psi_{a,t} L_t(i)$ is the individual production function and ϑ is the elasticity of substitution between differentiated goods. $\Psi_{a,t}$ is the neutral technology shock which is assumed to follow AR(1) process

$$\Psi_{a,t} = \rho_a \Psi_{a,t-1} + \varepsilon_{a,t} \;\; and \;\; \varepsilon_{a,t} \sim \; i.i.d\; N\,(0, \sigma_a) \tag{3.11}$$

We assumed Calvo-style price setting that in each period only $1 - \zeta_H$ fraction of firms sets prices optimally where $0 < \zeta_H < 1$. ζ_H fraction of firms can adjust their prices according to past inflation rate

$$P_{H,t}(i) = P_{H,t}(i)\left(\frac{P_{H,t-1}}{P_{H,t-2}}\right)^{\delta_H} \tag{3.12}$$

where $\delta_H \in (0,1)$ is the degree of inflation indexation to past inflation rate. Given Calvo-style price setting, the evolution of the Dixit-Stiglitz aggregate price index for domestic goods is given by:

$$P_{H,t} = \left[(1 - \zeta_H)\left(P_{H,t}^{new}\right)^{1-\vartheta} + \zeta_H \left[P_{H,t-1}\left(\frac{P_{H,t-1}}{P_{H,t-2}}\right)^{\delta_H}\right]^{1-\vartheta}\right]^{\frac{1}{1-\vartheta}} \tag{3.13}$$

Domestic firms sell their products domestically and abroad. The demand curve faced by a domestic firm is given by:

$$Y_{H,t+s}(i) = \left[\frac{P_{H,t}^{new}(i)}{P_{H.t+s}}\left(\frac{P_{H,t+s-1}}{P_{H,t-1}}\right)^{\delta_H}\right]^{-\vartheta} \left(C_{H,t+s} + C_{H,t+s}^F\right) \tag{3.14}$$

where, $C_{H,t+s}$ is domestic demand and $C_{H,t+s}^F$ is foreign demand.

The domestic firm's price-setting problem in period t is to maximize the expected present discounted value of profits, subject to the demand curve:

$$E_t \sum_{s=0}^{\infty} \text{ʒ}_H Q_{t,t+s} Y_{H,t+s|t}(i) \left[P_{H,t}^{new}(i)\left(\frac{P_{H,t+s-1}}{P_{F,t-1}}\right)^{\delta_H} - \left(\frac{\vartheta}{\vartheta-1}\right) P_{H,t+s}(i) MC_{H,t+s}\right] \tag{3.15}$$

where $MC_{H,t+s}$ is real marginal cost function, and $Q_{t,t+s}$ is the time dependent stochastic discount factor. ʒ_h is the probability that the firm will not adjust its price for the next s periods.

$$MC_{H.t}(i) = \frac{\left(\frac{\partial TC_{H.t}(i)}{\partial L_t(i)}\right) \Big/ \left(\frac{\partial Y_{H.t}(i)}{\partial L_t(i)}\right)}{\Psi_{a,t} P_{H,t}(i)} \tag{3.16}$$

where, $TC_{H.t}(i)$ is the total cost for each domestic firm.

The firm i's optimization problem implies the first order condition:

$$E_t \sum_{s=0}^{\infty} \text{ʒ}_H Q_{t,t+s} Y_{H,t+s|t} \left[P_{H,t}^{new}\left(\frac{P_{H,t+s-1}}{P_{H,t-1}}\right)^{\delta_H} - \left(\frac{\vartheta}{\vartheta-1}\right) P_{H,t+s} MC_{H,t+s}\right] = 0 \tag{3.17}$$

if we leave optimal price alone on the left and write the other variables which we get from the first order condition equation, on the right side of the equation, than we get,

$$P_{H,t}^{new} = \left(\frac{\vartheta}{\vartheta-1}\right) \frac{\sum_{s=0}^{\infty} \text{ʒ}_H E_t\left[Q_{t,t+s} Y_{H,t+s|t} P_{H,t+s} MC_{H,t+s}\right]}{\sum_{s=0}^{\infty} \text{ʒ}_H E_t\left[Q_{t,t+s} Y_{H,t+s|t} (P_{H,t+s-1}/P_{H,t-1})^{\delta_H}\right]} \tag{3.18}$$

where $P_{H,t}^{new}$ is the optimal price of domestic firm in period t.

2.3 Importing Firms

Importing firms are assumed to buy foreign differentiated goods at competitive prices. However, determining the domestic price of the imported goods, importing firms are assumed to be monopolistically competitive. This small degree of pricing power leads to a violation of the law of one price in the short-run. The law of one price (LOP) gap, that is, the difference between the price of imported goods in domestic currency terms and the domestic retail price of imported goods.

Importing firms also face a Calvo-style price setting problem allowing for indexation to past inflation. The Dixit-Stiglitz aggregate price index for imported good is given by:

$$P_{F,t} = \left[(1 - ʒ_F)\left(P_{F,t}^{new}\right)^{1-\vartheta} + ʒ_F\left[P_{F,t-1}\left(\frac{P_{F,t-1}}{P_{F,t-2}}\right)^{\delta_F}\right]^{1-\vartheta}\right]^{\frac{1}{1-\vartheta}} \tag{3.19}$$

where, in any period t, according to Calvo-style price setting rule only $(1 - ʒ_F)$ fraction of firms sets prices optimally, $ʒ_F$ fraction of firms can only adjust their prices according to past inflation rate and $\delta_F \in (0,1)$ is the degree of inflation indexation to past inflation rate.

Importing firm's setting prices in period t + s face a demand curve, conditional on having last re-optimized its price in period t is

$$Y_{F,t+s}(i) = \left[\frac{P_{F,t}^{new}(i)}{P_{F.t+s}}\left(\frac{P_{F,t+s-1}}{P_{F,t-1}}\right)^{\delta_F}\right]^{-\vartheta} C_{F,t+s} \tag{3.20}$$

Importing firm's price setting problem in period t is to maximize the expected present discounted value of profits, subject to the demand curve:

$$E_t\sum_{s=0}^{\infty} ʒ_F Q_{t,t+s} Y_{F,t+s|t}(i)\left[P_{F,t}^{new}(i)\left(\frac{P_{F,t+s-1}}{P_{F,t-1}}\right)^{\delta_F} - ě_{t+s}{P^*}_{F,t+s}(i)\Psi_{cp,t}\right] \tag{3.21}$$

where, P^* is the price of imported good and $\Psi_{cp,t}$ is the cost push shock which is assumed to follow AR (1) process

$$\Psi_{cp,t} = \rho_{cp}\Psi_{cp,t-1} + \varepsilon_{cp,t} \quad and \quad \varepsilon_{cp,t} \sim i.i.d\ N\,(0,\sigma_{cp}) \tag{3.22}$$

Importing firm's optimization problem implies the first order condition:

$$E_t \sum_{s=0}^{\infty} ʒ_F Q_{t,t+s} Y_{F,t+s|t} \left[P_{F,t}^{new} \left(\frac{P_{F,t+s-1}}{P_{F,t-1}} \right)^{\delta_F} - \left(\frac{\vartheta}{\vartheta - 1} \right) ě_{t+s} P^*{}_{F,t+s} \Psi_{cp,t} \right] \tag{3.23}$$

Leaving optimal price for importing firm alone on the left and write the other variables which we get from the first order condition equation, on the right side of the equation, than we get,

$$P_{F,t}^{new} = \left(\frac{\vartheta}{\vartheta - 1} \right) \frac{\sum_{s=0}^{\infty} ʒ_F E_t \left[Q_{t,t+s} Y_{F,t+s|t} ě_{t+s} P^*{}_{F,t+s} \Psi_{cp,t} \right]}{\sum_{s=0}^{\infty} ʒ_H E_t \left[Q_{t,t+s} Y_{H,t+s|t} (P_{F,t+s-1}/P_{F,t-1})^{\delta_F} \right]} \tag{3.24}$$

where $P_{F,t}^{new}$ is the optimal price of importing firm in period t.

2.4 International Risk Sharing and Uncovered Interest Parity

Domestic and foreign bonds holdings which are determined by asset price holdings yields the uncovered interest rate parity condition or a no-arbitrage condition under the assumption of complete international markets.

$$B_t = E_t \left(B_{t+1} \left(\frac{ě_{t+1}}{ě_t} \right) \right) \tag{3.25}$$

Combining the riskless price of a foreign bond pricing equation with domestic bond yields

$$(r_t - E_t\pi_{t+1}) - (r_t^* - E_t\pi_{t+1}^*) - (E_t q_{t+1} - q_t) B_{t+1} = 0 \tag{3.26}$$

where q_t is is the real exchange rate and $ě_{t+1}$-$ě_t = \pi_t - \pi_t^* + E_t q_{t+1} - q_t$. Real exchange rate differences between foreign and domestic economy equals to real exchange rate differences to obtain an uncovered interest rate parity condition.

Modified uncovered interest rate parity (MUIP) condition is a mechanical implement to improve the persistence of the real exchange rate.

$$(r_t - E_t\pi_{t+1}) - (r_t^* - E_t\pi_{t+1}^*) = (1 - \boldsymbol{\Gamma})E_t\Delta q_{t+1} - \boldsymbol{\Gamma}\Delta q_t - \Theta_a\Lambda_t + \Psi_{p,t} \quad (3.27)$$

where $\boldsymbol{\Gamma}$ is the MUIP parameter. MUIP parameter allows a gradual appreciate in real exchange rates when the domestic real interest rates increases.

2.5 Terms of Trade

Terms of trade (TOT) is defined as the ratio between foreign good prices and the domestic good prices.

$$S_t = P_t^* \frac{\Psi_{tot,t}}{P_t} \quad (3.28)$$

where S_t is the terms of trade and $\Psi_{tot,t}$ is the terms of trade shock given by:

$$\Psi_{tot,t} = \rho_a\Psi_{tot,t-1} + \varepsilon_{tot,t} \;\; and \;\; \varepsilon_{tot,t} \sim i.i.d\, N\,(0,\sigma_a) \quad (3.29)$$

2.6 Monetary Policy

As stated in the previous pages, interest rates are conducted by monetary policy. We assumed Turkish Central Bank follows a simple reaction function given by:

$$r_t = \rho_r r_{t-1} + \varphi_\pi\left(\frac{P_t}{P_{t-1}}\right) + \varphi_{\Delta y}\left(\frac{Y_t}{Y_{t-1}}\right) + \varphi_e q_t + \varphi_{e-1}q_{t-1} + \Psi_{m,t} \quad (3.30)$$

Unlike Justiniano and Preston (2010), we used the augmented Taylor-Rule. (Taylor 2001) The central bank sets the short-term nominal interest rate, r_t, with a certain degree of inertia in response to departures of demand, inflation and the nominal exchange rate from their target levels. $\Psi_{mp,t}$ is the exogeneous monetary policy shock which is assumed to follow AR(1) process

$$\Psi_{m,t} = \rho_m\Psi_{m,t-1} + \varepsilon_{m,t} \;\; and \;\; \varepsilon_{m,t} \sim i.i.d\, N\,(0,\sigma_m) \quad (3.31)$$

We assumed φ_{e-1}=0 which we think central bank is following the current deviations of the nominal exchange rate.

2.7 Foreign Shocks

In the small open economy DSGE estimation, 3 foreign shocks are introduced into the small open economy model such as Foreign output growth shocks, foreign inflation shocks and foreign interest rate shocks. All foreign variables and parameters are denoted by the symbol " * ".

All the information about the linearized model, variables and exogeneous shocks used in the estimation are presented in Appendix A and Appendix B.

3. The Log-linearized Model

A detailed optimization and log-linearization procedure around steady stade is presented in Appendix. Consumption Euler equation is given by:

$$c_t - hc_{t-1} = (E_t c_{t+1} - hc_t) - {\sigma_c}^{-1}(1-h)(r_t - E_t\pi_{t+1}) + {\sigma_c}^{-1}(1 - h)(\Psi_{g,t} + E_t\Psi_{g,t+1}) \tag{3.32}$$

The habit induced consumption Euler equation is a function of previous consumption, expected future consumption, short term interest rates, expected future inflation and a preference shock. Goods market clearing condition is the equity of the domestic and foreign output and the domestic output of the domestic produced consumption goods:

$$(1-\varrho)c_t = y_t - \varrho\tau(2-\varrho)s_t - \varrho\tau\Gamma_{F,t} - \varrho y_t^* \tag{3.33}$$

Terms of trade is given by:

$$s_t - s_{t-1} = \pi_t^f - \pi_t^h + \Psi_{tot,t} \tag{3.34}$$

Growth rate of terms of trade is a function of inflation differences between foreign and domestic economies and a terms of trade shock.

Law of one price gap emerges when there is a price differences of consumption good between foreign and domestic economies. Law of one price gap is defined as:

$$\Gamma_{F,t} = q_t - (1 - \varrho)s_t \tag{3.35}$$

Domestic inflation contains Calvo price setting and price indexation to the previous inflation level.

$$\pi_t^h - \delta_{\mathrm{H}}\pi_{t-1}^h = \mathfrak{z}_H{}^{-1}(1 - \mathfrak{z}_H)(1 - \beta\mathfrak{z}_H)mc_t + \beta\left(E_t\pi_{t+1}^h - \delta_{\mathrm{H}}\pi_t^h\right) \tag{3.36}$$

Domestic inflation depends on previous inflation and expected future inflation which is generally expressed hybrid inflation function. Additionally, main contributer of domestic inflation, marginal cost which is defined as:

$$mc_t = \sigma_l y_t - (1 + \sigma_l)\Psi_{a,t} + \varrho s_t + \sigma_c{}^{-1}(1 - h)(c_t - hc_{t-1}) \tag{3.37}$$

Marginal cost is introduced as a function of output growth, terms of trade, consumption and a technology shock.

Foreign inflation is also subject to a hybrid formation. Apart form those, it contains a cost push shock which is defined as:

$$\pi_t^f - \delta_{\mathrm{F}}\pi_{t-1}^f = \mathfrak{z}_F{}^{-1}(1 - \mathfrak{z}_F)(1 - \beta\mathfrak{z}_F)\Gamma_{F,t} + \beta\left(E_t\pi_{t+1}^f - \delta_{\mathrm{F}}\pi_t^f\right) + \Psi_{cp,t} \tag{3.38}$$

CPI inflation is expressed as the domestic inflation and the growth rate of terms of trade.

$$\pi_t = \pi_t^h + \varrho(s_t - s_{t-1}) \tag{3.39}$$

Modified uncovered interest rate parity condition:

$$(r_t - E_t\pi_{t+1}) - (r_t^* - E_t\pi_{t+1}^*) = (1 - \Gamma)E_t q_{t+1} - \Gamma q_t - \Theta_a\varrho - \Psi_{p,t} \tag{3.40}$$

Budget constraint:

$$c + \Lambda_t = \beta^{-1}\Lambda_{t-1} - \varrho\left(s_t + \Gamma_{F,t}\right) + y_t \tag{3.41}$$

Monetary authorities are assumed to follow a simple Taylor Rule which includes a monetary policy shock

$$r_t = \rho_r r_{t-1} + \varphi_\pi \pi_t + \varphi_y y_t + \varphi_{\Delta y}(y_t - y_{t-1}) + \varphi_{\Delta e}(q_t - q_{t-1}) + \Psi_{m,t} \tag{3.42}$$

Real exchange rate is a function of nominal exchange rate and inflation differences between domestic and foreign economies which is given by:

$$q_t = \breve{e}_t + \pi_t^* - \pi_t \tag{3.43}$$

Output growth rate of a foreign economy which is subject to a foreign output growth shock:

$$y_t^* = \rho_{y^*} y_{t-1}^* + \sigma_{y^*} \varepsilon_{y^*,t} \tag{3.44}$$

Foreign inflation consists of a inflation persistency and a foreign inflation shock:

$$y_t^* = \rho_{y^*} y_{t-1}^* + \sigma_{y^*} \varepsilon_{y^*,t} \tag{3.45}$$

Foreign interest rates:

$$r_t^* = \rho_{r^*} r_{t-1}^* + \sigma_{r^*} \varepsilon_{r^*,t} \tag{3.46}$$

Exogeneous shocks are technology shock, risk premium shock, cost-push shock, preference shock, monetary policy shock, terms of trade shock, foreign output growth shock, foreign inflation shock and foreign interest rate shock, respectively:

$$\Psi_{a,t} = \rho_a \Psi_{a,t-1} + \sigma_a \varepsilon_{a,t} \tag{3.47}$$

$$\Psi_{p,t} = \rho_p \Psi_{p,t-1} + \sigma_p \varepsilon_{p,t} \tag{3.48}$$

$$\Psi_{g,t} = \rho_g \Psi_{g,t-1} + \sigma_g \varepsilon_{g,t} \tag{3.49}$$

$$\Psi_{g,t} = \rho_g \Psi_{g,t-1} + \sigma_g \varepsilon_{g,t} \tag{3.50}$$

$$\Psi_{m,t} = \rho_m \Psi_{m,t-1} + \sigma_m \varepsilon_{m,t} \tag{3.51}$$

$$\Psi_{tot,t}=\rho_{tot}\Psi_{tot,t-1}+\sigma_{tot}\varepsilon_{tot,t} \tag{3.52}$$

$$\Psi_{y^*,t}=\rho_{y^*}\Psi_{y^*,t-1}+\sigma_{y^*}\varepsilon_{y^*,t} \tag{3.53}$$

$$\Psi_{\pi^*,t}=\rho_{\pi^*}\Psi_{\pi^*,t-1}+\sigma_{\pi^*}\varepsilon_{\pi^*,t} \tag{3.54}$$

$$\Psi_{r^*,t}=\rho_{r^*}\Psi_{r^*,t-1}+\sigma_{r^*}\varepsilon_{r^*,t} \tag{3.55}$$

4. The Empirical Analysis

This section outlines the data and priors used for the estimation, Bayesian estimation procedure and estimation methodology.

4.1 Data

Taking model to data is an important subject in DSGE modelling. As it is stated in literature main focus of DSGE models is to explain business cycle fluctuations. Real macroeconomic variables exhibit trends and cycles, so we need to transform the data before we introduce the real data into the model. In this case it is needed to form and specify measurement equations to introduce real data. There are some different methodologies to form these equations. There are some studies which the data is first detrended (in some cases filtered) than introduce to the model. There are some others used demeaning methodologies before introduction of real data to the model. In our study we exactly followed Smets and Wouters (2007) paper to form the data sources and transformations.

We use quarterly regulated time series of the following macro-economic variables for Turkey: real GDP per capita, consumer price index, short-term interest rates, real effective exchange rate and terms of trade for domestic observable data. The foreign variables are US real GDP, US short-term nominal interest rate and US consumer price index as a proxy for foreign economy. Our estimation uses quarterly data from the period 2003Q2 to 2020Q1, covering most of Turkey's inflation targeting era, since quarterly data are not available for some observed variables before 2003. All variables (except interest rates) are seasonally adjusted. Real GDP per capita, consumer price index, real exchange rate and terms of trade data are log differenced. All the data except real effective exchange rates and short-term interest rates obtained from Federal Reserve Bank of St. Louis economic research data[7]. Real effective exchange rates and short-term interest rates data are obtained from TCB databank[8].

The corresponding measurement equations are formed as

Table 5 : Measurement Equations for Small Open Economy Model

$$\begin{bmatrix} Diff.(LogGDPperCapita_t) * 100 \\ Log\left(\frac{GDPDEF_t}{GDPDEF_{t-1}}\right) * 100 \\ \left(\frac{Short-Term\ IR}{4}\right) * 100 \\ Diff.\left(Log\left(\frac{Exports_t}{Imports_t}\right)\right) * 100 \\ Diff.\left(Log(Nom.Exchnage\ Rate)\right) * 100 \\ Diff.(LogGDPperCapita_t) * 100 \\ Log\left(\frac{GDPDEF_t}{GDPDEF_{t-1}}\right) * 100 \\ \left(\frac{Fed\ Fund\ Rate}{4}\right) * 100 \end{bmatrix} = \begin{bmatrix} Y_t - Y_{t-1} + trendgrowth \\ Inflation + trendinflation \\ Interest\ Rate + trendeIR \\ S_t - S_{t-1} + trendtot \\ q_t - q_{t-1} + trendexc. \\ Y_t{}^* - Y_{t-1}{}^* + trendUSgrowth^* \\ Inflation^* + trendinflation^* \\ Fed\ Fund\ Rate + trendeIR^* \end{bmatrix}$$

[7] https://fred.stlouisfed.org

[8] https://evds2.tcmb.gov.tr/index.php?/evds/serieMarket

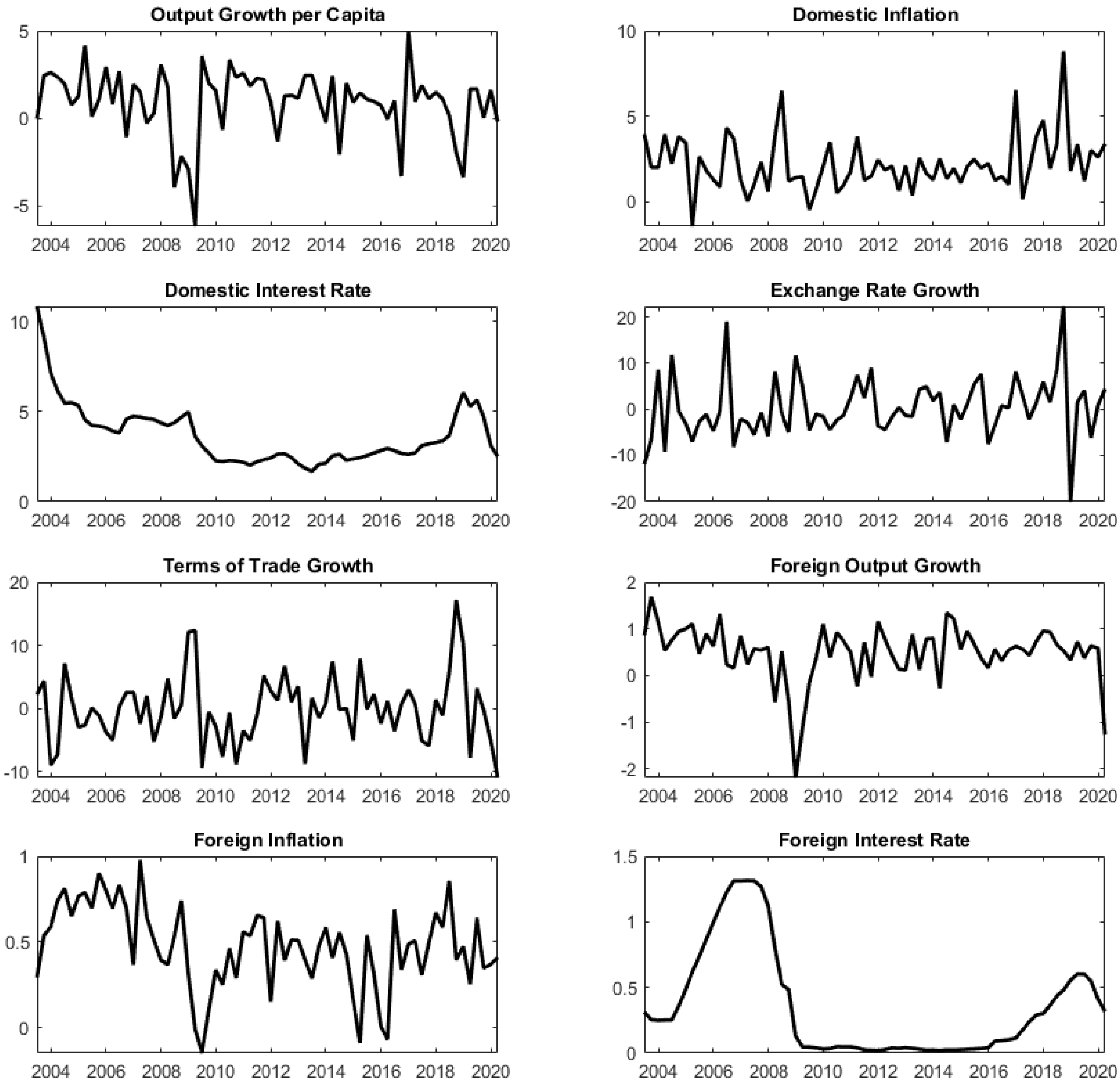

Figure 4 : Real Data Time Series

4.2 Priors

All the model parameters are in line with previous DSGE studies. The estimated structural parameters and their standard errors are reported in Table 6. Following Justiniano and Preston (2010), Philip Liu (2006) and Gregor and Tobias (2008), In particular, we fix the intertemporal discount factor β as 0.98 to set approximately annual 0.08 steady state interest rate and the real net foreign asset position parameter Θ_a as 0.01, which are mostly fixed in small open economy model literature. Based on small open economy model literature, we set other parameters to be estimated by the model. The parameter value of share of foreign goods in domestic consumption bundle ϱ as 0.60 with standard deviation 0.1. Following Kitano and Takaku (2017) we used the inverse elasticity of intertemporal substitution σ_c and following Phuong Van Nguyen (2020) the inverse elasticity of labour supply σ_l are assumed to have the value equal to 2 and 0.5, and with standard deviations equal to 0.40 and 0.10, respectively. Based on the study of Philip Liu (2006) the habits in consumption parameter is assumed to have 0.70 prior value with 0.10 standard deviation. Following Kitano and Takaku (2017) the elasticity of substitution between domestic and foreign goods parameter τ is set to 1.50 with standard deviation 0.1. The degree of inflation indexation to past inflation rate for domestic goods δ_H and the degree of inflation indexation to past inflation rate for imported goods δ_F are assumed to have 0.60 prior value and 0.10 standard deviation. The fraction of domestic firms can’t set prices optimally $\mathfrak{z}_H$ and the fraction of importers can’t set prices optimally $\mathfrak{z}_F$ are both set to 0.75 and 0.10 standard deviation.

The prior mean of the interest rate persistence parameter ρ_r is set to 0,80 and standard deviation 0.25. We construct the prior of the interest rate response of central bank to inflation movements parameter φ_π to 1.50 and 0.25 standard deviation. We assume the response of central bank to output per capita level φ_y, the response to exchange rate growth $\varphi_{\Delta e}$ and the response to output per capita growth $\varphi_{\Delta y}$ to 0.50 and 0.25 standard deviation.

Table 6 : Parameter priors, distributions and posterior estimates

Parameters		Priors			Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
		D	Mean	SD	Mean	90% HPD I.	Mean	90% HPD I.	Mean	90% HPD I.	Mean	90% HPD I.	Mean	90% HPD I.	Mean	90% HPD I.
Share of foreign goods	ϱ	B	0.60	0.10	0.651	[0.506,0.792]	0.651	[0.511,0.765]	0.632	[0.520,0.739]	0.652	[0.530,0.764]	0.583	[0.450,0.714]	0.572	[0.497,0.651]
Inverse elasticity of intertemporal substitution	σ_c	G	2.00	0.40	1.725	[1.218,2.231]	2.714	[2.204,3.244]	1.691	[1.182,2.231]	1.669	[1.194,2.088]	1.768	[1.247,2.298]	1.530	[1.209,1.836]
Inverse elasticity of labor supply	σ_l	G	0.50	0.10	0.526	[0.395,0.657]	0.570	[0.407,0.723]	0.560	[0.379,0.728]	0.615	[0.433,0.765]	0.564	[0.383,0.737]	0.594	[0.389,0.825]
Elasticity of substitution between domestic and foreign goods	τ	I	1.50	Inf.	0.312	[0.233,0.383]	0.344	[0.235,0.458]	0.301	[0.228,0.372]	0.318	[0.244,0.386]	0.322	[0.235,0.404]	0.290	[0.230,0.347]
The degree of inflation indexation to past inflation rate for domestic products	δ_H	B	0.60	0.10	0.490	[0.320,0.658]	0.430	[0.316,0.574]			0.484	[0.300,0.681]	0.489	[0.323,0.648]	0.368	[0.229,0.508]
The degree of inflation indexation to past inflation rate for foreign products	δ_F	B	0.60	0.10	0.449	[0.287,0.594]	0.302	[0.197,0.402]			0.411	[0.244,0.618]	0.480	[0.325,0.631]	0.564	[0.424,0.723]
Calvo-style price setting for domestic firms	$ʒ_H$	B	0.75	0.10	0.319	[0.224,0.417]	0.359	[0.236,0.490]	0.451	[0.339,0.552]	0.319	[0.214,0.416]	0.332	[0.235,0.433]	0.480	[0.430,0.533]
Calvo-style price setting for importing firms	$ʒ_F$	B	0.75	0.10	0.423	[0.298,0.528]	0.486	[0.430,0.544]	0.474	[0.407,0.537]	0.422	[0.304,0.524]	0.346	[0.279,0.415]	0.331	[0.285,0.370]
Habit parameter	h	B	0.70	0.10	0.460	[0.324,0.607]			0.436	[0.313,0.563]	0.485	[0.358,0.616]	0.485	[0.344,0.629]	0.572	[0.489,0.640]
Modified Uncovered Interest Rate Parity parameter	$\mathit{\Gamma}$	U	0.50	0.25	0.418	[0.372,0.463]	0.398	[0.363,0.431]	0.453	[0.426,0.480]	0.413	[0.365,0.464]	0.444	[0.417,0.474]		
Taylor Rule – Interest Rate persistence	ρ_r	B	0.80	0.10	0.971	[0.913,1.000]	0.960	[0.876,1.000]	0.971	[0.915,1.000]	0.972	[0.911,1.000]	0.966	[0.895,1.000]	0.985	[0.953,1.000]
Taylor Rule – Inflation	φ_π	G	1.50	0.25	1.433	[1.056,1.812]	1.603	[1.156,2.108]	1.495	[1.104,1.879]	1.345	[0.979,1.702]	1.563	[1.152,1.955]	1.325	[1.059,1.626]
Taylor Rule - Output	φ_y	G	0.50	0.25	0.137	[0.049,0.225]	0.214	[0.078,0.362]	0.128	[0.042,0.205]	0.140	[0.050,0.223]	0.130	[0.042,0.213]	0.188	[0.078,0.290]
Taylor Rule - Output growth	$\varphi_{\Delta y}$	G	0.50	0.25	0.288	[0.115,0.458]	0.308	[0.119,0.489]	0.239	[0.083,0.390]	0.249	[0.090,0.392]	0.260	[0.088,0.416]	0.264	[0.116,0.405]
Taylor Rule - Exchange rate	φ_e	G	0.50	0.25	0.035	[0.006,0.061]	0.059	[0.014,0.101]	0.028	[0.006,0.050]			0.031	[0.007,0.054]	0.031	[0.007,0.053]
AR(1) of technological shock	ρ_a	B	0.80	0.10	0.701	[0.524,0.893]	0.736	[0.618,0.852]	0.825	[0.711,0.952]	0.747	[0.577,0.899]	0.788	[0.657,0.942]	0.899	[0.838,0.962]
AR(1) of preference shock	ρ_g	B	0.80	0.10	0.705	[0.583,0.842]	0.851	[0.769,0.929]	0.716	[0.585,0.832]	0.696	[0.566,0.834]	0.669	[0.537,0.799]	0.682	[0.623,0.738]
AR(1) of risk premium shock	ρ_p	B	0.80	0.10	0.901	[0.839,0.968]	0.884	[0.802,0.972]	0.914	[0.864,0.967]	0.890	[0.822,0.968]	0.909	[0.857,0.960]	0.934	[0.889,0.977]
AR(1) of cost-push shock	ρ_{cp}	B	0.80	0.10	0.832	[0.671,0.971]	0.904	[0.835,0.979]	0.760	[0.661,0.861]	0.832	[0.689,0.964]	0.730	[0.619,0.839]	0.926	[0.889,0.965]
AR(1) of monetary shock	ρ_m	B	0.80	0.10	0.283	[0.203,0.367]	0.259	[0.181,0.332]	0.244	[0.178,0.312]	0.329	[0.253,0.404]	0.311	[0.230,0.387]	0.518	[0.439,0.604]

AR(1) of terms of trade shock	ρ_{tot}	B	0.80	0.10	0.797	[0.677,0.919]	0.775	[0.659,0.898]	0.799	[0.648,0.958]	0.742	[0.579,0.915]			0.873	[0.776,0.979]
SD of technological shock	σ_a	I	0.50	Inf.	3.434	[1.999,4.639]	3.994	[2.003,5.966]	3.777	[2.266,5.241]	3.237	[2.165,4.269]	3.246	[2.008,4.482]	4.509	[3.058,6.104]
SD of preference shock	σ_g	I	0.50	Inf.	5.311	[2.178,8.579]	2.500	[1.238,3.640]	4.266	[1.894,6.917]	5.601	[2.310,8.616]	5.258	[1.770,9.166]	4.615	[2.873,6.300]
SD of risk premium shock	σ_p	I	0.50	Inf.	0.422	[0.205,0.610]	0.383	[0.199,0.558]	0.565	[0.447,0.692]	0.427	[0.214,0.617]	0.534	[0.418,0.653]	0.653	[0.492,0.812]
SD of cost-push shock	σ_{cp}	I	0.50	Inf.	3.889	[0.574,8.931]	1.092	[0.158,1.797]	3.377	[2.033,4.647]	3.871	[0.571,8.303]	7.294	[4.327,10.289]	7.665	[5.938,9.431]
SD of monetary shock	σ_m	I	0.50	Inf.	2.758	[1.914,3.548]	3.233	[2.103,4.441]	2.743	[1.930,3.533]	2.410	[1.673,3.114]	2.948	[2.073,3.790]	2.854	[2.133,3.570]
SD of terms of trade shock	σ_{tot}	I	0.50	Inf.	3.281	[0.120,6.098]	6.683	[3.554,11.043]	0467.	[0.114,0.873]	3.312	[0.146,6.480]			0.418	[0.119,0.722]
SD of foreign output shock	σ_{y^*}	I	0.50	Inf.	0.711	[0.610,0.815]	0.706	[0.606,0.801]	0.708	[0.607,0.805]	0.713	[0.621,0.820]	0.708	[0.606,0.807]	0.708	[0.606,0.812]
SD of foreign inflation shock	σ_{π^*}	I	0.50	Inf.	0.239	[0.204,0.270]	0.238	[0.203,0.272]	0.239	[0.204,0.272]	0.239	[0.204,0.272]	0.238	[0.204,0.272]	0.241	[0.204,0.275]
SD of foreign interest rate shock	σ_{r^*}	I	0.50	Inf.	0.127	[0.108,0.143]	0.127	[0.109,0.144]	0.126	[0.107,0.144]	0.127	[0.109,0.144]	0.127	[0.108,0.143]	0.127	[0.107,0.144]

where Standard Deviations (SD), Distributions (D), Beta Distributions (B), Gamma Distributions (G), Inverse-gamma Distributions (I) and Uniform Distributions (U) . β parameter set 0.98 and Θ_a parameter set 0.01.

where HPD is the highest posterior density region. 2 MCMC chains of 500,000 draws each used for estimations of posterior distributions. 20 % of draws dropped as an initial burn-in phase.

4.3 Bayesian estimation procedure and estimation methodology

Since our objective is to estimate variants of the model outlined above, Bayesian DSGE method is used for the estimation. Posterior distributions of the model parameters obtained through the Metropolis Hasting sampling Algorithm[9]. (Smets and Wouters 2007) 500,000 draws from posterior distribution used with two parallel chains for each and 20% of the draws discarded to remove the effects of initial conditions. In the measurement equations which is used to combine the system of equations with logarithmic observable data, only intercept is included and error terms are ignored. In the most of the scholar papers, the error terms in measurement equations has been ignored. (Smets and Wouters 2007) and (Del Negro et al. 2013)

4.4 Model Comparisons

Model evaluation is an important part of the empirical work with DSGE models. (An and Schorfheide 2007). We derived 6 versions of the benchmark model (Model 1). Excluding habit parameter (Model 2) which we set habit parameter as 0. We ran the model without price indexation (Model 3) parameter by setting these parameters as 0. Without exchange rate parameter in Taylor Rule, which we assume that the central bank do not give any weight to the exchange rates in optimizing the interest rates (Model 4). As we have stated the we have two different dimensions from the original paper of Justiniano and Preston (2010) a terms of trade shock and modified uncovered interest rate parity parameter. We ran the model by excluding each of these. (Model 5 and Model 6, respectively) we compared these models based on posterior odds.

Conditional density on the model m_i can be defined by using Bayesian inference.

---

[9] Dynare 4.5.7 version used for estimations (Adjemian et al. 2018)

$$p\,(y|m_i) = \int_{\Theta} p\,(y|\Theta, m_i)p(\Theta|m_i)d\Theta \tag{3.56}$$

where $p(\Theta|m_i)$ is the prior density of the model m_i and $p\,(y|m_i)$ is the marginal likelihood associated with the model m_i. Models can be compared according to their marginal likelihood.

Geweke (1999) proposed modified harmonic mean estimator method which we have used to compare models, to obtain the numerical approximations of the marginal likelihood. (Geweke 1999)

$$\widehat{p(y)} = \left[\frac{1}{G}\sum_{g=1}^{G}\frac{f\left(\Theta^{[G]}\right)}{p\,(y|\Theta^{[G]})p\,(\Theta^{[G]}))}\right]^{-1} \tag{3.57}$$

where G is the number of samples used in the Metropolis Hastings algorithm. $f\left(\Theta^{[G]}\right)$ is the support contained in the region of $p\,\left(\Theta^{[G]}\right)$[10].

5. Estimation Results

This section investigates the identification concern of parameters, posterior estimates of the model parameters, the impulse response functions, variance decompositions and historical decompositions of the estimated models.

5.1 Convergence

Figure 5 reflects the convergence diagnostics according to Brooks and Gelman (1998). The blue line is the scale from the mixture of the 500,000 simulated sequences, and the red line is the average scale of the 500,000 individual sequences. Approximate convergence is reached after 150,000 iterations. Upper figure represents convergence based on intervals, middle and the lower figures represent the convergence based on second and third moments, respectively.

[10] Please see Geweke (1999) for detailed information.

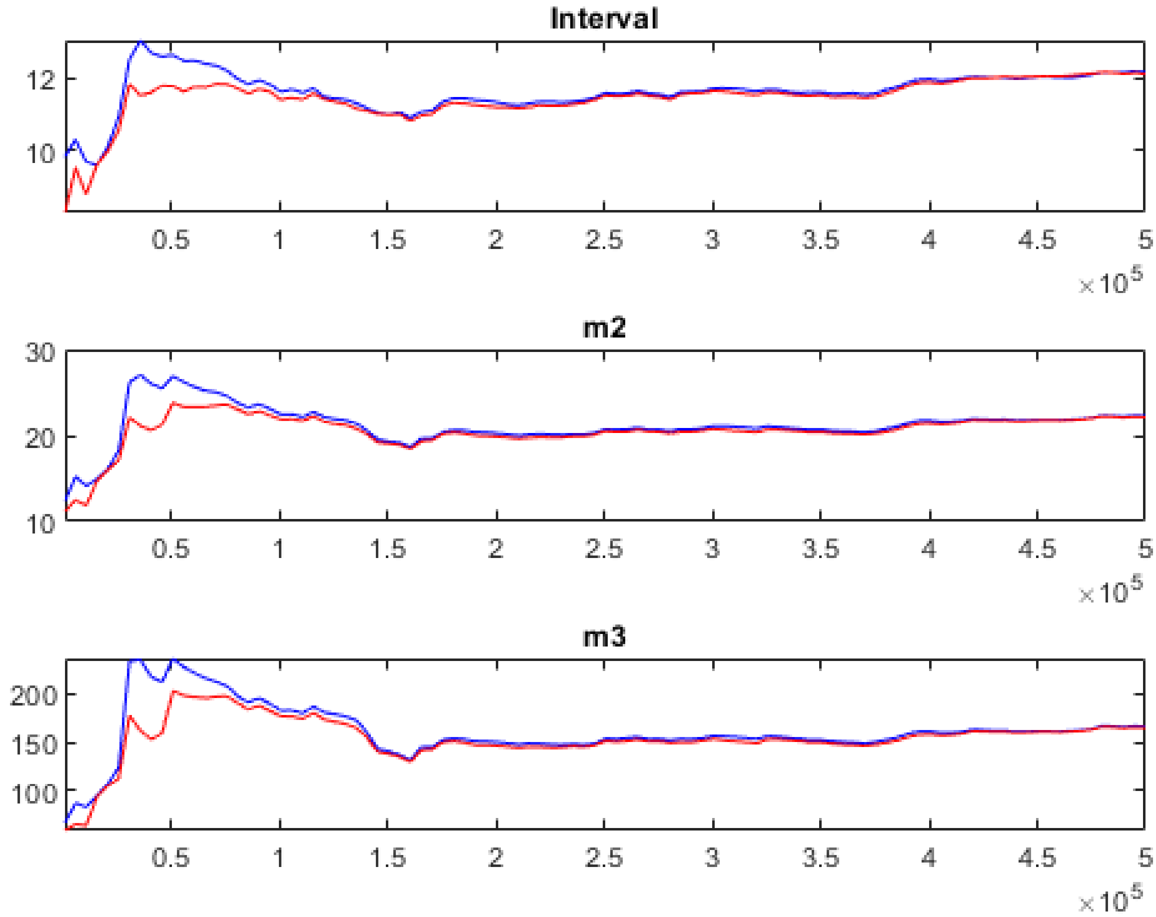

Figure 5 : Convergence Diagnostics

5.2 Identification of parameters

Parameter identification in DSGE models is a prerequisite for the effectiveness of parameters and models. Although parameter identification is a major problem for DSGE models, the issue of parameter identification is ignored in most studies in the literature. Specially, in DSGE models that are planned to be used when designing macroeconomic policies to raise the level of welfare to higher levels, the issue of parameter identification should be taken into consideration with precision. (Beyer and Farmer 2004) Linear approximation which is used in DSGE models is one of the major cause of poor parameter identification. (McManus 1992) Different methodologies have been developed in many studies on identification failure detection. (See Canova and Sala 2009 and (Dynamic Identification of Dynamic Stochastic General Equilibrium Models 2011) Komunjer, I. and

Ng, S. 2011) Following these studies, the most comprehensive study was put forward by Iskrev (2008), and with the methodology developed, the identifiable powers of the parameters and the weak ones, if any, can be determined. (See Iskrev 2008a, Iskrev 2008b and Ratto and Iskrev 2011)

Following Ratto and Iskrev (2011) identification strength of the parameters of the benchmark model are depicted in figure 6. Blue bars represent the identification strength of the parameter based on the Fischer information matrix normalized by parameter at the prior means and red bars represent the identification strength of the parameter based on the Fischer information matrix normalized by parameter at the standard deviations.

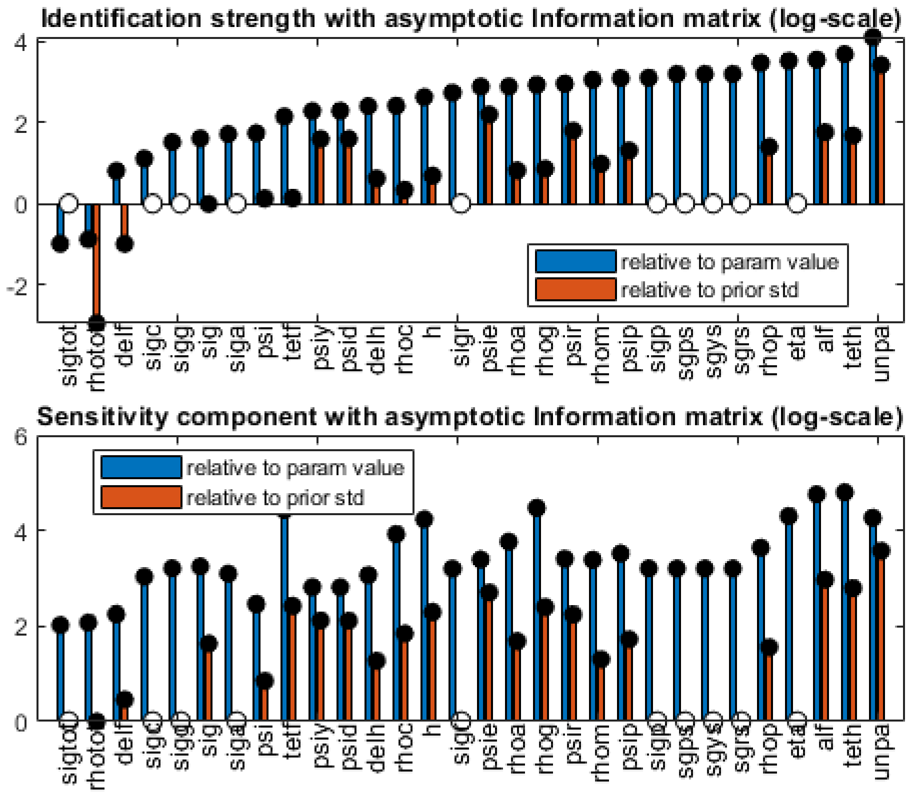

Figure 6 : Identification of Parameters

According to the results of identification strength modified uncovered interest rate parity parameter is the most identified parameter in terms of parameter values. All parameters used in the estimation are quite identified. Blue bars are all far from zero, it does not matter on negative or positive, which is the sign of a good identification. Red bars are also quite good but some parameters are at zero level. The reason is that standard deviations of the shocks are not restricted, which are set to infinity. This is also normal procedure in DSGE modelling estimations.

In the identification problem of parameters, the effects of the collinearity between parameters level on the likelihood should be examined. Table 7 represents the highest collinearity between the parameters. Some parameters have high collinearity which can be problematic for the Bayesian estimation. Calvo-style price setting for domestic firm parameter and Standard Deviation of cost-push shock are highly collinear according to the estimation results. Second highest relationship is between persistence parameter of preference shock and the Standard Deviation of preference shock. There is also same relationship between persistence parameter of terms of trade shock and the Standard Deviation of terms of trade shock and persistence parameter of technology shock and the Standard Deviation of technology shock. On the other side, Inverse elasticity of labor supply and the Calvo-style price setting for domestic firm parameter are highly correlated.

Table 7 : Collinearity of Parameters

Parameter 1	Parameter 2	Collinearity
$ʒ_H$	σ_{cp}	0.9964642
ρ_g	σ_g	0.9903567
ρ_{tot}	σ_{tot}	0.9896856
σ_l	$ʒ_H$	0.9839948
ρ_a	σ_a	0.9783707
ρ_p	ρ_g	0.9659119
ρ_{cp}	$ʒ_F$	0.9581720
ρ_m	ρ_a	0.9566666
$\varphi_{\Delta y}$	φ_e	0.9558334
σ_p	ρ_p	0.9520299
δ_F	$ʒ_F$	0.9517633

Lastly about identification, following Canova (2017), prior and posterior distributions provide information about identification of the parameters in terms of included observables. In figure 7, black line depicts the density of posterior distribution, while gray line shows the prior densities of the parameters. It is expected that the posterior distribution does not look like prior distribution. The observed data mostly informative in terms of the estimated parameters. (Canova 2007). Results of the posterior distributions shows that, Inverse elasticity of labor supply parameter, Taylor Rule – Inflation parameter and persistence parameter of terms of trade shock are somehow problematic about the identification in terms of prior and posterior densities. Other parameters are informative which means the prior densities are changed after introducing real data into the model.

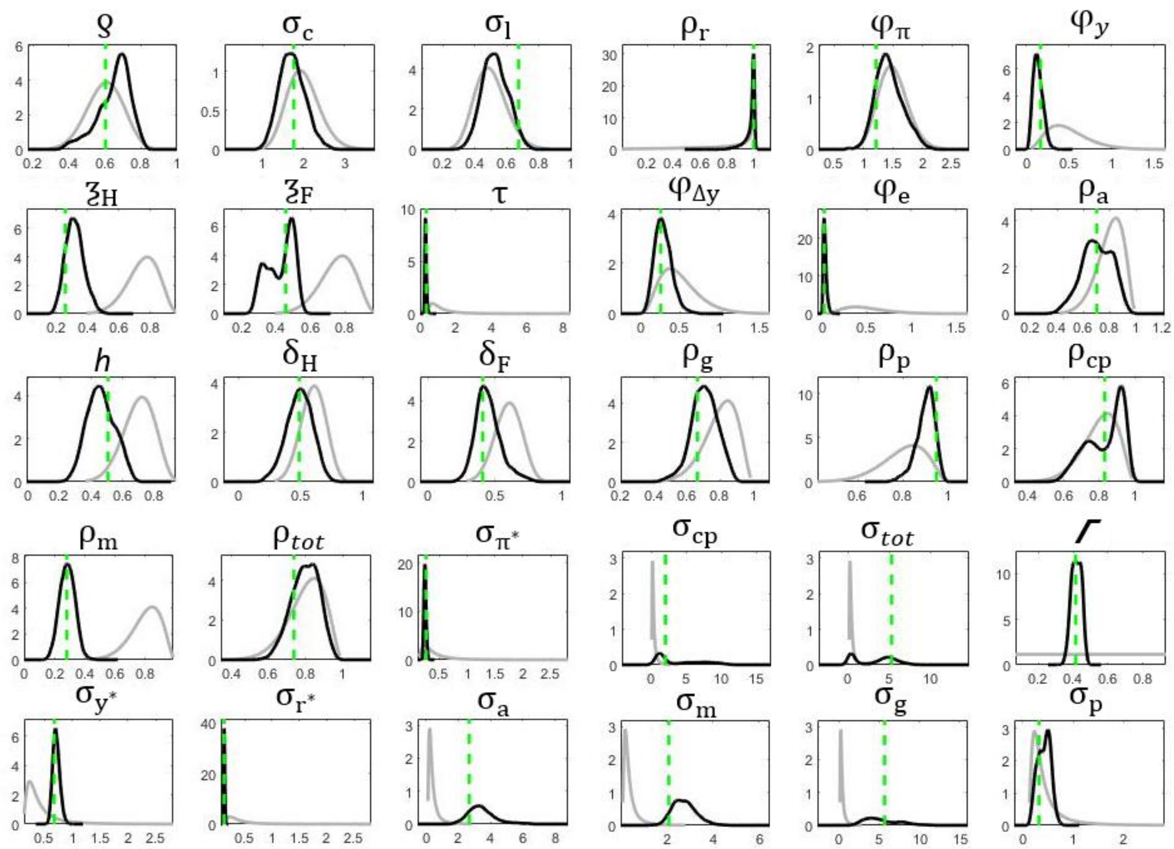

Figure 7 : Estimated Parameters of the Model

5.3 Posterior estimates

Estimated parameters of the models are depicted in Table 6. Table 7 reports the estimated means of the parameters and 90% confidence intervals for the benchmark model, without habit model, without indexation model, without exchange rate model, without modified uncovered interest rate parity condition parameter and terms of trade shock. Model differences do not have important effect on model parameters.

