

# **NEW KEYNESIAN SMALL OPEN ECONOMY: TURKISH CASE**



A Master's Thesis

by

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Economics

İhsan Doğramacı Bilkent University

Ankara

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**NEW KEYNESIAN SMALL OPEN ECONOMY: TURKISH CASE**

**The Institute of Economics and Social Sciences**

**of**

**İhsan Doğramacı Bilkent University**

**By**

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**İHSAN DOĞRAMACI BILKENT UNIVERSITY**

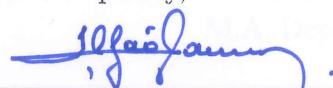
**ANKARA**

**June 2016**


I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Arts in Economics.

  
Assist. Prof. Dr. Sang Seok Lee  
Supervisor

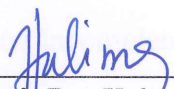
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Prof. Dr. Halime Demirkan  
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## **ABSTRACT**

### **NEW KEYNESIAN SMALL OPEN ECONOMY: TURKISH CASE**

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Turkey experienced substantial declines in inflation after 2002. Was it due to good policy, good luck, or both? To address this question, we incorporate stochastic volatility into a small open new Keynesian model of Monacelli (2005). As demonstrated by Fernandez-Villaverde, Guerron-Quintana, Rubio-Ramirez (2010), volatility shocks are an importance source of macroeconomic fluctuations so they need to be accounted for in order to examine the good luck hypothesis rigorously. Our estimated model suggests that both good policy and good luck played roles in bringing down the inflation.

*Keywords:* Incomplete pass-through of exchange rate, Particle filter, Pruning, Stochastic Volatility

## ÖZET

### DIŐA AÇIK KÜÇÜK EKONOMİ İÇİN YENİ KEYNESYEN MODEL: TÜRKİYE OLAYI

ERSOY, Sedat

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Türkiye'nin 2002 yılından sonraki enflasyon oranlarında çok ciddi bir azalma görülmektedir. Sebebi iyi politika mıdır, iyi şans mıdır yoksa her ikisinin sonucunda mı oluşmuştur? Bu soruya cevap bulabilmek için Monacelli (2005) te ki Yeni Keynesyen dışa açık küçük ekonomi modeline stokastik volatilitate eklenilmiştir. Fernandez-Villaverde, Guerron-Quintana, Rubio-Ramirez (2010) da gösterildiği gibi, stokastik volatilitate makroekonomik dalgalanmaları açıklamada önemli bir kaynak, bu yüzden iyi şans hipotezimizi incelerken dikkate alınıp modele eklenmiştir. Türkiye verisiyle tahmin edilmiş modelimiz iddia ediyor ki; enflasyon oranlarının bu denli düşmesinde hem iyi politika hem de iyi şans rol almıştır.

*Anahtar Kelimeler:* Budama, Eksik Döviz Yansıması, Partikül Filtresi, Stokastik Volatilitate

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# **CHAPTER 1**

## **INTRODUCTION**

When we look at the inflation rate in Turkey between 1998-2015 (see Figure 1) we have observed that there is a huge inflation rate before 2002, and it sharply goes down after 2002 and mostly have a single digit inflation rate after 2006. Interestingly the period between 2002 and 2005 corresponds to the implicit inflation targeting period in Turkey. After 2006 Turkey has an explicit inflation targeting and the main objective of the Central Bank of Turkey became to achieve and maintain price stability. As stated in Kara and Orak (2008) inflation targeting become successful in Turkey and Turkey has reached more stabilized price levels. At that point, we need to ask the following question: Even though many reforms and actions done in Turkey such as inflation targeting, establishing the Bank Regulatory and Supervisory Board, etc., might there be some possibilities of good luck in the economy in order to account for some part of the decline in inflation in Turkey? Or does all this success come from good policy? In order to answer this crucial question for Turkey case, we first build a nonlinear dynamic stochastic general equilibrium (DSGE) model, and then estimate the model parameters using Turkish data and accordingly solve the model so as to observe the dynamics of the Turkish economy. Hence, the rest of the paper follows as; in chapter 2 we will explain our model carefully, in chapter 3 using four

time series data we will do nonlinear estimation, and then using those estimated parameters we try to account for especially the changes in the inflation rate in Turkey. In chapter 4, we analyze the dynamics of the model. In chapter 5, we briefly conclude this project by mentioning our main findings and contributions to the literature and how we can go further in this project and what else can we do as a future research.

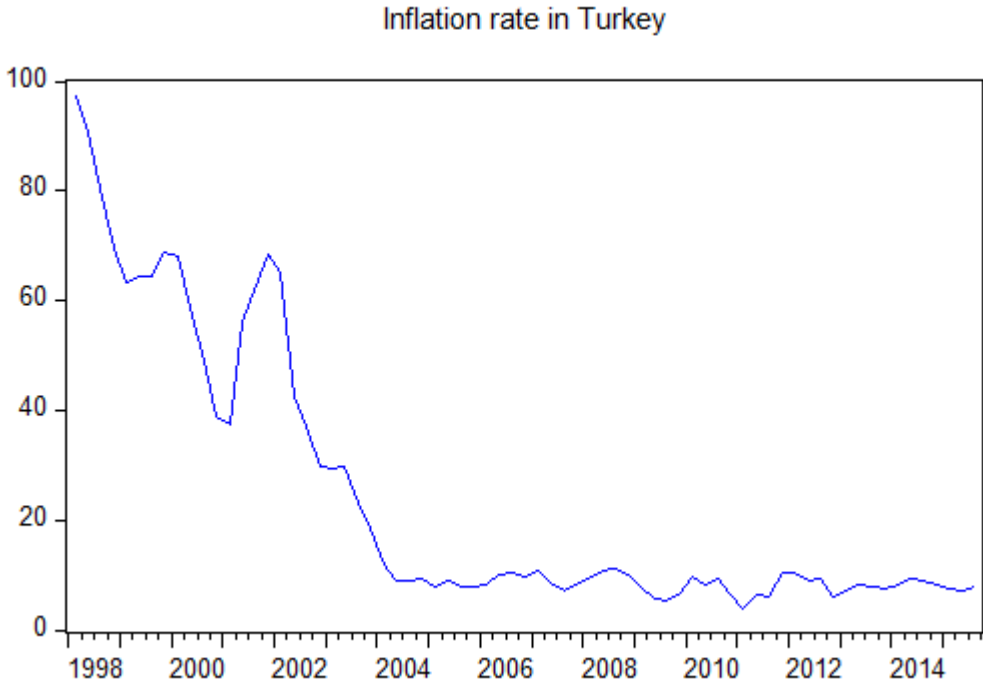


Figure 1 Inflation Rate in Turkey

## CHAPTER 2

### THE MODEL

In this setup, following Monacelli (2005) closely we have just two countries which are home and foreign<sup>1</sup>. Home country is a small open economy and foreign country is the rest of the world. Small economy has no effect on the foreign economy because it is negligibly small compared to the rest of the world, hence it is assumed that variables in the foreign economy is exogenously determined. We will see in the next sections that foreign country has only one possible way to have an impact on small open economy which is just the foreign aggregate price level and foreign aggregate consumption level, hence we will focus on only the dynamics of the small open economy.

#### 2.1) HOUSEHOLDS

One of the main actors in our model is households. There is a continuum of them located between 0 and 1, i.e. each individuals are indexed by  $k$  and  $k \in [0, 1]$ , and by doing so its mass is normalized to 1. However, we assume that there is a representative household in this economy so we can drop the  $k$  index. Representative household gets utility from consumption and disutility from number of hours worked, so we can express their life time utility which is separable in both consumption and number of hours labor as the following;

---

<sup>1</sup> Throughout this paper, we use the domestic and home interchangeably.

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left( \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \right) \right\} \quad (1)$$

where  $\beta$  is the discount factor,  $\sigma$  is the inverse elasticity of intertemporal substitution,  $\varphi$  is the inverse elasticity of labor supply.  $N_t$  denotes hours of labor,  $C_t$  denotes consumption index of foreign and domestically produced goods which can be defined as:

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

where  $\alpha \in [0, 1]$  is the degree of openness for the domestic country,  $\eta > 0$  is the elasticity of substitution between domestic and foreign goods. The aggregate consumption indices of domestically and foreign produced goods can be defined respectively as:

$$C_{h,t} = \left( \int_0^1 C_{h,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}} \quad (3)$$

$$C_{f,t} = \left( \int_0^1 C_{f,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}} \quad (4)$$

Above indexes are valid under the assumption that there are infinitely many goods indexed by  $i \in [0, 1]$ , and  $\varepsilon > 1$  which is the elasticity of substitution between varieties of goods.  $C_{h,t}(i)$  is the consumption of domestic good  $i$  by domestic household at time  $t$ , similarly  $C_{f,t}(i)$  denotes the consumption of foreign good  $i$  by domestic household at time  $t$ . In this model representative household faces two problems which are expenditure minimization and maximization of the expected life time utility.

