A New Keynesian Small Open Economy DSGE Model in Islamic Economic Framework: The Case of Iran*

Mehdi Feizi†

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Abstract

Prohibition of interest rate in Islamic economic framework have posed a number of problematic challenges in macro model building and execution of monetary policy mechanisms that have not been fully analyzed in the literature that is basically focused on developed countries. This paper makes a first attempt to develop and estimate a New Keynesian small open economy DSGE Model for Iran using a Bayesian methodology. The choice of Iran is based on the fact that Iran is among the pioneering countries whose banking operations comply with the Sharia. The central banks in an Islamic framework should develop innovative types of shariah-compliant financial instruments that are also complying with conventional economics. Since we don't have actual data on interest rate and enough data on other possible monetary instruments in Iran, We introduced the exchange rate as an alternative monetary policy instrument for Iranian economy.

Keywords: New Keynesian DSGE Model, Small Open Economy, Islamic Banking, Monetary Policy Instrument, Exchange Rate.

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†Address: Room 4.52, Institute for Monetary and Financial Stability (IMFS), House of Finance, Campus Wesend, Goethe University Frankfurt, Grüneburgplatz 1, D-60323, Frankfurt am Main, Germany. E-mail: feizi@wiwi.uni-frankfurt.de.

1 Introduction

Interest rate is the most important instrument for implementation of monetary policy. Prohibition of interest rate in Islamic economic framework, have posed a number of problematic challenges in macro model building and execution of monetary policy mechanisms that have not been fully analyzed in the literature. This paper makes a first attempt to develop and estimate a New Keynesian small open economy *Dynamic Stochastic General Equilibrium (DSGE)* Model for Iran. The choice of Iran is based on the fact that Iran is among the pioneering countries whose banking operations comply with the *sharia*[1] rules of Islam;[2] While many other Islamic countries have established mixed systems which combine aspects of conventional and Islamic banking practices. Although unstable volatile changes in economic variables caused by structural changes of the economy, may raise some weaknesses regards of model building; this fact that Iran is also a developing country, makes it an interesting case to investigate the behavior of economy in a DSGE framework.

Iran has received much attention from a geopolitical and regional standpoint, but its economic challenges have not attracted a similar degree of interest. Since 1979 revolution, Iran has undergone important socio-economic and institutional changes and has been affected by significant economic and political upheavals[3]. It has witnessed several changes in policy regimes and undergone numerous exogenous shocks during the past three decades; some of them are external factors including eight years war with Iraq, sanctions[4], etc. However, major imbalances in the Iranian economy were also internal factors e.g. government deficits, institutional economics and structural regime changes.

Iran has a history of relatively persistence double-digit inflation[5]. Moreover, measured

[1]Sharia is the legal framework within which the public and some private aspects of life are regulated for those living in a legal system based on Islamic principles of jurisprudence.

[2]The Islamic banking bill became law in Iran on 21 March 1984 that banned the payment of interest on all lending and borrowing activities. An exception was made for the ordinary transactions of the Central Bank with the government, government institutions, public enterprises, as well as banks, as long as these institutions use their own resources.

[3]For a wide review on economic transformation of Iran in a global context through the twentieth century see Salehi Esfahani and Pesaran (2008).

[4]Torbat (2005) presents a case study of the effectiveness of the US unilateral trade and financial sanctions on Iran. It is found that the financial sanctions have had a more powerful impact than the trade sanctions. The analysis also shows that the unilateral import sanctions on the fungible crude oil have been ineffective. It is concluded that, overall, the sanctions' economic effect has been significant, while its political effect has been minimal.

[5]Alavi and Athawale (2005) show budget deficits, as well as liquidity, do have a significant impact on inflation rates in Iran. Bahmani-Oskooee (1995) have also emphyed the monetarist model of inflation,

inflation is likely to underestimate true inflation owing to price controls and direct and indirect government subsidies. The Iranian economy is heavily dependent on oil revenues. Given that the production of crude oil is relatively fixed in the short term, Iran's crude oil export revenues are highly correlated with the oil price. Hence budgetary expenditures are rather pro cyclical with oil prices and domestic demand booms induced by fiscal expansions in periods of high oil prices generate pressures for real exchange rate appreciation.