The posterior mean of the share of foreign goods parameter (ϱ) is 0.651 in the benchmark model. This parameter implies that the share of foreign goods in domestic consumption bundle is slightly more than expected. Turkish citizens is consuming only % 35 domestic produced consumption goods which we think very low. Phuan Van Nguyen (2020) estimated degree of openness 0.556 for Vietnam Economy. Inverse elasticity of intertemporal substitution parameter (σ_c), inverse elasticity of labour supply parameter (σ_l) and elasticity of substitution between domestic and foreign goods (τ) are 2.714, 0.570 and 0.344, respectively. High value of inverse elasticity of intertemporal substitution parameter (σ_c) implies households to be more changeable consumption behavior over time than a uniform consumption behavior. Two estimated price indexation parameters posterior means are lower than expected, such as δ_H=0.490 and δ_H=0.449. These values are slightly lower in the without habit model, while they are slightly higher in the model without exchange rate model. Price levels in the Turkish economy are not only affected by expected future inflation, but also highly affected by its previous inflation rates. The posterior estimates of Calvo prices are 0.319 for the domestic firms and 0.423 for the importing firms. This implies that in Turkey the frequency of changing price for domestic firm is every two quarters and the frequency of changing price for importing firm is every two quarters. Here, we believe that the reason why importers can optimize their prices late than expected is the purchasing power that falls as the Turkish lira depreciates against the exchange rate. Domestic firms can make price optimization a little more comfortable in this regard. Habit parameter is estimated as 0.460 and modified uncovered interest rate parity parameter estimated as 0.418 in the benchmark model. Estimated value of interest rate persistence parameter (ρ_r) is 0.971 which implies the policy interest rate is highly persistent in Turkey. This value is 0.88 in the study of Gregor and Tobias (2008), 0.83 in the study of Philip Liu (2008). Moreover, the posterior estimation of Taylor rule inflation parameter (φ_π), Taylor rule output level parameter (φ_y), Taylor rule output difference parameter ($\varphi_{\Delta y}$), and the exchange rate parameter (φ_e), are 1.433, 0.137,0.288 and 0.035, respectively. Our conclusion here is that the Central Bank of the Republic of Turkey is more concerned about inflation stabilization during the estimation period. Inflation sensitivity of Vietnam according to the study of Phuong Van Young (2020) is 1.03, which much more lower of the Turkish Economy. Based on the study of Fernando de Menzeres Linardi (2016) inflation sensitivity of the central bank of Brasil is 0.956 according to the benchmark model. These results show that Turkish Central Bank inflation sensitivity is much more than some other emerging markets. Output growth sensitivity is 0.349 in Vietnam economy, but in Turkish economy output growth sensitivity of Central Bank is 0.288. Exchange Rate sensitivity is 0.035 in Turkish economy but it is 0.301 in Vietnam and 0.271 in Brasil according to the studies of Phuong Van Young (2020) and Fernando de Menzeres Linardi (2016), respectively.

5.4 Model Fit

Several different methods are used to determine the suitability of DSGE models to real data. One of the most widely used methods in the literature is the harmonic mean estimator method proposed by Geweke. In this way, it is possible to determine which version of the model we are working on is more realistic. Or, within the framework of the new Keynesian approach, we have the opportunity to measure the effectiveness of the parameters in the model. Another method is the comparison of second moments. Hereby, we can compare the moments simulated by the model, the standard deviations, their correlations with each other and their auto-correlations, with the counterparts of the values of the real data to determine which model is more effective.

Table 8 depicts the estimation results of the harmonic mean estimations in terms of Marginal Likelihood and Bayes Factor. The model which is the one that exchange rate parameter excluded is the best fit model with the marginal likelihood value -793.51 and % 83 from all six different variant of the model. What could be the main reason why omitting exchange rate parameter from the benchmark model is the best fit for Turkish Economy? Turkish economy is vulnerable to exchange rate fluctuations as an emerging market. How central bank manage the economy without exchange rate sensitivity. This could be a reason of model dynamics which needed to be improved. On the other hand, the excessive inflation sensitivity of the central bank may have overshadowed the exchange rate sensitivity.

Table 8 : Log-Marginal Likelihood and Bayes Factor estimations

Model	Marginal Likelihood	Bayes Factor	Probability
Model 4	-793.51	0	0.8315
Model 3	-795.11	-1.60	0.1685
Model 1	-803.72	-10.21	0
Model 5	-804.61	-11.10	0
Model 2	-812.02	-18.51	0
Model 6	-826.98	-33.47	0

Log-marginal likelihoods are estimated according to modified harmonic mean estimations proposed by Geweke (1999).

Second best fit model is the without price indexation model. The marginal likelihood of this model is -795.11 and -1.60 Bayes factor to the best fit model. The probability of this model is % 16.85 of the different variants of the model. Price indexation is a formation of the new Keynesian synthesis framework. This could be a result of the problem of pricing problem in companies and/or there could be a relation between the decrease in the purchasing power of the citizens and the pricing problem.

The benchmark model including all new Keynesian sensitivities is the best third model with a maximum likelihood value of -803.72 and the Bayes factor is -10.21 versus the best fit model. Excluding exchange rate sensitivity of central bank and the indexation formation improved the model fit. But in this study, including habit formation, modifying uncovered interest parity condition and the terms of trade shock improved the model significantly. Marginal likelihood of the model without terms of trade shock is -804.61 and the Bayes Factor is -11.10. The maximum likelihood of the models without habit formation and modified uncovered interest rate parity parameter are -812.02 and -826.98, respectively.

According to the study of Matheson (2010) the model which do not include habit and indexation formation is the best fit model. Our results are in line with Fernando de Menezes Linardi (2016).

The second comparison method is second moments comparisons in terms of standard deviation, cross-correlation with output and autocorrelations. Table 9 depicts the results of the model comparisons according to the second moments of real data versus simulated data by the model. First rows of the are the real data values. Standard deviation of the output is 1.954 in reality but the model is not successful to match this value. Model 2 without habit formation is 3.644 and it is the closest model, which is approximately 1.8 times larger than the actual value. Benchmark model is far from model 2. Inflation standard deviation is 1.638 in reality. The closest model is model 3 by 1.918. Benchmark also is not bad to match with inflation. Benchmark model is successful to match interest rates and it is close to real data. Standard deviation of the real data is 1.674 and benchmark model simulated this data with 1.692. Model is not successful to match exchange rate and terms of trade. Model 3 is the best for exchange rate standard deviation and benchmark model is the best for the terms of trade. However, the results could only simulate values up to twice as close.

Table 9 : Standard deviations, cross-correlations and autocorrelations

	output	inflation	int. rate	ex. rate	t.o.t
Standard Deviation					
Real Data	1.954	1.638	1.674	6.700	5.434
Model 1	4.378	1.944	<u>1.692</u>	11.551	<u>11.123</u>
Model 2	<u>3.644</u>	1.968	1.778	11.211	14.912
Model 3	4.271	<u>1.918</u>	1.723	<u>10.636</u>	11.651
Model 4	4.369	1.921	1.699	11.646	11.893
Model 5	4.590	1.978	1.560	11.177	13.561
Model 6	6.517	2.681	2.270	20.142	27.321
Cross-correlation with output					
Real Data	1.000	-0.170	-0.109	0.095	0.392
Model 1	1.000	-0.101	-0.098	0.002	-0.252
Model 2	1.000	-0.097	-0.115	0.195	<u>0.112</u>
Model 3	1.000	-0.097	<u>-0.104</u>	-0.010	-0.214
Model 4	1.000	-0.099	-0.080	0.015	-0.212
Model 5	1.000	<u>-0.109</u>	-0.185	<u>0.036</u>	-0.140
Model 6	1.000	-0.270	-0.486	-0.088	-0.050
Autocorrelations (order=1)					
Real Data	0.096	0.003	0.805	-0.167	0.153
Model 1	0.839	0.431	<u>0.925</u>	0.721	<u>0.876</u>
Model 2	<u>0.763</u>	0.402	0.952	0.665	0.910
Model 3	0.834	<u>0.378</u>	0.932	0.690	0.897
Model 4	0.840	0.427	0.931	0.714	0.887
Model 5	0.850	0.426	0.934	0.726	0.906
Model 6	0.929	0.638	0.954	0.928	0.971

This table is prepared for to compare Standard deviations, cross-correlations and autocorrelations of real data with six estimated models.

Cross-correlation with output in real data is negative with inflation and output and it is positive with exchange rate and terms of trade in real data. Signs are very correct for the model 2. Benchmark model matched the data with inflation and interest rates very well. The signs are correct. But it is not possible to say this for exchange rate and terms of trade. For example, benchmark model generated 0 cross-correlation with output whereas the real data is 0.095. Habit formation generated 0.195 which is also close to real data.

According to the first order autocorrelations model is only successful to match interest rates. Interest rate is 0.805 and benchmark model simulated 0.925. Other models are not bad in terms of interest rates. Output, inflation and terms of trade real data is very low and non of the models are able to match this value in terms of first order autocorrelations. On the other hand, exchange rate real data first order autocorrelation is negative. Again, models are not good to match negative sign.

Figure 8 shows the autocorrelations up to order 10. First five models are very sensitive to match interest rate. This model predicts successful foresight in interest rate. This is also a good possibility of forecast interest rates for the future. But on the other side, it is not possible to say these words for the other important macroeconomic variables.

According to the second order properties model is only successful to match interest rate so closely. High and irregular fluctuations are not possible to match exactly in DSGE modelling. 2008 financial crisis and 2018 currency crisis caused real macroeconomic variables high fluctuations which the model is not able to predict.

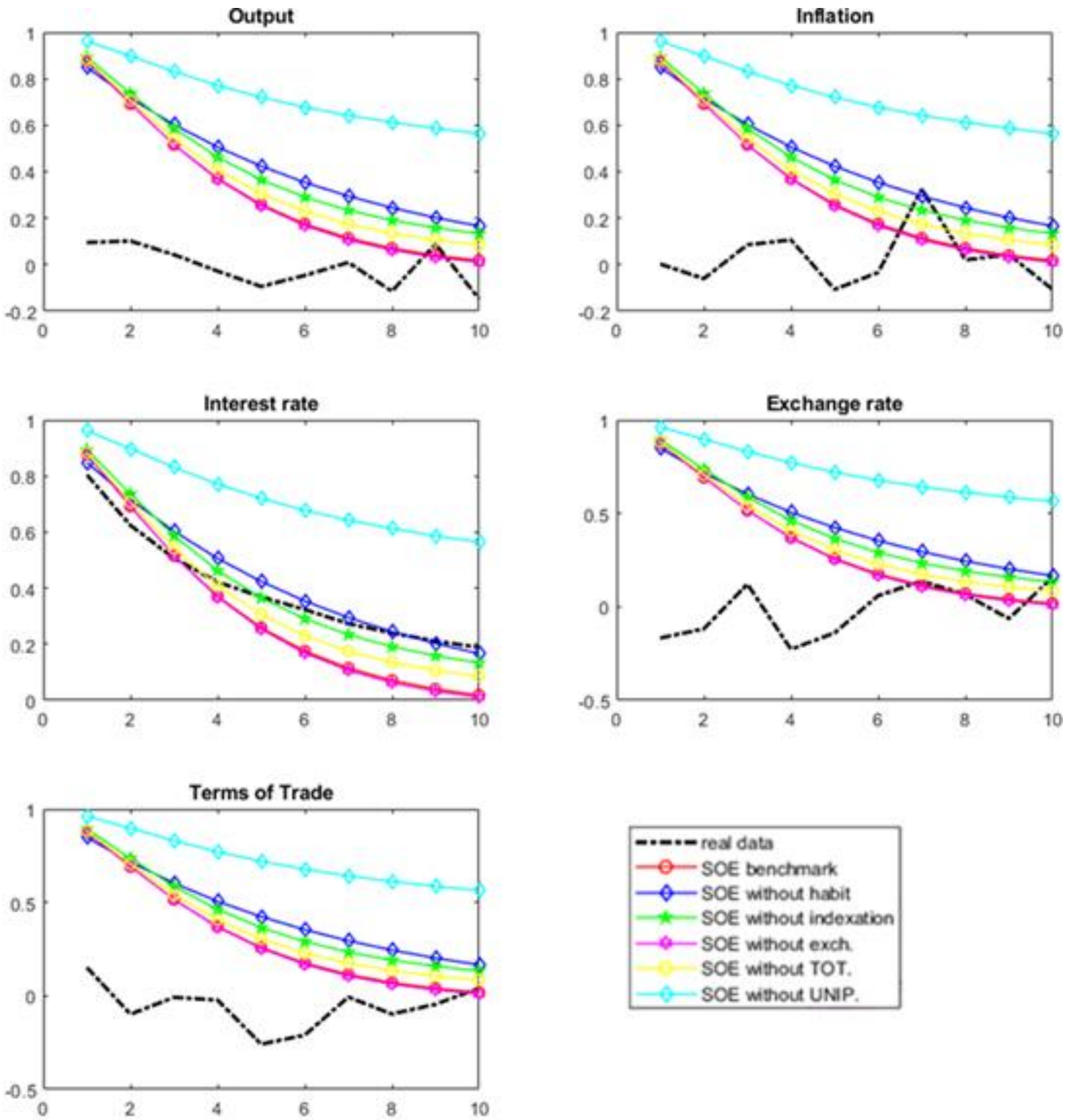

Figure 8 : Autocorrelations up to order 10

5.5 Impulse responses

In this section, we examined all four of our models in detail in terms of the responses of consumption, output, inflation, interest rate, terms of trade, and the exchange rate to the mentioned shocks in the economy. As mentioned earlier, there are a total of nine shocks in our model, six of which are shocks originating in the domestic and three of which originating in the foreign countries. The black-colored lines seen in the figures represent the benchmark model, the red dashed lines represent without habit model, the green lines represent without indexation model, and the blue color represents the model without exchange rate and the turquoise color represents the model in terms of unmodified uncovered interest rate parity condition.

All impulse response figures, which combine all the models, will provide a possibility of comparison between the models.

5.5.1 Impulse responses to a shock to technology

Figure 9 shows the response of the economy to a positive shock to technology. As a result of this shock, consumption, interestingly, decreases by % 0.5 to % 1 for about a 10 period in the benchmark model. In the other models, we see that the decrease experienced is much deeper. Here, the expectation was that consumption would increase with the technology shock. In this case, we have to express that the model has acted contrary to what was expected at this point. With the technology shock, by the expectations, the output growth is positively etched to continue 8-10 periods. Here, the unmodified uncovered interest rate parity model is not moving parallel to the other models. This shows how the modified uncovered parity parameter improved the model. Inflation movement is starting with negative values for 3-4 periods. But after it reaches to its steady state. As it can be seen from the figure, the unmodified uncovered interest rate parity model never reaches its steady state. There is also a slight increase in interest rates for 3-4 periods which is very normal and then a slight return to its steady state. We see a strong uptrend in terms of trade which approaches to about % 5 rises in the first 2 periods. Terms of trade reaches to its steady state after 15 periods. Other models except for the unmodified uncovered interest rate parity model moves parallel in terms of terms of trade responses. On the other hand, we see a noticeable increase in exchange rates. The exchange rate appreciates by about % 3 in the beginning and then it moves to its steady-state after 15 periods.

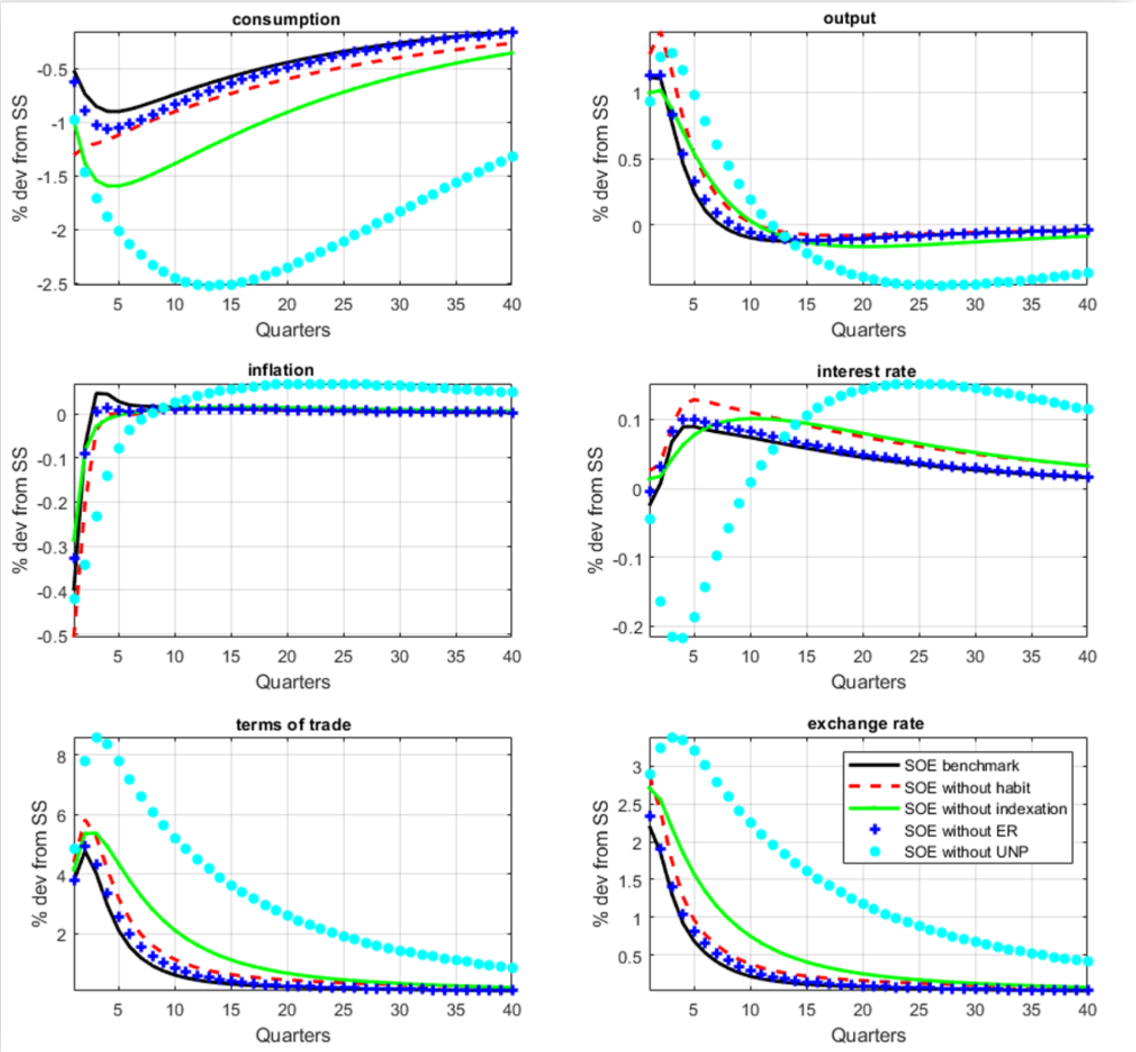

Figure 9 : Impulse Response to a shock to Technology

5.5.2 Impulse responses to a shock to monetary policy

Figure 10 shows the response of the macroeconomic variables to a positive shock to monetary policy. Contrary to the technological shock responses, we see a parallel movement here with consumption and output. Both react with a decrease for 3-4 periods first, then gradually return to their steady state. All models move approximately parallel. inflation reacts with a very strong fall at the beginning. Inflation returns to its steady state after the fourth period in all models. The response of the interest rate varies from model to model. The benchmark model, without habit formation and the model without price indexation responses with a rise in the first 3 periods. But on the other side, without exchange rate model and the model without uncovered interest rate parity parameter responses with a fall. All models return to their steady states gradually after the fifth period. We see a parallel movement for all models in the response of terms of trade. On one side, benchmark model responses with % 0.4 decrease and on the other side the model without price indexation responses with a % 0.6 decrease. Beyond these, the model without modified uncovered interest rate parity parameter starts with a much stronger decline and then moves towards its steady state. We see that all models react very gravely in terms of exchange rates. We know that in real life, exchange rates respond to the rise in interest rates with a decrease. In this respect, the model shows realistic behavior. However, it is necessary to evaluate separately in terms of the magnitude of the reaction. The response to a one percent monetary policy shock in the model is around a four percent drop.

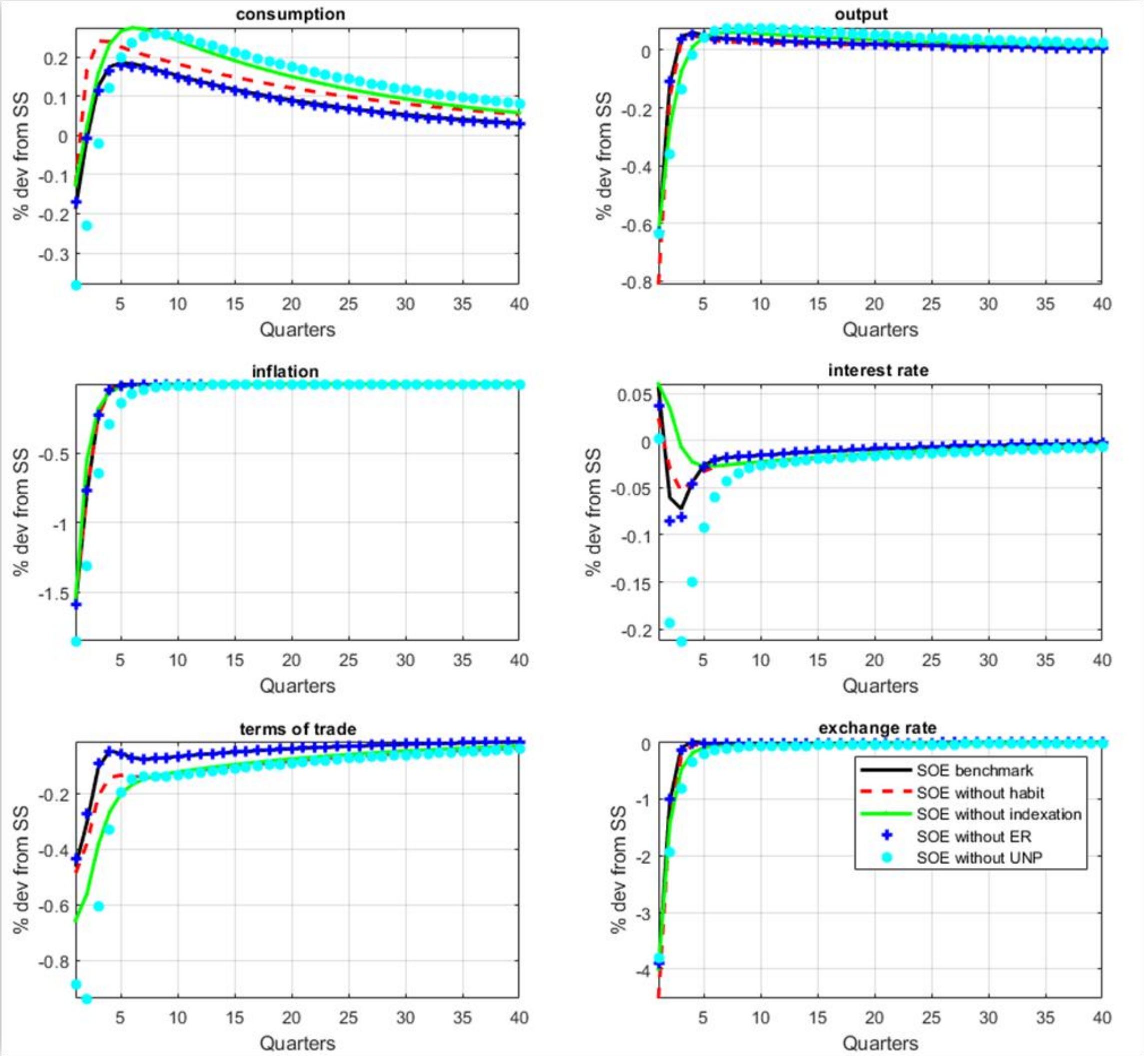

Figure 10 : Impulse Response to a shock to Monetary Policy

5.5.3 Impulse responses to a shock to preferences

Preference shocks are the demand shocks by the households. Figure 11 is the impulse responses of % 1 shock household preferences. the model shows a strong reaction of consumption to preference shocks. All models go up to % 8 change from their steady-state for a 3 quarter then move to their means quickly. Response of output is about % 1.5 for a 3-4 quarter. Without habit formation model moves differently. While other models appear hump-shape, the without habit formation model appears downward sloping. On the other hand, we observe a small decrease and then a much smaller increase in inflation. In fact, our expectation in this sense was that there would be a significant increase in inflation along with demand increase. The inflation response of all models is almost the same. Interest rate response is positive but more permanent than other macroeconomic variables. All models except without habit formation starts from % 0.05 and goes up to % 0.3 deviation in 6-7 quarters. They all move back to their steady state very slowly which is about more than 30 periods. Without habit formation model starts from % 0.05 and then goes down and moves up again. We see a negative terms of trade response to a shock to preferences. There is also a negative deviation on exchange rate.

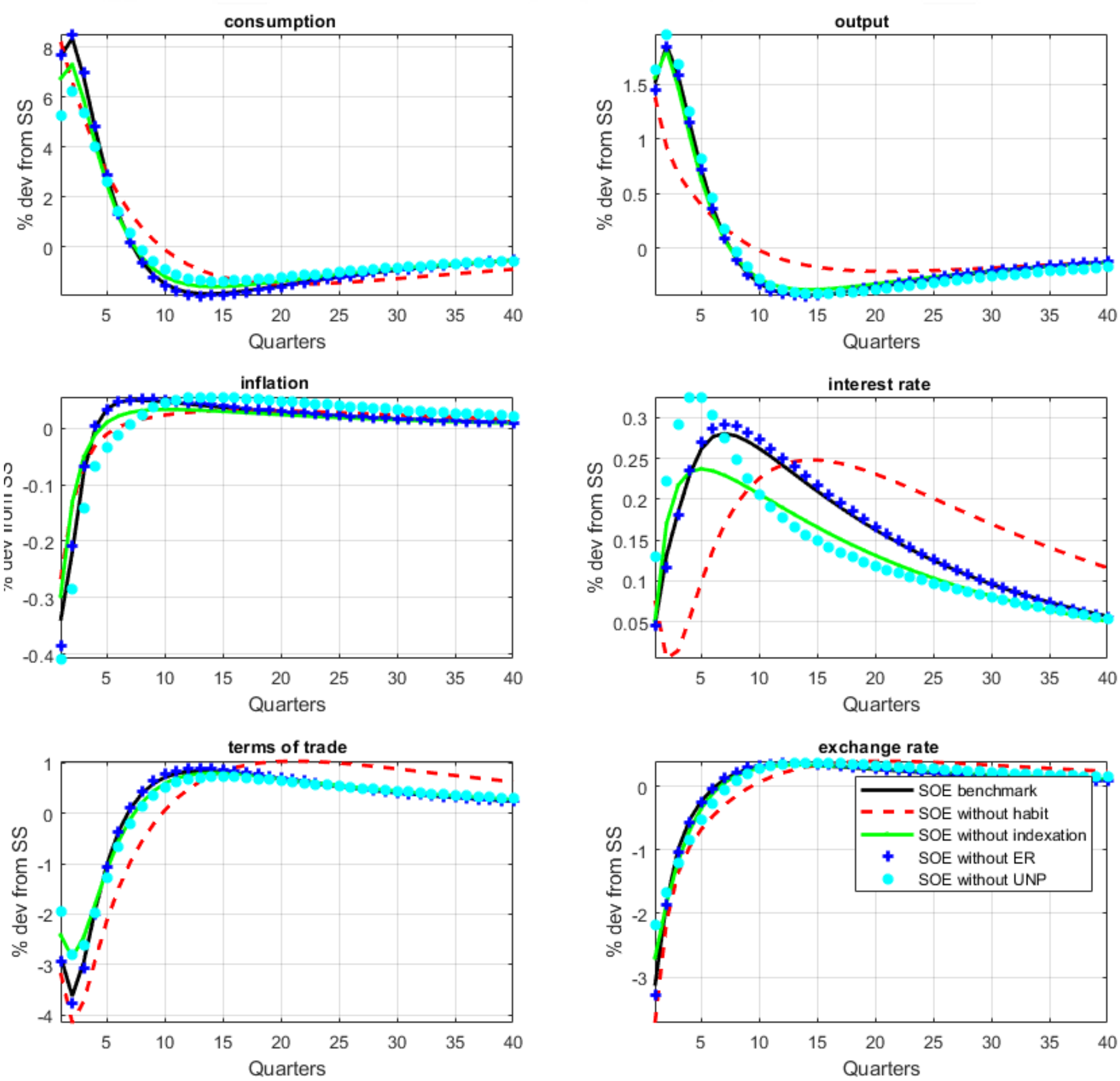

Figure 11 : Impulse Response to a shock to Preferences

5.5.4 Impulse responses to a shock to risk premium

A positive shock to risk premium impulse responses are figured in Figure 12 Consumption reacts positive to a change in risk premium. The Benchmark model moves to % 1 and returns to steady state gradually. We see that all models move almost the same. Without habit formation and the model without price indexation reacts twice as the other models. We see the almost same response in output growth as the consumption responses. Reaction goes to % 0.2 for the benchmark model, % 0.4 for the model without price indexation model and % 0.6 for the model without habit formation model. Response of inflation and interest rates are on the same negative side which is good for the economy and the response of interest rate is more permanent. Response to inflation is more temporary. At the same time terms of trade reacts negatively. There is also a Turkish Lira appreciation to a positive shock to risk premium.

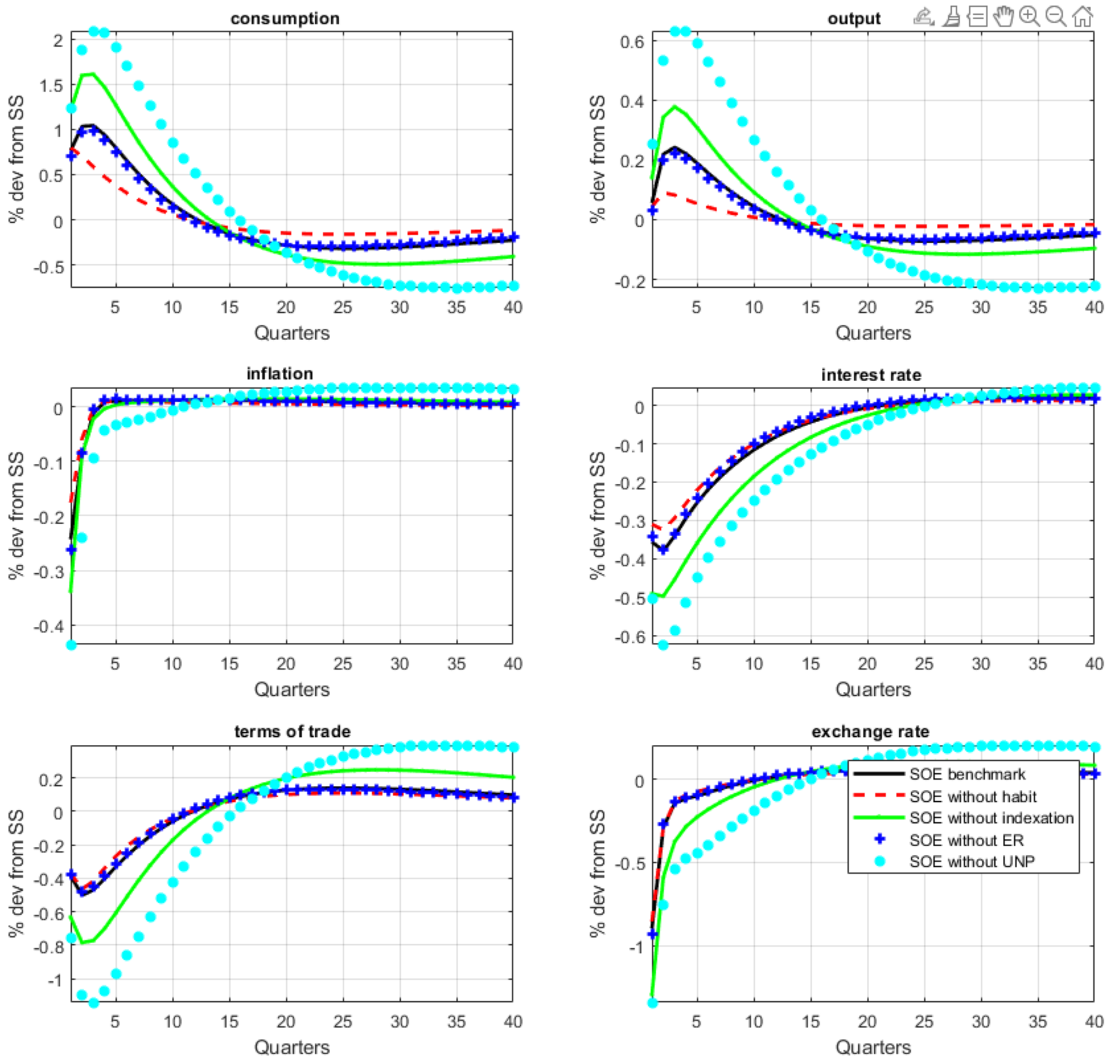

Figure 12 : Impulse Response to a shock to Risk Premium

5.5.5 Impulse responses to a shock to cost push

Figure 13 shows the response of the macroeconomic variables to a positive shock to cost push. Cost push shock is the shock of imported goods costs. A positive cost push shock increases the consumption as expected approximately one to one. But we see different responses of different models in consumption. As the decrease in the cost of imported goods increases the demand for imported products, we can observe a decrease in output growth. According to the model the response of inflation is not high as expected. But the reaction of interest rate is not same for the models. Some models move on the positive side while the others move on negative side. For example, the model without habit formation and the model without price indexation responses positively. We see a downtrend in terms of trade up to % 0.2 and then a gradual move to its steady state. We see a % 5 depreciation in Turkish Lira according to the benchmark model. As it can be seen from the figure, the model without modified uncovered interest rate parity parameter reacts differently from the other model. This also shows the importance of the modified uncovered interest rate parity parameter.

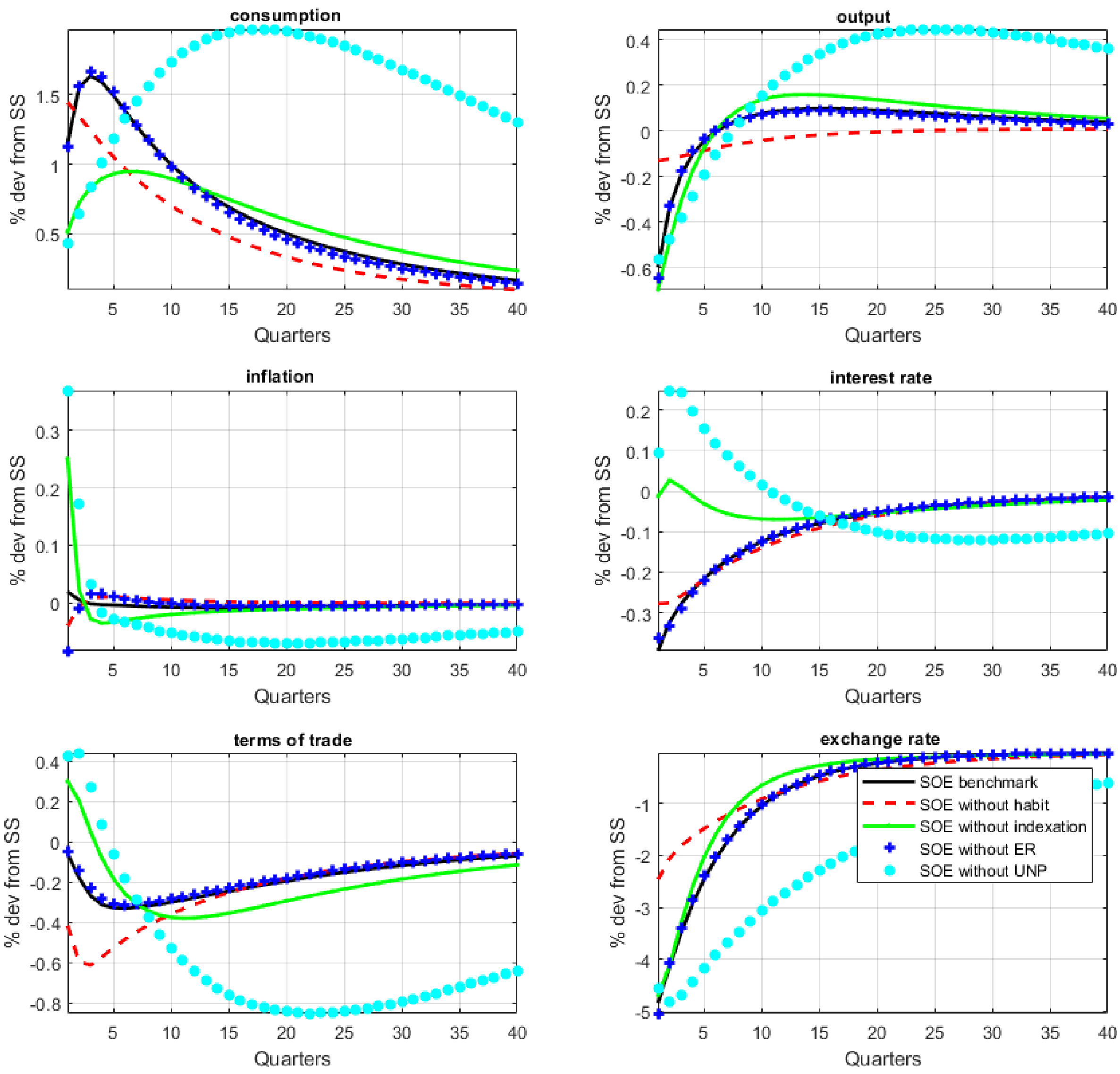

Figure 13 : Impulse Response to a shock to Cost Push

5.5.6 Impulse responses to a shock to terms of trade

Figure 14 shows the response of the economy to a positive shock to terms of trade. As a result of this shock, consumption increases up to % 0.5 in the without habit formation model. It reaches to a % 0.2 uptrend in the benchmark model and the model without exchange rate sensitivity of central bank. We can’t see any response in the model without price indexation and the model without modified uncovered interest rate parity parameter. Output growth decreases to % 0.6 in the model without habit formation and % 0.3 in the benchmark model and the model without exchange rate sensitivity in the central bank. The inflation first increases and then deceases temporarily. Interest rates responses positively to a terms of trade shock for a while. Terms of trade increases as expected and we see a strong appreciation in Turkish Lira.

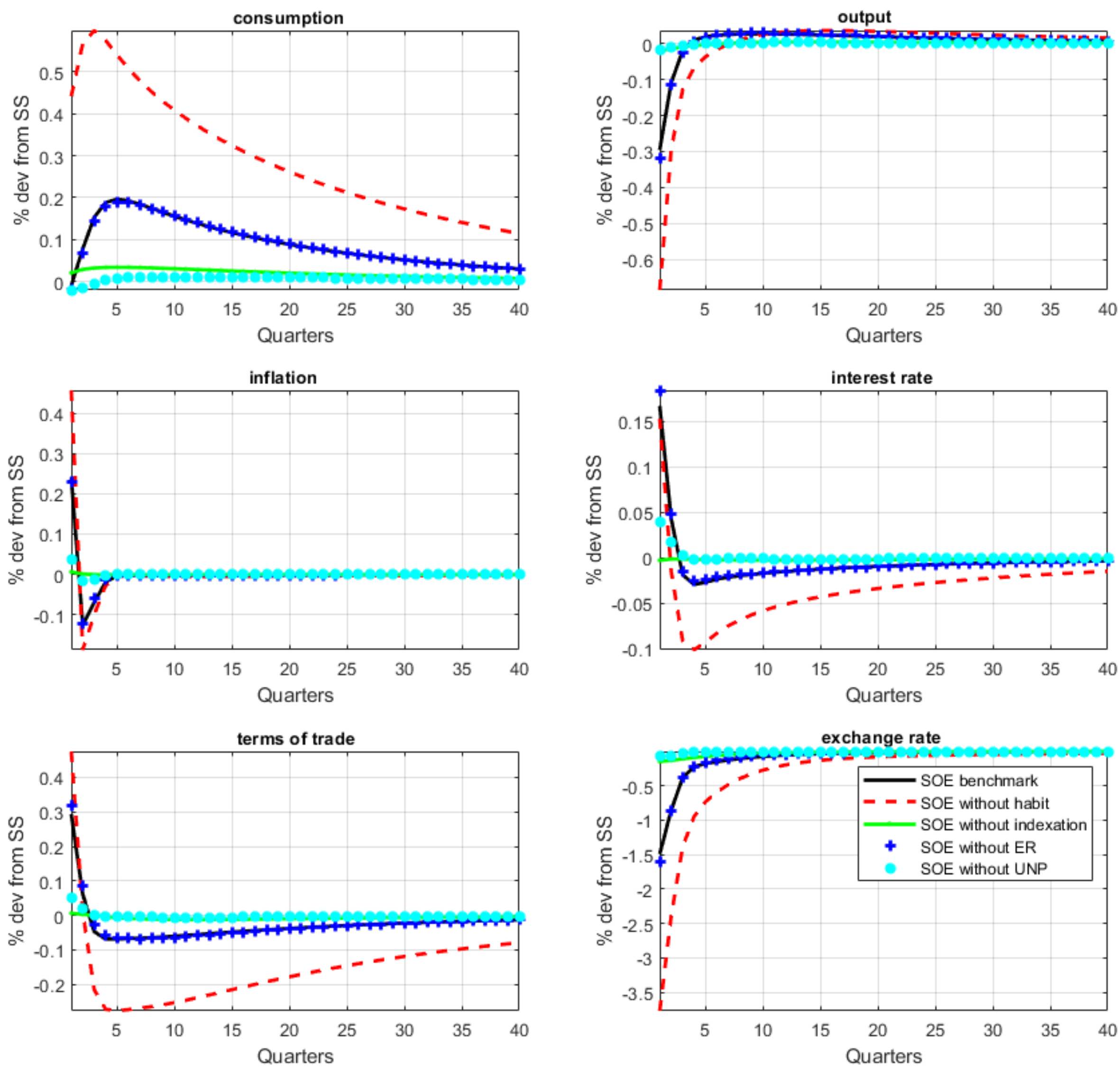

Figure 14 : Impulse Response to a shock to Terms of Trade

5.5.7 Impulse responses to a shock to foreign output growth

Figure 15 is the impulse responses of the macroeconomic variables to % 1 foreign output growth shock. Positive growth in foreign output has a positive contribution to domestic consumption. We see a % 0.35 hump shaped rise in consumption and a gradual return to steady state. Domestic output is also affected positively to an extent. Beginning with % 0.4 rise and later on a decreasing function which drives up to 30 quarters to its steady state. On the other side, there appears a decrease in domestic inflation and also interest rates but not permanent. Terms of trade also appear a negative movement. Then we see a Turkish Lira a temporary appreciation for about % 0.5.

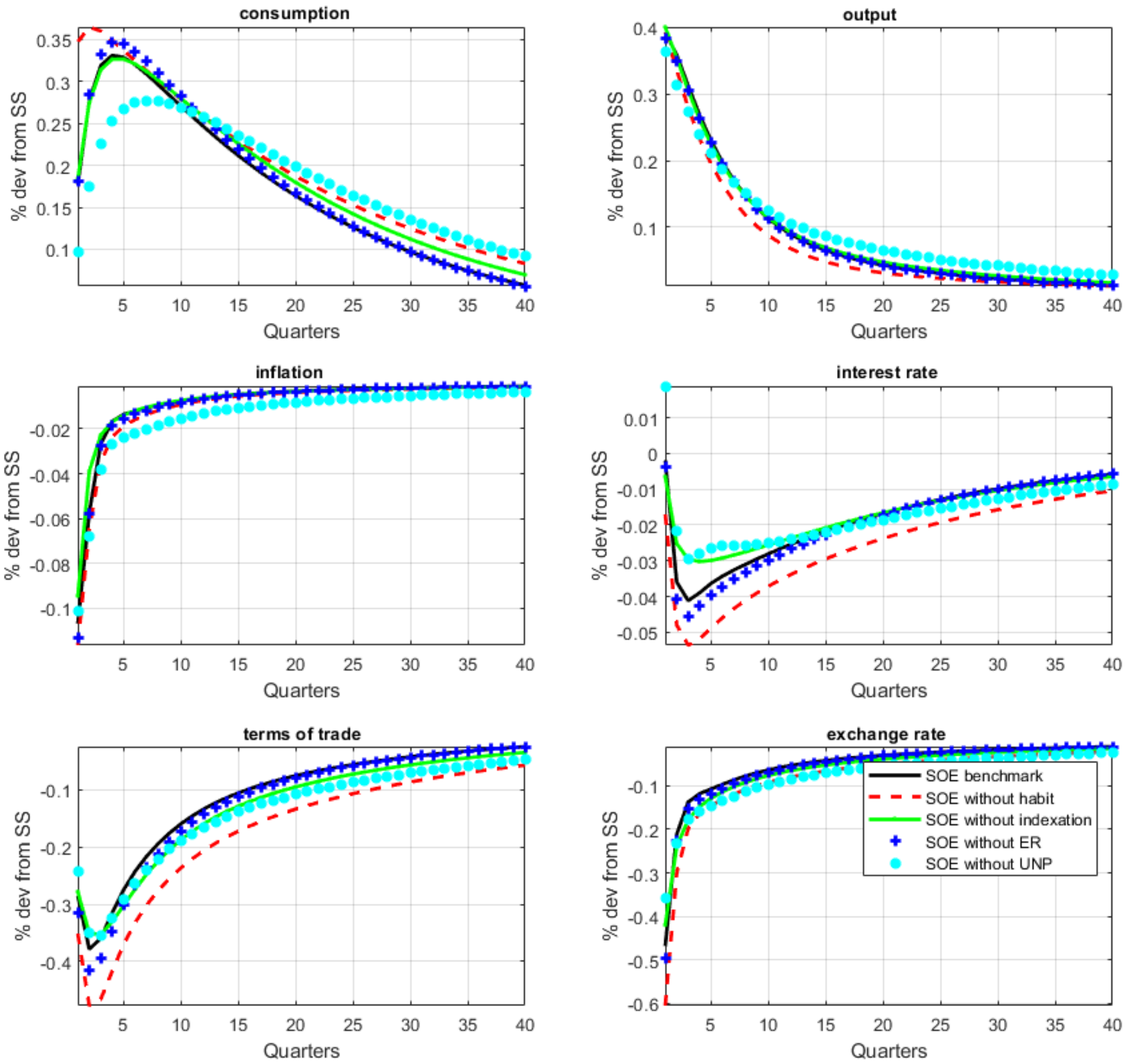

Figure 15 : Impulse Response to a shock to Foreign Output Growth

5.5.8 Impulse responses to a shock to foreign inflation

Impulse responses to a % 1 foreign inflation shock is depicted in Figure 16 Consumption responses temporarily for about % 0.25 like a hump shaped form. It moves on the positive side for 10 quarters but then it moves reversely and we see a % 0.05 negative and more permanent movement. Output growth responses a positive like a hump shaped form reaction. Inflation and interest rates appears similar and an approximately % 0.1 negative response. Similarly, terms of trade responses negatively for about 6-7 quarters. Again, we see a small appreciation of Turkish Lira.

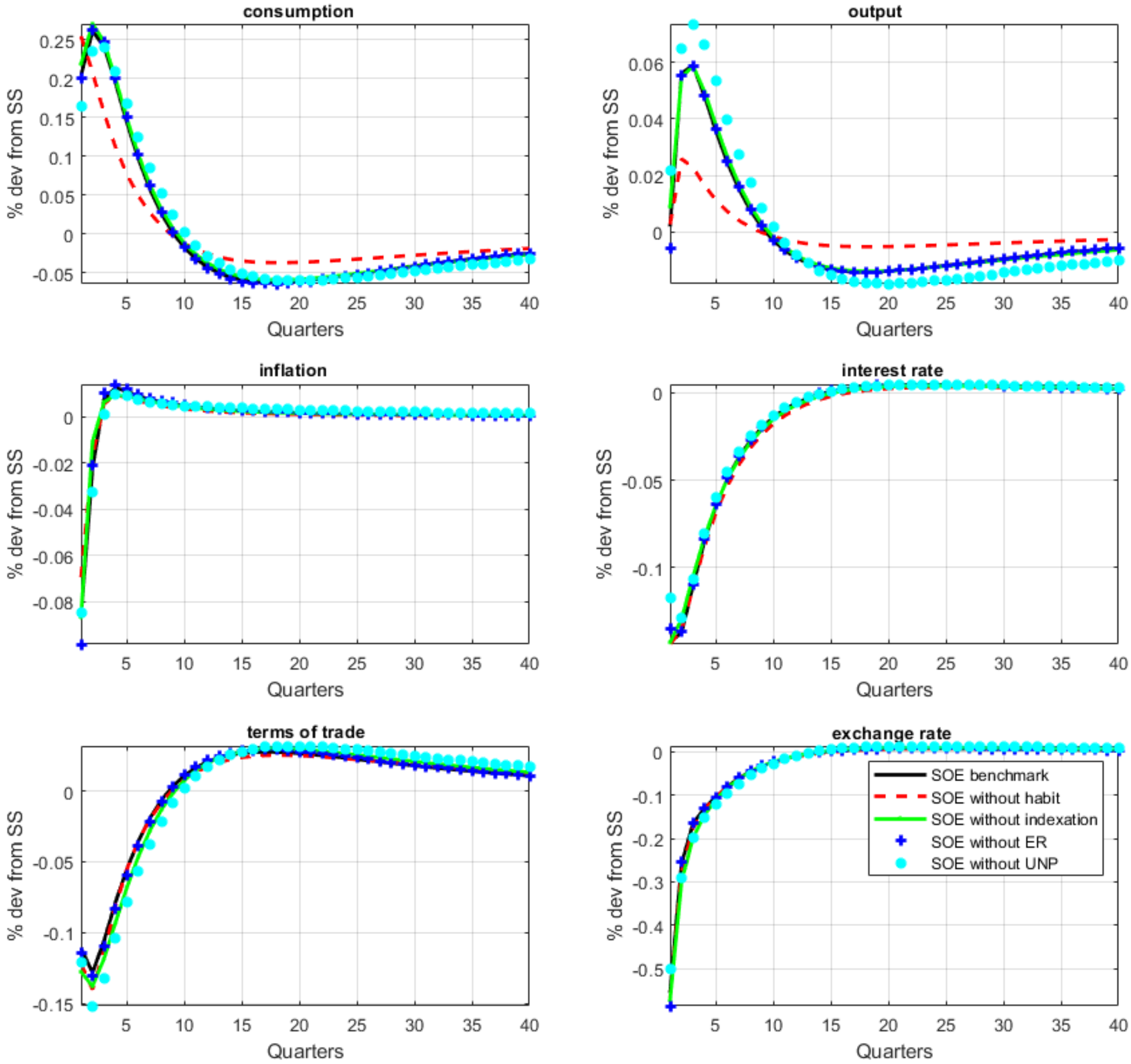

Figure 16 : Impulse Response to a shock to Foreign Inflation

5.5.9 Impulse responses to a shock to foreign interest rates

Figure 17 is the impulses responses to a shock to foreign interest rates. Consumption and output growth decreases for about 10 quarters. Inflation and interest rates responses positively. Inflation returns to its steady state after third period while interest rates return to its steady state after 15 periods. Terms of trade increases and we see a Turkish Lira depreciation for about % 0.2.