At any point in time they have expenditure in both domestically produced goods and foreign produced goods, so their total expenditure will be the following;

$$\int_0^1 (P_{h,t}(i)C_{h,t}(i) + P_{f,t}(i)C_{f,t}(i))di$$

Then representative household will minimize their expenditure subject to (3).

$$\begin{aligned} \mathcal{L} = & \int_0^1 (P_{h,t}(i)C_{h,t}(i) + P_{f,t}(i)C_{f,t}(i)) di + \lambda_{1,t} \left( C_{h,t} - \left( \int_0^1 C_{h,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}} \right) \\ & + \lambda_{2,t} \left( C_{f,t} - \left( \int_0^1 C_{f,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}} \right) \end{aligned}$$

FOC with respect to  $C_{h,t}(i)$  will give the following condition;

$$P_{h,t}(i) - \lambda_{1,t} C_{h,t}^{\frac{1}{\varepsilon}} C_{h,t}(i)^{-\frac{1}{\varepsilon}} = 0$$

$$\Rightarrow C_{h,t}(i) = \left( \frac{P_{h,t}(i)}{\lambda_{1,t}} \right)^{-\varepsilon} C_{h,t} \quad (5)$$

Here, we find inverse demand function for each domestically produced goods  $i$ , but the form can be rewritten in more elegant version because we do not have an idea about  $\lambda_{1,t}$ .

Put equation (5) into (4), then  $\lambda_{1,t}$  can be obtained as

$$P_{h,t} := \lambda_{1,t} = \left( \int_0^1 P_{h,t}(i)^{1-\varepsilon} di \right)^{\frac{1}{1-\varepsilon}} \quad (6)$$

where  $P_{h,t}$  is the price index of domestically produced goods. Now equation (5) can be expressed as

$$C_{h,t}(i) = \left( \frac{P_{h,t}(i)}{P_{h,t}} \right)^{-\varepsilon} C_{h,t} \quad (7)$$

By symmetry we can also define price index of foreign produced goods and by using it we can obtain inverse demand function for each foreign produced goods.

$$P_{f,t} := \lambda_{2,t} = \left( \int_0^1 P_{f,t}(i)^{1-\varepsilon} di \right)^{\frac{1}{1-\varepsilon}}$$

$$C_{f,t}(i) = \left( \frac{P_{f,t}(i)}{P_{f,t}} \right)^{-\varepsilon} C_{f,t} \quad (8)$$

If we use equation (7) and equation (8) respectively, we have the following forms

$$\int_0^1 (P_{h,t}(i)C_{h,t}(i)) di = P_{h,t}C_{h,t}$$

$$\int_0^1 (P_{f,t}(i)C_{f,t}(i)) di = P_{f,t}C_{f,t}$$

So in aggregate indexes total expenditure function can be rewritten as

$$\int_0^1 (P_{h,t}(i)C_{h,t}(i) + P_{f,t}(i)C_{f,t}(i)) di = P_{h,t}C_{h,t} + P_{f,t}C_{f,t} \quad (9)$$

Since we express all the variables without index  $i$ , equivalently we can minimize total expenditure function subject to equation (2). From the FOC conditions, and using the same tricks used as in above case we have;

$$C_{h,t} = (1 - \alpha) \left( \frac{P_{h,t}}{P_t} \right)^{-\eta} C_t \quad (10)$$

$$C_{f,t} = \alpha \left( \frac{P_{f,t}}{P_t} \right)^{-\eta} C_t \quad (11)$$

Now if we combine equations (10) and (11) with the right hand side of the equation (9), we have;

$$P_{h,t}C_{h,t} + P_{f,t}C_{f,t} = P_t C_t \quad (12)$$

where  $P_t := \left( (1 - \alpha)P_{h,t}^{1-\eta} + \alpha P_{f,t}^{1-\eta} \right)^{\frac{1}{1-\eta}}$  can be defined as overall consumer price index. So in our model CPI (consumer price index) and the price index of domestically produced goods are differentiated.

Representative household has expenditure due to consumed goods, and holding financial portfolio, and getting wage due to number of labor she supplies, hence she has the following budget constraint;

$$P_t C_t + E_t\{Q_{t,t+1}D_{t+1}\} = D_t + W_t N_t \quad (13)$$

where  $Q_{t,t+1}$  is the stochastic discount factor, i.e. discounting the value of any variable at  $t+1$  to the value of it at  $t$ , and  $D_{t+1}$  is the nominal payoff in  $t+1$  of a financial portfolio held in  $t$ . Actually when we discount it today, it will be equal to the price of this portfolio so that household pays this amount of money to get this portfolio. However, as of today she will get wage for each hour of labor supplied and she will get  $D_t$  nominal payoff of a financial portfolio held in  $t-1$ . Hence we have the above budget constraint in  $t$ .

Representative household determines the level of  $C_t$ ,  $N_t$  and  $D_{t+1}$  at time  $t$ , so she will maximize her life time discounted utility subject to (13) with respect to those variables.

FOC with respect to  $C_t$  will give:  $C_t^{-\sigma} = \lambda_{3,t}P_t$  and FOC with respect to  $N_t$  will give:  $N_t^{\varphi} = \lambda_{3,t}W_t$  where  $\lambda_{3,t}$  is the Lagrange multiplier corresponding to budget constraint of the representative household. If we combine above two conditions and get rid of the  $\lambda_{3,t}$ , we get the following intratemporal condition:

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

This condition actually equates the marginal rate of substitution between consumption and hours of labor to the ratio of the prices of them respectively.

As stated by Schmitt-Grohe and Uribe (2003) small open economies with incomplete financial market has non-stationary dynamics because when there is no complete financial market, marginal utility will follow random walk as showed in Hall (1978) hence to make it stationary Schmitt-Grohe and Uribe (2003) proposes 5 different way to cope with this non-stationarity. For simplicity we choose the easiest option hence we assume that there is a complete financial market. Before obtaining the intertemporal FOC condition, we need more calculations. In the complete market, we have

$$V_{t,t+1} \frac{C_t^{-\sigma}}{P_t} = \xi_{t,t+1} \beta \frac{C_{t+1}^{-\sigma}}{P_{t+1}}$$

where  $V_{t,t+1}$  is the domestic price of an Arrow security in t (i.e. when a specific state is realized in t+1, it is a one period security that yields one unit of home currency), and  $\xi_{t,t+1}$  is the probability of that state is realized. Here since we have complete financial market assumption we will have  $Q_{t,t+1} = \frac{V_{t,t+1}}{\xi_{t,t+1}}$ , hence we can rewrite the above equality as

$$Q_{t,t+1} = \beta \frac{P_t}{P_{t+1}} \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma}$$

Compared to the incomplete market, this condition is satisfied for all possible states in t+1, instead this is satisfied only under the expectation operator in the incomplete market. However, since we know that gross return of a risk free nominal bond can be expressed

as  $R_t = \frac{1}{E_t\{Q_{t,t+1}\}}$ , after taking the expectation of the above expression it can be rewritten as

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

which is the Euler equation derived from intertemporal FOC.

## 2.2) Firms

There is a continuum of firms which are owned by households and indexed by  $j$  and they have linear production function  $Y_t(j) = Z_t N_t(j)$  where  $Y_t(j)$  is the level of production by firm  $j$  and  $N_t(j)$  is the labor input of the firm  $j$  and  $Z_t$  is the total factor productivity (TFP) which is same for all the firms.  $Z_t$  has stochastic AR(1) process<sup>2</sup>:

$$Z_t = (1 - \rho_z) + \rho_z Z_{t-1} + \sigma_{z,t} \xi_{z,t}$$

where  $\xi_{z,t} \sim N(0,0.01)$ . As you can notice here, standard deviations  $\sigma_{z,t}$  of the innovation  $\xi_{z,t}$  is not constant, and it evolves over time. Hence we add time varying stochastic volatility to our model as in Fernandez-Villaverde, Guerron-Quintana, Rubio-Ramirez (2010) [FGR (2010) henceforth]. Now there is no unique way to express the evolution of  $\sigma_{z,t}$ , even it can follow Markov chain and takes different values for different states, but as FGR (2010) states this will make the estimation procedure harder because we need to use global solution methods instead of perturbation method, and estimation with global solution methods takes much more time than the estimation with perturbation method. Therefore, we closely follow FGR (2010), and  $\sigma_{z,t}$  has an AR(1) process in logs:

---

<sup>2</sup> Here we assume that  $Z_t$  is equal to 1 at the steady state.

$$\log \sigma_{z,t} = (1 - \rho_{\sigma_z}) \log \sigma_z + \rho_{\sigma_z} \log \sigma_{z,t-1} + U_{z,t}$$

where  $U_{z,t} \sim N(0,1)$ , and  $\sigma_z$  is the steady state level of  $\sigma_{z,t}$ .

Since we are only interested in the symmetric equilibrium, we can drop the  $j$  index for the firms, hence we can say that there is a representative monopolistic firm. We assume that they are not able to change their prices each period, there is a Calvo (1983) pricing friction in such a way that  $\theta_h$  fraction of the firms cannot set their prices in the period  $t$ , where  $\theta_h \in [0, 1]$ .

Firms in this model have both cost minimization problem and profit maximization problem under the Calvo pricing mechanism. The former can be written as:

$$\min_{N_t} \frac{W_t}{P_{h,t}} N_t + \lambda_{3,t} (Y_t - Z_t N_t)$$

The FOC is:

$$MC_t := \lambda_{3,t} = \frac{W_t}{P_{h,t} Z_t}$$

where  $MC_t$  is the real marginal cost of the firm and we can also define nominal marginal cost as  $MC_t^n := \frac{W_t}{Z_t}$ .