Mazarei (1996) examining developments in economic institutions and the macroeconomic performance of Iran since the 1979 revolution; argued that the prevailing economic conditions in Iran are largely the outcome of populist economic policies adopted by the Iranian government. The economy continues to be saddled with high tariffs, trade restrictions, large implicit and explicit inefficient subsidies to tradable goods, distortions in the pricing system and administrative allocation of resources, credit and foreign exchange. Hakimian (1999) examines macroeconomic challenges during different phases in the post-revolutionary period and argues that, fundamental economic transformation is still unrealized and Iran continues to grapple with important, unresolved dilemmas affecting the nature of her economic policy and institutions. To a large extent, these internally imposed constraints as Liu and Adedeji (2000) argued, have prevented Iran from taking the full advantage of productivity gains, rendered the government incapable of formulating effective and consistent policy responses, made the economy less competitive and weakened its capacity to response to external shocks.

The remainder of the paper is structured as follows. Section 2 gives a outline of monetary policy in Islamic economics framework, discussing riba and possible monetary instruments. In Section 3 we introduce the nominal exchange rate as a new monetary instrument. The transmission mechanism of domestic and foreign economy are discussed in Section 4. Section 5 describe the methodology and result of estimation of the model and finally we bring to a close in section 6 with concluding remarks and possible model extensions

augmented with the exchange rate and import prices to identify the determinant of inflation in Iran.

2 Monetary Policy in Islamic Economics Framework

Even though there are several verses in the *Qur'an* that condemn a practice called riba, we do not know exactly what riba is and whether any prohibition against interest applies to nominal or real rates. For instance, while the Qur'an prohibits a fixed or predetermined rate of return on financial assets, it does not forbid uncertain rates of return (such as profits) on financial transactions. The interpretation of riba varies even among different scholars of Islamic law and jurisprudence[6].

Recent developments in this area have revived the ancient controversy concerning the legitimacy of riba. The problem is compounded by a tendency to interpret riba, as both usury[7] and interest. In an Islamic financial system, interest is actually is a profit sharing system in which risks are shared between lenders and borrowers[8]. Mews and Ibrahim (2007) argue that by retrieving the necessary distinction between demanding usury as illegitimate predatory lending and interest as legitimate compensation, we can discover common ground behind the driving principles of financial ethics within both Islamic and Christian tradition[9].

Although some scholars argues that, the absence of interest rate in Islamic economics, and the existence of some institutions (e.g. *zakat*), minimize the speculative demand of money and make total demand for money more stable; as consequence of abolition of riba-based transactions in Islamic banking, price ceilings in financial markets may distort saving and investment, potentially reduce the pace of economic development.

Islamic banking refers to a system of banking that is based on legally Sharia consistent financial contracts and transactions. In particular, conventional transactions based on an

[6]In classical Islamic jurisprudence, *riba* is defined as "surplus value without counterpart". For more details on the broader definition of riba in Muslim countries especially Iran and Modern interpretations of riba and Islamic financial contracts, instruments and institutions see Nomani (2003). It shed light on the development of the debate on riba among Sunni and Shi'i scholars, the position of governments on the problem of interest-free banking in the twentieth century in Egypt, Iran and Pakistan and also the implications of this debate for Islamic financial contracts.

[7]Usury was defined originally as charging a fee for the use of money. This usually meant paying interest on loans. Today, it refers to the charging of unreasonable or relatively high rates of interest.

[8]Haque and Mirakhor (1986) formulate investment behavior in such a system as a principal-agent problem and investigate the relevant issues under conditions of uncertainty and moral hazard. As a major conclusion, no only the assertion of investment decline cannot be justified but also under certain conditions, a profit-sharing system may lead to an increase in investment.