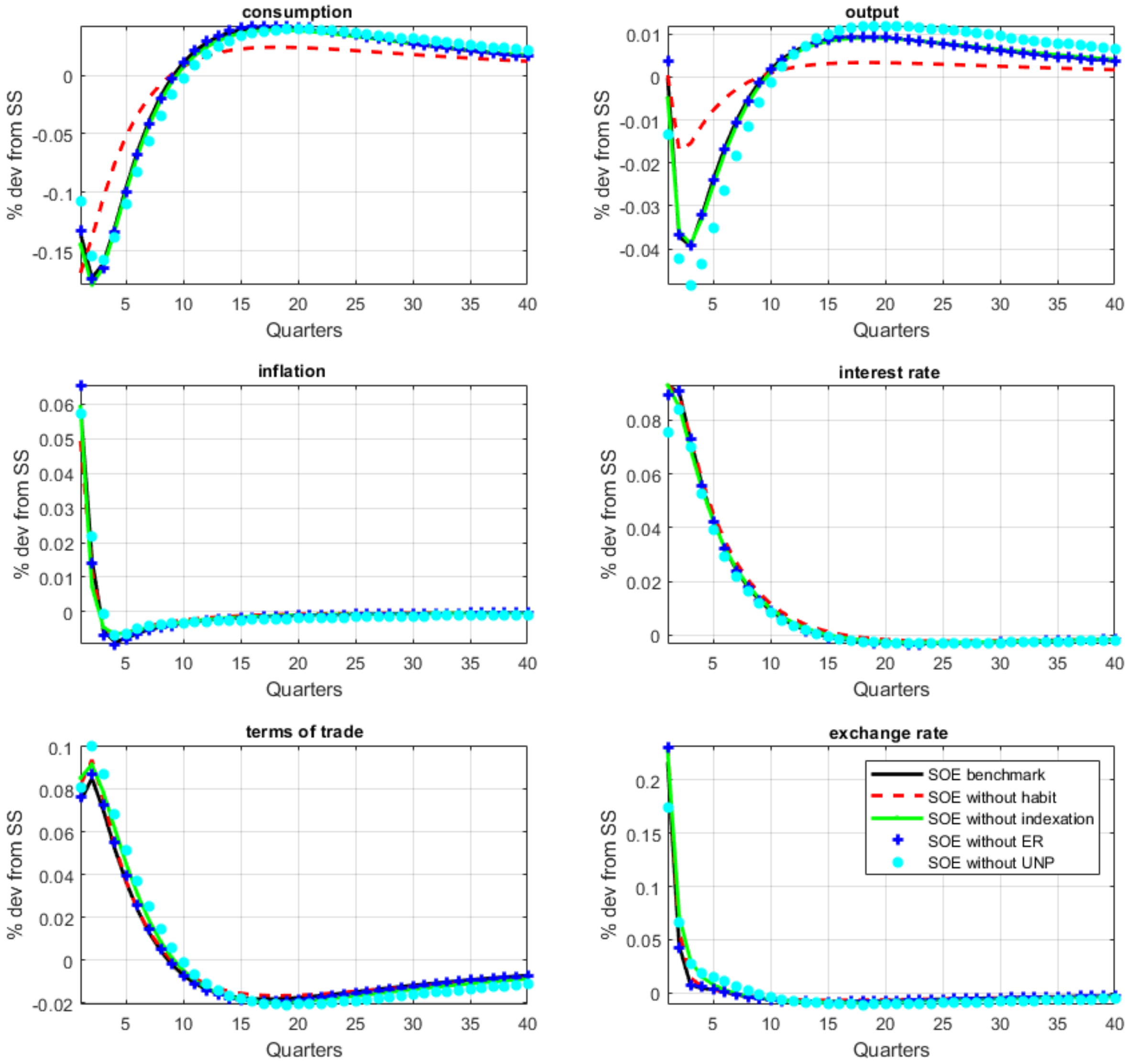

Figure 17 : Impulse Response to a shock to Foreign Interest Rates

5.6 Variance decompositions

Table 10 depicts the contribution of each structural shock to the variance of macroeconomic variables throughout the period 2003Q1 – 2020 Q1 for the benchmark model. Approximately 84.77 % of consumption variance is explained by preference shocks. Cost push shocks also affects the consumption variances for about 8.11 %. Technology shocks are not effective as demand side shocks. Monetary policy shocks, risk premium shocks, terms of trade shocks and foreign shocks are trivial for consumption. Variance of output is influenced by 68.95 % preference shocks and 18.64 % technology shock. These two shocks explain 88 % of the output growth variances. Monetary policy shocks have 2.44 % effect and foreign output growth have 3.57 % effect on output growth variances. Other shocks have unimportant effects on output growth. Inflation is highly affected by monetary policy shocks. Inflation variance are explained 85.16 % of monetary shocks. Preferences shocks 5.43 % and technology shocks 4.61 % affects on inflation. Interest rates fluctuations are mainly influenced by 42.53 % preference shocks, 24.93 % risk premium shocks and 22.95 % cost push shocks. Technology shocks are not account for more than 4.61 % on interest rate variances. The main contributor of terms of trade is technology shock with 58.85 % and preference shocks with 37.23 %. Terms of trade variances are mainly influenced by preference shock and cost push shock. Cost push shock explain the 65.83% of inflation variances. Cost push shocks, technology shocks and monetary policy shocks and preference shocks account for more than 96.13 % of the variance on exchange rate.

Table 10 : Variance decompositions

	ε_a	ε_m	ε_g	ε_p	ε_{cp}	ε_{tot}	ε_{y^*}	ε_{π^*}	ε_{r^*}
Consumption	3.69	0.15	<u>84.77</u>	2.49	8.11	0.15	0.50	0.10	0.04
Output	<u>18.64</u>	2.44	<u>68.95</u>	1.98	3.72	0.59	3.57	0.08	0.03
Inflation	4.61	<u>85.16</u>	5.42	1.88	0.05	2.09	0.44	0.23	0.11
Interest Rate	3.65	0.65	<u>42.53</u>	<u>24.93</u>	<u>22.95</u>	1.25	0.62	2.38	1.03
Terms of Trade	<u>58.85</u>	0.31	<u>37.23</u>	1.24	1.44	0.13	0.72	0.05	0.02
Exchange Rate	9.15	12.96	12.23	0.77	<u>61.79</u>	2.45	0.27	0.33	0.04

Variance decompositions indicates the amount of each shock contribute to the variance of the correspond macroeconomic variables.

5.7 Historical decompositions

This section evaluates the sources that drive the output growth, inflation, interest rates, exchange rates and terms of trade in Turkey for the period between 20013Q1 and 2020Q1 via using historical decomposition technique according to the benchmark model. The yellow areas in the figures show the global crisis of 2008 and the Turkish lira crisis of

2018, which the Turkish economy has faced over the past 20 years. In figures colours of the bars represent different type of shocks and grey bars depict the initial values of the variables. Black line is the deviation of the corresponding variable from its steady state level.

5.7.1 Historical decomposition of output

Figure 18 demonstrates the contribution of the structural shocks to output growth of Turkish economy. Output growth is mainly influenced by technology shocks and monetary shocks during last two decades. First of all, prior to the 2008 financial crisis period, preference shocks are effective. However, technology shocks and monetary shocks have been effective from time to time. Cost shocks did not contribute positively to growth in this period. During the 2008 financial crisis, a serious demand contraction was experienced. This demand contraction continued for 4 periods. Although a negative technology shock prevailed in the first quarter of the crisis, technology shocks triggered growth for the next 3 quarters. In addition, one of the most effective shocks in the emergence of this crisis was the negative external growth shocks. Demand expanded for a while after the financial crisis of 2008. However, it did not last long and a demand contraction shock was experienced again in 2013. In the course of the 2018 financial crisis, technology and monetary policy shocks have been the main sources of fluctuations. In the 2018 exchange rate crisis, the Turkish economy faced an effective negative priority shock and this situation continued for approximately three quarters. As a result of the depreciation of the Turkish Lira, technology shocks prevented a deeper loss of growth. In the immediate aftermath of the currency crisis, negative technology shocks were an obstacle to growth. During this period, trade shocks prevented a deep production shrinkage.

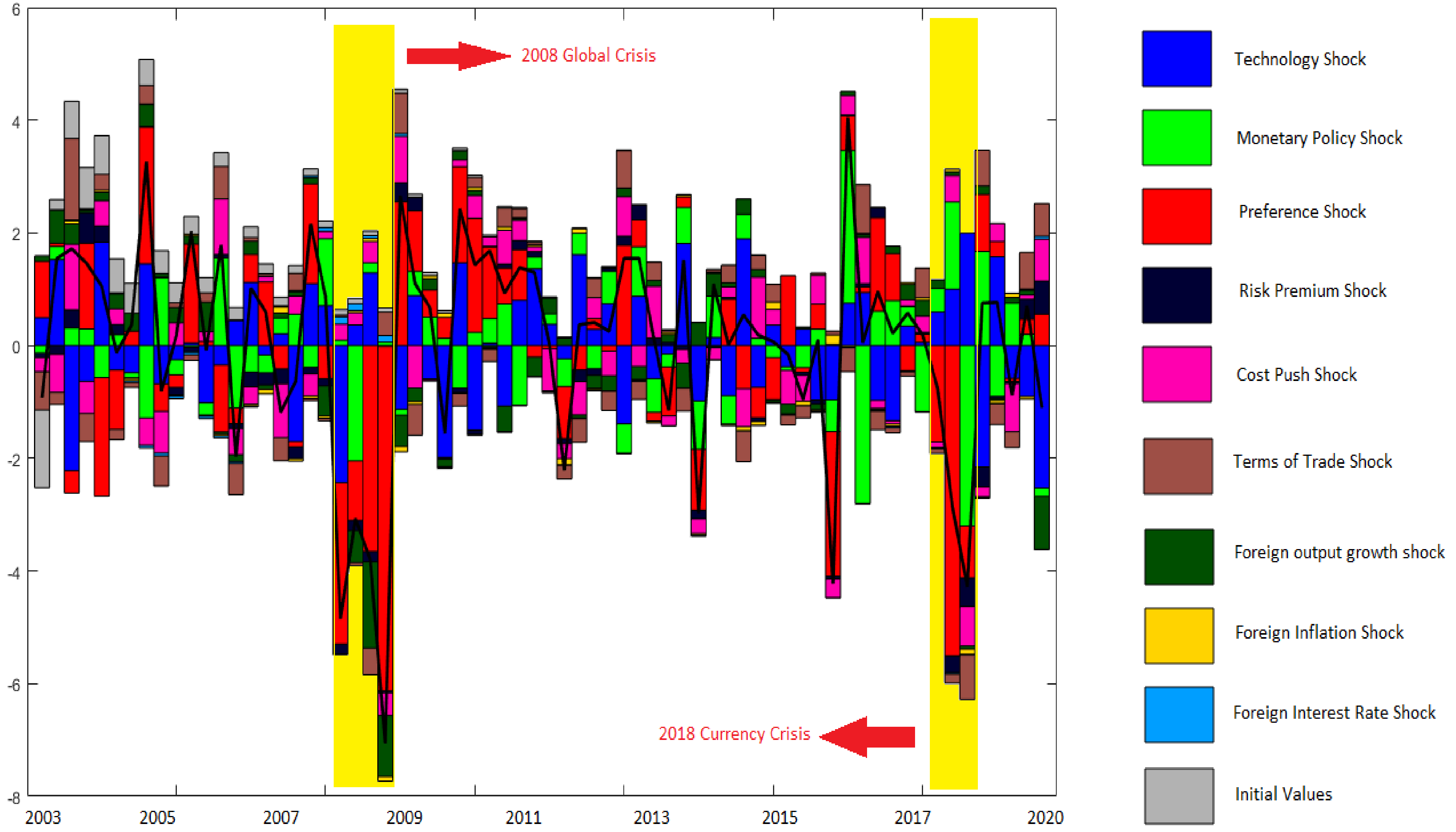

Figure 18 : Historical Decomposition of output growth

5.7.2 Historical decomposition of inflation

Figure 19 shows the historical decomposition for inflation. As can be seen from this figure, monetary shocks have a very high effect on inflation fluctuations. While monetary shocks after the 2001 financial crisis had a positive effect on inflation, technology shocks and risk premium shocks contributed to the fall in inflation. Before the 2008 financial crisis, the inflation increase caused by global effects was tried to be reduced by monetary shocks. The effective monetary policies created in 2008 and 2009 have been provided to reduce the negative effects on the general price level that may occur as a result of the demand shrinkage. After the 2008 financial crisis, the negative effects of technology shocks and terms of trade shocks at the point of the increase in the price level were mainly tried to be controlled by monetary policy shocks. From 2008 to 2016, the central bank used a significant part of its resources in the fight against inflation, and inflation was brought under control. The central bank has taken steps towards growth since 2016, but soon faced a currency crisis in 2018. Demand shocks and risk premium shocks were effective in the 2018 financial crisis. Technology shocks that emerged as the Turkish lira depreciated significantly after the 2018 financial crisis had a positive impact on inflation. It is striking that the risk premium shocks in and after the 2018 currency crisis deepened the crisis.

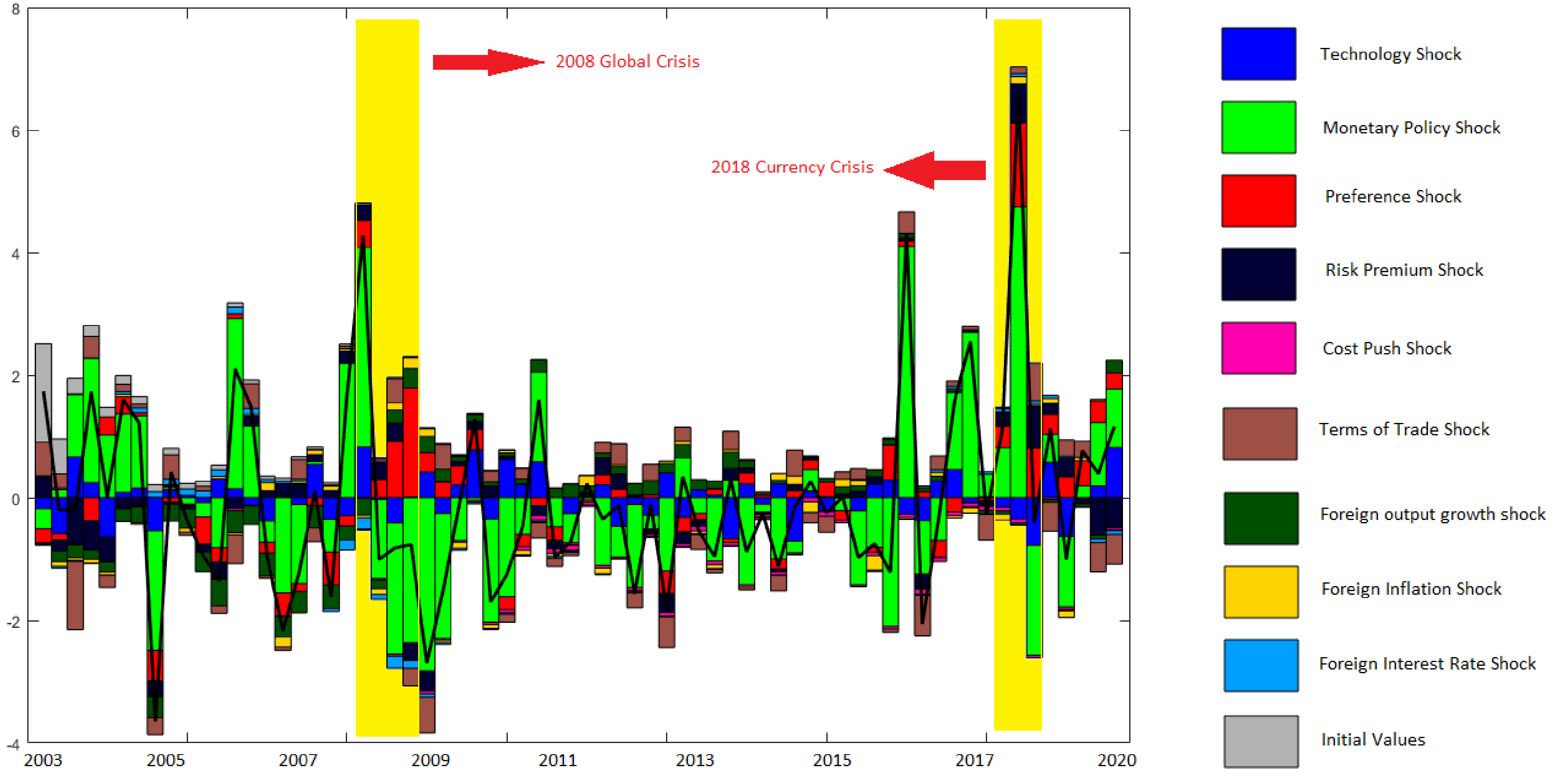

Figure 19 : Historical decomposition of inflation

5.7.3 Historical decomposition of interest rate

Figure 20 is the historical decomposition of the interest rates. The 2001 financial crisis was a period when interest rates were at very high levels with rising risk premiums. The important steps taken immediately afterward caused the country's risk premiums to fall and interest rates to fall to lower levels. However, we can observe from the gray bars that the interest rate inertia that occurred before and during the 2001 crisis gradually decreased until the 2008 financial crisis. Until the 2008 financial crisis, risk premium shocks were one of the most effective shocks in the fall of interest rates. Falling interest rates stimulated domestic demand, leading to preference shocks after 2005. With the 2008 financial crisis, the effect of preference shocks gradually decreased. From 2007 to 2017, cost push shocks have long been effective in keeping interest rates at low levels. I think that this situation occurred because of the Turkish Lira not depreciating for a long time. In addition, technology shocks between 2011 and 2015 and risk premium shocks between 2013 and 2017 caused interest rates to remain at low levels for a long time. In the 2018 currency crisis, there is an increase in interest rates. Here, two shocks come to the fore. The first is risk premium shocks and the second is cost push shocks. The model here makes an extremely successful analysis. Because during this period, the country's risk premium increased and cost push shocks emerged due to the increasing exchange rates. We can see the effectiveness of the preference shocks caused by the demand shrinkage after the currency crisis, in the red bars after 2018. This situation actually contributed to the stabilization of interest rates after the crisis, without the need for additional policies by the central bank.

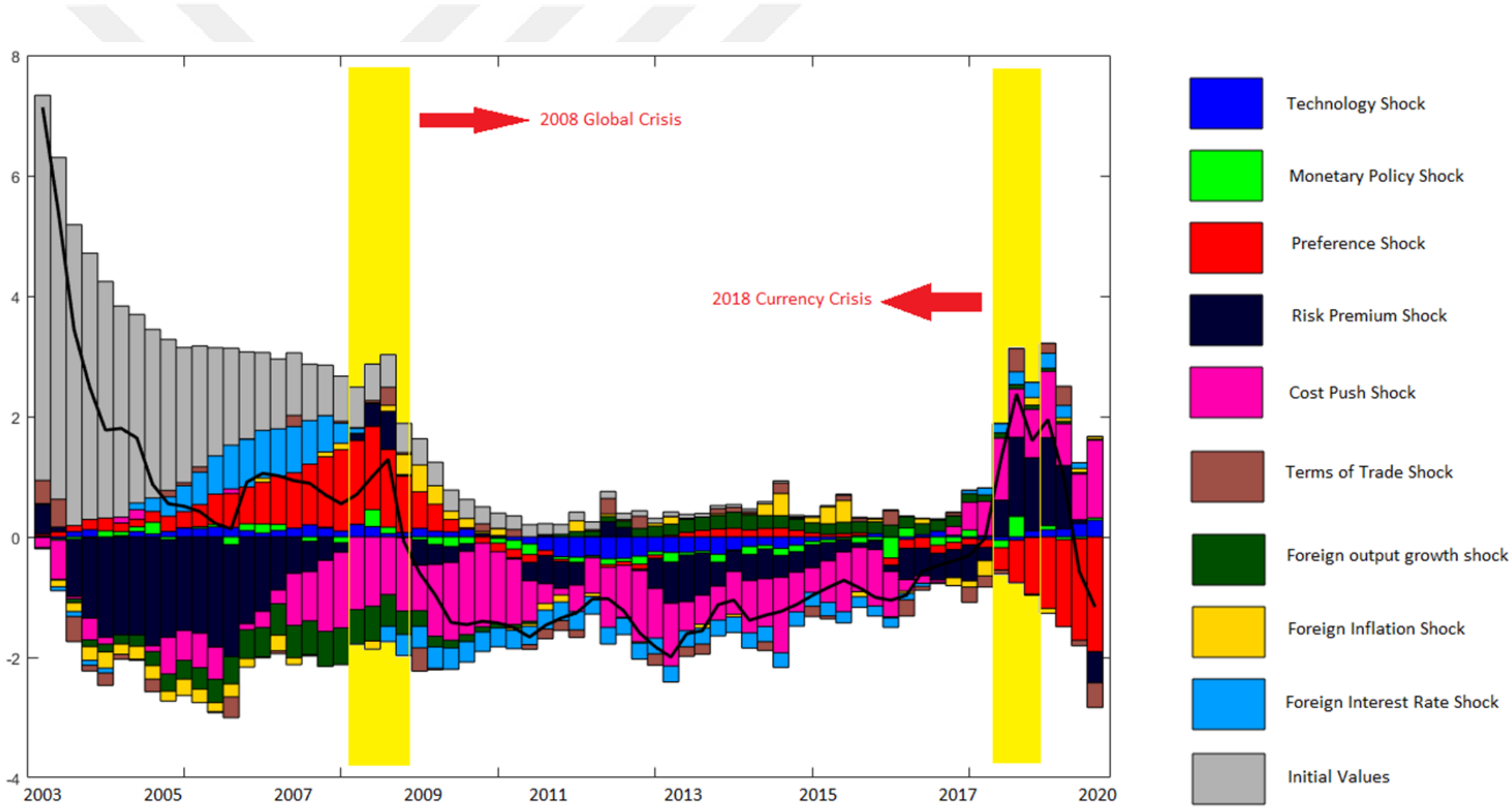

Figure 20 : Historical decomposition of interest rate

5.7.4 Historical decomposition of real exchange rate

The historical decomposition of the exchange rate is depicted in Figure 21. Turkish Lira depreciated significantly with the 2001 financial crisis. The steps were taken after the 2001 crisis have caused gradually appreciated the Turkish Lira. We can see the reflections of the depreciation of the Turkish Lira in 2001 in the gray bars in the first parts of the figure. Until the 2008 financial crisis, cost push shocks were extremely effective. However, monetary shocks, technology shocks, and preference shocks are also very effective. While preference shocks had a negative effect on the Turkish lira in the 2008 financial crisis, monetary shocks and cost shocks had a positive effect. The effectiveness of preference shocks has continued for another six quarters since the 2008 financial crisis. From 2008 to 2013, technology shocks effectively contributed to the Turkish Lira remaining valuable. After 2013, this situation is reversing. Until 2016, cost push shocks effectively played an important role in the depreciation of the Turkish Lira against foreign currencies. On the other hand, the central bank intervened from time to time to prevent the depreciation of the Turkish Lira and created monetary shocks. In the 2018 currency crisis, the Turkish Lira experienced one of the highest losses in the last two decades. In the process leading to the 2018 currency crisis, cost push shocks attract attention. Since 2016, unlike before, cost push shocks started to depreciate the Turkish Lira. This situation continued until the end of the estimation period. Preference shocks and technology shocks have been effective in the fluctuations in the Turkish Lira after the 2018 currency crisis. We can see in figure 21 that terms of trade shocks and external shocks are also effective in the fluctuation of the Turkish Lira during the estimation period, even if it is small.

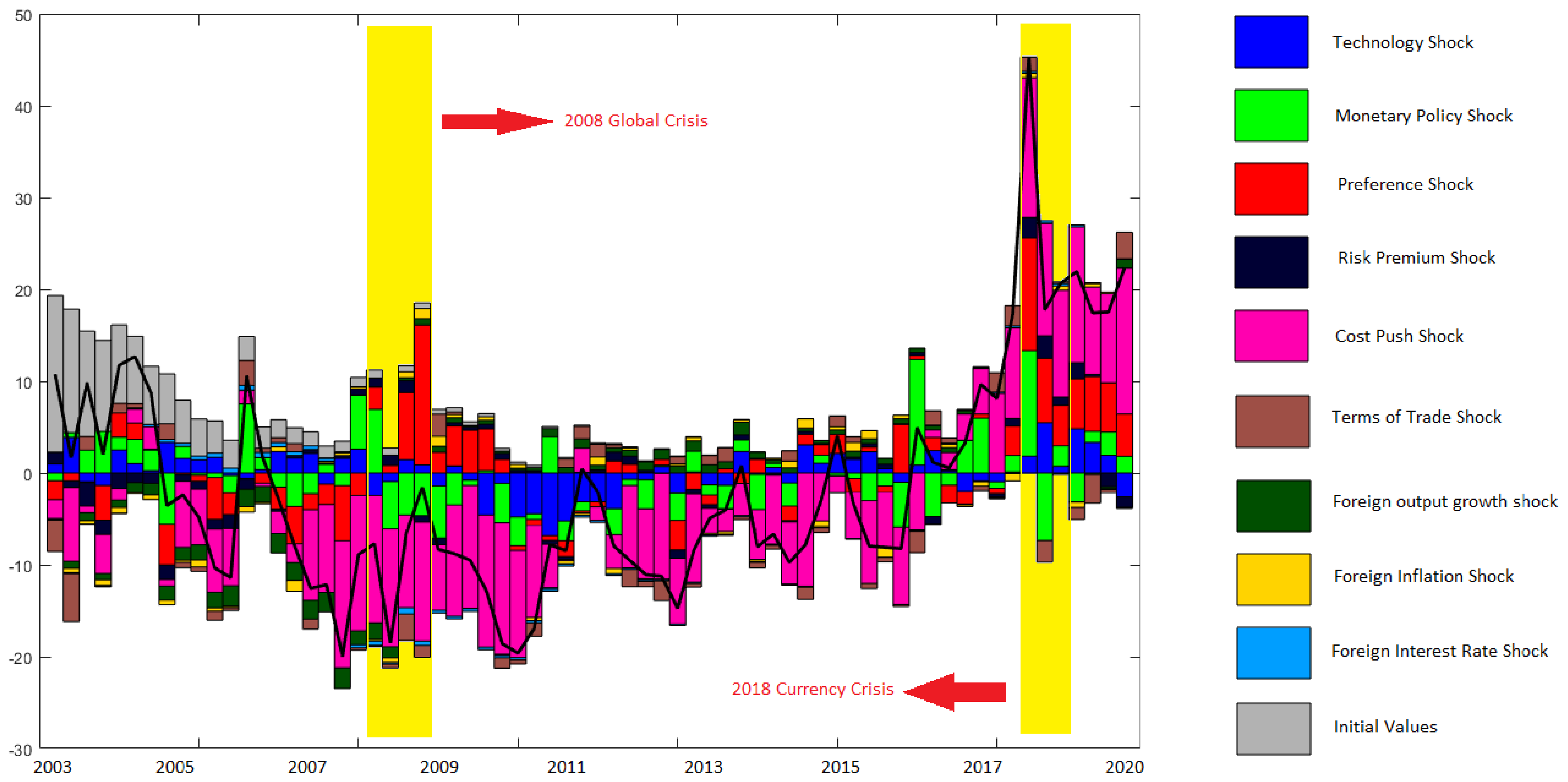

Figure 21 : Historical decomposition of real exchange rate

5.7.5 Historical decomposition of terms of trade

Figure 22 shows the historical decomposition of terms of trade during the estimation period. At first glance, we can say that terms of trade data has been positively affected both by the 2008 global crisis and the 2018 currency crisis. The impact of the initial conditions continued until the 2008 financial crisis. Until 2010, technology shocks triggered terms of trade to move above its steady state. However, the impact of preference shocks and foreign output growth shocks on terms of trade until the 2008 global crisis was negative. After the 2008 global crisis, the effectiveness of preference shocks stands out. However, the severity effect of these shocks completely disappeared after seven quarters. Contrary to the situation before the 2008 global crisis, technology shocks between 2011 and 2013 had a negative impact on terms of trade. Between 2015 and 2017, technology shocks had a positive impact on terms of trade. Similarly, in the 2018 currency crisis, the impact of preference shocks stood out as an important factor in the increase in terms of trade.

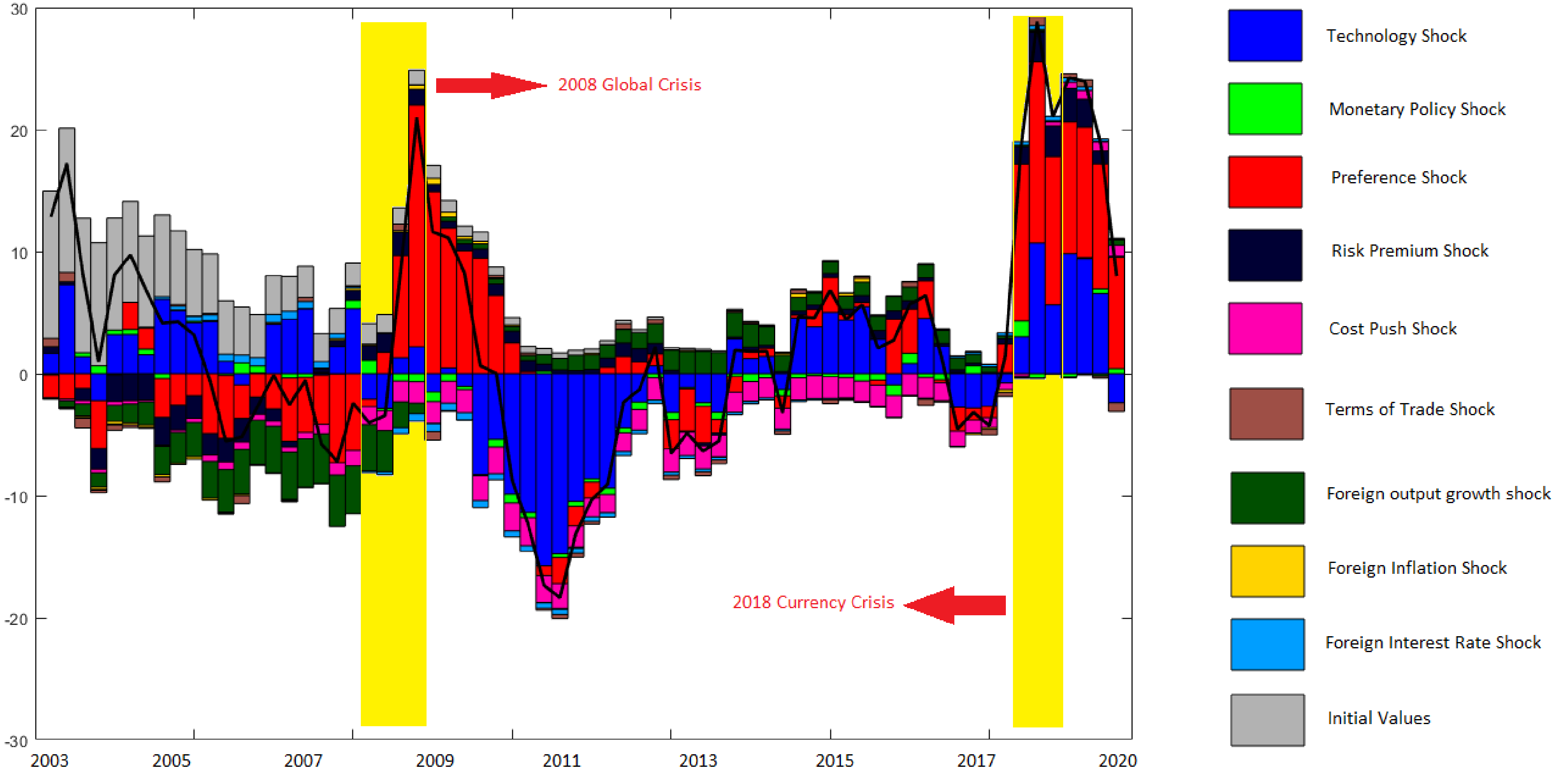

Figure 22 : Historical decomposition of terms of trade

6. Conclusions

In this chapter, a small open economy DSGE model with Bayesian approach for Turkish Economy was constructed. Indeed, we closely followed the model developed by Justiniano and Preston (2010). The model includes habit formation, Calvo price setting, price indexation and modified uncovered interest rate parity condition. On the other hand, the model includes several domestic disturbances such as technology shocks, preference shocks, cost push shocks, monetary policy shocks, terms of trade shocks and risk premium shocks. And also, foreign disturbances such as foreign output growth shocks, foreign inflation shocks and foreign interest rate shocks.

According to the estimation results, convergence is reached after 150,000 iterations and identification of parameters are quite well according to the posterior estimates. There are several results from posterior estimates. Domestic producers and importers reoptimize their prices every two quarters. Interest rate persistency is high for the central bank. Central Bank is sensitive to inflation, but central bank is not sensitive to exchange rate changes.

Adding habit formation, terms of trade and modifying uncovered interest rate parity condition improved the model fit in terms of Marginal Likelihood and Bayes Factor. On the other side, excluding price rigidities and exchange rate sensitivity of central bank enhanced the model fit. The model matched the inflation and interest rates in terms of second moments comparisons. Model is not successful to match output growth, exchange rate and terms of trade.

Output volatilities are highly affected from technology shocks and preference shocks. Monetary policy shocks explain 85 % of inflation fluctuations. Interest rates are driven by preference shocks, risk premium shocks and cost push shocks. Technology shocks and preference shocks are the dominant shocks to impact terms of trade shocks.

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Appendix

Household Optimization Problem

Households solve two optimization problems. In a small open economy model, households choose the portion of the domestic and foreign consumption goods bundle to minimize the costs of their consumption. On the other side, households choose how much to consume and work to maximize lifetime utility.

To solve the optimization problem of the household, the Lagrangian Function is needed to be constructed.

$$\begin{aligned}\mathcal{L}_t = E_t \sum_{t=0}^{\infty} \beta^t \Big(\Psi_{g,t}\big[(1-\sigma_c)^{-1}(C_t - hC_t)^{1-\sigma_c} - (1+\sigma_l){L_t}^{1+\sigma_l}\big] \\ - \lambda_t\big[C_t P_t + D_t + ĕ_t B_t - \big(1+R^h_{t-1}\big)D_{t-1} \\ - \big(1+R^f_{t-1}\big)ĕ_{t-1}B_{t-1}\Theta_t - W_t L_t - \pi_{H,t} - \pi_{F,t} - T_t\big]\Big)\end{aligned} \tag{6.1}$$

After forming Lagrangian Function it is required to take derivative of Lagrangian function with respect to Consumption, Labor, Domestic and Foreign Bonds;

FOC:

$$\frac{\partial \mathcal{L}_t}{\partial C_t} = \beta^t\big(\Psi_{g,t}(C_t - hC_t)^{-\sigma_c} - \lambda_t P_t\big) = 0 \tag{6.2}$$

$$\frac{\partial \mathcal{L}_t}{\partial L_t} = \beta^t\big(-\Psi_{g,t}{L_t}^{\sigma_l} - \lambda_t W_t\big) = 0 \tag{6.3}$$

$$\frac{\partial \mathcal{L}_t}{\partial D_t} = -\beta^t\lambda_t + \beta^{t+1}E_t\left(\lambda_{t+1}\big(1+R^h_t\big)\right) = 0 \tag{6.4}$$

$$\frac{\partial \mathcal{L}_t}{\partial D_t} = -\beta^t\lambda_t ĕ_t + \beta^{t+1}E_t\big(\lambda_{t+1}ĕ_{t+1}\big(1+R^f_t\big)\Theta_{t+1}\big) = 0 \tag{6.5}$$

(1.2) and (1.3) yields Labor supply schedule

$$(C_t - hC_t)^{\sigma_c} {L_t}^{\sigma_l} = \frac{W_t}{P_t} \tag{6.6}$$

(6.2) and (6.4) yields

$$\beta^{t+1} E_t \left(\lambda_{t+1}\left(1 + R_t^h\right)\right) = -P_t^{-1} \beta^t \left(\Psi_{g,t}(C_t - hC_t)^{-\sigma_c}\right) \tag{6.7}$$

(6.3) and (6.4) yields arbitrage condition to the relative movements of domestic and foreign interest rates and changes in nominal exchange rate

$$E_t \left(\lambda_{t+1}\left(1 + R_t^h\right) - \left(1 + R_t^f\right) \frac{\breve{e}_{t+1}}{\breve{e}_t} \Theta_{t+1}\right) \tag{6.8}$$

Domestic Producer Optimization Problem

Domestic Producers choose the prices of the goods they sell to maximize profit. To solve the optimization problem of the household, the Lagrangian Function is needed to be constructed.

$$\begin{aligned} \mathcal{L}_t = \sum_{t=0}^{\infty} \text{ʒ}_{H,t} E_t \Bigg\{ & Q_t Y_{H,t} \left[P_{H,t}^{new} \left(\frac{P_{H,t}}{P_{H,t}}\right)^{\delta_H} - P_{H,t} MC_{H,t} \right] \\ & - \lambda_t \left(C_{H,t} - \left(\frac{P_{H,t}^{new}}{P_{H,t}} \left(\frac{P_{H,t}}{P_{H,t-1}}\right)^{\delta_H} \right)^{\vartheta} \left(C_{H,t} - C_{H,t}^{*}\right) \right) \Bigg\} \end{aligned} \tag{6.9}$$

Taking derivative of Lagrangian function with respect to optimal price, demand and Lagrangian multiplier;

FOC:

$$\begin{aligned} \frac{\partial \mathcal{L}_t}{\partial P_{H,t}^{new}} = \sum_{t=0}^{\infty} \text{ʒ}_{H,t} E_t \Bigg\{ & Q_t Y_{H,t} \left(\frac{P_{H,t}}{P_{H,t-1}}\right)^{\delta_H} \\ & - \lambda_t \vartheta \left(\frac{1}{P_{H,t}} \left(\frac{P_{H,t}}{P_{H,t-1}}\right)^{\delta_H} \right)^{-\vartheta} {P_{H,t}^{new}}^{-1-\vartheta} \left(C_{H,t} - C_{H,t}^{*}\right) \Bigg\} = 0 \end{aligned} \tag{6.10}$$

$$\frac{\partial \mathcal{L}_t}{\partial C_{H,t}} = \sum_{t=0}^{\infty} \mathfrak{z}_{H,t} E_t \left\{ Q_t \left[P_{H,t}^{new} \left(\frac{P_{H,t}}{P_{H,t-1}} \right)^{\delta_H} - P_{H,t} MC_{H,t} \right] - \lambda_t \right\} = 0 \tag{6.11}$$

$$\frac{\partial \mathcal{L}_t}{\partial \lambda_t} = \left(\frac{P_{H,t}^{new}}{P_{H,t}} \left(\frac{P_{H,t}}{P_{H,t-1}} \right)^{\delta_H} \right)^{-\vartheta} \left(C_{H,t} - C_{H,t}^{*} \right) - Y_{H,t} = 0 \tag{6.12}$$

(6.11) and (6.12) yields

$$P_{H,t}^{new} = \frac{\vartheta}{\vartheta - 1} \frac{\sum_{t=0}^{\infty} \mathfrak{z}_{H,t} E_t \left\{ Q_t Y_{H,t} P_{H,t} MC_{H,t} \right\}}{\sum_{t=0}^{\infty} \mathfrak{z}_{H,t} E_t \left\{ Q_t Y_{H,t} \left(\frac{P_{H,t}}{P_{H,t-1}} \right)^{\delta_H} \right\}} \tag{6.13}$$

Dynare 4.5.7 and Matlab Codes SOE

```
var
c y r q s pie pih pif lop a ys pis rs er
cepsg cepsa cepsc cepsp cepsm ceptot
dy pinfobs robs sobs ysobs erobs pinsobs rsobss ;


varexo
epsa                    // technology shock
epsm                    // monetary policy shock
epsg                    // preference shock
epsp                    // risk premium shock
epsc                    // cost push shock
epys                    // foreign output shock
epps                    // foreign inflation shock
eprs                    // foreign interest rate shock
eptot;                  // terms of trade shock


parameters
alf bet delh delf teth tetf eta psi sig h chi
psir psip psiy psid psie
rhoa rhog rhop rhoc rhom roys rops rors rhotot
sgps sgys sgrs siga sigr sigg sigp sigc sigtot
trend conspie consr constrade consys conspies consrs consexc unpa;


bet         = 0.98;     // discount factor
alf         = 0.60;     // share of foreign goods in domestic consumption
                        bundl
chi         = 0.01;     // real net foreign asset position parameter
sig         = 2;        // inverse elasticities of intertemporal
                        // substitution
```

```
psi         = 0.5;     // marginal cost domestic output parameter

teth        = 0.75;    // Calvo domestic prices

tetf        = 0.75;    // Calvo foreign prices

eta         = 1.5;     // elasticity of substitution between domestic and
                       // foreign goods
h           = 0.70;    // habit

delh        = 0.60;    // indexation to past domestic inflation

delf        = 0.60;    // indexation to past foreign inflation

unpa        = 0.5;     // uncovered interest rate parity parameter

// central bank parameters

Psir        = 0.80;

Psip        = 1.50;

Psiy        = 0.50;

Psid        = 0.50;

psie        = 0.50;

// measurement equations

trend       = 0.9166;

consr       = 3.6821;

conspie     = 2.2217;

constrade   = 0;

consys      = 0.4889;

conspies    = 0.4765;

consrs      = 0.3514;

consexc     = 0.3351;
```

```
// persistence parameters of shocks

rhoa           = 0.80;

rhog           = 0.80;

rhop           = 0.80;

rhoc           = 0.80;

rhom           = 0.80;

roys           = 0.80;

rops           = 0.80;

rors           = 0.80;

rhotot         = 0.80;

// Std. Dev. of shocks

sgps           = 0.50;

sgys           = 0.50;

sgrs           = 0.50;

siga           = 0.50;

sigr           = 0.50;

sigg           = 0.50;

sigp           = 0.50;

sigc           = 0.50;

sigtot         = 0.50;
```

```
model(linear);

// Euler equation
c - h*c(-1) = (c(+1)-h*c) - ((1-h)/sig)*(r - pie(+1))+((1-h)/sig) * (cepsg
+ cepsg(+1));

// Goods market clearing
(1-alf)*c = y - alf*eta*(2-alf)*s - alf*eta*lop - alf*ys;

// Terms of trade
s - s(-1) = pif - pih + ceptot;

// Real exchange rate
q = lop + (1-alf)*s;

// Firms' optimal prices
pih - delh*pih(-1) = (1-teth)/teth*(1-bet*teth)*( psi*y - (1+psi)*cepsa +
alf*s + (1-h)*(c-h*c(-1))/sig) + bet*(pih(+1)-delh*pih);

// Retailers' optimal prices
pif - delf*pif(-1) = ((1-tetf)/tetf)*(1-bet*tetf)*lop + bet*(pif(+1)-
delf*pif) + cepsc;

// CPI identity
pie = pih + alf*(s-s(-1));

// Uncovered interest rate parity
//(r - pie(+1)) - (rs - pis(+1)) = (q(+1)-q) - chi*a - cepsp;
(r - pie(+1)) - (rs - pis(+1)) = ((1-unpa)*q(+1))- unpa*q - chi*a - cepsp;
```

```
// Flow budget constraint
c + a = (a(-1)/bet) - alf*(s+lop) + y;

// Taylor rule
r = psir*r(-1) + psip*pie + psiy*y + psid*(y-y(-1))+ psie*(er-er(-1)) +
cepsm;

// Nominal exchange rate (identity!)
//lop-lop(-1)=er-er(-1) + pis - pie - (1-alf)*(s - s(-1));
q = er+ pis - pie;

// AR(1) for ys
ys = roys*ys(-1) + sgys*epys;

// AR(1) for pis
pis = rops*pis(-1) + sgps*epps;

// AR(1) for rs
rs = rors*rs(-1) + sgrs*eprs;

cepsg = rhog*cepsg(-1) + sigg*epsg;
cepsa = rhoa*cepsa(-1) + siga*epsa;
cepsc = rhoc*cepsc(-1) + sigc*epsc;
cepsp = rhop*cepsp(-1) + sigp*epsp;
cepsm = rhom*cepsm(-1) + sigr*epsm;
ceptot = rhotot*ceptot(-1) + sigtot * eptot;
```

```
// Measurement Equations
dy = y - y(-1) + trend;
pinfobs = pie + conspie;
robs = r + consr;
sobs=s-s(-1)+constrade;
erobs1=q-q(-1)+consexc;
ysobs = ys - ys(-1) + consys;
rsobss = rs + consrs;
pinsobs= pis + conspies;
end;

steady_state_model;
dy=trend;
pinfobs=conspie;
robs=consr;
sobs=constrade;
ysobs=consys;
rsobss = consrs;
pinsobs= conspies;
erobs1=consexc;
end;

shocks;
var epsa;                     stderr 1;
var epsm;                     stderr 1;
var epsg;                     stderr 1;
var epsp;                     stderr 1;
var epsc;                     stderr 1;
var epys;                     stderr 1;
var epps;                     stderr 1;
var eprs;                     stderr 1;
```

```
var eptot;                    stderr 1;


estimated_params;
alf,          BETA_PDF,          0.60,          0.10;
sig,          GAMMA_PDF,         2,             0.40;
psi,          GAMMA_PDF,         0.50,          0.10;
teth,         BETA_PDF,          0.75,          0.10;
tetf,         BETA_PDF,          0.75,          0.10;
eta,          INV_GAMMA_PDF,     1.50,          inf;
h,            BETA_PDF,          0.70,          0.10;
delh,         BETA_PDF,          0.60,          0.10;
delf,         BETA_PDF,          0.60,          0.10;
unpa,         UNIFORM_PDF,       0.50,          0.25;

psir,         BETA_PDF,          0.80,          0.25;
psip,         GAMMA_PDF,         1.50,          0.25;
psiy,         GAMMA_PDF,         0.50,          0.25;
psid,         GAMMA_PDF,         0.50,          0.25;
psie,         GAMMA_PDF,         0.50,          0.25;

rhoa,         BETA_PDF,          0.80,          0.10;
rhog,         BETA_PDF,          0.80,          0.10;
rhop,         BETA_PDF,          0.80,          0.10;
rhoc,         BETA_PDF,          0.80,          0.10;
rhom,         BETA_PDF,          0.80,          0.10;
rhotot,       BETA_PDF,          0.80,          0.10;

sgps,         INV_GAMMA_PDF,     0.50,          inf;
sgys,         INV_GAMMA_PDF,     0.50,          inf;
sgrs,         INV_GAMMA_PDF,     0.50,          inf;
```

```
siga,               INV_GAMMA_PDF,     0.50,               inf;
sigr,               INV_GAMMA_PDF,     0.50,               inf;
sigg,               INV_GAMMA_PDF,     0.50,               inf;
sigp,               INV_GAMMA_PDF,     0.50,               inf;
sigc,               INV_GAMMA_PDF,     0.50,               inf;
sigtot,             INV_GAMMA_PDF,     0.50,               inf;
end;

varobs
dy pinfobs robs erobs1 ysobs sobs pinsobs rsobss;

options_.plot_priors=0;
model_diagnostics;                  // identification
identification (advanced=1);        // identification

estimation(datafile=Turkey_JP_0903,mode_compute=0,first_obs=1,presample=4,p
refilter=0,mh_replic=500000,mh_nblocks=2,mh_jscale=0.12,mh_drop=0.2,mode_fi
le=JP10_benchmark_8obs26_mode);

stoch_simul(irf=40,ar=10) c y r s pie er;

// produce historical decomposition
shock_decomposition (parameter_set=posterior_mean) dy pinfobs robs erobs ;
```

Chapter 4

The Efficacy of New Keynesian Approaches in a Middle Open Economy Modelling

Abstract

Macroeconomic models shaped by New Keynesian approaches play an important role in determining optimal monetary and interest rate policies. Strictly following Adolfson et al. (2007) we modeled the Turkish Economy for the period between 2003 and 2020. In the model consumption and investment goods are domestically produced and imported, as well as price and wage rigidities, habit formation, capital adjustment costs, and employment included. The model comprises the import of consumption and investment goods. Although the estimation generated high volatilities compared to real data, the model successfully handled comprehensive and various macroeconomic data. On the other hand, model enabled to decompose various types of shocks that driving the fluctuations of the comprehensive data set.

Keywords; New-Keynesian economics, open economy DSGE models, price and wage rigidities, capital adjustment costs, Bayesian Approach

1. Introduction

In chapter 3 we assessed the Turkish Economy using a small open economy DSGE modeling omitting capital and employment. Results show us that the small open economy DSGE model enabled to match only the second moments of the interest rates and inflation successfully. Other variables are overpredicted. In this study, apart from price rigidities and habit formation, we introduced wage rigidities, capital adjustment costs, and additional shocks such as mark-up shocks and different types of technology shocks. In this manner, we elaborated the model fit of a medium open economy DSGE model, whether the second moments are matching by using different specifications of the model.

Estimation results show that the model without price indexation is the best fit to real data. Second best fit model is the model without exchange rate sensitivity model. The results we have obtained here are largely the same as the results we obtained in the previous chapter. Excluding price indexation and exchange rate sensitivity from central bank equation improves the model. Introducing habit formation, modified interest rate parity condition and terms of trade improved the model fit. However, the model failed to match standard deviations with the real data as in the small open economy model.

Output growth is highly affected by monetary policy shocks. This result is incompatible with the result we obtained in the small open economy model. Main driver of the consumption is technology shocks in the middle open economy model. Whereas in the previous model, preference shocks were the most obvious drivers for consumption. Investment is highly affected from permanent technology shocks and investment specific technology shocks. The model predicts several shocks for inflation. Main drivers of interest rates are risk premium shocks and investment specific technology shocks.

This remainder of Chapter 4 is constructed as follows. In section 2 we described the structure of the model. Section 3 presents the log-linearized model and Section 4 outlines estimation results and the variance and historical decompositions of the macroeconomic variables discussed in section 5. Finally, section 6 concludes this chapter.

2. Structure of the Model

We followed Adolfson et al. (2007), Christiano et al. (2005) and Altig et al. (2003) to construct the medium open economy DSGE model. Different from these studies we omitted fiscal policy and included modified uncovered interest rate parity and terms of trade. Households are attained utility from consuming consumption goods and holding cash balances. They also invest in physical capital to increase their capital stocks. Household utility function is also subject to preference shocks. Domestic firms are separated into three groups. One of them is the one which hires labor and transform this input to a homogeneous good. Second group of domestic firms buy the homogeneous goods and rents capital and transform these inputs to an intermediate good. Third group is the transformer of the intermediate goods to a final homogenous final goods. Final goods can be investment goods or consumption goods. On the other hand, there are importers in the economy which buy consumption and investment goods from the world and sell them in the domestic economy. There are also exporters in the economy which buy goods from domestic producers and sell them in the foreign economy. Central Bank is the agent to adjust interest rates in response to inflation, exchange rate and output growth. Interest rate smoothing is also allowed to retain persistency in interest rates.

2.1 Households

The economy consists of identical and infinitely lived agents indexed by $q \in (0,1)$, who derive utility from consuming consumption goods and disutility from supplying labor services to firms and holding cash balances. Households lifetime utility is given by:

$$E_t \sum_{s=0}^{\infty} \beta^s \left[\Psi_{g,t} ln\big(C_{t+s}(q) - hC_{t+s-1}(q)\big) - \Psi_{l,t} A_l \left(\frac{1}{1+\sigma_l} L_{t+s}(q)^{1+\sigma_l}\right) + A_q \left(\frac{1}{1-\sigma_q} \frac{\theta_q}{z_t P_t}^{1-\sigma_q}\right)\right] \tag{4.1}$$

where $\beta^s \in (0,1)$ is the intertemporal discount factor, household q consume C_t, works in hourly basis L_t, real assets $\frac{\theta_q}{P_t}$, Labor disutility function A_l and Cash to money ratio A_l . We allow h as habits in consumption. The inverse elasticity of intertemporal substitution is given by $\sigma_c > 0$, and the inverse elasticity of labour supply is given by $\sigma_l > 0$. $\Psi_{g,t}$ and $\Psi_{l,t}$ are the preference shocks and labor supply shocks, respectively. These shocks are assumed to evolve according to the following AR (1) specifications:

$$\Psi_{g,t} = \rho_g \Psi_{g,t-1} + \varepsilon_{g,t} \quad and \quad \varepsilon_{g,t} \sim i.i.d\, N\,(0,\sigma_g) \tag{4.2}$$

$$\Psi_{l,t} = \rho_l \Psi_{l,t-1} + \varepsilon_{l,t} \quad and \quad \varepsilon_{l,t} \sim i.i.d\, N\,(0,\sigma_l) \tag{4.3}$$

CES function for consumption is defined as:

$$C_t = \left[(1-\varrho_c)^{\frac{1}{\tau_c}} C_{H,t}{}^{\frac{\tau_c-1}{\tau_c}} + \varrho_c{}^{\frac{1}{\tau_c}} C_{F,t}{}^{\frac{\tau_c-1}{\tau_c}}\right]^{\frac{\tau_c}{\tau_c-1}} \tag{4.4}$$

where $C_{H,t}$ and $C_{F,t}$ are Dixit-Stiglitz aggregates of domestic and foreign produced consumption goods respectively given by:

$$C_{H,t}(q) = (1-\varrho_c)\left(\frac{P_{H,t}{}^c(q)}{P_{H,t}{}^c}\right)^{-\tau_c} C_{H,t} \; and \; C_{F,t}(q) = \varrho_c \left(\frac{P_{F,t}{}^c(q)}{P_{F,t}{}^c}\right)^{-\tau_c} C_{F,t} \tag{4.5}$$

where $\varrho_c \in [0,1]$ is the share of foreign consumption goods, and $\tau_c > 0$ is the elasticity of substitution between domestic and foreign consumption goods.