Before stating the profit maximization problem let's define stochastic discount factor<sup>3</sup> between period  $t$  and period  $t+k$ :

---

<sup>3</sup> Since we assume that firms are owned by households, we can use the same discount factor in the firm's problem as in the household problems.

$$Q_{t,t+k} = \beta^k \frac{P_t}{P_{t+k}} \left( \frac{C_{t+k}}{C_t} \right)^{-\sigma}$$

Normally, from the goods market equilibrium it must be that  $Y_t = C_{h,t} + C_{h,t}^*$  where  $C_{h,t}^*$  is the consumed level of domestic goods by foreign country. Since small open economy is so small compared to the foreign one we can assume that  $C_{h,t}^* = 0$ , hence goods market equilibrium becomes  $Y_t = C_{h,t}$ .

Then, we can formulate the profit maximization problem as follows:

$$\max_{P_{h,new,t}} E_t \left\{ \sum_{k=0}^{\infty} \theta_h^k Q_{t,t+k} [P_{h,new,t} - MC_{t+k}^n] Y_{t+k} \right\}$$

$$\text{subject to } Y_{t+k} = \left( \frac{P_{h,new,t}}{P_{h,t+k}} \right)^{-\eta} C_{h,t+k}$$

Equivalently, we have:

$$\max_{P_{h,new,t}} E_t \left\{ \sum_{k=0}^{\infty} \theta_h^k Q_{t,t+k} [P_{h,new,t}^{1-\eta} - MC_{t+k}^n P_{h,new,t}^{-\eta}] P_{h,t+k}^\eta C_{h,t+k} \right\}$$

The FOC is:

$$E_t \left\{ \sum_{k=0}^{\infty} \theta_h^k Q_{t,t+k} [(1-\eta) P_{h,new,t}^{-\eta} + \eta MC_{t+k}^n P_{h,new,t}^{-\eta-1}] P_{h,t+k}^\eta C_{h,t+k} \right\} = 0$$

Then we have:

$$E_t \left\{ \sum_{k=0}^{\infty} \theta_h^k Q_{t,t+k} [(1-\eta) + \eta MC_{t+k}^n P_{h,new,t}^{-1}] Y_{t+k} \right\} = 0$$

After some manipulations we have:

$$P_{h,new,t} = \frac{\eta}{\eta - 1} \frac{E_t \left\{ \sum_{k=0}^{\infty} \theta_h^k Q_{t,t+k} [MC_{t+k}^n] Y_{t+k} \right\}}{E_t \left\{ \sum_{k=0}^{\infty} \theta_h^k Q_{t,t+k} Y_{t+k} \right\}}$$

Let the numerator and the denominator be respectively  $f_t^1$  and  $f_t^2$  as

$$f_t^1 = E_t \left\{ \sum_{k=0}^{\infty} \theta_h^k Q_{t,t+k} [MC_{t+k}^n] Y_{t+k} \right\}$$

$$f_t^2 = E_t \left\{ \sum_{k=0}^{\infty} \theta_h^k Q_{t,t+k} Y_{t+k} \right\}$$

Now, we need to express these terms in recursive forms so after evaluating them for  $k=0$ , and some manipulations we have:

$$f_t^1 = \frac{W_t}{Z_t} Y_t + \beta \theta_h E_t \left\{ f_{t+1}^1 \frac{P_t}{P_{t+1}} \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \right\}$$

$$f_t^2 = Y_t + \beta \theta_h E_t \left\{ f_{t+1}^2 \frac{P_t}{P_{t+1}} \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \right\}$$

$$P_{h,new,t} = \frac{\eta}{\eta - 1} \frac{f_t^1}{f_t^2}$$

At time  $t$ ,  $\theta_h$  portion of the firms cannot reset their prices hence they will use the previous period's prices, but  $(1 - \theta_h)$  portion will set their prices as  $P_{h,new,t}$ , so overall price level of domestic goods can be written as the geometric average of both these prices:

$$P_{h,new,t} = \left( \theta_h P_{h,t-1}^{1-\eta} + (1 - \theta_h) P_{h,new,t}^{1-\eta} \right)^{\frac{1}{1-\eta}}$$

In our model, we can define the nominal exchange rate  $\epsilon_t$  as the amount of domestic currency per unit of foreign currency. Under the assumption of no arbitrage opportunity, any goods must hold with the same price in all locations which is called law of one price (LOP, hereafter) hence it must be that  $P_{f,t}(i) = \epsilon_t P_t^*(i)$  where  $P_t^*(i)$  is the price of a foreign goods in foreign country for  $i \in [0, 1]$ , after aggregating<sup>4</sup> over goods  $i$  we have LOP condition in aggregate levels  $P_{f,t} = \epsilon_t P_t^*$ . As stated in Monacelli (2005) that we present incomplete exchange rate pass-through on import prices. For a small economy it is intuitive to add such rigidity because of the size of the domestic country. When there is no influence on the rest of the world, they cannot have a bargaining power over the imported goods. So we can say that LOP holds at the dock, but there will be price dispersion between the domestic price of the imported goods and foreign price of the foreign goods. Hence Monacelli (2005) introduces the LOP gap by:

$$\psi_t = \frac{\epsilon_t P_t^*}{P_{f,t}}$$

If there is a complete exchange rate pass-through, then  $\psi_t$  must be 1 and LOP will hold, so any deviation of  $\psi_t$  from 1 can be interpreted as the LOP gap. Furthermore, we assume that LOP gap has a stochastic AR(1) process in levels<sup>5</sup>:

$$\psi_t = (1 - \rho_l) + \rho_l \psi_{t-1} + \sigma_{l,t} \xi_{l,t}$$

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<sup>4</sup> Here we assume that foreign economy has the identical preferences as home economy has, hence we can aggregate over goods  $i$  properly.

<sup>5</sup> Since we know that in the long run there will be complete exchange rate pass-through, LOP holds at the steady state.

where  $\xi_{l,t} \sim N(0,0.01)$ . Again as in the total factor productivity, standard deviations  $\sigma_{l,t}$  of the innovation  $\xi_{l,t}$  is not constant, and it evolves over time. Hence we assume that  $\sigma_{l,t}$  has an AR(1) process in logs:

$$\log \sigma_{l,t} = (1 - \rho_{\sigma_l}) \log \sigma_l + \rho_{\sigma_l} \log \sigma_{l,t-1} + U_{l,t}$$

where  $U_{l,t} \sim N(0,1)$ , and  $\sigma_l$  is the steady state level of  $\sigma_{l,t}$ .

### 2.3.) MONETARY POLICY

Monetary policy follows the modified Taylor rule as in FGR (2010):

$$\log \frac{R_t}{\bar{R}} = \rho_r \log \frac{R_{t-1}}{\bar{R}} + (1 - \rho_r) [\theta_{\pi,t} \log \pi_t + \theta_{y,t} (\log Y_t - \log Y_{t-1})] + \sigma_{r,t} \xi_{r,t}$$

where  $\bar{R}$  is the steady state level of the gross rate of return,  $\rho_r$  is the interest rate smoothing parameter,  $\theta_{\pi,t}$  is the response to change in the price level,  $\theta_{y,t}$  is the response to change in the output level, and  $\xi_{r,t} \sim N(0,0.01)$ . They called it modified Taylor rule because in the simple policy rule  $\theta_{\pi,t}$  and  $\theta_{y,t}$  are constant, but in our case just like in FGR (2010) they evolve over time. The reasoning behind this is the following; the members of the monetary policy committee can change or their belief about the economy can change over time, so the overall reaction of the committee for inflation and change in the output level can be different, hence we assume that they have also AR(1) process in logs<sup>6</sup>:

$$\log \theta_{\pi,t} = (1 - \rho_{\theta_\pi}) \log \theta_{\bar{\pi}} + \rho_{\theta_\pi} \log \theta_{\pi,t-1} + \xi_{\pi,t}$$

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<sup>6</sup> Here assuming AR(1) process in logs we restrict ourselves to have positive values for Taylor rule parameters, because it is not intuitive to have non-positive values for these parameters. As a future research we can consider the cases where these might be non-positive values too.

$$\log \theta_{y,t} = (1 - \rho_{\theta_y}) \log \theta_{\bar{y}} + \rho_{\theta_y} \log \theta_{y,t-1} + \xi_{y,t}$$

where  $|\rho_{\theta_\pi}| < 1$ , and  $|\rho_{\theta_y}| < 1$ ,  $\xi_{\pi,t} \sim N(0,0.01)$ ,  $\xi_{y,t} \sim N(0,0.01)$ , and  $\theta_{\bar{\pi}}$  and  $\theta_{\bar{y}}$  are the steady state levels of the  $\theta_{\pi,t}$  and  $\theta_{y,t}$  respectively.

We also introduce the time varying volatility for standard deviations of the monetary policy shock:

$$\log \sigma_{r,t} = (1 - \rho_{\sigma_r}) \log \sigma_r + \rho_{\sigma_r} \log \sigma_{r,t-1} + U_{r,t}$$

where  $U_{r,t} \sim N(0,1)$ , and  $\sigma_r$  is the steady state level of  $\sigma_{r,t}$ .

## CHAPTER 3

### ESTIMATION RESULTS

#### 3.1) Data

In order to estimate our model, we use four time series covering the period 1998Q1-2015Q3 for Turkish economy. There are no a priori grounds to suspect trend components in these series so I take them to my detrended model. We use the following variables as observable: (i) the growth rate of the real GDP<sup>7</sup>, (ii) inflation rate by using the consumer price index (CPI), (iii) nominal exchange rate, and (iv) short term policy interest rate.