[9]In Christian tradition usury has always evoked the notion of money demanded in excess of what is owed on a loan, disrupting a relationship of equality between people, whereas interest was seen as referring to just compensation to the lender.

ex-ante promise of a risk-free rate of return are forbidden in Islamic economic jurisprudence. Errico and Farahbaksh (1998) analyzes the implications of Islamic precepts on banks' structure and activities, focusing on banking supervision issues in the context of a paradigm version of Islamic banking, a conventional system and also a mixed framework of those.[10]

Although In an Islamic economic framework, the central banks have the same functions as an interest-based economy; they should develop innovative types of *sharia-compliant financial instruments* (e.g. *sukuk*) that are also complying with conventional economics. Imran Usmani (2007) evaluates the nature of conventional fixed income securities from the sharia perspective and outlines the reason for its impermissibility. It also discusses different types of sukuk that can be issued in place of conventional fixed income securities for not only meeting funding requirements but also to develop an efficient and diversified capital market institution.

Partnership Contracts in Islamic banking are also innovative in the sense that they are neither fully an equity nor a debtor-creditor relationship. *Musharaka* (equity participation) is also a special partnership contract between shareholders of equity and lenders or depositors in conventional systems. In this case the bank and the public jointly contribute capital, with or without joint management of business ventures. The profit or loss of such contracts is shared by all partners according to contribution or on a negotiated basis.

Another possible tool is *Central Bank Musharaka Certificates (CMC)* that refers to an equity-based instrument that is issued against the government or central bank ownership in commercial banks. Since these securities can be traded in a secondary market, they enable the central bank to regulate domestic liquidity through open market operations. The central bank could also extend refinancing to commercial banks (Refinance Ratio) for some of all types of loans granted by commercial banks to the public that would affect the liquidity of the banks.

2.1 Monetary Policy in Iran

There is no record of inflation targeting in Iran before implementing the First and Second *Five Year Development Plan (FYDP)*. However, inflation targets have been set within the first two plans (1989-1994 and 1996-2001); but at much higher levels compared with other

[10]For more complete review of literature on Islamic banking and finance see Ahmed (1989) or Khan and Mirakhor (1989b). Khan and Mirakhor (1989a) has also a describtion of the developments in Islamic Banking in Iran.

countries (For instance 12%, for the second FYDP and 15% for the third one). The finding of Khashadourian, and Grammy (2007) would cast doubt on the compatibility between inflation and growth targets outlined in the third five-year economic plan of the country.

Indeed, the dominance of the fiscal sector on the monetary authorities has undermined the independence of the central bank, leaving small room for the success of inflation targeting strategy. Monetary authorities have been unable to use money market operations, discount rate, and the reserve requirement effectively. Also the decomposition of monetary base in Iran reveals that government debt to the central bank has adversely affected the effectiveness of monetary instruments. No wonder that monetary authorities have not succeeded to achieve the goals, undermining the credibility of the policies.

Since the outset of the revolution, the major concern of the Iranian authorities was to compliance all aspects of society with Islamic teachings. These attempts in the banking system lead to establishment of a usury-free banking system. The "*Usury-Free Banking Law (UFBL) Operations*" states that banks as representatives of the depositors and trustee of people invest the deposits in the form of Islamic contracts e.g. Musharakah, on behalf of their clients. Based on this relationship the funds are being utilized in generative and profit-making investments. The benefit is then paid to the depositors after deducting service fees of the banks.

The regulations pertaining to determination of banking profit rate, as is stipulated in UFBL, are determined by the *Money and Credit Council (MCC)*. Moreover, the CBI can intervene in determining these rates both for investment projects or partnership and for other facilities extended by banks. According to *Monetary and Banking Law (MBL)* of Iran, the CBI also can intervene in and supervise monetary and banking affairs By using for instance Selective Credit Control or Profit Sharing Ratio through limiting banks, specifying the mechanisms for use of funds and determining the ceiling of loans and credits in each sector.

In implementing monetary policy, the central bank can directly resort to its regulating power or affect money market conditions indirectly as issuer of high-powered money (notes and coins in circulation and deposits held with Central Bank). On this basis, two different monetary policy instruments are being utilized: direct instruments with no reliance on market conditions (Banking profit rates and Credit ceiling) and indirect instruments (Reserve Requirement Ratio, Open deposit account and CBI Participation Papers) that

are market-oriented.

Required Reserve Ratio (RRR) is the percentage of deposits that a commercial bank must hold in a form determined by the central bank. If the central bank decides to curtail the availability of the loanable funds, it could raise the required reserve ratio and if it wants to expand the loanable funds availability, it could decrease the required reserve ratio. According to MBL, the CBI is authorized to determine RRR within 10 to 30 percent depending on banks' liabilities' composition and field of activity.