CES function for investment is defined as:

$$I_t = \left[(1-\varrho_i)^{\frac{1}{\tau_i}} I_{H,t}{}^{\frac{\tau_i-1}{\tau_i}} + \varrho_i{}^{\frac{1}{\tau_i}} I_{F,t}{}^{\frac{\tau_i-1}{\tau_i}}\right]^{\frac{\tau_i}{\tau_i-1}} \tag{4.6}$$

where $I_{H,t}$ and $I_{F,t}$ are Dixit-Stiglitz aggregates of domestic and foreign produced investment goods respectively given by:

$$I_{H,t}(q) = (1-\varrho_i)\left(\frac{P_{H,t}{}^{i}(q)}{P_{H,t}{}^{i}}\right)^{-\tau_i} I_{H,t} \; and \; I_{F,t}(q) = \varrho_i\left(\frac{P_{F,t}{}^{i}(q)}{P_{F,t}{}^{i}}\right)^{-\tau_i} I_{F,t} \tag{4.7}$$

where $\varrho_i \in [0,1]$ is the share of foreign investment goods, and $\tau_i > 0$ is the elasticity of substitution between domestic and foreign investment goods.

CPI price index is defined by:

$$P_{H,t}{}^{c} = \left[(1-\varrho_c) P_{H,t}{}^{c\,1-\tau_c} + \varrho_c P_{F,t}{}^{c\,1-\tau_c}\right]^{\frac{1}{1-\tau_c}} \tag{4.8}$$

Aggregate investment price index is defined by:

$$P_{H,t}{}^{i} = \left[(1-\varrho_i) P_{H,t}{}^{i\,1-\tau_i} + \varrho_i P_{F,t}{}^{i\,1-\tau_i}\right]^{\frac{1}{1-\tau_i}} \tag{4.9}$$

physical capital stock K of the household q at time t+1 is defined as:

$$K_{q,t+1} = (1-\delta)K_{q,t} + \Psi_{i,t}\left(1 - \acute{S}\left(\frac{I_t}{I_{t-1}}\right)\right) I_t \tag{4.10}$$

where $\acute{S}\left(\frac{I_t}{I_{t-1}}\right)$ [11] is the investment adjustment cost and δ is the depreciation rate of capital. $\Psi_{i,t}$ is the investment specific technology shock which is assumed to evolve according to the following AR (1) specifications:

$$\Psi_{i,t} = \rho_i \Psi_{i,t-1} + \varepsilon_{i,t} \;\; \text{and} \;\; \varepsilon_{i,t} \sim i.i.d\, N\,(0,\sigma_i) \tag{4.11}$$

optimality conditions yields each household to have same budget constraint which can be written as:

[11] For detailed information please visit Adolfson et al. (2007) and Christiano et al. (2005)

$$P_t^c C_t(q) + P_t^i I_t(q) + P_t\big(a(u_t(q)K_t(q) + P_{k'})\big) + M_t(q) + D_t(q)$$
$$+ \check{e}_t B_t(q)$$
$$= \big(1 + R_{t-1}^h\big)D_{t-1}(q) + \big(1 + R_{t-1}^f\big)(\check{e}_t)B_{t-1}(q)(\Theta_t)$$
$$+ \Theta_q(q) + \big(1 + R_{t-1}^h\big)\Big(M_t(q) - \Theta_q(q)\Big) \tag{4.12}$$
$$+ \big(1 + R_{t-1}^h\big)K_t(q) + W_t(q)L_t(q) + Div_t^h(q) + Div_t^f(q)$$
$$+ T_t(q)$$

where P_t^c is consumer price index for consumption goods, P_t^i is aggregate price index for investment goods, D_t is the household's holding of one-period domestic bonds with corresponding interest rate, R_t^h, B_t is the household's holding of one-period foreign bonds with corresponding interest rate R_t^f, M_t is the total nominal domestic assets, Θ_q is the total form of cash and $(M_t - \Theta_q)$ is the domestic interest earnings, $\check{e}_t$ is the nominal exchange rate which is the domestic price of foreign currency. The households earn nominal wages from labour supply, W_t, and they earn Div_t^h and Div_t^h profits from equity holdings of the domestic and imported goods firms, respectively. u_t is the utilization cost and the $P_{k'}$ is the price of capital. T_t, is the lump-sum taxes and transfers. In Chapter 3, we defined Θ_t as the country risk premium which is given by:

$$\Theta_t\big(\Lambda_t, \check{e}_{t,}\Psi_{p,t}\big) = \exp\left(-\Theta_a\Lambda_t - \Phi_e\left(\frac{E_t\check{e}_{t+1}}{\check{e}_t}\frac{\check{e}_t}{\check{e}_{t-1}} - \frac{\pi}{\pi^*}\right) + \Psi_{p,t}\right) \tag{4.13}$$

where $\Lambda_t = \frac{\check{e}_t B_t}{\hat{Y} P_t}$ is the real quantity of outstanding net foreign debt which is proportional to the nominal exchange rate and foreign bond holdings and reversely proportional to the steady-state output and domestic price level. $\Psi_{p,t}$ is the country risk premium shock which is assumed to follow AR (1) process:

$$\Psi_{p,t} = \rho_p\Psi_{p,t-1} + \varepsilon_{p,t} \quad and \quad \varepsilon_{p,t} \sim i.i.d\, N\,(0,\sigma_p) \tag{4.14}$$

2.2 Domestic Firms

As stated before, there are three types of firms. One of them hires labor and transform into a homogeneous input good. The other one, buys homogeneous input good and rents capital. This type of firm produces intermediate good by using input goods and rented capital. Third type of the firm buys intermediate good and produce consumption good and investment good. There is a continuum of monopolistically competitive domestic firms which of each indexed by $i \in (0,1)$. Aggregate production function is given by:

$$Y_t = \left[\int_0^1 Y_t(i)^{\frac{1}{\Psi_{\text{ɣ}^d,t}}} di\right]^{\Psi_{\text{ɣ}^d,t}} \tag{4.15}$$

$\Psi_{\text{ɣ}^d,t}$ is the domestic product mark-up shock which is assumed to follow AR (1) process:

$$\Psi_{\text{ɣ}^d,t} = \rho_{\text{ɣ}^d}\Psi_{\text{ɣ}^d,t-1} + \varepsilon_{\text{ɣ}^d,t} \quad and \quad \varepsilon_{\text{ɣ}^d,t} \sim i.i.d\, N\,(0,\sigma_{\text{ɣ}^d}) \tag{4.16}$$

Production function of the intermediate good producer is given by:

$$Y_t(i) = z_t^{1-\alpha}\Psi_{a,t}K_t^{\alpha}(i)L_t^{1-\alpha}(i) - z_t\emptyset \tag{4.17}$$

where K is capital, L is labor, $\emptyset$ fixed costs and $\Psi_{a,t}$ is the temporary technology shock which is assumed to follow AR(1) process

$$\Psi_{a,t} = \rho_a\Psi_{a,t-1} + \varepsilon_{a,t} \quad and \quad \varepsilon_{a,t} \sim i.i.d\, N\,(0,\sigma_a) \tag{4.18}$$

z_t is the permanent technology process and is given by:

$$\frac{z_t}{z_{t-1}} = \Psi_{gr,t} \tag{4.19}$$

$\Psi_{gr,t}$ is the permanent technology shock which is assumed to follow AR(1) process

$$\Psi_{gr,t} = \rho_{gr}\Psi_{gr,t-1} + \varepsilon_{gr,t} \quad and \quad \varepsilon_{gr,t} \sim i.i.d\, N\,(0,\sigma_{gr}) \tag{4.20}$$

We assumed Calvo-style price setting that in each period only $1 - \zeta_H$ fraction of firms sets prices optimally where $0 < \zeta_H < 1$. ζ_H fraction of firms can adjust their prices according to past inflation rate.

$$P_{H,t}(i) = P_{H,t}(i)\left(\frac{P_{H,t-1}}{P_{H,t-2}}\right)^{\delta_H} \tag{4.21}$$

where $\delta_H \in (0,1)$ is the degree of inflation indexation to past inflation rate. The domestic firm's price-setting problem in period t is to maximize the expected present discounted value of profits, subject to the demand curve:

$$\begin{aligned} E_t \sum_{s=0}^{\infty} \zeta_H Q_{t,t+s} \left(P_{H,t}^{new}(i) \left(\frac{P_{H,t+s-1}}{P_{F,t-1}} \right)^{\delta_H} \right)^{-\frac{\Psi_{\Upsilon^d,t+s}}{\Psi_{\Upsilon^d,t+s}-1}} Y_{H,t+s|t}(i) \\ * \left[\left(P_{H,t}^{new}(i) \left(\frac{P_{H,t+s-1}}{P_{F,t-1}} \right)^{\delta_H} \right) - P_{H,t+s}(i) \Psi_{\Upsilon^d,t} MC_{H,t+s} \right] \end{aligned} \tag{4.22}$$

where $MC_{H,t+s}$ is real marginal cost function, and $Q_{t,t+s}$ is the time dependent stochastic discount factor. ζ_h is the probability that the firm will not adjust its price for the next s periods.

$$MC_{H.t}(i) = \frac{\left(\frac{\partial TC_{H.t}(i)}{\partial L_t(i)}\right) \Big/ \left(\frac{\partial Y_{H.t}(i)}{\partial L_t(i)}\right)}{\Psi_{gr,t} P_{H,t}(i)} \tag{4.23}$$

where, $TC_{H.t}(i)$ is the total cost for each domestic firm.

The firm i's optimization problem implies the first order condition:

$$\begin{aligned} E_t \sum_{s=0}^{\infty} \zeta_H Q_{t,t+s} \left(P_{H,t}^{new}(i) \left(\frac{P_{H,t+s-1}}{P_{F,t-1}} \right)^{\delta_H} \right)^{-\frac{\Psi_{\Upsilon^d,t+s}}{\Psi_{\Upsilon^d,t+s}-1}} Y_{H,t+s|t}(i) \\ * \left[\left(P_{H,t}^{new}(i) \left(\frac{P_{H,t+s-1}}{P_{F,t-1}} \right)^{\delta_H} \right) - P_{H,t+s}(i) \Psi_{\Upsilon^d,t} MC_{H,t+s} \right] \end{aligned} \tag{4.24}$$

if we leave optimal price alone on the left and write the other variables which we get from the first order condition equation, on the right side of the equation, than we get,

$$P_{H,t}^{new} = \left[ʒ_H \left(P_{H,t-1}^{new}(i) \left(\frac{P_{H,t+s-1}}{P_{F,t-1}} \right)^{\delta_H} \right)^{\frac{1}{1-\Psi_{ɣ^d,t}}} + \left((1-ʒ_H) P_{H,t}^{new} \right)^{\frac{1}{1-\Psi_{ɣ^d,t}}} \right]^{1-\Psi_{ɣ^d,t}} \tag{4.25}$$

where $P_{H,t}^{new}$ is the optimal price of domestic firm in period t.

2.3 Importing Firms

There are importers in the economy who import two different product groups and sell them to households in the domestic market. While a group of importers buy homogeneous consumption goods from the world market and sell them in the domestic market, another group of importers buy homogeneous investment goods from the world market and sell them in the domestic market. Both groups of importers buy homogeneous types of goods, transform these products into differentiated product groups and sell them.

Consumption good importers:

$$M_t^c = \left[\int_0^1 M_t^c(j)^{\frac{1}{\Psi_{ɣ^{mc},t}}} dj \right]^{\Psi_{ɣ^{mc},t}} \tag{4.26}$$

where M_t^c is the final import of the composite of differentiated consumption good indexed by $j \in (0,1)$. $\Psi_{ɣ^{mc},t}$ is the imported consumption good mark-up shock which is assumed to follow AR (1) process:

$$\Psi_{ɣ^{mc},t} = \rho_{ɣ^{mc}} \Psi_{ɣ^{mc},t-1} + \varepsilon_{ɣ^{mc},t} \quad and \quad \varepsilon_{ɣ^{mc},t} \sim i.i.d\, N(0, \sigma_{ɣ^{mc}}) \tag{4.27}$$

Demand for the consumption good for the firm j is given by:

$$M_{j,t}^{c} = \left(\frac{P_{j,mc,t}}{P_{mc,t}}\right)^{-\frac{\Psi_{\Upsilon^{mc},t}}{\Psi_{\Upsilon^{mc},t}-1}} M_{t}^{c} \tag{4.28}$$

Investment good importers:

$$M_{t}^{i} = \left[\int_{0}^{1} M_{t}^{i}(j)^{\frac{1}{\Psi_{\Upsilon^{mi},t}}} dj\right]^{\Psi_{\Upsilon^{mi},t}} \tag{4.29}$$

Where M_{t}^{i} is the final import of the composite of differentiated investment good indexed by $j \in (0,1)$. $\Psi_{\Upsilon^{mi},t}$ is the imported investment good mark-up shock which is assumed to follow AR (1) process:

$$\Psi_{\Upsilon^{mi},t} = \rho_{\Upsilon^{mi}}\Psi_{\Upsilon^{mi},t-1} + \varepsilon_{\Upsilon^{mi},t} \quad and \quad \varepsilon_{\Upsilon^{mi},t} \sim i.i.d\, N\,(0,\sigma_{\Upsilon^{mi}}) \tag{4.30}$$

Demand for the investment good for the firm j is given by:

$$M_{j,t}^{i} = \left(\frac{P_{j,mi,t}}{P_{mi,t}}\right)^{-\frac{\Psi_{\Upsilon^{mi},t}}{\Psi_{\Upsilon^{mi},t}-1}} M_{t}^{i} \tag{4.31}$$

We assumed Calvo-style price setting that in each period only $1-\xi_{m,c}$ and $1-\xi_{m,i}$ fraction of importers sets prices optimally where $0 < \xi_{m,c} < 1$ and $0 < \xi_{m,i} < 1$. $\xi_{m,c}$ fraction of consumption good importers and $\xi_{m,i}$ fraction of investment good importers can adjust their prices according to past inflation rate.

$$P_{mc,t}(j) = P_{mc,t}(j)\left(\frac{P_{mc,t-1}}{P_{mc,t-2}}\right)^{\delta_{mc}} \; and \; P_{mc,t}(j) = P_{mi,t}(j)\left(\frac{P_{mi,t-1}}{P_{mi,t-2}}\right)^{\delta_{mi}} \tag{4.32}$$

where $\delta_{mc} \in (0,1)$ is the degree of inflation indexation to past inflation rate for consumption good importers and $\delta_{mi} \in (0,1)$ is the degree of inflation indexation to past inflation rate for investment good importers. The domestic firm's price-setting problem in period t is to maximize the expected present discounted value of profits of consumption good importers and investment good importers, subject to the demand curve:

$$E_t \sum_{s=0}^{\infty} ʒ_{mc} Q_{t,t+s} \left(P_{mc,t}^{new}(j) \left(\frac{P_{mc,t+s-1}}{P_{mc,t-1}} \right)^{\delta_{mc}} \right)^{-\frac{\Psi_{\gamma^{mc},t+s}}{\Psi_{\gamma^{mc},t+s}^{-1}}} M_{t+s}^{c}(j)$$

$$* \left[\left(P_{mc,t}^{new}(i) \left(\frac{P_{mc,t+s-1}}{P_{mc,t-1}} \right)^{\delta_{mc}} \right) - P_{mc,t+s}(i) \Psi_{\gamma^{mc},t+s} \check{e}_{t+s} P_{mc,t+s}^{*} \right] \quad (4.33)$$

$$E_t \sum_{s=0}^{\infty} ʒ_{mi} Q_{t,t+s} \left(P_{mi,t}^{new}(j) \left(\frac{P_{mi,t+s-1}}{P_{mi,t-1}} \right)^{\delta_{mi}} \right)^{-\frac{\Psi_{\gamma^{mi},t+s}}{\Psi_{\gamma^{mi},t+s}^{-1}}} M_{t+s}^{i}(j)$$

$$* \left[\left(P_{mi,t}^{new}(i) \left(\frac{P_{mi,t+s-1}}{P_{mi,t-1}} \right)^{\delta_{mi}} \right) - P_{mi,t+s}(i) \Psi_{\gamma^{mi},t+s} \check{e}_{t+s} P_{mi,t+s}^{*} \right] \quad (4.34)$$

Aggregate price indices for imported consumption good is given by:

$$P_{mc,t}^{new} = \left[ʒ_{mc} \left(P_{mc,t-1}^{new}(j) \left(\frac{P_{mc,t+s-1}}{P_{mc,t-1}} \right)^{\delta_{mc}} \right)^{\frac{1}{1-\Psi_{\gamma^{mc},t}}} + \left((1 - ʒ_{mc}) P_{mc,t}^{new} \right)^{\frac{1}{1-\Psi_{\gamma^{mc},t}}} \right]^{1-\Psi_{\gamma^{mc},t}} \quad (4.35)$$

Aggregate price indices for imported investment good is given by:

$$P_{mi,t}^{new} = \left[ʒ_{mi} \left(P_{mi,t-1}^{new}(j) \left(\frac{P_{mi,t+s-1}}{P_{mi,t-1}} \right)^{\delta_{mi}} \right)^{\frac{1}{1-\Psi_{\gamma^{mi},t}}} + \left((1 - ʒ_{mi}) P_{mi,t}^{new} \right)^{\frac{1}{1-\Psi_{\gamma^{mi},t}}} \right]^{1-\Psi_{\gamma^{mi},t}} \quad (4.36)$$

2.4 Exporting Firms

Exporting firms buy final goods from domestic market and sell them in foreign market. Demand for the investment good for the firm j is given by:

$$\mathcal{X}_{j,t} = \left(\frac{P_{j,x,t}}{P_{x,t}}\right)^{-\frac{\Psi_{Ɣ^x,t}}{\Psi_{Ɣ^x,t}-1}} \mathcal{X}_t \tag{4.37}$$

where $\mathcal{X}_{j,t}$ is the final export of the exported good indexed by $j \in (0,1)$. $\Psi_{Ɣ^x,t}$ is the exported good mark-up shock which is assumed to follow AR (1) process:

$$\Psi_{Ɣ^x,t} = \rho_{Ɣ^x}\Psi_{Ɣ^x,t-1} + \varepsilon_{Ɣ^x,t} \quad and \quad \varepsilon_{Ɣ^x,t} \sim i.i.d\, N\,(0,\sigma_{Ɣ^x}) \tag{4.38}$$

We assumed Calvo-style price setting that in each period only $1 - ʒ_x$ fraction of importers sets prices optimally where $0 < ʒ_x < 1$. $ʒ_x$ fraction of exporters can adjust their prices according to past inflation rate.

$$P_{x,t}(j) = P_{x,t}(j)\left(\frac{P_{x,t-1}}{P_{x,t-2}}\right)^{\delta_x} \tag{4.39}$$

where $\delta_x \in (0,1)$ is the degree of inflation indexation to past inflation rate for exporters. The domestic firm's price-setting problem in period t is to maximize the expected present discounted value of profits of exporters, subject to the demand curve:

$$E_t \sum_{s=0}^{\infty} ʒ_x Q_{t,t+s} \mathcal{X}_{j,t}(j)\left[\left(P_{x,t}^{new}(i)\left(\frac{P_{x,t+s-1}}{P_{x,t-1}}\right)^{\delta_x}\right) - \frac{P_{x,t+s}(i)}{\breve{e}_{t+s}}\left(\mathcal{X}_{j,t}(j) + z_t\right)\right] \tag{4.40}$$

2.5 Wage Setting

Following Christiano et al. (2005) and Adolfson et al. (2007), Households sell its workforce to the domestic firms. Production function of the household is given by:

$$L_t = \left[\int_0^1 L_t(q)^{\frac{1}{\Psi_{w,t}}} dj\right]^{\Psi_{Ɣ^w,t}} \tag{4.41}$$

$\Psi_{Ɣ^w,t}$ is the wage mark-up shock which is assumed to follow AR (1) process:

$$\Psi_{\gamma^{w},t} = \rho_w \Psi_{\gamma^{w},t-1} + \varepsilon_{\gamma^{w},t} \quad \text{and} \quad \varepsilon_{\gamma^{w},t} \sim i.i.d\, N\,(0,\sigma_{\gamma^{w}}) \tag{4.42}$$

Demand for the labor is given by:

$$L_t = \left(\frac{W_{q,t}}{W_t}\right)^{\frac{\Psi_{\gamma^{w},t}}{1-\Psi_{\gamma^{w},t}}} L_t \tag{4.43}$$

We assumed Calvo-style price setting that in each period only $1 - \mathfrak{z}_w$ fraction of household prices optimally where $0 < \mathfrak{z}_w < 1$. $\mathfrak{z}_w$ fraction of household can adjust their prices according to:

$$W_{t+1}(q) = \left(\frac{P_{H,t-1}}{P_{H,t-2}}\right)^{\delta_w} W_t(q)\Psi_{gr,t} \tag{4.44}$$

where $\delta_w \in (0,1)$ is the degree of inflation indexation to past inflation rate. The household wage-setting problem in period t is:

$$E_t \sum_{s=0}^{\infty} \mathfrak{z}_w Q_{t,t+s} Y_{H,t+s|t}(i) \left[-\Psi_{l,t} A_l \left(\frac{1}{1+\sigma_l} L_{t+s}(q)^{1+\sigma_l}\right) + \left(\left(\frac{P_{H,t+s-1}}{P_{F,t-1}}\right)^{\delta_w} \Psi_{gr,t+s} W_t(q)\right) L_{t+s}(q) \right] \tag{4.45}$$

2.6 Relative Prices

In this part, we will assess the Relative prices between imported goods and domestic goods from the perception of the domestic agents by dividing domestic price level.

Domestic agents face with the relative prices of consumption goods and investment goods:

$$\gamma_{c,d,t} \equiv \frac{P_{c,t}}{P_t} \tag{4.46}$$

$$\gamma_{i,d,t} \equiv \frac{P_{i,t}}{P_t} \tag{4.47}$$

Domestic agents use the following relative prices to determine their consumption and investment basket:

$$\gamma_{mc,d,t} \equiv \frac{P_{mc,t}}{P_t} \tag{4.48}$$

$$\gamma_{mi,d,t} \equiv \frac{P_{mi,t}}{P_t} \tag{4.49}$$

Exported products are also subject to relative prices between domestic production and foreign production:

$$\gamma_{x,*,t} \equiv \frac{P_{x,t}}{P_{*,t}} \tag{4.50}$$

2.7 Monetary Policy

We followed Sheen et al. (2014) to construct central bank response function:

$$\begin{aligned} r_t = \rho_r r_{t-1} + \Big((1-\rho_r)\big(\varphi_\pi \pi_{t+1} + \varphi_y y_{t-1} + \varphi_e q_t\big)\Big) + \varphi_{\Delta\pi}(\pi_t - \pi_{t-1}) \\ + \varphi_{\Delta y}(y_t - y_{t-1}) + \Psi_{m,t} \end{aligned} \tag{4.51}$$

$\Psi_{mp,t}$ is the exogeneous monetary policy shock which is assumed to follow AR(1) process

$$\Psi_{m,t} = \rho_m \Psi_{m,t-1} + \varepsilon_{m,t} \quad \text{and} \quad \varepsilon_{m,t} \sim \ i.i.d\ N\,(0,\sigma_m) \tag{4.52}$$

2.8 Foreign Shocks

Foreign shocks are introduced to the model as the same process described in Chapter 3.

3. The Log-linearized Model

While constructing linear equations, we followed the literature studies closely. Adolfson et al (2007), Jaaskela et al. (2011), Shen et al (2014) and Kemp et al (2020) are the main literature studies to helped us during the composition of the linear equations set.

Domestic production is subject to two important shocks in the model. One of them is the permanent technology shock and the other one is the stationary technology shock of which is the main starting point of the middle open economy model. This is a remarkable difference of the middle open economy models from the small open economy models. Output growth deviation from its steady state is a function of capital, labor and steady growth rate which is defined as:

$$\bar{\mathrm{y}}_t = \Psi_{\mathrm{Y}^d,t}\left(\Psi_{a,t} + \alpha\left(\check{\mathrm{k}}_t - gr_t\right)\right) + (1-\alpha)\acute{\mathrm{L}}_t \tag{4.53}$$

Rental rate of capital deviations is related to steady growth rate, wages, capital, and labor given by:

$$rk_t = \Psi_{gr,t} + \hat{\mathrm{w}}_t + \acute{\mathrm{L}}_t - \check{\mathrm{k}}_t \tag{4.54}$$

Domestic marginal costs are given by:

$$mc_t = (\alpha)rk_t + \left((1-\alpha)\hat{\mathrm{w}}_t\right) - \Psi_{a,t} \tag{4.55}$$

Domestic production Philips curve which is subject to Calvo price setting, and price indexation is given by:

$$\begin{aligned}\pi_t = \frac{\beta}{1+\delta_{\mathrm{H}}\beta}\pi_{t+1} + \frac{\delta_{\mathrm{H}}}{1+\delta_{\mathrm{H}}\beta}\pi_{t-1} + \frac{(1-\mathfrak{z}_H)(1-\beta\mathfrak{z}_H)}{\mathfrak{z}_H + \mathfrak{z}_H\delta_{\mathrm{H}}\beta}mc_t \\ - \frac{(1-\mathfrak{z}_H)(1-\beta\mathfrak{z}_H)}{\mathfrak{z}_H + \mathfrak{z}_H\delta_{\mathrm{H}}\beta}\Psi_{\mathrm{Y}^d,t}\end{aligned} \tag{4.56}$$

Marginal cost of imported consumption goods is given by:

$$mc_t^{mc} = -\gamma_{x,*,t} - \gamma_{mc,d,t} \tag{4.57}$$

Imported consumption good Philips curve is adorned by Calvo price setting, and price indexation given by:

$$\pi_t^{mc} = \frac{\beta}{1+\delta_{mc}\beta}\pi_{t+1}^{mc} + \frac{\delta_{mc}}{1+\delta_{mc}\beta}\pi_{t-1}^{mc} + \frac{(1-ʒ_{mc})(1-\beta ʒ_{mc})}{ʒ_{mc}+ʒ_{mc}\delta_{mc}\beta}mc_t^{mc} - \frac{(1-ʒ_{mc})(1-\beta ʒ_{mc})}{ʒ_{mc}+ʒ_{mc}\delta_{mc}\beta}\Psi_{ɣ^{mc},t} \tag{4.58}$$

Marginal cost of imported investment goods is given by:

$$mc_t^{mi} = -\gamma_{x,*,t} - \gamma_{mi,d,t} \tag{4.59}$$

Imported investment good Philips curve is adorned by Calvo price setting, and price indexation given by:

$$\pi_t^{mi} = \frac{\beta}{1+\delta_{mi}\beta}\pi_{t+1}^{mi} + \frac{\delta_{mi}}{1+\delta_{mi}\beta}\pi_{t-1}^{mi} + \frac{(1-ʒ_{mi})(1-\beta ʒ_{mi})}{ʒ_{mi}+ʒ_{mi}\delta_{mi}\beta}mc_t^{mi} - \frac{(1-ʒ_{mi})(1-\beta ʒ_{mi})}{ʒ_{mi}+ʒ_{mi}\delta_{mi}\beta}\Psi_{ɣ^{mi},t} \tag{4.60}$$

Costs of exported goods:

$$mc_t^{x} = mc_{t-1}^{x} + \pi_t - \pi_t^{x} - (\breve{e}_t - \breve{e}_{t-1}) \tag{4.61}$$

Exported good Philips curve is adorned by Calvo price setting, and price indexation given by:

$$\pi_t^{x} = \frac{\beta}{1+\delta_{x}\beta}\pi_{t+1}^{x} + \frac{\delta_{x}}{1+\delta_{x}\beta}\pi_{t-1}^{x} + \frac{(1-ʒ_{x})(1-\beta ʒ_{x})}{ʒ_{x}+ʒ_{x}\delta_{x}\beta}mc_t^{x} - \frac{(1-ʒ_{x})(1-\beta ʒ_{x})}{ʒ_{x}+ʒ_{x}\delta_{x}\beta}\Psi_{ɣ^{x},t} \tag{4.62}$$

Wages equation is subject to wage stickiness in accordance with Calvo price setting. Wages are a function of previous wages, expected future wages, todays inflation, expected future inflation, previous CPI, todays CPI, and labor:

$$\hat{\mathrm{w}}_t = \frac{b_w ʒ_w}{\sigma_l \Psi_{\mathrm{ɣ}^w} - b_w(1+\beta)ʒ_w{}^2}\hat{\mathrm{w}}_{t-1} + (b_w \beta ʒ_w)\hat{\mathrm{w}}_{t+1} - (b_w ʒ_w)\pi_t + (b_w \beta ʒ_w)\pi_{t+1} + (b_w ʒ_w \delta_x)\pi_{t-1}^c - (b_w \beta ʒ_w \delta_x)\pi_t^c + \left(1-\Psi_{\mathrm{ɣ}^w}\right)\psi_t - \left(\sigma_l - \sigma_l \Psi_{\mathrm{ɣ}^w}\right)\acute{\mathrm{L}}_t - \left(1-\Psi_{\mathrm{ɣ}^w}\right)\Psi_{g,t} \tag{4.63}$$

Where b_w is given by:

$$b_w = \frac{\left(\Psi_{\mathrm{ɣ}^w}\sigma_l - \left(1-\Psi_{\mathrm{ɣ}^w}\right)\right)}{(1-\beta ʒ_w)(1-ʒ_w)} \tag{4.64}$$

Consumption of the household is subject to habit formation and preference shocks therefor given by Euler equation:

$$\hat{\mathrm{c}}_t = \frac{\acute{\mathrm{g}}h}{\acute{\mathrm{g}}^2+\beta h^2}\hat{\mathrm{c}}_{t-1} + \frac{\beta\acute{\mathrm{g}}h}{\acute{\mathrm{g}}^2+\beta h^2}\hat{\mathrm{c}}_{t+1} - \frac{\acute{\mathrm{g}}h}{\acute{\mathrm{g}}^2+\beta h^2}\left(\Psi_{gr,t_t} - \beta\Psi_{gr,t+1}\right) - \frac{(\acute{\mathrm{g}}-h\beta)(\acute{\mathrm{g}}-h)}{\acute{\mathrm{g}}^2+\beta h^2}\left(\psi_t - \gamma_{c,d,t}\right) + \frac{\acute{\mathrm{g}}(\acute{\mathrm{g}}-h)}{\acute{\mathrm{g}}^2+\beta h^2}\Psi_{g,t} - \frac{\beta(\acute{\mathrm{g}}-h)}{\acute{\mathrm{g}}^2+\beta h^2}\Psi_{g,t+1} \tag{4.65}$$

Investment of the household is given by:

$$\hat{\mathrm{\imath}}_t = \frac{1}{1+\beta}\hat{\mathrm{\imath}}_{t+1} + \hat{\mathrm{\imath}}_{t-1} + \beta\Psi_{gr,t+1} - \Psi_{gr,t} + \frac{\acute{\mathrm{S}}(1+\beta)}{\acute{\mathrm{g}}^2}P_{k',t} + \frac{\acute{\mathrm{S}}(1+\beta)}{\acute{\mathrm{g}}^2}\Psi_{i,t} - \frac{\acute{\mathrm{S}}(1+\beta)}{\acute{\mathrm{g}}^2} * \gamma_{i,d,t} \tag{4.66}$$

Price of installed capital:

$$P_{k',t} = \frac{\beta(1-\delta)}{\acute{\mathrm{g}}}P_{k',t+1} + \psi_{t+1} - \psi_t - \Psi_{gr,t+1} + \frac{\acute{\mathrm{g}} - \beta(1-\delta)}{\acute{\mathrm{g}}}rk_{t+1} \tag{4.67}$$

Law of motion capital is embeded as described below

$$\underline{\mathrm{k}}_t = \frac{(1-\delta)}{\acute{\mathrm{g}}}\check{\mathrm{k}}_{t-1} - \frac{(1-\delta)}{\acute{\mathrm{g}}}\Psi_{gr,t} + \left(1 - \frac{(1-\delta)}{\acute{\mathrm{g}}}\right)\hat{\mathrm{i}}_t + \left(1 - \frac{(1-\delta)}{\acute{\mathrm{g}}}\right)\Psi_{i,t} \tag{4.68}$$

Capital utilization is given by

$$u_t = \frac{rk_t}{\sigma_A} \tag{4.69}$$

And

$$\check{\mathrm{k}}_t = \underline{\mathrm{k}}_t + u_t \tag{4.70}$$

Optimality conditions of asset holdings

$$\psi_t = \psi_{t+1} - \Psi_{gr,t+1} - \hat{\mathrm{r}}_t - \pi_t \tag{4.71}$$

Uncovered interest rate parity condition as described in chapter 3

$$\hat{\mathrm{r}}_t - \hat{\mathrm{r}}_t^* = (1-\Gamma)E_t q_{t+1} - \Gamma q_t - \Theta_a \hat{\mathrm{a}}_t + \Psi_{p,t} \tag{4.72}$$

Taylor as stated above is given by:

$$r_t = \rho_{\mathrm{r}} r_{t-1} + \left((1-\rho_{\mathrm{r}})\left(\varphi_{\pi}\pi_{t+1} + \varphi_{\mathrm{y}} y_{t-1} + \varphi_{\mathrm{e}} q_t\right)\right) + \varphi_{\Delta\pi}(\pi_t - \pi_{t-1}) + \varphi_{\Delta\mathrm{y}}(y_t - y_{t-1}) + \Psi_{m,t} \tag{4.73}$$

CPI inflation is given by:

$$\pi_t^c = (1-\varrho_c)(\gamma_{dc})^{1-\tau_c}\pi_t + \varrho_c(\gamma_{mcc})^{1-\tau_c}\pi_t^{mc} \tag{4.74}$$

Relative prices for domestic consumption and investment goods given by:

$$\gamma_{c,d,t} = \varrho_c(\gamma_{mcc})^{1-\tau_c}\gamma_{mc,d,t} \tag{4.75}$$

$$\gamma_{i,d,t} = \varrho_i(\gamma_{mii})^{1-\tau_i}\gamma_{mi,d,t} \tag{4.76}$$

Relative prices for imported consumption and investment goods given by:

$$\gamma_{mc,d,t} = \gamma_{mc,d,t-1} + \pi_t^{mc} - \pi_t \tag{4.77}$$

$$\gamma_{mi,d,t} = \gamma_{mi,d,t-1} + \pi_t^{mi} - \pi_t \tag{4.78}$$

Relative prices for exported goods given by:

$$\gamma_{x,*,t} = \gamma_{x,*,t-1} + \pi_t^{x} - \pi_t^{*} \tag{4.79}$$

Relative prices for domestic and foreign goods given by:

$$\gamma_{f,t} = \gamma_{x,*,t} + mc_t^{x} \tag{4.80}$$

Real exchange rate is defined as:

$$q = -\frac{\varrho_c}{(\gamma_{mcc})^{1-\tau_c}}\gamma_{mc,d,t} - \gamma_{x,*,t} - mc_t^{x} \tag{4.81}$$

Goods market clearing conditions is given by:

$$\begin{aligned}\bar{y}_t = \frac{(1-\varrho_c)(\gamma_{cd})^{\tau_c}c}{y}\hat{c}_t + \frac{\tau_c(1-\varrho_c)(\gamma_{cd})^{\tau_c}c}{y}\gamma_{c,d,t} + \frac{(1-\varrho_i)(\gamma_{id})^{\tau_i}i}{y}\hat{\imath}_t \\ + \frac{\tau_i(1-\varrho_i)(\gamma_{id})^{\tau_i}i}{y}\gamma_{i,d,t} + g\Psi_{gov,t} + \frac{y^*}{y}\bar{y}_t^* - \frac{y^*\tau_f\gamma_{x,*}}{y}\Psi_{zt,t} \\ + \frac{rk}{k}\check{k}_t - \frac{rk}{k}\underline{k}_{t-1}\end{aligned} \tag{4.82}$$

where $\Psi_{zt,t}$ is the asymmetric technology shock and $\Psi_{gov,t}$ is the government spending shock which are assumed to follow AR (1) process:

$$\Psi_{zt,t} = \rho_{zt}\Psi_{zt,t-1} + \varepsilon_{zt,t} \quad \text{and} \quad \varepsilon_{zt,t} \sim i.i.d\ N\,(0,\sigma_{zt}) \tag{4.83}$$

$$\Psi_{gov,t} = \rho_{gov}\Psi_{gov,t-1} + \varepsilon_{gov,t} \quad \text{and} \quad \varepsilon_{gov,t} \sim i.i.d\ N\,(0,\sigma_{gov}) \tag{4.84}$$

Foreign bond market clearing is given by:

$$\hat{a}_t = \frac{\pi^*}{\pi\beta}\hat{a}_{t-1} - y^* mc_t^x - y^*\tau_f\gamma_{x,*,t} + y^*\bar{y}_t + y^*\Psi_{zt,t} + \left(c^m + c^i\right)\gamma_{f,t} - \left(c^m(1-\varrho_c)(\gamma_{dc})^{\tau_c - 1}\right)\gamma_{mc,d,t} + c^m\hat{c}_t + \left(c^i(1-\varrho_i)(\gamma_{di})^{\tau_i - 1}\right)\gamma_{mi,d,t} + c^i\hat{\imath}_t \tag{4.85}$$

Employment is defined as follows:

$$\hat{E}_t = \frac{\beta}{1+\beta}\hat{E}_{t+1} + \frac{1}{1+\beta}\hat{E}_{t-1} - \frac{(1-\beta\mathfrak{z}_e)(1-\mathfrak{z}_e)}{(1+\beta)\mathfrak{z}_e}\hat{E}_t + \frac{(1-\beta\mathfrak{z}_e)(1-\mathfrak{z}_e)}{(1+\beta)\mathfrak{z}_e}\acute{L}_t \tag{4.86}$$

Other shocks defined in the model are given by:

$$\Psi_{tot,t} = \rho_{tot}\Psi_{tot,t-1} + \sigma_{tot}\varepsilon_{tot,t} \quad \text{and} \quad \varepsilon_{tot,t} \sim i.i.d\, N\,(0,\sigma_{tot}) \tag{4.87}$$

$$\Psi_{y^*,t} = \rho_{y^*}\Psi_{y^*,t-1} + \sigma_{y^*}\varepsilon_{y^*,t} \quad \text{and} \quad \varepsilon_{y^*,t} \sim i.i.d\, N\,(0,\sigma_{y^*}) \tag{4.88}$$

$$\Psi_{\pi^*,t} = \rho_{\pi^*}\Psi_{\pi^*,t-1} + \sigma_{\pi^*}\varepsilon_{\pi^*,t} \quad \text{and} \quad \varepsilon_{\pi^*,t} \sim i.i.d\, N\,(0,\sigma_{\pi^*}) \tag{4.89}$$

$$\Psi_{r^*,t} = \rho_{r^*}\Psi_{r^*,t-1} + \sigma_{r^*}\varepsilon_{r^*,t} \quad \text{and} \quad \varepsilon_{r^*,t} \sim i.i.d\, N\,(0,\sigma_{r^*}) \tag{4.90}$$

where (4.87) is the terms of trade shock, (4.88) is the foreign output growth shock, (4.89) is the foreign inflation shock, and (4.90) is the foreign interest rate shock.

4. The Empirical Analysis

In the previous part, we constructed a middle open economy model consisting of equilibrium conditions and first-order conditions of the economic agents such as households, domestic producers, importers, exporters, and central bank in a set of log-linearized equations. In the model, we introduced price and wage stickiness in a form of Calvo type price setting in each sector, habit formation, risk premium, modified uncovered interest rate parity condition, real exchange rate, terms of trade and as well as capital which was excluded in the previous small open economy model. Bayesian framework is used to estimate the model following Smets and

Wouters (2007) study which was stated that the Bayesian framework is better than frequentist statistical techniques. We calibrated priors in accordance with the middle open economy literature.

4.1 Data

As main goal of the DSGE models is to focus on explaining business cycle fluctuations around their steady state, we constructed the real data by transforming the real data to fit properties of the model. We used data in first difference of logs which gives the growth rates of the real data. We used the same data series as we explained in the previous chapter: real GDP per capita, consumer price index, short-term interest rates, real effective exchange rate and terms of trade for domestic observable data. In this chapter more real data series as we have totally 17 shocks introduced in the model. Apart from previous data series, we added real private consumption expenditure, gross fixed capital formation as investment, Private Consumption Expenditure Deflator: Implicit Price Deflator as consumption deflator, investment deflator, and employment. By doing so, we reached 13 real data series.

As in the previous chapter, the foreign variables are US real GDP, US short-term nominal interest rate and US consumer price index as a proxy for foreign economy. Our estimation uses quarterly data from the period 2003Q2 to 2020Q1, covering most of Turkey's inflation targeting era, since quarterly data are not available for some observed variables before 2003. All variables (except interest rates) are seasonally adjusted. Real GDP per capita, consumption per capita, investment per capita, consumer price index, consumption deflator, investment deflator, real exchange rate, and terms of trade data are log differenced. All the data except real effective exchange rates and short-term interest rates obtained from Federal

Reserve Bank of St. Louis economic research data[12]. Real effective exchange rates and short-term interest rates data are obtained from TCB databank[13].

The corresponding measurement equations are formed as described in Table 11.

Table 11 : Measurement Equations of MOE

$$\begin{bmatrix} Diff.(LogGDPperCapita_t)*100 \\ Log\left(\frac{GDPDEF_t}{GDPDEF_{t-1}}\right)*100 \\ \left(\frac{Short-Term\ IR}{4}\right)*100 \\ Diff.\left(Log\left(\frac{Exports_t}{Imports_t}\right)\right)*100 \\ Diff.(LogCons.perCapita_t)*100 \\ Diff.(LogInv.perCapita_t)*100 \\ Log\left(\frac{Cons.DEF_t}{Cons.DEF_{t-1}}\right)*100 \\ Log\left(\frac{Inv.DEF_t}{Inv.DEF_{t-1}}\right)*100 \\ Diff.(LogEmp.perCapita_t)*100 \\ Diff.\big(Log(Nom.Exchnage\ Rate)\big)*100 \\ Diff.(LogGDP^{*}perCapita_t)*100 \\ Log\left(\frac{GDP^{*}DEF_t}{GDP^{*}DEF_{t-1}}\right)*100 \\ \left(\frac{Fed\ Fund\ Rate}{4}\right)*100 \end{bmatrix} = \begin{bmatrix} Y_t - Y_{t-1} + trendgrowth \\ Inflation + trendinflation \\ Interest\ Rate + trendeIR \\ a \\ b \\ c \\ Cons.Inf. + trendinflation \\ Inv.Inf. + trendinflation \\ E_t - E_{t-1} + trendgrowth \\ q_t - q_{t-1} + trendexc \\ {Y_t}^{*} - {Y_{t-1}}^{*} + trendUSgrowth^{*} \\ Inflation^{*} + trendinflation^{*} \\ Fed\ Fund\ Rate + trendeIR^{*} \end{bmatrix}$$

Measurement equation of terms of trade is given by:

$$a = \tau_c\pi_t^x - \tau_c\pi_t^* + y_t^* - y_{t-1}^* + \Psi_{zt,t} - \Psi_{zt,t-1} + \frac{c^m}{(c^m+c^i)}\hat{c}_t - \frac{c^m}{(c^m+c^i)}\hat{c}_{t-1} + \frac{c^m}{(c^m+c^i)}\tau_c(1-\varrho_c)\frac{1}{(\gamma_{cd})^{1-\tau_c}}\pi_t - \frac{c^m}{(c^m+c^i)}\tau_c(1-\varrho_c)\frac{1}{(\gamma_{cd})^{1-\tau_c}}\pi_t^{mc} + \frac{c^i}{(c^m+c^i)}\hat{\imath}_t - \frac{c^i}{(c^m+c^i)}\hat{\imath}_{t-1} + \tag{4.91}$$

[12] https://fred.stlouisfed.org

[13] https://evds2.tcmb.gov.tr/index.php?/evds/serieMarket

$$\frac{c^i}{(c^m+c^i)}\tau_i(1-\varrho_i)\frac{1}{(\gamma_{id})^{1-\tau_i}}\pi_t - \frac{c^i}{(c^m+c^i)}\tau_i(1-\varrho_i)\frac{1}{(\gamma_{id})^{1-\tau_i}}\pi_t^{mc} + \Psi_{tot,t} +$$

$$trendtot$$

Measurement equation of consumption is given by:

$$\begin{aligned} b = \hat{c}_t - \hat{c}_{t-1} + \Bigg(&\frac{c^d}{(c^d+c^m)}\tau_c\varrho_c(\gamma_{cmc})^{\tau_c-1} \\ &- \frac{c^m}{(c^d+c^m)}\tau_c\varrho_c(\gamma_{cd})^{\tau_c-1}\Bigg)\pi_t^{mc} \\ &- \Bigg(\frac{c^d}{(c^d+c^m)}\tau_c\varrho_c(\gamma_{cmc})^{\tau_c-1} \\ &- \frac{c^m}{(c^d+c^m)}\tau_c\varrho_c(\gamma_{cd})^{\tau_c-1}\Bigg)\pi_t + trendgrowth \end{aligned} \tag{4.92}$$

Measurement equation of investment is given by:

$$\begin{aligned} c = \hat{\imath}_t - \hat{\imath}_{t-1} + &\left(\frac{i^d}{(i^d+i^m)}\tau_i\varrho_i(\gamma_{imi})^{\tau_i-1} - \frac{i^m}{(i^d+i^m)}\tau_i\varrho_i(\gamma_{id})^{\tau_c-1}\right)\pi_t^{mc} \\ &- \left(\frac{i^d}{(i^d+i^m)}\tau_i\varrho_i(\gamma_{imi})^{\tau_i-1} - \frac{i^m}{(i^d+i^m)}\tau_i\varrho_i(\gamma_{id})^{\tau_i-1}\right)\pi_t \\ &+ trendgrowth \end{aligned} \tag{4.93}$$

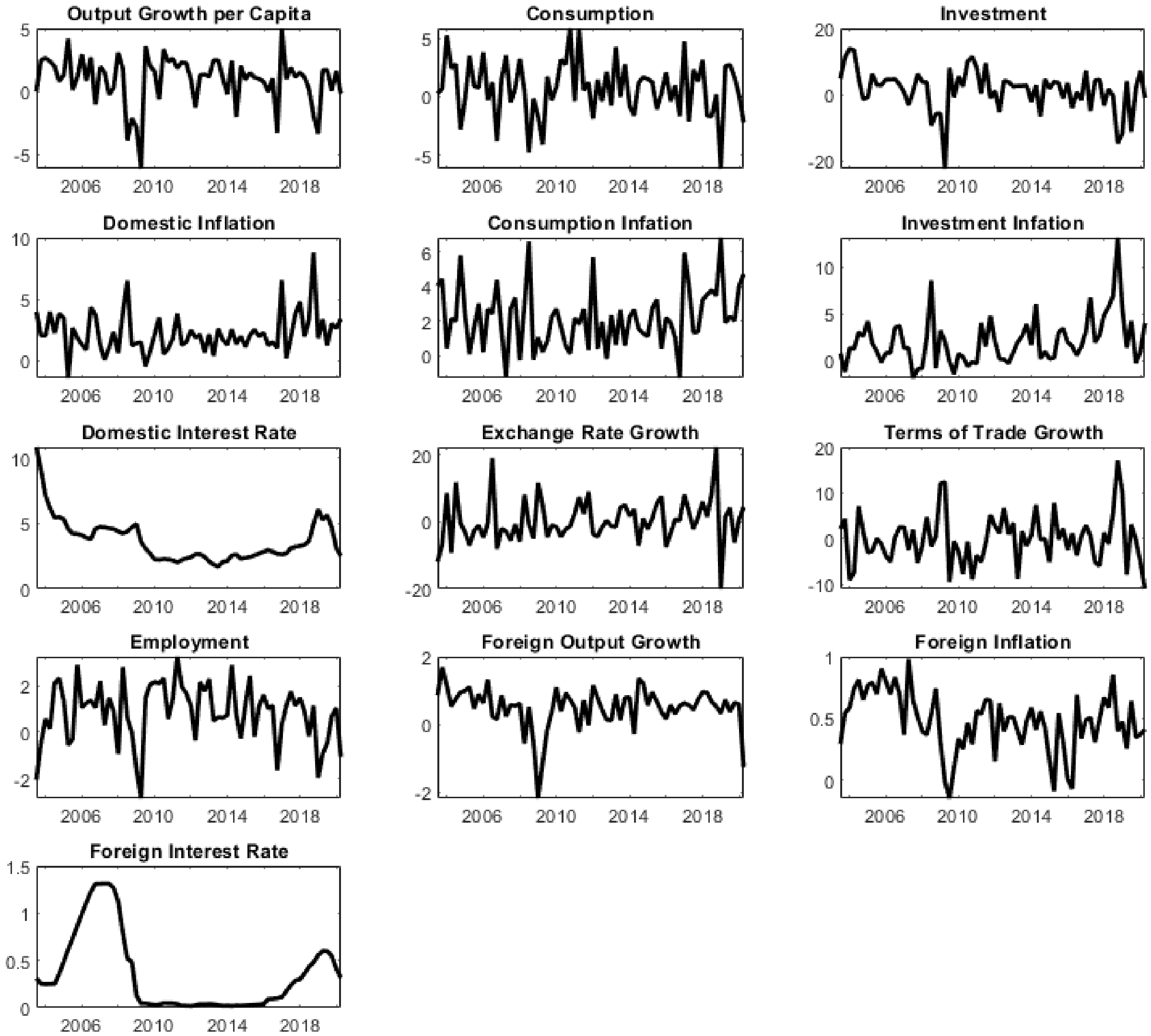

Figure 23 : Real Data Series Middle Open Economy Model

4.2 Priors

Priors are important for the Bayesian estimation technique to give more curvature to the Maximum Likelihood posterior kernel. In order to concentrate on the efficacy of the New Keynesian parameters we calibrated some parameters in accordance with the literature. Following the middle open economy literature we set the calibrations as stated in Table 12.