#### 3.2) Estimation

Most of the literature linearize the model, and estimate their model with Kalman filter because Kalman filter is optimal when the shocks have Gaussian distribution and the model is linear<sup>8</sup>. Linear model is required because when it is so, the solution of the model can be written linearly. Hence linear combination of independent Gaussian distributions will again be Gaussian distribution and Kalman filter will be optimal in that case. However, we have a non-linear transition and a non-linear policy function, hence we use

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<sup>7</sup> Firstly, we try to use the output gap instead of the growth rate of the real GDP, but after we use HP filter to get rid of the trend component and to obtain output gap, we faced so negative values for this variables and it makes us get in trouble in the estimation part, hence instead we used the growth rate of the real GDP as an observable.

<sup>8</sup> Even though we have Gaussian distributed error terms, we cannot use Kalman filter because of the nonlinearities of the model.

particle filter estimation<sup>9</sup> as done in FGR (2010). If there are more observables than the shocks in the model, then it will cause stochastic singularity. To cope with this situation, measurement errors can be used<sup>10</sup>. However, in our case we have more than 4 shocks, so no need to worry about it. Due to the curse of dimensionality we have to reduce the number of the parameters to be estimated. We calibrate the following parameters as in the Monacelli (2005):  $\alpha$ ,  $\eta$ ,  $\varphi$ ,  $\sigma$ ,  $\theta_h$ . The only exception is in the discount factor, we set<sup>11</sup>  $\beta = 0.92$ .

In order to estimate the model with particle filter, we should first propose valid priors for the parameters to be estimated. As stated in Sims (2014), it is quite common in the literature to use beta distributions for the parameters range between 0 and 1, and to use inverse gamma distributions for shock standard deviations and to use normal distributions for the other parameters. Hence we set our parameters accordingly. In the first column of the table<sup>12</sup> 1, we have the names of the parameters that we try to estimate, in the second column, we have the type of the distributions of the parameters, in the third column we assign some reasonable initial values for each of these parameters, in the fourth and the fifth column we determine the mean and standard deviations of these parameters, respectively. Lastly in the sixth column, we have the estimated mode values of these parameters after we use the particle filter. At first sight, we can say that Turkey has a quite

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<sup>9</sup> For an illustrative example for how the particle filter works, you can check Fernandez-Villaverde, Rubio-Ramirez (2004).

<sup>10</sup> We know that aggregate variables are calculated with big measurement errors, but we did not add the measurement shocks for the observables since we have already 8 shocks in our model and adding 4 more shocks will affect the duration of the estimation part.

<sup>11</sup> Otherwise with the previous value of discount factor particle filter does not work since the data and the model does not match properly. Actually, the steady state level of the gross interest rate is equal to  $1/\beta$ , and we know that historical values of gross interest rate is much higher than 1, hence in Turkey case this is quite intuitive to calibrate it as lower than 0.99.

<sup>12</sup> The priors of the most of the parameters which estimated here are obtained from FGR (2010).

persistence TFP coefficients, which is 0.9688. Moreover, parameter that governs the interest rate smoothing is persistent too, that is to say that Central Bank of Turkey actually makes interest rate smoothing. Although we choose a small prior mean for the steady state level of the response of monetary policy to change in the output level, it still decreases, hence we can conclude that Central Bank of Turkey actually does not react so much to change in the output level. However, the steady state level of the response of monetary policy to inflation is 1,6494, this is much higher than the one in U.S case which is 1.045 (i.e. estimated with U.S data in FGR (2010)).

Table 1 Particle Filter Estimation Results

Parameter	Prior Distribution	Initial Point	Prior Mean	Prior Std.	Posterior Mode
$\rho_z$	Beta	0.9	0.88	0.05	0.9688
$\rho_l$	Beta	0.9	0.8	0.1	0.9056
$\rho_r$	Beta	0.9	0.88	0.05	0.8080
$\rho_{\theta_\pi}$	Beta	0.8	0.63	0.2	0.9557
$\rho_{\theta_y}$	Beta	0.2	0.10	0.01	0.0930
$\rho_{\sigma_r}$	Beta	0.5	0.5	0.2	0.8115
$\rho_{\sigma_l}$	Beta	0.5	0.5	0.2	0.6105
$\rho_{\sigma_z}$	Beta	0.5	0.5	0.2	0.5056
$\theta_{\bar{y}}$	Normal	0.013	0.013	0.005	0.0104
$\theta_{\bar{\pi}}$	Normal	1.5	1.5	0.1	1.6494
$\sigma_{\xi_r}$	Inverse Gamma	0.01	0.01	0.002	0.0121
$\sigma_{\xi_l}$	Inverse Gamma	0.01	0.01	0.002	0.0077
$\sigma_{\xi_z}$	Inverse Gamma	0.01	0.01	0.002	0.0106
$\sigma_{\xi_\pi}$	Inverse Gamma	0.01	0.01	0.002	0.0071
$\sigma_{\xi_y}$	Inverse Gamma	0.01	0.01	0.002	0.0072

Parameter that captures the openness of the small economy  $\alpha$  is set to 0.4, discount factor  $\beta$  is set to 0.92 and  $\sigma = 1$ ,  $\eta = 1.5$ ,  $\varphi = 3$ ,  $\theta_h = 0.75$ . The values of these parameters can be found in Table 2.

Table 2 Calibrated Values

Parameter	Value
$\alpha$	0.4
$\beta$	0.92
$\sigma$	1
$\eta$	1.5
$\varphi$	3
$\theta_h$	0.75

In order to make a comparison between the linear model and the nonlinear model we estimated the model with Kalman filter too. The estimated values can be found in Table 3.

Table 3 Kalman Filter Estimation Results

Parameter	Prior Distribution	Initial Point	Prior Mean	Prior Std.	Posterior Mode
$\rho_z$	Beta	0.9	0.88	0.05	0.9994
$\rho_l$	Beta	0.9	0.8	0.1	0.9735
$\rho_r$	Beta	0.9	0.88	0.05	0.9994
$\rho_{\theta_\pi}$	Beta	0.8	0.63	0.2	0.8030
$\rho_{\theta_y}$	Beta	0.2	0.10	0.01	0.2009
$\theta_{\bar{y}}$	Normal	0.013	0.013	0.005	0.2360
$\sigma_{\xi_r}$	Inverse Gamma	0.01	0.01	0.002	1.4101
$\sigma_{\xi_l}$	Inverse Gamma	0.01	0.01	0.002	0.2488
$\sigma_{\xi_z}$	Inverse Gamma	0.01	0.01	0.002	0.6118

As we can see that since there is no stochastic volatility of the monetary policy shock, monetary policy shock itself tries to account for the whole changes in the monetary policy therefore its variance is so big. Another crucial difference is that coefficient of interest rate smoothing is almost 1, and it actually says that monetary policy mainly does not depend on the changes in the inflation rate in Turkey, which is not sensible at all. Besides, the steady states level of the Taylor Rule parameter on output difference is 0.2360, which is almost twenty times higher than the one in particle filter side<sup>13</sup>.

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<sup>13</sup> Even when we use simple OLS regression for the monetary policy rule we find the estimated values of the  $\theta_{\pi}$  is around 0.02, which is much more close to particle filter result compared to the Kalman filter result.

## CHAPTER 4

### SOLUTION AND THE DYNAMICS

#### 4.1) Solution

In our models we have 18 state variables, 3 innovations to the structural shocks  $(\xi_{z,t}, \xi_{l,t}, \xi_{r,t})$ , 3 innovations to the volatility shocks  $(U_{z,t}, U_{l,t}, U_{r,t})$ , and 2 innovations to the parameter drifts  $(\xi_{\pi,t}, \xi_{y,t})$ , hence as in FGR (2010) we will use the perturbation method<sup>14</sup>. Since most of the literature linearize or log-linearize the model around the steady state, they use the first order perturbation method. However, in our model we add the time varying volatilities and in order to capture this second order information we haven't linearize the model otherwise it will be certainty equivalence. Besides, we need to solve the model with at least second order perturbation method, otherwise time varying volatilities disappear and don't have an impact on the economy.

As stated in Andreasen *et al.* (2016) even though first order approximations are stable, second order approximation can be unstable because of the explosive sample path<sup>15</sup>. However, Kim, Kim, Schaumburg and Sims (2008) proposes a solution to get rid of this explosive sample path, called pruning meaning that do not include the terms that have

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<sup>14</sup>As an alternative we have could use the value function iteration, but then we have to take 26 variables into consideration, and it almost makes impossible to use this kind of solution method.

<sup>15</sup> For illustrative example for explanation of how higher order approximations can be unstable you can check Den Haan and De Wind (2012).

higher order effects than the order of the approximation<sup>16</sup>. In our case, we will solve the model with second order approximation so the system of solution should not include the third and higher effects. Similar to example given in Andreasen *et al.* (2016), we will have a solution for  $Z_t$  and since we have second order approximation it will be a function of  $Z_{t-1}Z_{t-2}$ ,  $Z_{t-1}^2$ ,  $Z_{t-2}^2$ . In the same method  $Z_{t-1}$  will be a function of  $Z_{t-2}^2$ . If we put quadratic function of  $Z_{t-2}^2$  instead of  $Z_{t-1}$ , then  $Z_t$  will be a function of  $Z_{t-2}$ ,  $Z_{t-2}^2$ ,  $Z_{t-2}^3$ ,  $Z_{t-2}^4$ . Pruning will leave out the terms  $Z_{t-2}^3$ ,  $Z_{t-2}^4$  since they are the third and fourth order effects, respectively. By using this methodology we solve the model with second order approximation.