One of the bold measures taken for the efficient utilization of indirect monetary instruments in the framework of the UFBL is to allow banks to open a special deposit account with the CBI. The main objective of this plan was the adoption of appropriate monetary policies to control liquidity through absorption of banks' excess resources. The CBI pays profit to these deposits on the basis of specific rules.

Utilization of bonds, owing to its fixed interest rate nature, is prohibited according to Islamic Sharia; however, utilization of participation papers and investors' partnership in economic activities and payment of profit is encouraged. By using this instrument, the CBI could affect broad money (M2) through monetary base, thereby controlling the rate of inflation. Appropriate implementation of monetary policies by the CBI could be done through open market operations e.g. *National Participation Paper (NPP)* that promises on maturity to pay a rate of return that is equal to or above an estimate rate of return in the private sector.

In fact a variety of methods have been proposed for approximating the rate of return on private sector activities and hence the rate of return on the NPP. Ul Haque and Mirakhor (1998), presents the approach for the design of national participation paper as an instrument of government finance and monetary management in an Islamic economy and discusses various conceptional issues underpinning the introduction of such an instrument and methods of calculating a corresponding rate of return. Ideally, such a rate of return should be obtained either on the stock market or the participation paper market. However, there is little or no development of the corporate paper market along Islamic lines. Given the relatively limited state of development of financial markets in Islamic countries with high likelihood of distortions and speculative behavior in nascent markets, it is still hard to obtain the sort of return that is required for NPPs.

Other possibilities for measuring private sector rate of return include constructing an

index based on the ratio of market price of capital to its replacement cost (Tobin's q), or an index using information such as earnings per share and price earnings ratio, or a composite general index that uses elements from all of the above. The operational effectiveness of such indices would depend upon the stability and transparency of the estimates.

The efficient implementation of NPP would require a relatively developed and efficient stock market to capture a sufficiently large segment of private sector activities in the economy, and the use of a filtering formula to eliminate signals emanating from expectations of future earnings, speculative fervor and seasonal variations. In addition, beyond technical issues of *Central Bank Musharaka Certificates (CMC)* involving accounting, asset valuation and calculation of yields, the central bank will need to develop the techniques for primary issuance of the CMCs that would make them impractical to use. Since we don't have actual data on interest rate and enough data on other possible monetary instruments in Iran (e.g. Regulation on Open deposit account (ODA) was approved at 1999), the exchange rate could plays an important role in the monetary process.

3 Exchange Rate as a New Monetary Instrument

The vast literature on the *Science of Monetary Policy* is deals mainly with various regulatory, monetary and institutional aspects of the central banking in industrial countries with interest-based economy, providing limited insights and less attention to the conduct of monetary policy in either Islamic framework or developing countries where the characteristics of the economy and monetary policy setting is quite different; e.g. besides the conceptual problem of interest rate prohibition, in most Islamic countries we also have institutional problem in sense of underdeveloped financial market.

Research on monetary policy rules like other parts of literature, has basically focused on developed countries, whose debt and foreign exchange markets are developed and sophisticated. The question is being raised as to what modifications need to be made for the effectiveness of modern monetary policy in emerging market economies and especially Islamic framework. Taylor (2000) lists five issues: What is the appropriate instrument in the policy rule? What is the appropriate specification in the policy rule? What is the relationship of the policy rule to inflation targeting? What are the implications of underdeveloped long-term bond markets for the choice of a policy rule? And finally what is the role of the exchange rate in the policy rule?

because monetary policy rules affect expectations, Taylor (2000) asses that the explicit use of a monetary policy rule is a more critical decision than any change in the chosen policy instruments. While the interest rate is most commonly used by the central banks of industrial countries, its usage is not universal. Peiris and Saxegaard (2007) state that only in the very few cases in developing countries, interest rates represent a reliable instrument of monetary policy where inter-bank money markets and secondary markets for government debt are well developed which is not the case for the majority of Islamic countries. Hence even without Islamic economic framework, interest rates could not play a role of reliable monetary policy instrument in these countries, at least in short run.