Table 12 : Calibrated Parameters

β	Discount Factor parameter	0.9975	Authors estimation
$\acute{g}$	Quarterly output growth parameter	1.0085	Authors estimation
$\acute{g}_z$	Money growth parameter	1.02	M1 Money Growth
α	Share of Capital in production parameter	0.23	Sheen et al. (2014)
δ	Depreciation Rate paramater	0.025	Authors estimation
g	Government expenditure to GDP ratio	0.197	Steinbach (2014)
A_l	Labor disutility parameter	7.500	Adolfson et al. (2007)
A_q	Cash to money ratio	0.378	Adolfson et al. (2007)
σ_l	Labor supply inverse elasticity	5	Martinez et al. (2012)
σ_q	Curvature parameter related to money demand	10.62	Adolfson et al. (2007)
ϱ_c	Share of imports in Aggregate Consumption	0.36	Steinbach (2014)
ϱ_i	Share of imports in Aggregate Investment	0.48	Steinbach (2014)
δ_W	Indexation parameter wages	0.50	Adolfson et al. (2007)
$ʒ_e$	Calvo wage setting	0.675	Adolfson et al. (2007)

We set β discount parameter to 0.9975 to get steady state annual interest rate roughly 13.2 % which is given by:

$$R = \frac{\pi \acute{g}}{\beta} \tag{4.94}$$

Steady state inflation in the model is described as the ratio of output growth to money growth given by:

$$\pi = \frac{\acute{g}_z}{\acute{g}} \tag{4.95}$$

We followed Kemp et al (2020) for steady state quarterly inflation rate set π 1.011. To do so, we set $\acute{g}$ steady quarterly growth rate to 1.0085 and we set money growth parameter which is approximate M1 money growth is 2 % in Turkey.

Following Sheen et al. (2016) we set α capital share in production parameter to 0.23. We assumed annual depreciation rate of capital in Turkey is about 10 %, so we set depreciation rate parameter to 0.025. Following Steinbach (2014) we set g government spending to GDP ratio as 0.197. We followed Adolfson et al (2007) to set Labor disutility parameter A_l and Cash to money ratio A_q as 7.5 and 0.378, respectively. Based on the study of Martinez et al. we set inverse elasticity of labor supply σ_l to 5. Curvature parameter related to money demand σ_q to 10.62 following Adolfson et al. (2007). Share of imports in Aggregate Consumption ϱ_c and Share of imports in Aggregate Investment ϱ_i is set to 0.36 and 0.48, respectively. As we do not have wages in our data set, we calibrated indexation parameter of wages to 0.50 and we calibrated Calvo wage setting parameter to 0.675, following Adolfson et al (2007).

Table 13 represents the priors, distributions and posterior estimates of the parameters. We set price indexation parameters to past inflation rates parameters for domestic producers, consumption good importers, investment good importers, and exporters as 0.50 mean and 0.15 standard deviation following Adolfson et al. (2007). Based on the study of Steinbach et al. (2014) we set mean of the Calvo setting parameter for domestic producers as 0.715 and standard deviation 0.05 and for other Calvo setting parameter we set mean as 0.675 and standard deviation as 0.10. We set habit parameter 0.65 and 0.10, as mean and standard deviation, respectively. As same with previous chapter we set modified uncovered interest rate parity parameter for mean 0.50 and standard deviation 0.25. Following Adolfson et al.

(2007) we set investment adjustment parameter 7.694 for mean and 1.50 for standard deviation.

Table 13 : Parameter priors, distributions and posterior estimates

Parameters		Priors			Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
		D	Mean	SD	Mean	90% HPD I.	Mean	90% HPD I.	Mean	90% HPD I.	Mean	90% HPD I.	Mean	90% HPD I.	Mean	90% HPD I.
The degree of inflation indexation to past inflation rate for domestic products	δ_H	B	0.50	0.15	0.166	[0.058,0.268]	0.142	[0.051,0.230]			0.162	[0.056,0.261]	0.165	[0.056,0.267]	0.170	[0.062,0.272]
The degree of inflation indexation for foreign consumption goods	δ_{mc}	B	0.50	0.15	0.173	[0.045,0.297]	0.148	[0.044,0.255]			0.172	[0.047,0.297]	0.157	[0.043,0.270]	0.151	[0.044,0.258]
The degree of inflation indexation for foreign investment goods	δ_{mi}	B	0.50	0.15	0.272	[0.099,0.439]	0.276	[0.094,0.446]			0.274	[0.098,0.442]	0.298	[0.128,0.464]	0.277	[0.109,0.444]
The degree of inflation indexation for exported goods	δ_x	B	0.50	0.15	0.387	[0.173,0.602]	0.448	[0.229,0.670]			0.383	[0.169,0.595]	0.492	[0.282,0.706]	0.404	[0.184,0.608]
Calvo-style price setting for domestic firms	ξ_H	B	0.715	0.05	0.698	[0.626,0.771]	0.680	[0.592,0.795]	0.672	[0.611,0.734]	0.701	[0.631,0.779]	0.819	[0.752,0.883]	0.701	[0.626,0.781]
Calvo-style price setting for consumption good importer	ξ_{mc}	B	0.675	0.10	0.476	[0.339,0.627]	0.544	[0.401,0.729]	0.589	[0.448,0.707]	0.474	[0.342,0.616]	0.537	[0.398,0.704]	0.525	[0.365,0.687]
Calvo-style price setting for investment good importer	ξ_{mi}	B	0.675	0.10	0.451	[0.330,0.575]	0.459	[0.331,0.587]	0.484	[0.376,0.593]	0.457	[0.331,0.578]	0.461	[0.340,0.579]	0.453	[0.334,0.573]
Calvo-style price setting for exporting firms	ξ_x	B	0.675	0.10	0.721	[0.638,0.801]	0.720	[0.632,0.810]	0.753	[0.678,0.829]	0.720	[0.640,0.800]	0.723	[0.660,0.785]	0.738	[0.666,0.813]
Calvo-style price setting for employment	ξ_e	B	0.675	0.10	0.622	[0.549,0.695]	0.593	[0.521,0.671]	0.611	[0.544,0.676]	0.620	[0.548,0.693]	0.784	[0.731,0.837]	0.624	[0.553,0.697]
Habit parameter	h	B	0.65	0.10	0.748	[0.662,0.838]			0.708	[0.625,0.793]	0.745	[0.647,0.843]	0.803	[0.756,0.850]	0.745	[0.656,0.839]
Modified Uncovered Interest Rate Parity parameter	Γ	U	0.50	0.25	0.471	[0.263,0.756]	0.622	[0.387,0.849]	0.715	[0.551,0.933]	0.472	[0.268,0.772]	0.848	[0.759,0.933]		
Investment Adjustment parameter	Ś	N	7.694	1.50	7.429	[5.419,9.426]	5.633	[3.771,7.593]	7.599	[6.025,9.152]	7.399	[5.412,9.311]	7.712	[5.438,9.875]	7.513	[5.635,9.421]
Taylor Rule – Interest Rate persistence	ρ_r	B	0.80	0.05	0.772	[0.722,0.822]	0.687	[0.636,0.738]	0.748	[0.695,0.803]	0.769	[0.718,0.818]	0.839	[0.802,0.877]	0.777	[0.731,0.825]
Taylor Rule – Inflation	φ_π	N	1.70	0.10	1.575	[1.420,1.746]	1.511	[1.348,1.675]	1.653	[1.479,1.813]	1.569	[1.404,1.736]	1.609	[1.440,1.793]	1.581	[1.421,1.730]
Taylor Rule - Output	φ_y	N	0.25	0.05	0.312	[0.242,0.382]	0.358	[0.292,0.426]	0.312	[0.252,0.375]	0.309	[0.237,0.382]	0.282	[0.202,0.363]	0.312	[0.245,0.379]
Taylor Rule - Exchange rate	φ_e	N	0.01	0.05	0.002	[-0.05,0.054]	0.022	[-0,01,0.057]	0.016	[-0.03,0.062]			-0.04	[-0.08,-0.01]	0.012	[-0.03,0.056]
Taylor Rule – Inflation change	$\varphi_{\Delta\pi}$	N	0.30	0.10	-0.08	[-0.12,-0.04]	-0.12	[-0.16,-0.08]	-0.07	[-0.11,-0.04]	-0.08	[-0.12,-0.04]	-0.08	[-0.12,-0.05]	-0.08	[-0.12,-0.05]
Taylor Rule - Output growth	$\varphi_{\Delta y}$	N	0.125	0.05	0.117	[0.076,0.157]	0.129	[0.088,0.167]	0.102	[0.061,0.141]	0.118	[0.079,0.159]	0.103	[0.061,0.146]	0.111	[0.072,0.152]
AR(1) of permanent technological shock	ρ_{gr}	B	0.80	0.10	0.947	[0.903,0.991]	0.848	[0.660,0.988]	0.954	[0.924,0.985]	0.949	[0.914,0.989]	0.748	[0.700,0.796]	0.941	[0.893,0.990]
AR(1) of temporary technology shock	ρ_a	B	0.80	0.10	0.801	[0.703,0.902]	0.702	[0.584,0.818]	0.789	[0.704,0.874]	0.805	[0.710,0.902]	0.860	[0.800,0.920]	0.793	[0.707,0.882]

AR(1) of investment specific technology shock	ρ_i	B	0.80	0.10	0.422	[0.281,0.563]	0.403	[0.269,0.531]	0.431	[0.327,0.537]	0.418	[0.282,0.557]	0.617	[0.481,0.757]	0.437	[0.302,0.573]
AR(1) of asymmetric technology shock	ρ_{zt}	B	0.80	0.10	0.808	[0.716,0.905]	0.819	[0.729,0.915]	0.812	[0.712,0.915]	0.814	[0.721,0.909]	0.898	[0.830,0.970]	0.810	[0.717,0.908]
AR(1) of preference shock	ρ_g	B	0.80	0.10	0.484	[0.236,0.717]	0.823	[0.701,0.957]	0.546	[0.305,0.889]	0.480	[0.238,0.700]	0.517	[0.346,0.684]	0.461	[0.259,0.643]
AR(1) of labor supply shock	ρ_l	B	0.80	0.10	0.805	[0.658,0.960]	0.937	[0.884,0.990]	0.804	[0.641,0.965]	0.798	[0.649,0.959]	0.797	[0.637,0.961]	0.823	[0.667,0.970]
AR(1) risk premium shock	ρ_p	B	0.80	0.10	0.664	[0.366,0.880]	0.446	[0.239,0.694]	0.343	[0.151,0.534]	0.670	[0.369,0.863]	0.400	[0.274,0.528]	0.526	[0.401,0.651]
AR(1) domestic markup shock	ρ_{Υ^d}	B	0.80	0.10	0.375	[0.217,0.526]	0.344	[0.225,0.471]	0.551	[0.405,0.695]	0.367	[0.222,0.507]	0.530	[0.308,0.774]	0.392	[0.240,0.529]
AR(1) consumption good importer markup shock	$\rho_{\Upsilon^{mc}}$	B	0.80	0.10	0.574	[0.386,0.759]	0.574	[0.393,0.758]	0.612	[0.421,0.825]	0.576	[0.392,0.758]	0.634	[0.473,0.807]	0.576	[0.368,0.787]
AR(1) investment good importer markup shock	$\rho_{\Upsilon^{mi}}$	B	0.80	0.10	0.741	[0.591,0.901]	0.718	[0.559,0.894]	0.791	[0.674,0.915]	0.736	[0.569,0.907]	0.766	[0.630,0.912]	0.737	[0.588,0.891]
AR(1) exporter markup shock	ρ_{Υ^x}	B	0.80	0.10	0.838	[0.694,0.979]	0.822	[0.672,0.975]	0.810	[0.671,0.957]	0.823	[0.679,0.973]	0.816	[0.676,0.963]	0.823	[0.683,0.966]
AR(1) of terms of trade shock	ρ_{tot}	B	0.80	0.10	0.487	[0.321,0.650]	0.501	[0.340,0.673]	0.536	[0.384,0.688]	0.495	[0.328,0.657]			0.491	[0.320,0.657]
SD of permanent technological shock	σ_{gr}	I	0.50	Inf.	0.292	[0.122,0.458]	0.254	[0.117,0.402]	0.284	[0.125,0.455]	0.309	[0.122,0.446]	5.860	[4.983,6.691]	0.287	[0.115,0.460]
SD of temporary technology shock	σ_a	I	0.50	Inf.	3.583	[2.330,4.783]	3.396	[2.202,4.537]	3.371	[2.300,4.378]	3.532	[2.340,4.727]	9.475	[5.719,13.24]	3.609	[2.438,4.754]
SD of investment specific technology shock	σ_I	I	0.50	Inf.	31.54	[22.04,40.62]	24.95	[17.59,33.30]	33.31	[25.28,42.22]	31.44	[21.91,40.52]	28.34	[20.03,35.93]	31.38	[22.63,39.81]
SD of asymmetric technology shock	σ_{zt}	I	0.50	Inf.	5.806	[4.917,6.712]	5.768	[4.891,6.646]	5.880	[4.941,6.808]	5.839	[4.916,6.764]	5.897	[5.005,6.782]	5.824	[4.836,6.729]
SD of preference shock	σ_g	I	0.50	Inf.	8.415	[0.122,12.33]	0.633	[0.103,1.722]	5.939	[0.121,10.05]	8.520	[0.131,12.43]	12.64	[9.124,16.08]	8.680	[5.148,13.25]
SD of labor supply shock	σ_l	I	0.50	Inf.	0.490	[0.110,0.901]	10.47	[0.091,28.14]	0.398	[0.119,0.699]	0.479	[0.114,0.858]	0.447	[0.115,0.820]	0.470	[0.113,0.882]
SD risk premium shock	σ_p	I	0.50	Inf.	2.965	[1.147,5.784]	4.683	[2.405,6.780]	5.379	[3.517,7.719]	3.003	[1.207,5.899]	6.790	[5.310,8.279]	6.083	[4.641,7.484]
SD domestic markup shock	σ_{Υ^d}	I	0.50	Inf.	14.70	[7.646,21.73]	13.90	[5.249,22.82]	10.36	[6.362,14.05]	15.24	[7.541,22.78]	41.19	[10.99,.75.71]	15.16	[7.229,23.18]
SD consumption good importer markup shock	$\sigma_{\Upsilon^{mc}}$	I	0.50	Inf.	12.92	[6.727,19.46]	17.97	[1.497,36.59]	18.34	[7.764,27.41]	12.73	[6.982,19.05]	16.31	[7.066,26.98]	16.48	[6.830,28.17]
SD investment good importer markup shock	$\sigma_{\Upsilon^{mi}}$	I	0.50	Inf.	4.031	[2.551,5.492]	4.450	[2.613,6.505]	4.033	[2.668,5.451]	4.136	[2.559,5.669]	4.218	[2.654,5.755]	4.161	[2.620,5.686]
SD exporter markup shock	σ_{Υ^x}	I	0.50	Inf.	1.267	[0.110,3.411]	1.161	[0.108,3.177]	0.479	[0.114,0.896]	1.350	[0.109,3.815]	0.755	[0.104,1.915]	0.831	[0.102,2.264]
SD of monetary shock	σ_m	I	0.50	Inf.	0.556	[0.449,0.661]	0.545	[0.441,0.649]	0.539	[0.438,0.637]	0.560	[0.454,0.664]	0.559	[0.455,0.658]	0.550	[0.449,0.647]
SD of terms of trade shock	σ_{tot}	I	0.50	Inf.	5.429	[4.554,6.255]	5.477	[4.651,6.294]	5.501	[4.622,6.358]	5.453	[4.568,6.340]			5.465	[4.592,6.286]

where Standard Deviations (SD), Distributions (D), Beta Distributions (B), Normal Distributions (N), Inverse-gamma Distributions (I) and Uniform Distributions (U) .

where HPD is the highest posterior density region. 2 MCMC chains of 500,000 draws each used for estimations of posterior distributions. 20 % of draws dropped as an initial burn-in phase.

We strictly followed Smets and Wouters (2003) to set the parameters of monetary policy. We set the Interest rate persistence parameter as mean 0.80 and 0.05 standard deviation. Inflation parameter mean 1.70 and standard deviation 0.10, Output growth parameter mean 0.25 and standard deviation 0.05, exchange rate parameter mean 0.01 and standard deviation 0.05, inflation change difference from the previous inflation parameter mean 0.30 and standard deviation 0.10, and lastly, output growth change difference from previous output growth parameter 0.125 mean and standard deviation 0.05.

We set shocks persistence parameters and standard deviations as same with the previous chapter. Persistence parameters of shock mean 0.80 and standard deviation 0.10. Standard deviations of shocks parameters are set to 0.50 as mean and infinitive as the standard deviation.

For the prior distribution, we set indexation parameters, Calvo price setting parameters, habit parameters, Interest rate persistence parameter and persistence parameters of the shocks with Beta distributions. Modified uncovered interest rate parity parameter is set to Uniform distributions. Other monetary policy parameters are set to Normal distributions. Standard deviations of the shock standard deviations are set to Inverse gamma distributions.

5. Estimation Results

In this section we assessed the identifications, posterior estimates, model comparison, impulse response functions, variance decompositions and historical decompositions.

5.1 Convergence

Figure 20 reflects the convergence diagnostics of benchmark models' which is proposed by Brooks and Gelman (1998). The first graph is for the interval which refers to the 80 % quantile range. m2 and m3 refer to the second and third moments. As it can be seen from the figure convergence is reached approximately after 350.000 iterations.

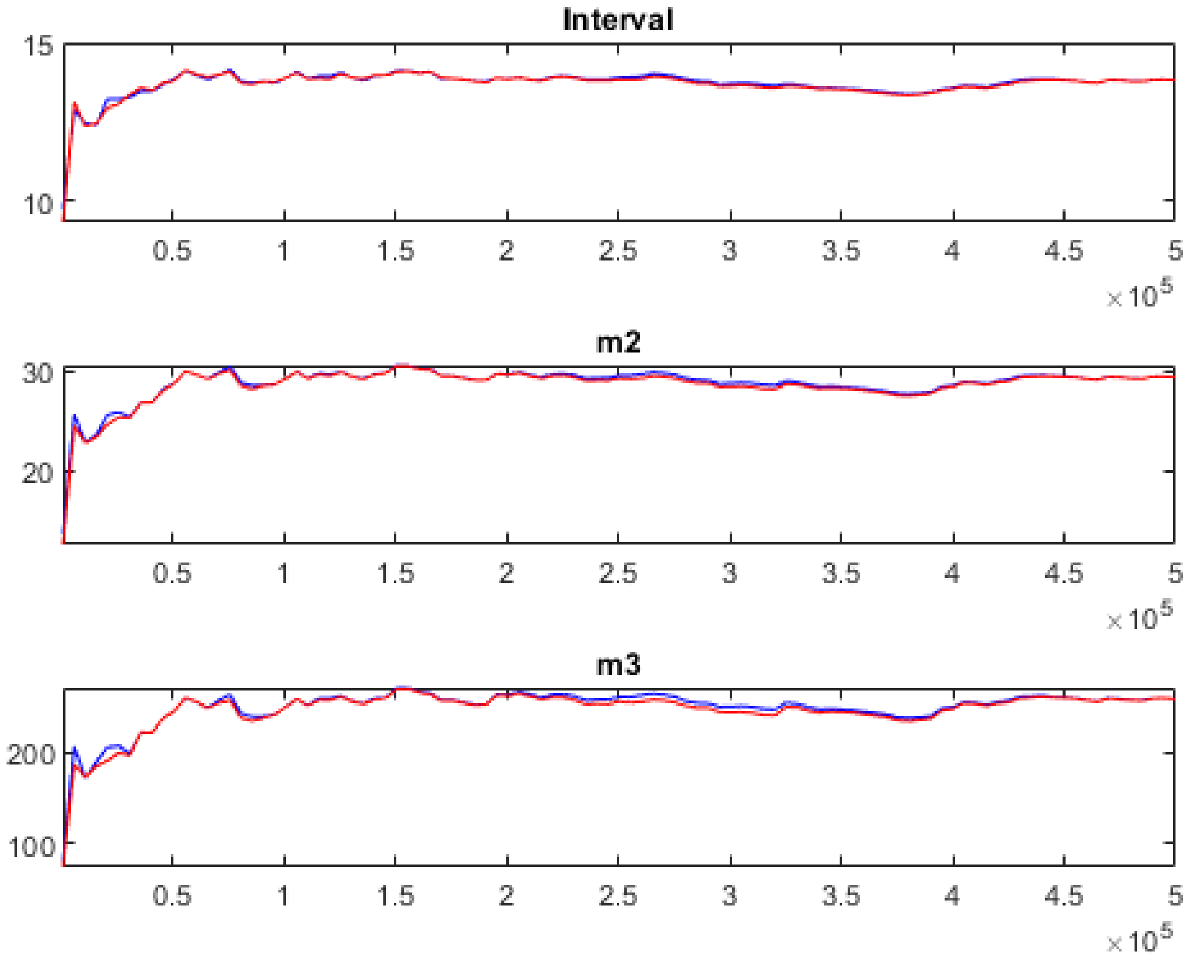

Figure 24 : Convergence Diagnostics

5.2 Identification of parameters

We have already explained a detail identification problem in open economy models. According to the Figure 21 identification of the parameters are shown following Ratto and Iskrev (2011). Blue bars, specially, which represents the identification strength of the parameter based on the Fischer information matrix normalized by parameter at the prior means, are far from zero level. This is a big sign of identification is very good for all the parameters presented in the model.

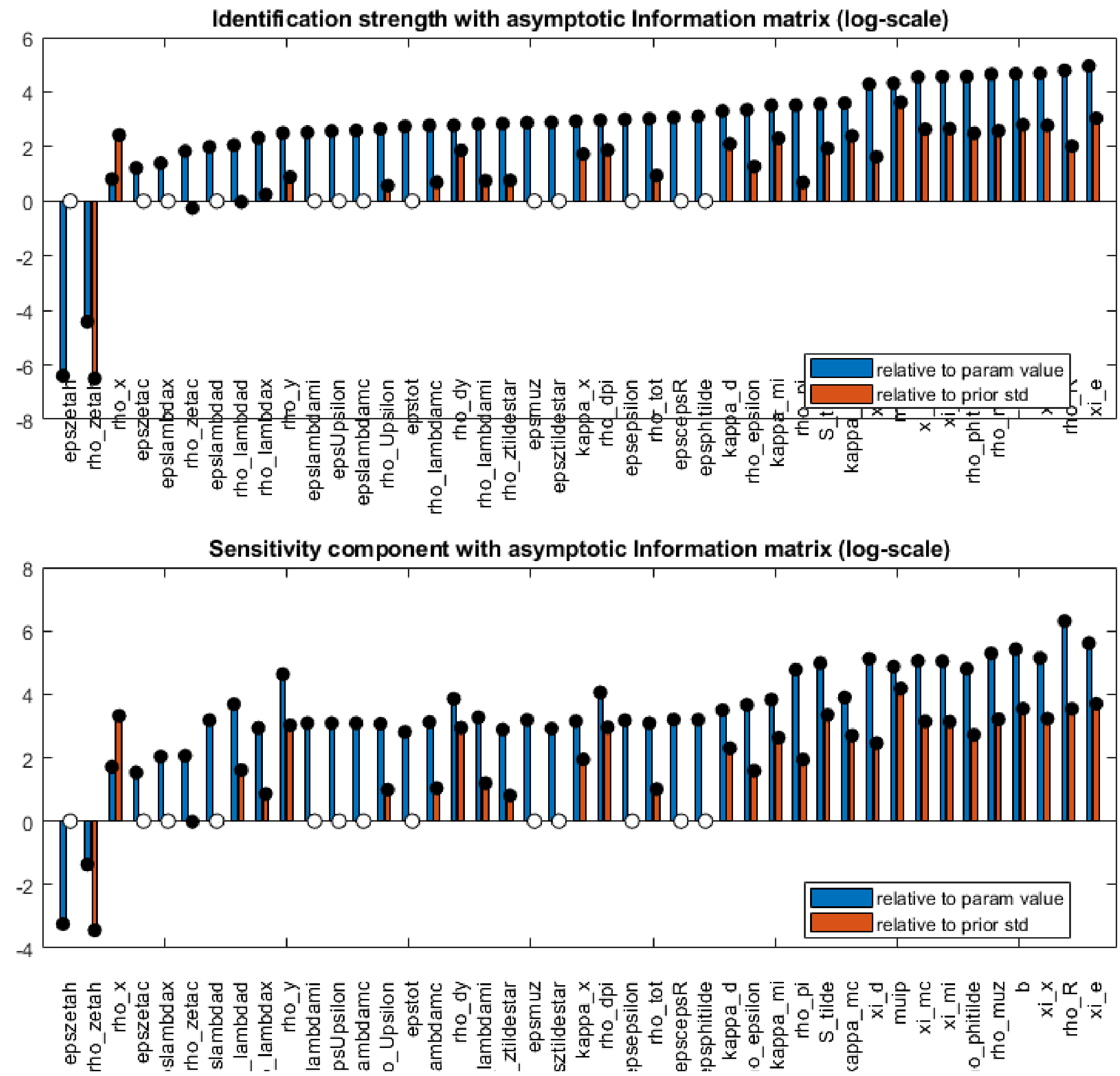

Figure 25 : Identification of Parameters

As stated before, collinearity between parameters is also required to be evaluated which also generally omitted in literature. Table 14 depicts the highest collinearity between the parameters. The persistence parameter of preferences shock and the standard deviation parameter of the preference shock has the highest collinearity patterns. The second collinearity pairs are the persistence parameter of permanent technology shock and the standard deviation parameter of permanent technology shock. The list continues with the collinearity between persistence parameter of terms of trade shock and the standard deviation parameter of terms of trade shock.

Table 14 : Collinearity of parameters

Parameter 1	Parameter 2	Collinearity
ρ_{g}	σ_{g}	0.9985552
ρ_{gr}	σ_{gr}	0.9925588
ρ_{tot}	σ_{tot}	0.9924448
$\rho_{\gamma^{d}}$	$\sigma_{\gamma^{d}}$	0.9839045
ρ_{i}	ρ_{g}	0.9836182
$\rho_{\gamma^{mi}}$	$\sigma_{\gamma^{mi}}$	0.9730460
ρ_{a}	σ_{a}	0.9729822
φ_{e}	ρ_{gr}	0.9625234
ρ_{m}	σ_{m}	0.9597959
$\rho_{\gamma^{mc}}$	$\sigma_{\gamma^{mc}}$	0.9512015
ρ_{p}	σ_{p}	0.9501574

Figure 26 shows the estimated parameters distributions and the prior parameters. Elaborating this figures will also provide an idea of the parameters if the data is informative in terms of the estimated parameters. As it can be seen from the figure, most of the parameters are very informative. Only four of 43 estimated parameters are problematic. Investment adjustment cost parameter, Calvo price setting parameter for domestic producers, persistence parameter of export markup shock, and standard deviation parameter of permanent technology shock are not at the desired level of information given from data.

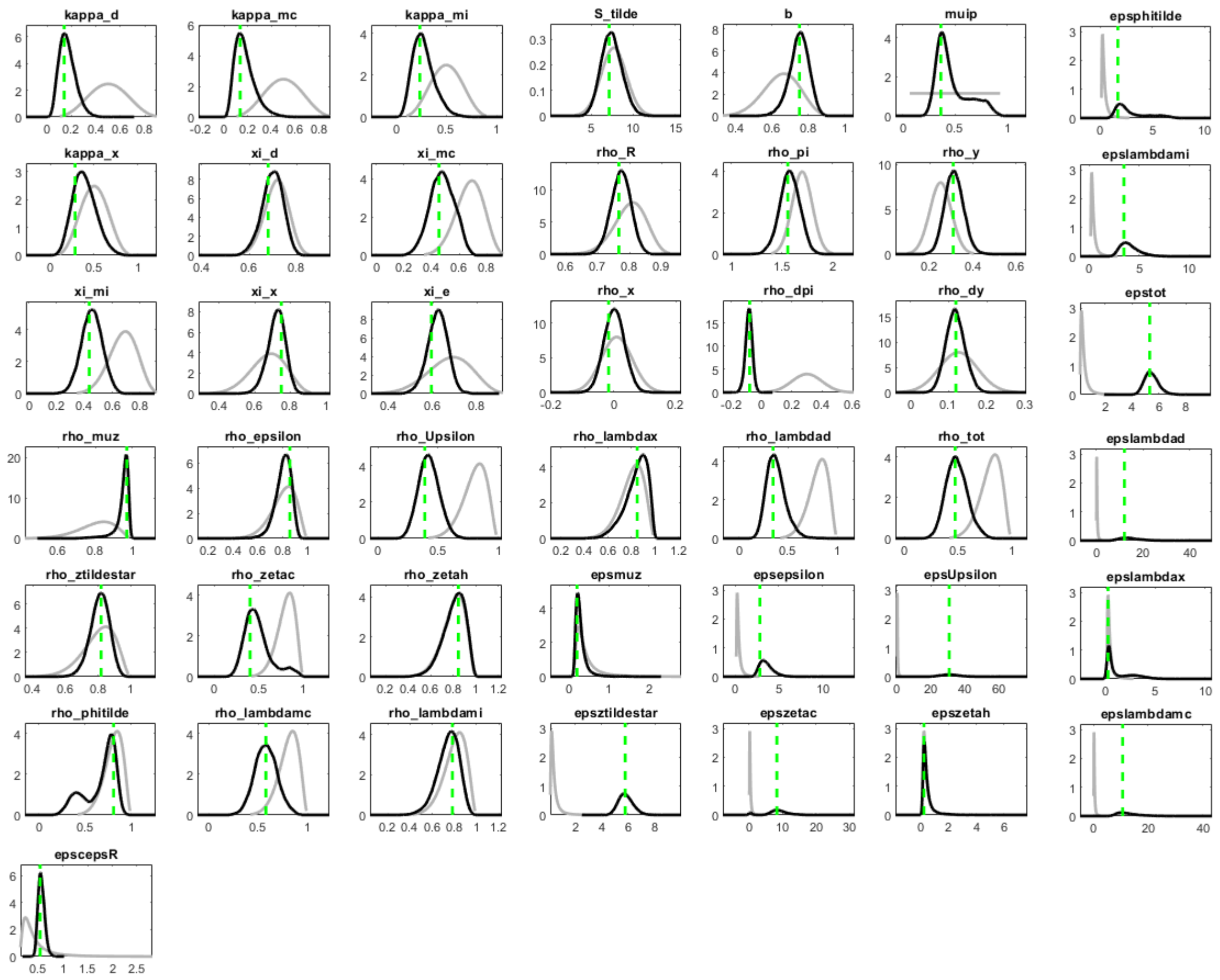

Figure 26 : Estimated Parameters of the Model

5.3 Posterior estimates

Table 13 presents the posterior estimates of the middle open economy benchmark model (Model 1), without habit formation model (Model 2), without price indexation model (Model 3), without exchange rate sensitivity of central bank model (Model 4), without terms of trade shock model (Model 5), and without modified uncovered interest rate parity parameter model (Model 6).

The posterior mean of the price indexation parameter of domestic producer is 0.166 for the benchmark model. Posterior mean of this parameter in small open economy model benchmark model was 0.490. There is an significant difference between two model in terms of domestic producer inflation indexation to past inflation parameter. For the consumption good importers inflation indexation to past inflation parameter posterior mean for the benchmark model is 0.173. Investment good importers index their prices to the previous inflation rate is 0.272 for the middle open economy benchmark model. Compare to the small open economy model, middle open economy estimated lower values of price indexation. These results are compatible with the findings of Adolfson et al (2007) and Kemp and Hollander (2020).

Approximately 30 % of domestic producers can optimize their prices optimally. This implies that the frequency of changing prices for domestic producers is every three four quarters. In the middle economy benchmark model, the Calvo price setting parameter for domestic producers is 0.698, while it is 0.490 in its small open economy counterpart. Calvo setting parameter for consumption good importers and investment good importers are 0.476 and 0.451, respectively. These results are similar for their counterparts in the small open economy model. Calvo price setting parameter for exporters is 0.721, which implies a 28 % of the exporters can optimize their prices. Employment Calvo price setting parameter is 0.622. All these results are compatible with Adolfson et al (2007), Kemp and Hollander (2020) and Sheen and Wang (2014).

Habit parameter posterior mean estimate is 0.748. Small open economy model predicted habit parameter as 0.460. Our finding is very close to the estimation of Adolfson et al. (2007) and Sheen and Wang (2014). The findings of Jaaskela and Nimark (2011) and Kemp and Hollander (2020) are higher than our results in habit parameter value. Modified uncovered interest rate parameter is estimated as 0.472 mean value. If we look at to the posterior mean estimate for the small open economy model, we see approximately the same result. Investment adjustment parameter, which was not included in small open economy model, posterior mean is 7.429. Adolfson et al. (2007) estimated investment adjustment parameter 9.052 posterior value, Jaaskela and Nimark (2011) estimated 5.709, Sheen and Wang (2014) estimated, 6.66 and Kemp and Hollander (2020) estimated 9.493.

We estimated Central Bank persistence parameter for interest rate 0.971 in the small open economy model. In the middle open economy model posterior mean of persistence parameter for interest rate is 0.772. This parameter estimate is lower than Adolfson et al. (2007), Jaaskela and Nimark (2011), Sheen and Wang (2014), and Kemp and Hollander (2020) estimates. Average estimate of these studies is about 0.850. Inflation sensitivity of Turkish Central Bank according to the middle open economy model is 1.575 which is line with Adofson et al. (2007) and Sheen and Wang (2014). Output growth sensitivity posterior mean is 0.312. Exchange rate sensitivity parameter posterior mean is 0.002. Inflation difference sensitivity is negative -0.08. And output growth difference sensitivity is 0.117.

5.4 Model Fit

Table 15 shows the Log-Marginal Likelihood and Bayes Factor estimations. The estimation results from Middle Open Economy model are in line with the results from Small Open Economy Model. In the Middle Open Economy model, the model without Price Indexation to previous inflation (Model 3) is the best fitting model to the real data. Marginal Likelihood is -1640.99 and the probability among all six different model is 100 %. The second best fitting model is the model without exchange rate sensitivity of the central bank (Model 4). Marginal Likelihood of the Model 3 is -1651.90 and Bayes Factor is -10.91. In the Small Open Economy model, these two models were the best fitting models. The results of these two different model are compatible. It should be noted that it is not possible to say there is a far difference between these two models and the benchmark model in terms of fitting to real data. The benchmark model (Model 1) is the third best fitting model and the Marginal Likelihood is -1653.37 and Bayes Factor -12.38. As same with the Small Open Economy model, introducing habit formation, terms of trade shock and modified uncovered interest rate parity parameter improved the model in Middle Open Economy model. The fourth best fitting model is the model excluding the modified uncovered interest rate parity parameter model with -1654.87 Marginal Likelihood and -13.88 Bayes Factor. According to the results, without habit formation model (Model 2) and the model without terms of trade (Model 5) are at the end of the list. Habit formation, modified uncovered interest rate parity and the terms of trade shock improved model fit significantly.

Table 15 : Log-Marginal Likelihood and Bayes Factor estimations

Model	Marginal Likelihood	Bayes Factor	Probability
Model 3	-1640.99	0	1
Model 4	-1651.90	-10.91	0
Model 1	-1653.37	-12.38	0
Model 6	-1654.87	-13.88	0
Model 2	-1682.75	-41.76	0
Model 5	-1683.91	-42.92	0

Log-marginal likelihoods are estimated according to modified harmonic mean estimations proposed by Geweke (1999).

Table 16 shows the standard deviations of each model, their cross-correlations with the output, and their first order autocorrelations. The results obtained differ slightly from the small open economy model. We cannot say that the model performs well in capturing standard deviations. When we evaluate the results in general, the standard deviations resulting from the simulations we obtain with the models are well above the standard deviation values of the real data. When we look at the studies conducted with the other medium open economy models, the standard deviation values were not found to be this high. For example, Adolfson et al. (2007), the standard deviation values are very close to the real values. In this context, the model we developed did not do better than the small open economy model in terms of catching standard deviations. We matched the closest standard deviation in terms of output in the model without habit formation. Here the model produced 3 times the standard deviation. When we evaluate the standard deviation of consumption, the simulated values are much higher than the real values. The results are the same for investment. There is a similar situation in inflation values. When we evaluate the interest rate, we see that the simulated values are produced closer to the truth than the others. Exchange rate and employment standard deviations are also significantly higher than the real values. We see that the high volatility values experienced in the past period caused some problems in the model. Especially the volatility in exchange rates causes many macroeconomic variables to be negatively affected. However, the model needs to be improved in this aspect.

When we evaluate the model in terms of cross correlation with output, we see that the model gives successful results. The cross-correlation of output with consumption and investment values is 0.64 and 0.74, respectively. The model here produces very close results with 0.58 and 0.56. The results are very close to inflation and interest rates. On the other hand, very satisfactory results have emerged in terms of the direction of the signs. Only, the direction in the exchange rate did not be predicted correctly. While the actual value was 0.09, the simulation produced a value of -0.09.

Unfortunately, the results obtained at the point of matching model first order autocorrelations are far from true values. Due to the low actual values, the model falls short here. For example, first-order autocorrelations of consumption, consumer goods inflation, and exchange rate are negative. CPI inflation is about zero. Of course, these real values are difficult to simulate for any model. First-order auto correlation of output and investment is quite low. The interest rate has a first-degree autocorrelation of 0.80. We see that the Habit formation neglected model has reached the closest result. As a result, although our model does not yield the expected results at the point of matching standard deviations and first-order autocorrelations, which are related to the extreme volatility of real streams, it is quite successful at capturing cross-correlations with output. When we evaluate it with the small open economy model, we cannot say that both models are successful in matching second moments.

Table 16 : Standard deviations, cross-correlations and autocorrelations

	O	C	I	π	π_c	π_i	I.R.	Ex	ToT	Emp.
Standard Deviation										
Real Data	1.95	2.39	6.30	1.63	1.75	2.55	1.67	6.70	5.43	1.28
Model 1	8.94	35.3	53.6	4.89	7.39	5.60	4.21	25.1	12.23	9.13
Model 2	6.17	21.2	34.8	4.00	7.08	4.61	2.99	20.7	12.50	6.69
Model 3	7.72	35.0	53.2	3.62	6.41	4.20	3.16	26.8	11.75	9.96
Model 4	8.93	36.2	54.9	4.90	7.40	5.65	4.24	25.8	12.48	9.23
Model 5	15.2	94.3	154	10.1	11.3	10.0	10.2	56.6	18.17	22.3
Model 6	9.08	35.8	54.5	4.90	7.59	5.39	4.29	24.7	12.08	9.06
Cross-correlation with output										
Real Data	1.00	0.64	0.74	-0.16	-0.11	-0.23	-0.10	0.09	-0.39	0.44
Model 1	1.00	0.58	0.56	-0.29	-0.16	-0.25	-0.49	-0.09	0.05	0.27
Model 2	1.00	0.50	0.48	-0.19	-0.10	-0.24	-0.35	-0.16	-0.04	0.34
Model 3	1.00	0.53	0.53	-0.23	-0.11	-0.21	-0.36	-0.16	0.03	0.30
Model 4	1.00	0.56	0.54	-0.28	-0.15	-0.24	-0.47	-0.08	0.05	0.28
Model 5	1.00	0.50	0.39	-0.45	-0.29	-0.35	-0.53	-0.17	0.33	-0.22
Model 6	1.00	0.64	0.62	-0.33	-0.18	-0.31	-0.53	-0.20	0.04	0.25
Autocorrelations (order=1)										
Real Data	0.09	-0.08	0.23	0	-0.03	0.38	0.80	-0.16	0.15	0.23
Model 1	0.94	0.99	0.99	0.75	0.55	0.80	0.98	0.92	0.52	0.97
Model 2	0.89	0.97	0.97	0.62	0.46	0.74	0.96	0.88	0.44	0.96
Model 3	0.94	0.99	0.99	0.63	0.46	0.71	0.97	0.94	0.49	0.98
Model 4	0.94	0.99	0.99	0.75	0.56	0.80	0.98	0.92	0.53	0.97
Model 5	0.97	0.99	0.99	0.93	0.80	0.93	0.99	0.98	0.75	0.99
Model 6	0.95	0.99	0.99	0.74	0.53	0.80	0.98	0.92	0.51	0.97

This table is prepared for to compare Standard deviations, cross-correlations and autocorrelations of real data with six estimated models.

O: Output growth, C: Consumption, I: Investment, π: Inflation, π_c: imported consumption good inflation, π_i:imported investment good inflation, I.R.: Interest Rates, Ex: Real Exchange Rate, ToT: Terms of Trade, Emp.: Employment

Figure 27 and Figure 28 depicts the autocorrelations of the macroeconomic variables' up to order 10. According to these figures models are not good at to match autocorrelations of the variables. Only at the point of interest rates, the Middle Open Economy model was able to estimate closer results. Similarly, in the small open economy model, it was able to estimate successful results in terms of interest rates, only. One of the main reasons for this is that the time series of variables for the Turkish economy is not consistent and stable. It seems unlikely that both the small open economy model and the medium economy model can catch up with these inconsistencies.

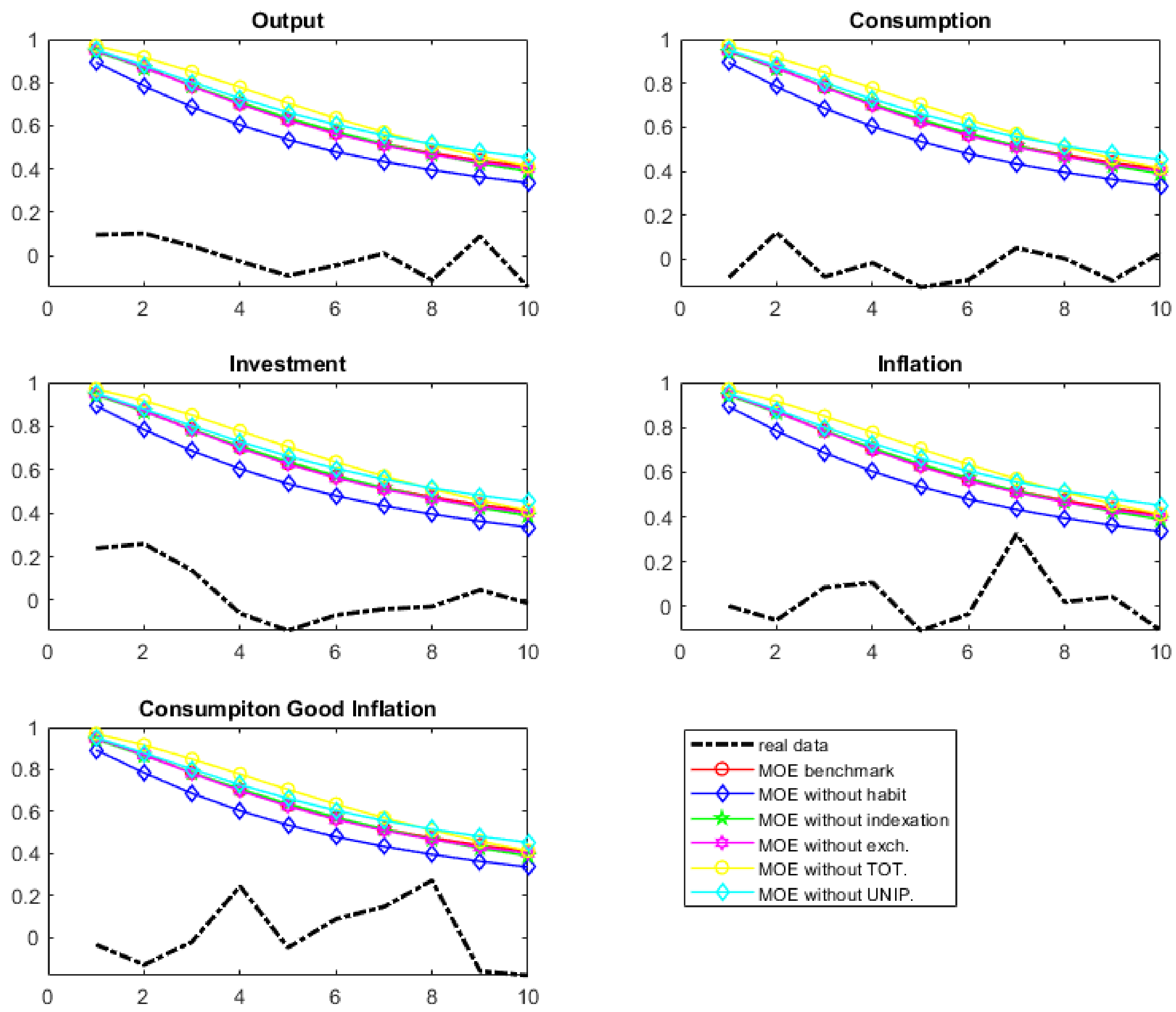

Figure 27 : Autocorrelations up to order 10 - Set 1

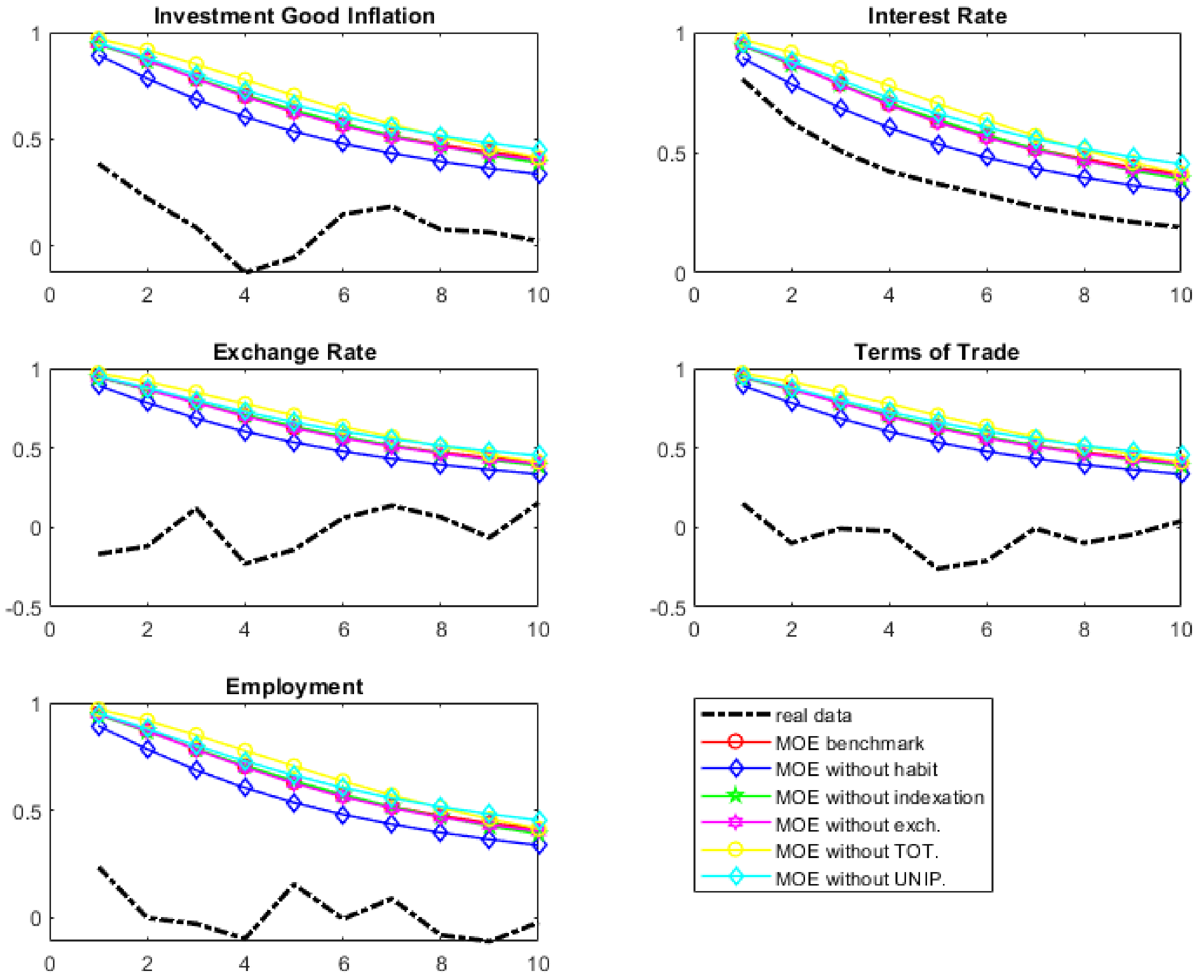

Figure 28 : Autocorrelations up to order 10 - Set 2

5.5 Impulse responses

In this section, we assessed the impulse response functions generated by the middle open economy model. As we have 17 shocks, we figured each of the shocks for 10 different macroeconomic variables. In these figures, it is also possible to examine each model which we derived to assess different specifications of the middle open economy model. Black line shows the benchmark model, red line is the model without habit formation, green line is the without price indexation model, blue line is the model which the exchange rate sensitivity of the central bank is omitted and turquoise line is without uncovered modified interest rate parity model.

5.5.1 Impulse responses to a shock to permanent technology

Figure 29 depicts the impulse response functions to macroeconomic variables. Output growth rises for each model for about ten periods and then we see a permanent rise for a while. All the models except habit formation consumption rises for more then 3 % and it continue persistently. Consumption response of the model without habit formation do not response accordingly. Investment rises up to 5 % with a shock to permanent technology and it takes for a long time to return its steady state level. Inflation rises for ten to fifteen periods and we see a negative inflation and after fifteen periods for all specifications. On the other hand, we see a fluctuating movement in the inflation of imported consumption and investment goods.

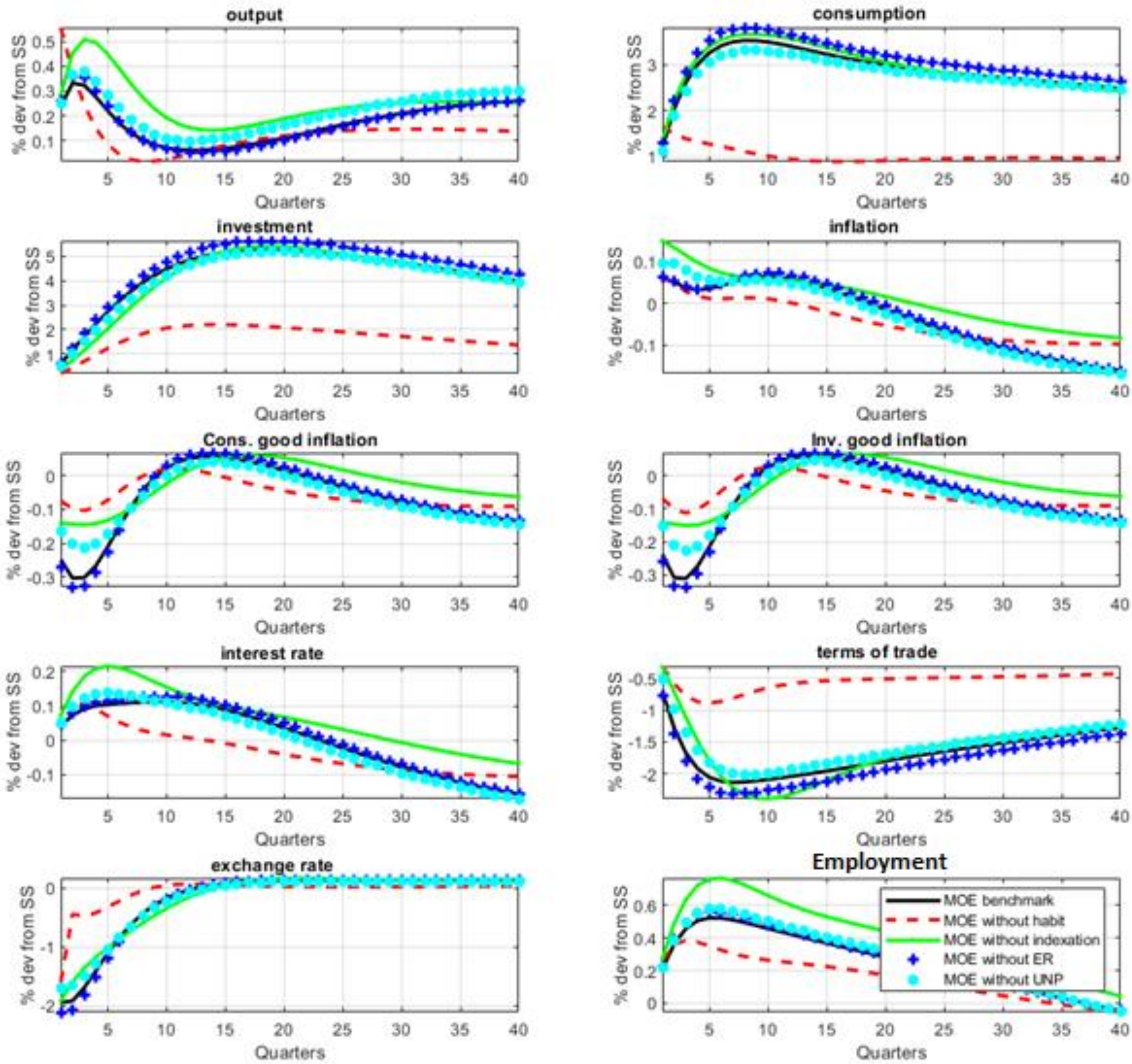

Figure 29 : Impulse responses to a shock to permanent technology

As in the inflation, interest rates first increase for a while but then decreases permanently. Terms of trade decreases up to 2 %. Permanent technology shock gives a rise to Turkish Lira appreciation for a long time. Employment rises with a positive shock to permanent technology.