## 4.2) Dynamics

Since our non-linear DSGE model is hugely complicated we cannot obtain the closed form solution. Instead we are interested in the simulation results in a consequence of shocks hit the economy. In Figure 2, we have a one standard deviation shock<sup>17</sup> to the monetary policy, then nominal interest will go up and the effect completely dies up after 2 years<sup>18</sup>. It also affects the level of prices and the output negatively.

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<sup>16</sup> Even though we lose information when we exclude those terms, Andreasen *et al.* (2016) compares the root mean squared Euler-equation errors (RMSE) of the first, second and third order pruned system and not pruned system. It shows that average error of the system with pruning is less than the average error of the system without pruning, hence losing that much information is not a big issue in that case.

<sup>17</sup> The magnitude of all shocks are positive one standard deviation, and the simulation results are obtained from Dynare.

<sup>18</sup> Each period corresponds to one quarter.

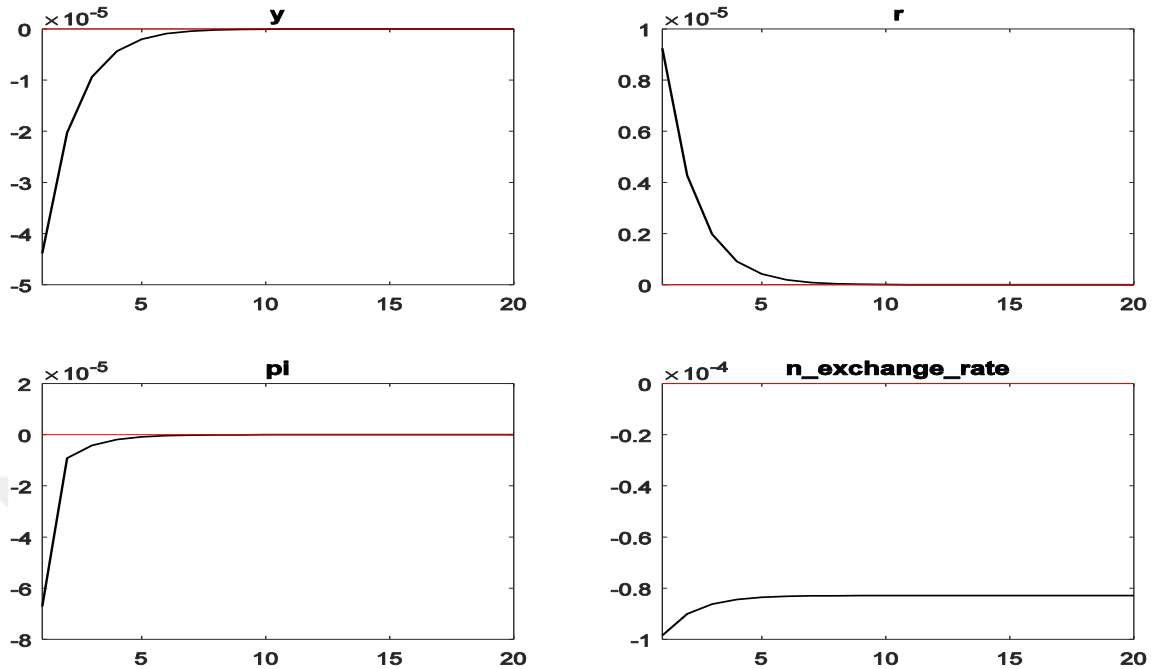


Figure 2 The Impulse Response Functions to a Monetary Policy Shock (PF)<sup>19</sup>

In Figure 3, we have a one standard deviation shock to the monetary policy volatility shock, even if the results are not smooth as in Figure 1, initial reaction quite similar to each other. When we have a volatility shock that hit the economy, actually we change the volatility of the gross interest rate, and hence we change the uncertainty of gross interest rate. Then agents will save more. Compared to the Figure 2, inflation rate does not decrease initially in this case.

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<sup>19</sup> PF and KF stand for the results under the Particle Filter estimation and the Kalman Filter estimation, respectively.

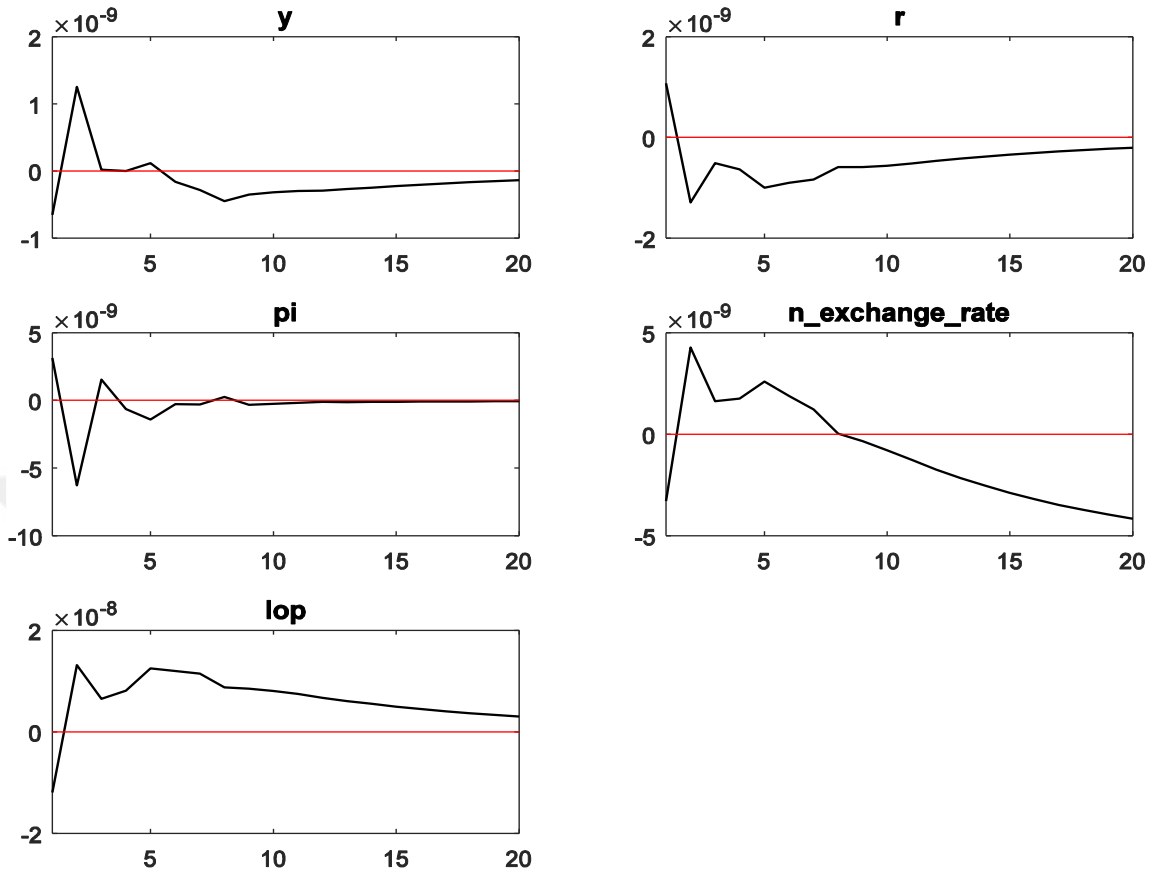


Figure 3 The Impulse Response Functions to a Monetary Policy Volatility Shock (PF)

In Figure 4 and Figure 5, we have a shock to Taylor Rule parameter for the inflation and Taylor Rule parameter for the change in the output levels, respectively.