Therefore, one should think of another instrument. In this respect, the relevant policy questions are not wholly those concerned with how, and over what horizon, countries may make the move towards optimum inflation targeting; rather they must include how best the available instruments of monetary policy be deployed in this kind of economies with distorted instruments and high inflation rate. The designed instrument of market-based monetary operations should have the potential to be widely held so that monetary signals can be transmitted efficiently through the market.

Numerous past empirical studies addressed various questions on the relationship between monetary policy and the exchange rate. For instance, Bahmani-Oskooee (1991) argue that exchange rate variability is a factor contributing to inflation variability. In another paper, Bahmani-Oskooee and Malixi (1991) try to investigate the effects of effective exchange rates of developing countries on their demand for money. It is shown that in most developing countries, while the short-run effects of depreciation could be in either direction, its long-run effects are negative indicating that depreciation causes a decline in the demand for domestic currency.

Some recent studies e.g. Dueker and Fischer (1996) and Malikane and Semmler (2006), examined the effects of monetary policy shocks on the exchange rate. Other, so-called monetary reaction function literature, addressed how the monetary authority reacts to exchange rate changes. According to Dennis (2003) policymakers should allow for movement in the real exchange rate and the terms-of-trade when they set interest rates. Further, taking real exchange rate movement into account appears even more important with price level targeting than with inflation targeting.

Another trend in the literature was to examined how the foreign exchange intervention

affected the exchange rate, while others analyzed how foreign exchange intervention reacted to the exchange rate. Intervention refers to official purchases or sales of foreign exchange undertaken to influence exchange rates. Sarno and Taylor (2001) assesses that, unlike the profession's consensus of the 1980s, official intervention can be effective, especially as a signal of policy intentions and when publicly announced and concerted. Kim (2003) is developed the structural VAR model to jointly analyze the effects of foreign exchange intervention and conventional monetary policy on the exchange rate. It shown that foreign exchange intervention has substantial effects on the exchange rate, reacts to the exchange rate significantly (to stabilize the exchange rate), and signals future conventional monetary policy stance changes (to back up the intervention).

Humpage (2003) asses that by intervening in the foreign exchange market, the monetary authority aims to affect the exchange rate through three main channels. First, if interventions are not sterilized, they alter the money supply and hence the exchange rate directly. In this case, interventions and the monetary stance are clearly interconnected Second, when sterilized, interventions change the supply of bonds denominated in domestic and foreign currency. Because these securities are not perfectly substitutable, the exchange rate is affected by an ensuing change in portfolio composition. Finally, interventions may signal future monetary policy moves, even when they are sterilized; purchases of foreign currency should indicate an impending monetary easing, which also has a bearing on the exchange rate data. Interventions may signal a perception that the exchange rate is misaligned, which might subsequently trigger a change in the monetary stance. Market participants may therefore perceive interventions as an attempt by the central bank to target a specific level of the exchange rate, which would create interdependencies between interventions and monetary policy.

Within a simple model of monetary policy for an open economy, Vitale (2003) study how foreign exchange intervention may be used as a costly signal of the policy makers' objectives. The analysis indicates that foreign exchange intervention typically stabilizes the national economy and reduce the fluctuations of employment and output. this result is sensitive to the institutional structure of decision-making. Developing economies typically suffer from sizeable currency mismatches in debt portfolios which aggravate the balance-sheet effects of exchange-rate fluctuations. In such an environment, monetary policy itself may be responsive to exchange-rate developments, which creates a potential simultaneity

between intervention and monetary policies.

Given the possibility that fiscal policy remains pro-cyclical in the short term, the vulnerability of the Iranian income, output and real exchange rate to oil price shocks underscores the importance of adopting an exchange rate regime which facilitates increased nominal exchange rate flexibility. Especially choosing the exchange rate as a monetary policy instrument, naturally would lead to choosing managed float exchange rate regime (sometimes also called dirty float regime) that is especial kind of float exchange rate regime. In this regime central banks allow the market to determine the exchange rate but they would frequently intervene to avoid excessive appreciation/depreciation and prevent large fluctuations in the rate.