5.5.2 Impulse responses to a shock to temporary technology

The impulse response functions of the macroeconomic variables to a shock to temporary technology is given in Figure 30. Output growth rises up to 0.8 % for five periods and then returns to steady state after next five periods. Consumption response to a shock to temporary technology is at a very low level. Investment decreases for about fifteen periods like a reverse hump shape. Inflation starts with a negative shock and quickly returns to its steady state. Consumption and Investment goods inflation begins with a decrease and returns to its steady sate after fifteen periods. Imported goods inflation response is more permanent than inflation. Interest rates decrease and terms of trade increases in the beginning of the shock and returns to their steady state after ten periods. We see a significant appreciation in Turkish Lira. But interestingly, we see a decrease in employment after a shock to temporary technology. Whereas we found a significant increase in employment in permanent technology shocks. In terms of this situation, the model needs a separate evaluation. However, in general, we see that macroeconomic variables give a shorter period response to the temporary technology shock.

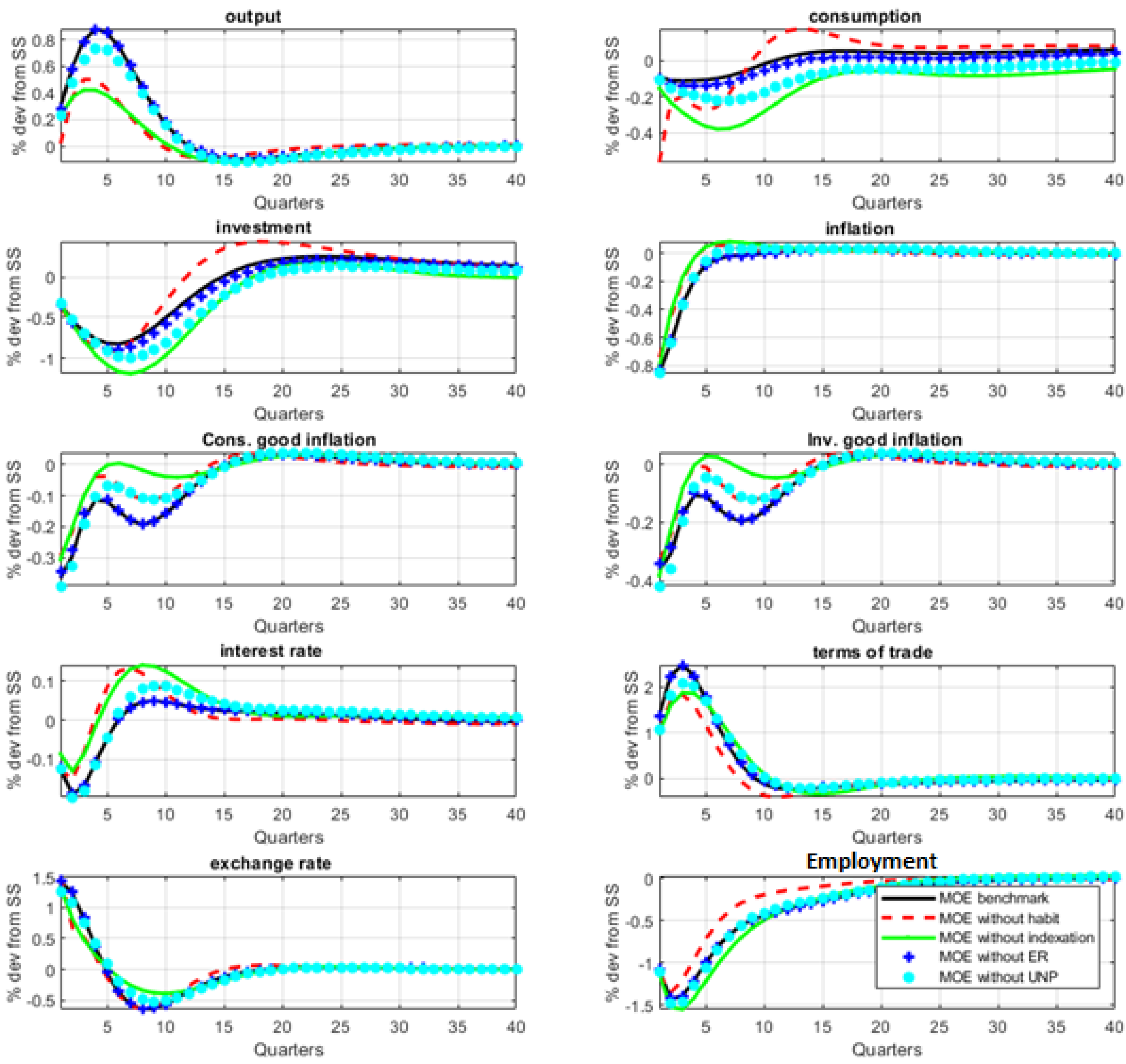

Figure 30 : Impulse responses to a shock to temporary technology

5.5.3 Impulse responses to a shock to investment specific technology

Figure 31 shows the impulse responses to a shock to investment specific technology. Output growth responses a positive rise which continues for a long period. Consumption increases to 3 % after ten period and slowly returns to its steady state. Investments increase to 6 % response. Inflation decreases permanently. We see a parallel response to imported consumption and investment goods inflation with CPI inflation. Rising investments decrease interest rates. Terms of trade decrease and we see a Turkish Lira depreciation. Employment also increases after a shock to investment specific technology.

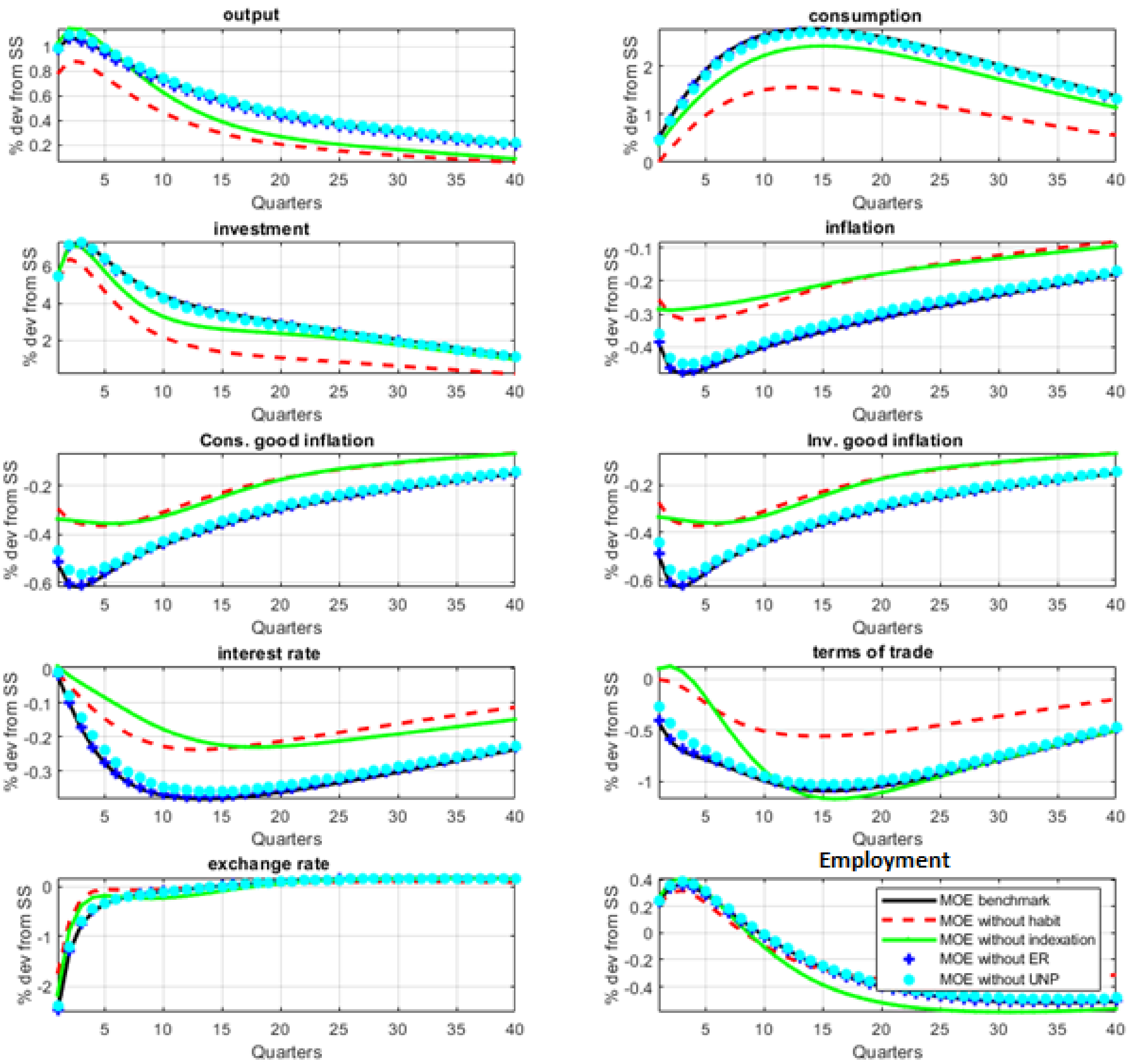

Figure 31 : Impulse responses to a shock to investment specific technology

5.5.4 Impulse responses to a shock to asymmetric technology

As it stated before asymmetric technology shock is the shock the technological differences between foreign and domestic economy. Output growth increases to shock to asymmetric technology. Consumptions and investments are increased to 1.5 % and 2 %, respectively. CPI Inflation decreases and imported goods inflation responses -0.4 % which means a descent in imports. Interest rates increases at a very low level. We see a decrease in terms of trade. In the model where price indexation is excluded, gives a strong response to asymmetric technology. Similarly, employment increases to 0.6 %.

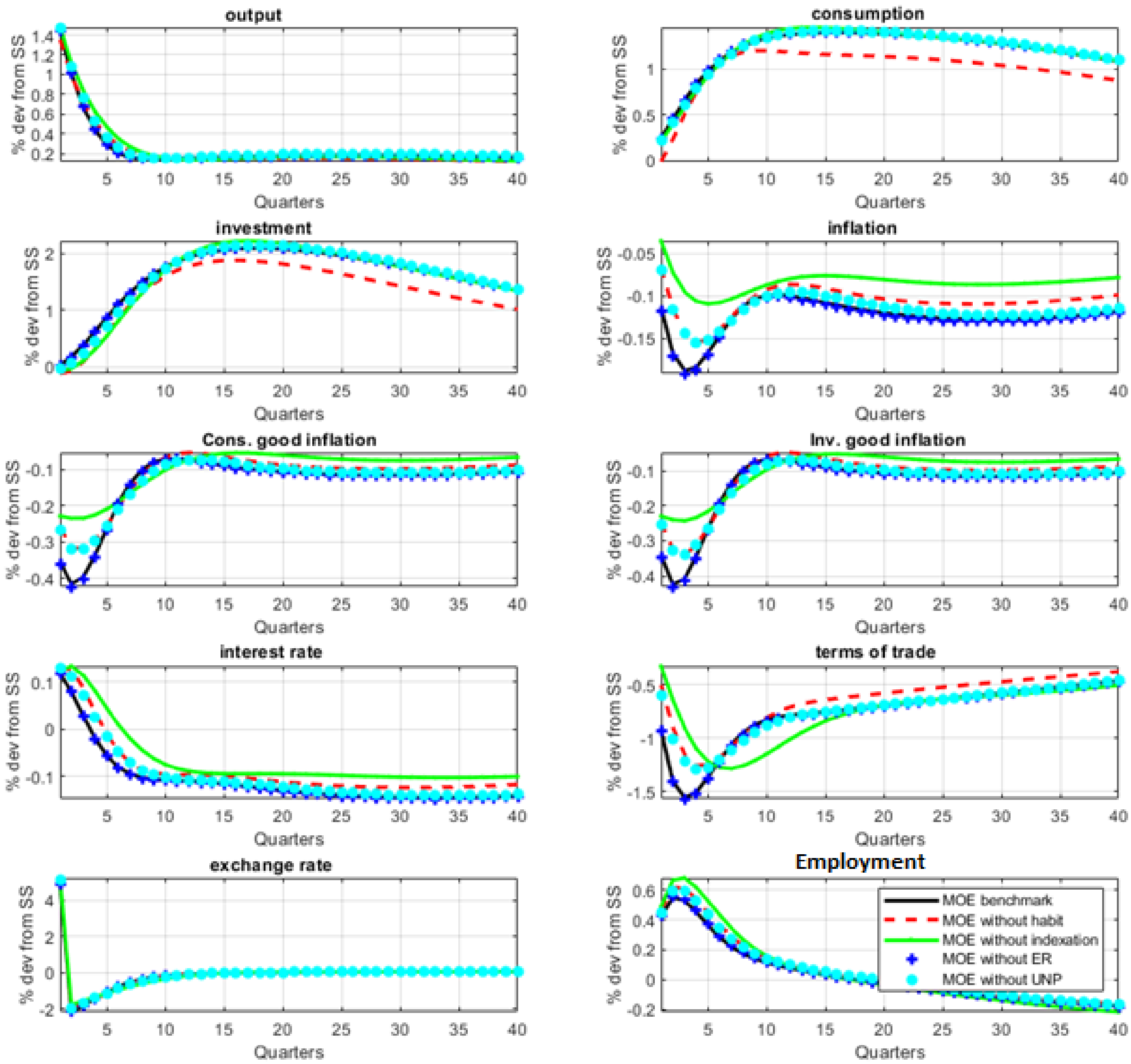

Figure 32 : Impulse responses to a shock to asymmetric technology

5.5.5 Impulse responses to a shock to domestic markup

Domestic Markup shock impulse responses functions are given in the Figure 33. Output growth decreases with a shock to domestic markup. This is an important reduction in domestic production. However, domestic markup shock causes a significant decrease in consumption expenditures and investment. Domestic production reduction triggers CPI inflation and imported consumption and investment goods inflation. Interest rates fluctuates around its steady state. Terms of trade first decreases for a three four period and then increases with a same dimension. Exchange rate and employment, similarly with interest rates fluctuates around its steady state.

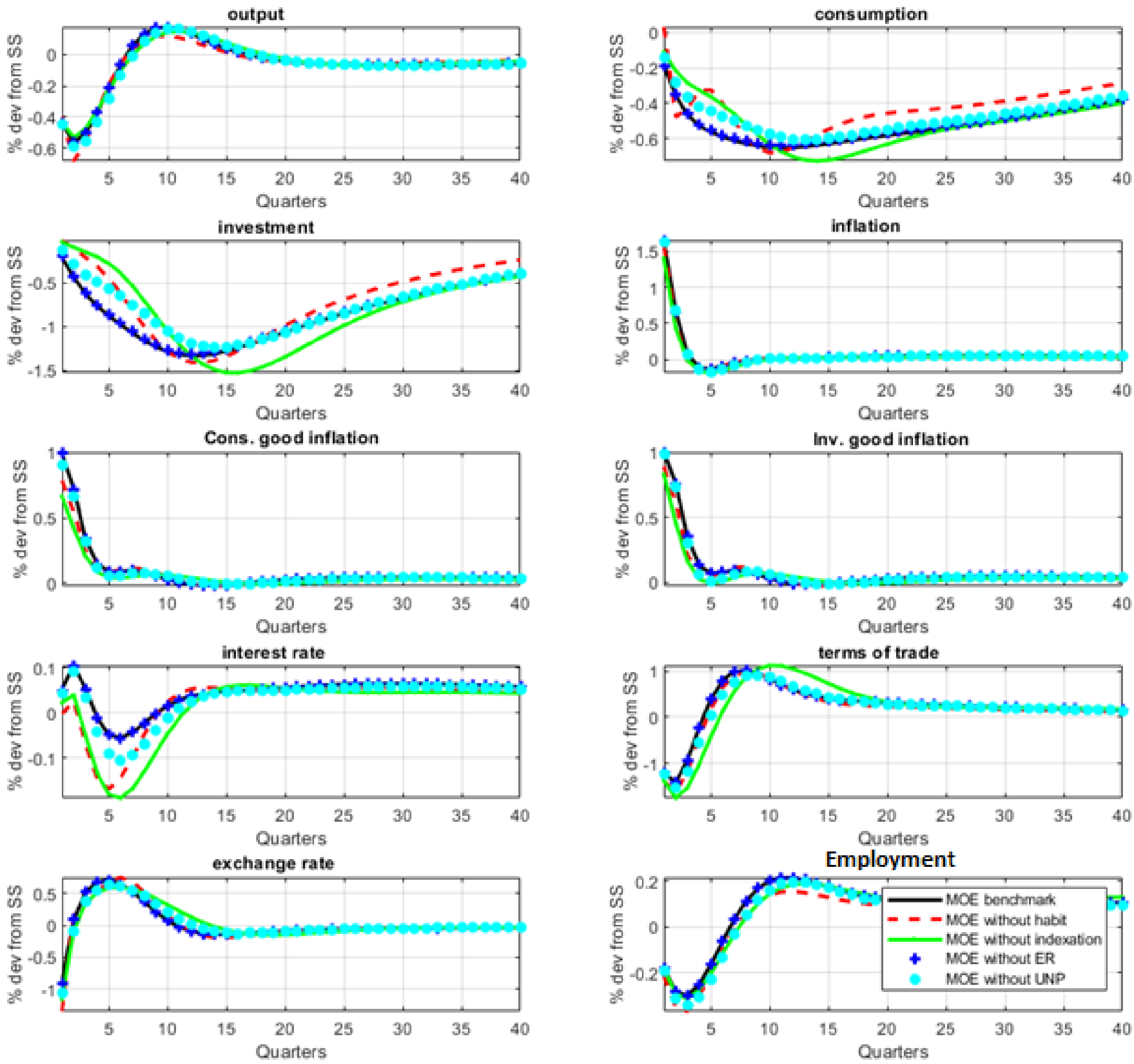

Figure 33 : Impulse responses to a shock to domestic markup

5.5.6 Impulse responses to a shock to consumption good importer markup

Figure 34 shows the consumption good importers markup shock. With this shock output growth increases. Consumption and Investment increase for a long time and take a longer time to return their steady state. This shock gives a rise to inflation. Imported consumption good increases while imported investment good fluctuates around its steady state. However, interest rates fluctuates around its steady state in small range. Terms of trade deceases up to -3 %. Turkish Lira depreciates up to 2 % then decreases 1 % after. Employment has an increase up to 0.8 %.

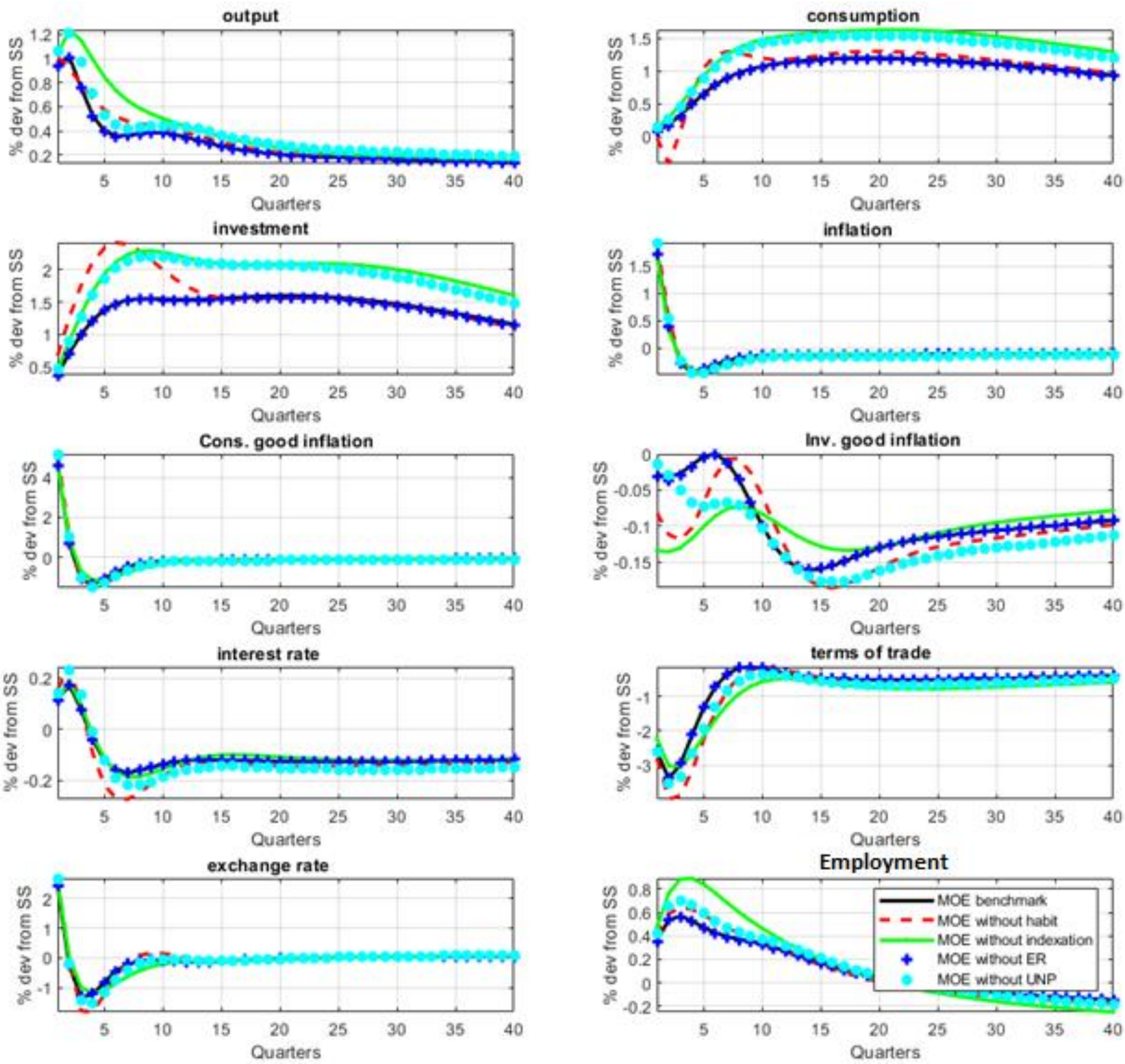

Figure 34 : Impulse responses to a shock to consumption good importer markup

5.5.7 Impulse responses to a shock to investment good importer markup

Investment markup shock is presented in Figure 35. Output growth, consumption expenditures and investment decreases following to investment good importer markup shock. Inflation and Imported consumption good inflation increases permanently. There is a high response of imported investment good inflation. Interest rates and terms of trade increases for a long time. Turkish Lira appreciates up to 0.6 %. Employment fluctuates around its steady state.

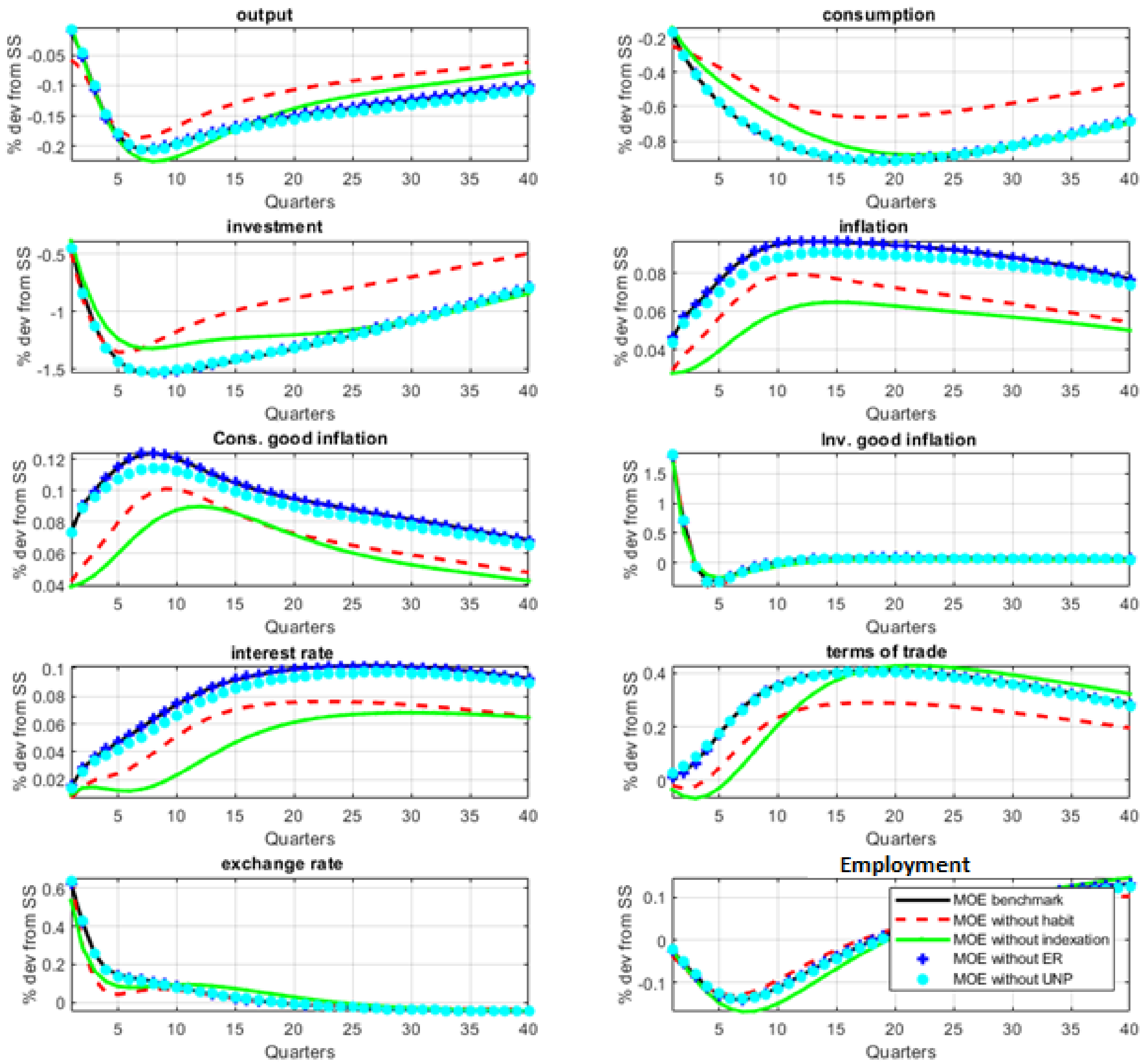

Figure 35 : Impulse responses to a shock to investment good importer markup

5.5.8 Impulse responses to a shock to exporter markup

Figure 36 shows the impulse responses of macroeconomic variables to a shock to exporter markup. Output growth decreases following an exporter markup shock. Consumption increases slightly but the without habit formation model follows a different path. This model first rises but after decreases. Investment increases slightly again. We see a decrease in CPI inflation and also imported consumption and investment goods. Interest rate decreases for a five period. Terms of trade increase up to 0.6 % then return to its steady state. Lastly, the Turkish Lira appreciates slightly and Employment reduces.

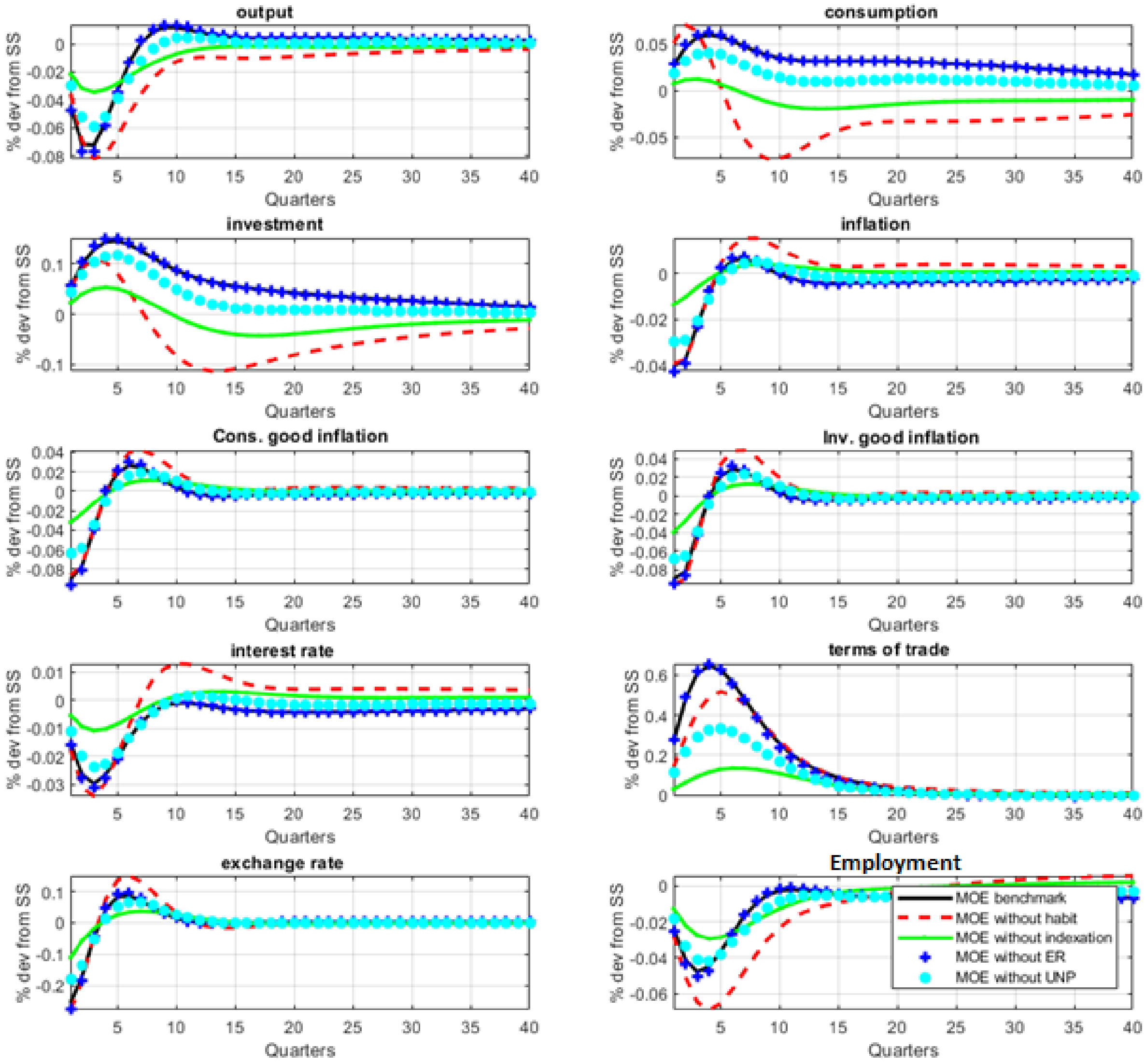

Figure 36 : Impulse responses to a shock to exporter markup

5.5.9 Impulse responses to a shock to preferences

Figure 37 represents the impulse response to preferences. Output growth increases up to 0.6 %. The model without habit formation increases output growth up to 0.2 5. Consumption first increases and then decreases. The model without habit formation do not response to shocks to preferences. This is also an indicator of efficacy of habit formation of the model. We see a permanent decrease in investments. Slight increase in CPI inflation and imported consumption goods and investment goods inflation. Terms of trade fluctuates around its steady state. Turkish Lira appreciates with a preference shock.

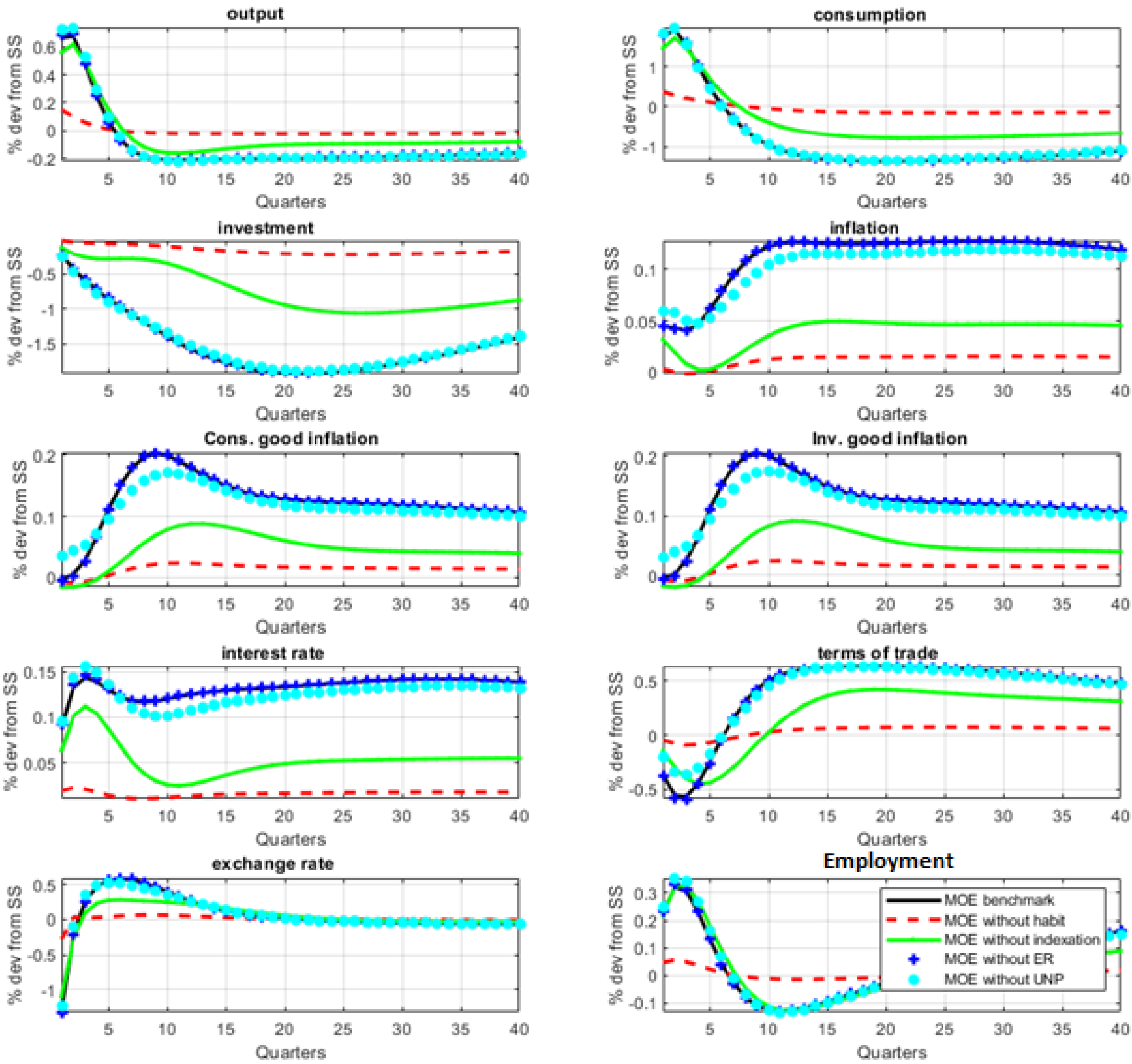

Figure 37 : Impulse responses to a shock to preferences

5.5.10 Impulse responses to a shock to labor supply

Figure 38 shows the impulse responses of the variables to 1% labor supply shocks. We see interesting results that should be evaluated in this way. All formations of models other than habitual structuring do not respond at all to labor supply shocks. This may be the result of an incorrect description of the labor supply shocks in the model.

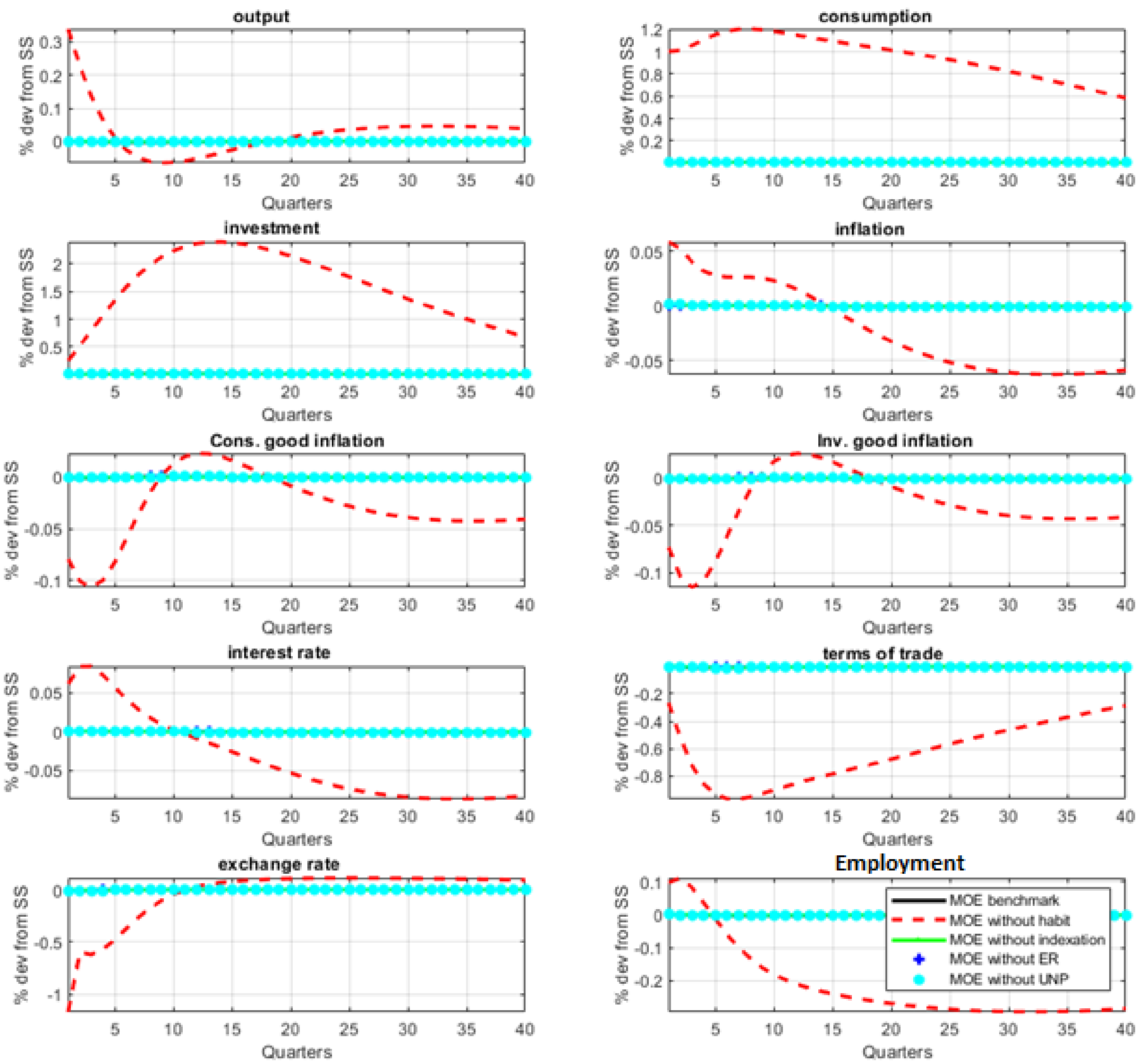

Figure 38 : Impulse responses to a shock to labor supply

5.5.11 Impulse responses to a shock to risk premium

Figure 39 is the impulse response functions of a shock to risk premium. Output growth fluctuates around its steady state. There is a significant decrease in consumption and investment up to -3% and -6%, respectively. CPI inflation and imported goods inflation rises. Interest rates increase for about next 10 periods in a hump shape. Terms of trade increase in a response to risk premium shock. There is a depreciation of Turkish Lira for about 4 %. Turkish Lira depreciation yields an increase in employment.

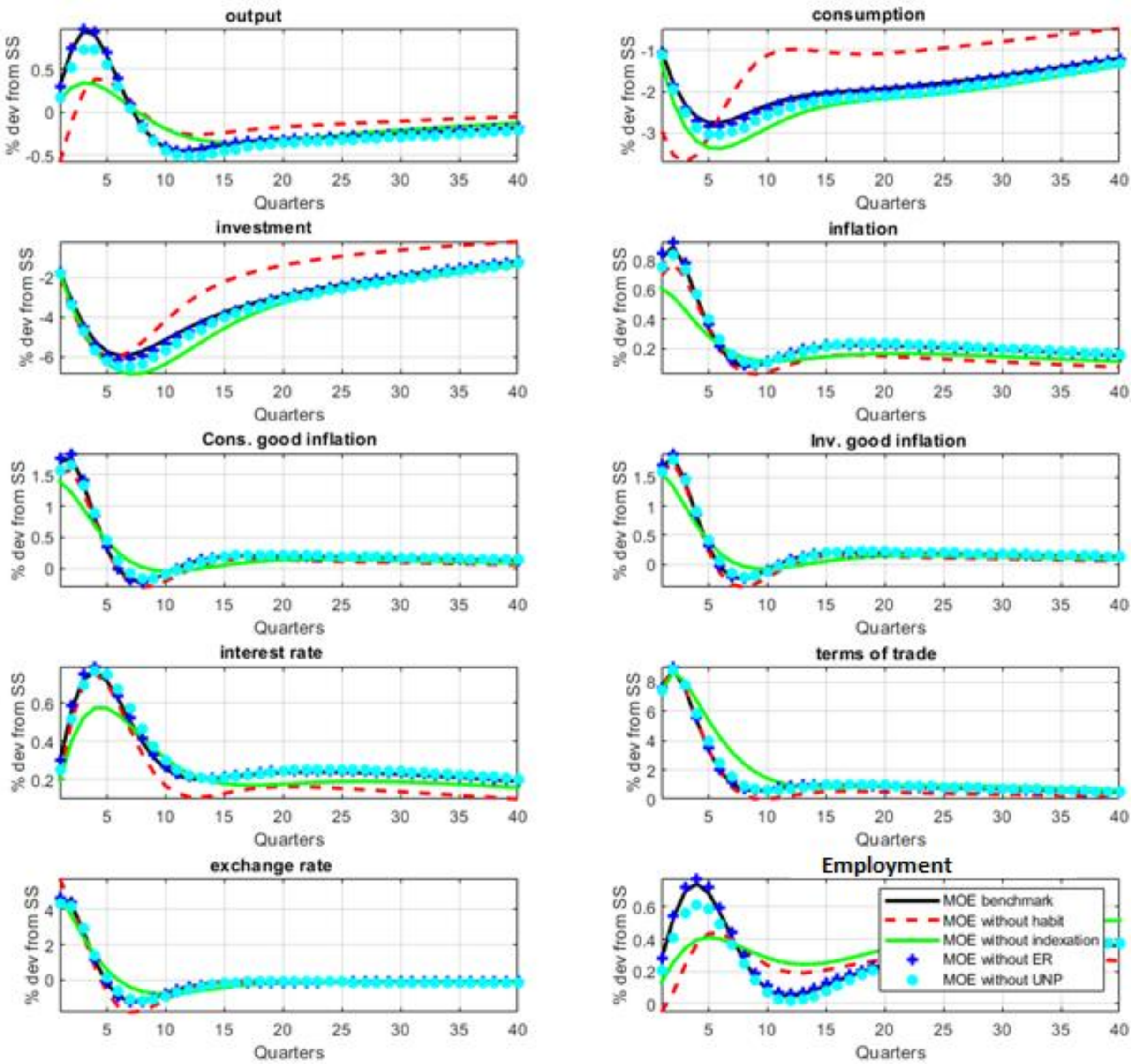

Figure 39 : Impulse responses to a shock to risk premium

5.5.12 Impulse responses to a shock to monetary policy

Figure 40 shows the impulse responses of macroeconomic variables to a 1 % shock to monetary policy. This shock decreases output growth 2 % for about 15 periods. Consumption decreases permanently. Investments are significantly negatively affected. CPI inflation and imported consumption and investment goods decreases in respond to a monetary policy shock. Interest rates increases while terms of trade decreases. Turkish Lira fluctuates arouns its steady state and Employment decreases for about 20 %.

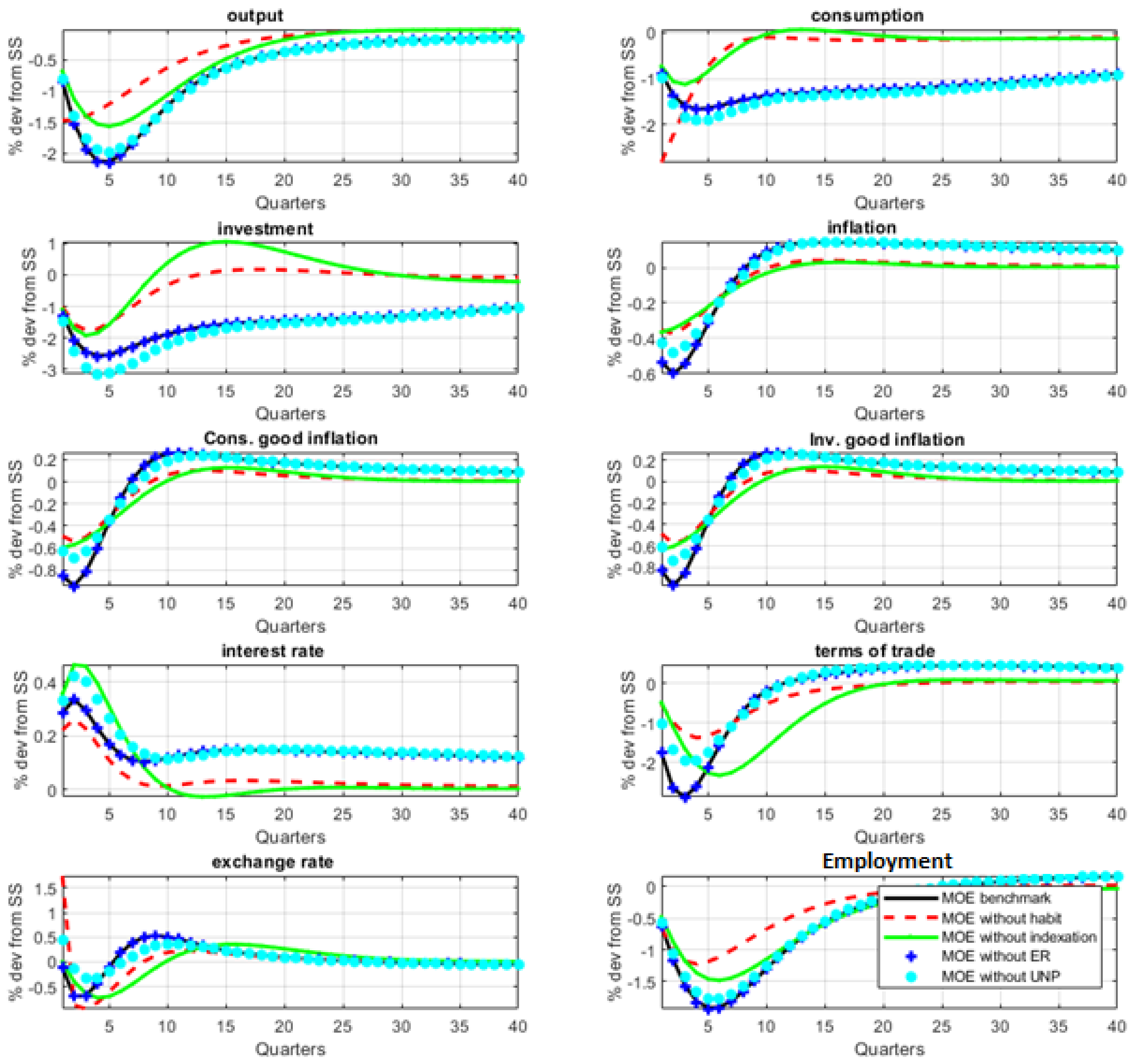

Figure 40 : Impulse responses to a shock to monetary policy

5.5.13 Impulse responses to a shock to government spending

Figure 41 shows the impulse responses to government spending shock. Government spending shock increases output growth slightly. Consumption expenditures and investments are affected at a low level. Inflation then gives a low negative response. Interest rates are faced with an upward movement. Terms of trade decrease and the Turkish Lira appreciates slightly. There is also a slight increase in employment.

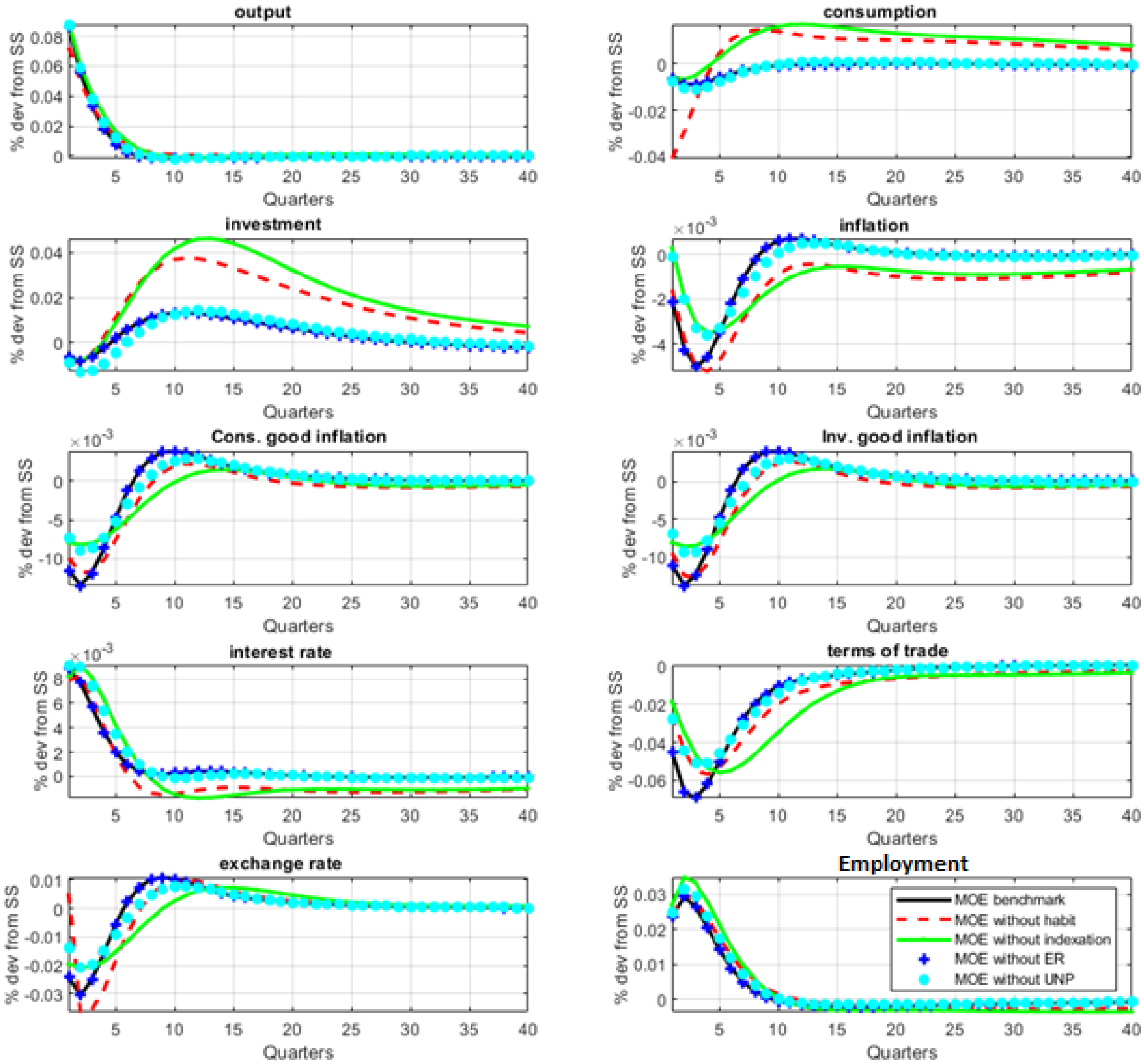

Figure 41 : Impulse responses to a shock to government spending

5.5.14 Impulse responses to a shock to terms of trade

Figure 42 is responses of a shock to terms of trade. In the model, as with labor supply shocks, response functions did not occur as expected. Model needs to be evaluated in terms of terms of trade shock.