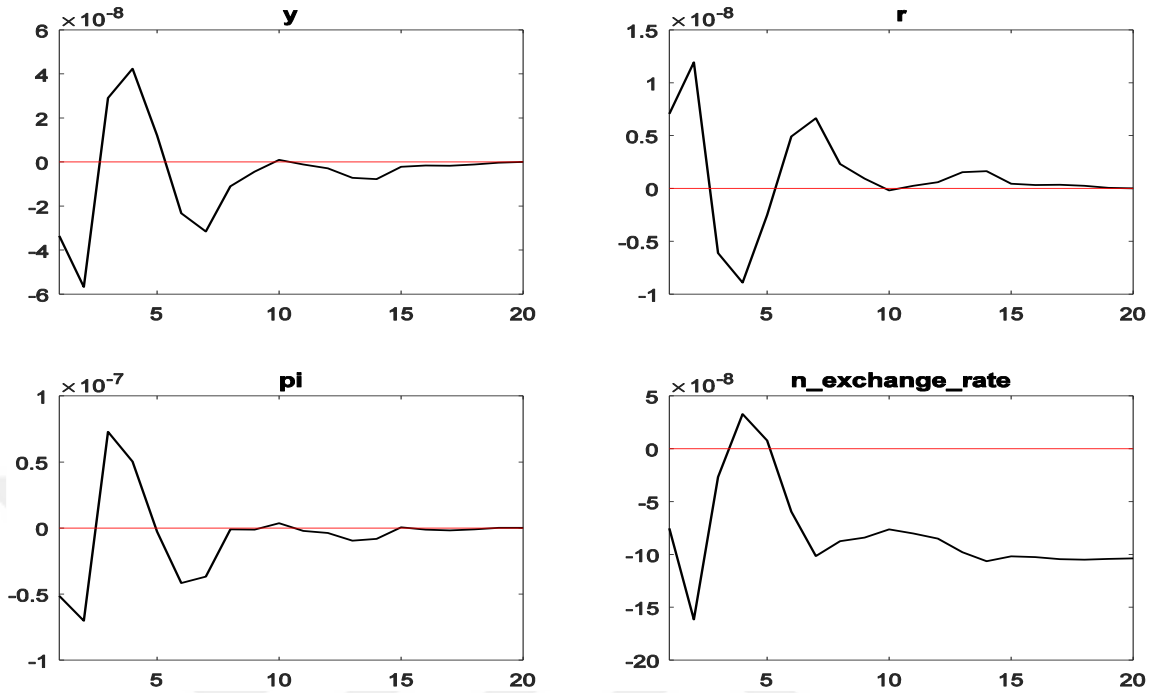


Figure 4 The Impulse Response Functions to a Taylor Rule parameter for the Inflation (PF)

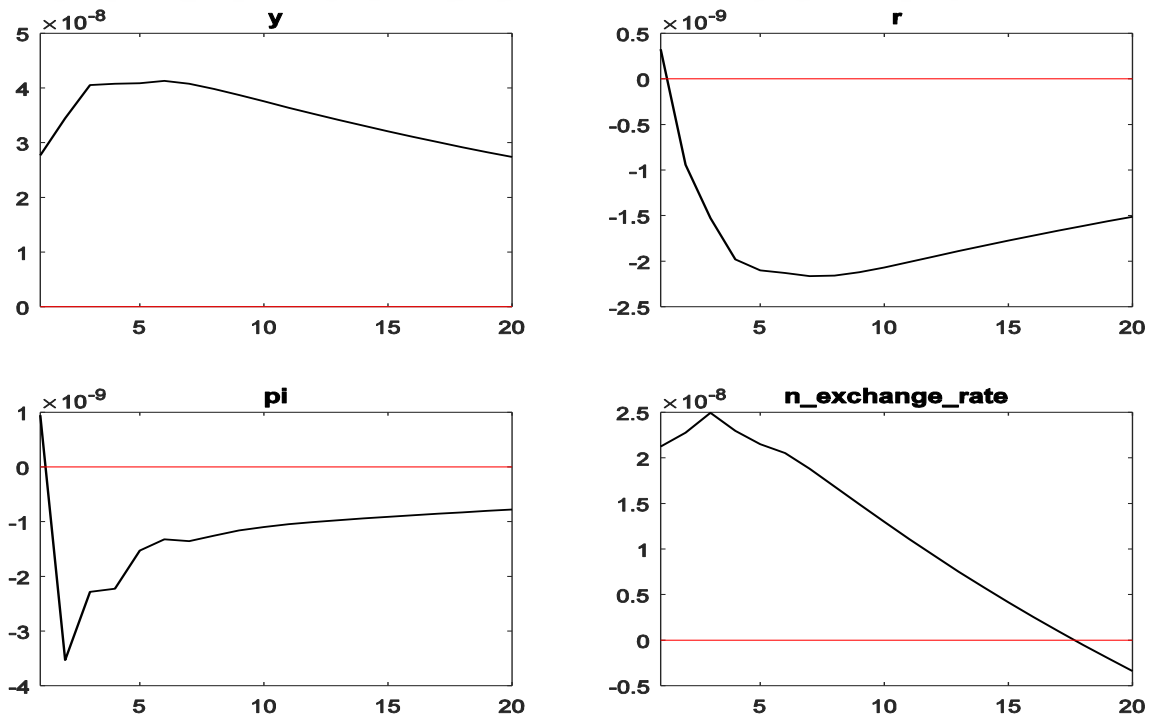


Figure 5 The Impulse Response Functions to a Taylor Rule parameter for the Change in the Output Level (PF)

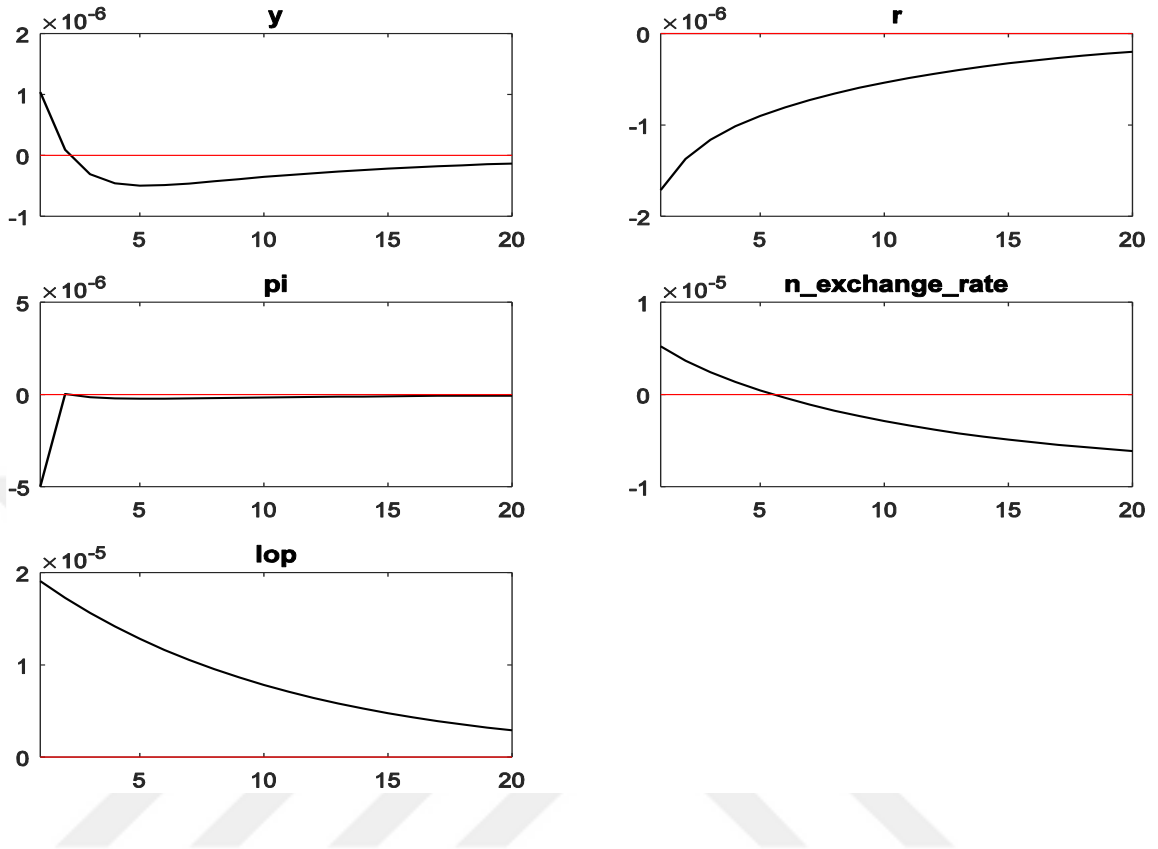


Figure 6 The Impulse Response Functions to a TFP Shock (PF)

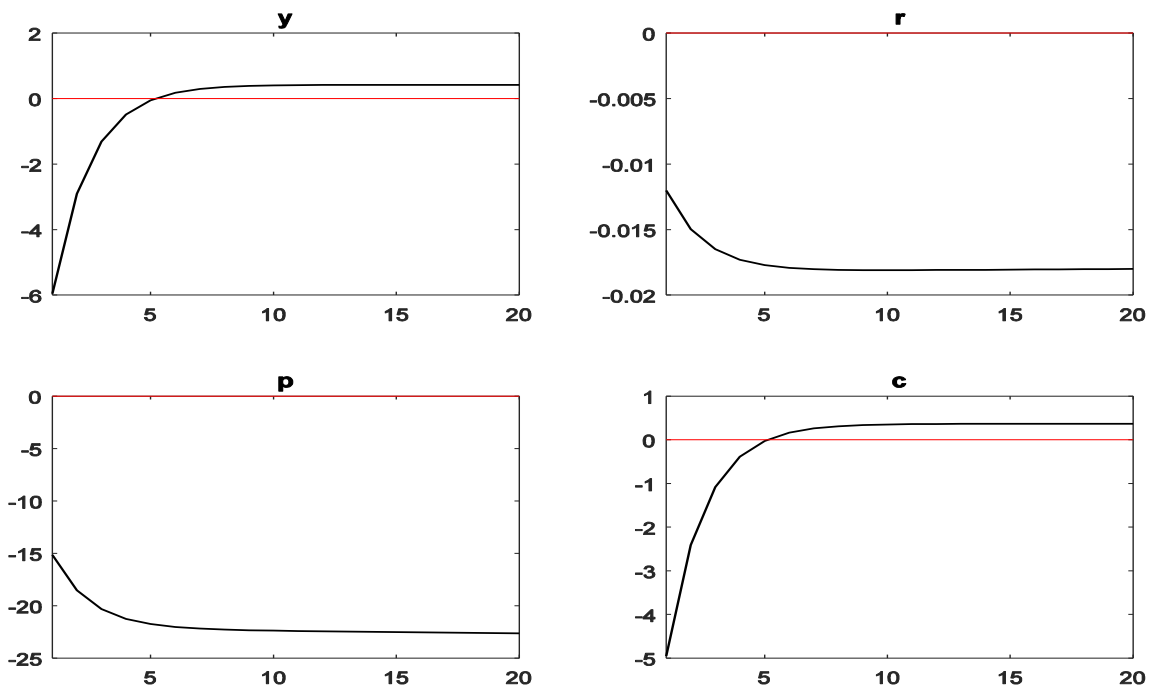


Figure 7 The Impulse Response Functions to a TFP Shock (KF)

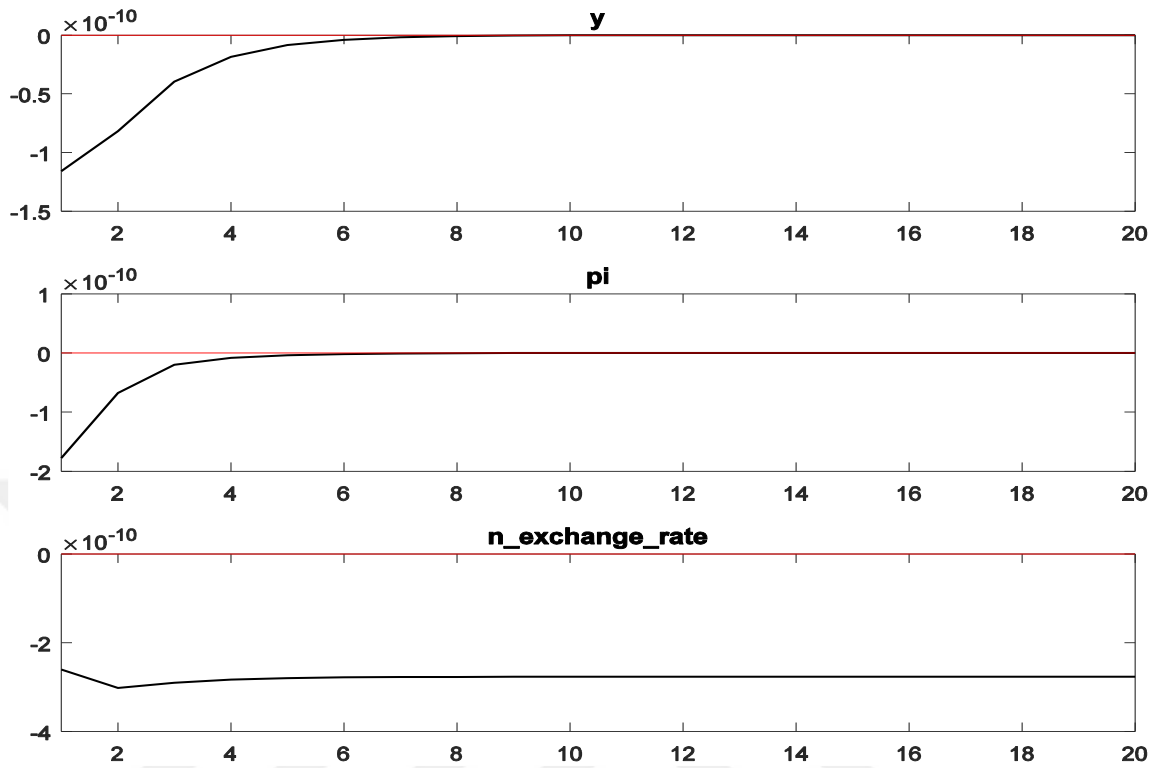


Figure 8 The Impulse Response Functions to a LOP Gap Shock (PF)

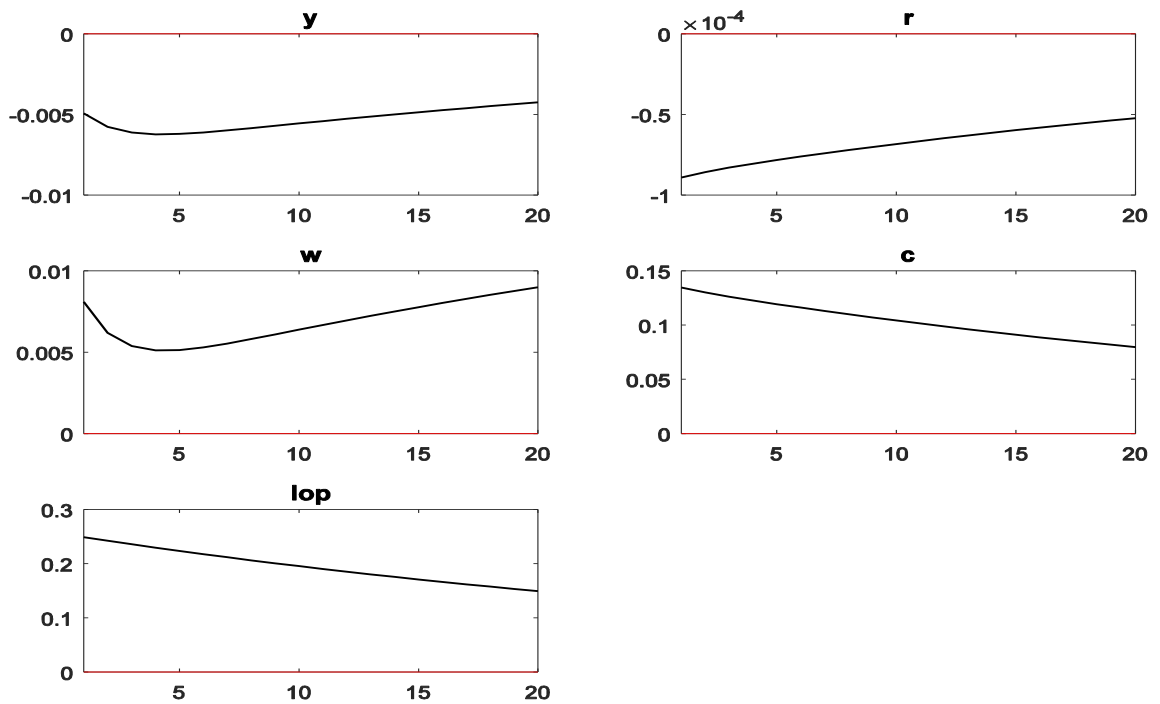


Figure 9 The Impulse Response Functions to a LOP Gap Shock (KF)

#### 4.3) Evolution of the Taylor Rule parameter for Inflation

As we can see in the Table 1, the response of the monetary policy to the change in output level is quite small, hence it is more interesting to consider the evolution of the Taylor Rule parameter on inflation, this is actually more intuitive and more reasonable because as we stated earlier the main objective of the Central Bank of Turkey (CBT) is to achieve and maintain the price stability in Turkey, so evolution of this parameter actually is a clue about the thought of CBT on inflation. We can also see the response of CBT on inflation throughout the history hence we can comment on it whether they had really good policy or not. In the following two figures show the inflation rate in Turkey and smoothed path for the Taylor Rule on inflation, respectively. The orange shaded area shows pre-implicit inflation targeting period, the gray shaded region shows implicit inflation targeting period, and the rest of the region shows the post implicit inflation targeting period or explicit inflation targeting period. As we can notice that, from 1998Q1 to 2002Q1 this parameter starts from around 0 level and reached above 1 in this period. At the same time we observe that inflation rate falls from around 100% to 40% until 2001Q1. Even though this parameter sharply goes up in year 2001, inflation rate reacts in opposite way. The reason comes from the history of Turkey since Turkey has faced 2001 Turkish economic crisis during this period. Importantly, even though the same parameter in FGR (2010) is not affected by two oil shocks in U.S., in our case we can see the negative effects of this crisis on the estimated  $\theta_{\pi,t}$ . Moreover, although this parameter does not change too much during the implicit inflation targeting period and around 1.3 on average, inflation rate falls from around 60% to 10%. Even though they react to inflation in the same way, it decreases tremendously. So we expect that good luck instead of good policy mostly works during

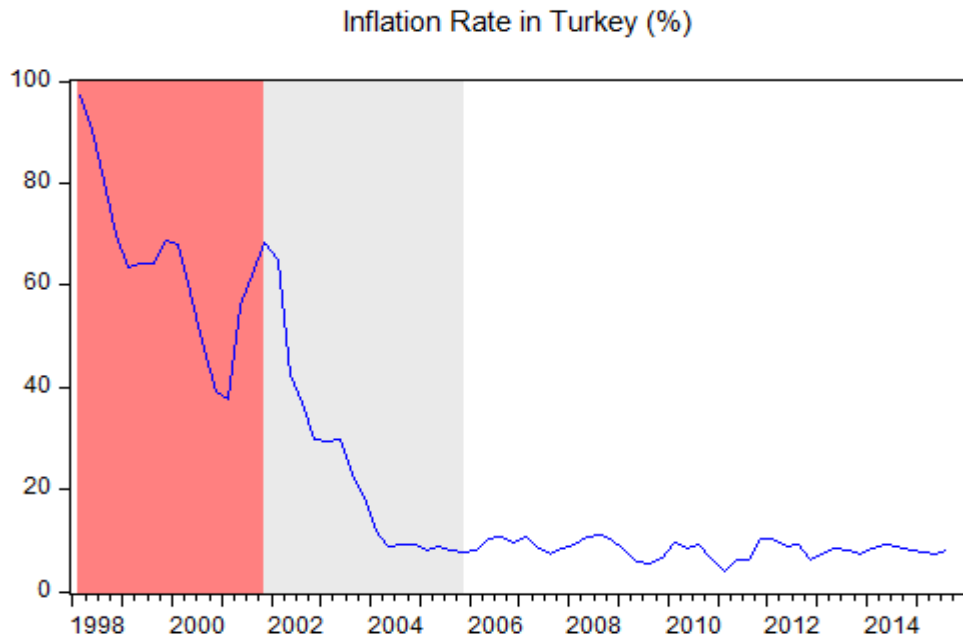


Figure 10 Inflation Rate in Turkey (%)