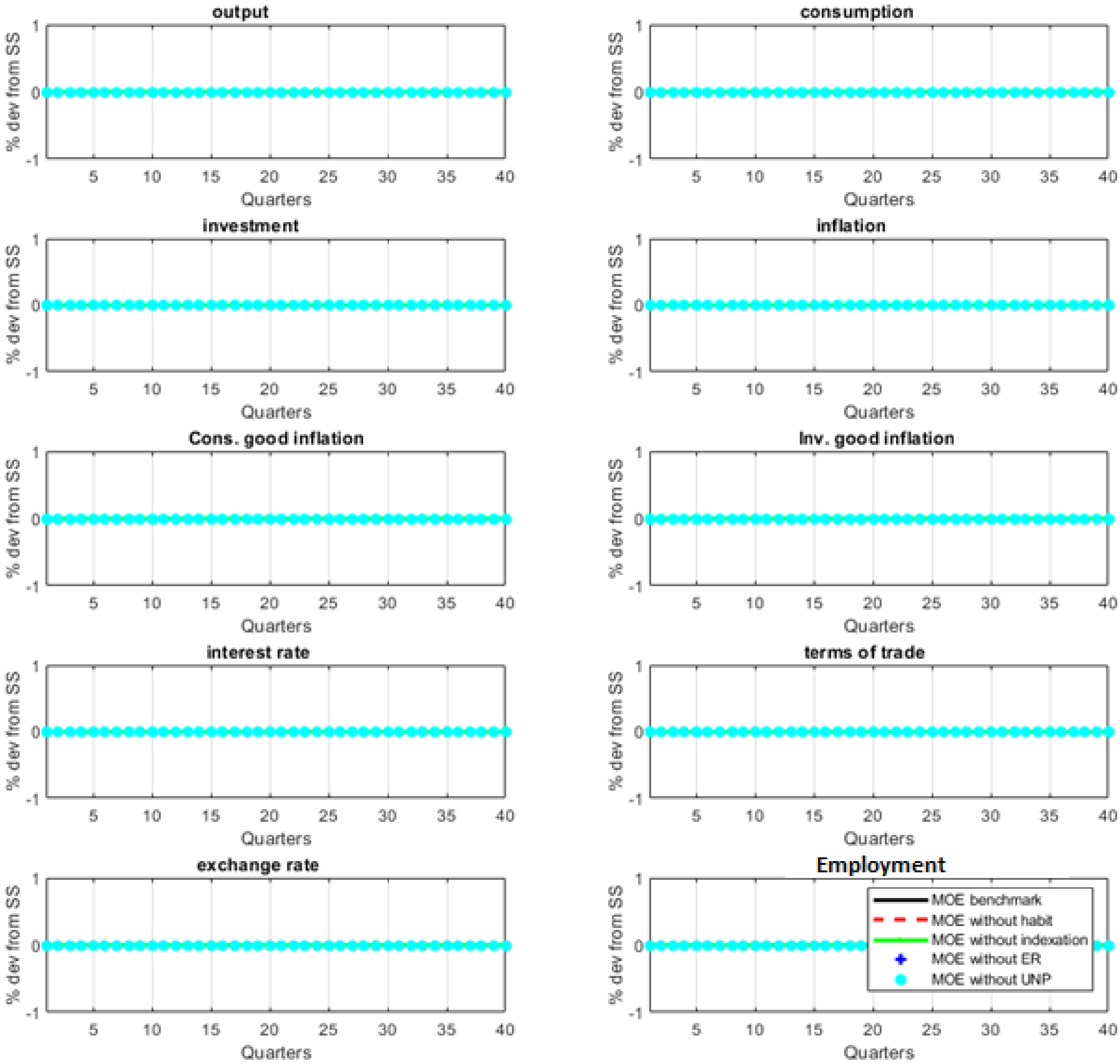

Figure 42 : Impulse responses to a shock to terms of trade

5.5.15 Impulse responses to a shock to foreign output growth

Impulse responses to a shock to foreign output growth are depicted in Figure 43. The impact of foreign output growth on the domestic economy is low. Output growth reacts only 0.12 % while consumption and investment responses approximately 0.15 %. CPI inflation decreases 0.015 % and imported goods inflation decreases 0.03 %. Inflation and the Turkish Lira fluctuate around their steady state. Employment increases 0.05 % in a hump shape form.

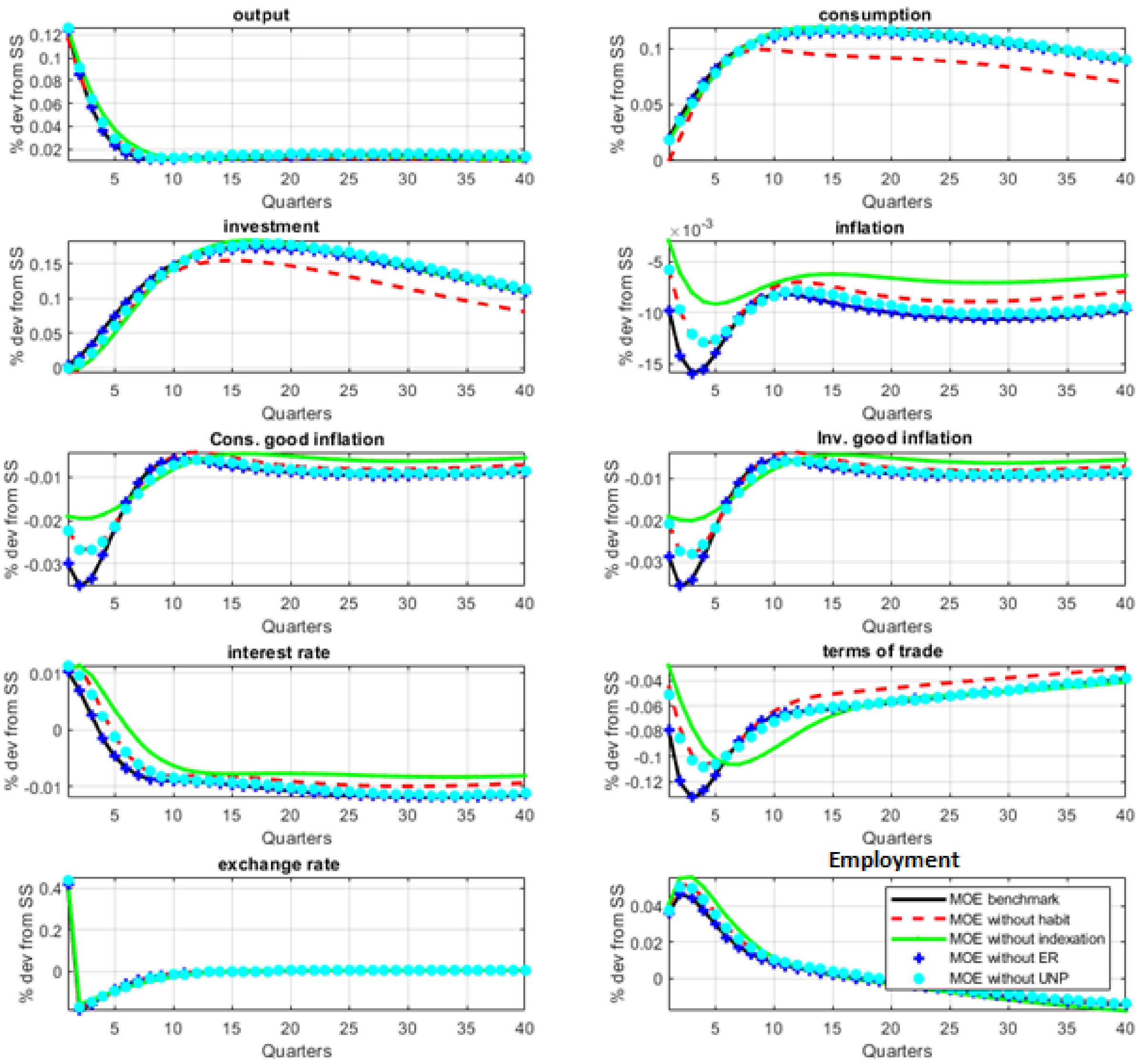

Figure 43 : Impulse responses to a shock to foreign output growth

5.5.16 Impulse responses to a shock to foreign inflation

Figure 44 shows the impulse response functions to foreign inflation shock. Similar to foreign output growth, foreign inflation has a low impact on the domestic economy. Domestic output growth fluctuates around its steady state. Different model formations follow different paths in terms of consumption expenditure. The model without price indexation falls to -0.6 %. It is similar for investment. The model without price indexation falls to -1.2 %. CPI inflation and imported goods inflation increase to 0.1 %. Interest rates responds only 0.08 %. The Turkish Lira depreciates 0.8 % due to a shock to foreign inflation.

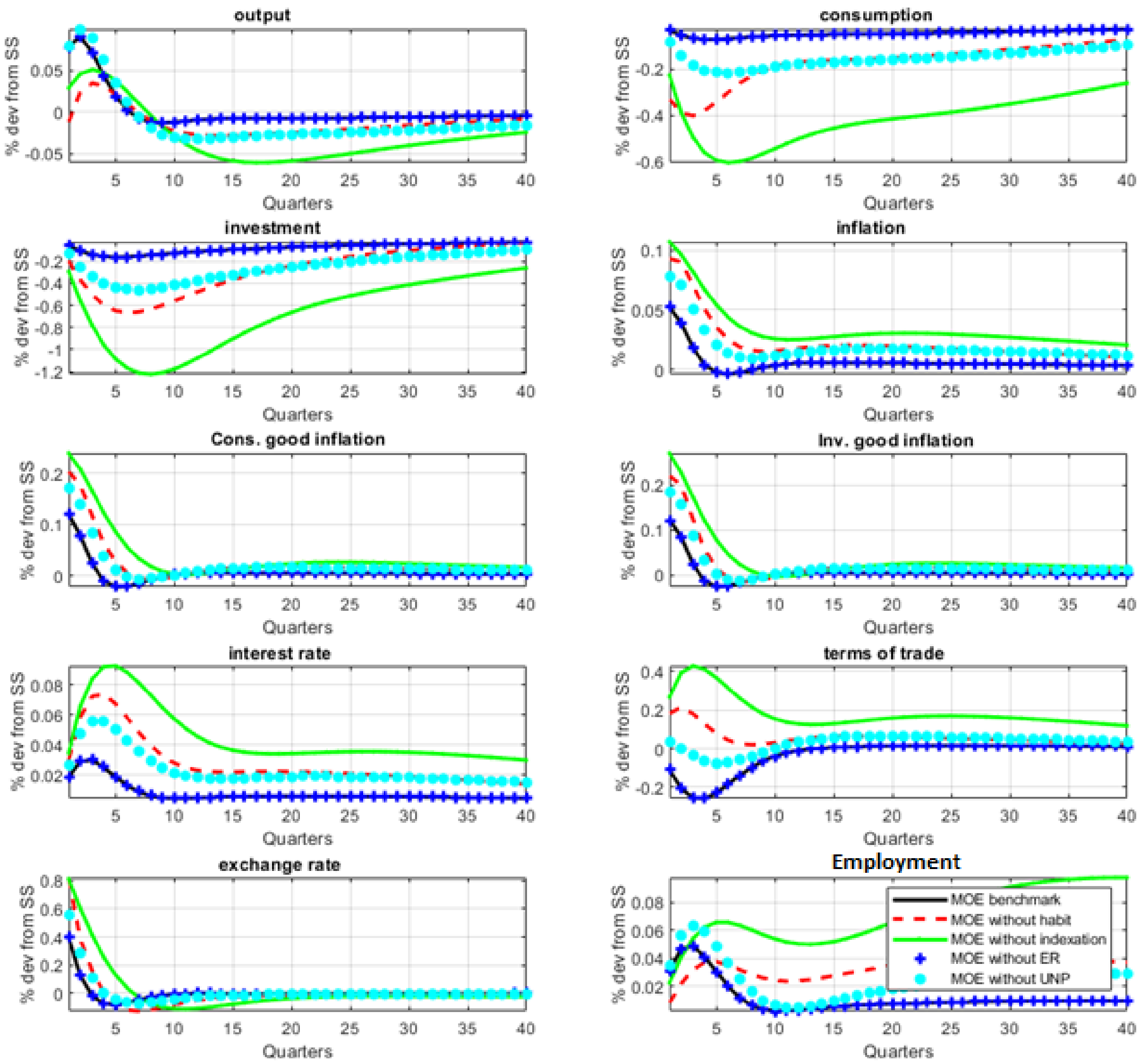

Figure 44 : Impulse responses to a shock to foreign inflation

5.5.17 Impulse responses to a shock to foreign interest rates

Figure 45 presents the Impulse responses to a 1 % shock to foreign interest rates. Output growth fluctuates around its steady state. Consumption and investment decrease -1.2 % and -2 %, respectively. This effect continues for a long time. Inflation increases 0.2 % in hump shape form. Imported consumption goods and imported investment goods inflation increases 0.4 % for seven eight periods. Interest rates increase 0.2 %. Terms of trade is also affected positively. The Turkish Lira depreciates for about 1 %. Employment is affected slightly.

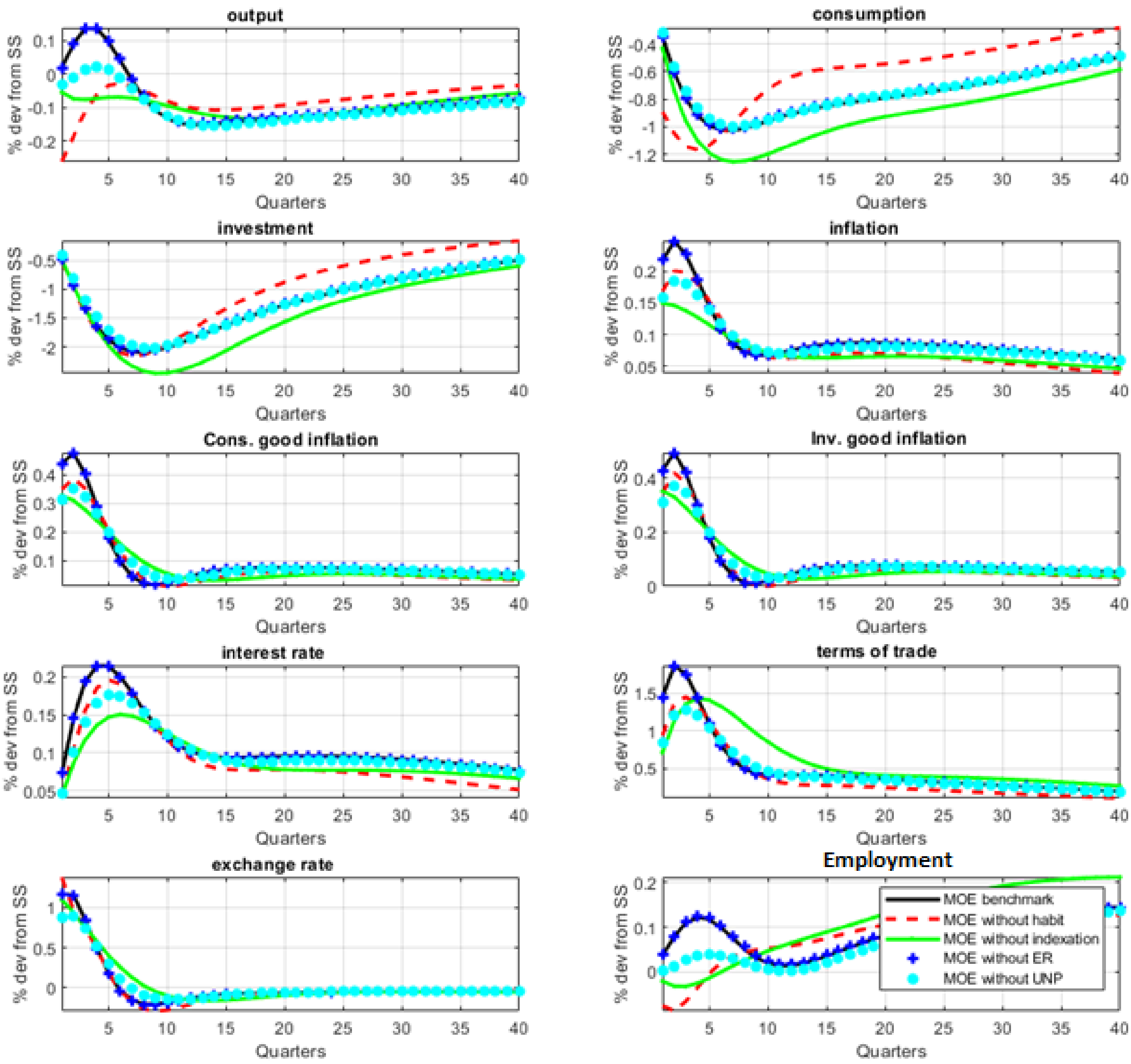

Figure 45 : Impulse responses to a shock to foreign interest rates

5.6 Variance decompositions

Table 17 shows the variance decompositions of the macroeconomic variable throughout the estimation period according to the middle open economy model. The contribution of foreign shocks accounts for a negligible percentage. These results are in line with the results of small open economy model. The macroeconomic variables are highly affected from domestic shocks. On the other hand, according to the middle open economy model Labor supply shock, Government spending shock and Terms of trade shock do not account in the variances of macroeconomic variables.

Output growth is highly affected from monetary policy shocks. 43.96 % of the fluctuations of the output growth is explained by monetary shocks. 18.04 % of fluctuations of the output growth is explained by investment specific technology shocks. The effect of risk premium shock is 7.95 %. Consumption good importer markup shock explain 6.64 of output growth variance. Permanent technology shocks, temporary technology shocks, and preference shocks effects the variances of output growth 4.71 %, 4.81 % and 3.64 %, respectively. Domestic producer markup shock and investment good importer markup shock has a very low impact for about 1.54 % and 1.30 %, respectively. Other than these shocks, the effect of other shocks on output growth is negligible.

39.27 % of consumption variances is explained by permanent technology shocks. Investment specific technology shocks and risk premium shocks effects the variances of consumption expenditures 17.90 % and 13.59 %, respectively. Variance of consumption is explained by 6.56 % risk premium shocks, 6.34 % asymmetric technology shocks, 5.83 % monetary policy shocks 4.60 % consumption good importer markup shocks. The effect of other shocks are at negligible level.

Investment is highly affected from permanent technology shocks. 37.56 % of investment variances is explained by permanent technology shocks. 21.35 % of fluctuations of investment is explained by investment specific technology shocks and 17.43 % of fluctuations is explained by risk premium shocks. Variance of investment is explained by 4.88 % asymmetric technology shocks, 4.48 % preference shocks, 4.17 % monetary policy shocks and 3.53 % consumption good importer markup shock.

CPI inflation is affected by various shocks. Investment specific technology shock accounts 20.06 % for inflation variances. Consumption good importer markup shock contributes 18.44 %. Meanwhile, Risk premium shocks accounts for 16.55 %. Domestic producer markup shock explains 13.85 % of inflation variances. On the other hand, the contribution of monetary shocks, permanent technology shocks, temporary technology shocks, asymmetric technology shocks, and preference shocks are 8.10 %, 6.37 %, 5.56 %, 3.80 %, and 3.45 %, respectively.

The shock to consumption good importer markup shock is the primary source in driving imported consumption good inflation. It contributes 51.73 % in variance of imported consumption good inflation. On the other hand, risk premium shocks accounts 17.99 %. Meanwhile, investment specific shocks explain 10.05 % of the fluctuations of imported consumption good inflation.

Imported investment good inflations is highly affected by risk premium shocks and investment specific technology shocks. The contribution of these shocks are 32.69 % and 17.54 %. On the other hand, investment good importer markup shock accounts 13.15 %. Meanwhile, monetary shocks accounts 12.63 %. The effect of technology shocks are 4.68 % for permanent technology shocks, 5.82 % domestic producer markup shocks and 4.01 % asymmetric technology shocks.

The main driver of interest rate fluctuations is the risk premium shocks. The contribution of the risk premium shock is 28.20 %. Investment specific technology shocks and permanent technology shocks contributes 27.06 % and 11.56 %, respectively. The contribution of monetary shocks to interest rate fluctuations is 7.17 %. Preference shocks, asymmetric technology shocks and consumption good importer markup shocks accounts 6.59 %, 5.86 % and 5.53 %, respectively.

The variations in exchange rates are mainly led by risk premium shocks for 40.57 %. Permanent technology shocks explain 23.78 % of exchange rate fluctuations. Consumption good importer markup shocks, monetary policy shocks, investment specific technology shocks, and asymmetric technology shocks contributes 6.82 %, 6.37 %, 5.59 5 and 4.69 %, respectively. On the other hand, interest rates in Turkey are mainly driven by risk premium shocks and

The main driver of terms of trade is risk premium shocks. The contribution of this shock is 36.15 %. Asymmetric technology shocks explain 24.18 % of variances of terms of trade. On the other hand, permanent technology shock accounts 10.87 %.

Employment variances are mainly affected by monetary shocks. The contribution of the monetary shock on employment variances are 36.21 %. Investment specific technology shocks, temporary technology shocks, permanent technology shocks and risk premium shocks account 14.86 %, 12.20 %, 10.71 % and 10.17 %.

Table 17 : Variance Decomposition

	ε_{γ^d}	$\varepsilon_{\gamma^{mc}}$	$\varepsilon_{\gamma^{mi}}$	ε_{γ^x}	ε_{gr}	ε_a	ε_i	ε_{zt}	ε_g	ε_l	ε_p	ε_m	ε_{gov}	ε_{tot}	ε_{y^*}	ε_{π^*}	ε_{r^*}
Output growth	1.54	6.64	1.30	0.02	4.71	4.81	18.04	6.55	3.64	0	7.95	43.96	0.02	0	0.05	0.03	0.74
Consumption	1.09	4.60	2.57	0	39.27	0.02	17.90	6.34	6.56	0	13.59	5.83	0	0	0.04	0.01	2.18
Investment	1.27	3.53	2.44	0.01	37.56	0.21	21.35	4.88	4.48	0	17.43	4.17	0	0	0.03	0.01	2.62
Inflation	13.85	18.44	1.71	0.02	6.37	5.56	20.06	3.80	3.45	0	16.55	8.10	0	0	0.03	0.02	2.04
Cons. Inf.	3.20	51.73	0.81	0.03	2.67	0.85	10.05	2.28	1.69	0	17.99	7.03	0	0	0.02	0.04	1.62
Inv. Inf.	5.82	1.95	13.15	0.06	4.68	1.51	17.54	4.01	2.96	0	32.69	12.63	0	0	0.03	0.08	2.89
Interest Rate	1.02	5.53	2.70	0.02	11.56	0.63	27.06	5.86	6.59	0	28.20	7.17	0	0	0.04	0.03	3.58
Exchange Rate	1.92	6.82	0.92	0.39	23.78	3.73	5.59	4.69	2.44	0	40.57	6.37	0	0	0.03	0.05	2.70
Terms of Trade	2.11	7.06	0.58	0.08	10.87	4.33	6.87	24.18	2.75	0	36.15	2.00	0	0	0.18	0.13	2.71
Employment	1.49	4.57	1.38	0.01	10.71	12.20	14.86	4.16	2.95	0	10.17	36.21	0	0	0.03	0.02	1.23

ε_{γ^d}: Domestic producer markup shock, $\varepsilon_{\gamma^{mc}}$: Consumption good importer markup shock, $\varepsilon_{\gamma^{mi}}$: Investment good importer markup shock, ε_{γ^x}: Exporter markup shock,

ε_{gr}: Permanent technology shock, ε_a: Temporary technology shock, ε_i: Investment specific technology shock, ε_{zt}: Asymmetric technology shock,

ε_g : Preference shock, ε_l: Labor supply shock, ε_p: Risk premium shock, ε_m: Monetary Shock, ε_{gov}: Government spending shock,

ε_{tot}: Terms of trade shock, ε_{y^*}: Foreign output growth shock, ε_{π^*}: Foreign inflation shock, ε_{r^*}: Foreign interest rate shock

5.7 Historical decompositions

Figures 46 – 55 decompose the historical time series with the Middle Open Economy model. Historical decompositions are constructed using the estimated parameters. Historical decompositions are the presentation of the contribution of each shock to the deviation of macroeconomic variables from their steady states. In the figures they are showed by the colored bars. Grey bars are the initial conditions which are the deviations from steady states of the macroeconomic variables explained by unknown initial conditions.

5.7.1 Historical decomposition of output

Figure 46 is the presentation of the output growth historical decompositions. Monetary shocks, asymmetric technology shocks, consumer good importer markup shocks, investment specific technology shocks, and temporary technology shocks have been determinant since the beginning of 2003 to the 2008 financial crisis. I think two important points should be considered in this section. First of all, we see that while monetary shocks had a positive effect on growth effectively after the 2001 financial crisis, its effect on growth before the 2008 financial crisis turned negative. The second of these important points is that permanent technology shocks had almost no effect in the process that prepared the Turkish economy for the 2008 financial crisis. These two important points enabled the Turkish economy to face a significant contraction in the 2008 financial crisis. We see that the effects of the 2008 financial crisis continued for approximately 4 quarters. During this period, both demand-side and supply side contractions stand out. After the 2008 financial crisis, we can say that temporary technology shocks and investment specific technology shocks are effective on the economy's supply side. In the 2018 currency crisis, the efficiency of supply side contractions comes to the fore. After the 2018 currency crisis, the negative effects of increased risk premium shocks on output growth were tried to be mitigated by monetary shocks.

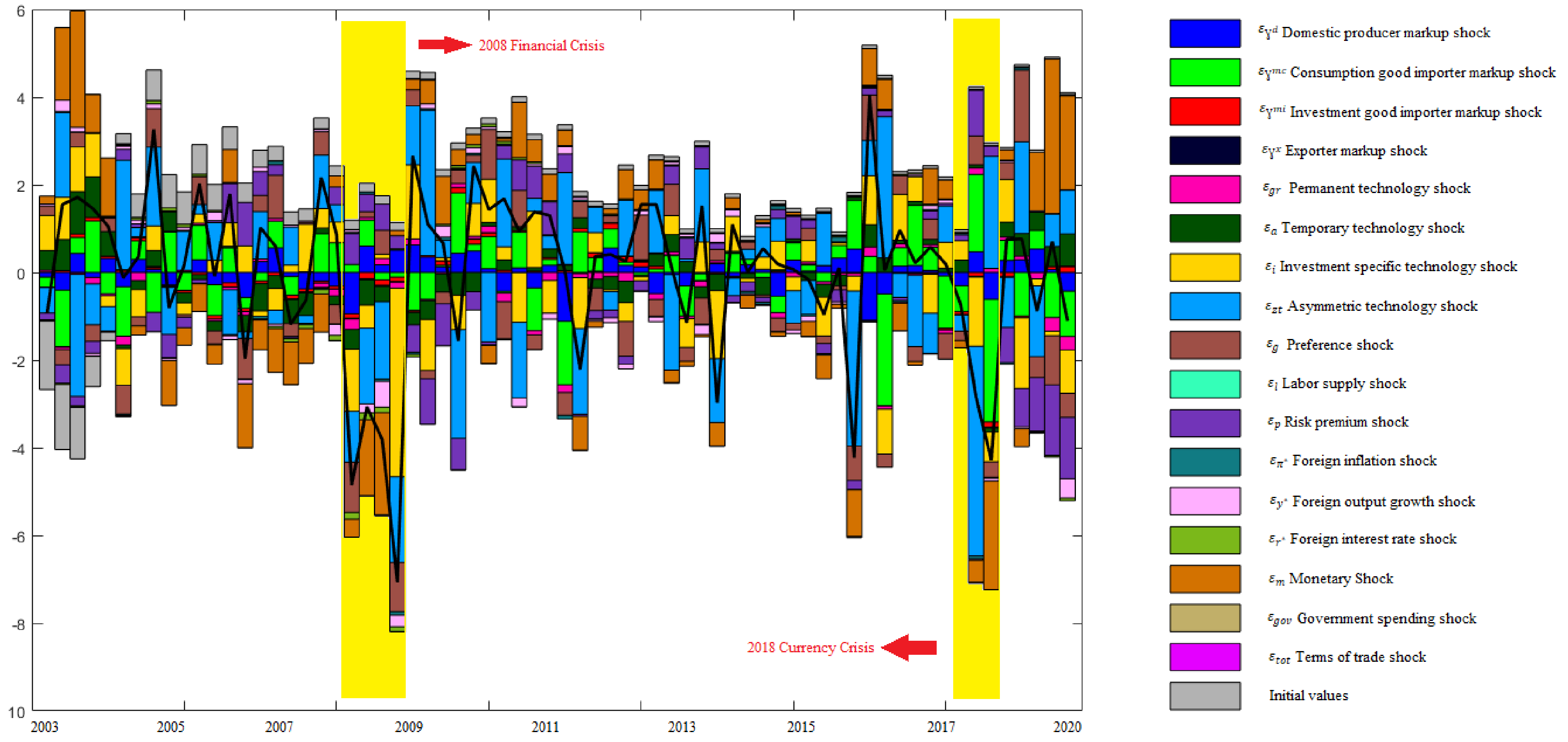

Figure 46 : Historical decomposition of output growth

5.7.2 Historical decomposition of consumption

Figure 47 shows which shocks caused the growth in consumption expenditures to deviate from its steady state in historical time series. It is observed that risk premium shocks triggered consumption growth before the 2008 financial crisis, and permanent technology shocks caused a decrease in consumption expenditures in the same period. During this period, the efficiency of investment technology shocks is also striking. In this period, we see that the profitability of domestic producers decreased and that of consumer goods importers increased their profitability. Demand shocks also increase consumption. In this period, as a result of the effects of the low exchange rate policy, we see that the households turned to imported products rather than domestic products. In the 2008 financial crisis, demand and supply contractions are evident. We can say that after the 2008 crisis, the imports of consumption goods remained attractive for a long time. During this period, the demand for domestic production changed positively compared to the period before the 2008 financial crisis. The effectiveness of monetary shocks in the period between 2008 and 2018 is extremely low. Just after the 2008 crisis, risk premium shocks increased consumption, while the risk premium negatively affected consumption expenditures in almost the last twelve quarters before 2018. Again, we can say that the effectiveness of permanent technology shocks is not positive in this period. Risk premium shocks had an extremely negative impact on consumption expenditures in the 2018 crisis. Exchange rates, which increased with this crisis, necessarily caused a rapid decline in the imports of consumption goods. The profitability of importers is no longer what it used to be. Despite all this, the profitability of domestic producers does not reach a sufficient level. The effectiveness of monetary shocks after the 2018 financial crisis is also striking.

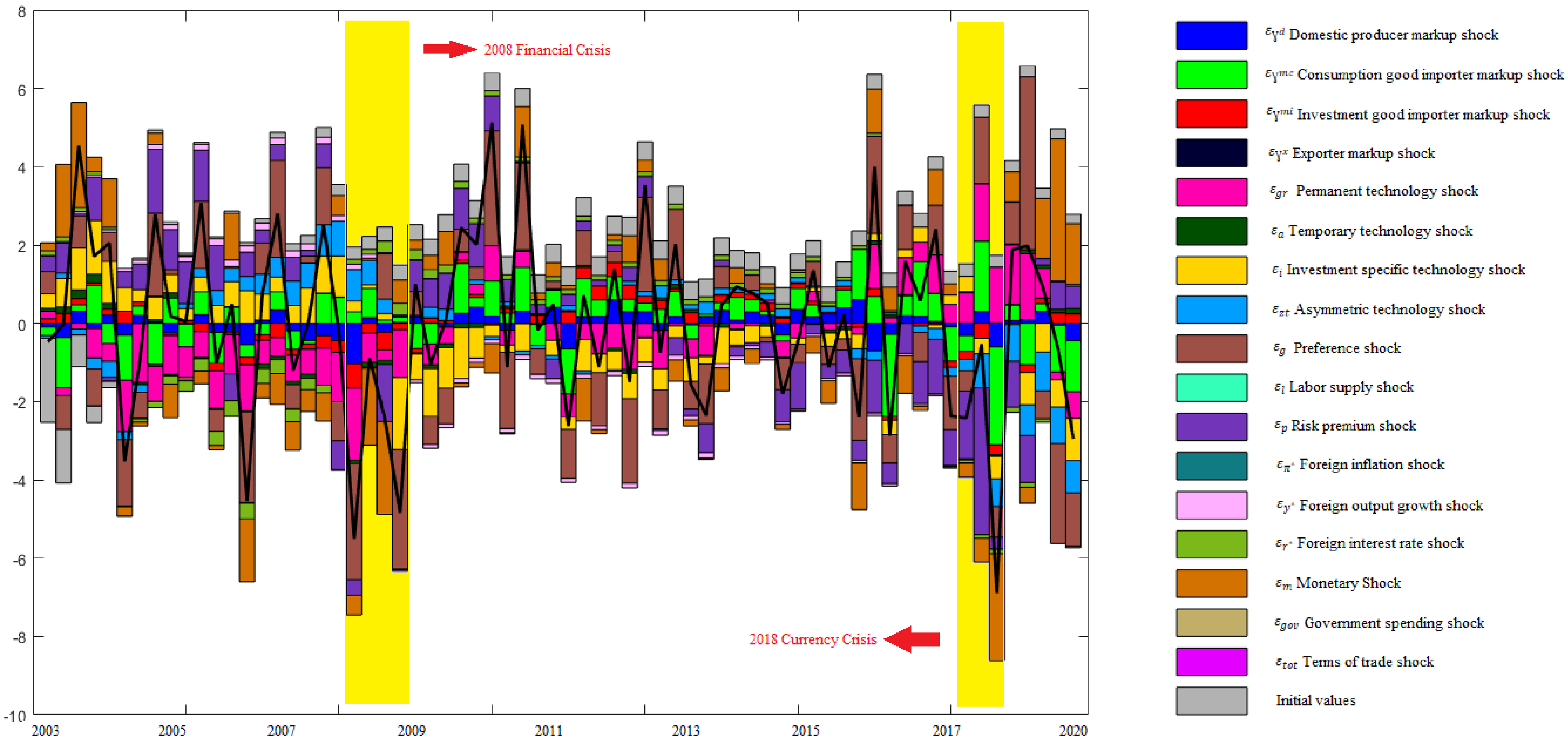

Figure 47 : Historical decomposition of consumption growth

5.7.3 Historical decomposition of investment

Historical decomposition of investment growth is shown in Figure 48. In the period before the 2008 financial crisis, investment specific shocks play an important role in the increase of investment expenditures, although there was a two-quarter reversal. Another remarkable point is that risk premium shocks contribute to the increase in investment expenditures in this period. As is known, this period is the period when the country risk premium is the lowest after the 2001 crisis. The decrease in risk premiums plays an important role in the increase of investment expenditures. On the other hand, permanent technology shocks reduced investment expenditures for a while. When we examine the 2008 financial crisis, investment-specific technology shocks reduced investment expenditures very rapidly. Risk premium shocks had similar negative effects. After the 2008 financial crisis, we see a fluctuating investment expenditure. During this period, investment-based technology shocks have sometimes positive and sometimes negative effects. Approximately since 2014, the impact of risk premium shocks on investment expenditures has continued to increase negatively. In the 2018 currency crisis, a sudden decline in investment expenditure is striking. The level of risk has increased and the weakness of permanent technology shocks has increased the depth of the crisis. Monetary shocks are extremely ineffective during the entire estimation period. Only, after the 2018 financial crisis, monetary shocks played a role in increasing spending on investment goods.

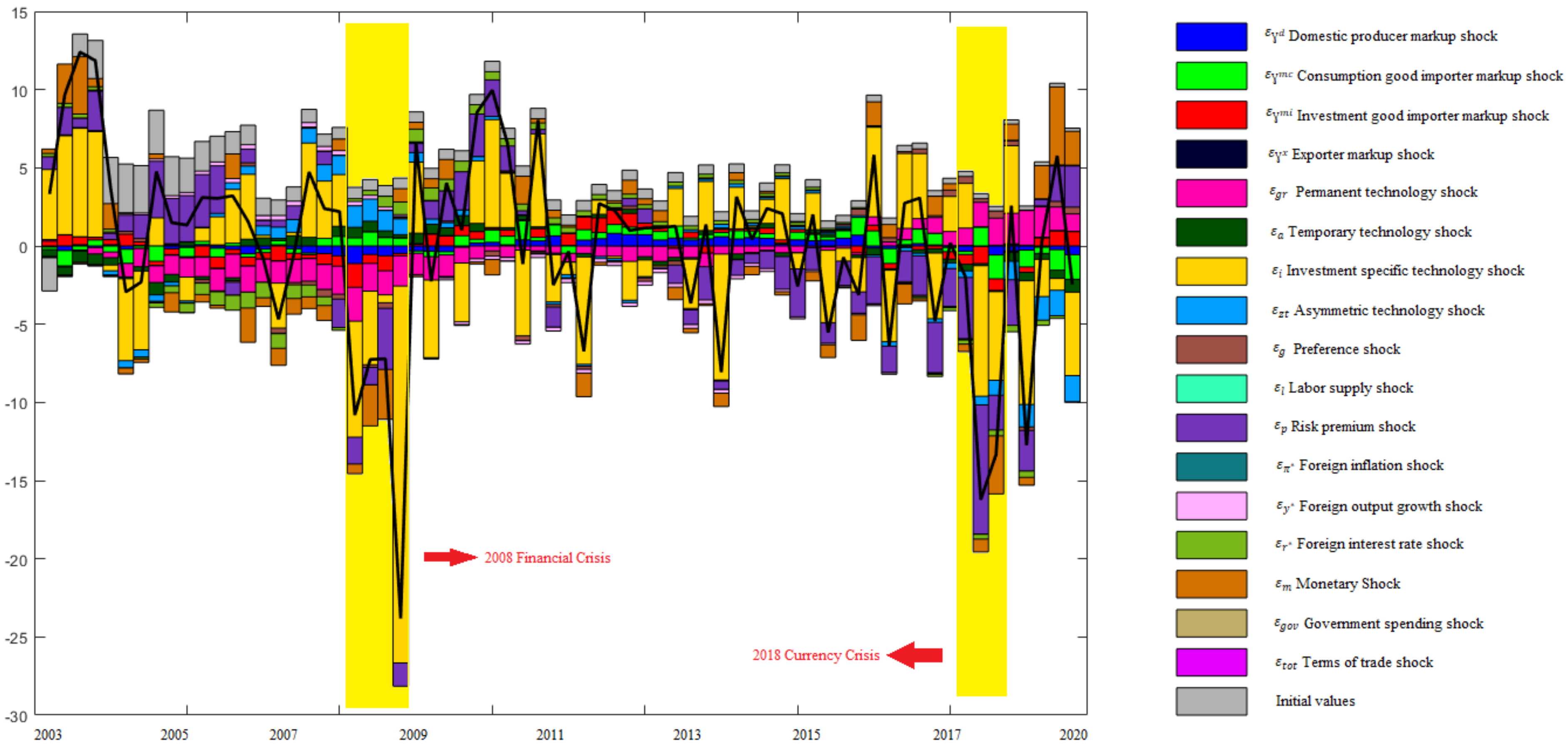

Figure 48 : Historical decomposition of investment growth

5.7.4 Historical decomposition of inflation

Figure 49 is the presentation of the inflation historical decompositions. There is a long impact of initial conditions during the estimation period. As it is known, the period before 2003 was the periods when the interest and inflation rates of the Turkish economy were much higher than today. For this reason, the fact that the effect of the initial conditions continues for a long time is an indication that the model produces realistic results. Prior to the 2008 financial crisis, while temporary technology shocks, investment specific technology shocks, and risk premium shocks played an important role in the downward movement of inflation, domestic producer markup shocks and consumption good importer markup shocks produced an upward trigger in inflation. We can see the effectiveness of monetary shocks in the 2008 financial crisis. After the 2008 financial crisis, the consumption good importer markup shocks and temporary technology shocks created an increasing effect on inflation. Technology shocks that persisted for a long time after 2014 had an increasing effect on inflation. At the same time, the impact of risk premium shocks is high. This risk premium shock effect is an indicator of the downward path of inflation. Asymmetric technology shocks also contributed to the downward movement in inflation. After the 2018 currency crisis, the consumption good importer markup shock role in suppressing inflation is high. In this period, permanent technology shocks and investment specific technology shocks are quite effective. During the estimation period, the effectiveness of monetary shocks is extremely ineffective compared to other shocks to reduce inflation. Only monetary shocks were effective at a low level during the period 2007-2009. In the post-currency crisis period, monetary policy decision makers implemented policies increasing inflation contrary to expectations.

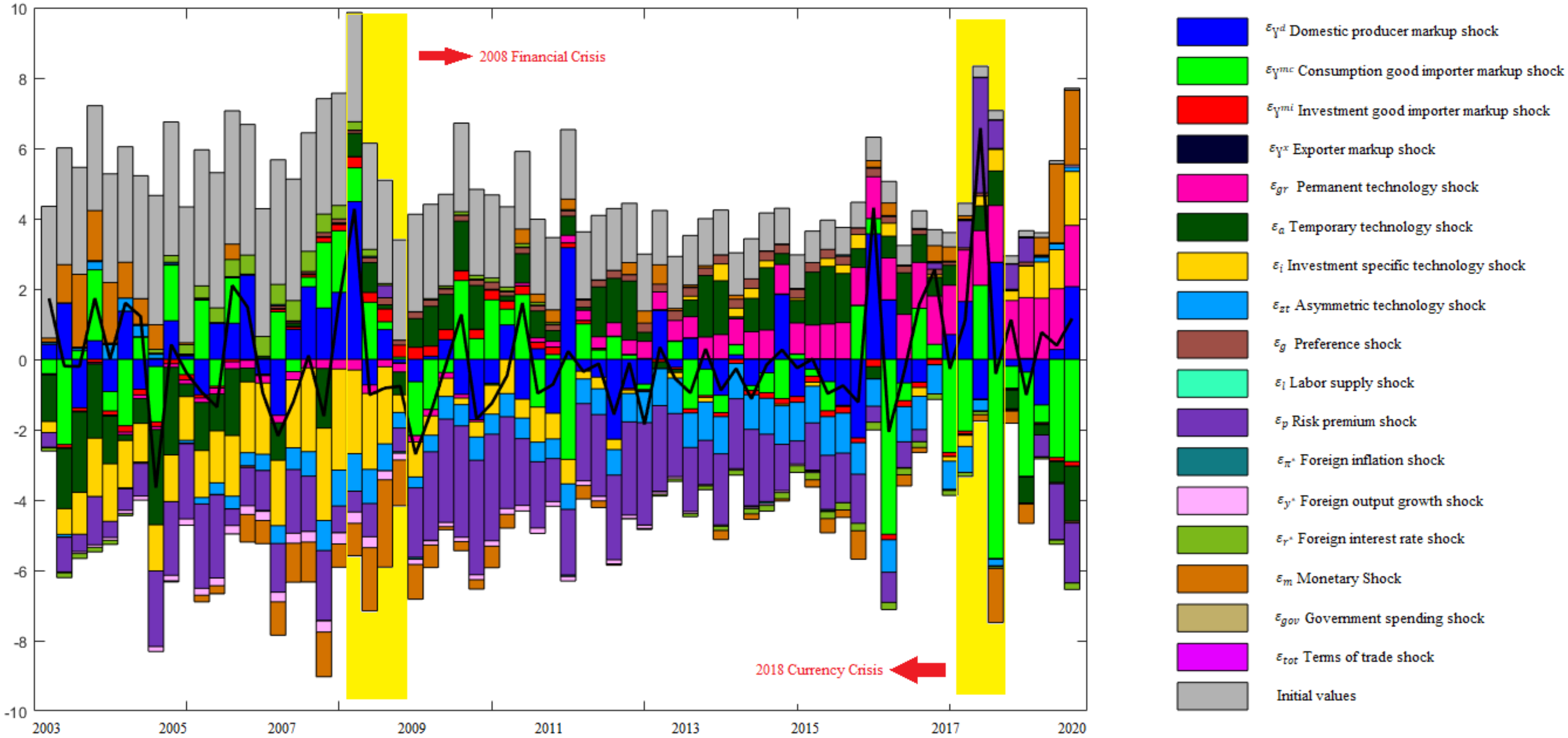

Figure 49 : Historical decomposition of inflation

5.7.5 Historical decomposition of consumption good inflation

Figure 50 shows the historical decomposition of consumption good inflation. According to the medium open economy model, the effect of initial conditions lasts until 2017. Before the 2018 financial crisis, monetary shocks and domestic producer markup shocks try to keep consumer goods inflation up. On the other hand, temporary technology shocks, investment specific technology shocks, and risk premium shocks put downward pressure on consumer goods inflation. This situation similarly continued in the 2008 financial crisis and immediately after it for a while. After the financial crisis of 2008, temporary technology shocks act to increase consumption good inflation. During this period, the impact of investment specific technology shocks has diminished. Risk premium shocks and asymmetric technology shock continued to put pressure on consumption good inflation for a long time. Since 2013, permanent technology shock have begun to follow a path to increase consumption good inflation and their intensity has increased steadily. In the period between 2008 and 2018, domestic producer markup shocks are mostly aimed at suppressing consumption good inflation. During the currency crisis of 2018 and beyond, permanent technology shocks exerted pressure to increase consumer goods inflation, while consumption goods importer markup shocks and temporary technology shocks followed a path towards reducing consumption goods inflation. Apart from all these, monetary shocks did not have a sufficient effect on consumption goods inflation.

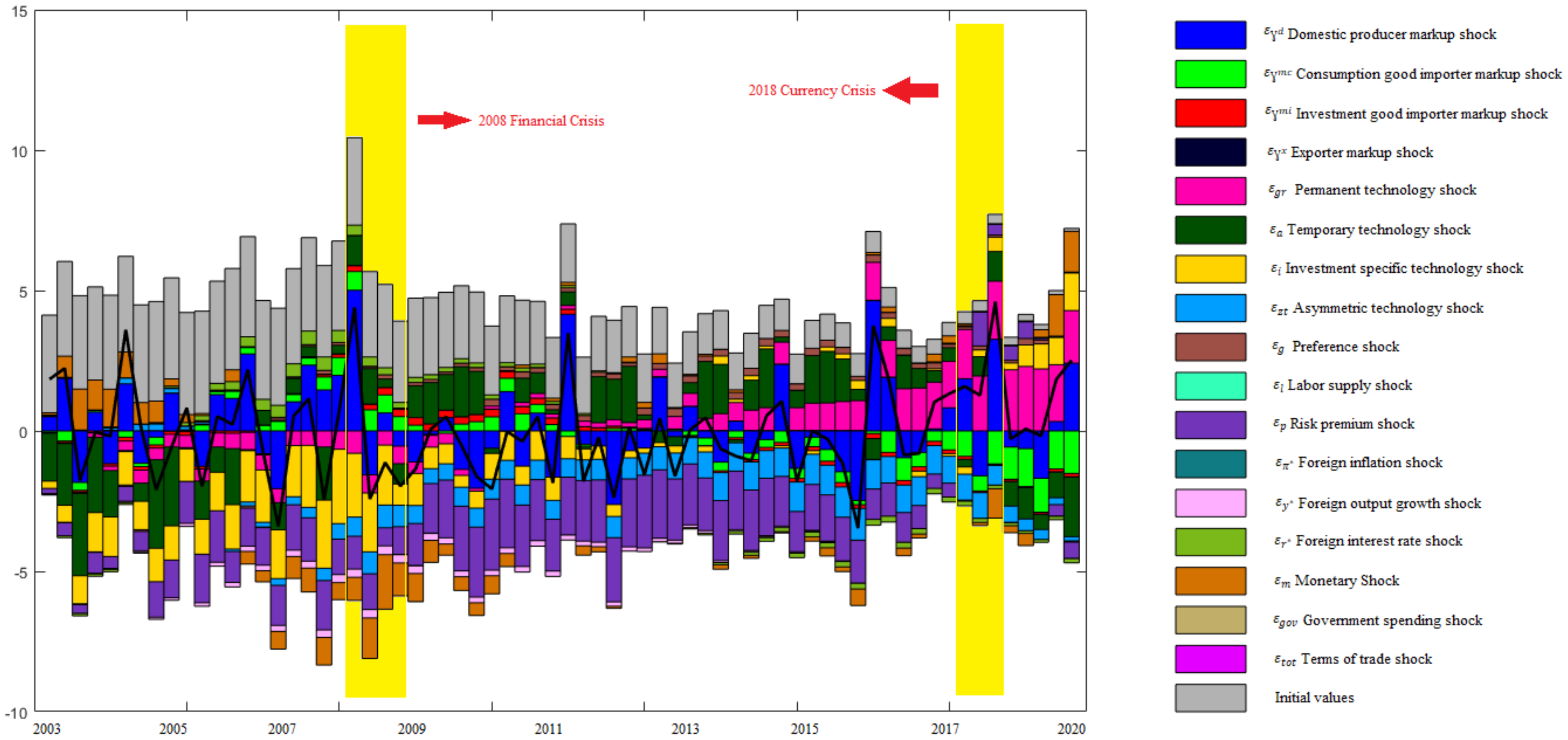

Figure 50 : Historical decomposition of consumption good inflation

5.7.6 Historical decomposition of investment good inflation

Historical decomposition of investment good inflation is shown in Figure 51. Initial conditions have been effective since the beginning of 2003 for a long time. Prior to the 2008 financial crisis, monetary shocks followed the direction to increase investment goods inflation for about eight periods, and monetary shocks in the last six or seven quarters before 2008 and even during the financial crisis put downward pressure on investment goods inflation. We see that the most effective shock in the decline of investment goods inflation in this period was the risk premium shock. permanent technology shocks, temporary technology shocks, and investment specific technology shocks have moved in the same direction with risk premium shocks. In the same period, after the suppression of the investment goods importers markup shocks to the investment goods inflation for a while, it turned into an intensifier shock until the 2008 financial crisis. After the 2008 financial crisis, we see that the impact of risk premium shocks on investment goods inflation gradually diminished. The investment goods importer markup shock has at times suppressed the investment goods inflation. Asymmetric technology shocks and domestic producer shocks have become more effective after the 2011 period. Contrary to all these shocks, permanent and temporary technology shocks have led to an increase in investment goods inflation. During the period leading up to the 2018 financial crisis, we observe a significant increase in investment goods inflation. One of the most important reasons for this increase is risk premium shocks. Immediately after the currency crisis, investment goods importers' markup shocks prevented the upward movement of investment goods inflation. In this period, investment goods inflation was tried to be brought under control by balancing risk premium shocks and monetary shocks. In the same period, we can say that investment specific technology shocks and asymmetric technology shocks were effective.

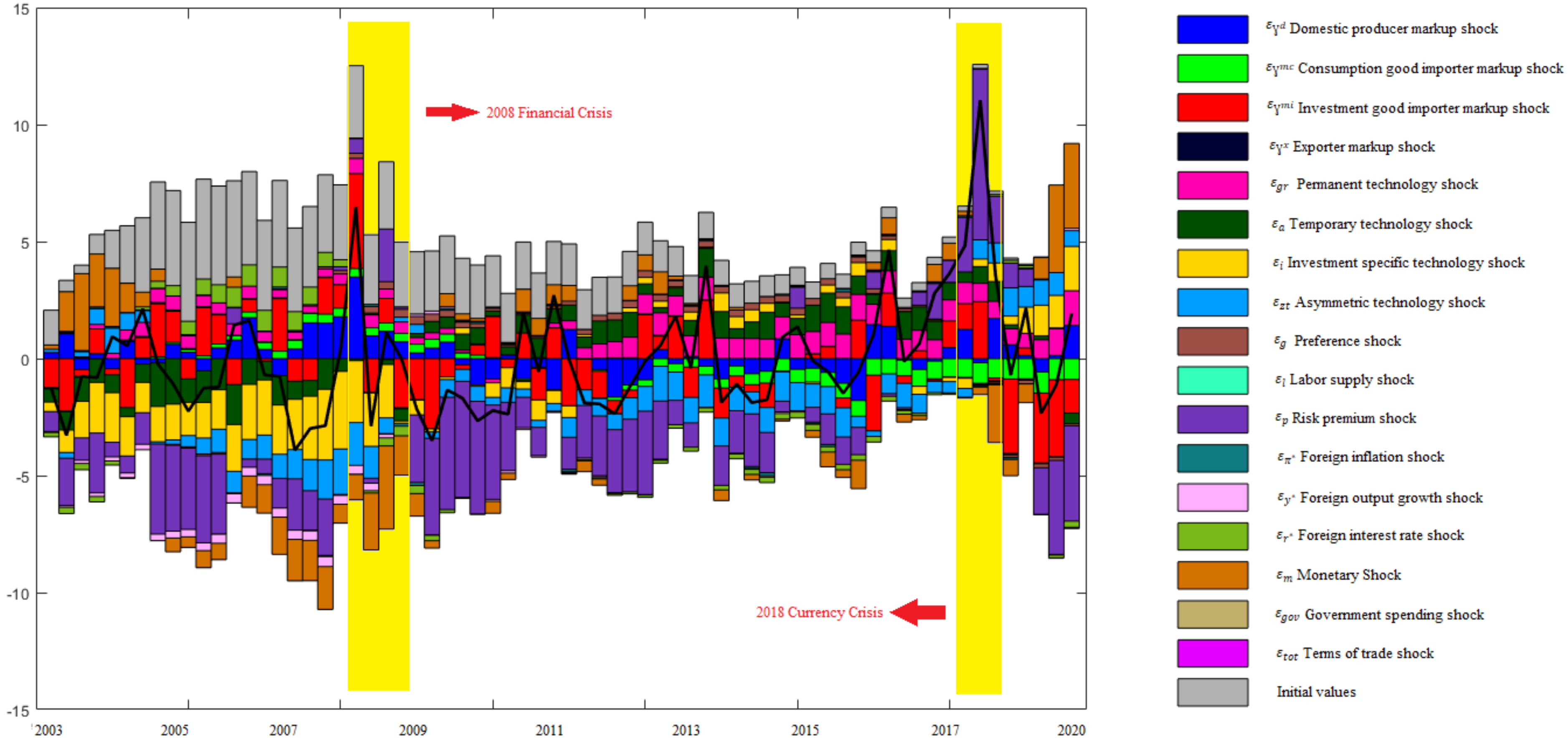

Figure 51 : Historical decomposition of investment good inflation

5.7.7 Historical decomposition of interest rate

Historical decomposition of interest rate is shown in Figure 52. In 2003, it was the period when interest rates were high. For this reason, the initial conditions are extremely effective and long-lasting. We can say that risk premium shocks and investment specific technology shocks are the main shocks in the decreasing interest rates towards the 2008 financial crisis. In particular, the effect of these shocks continues to 2015. However, monetary shocks and temporary technology shocks were effective in lowering interest rates for this pre-crisis period. On the other hand, the consumption goods importer markup shock and asymmetric technology shock triggered the interest rate upwards during the 2008 crisis. From the 2008 financial crisis until the end of the estimation period, the asymmetric technology shock emerges as a suppressive shock on the interest rate. Before the 2018 crisis, the domestic producer markup shock and the permanent technology shock increased continuously, causing the recent increase in interest rates. The exchange rate has continuously increased since 2014, and the shrinkage in the import market, on the contrary to the pre-2008 period, led to the pressure of the consumption goods importer markup shocks to lower the interest rate. The most striking point here is that the model's main reason for the increase in interest rates during and after the currency crisis in 2018 was the risk premium and monetary shocks. In the period after the currency crisis, interest rates were tried to be reduced by monetary shocks.

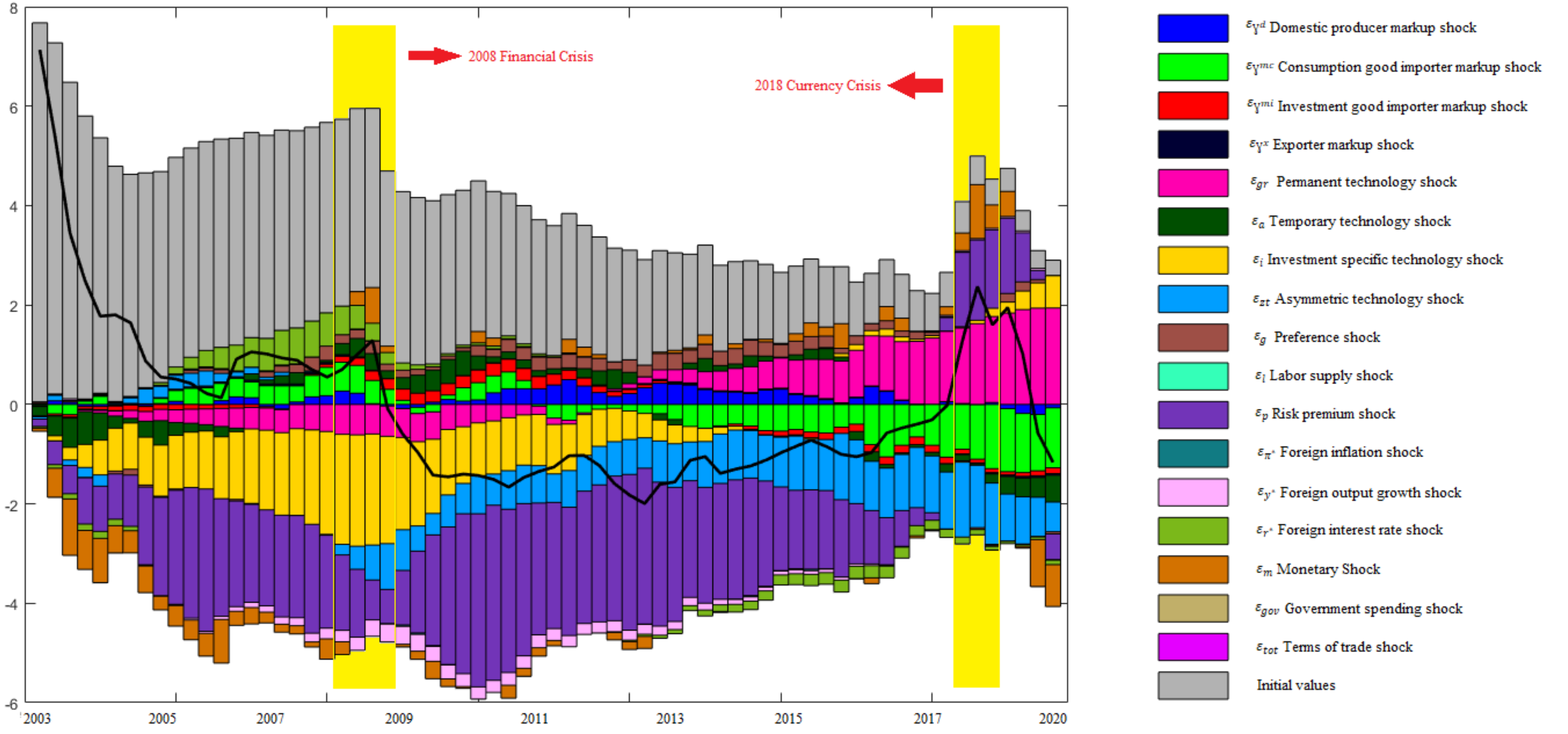

Figure 52 : Historical decomposition of interest rate

5.7.8 Historical decomposition of exchange rate

The historical decomposition of the exchange rate is given in Figure 53. Despite the financial crisis of 2008, the exchange rate continued to move with low volatility for a long time from 2003 to 2014. The effect of the initial conditions on the exchange rate did not last long. Only four quarters or so. In the period before the 2008 crisis, risk premium shocks, monetary shocks, and consumption goods importer markup shocks were the determinants of the volatility of exchange rates. Temporary technology shocks have also been effective in some periods. In the post-2008 period, the effectiveness of local producer markup shocks stands out. The sudden depreciation of the Turkish Lira, which is the main source of the 2018 exchange rate crisis, draws attention to the figure. Immediately afterwards, it was balanced with money shocks and risk premium shocks.

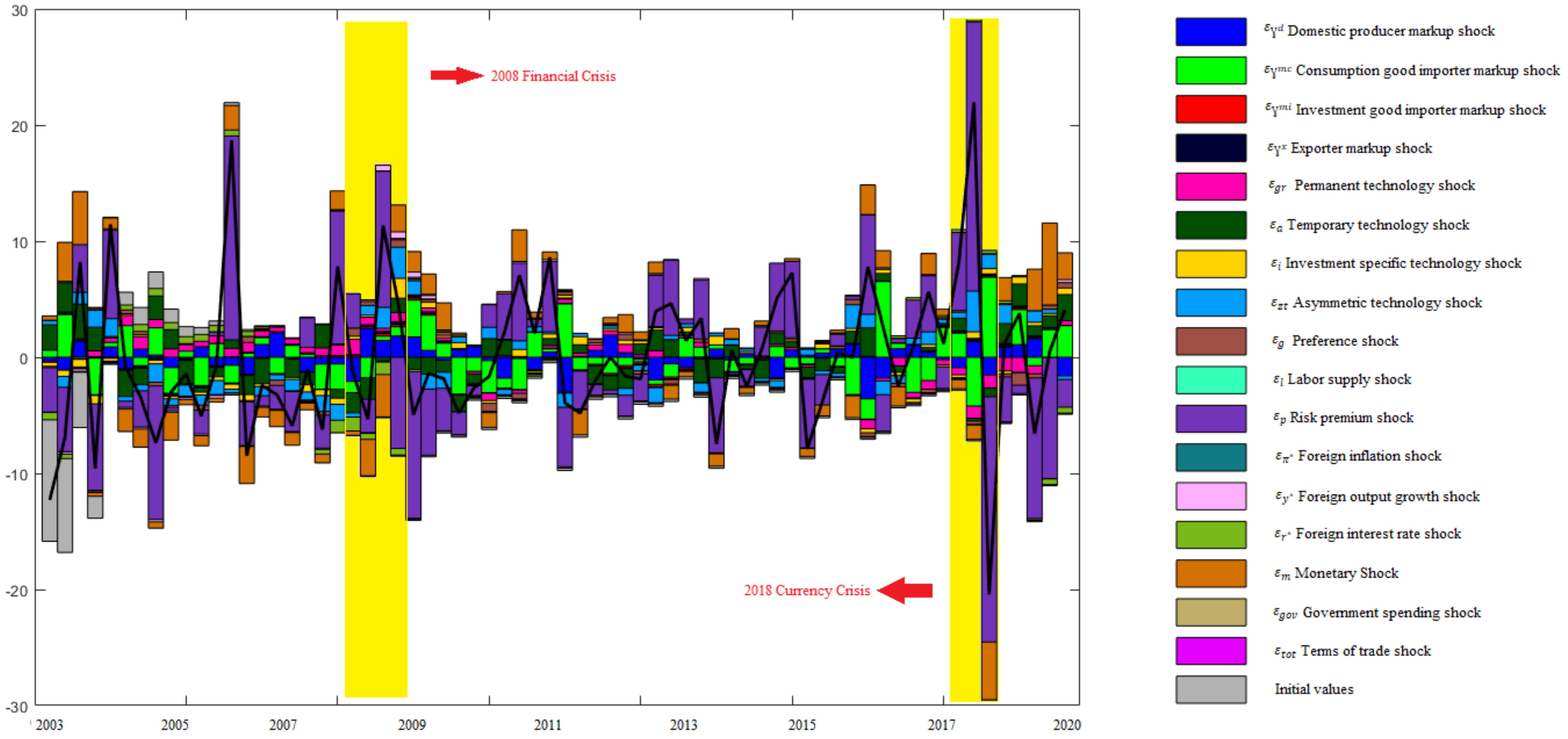

Figure 53 : Historical decomposition of exchange rate

5.7.9 Historical decomposition of terms of trade

Figure 54 is the historical decompositions of terms of trade. Prior to the 2008 global crisis, investment specific technology shocks had a negative pressure on terms of trade. However, asymmetric technology shocks and risk premium shocks were similarly effective. For this period, the effectiveness of consumption good importer shocks and permanent shocks moved towards balancing the terms of trade. When we come to the global crisis period, it is seen that the terms of trade is moving towards its steady state. Although there was an increasing trade volume in this period, asymmetric technology shocks prevented the further upward movement of terms of trade. After the 2008 crisis until 2010, there was a sharp decline in trade. At this point, risk premium shocks and trade shocks were effective. From 2010 to the currency crisis in 2018, risk premium shocks exerted a positive pressure, while asymmetric technology shocks exerted the opposite. Interestingly, the consumption good importer shocks between 2008 and 2018 do not seem to have a positive effect on terms of trade. In the period from 2017 to 2018 currency crisis, risk premium shocks have a positive pressure on terms of trade effectively. We think that this situation is related to the depreciation of the Turkish Lira. It is a natural result that attractive prices and wages increase sales in international markets. However, asymmetric technology shocks have emerged as an important obstacle. After the 2018 currency crisis, risk premium shocks created negative pressures on trade.

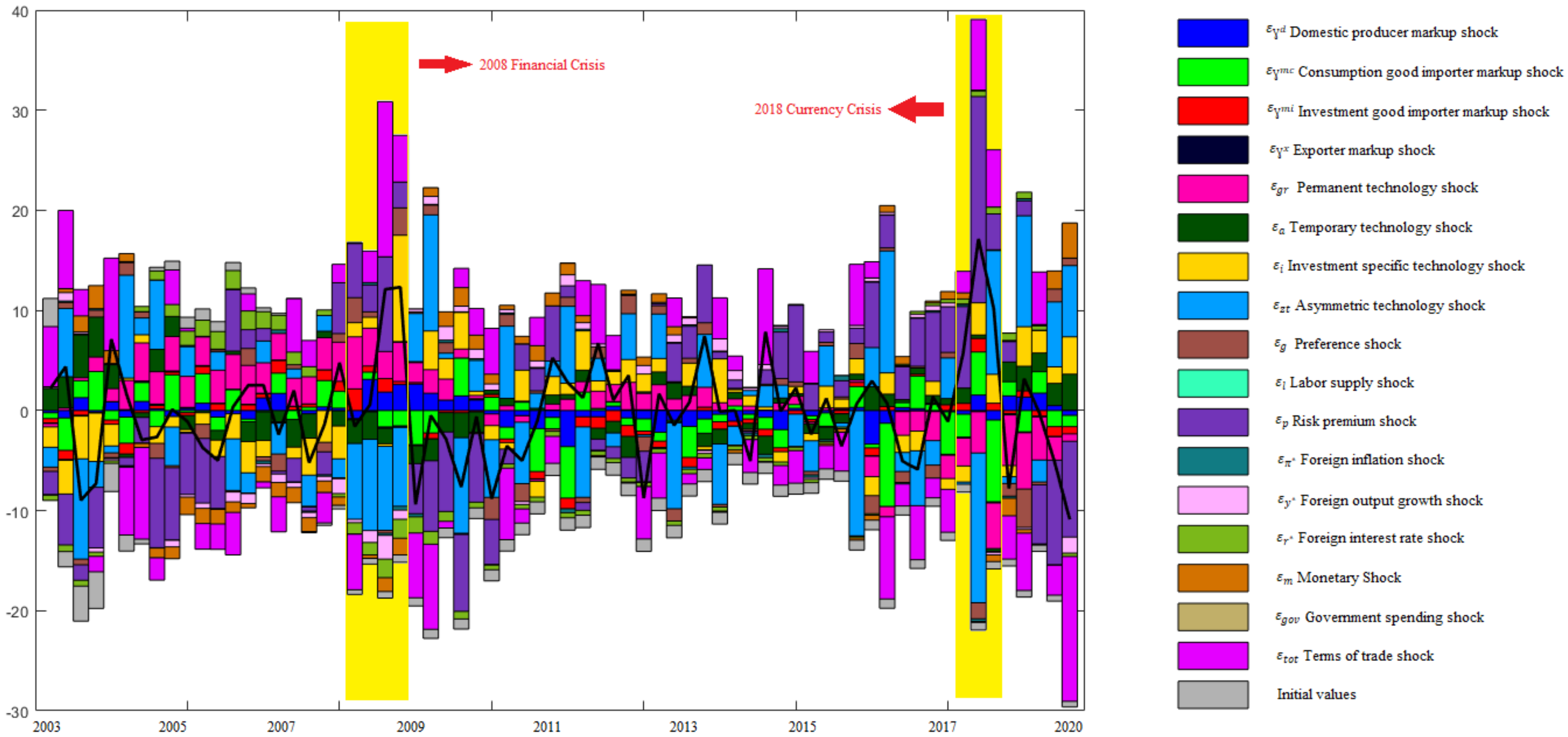

Figure 54 : Historical decomposition of terms of trade

5.7.10 Historical decomposition of employment

Historical decomposition of interest rate is shown in Figure 55. Following the 2001 financial crisis, there was a significant decrease in employment. We see that monetary policy shocks are quite effective in increasing employment after the crisis. During this period, as a result of the contraction in supply, the direction of the temporary technology shocks was to reduce employment. Until the 2008 financial crisis, temporary technology shocks and risk premium shocks had a positive impact on employment. The effectiveness of monetary contractions is striking both before the 2008 financial crisis and when the crisis is experienced. In this range, domestic producer markup shocks and consumption goods importer markup shocks, albeit small in intensity, have created positive pressures to increase employment. Employment continued to fluctuate after the 2008 financial crisis. In the period between the 2008 global crisis and the 2018 financial crisis, temporary technology shocks were more effective than permanent technology shocks. Consumption goods importer markup shocks were as effective as the effects of monetary policy shocks in the 2018 currency crisis. Later, the loss of employment was tried to be compensated with monetary steps.

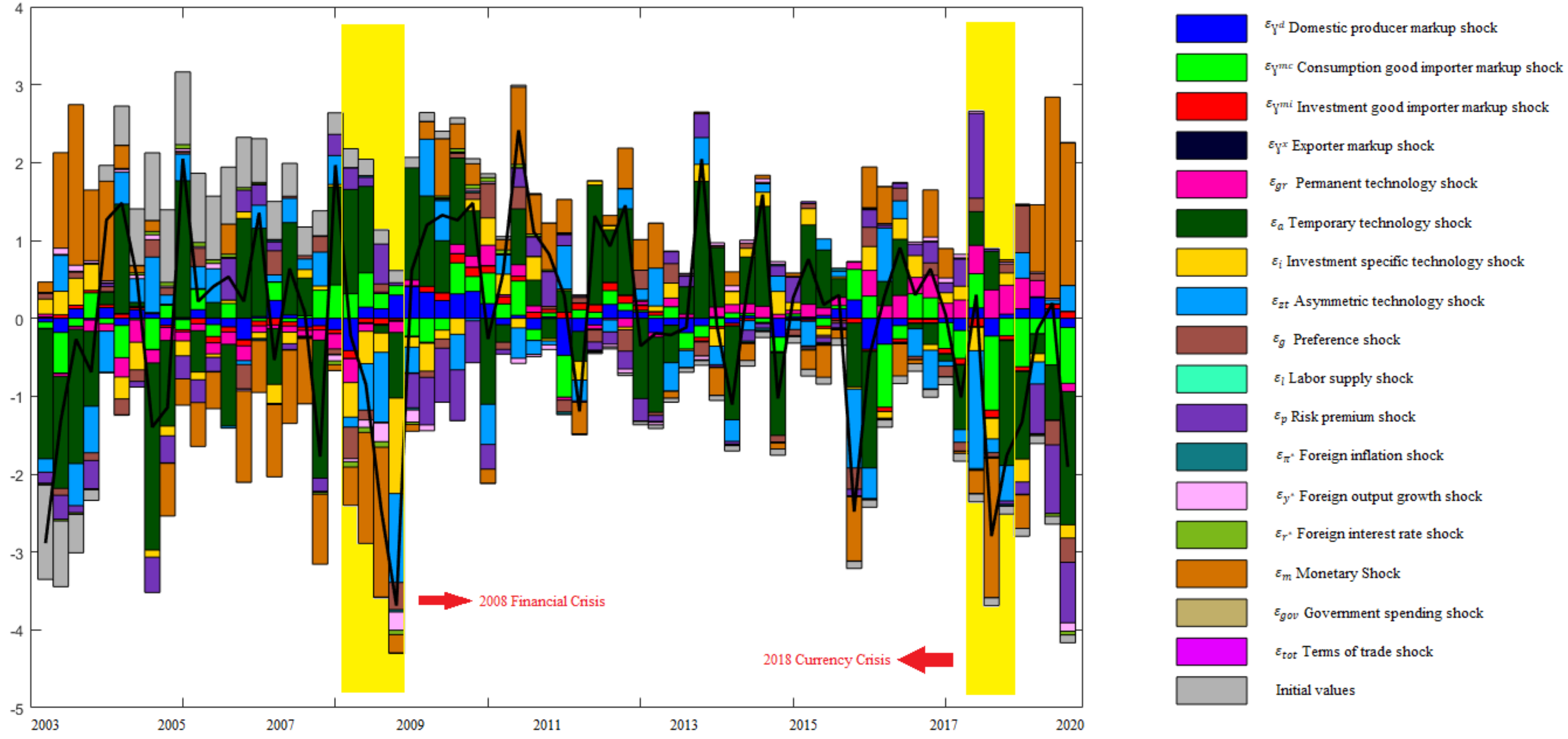

Figure 55 : Historical decomposition of employment

6. Conclusions

By extending our research to a middle open economy model in Chapter 4, we included several important sources of fluctuations. Moreover, the introduction of money holdings, investment, and capital adjustment costs are realistic and conducive to a comprehensive empirical performance. Model fit is not improved but provided an extensive explanation for the data variances.

In terms of Bayes Factor and Maximum Log-Likelihood, the model excluding price indexation and the model excluding exchange rate sensitivity of central bank are best to fit real data. On the other hand, habit formation, modified uncovered interest rate parity condition, and terms of trade shock improved the model fit. These findings are in line with the estimation results of small open economy model in Chapter 3. In terms of the standard deviations, all models generated relative high volatility compared to the real data. The model without habit formation performed successfully in generating contemporaneous correlations observed in the real data. The model without habit formation successfully generated cross-correlations observed in the real data. But model did not do a better job at matching the real data autocorrelations up to order one. The illustrated autocorrelations functions up to order 10 show that model exhibited inability to predict the dynamics of the real data except interest rates.

According to the benchmark model, monetary policy shocks account for around 44 % in output growth variances. Meanwhile, investment specific technology shocks is the second largest source of output growth fluctuations. The main driver of the consumption and investment is the permanent technology shocks. Regarding the inflation, investment specific technology shocks, consumption good importer markup shocks and risk premium shocks are the dominant sources. Interest rates in Turkey are mainly driven by risk premium shocks, investment specific technology shocks and permanent technology shocks.

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Appendix

Dynare 4.5.7 and Matlab Codes MOE

```
Var

pi_hat mc H_hat k_hat w_barhat rk_hat pi_mc mc_mc mc_x gamma_xstar

gamma_mcdhat pi_mi mc_mi gamma_midhat pi_x c_hat gamma_cdhat P_k

gamma_idhat i_hat R_hat dS Rstar_hat a g_hat ystar_hat z_tildestar k_barhat

u gamma_fhat pistar_hat x E lambda_dhat lambda_mchat lambda_mihat lambda_x

mu_zhat epsilon Upsilon zeta_c zeta_h phi_tilde cepsR pi_c y_hat psi_zhat

dy dc dinve pinfobs piedefc piedefi robs ysobs pinsobs rsobs erobs empobs

sobs ter tot;


varexo
epsilon_muz               // permanent technology growth shock

epsilon_epsilon           // temporary technology shock

epsilon_Upsilon           // investment specific technology shock

epsilon_ztildestar        // asymmetric technology shock

epsilon_lambdad           // domestic markup shock

epsilon_lambdamc          // consumption import markup shock

epsilon_lambdami          // investment import markup shock

epsilon_lambdax           // export markup shock

epsilon_zetac             // consumption preference shock

epsilon_zetah             // labor supply shock

epsilon_phitilde          // risk premium shock

epsilon_pistar            // Foreign inflation shock

epsilon_ystar             // Foreign output shock

epsilon_Rstar             // Foreign interest rate shock

epsilon_R                 // monetary policy shock

epsilon_g                 // government spending shock

epsilon_tot;              // terms of trade shock
```

```
Parameters
beta mu_z mu alpha A_L delta sigma_L lambda_w omega_c omega_i gr A_q
sigma_q sigma_a nu muip kappa_d kappa_mc kappa_mi kappa_x kappa_w
xi_d xi_mc xi_mi xi_x xi_w xi_e lambda_d lambda_mc lambda_mi
eta_c eta_i eta_f S_tilde b phi_a rho_R rho_pi rho_y rho_x rho_dpi rho_dy
condc condy condi conpinfobs conpiedefi conpiedefc conrobs conysobs
conpinsobs conrsobs conwobs conempobs conerobs condx condm consobs
rho_g rho_pistar rho_ystar rho_Rstar rho_lambdad rho_lambdamc rho_lambdami
rho_lambdax rho_muz rho_epsilon rho_Upsilon rho_ztildestar rho_zetac
rho_zetah rho_phitilde rho_cepsR epsg epspistar epsystar epsRstar
epslambdad epslambdamc epslambdami epslambdax epsmuz epsepsilon epsUpsilon
epsztildestar epszetac epszetah epsphitilde epscepsR rho_tot epstot;

beta        = 0.9975;   // discount factor
mu_z        = 1.0085;   // quarterly output growth 0.5 percent
mu          = 1.02;     // approximate M1 money growth 2 Percent quarterly
alpha       = 0.23;     // share of capital in production
delta       = 0.025;    // depreciation rate to match investment
gr          = 0.197;    // government exp. to GDP ratio
rho_pibar   = 0.975;    // persistence of inflation target
A_L         = 7.5;      // labor disutility function
A_q         = 0.378;    // cash to money ratio
sigma_L     = 5;        // labor supply elasticity
sigma_q     = 10.62;    // curvature parameter related to money demand
sigma_a     = 1000000;  // capacity utilization elasticity
omega_c     = 0.36;     // share of imports in aggregate consumption
```

```
omega_i     = 0.48;     // share of imports in aggregate investment

muip        = 0.50;     // modified uncovered interest rate parity param.

// indexation parameters

kappa_d     = 0.5;      // Indexation domestic prices

kappa_mc    = 0.5;      // Indexation import cons. prices

kappa_mi    = 0.5;      // Indexation import invest. prices

kappa_x     = 0.5;      // Indexation export prices

kappa_w     = 0.5;      // Indexation wages

// calvo price setting

xi_d        = 0.715;    // Calvo domestic prices

xi_mc       = 0.675;    // Calvo import cons. prices

xi_mi       = 0.675;    // Calvo import invest. prices

xi_x        = 0.675;    // Calvo export prices

xi_w        = 0.675;    // Calvo wages

xi_e        = 0.675;    // Calvo employment

// markups

lambda_d    = 1.1;      // markup domestic

lambda_mc   = 1.2;      // markup imported consump.

lambda_mi   = 1.2;      // markup power in wage setting

lambda_w    = 1.05;     // markup power in wage setting

// elasticity parameters

eta_c       = 1.5;      // elasticity of sustitution between domestic and
                        // foreign consumption goods
eta_i       = 1.0085;   // elasticity of sustitution between domestic and
                        // foreign investment goods
eta_f       = 1.25;     // elasticity of sustitution between foreign goods
```

```
S_tilde      = 7.694;    // investment adjustment cost
b            = 0.650;    // habit formation
phi_a        = 0.01;     // risk premium
// central bank parameters
rho_R        = 0.8;
rho_pi       = 1.7;
rho_y        = 0.25;
rho_x        = 0.01;
rho_dpi      = 0.3;
rho_dy       = 0.125;
// measurement equations
condc        = 0.7433;
condy        = 0.9166;
condi        = 1.4747;
conpinfobs   = 2.2217;
conpiedefi   = 2.0938;
conpiedefc   = 2.2059;
conrobs      = 3.6821;
conysobs     = 0.48889;
conpinsobs   = 0.4765;
conrsobs     = 0.3524;
conwobs      = 0.5266;
conempobs    = 0.8405;
```

```
conerobs        = 0.7433;

consobs         = 0;

// persistence parameters of shocks

rho_muz         = 0.80;

rho_epsilon     = 0.80;

rho_Upsilon     = 0.80;

rho_ztildestar  = 0.80;

rho_zetac       = 0.80;

rho_zetah       = 0.80;

rho_phitilde    = 0.80;

rho_lambdad     = 0.80;

rho_lambdamc    = 0.80;

rho_lambdami    = 0.80;

rho_lambdax     = 0.80;

rho_g           = 0.80;

rho_pistar      = 0.80;

rho_ystar       = 0.80;

rho_Rstar       = 0.80;

rho_cepsR       = 0.80;

rho_tot         = 0.50;

// Std. Dev. of shocks

epsmuz          = 0.50;

epsepsilon      = 0.50;

epsUpsilon      = 0.50;
```

```
epsmuz          = 0.50;

epsepsilon      = 0.50;

epsUpsilon      = 0.50;

epsztildestar   = 0.50;

epszetac        = 0.50;

epszetah        = 0.50;

epsphitilde     = 0.50;

epslambdad      = 0.50;

epslambdamc     = 0.50;

epslambdami     = 0.50;

epslambdax      = 0.50;

epscepsR        = 0.50;

epsg            = 0.50;

epspistar       = 0.50;

epsystar        = 0.50;

epsRstar        = 0.50;

epstot          = 0.50;


model(linear);

#pi=mu/mu_z;

#b_w=(lambda_w*sigma_L-(1-lambda_w))/((1-beta*xi_w)*(1-xi_w));

#eta_0=b_w*xi_w;

#eta_1=(sigma_L*lambda_w-b_w*(1+beta*xi_w^2));

#eta_2=b_w*beta*xi_w;

#eta_3=-b_w*xi_w;

#eta_4=b_w*beta*xi_w;
```

```
#eta_5=b_w*xi_w*kappa_w;

#eta_6=-b_w*beta*xi_w*kappa_w;

#eta_7=(1-lambda_w);

#eta_8=-(1-lambda_w)*sigma_L;

#eta_9=-(1-lambda_w);

#eta_10=-(1-lambda_w);

#eta_11=-(1-lambda_w);

#eta_mi=lambda_mi/(lambda_mi-1);

#gamma_imi=((1-omega_i)*((eta_mi-1)/eta_mi)^(1-eta_i)+omega_i)^(1/(1-
eta_i));

#R=(pi*mu_z-beta)/beta;

#R_f=nu*R+1-nu;

#gamma_id=((1-omega_i)+omega_i*(eta_mi/(eta_mi-1))^(1-eta_i))^(1/(1-
eta_i));

#r_k=(mu_z*gamma_id-beta*(1-delta)*gamma_id)/beta;

#w_bar= (1-alpha)*lambda_d^(-1/(1-alpha))*alpha^(alpha/(1-alpha))*r_k^(-
alpha/(1-alpha))*R_f^(-1);

#k_H=alpha/(1-alpha)*mu_z*w_bar*R_f*r_k^(-1);

#D2=(1-gr)/lambda_d*mu_z^(-alpha)*k_H^alpha-((1-
omega_i)*gamma_id^eta_i+omega_i*gamma_imi^eta_i)*(1-(1-delta)/mu_z)*k_H;

#eta_mc=lambda_mc/(lambda_mc-1);

#gamma_cd=((1-omega_c)+omega_c*(eta_mc/(eta_mc-1))^(1-eta_c))^(1/(1-
eta_c));

#D4=((mu_z-beta*b)/((mu_z-b)))*gamma_cd^(-1);

#D3=(((1)/lambda_w*w_bar/(1))/A_L)^(1/sigma_L);

#gamma_cmc=((1-omega_c)*((eta_mc-1)/eta_mc)^(1-eta_c)+omega_c)^(1/(1-
eta_c));

#D1=(1-omega_c)*gamma_cd^eta_c+omega_c*gamma_cmc^eta_c;

#H=(D3*D4^(1/sigma_L)*(D2/D1)^(-1/sigma_L))^(sigma_L/(1+sigma_L));

#y_bar=1/lambda_d*(mu_z)^(-alpha)*(k_H)^alpha*H;

#k=k_H*H;
```

```
#c=D2/D1*H;

#psi_z=1/c*D4;

#q=(A_q/(psi_z*(R-1)))^(1/sigma_q);

#m_bar=nu*w_bar*H+q;

#i=(1-(1-delta)/mu_z)*k;

#c_m =omega_c*gamma_cmc^eta_c*c;

#i_m=omega_i*gamma_imi^eta_i*i;

#y_star=omega_c*gamma_cmc^eta_c*c+omega_i*gamma_imi^eta_i*i;

#gamma_dc=1/gamma_cd;

#gamma_mcc=1/gamma_cmc;

#gamma_mii=1/gamma_imi;

#k_bar=k;

#i_d=(1-omega_i)*gamma_id^eta_i*i;   // same procedure as i_m

#c_d = (1-omega_c)*gamma_cd^eta_c*c;

#pistar=1.005;


// Firms

// Domestic Goods

// Production

y_hat=lambda_d*(epsilon+alpha*(k_hat-mu_zhat)+(1-alpha)*H_hat);


// Renatal Rate of Capital

rk_hat=mu_zhat+w_barhat+H_hat-k_hat;

// Real Marginal Cost

mc=alpha*rk_hat+((1-alpha)* w_barhat)-epsilon;


// New Keynesian Philips Curve

pi_hat=((beta/(1+kappa_d*beta))*(pi_hat(+1))) +

((kappa_d/(1+kappa_d*beta))*(pi_hat(-1))) +

(((1-xi_d)*(1-xi_d*beta))/(xi_d*(1+kappa_d*beta)))*(mc+lambda_dhat);
```

```
// Imported Goods
// New Keynesian Philips Curve:Imported Consumption Goods
pi_mc=((beta/(1+kappa_mc*beta))*(pi_mc(+1))) +
((kappa_mc/(1+kappa_mc*beta))*(pi_mc(-1))) +
(((1-xi_mc)*(1-xi_mc*beta))/(xi_mc*(1+kappa_mc*beta)))*(mc_mc
+lambda_mchat);

// Marginal Cost: imported consumption goods
mc_mc=-gamma_xstar-gamma_mcdhat;

// New Keynesian Philips Curve:Imported Investment Goods
pi_mi=((beta/(1+kappa_mi*beta))*(pi_mi(+1))) +
((kappa_mi/(1+kappa_mi*beta))*(pi_mi(-1))) +
(((1-xi_mi)*(1-xi_mi*beta))/(xi_mi*(1+kappa_mi*beta)))*(mc_mi +
lambda_mihat);

// Marginal Cost: imported investment goods
mc_mi=-gamma_xstar-gamma_midhat;

// New Keynesian Philips Curve:Exported Goods
pi_x=((beta/(1+kappa_x*beta))*(pi_x(+1))) +
((kappa_x/(1+kappa_x*beta))*(pi_x(-1))) +
(((1-xi_x)*(1-xi_x*beta))/(xi_x*(1+kappa_x*beta)))*(mc_x + lambda_x);

// Marginal Cost: exported goods
mc_x=mc_x(-1)+pi_hat-pi_x-dS;

// Households
// Wage setting
```

```
w_barhat=-(1/eta_1)*(eta_0*w_barhat(-
1)+eta_2*w_barhat(+1)+eta_3*(pi_hat)+eta_4*(pi_hat(+1))+eta_5*(pi_c(-
1))+eta_6*(pi_c)+eta_7*psi_zhat+eta_8*H_hat+ eta_11*zeta_h);


// Consumption Euler Equation
c_hat=((1/(mu_z^2+b^2*beta))*(mu_z*b*c_hat(-1)))+
((1/(mu_z^2+b^2*beta))*(beta*mu_z*b*c_hat(+1)))-
((1/(mu_z^2+b^2*beta))*(mu_z*b*(mu_zhat-beta*mu_zhat(+1))))-
((1/(mu_z^2+b^2*beta))*(mu_z-b*beta)*(mu_z-b)*(psi_zhat+gamma_cdhat))+
((1/(mu_z^2+b^2*beta))*(mu_z-b)*(mu_z*zeta_c-b*beta*zeta_c(+1)));


// Investment Euler Equation
i_hat=((1/(1+beta))*(i_hat(+1)+i_hat(-1)+(beta*mu_zhat(+1))-mu_zhat))+
((1/(mu_z^2*S_tilde*(1+beta)))*(P_k+Upsilon-gamma_idhat));


// Price of Installed Capital
P_k=((1/mu_z)*(beta*(1-delta))*P_k(+1))+psi_zhat(+1)-psi_zhat-
mu_zhat(+1)+(((mu_z-beta*(1-delta))/mu_z)*rk_hat(+1));


// Capital's law of motion
k_barhat=((1-delta)*(1/mu_z)*(k_barhat(-1)-mu_zhat))+(1-((1-
delta)*(1/mu_z)))*(i_hat+Upsilon);


// Capital utilisation
u=(1/sigma_a)*rk_hat;


// Capital services
k_hat=k_barhat+u;


// Optimal asset holdings
```

```
psi_zhat= (psi_zhat(+1)-mu_zhat(+1))+(R_hat-pi_hat(+1));


// Modified UIP condition

R_hat-Rstar_hat=((1-muip)*dS(+1))-(muip*dS)-phi_a*a+phi_tilde;


// The Central Bank

// Taylor Rule

R_hat=rho_R*R_hat(-1)+

((1-rho_R)*((rho_pi*pi_c(+1))+(rho_y*(y_hat(-1)))+(rho_x*(x(-1)))))+

rho_dpi*(pi_c-pi_c(-1))+rho_dy*(y_hat-y_hat(-1))+cepsR;


// CPI inflation

pi_c=((1-omega_c)*((gamma_dc)^(1-eta_c)))*pi_hat+

((omega_c)*((gamma_mcc)^(1-eta_c)))*pi_mc;


// Relative Prices

// Consumption and Invsestment goods

gamma_cdhat=omega_c*(gamma_mcc)^(1-eta_c)*gamma_mcdhat;

gamma_idhat=omega_i*(gamma_mii)^(1-eta_i)*gamma_midhat;


// Imported Consumption goods

gamma_mcdhat=gamma_mcdhat(-1)+pi_mc-pi_hat;

gamma_midhat=gamma_midhat(-1)+pi_mi-pi_hat;


// Export goods

gamma_xstar=gamma_xstar(-1)+pi_x-pistar_hat;


// Domestic and foreign goods relative price

gamma_fhat=mc_x+gamma_xstar;
```

```
// Real exchange rate
x=((-omega_c)*((1/gamma_cmc)^(eta_c-1))*gamma_mcdhat)-gamma_xstar-mc_x;


// Market Clearing
// Domestic goods market
y_hat=((1-omega_c)*(gamma_cd^eta_c)*(c/y_bar)*(c_hat+eta_c*gamma_cdhat))+
((1-omega_i)*(gamma_id^eta_i)*(i/y_bar)*(i_hat+eta_i*gamma_idhat))+
((gr*g_hat)+(y_star/y_bar)*(ystar_hat-eta_f*gamma_xstar+z_tildestar))+
((r_k*k_bar)/(y_bar*mu_z))*(k_hat-k_barhat(-1));


// Foreign bond market
a=(-y_star*mc_x)-
(eta_f*y_star*gamma_xstar)+(y_star*ystar_hat)+(y_star*z_tildestar)+((c_m+i_
m)*gamma_fhat)-
(c_m*(-eta_c*(1-omega_c)*((gamma_cd)^(eta_c-1))*gamma_mcdhat)+c_hat)+
(i_m*(-eta_i*(1-omega_i)*((gamma_id)^(eta_i-1))*gamma_midhat)+i_hat)+
((pistar/pi)*(1/beta)*a(-1));


// Employment
E=beta/(1+beta)*E(+1)+(1/(1+beta))*E(-1)+((1-xi_e)*(1-
beta*xi_e))/((1+beta)*xi_e)*(H_hat-E);


// Ar(1) Shock processes
// Domestic Shocks
zeta_c      = rho_zetac*zeta_c(-1)          + epszetac*epsilon_zetac;
Upsilon     = rho_Upsilon*Upsilon(-1)       + epsUpsilon*epsilon_Upsilon;
phi_tilde   = rho_phitilde*phi_tilde(-1)    + epsphitilde*epsilon_phitilde;
epsilon     = rho_epsilon*epsilon(-1)       + epsepsilon*epsilon_epsilon;
zeta_h      = rho_zetah*zeta_h(-1)          + epszetah*epsilon_zetah;
lambda_x    = rho_lambdax*lambda_x(-1)      + epslambdax*epsilon_lambdax;
```

```
lambda_dhat = rho_lambdad*lambda_dhat(-1)   + epslambdad*epsilon_lambdad;

lambda_mchat= rho_lambdamc*lambda_mchat(-1) + epslambdamc*epsilon_lambdamc;

lambda_mihat= rho_lambdami*lambda_mihat(-1) + epslambdami*epsilon_lambdami;

z_tildestar = rho_ztildestar*z_tildestar(-1)+

epsztildestar*epsilon_ztildestar;

mu_zhat     = rho_muz*mu_zhat(-1)            + epsmuz*epsilon_muz;

g_hat       = rho_g*g_hat(-1)                + epsg*epsilon_g;

cepsR       = rho_cepsR*cepsR(-1)            + epscepsR*epsilon_R;

tot         = rho_tot*tot(-1) + epstot*epsilon_tot;


// Foreign Shocks

pistar_hat  = rho_pistar*pistar_hat(-1)      + epspistar*epsilon_pistar;

ystar_hat   = rho_ystar*ystar_hat(-1)        + epsystar*epsilon_ystar;

Rstar_hat   = rho_Rstar*Rstar_hat(-1)        + epsRstar*epsilon_Rstar;


// Measurement Equations

dy = y_hat - y_hat(-1) + condy;

dc = c_hat-c_hat(-1) +

(((((1/(c_d+c_m))*eta_c)*(c_d)*(omega_c)*((gamma_cmc)^(eta_c-1)))-

(((1/(c_d+c_m))*eta_c)*(c_m)*(omega_c)*((gamma_cd)^(eta_c-1))))*(pi_mc-

pi_hat))+condc;

dinve = i_hat-i_hat(-1) +

(((((1/(i_d+i_m))*eta_i)*(i_d)*(omega_i)*((gamma_imi)^(eta_i-1)))-

(((1/(i_d+i_m))*eta_i)*(i_m)*(omega_i)*((gamma_id)^(eta_i-1))))*(pi_mc-

pi_hat))+condi;

ysobs=ystar_hat-ystar_hat(-1)+conysobs;

pinfobs=pi_c+conpinfobs;

piedefc=pi_hat+conpiedefc;

piedefi=pi_mi+conpiedefi;

pinsobs=pistar_hat+conpinsobs;

robs=R_hat+conrobs;
```

```
rsobs=Rstar_hat+conrsobs;
erobs=x-x(-1)+conerobs;
empobs=E-E(-1)+conempobs;
ter=(((-eta_f*(pi_x-pistar_hat))+ystar_hat-ystar_hat(-1)+(z_tildestar-
z_tildestar(-1)))-
((c_m/(c_m+i_m))*(c_hat-c_hat(-1))+(c_m/(c_m+i_m))*eta_c*(1-
omega_c)*(1/(gamma_cd^(1-eta_c)))*(pi_hat-pi_mc)
+(i_m/(c_m+i_m))*(i_hat-i_hat(-1))+(i_m/(c_m+i_m))*eta_i*(1-
omega_i)*(1/(gamma_id^(1-eta_i)))*(pi_hat-pi_mi)));
sobs=ter+tot+consobs;
end;

steady_state_model;
dy=condy;
dc=condc;
dinve=condi;
ysobs=conysobs;
pinfobs=conpinfobs;
piedefc=conpiedefc;
piedefi=conpiedefi;
pinsobs=conpinsobs;
robs=conrobs;
rsobs=conrsobs;
erobs=conerobs;
empobs=conempobs;
sobs=consobs;
end;

shocks;
var epsilon_lambdad;        stderr 1;
var epsilon_lambdamc;       stderr 1;
```

```
var epsilon_lambdami;       stderr 1;
var epsilon_lambdax;        stderr 1;
var epsilon_muz;            stderr 1;
var epsilon_epsilon;        stderr 1;
var epsilon_Upsilon;        stderr 1;
var epsilon_ztildestar;     stderr 1;
var epsilon_zetac;          stderr 1;
var epsilon_zetah;          stderr 1;
var epsilon_phitilde;       stderr 1;
var epsilon_pistar;         stderr 1;
var epsilon_ystar;          stderr 1;
var epsilon_Rstar;          stderr 1;
var epsilon_R;              stderr 1;
var epsilon_g;              stderr 1;
var epsilon_tot;            stderr 1;
end;

estimated_params;
kappa_d,            BETA_PDF,           0.50,               0.15;
kappa_mc,           BETA_PDF,           0.50,               0.15;
kappa_mi,           BETA_PDF,           0.50,               0.15;
kappa_x,            BETA_PDF,           0.50,               0.15;
xi_d,               BETA_PDF,           0.715,              0.05;
xi_mc,              BETA_PDF,           0.675,              0.10;
xi_mi,              BETA_PDF,           0.675,              0.10;
xi_x,               BETA_PDF,           0.675,              0.10;
xi_e,               BETA_PDF,           0.675,              0.10;
S_tilde,            NORMAL_PDF,         7.694,              1.50;
b,                  BETA_PDF,           0.65,               0.10;
muip,               UNIFORM_PDF,        0.50,               0.25;
```

```
rho_R,              BETA_PDF,           0.80,               0.050;
rho_pi,             NORMAL_PDF,         1.70,               0.100;
rho_y,              NORMAL_PDF,         0.25,               0.050;
rho_x,              NORMAL_PDF,         0.01,               0.050;
rho_dpi,            NORMAL_PDF,         0.3,                0.100;
rho_dy,             NORMAL_PDF,         0.125,              0.050;

rho_muz,            BETA_PDF,           0.80,               0.10;
rho_epsilon,        BETA_PDF,           0.80,               0.10;
rho_Upsilon,        BETA_PDF,           0.80,               0.10;
rho_ztildestar,     BETA_PDF,           0.80,               0.10;
rho_ztildestar,     BETA_PDF,           0.80,               0.10;
rho_zetac,          BETA_PDF,           0.80,               0.10;
rho_zetah,          BETA_PDF,           0.80,               0.10;
rho_phitilde,       BETA_PDF,           0.80,               0.10;
rho_lambdamc,       BETA_PDF,           0.80,               0.10;
rho_lambdami,       BETA_PDF,           0.80,               0.10;
rho_lambdax,        BETA_PDF,           0.80,               0.10;
rho_lambdad,        BETA_PDF,           0.80,               0.10;
rho_tot,            BETA_PDF,           0.80,               0.10;

epsmuz,             INV_GAMMA_PDF,      0.50,               inf;
epsepsilon,         INV_GAMMA_PDF,      0.50,               inf;
epsUpsilon,         INV_GAMMA_PDF,      0.50,               inf;
epsztildestar,      INV_GAMMA_PDF,      0.50,               inf;
epszetac,           INV_GAMMA_PDF,      0.50,               inf;
epszetah,           INV_GAMMA_PDF,      0.50,               inf;
epsphitilde,        INV_GAMMA_PDF,      0.50,               inf;
epslambdad,         INV_GAMMA_PDF,      0.50,               inf;
```

```
epslambdamc,        INV_GAMMA_PDF,     0.50,              inf;
epslambdami,        INV_GAMMA_PDF,     0.50,              inf;
epslambdax,         INV_GAMMA_PDF,     0.50,              inf;
epscepsR,           INV_GAMMA_PDF,     0.50,              inf;
epstot,             INV_GAMMA_PDF,     0.50,              inf;
end;



varobs
dy dc dinve pinfobs piedefc piedefi robs ysobs pinsobs rsobs sobs erobs
empobs;

options_.plot_priors=0;
model_diagnostics;                    // identification
identification (advanced=1);          // identification

estimation(datafile=Turkey_moe_3103,mode_compute=0,first_obs=1,presample=4,
prefilter=0,mh_replic=500000,mh_nblocks=2,mh_jscale=0.17,mh_drop=0.2);

stoch_simul(irf=40,ar=10) y_hat c_hat i_hat  pi_c  pi_mc pi_mi R_hat x ter
E ;

// produce historical decomposition
shock_decomposition (parameter_set=posterior_mean) dy dc dinve pinfobs
piedefc piedefi robs erobs sobs empobs;
```

Attendance Certificate -1

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14 September 2020

To whom it may concern

Certificate of Attendance at the CIMS Summer School on DSGE Macroeconomic Modelling and Conference

This confirms the attendance of **Mustafa Demirok** at the University of Surrey, Centre for International Macroeconomic Studies (CIMS) Summer School and conference on DSGE Macroeconomic Modelling 7th September – 12th September 2020.

Course: **Foundation**
Option: **DSGE-VAR Models and Forecasting**

If you require any further information please do not hesitate to get in touch with the CIMS team at cims@surrey.ac.uk.

Yours faithfully

Helen Dee
Assistant to Professor Joao Santos Silva
and School Administrator

Attendance Certificate -2

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15 April 2021

To whom it may concern

Certificate of Attendance at the CIMS Easter School on Macroeconomic Modelling and Policy

This confirms the attendance of **Mustafa Demirok** at the University of Surrey, Centre for International Macroeconomic Studies (CIMS) Easter School on Macroeconomic Modelling and Policy 6th April – 9th April 2021.

If you require any further information please do not hesitate to get in touch with the CIMS team at cims@surrey.ac.uk.

Yours faithfully

Helen Dee
Assistant to Professor Maurizio Zanardi
and School Administrator

Attendance Certificate -3

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CERTIFICATE OF PARTICIPATION

This is to certify that

Mustafa Demirok

presented

Impact of Domestic and Foreign Shocks in an Estimated New Keynesian Small Open Economy Model: Evidence from Turkey

Co-authored by Mustafa Demirok, Yeditepe University, and Veysel Ulusoy, Yeditepe University

at the

Midwest Economics Association
2021 Annual Meeting

held from

22-26 March 2021