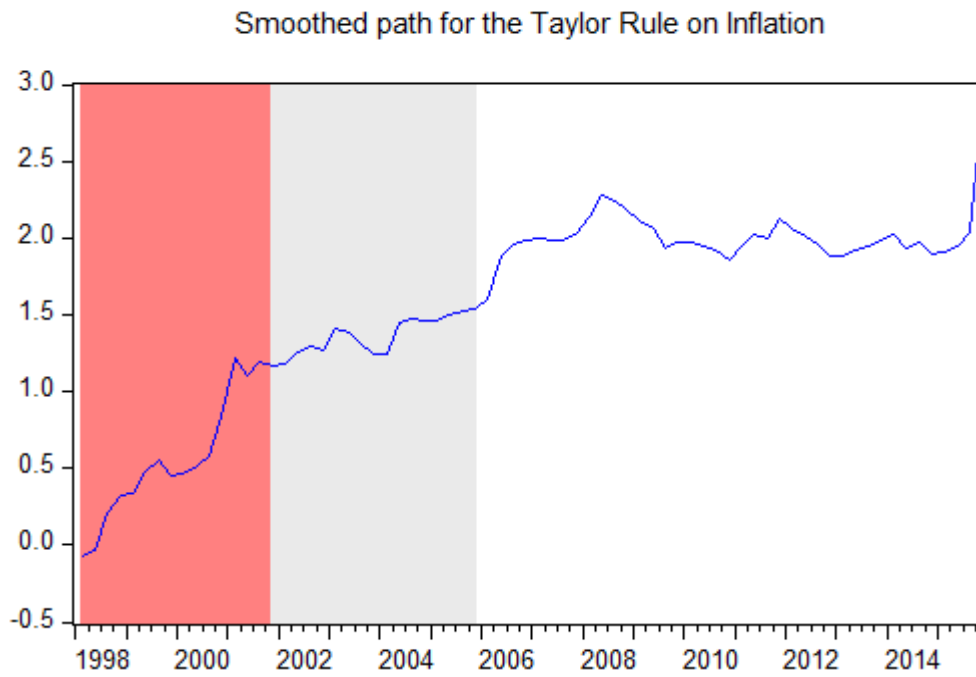


Figure 11 Smoothed path for the Taylor Rule on Inflation

this period. For the rest of the area we have seen that mostly this parameter is around 2 and the inflation rate is around 10% or in single digit. But still in these periods good luck should take place for example for the periods 2009 and 2010 although the parameter decreases, inflation rate declines as well.

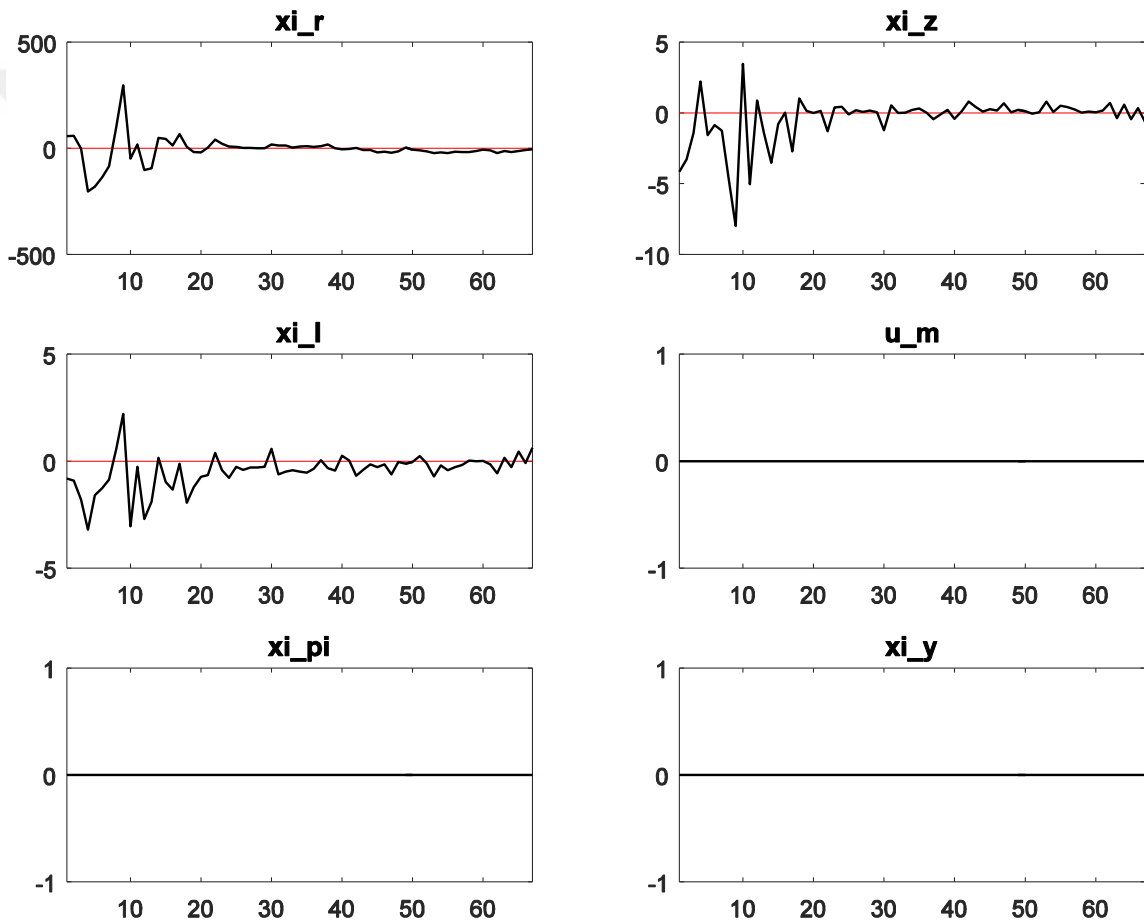


Figure 12 Smoothed Shocks<sup>20</sup>

<sup>20</sup> In this figure,  $\xi_r$ ,  $\xi_z$ ,  $\xi_l$ ,  $U_r$ ,  $\xi_\pi$ ,  $\xi_y$ , respectively. X axis shows the values from 0 to 71, where 0 corresponds 1998Q1 and 71 corresponds 2014Q3. Y axis shows the estimate of the smoothed structural shocks (deviations from their steady state levels). Notice that  $U_r$ ,  $\xi_\pi$ ,  $\xi_y$  do not evolve over time because they do not have a stochastic volatility.

Figure 12 proves the good luck argument after the period 2002, we see that there is a substantial decline in the stochastic volatility after that period in Turkish economy. Since SV decreases, uncertainty decreases as well. Combining with the fact that the Taylor Rule parameter on Inflation increases on average during this period, we concluded that our estimated model suggest that both good policy and good luck played roles in bringing down the inflation.



## **CHAPTER 4**

### **CONCLUSION**

In this paper we try to account for the decline in inflation in Turkey. To do better off we follow both Monacelli (2005) and FGR (2010) closely, and we build a nonlinear estimated DSGE model with law of one price gap, stochastic volatility and parameter drifting. Our main finding is that the success in decline in inflation after 2002 is not just because of the good policy, it is actually combination of both good policy and good luck.

This thesis can be extended in the future in the following ways; first because of the time constraint we could not estimate all parameters in the model all parameters can also be estimated. Second, we assume that there is a complete financial market to make our small open economy model stationary, by assuming one of the other 4 ways to make such a model stationary in Schmitt-Grohe and Uribe (2003) we can relax the complete financial market assumption. Third, for the small open economies like Turkey, exchange rate is a crucial part of the monetary policy hence we can add it into the policy rule so that we can see the effects of the incomplete pass-through of exchange rate over the policy rule more clearly. Fourth, we use the second order perturbation method to solve the model, we can extend it to the third order perturbation method because it will allow us the independent effects of volatility shocks. The reason why we should stop at the third order solution is

that Aruoba S. B. *et al.* (2006) compares the perturbation method to global solution methods such as value function iteration and collocation. When they solve the model up to fifth order, they see that beyond the third order the accuracy of the perturbation method does not increase so much hence third order perturbation solution is pretty good.

Moreover, we can use forecast error variance decomposition (FEVD) and historical decomposition (HD). By using former one we can find the average contribution of the structural shocks to the variance of the series. By using latter, we can see the actual contribution of the structural shocks to the level of the time series.

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