The choice depends on the level of distortions and control that the authorities would like to tolerate in the economy. The degree of intervention directly depends on the variance of the real shocks and the variance of the monetary shocks. In addition under this exchange regime, CBI would have this opportunity to determine the value of the currency not based on a political issues that's mostly the case in a fixed exchange rate regime and especially a multiple exchange rate one like what we had for a period of time in Iran.

The approach of the Iranian authorities to exchange rate policy over the past decade particularly until 1997 indicates a strong preference toward maintaining stable nominal exchange rates, as revealed by the application of fixed official rates to many external transaction categories. From the 1970s until the March 2002 unification, the exchange rate system of Iran was heavily controlled, featuring multiple exchange rate practices with associated exchange restrictions and import controls. Prior to March 1993, three official rates were used within the banking system, and a parallel market for foreign exchange operated outside the banking system.[11] Finally all remaining official exchange rates of the Iranian rial were unified in March 2002, after which the authorities adopted a market based managed floating exchange rate system.

[11] The basic official rate was applied to oil export receipts, imports of basic necessities, and official debt repayments. The competitive rate was applied to intermediate and capital goods imports, which were not eligible for the official rate. The floating rate, which was determined by the banks taking into account the parallel market rate, was applied to the remaining transactions in the banking system.

4 Model and Setting

In this paper we develop a New Keynesian[12] small open economy Dynamic Stochastic General Equilibrium (DSGE) model for Iranian economy, as an Islamic country. In recent years, considerable progress has been made in the estimation of New Keynesian DSGE models for a number of *Small Open Economies* (SOEs). For instance small-scale DSGE model of Buncic and Melecky (2008) for Australia, Olekah and Rasheed (2007) for Nigerian economy, Liu and Gupta (2007) for the South African economy, Liu (2006) for New Zealand economy, Silveira (2006) for Brazilian economy and Medina and Soto (2006) and also Caputo and Liendo (2005) for the Chilean economy. To the best knowledge of the author, besides Zanganeh (1995) that just formulated an interest-free economic system in terms of familiar Neoclassical macroeconomics models, no such study exit not only for Iran but also for all the Islamic countries. But one could not get that much out of this literature on developing countries to contribute for DSGE modeling in Islamic context.

We utilize a two-block model that falls into the general class of *New Keynesian Policy Models* (NKPMs): a domestic block comprising an IS equation, a Phillips curve and an uncovered interest parity (UIP) condition. Since Europe has the highest share of trade with Iran, we took Euro area as a proxy for the exogenous world economy. The foreign block is exogenous to the domestic one. The framework that we follow is analogous to the SOE New Keynesian models which make it redundant for us to go through its micro-foundation. In these models, behavioral equations are explicitly derived from intertemporal optimization of private sector agents with rational expectations and various real and nominal rigidities and under technological, budget and institutional constraints such as imperfections in factor, goods and financial markets.[13] In this framework, macroeconomic fluctuations can be seen as the optimal response of the private sector to demand and supply shocks in various markets, given the constraints mentioned above.

Representative infinitively-lived Household would decide optimally on consumption C_t, and labor, N_t:

$$E_t \sum_{i=0}^{t=\infty} \beta^i [\frac{C_{t+1}^{1-\sigma}}{1-\sigma} - \chi \frac{N_{t+1}^{1+\eta}}{1+\eta}].$$

where σ is the inverse of intertemporal elasticity of substitution, η is the inverse of

[12] For a short overview of the new Keynesian theory of optimal monetary policy see Zimmermann (2003).
[13] See Pagan (2003) for an outline and comparison of various macroeconomic modeling approaches.

elasticity of hours worked with respect to real wage and β is the subjective discount factor. The exchange rate's impact on the opportunity cost of holding domestic money especially in high-inflation country like Iran is highlighted in the budget constrain of household:

$$C_t + \frac{M_t^*}{P_{t-1}^*}\frac{P_{t-1}^*}{P_t^*}\frac{P_t^*}{P_t} = \frac{W_t}{P_t}N_t + \frac{M_{t-1}^*}{P_{t-1}^*}\frac{P_{t-1}^*}{P_t^*}\frac{P_t^*}{P_t} + \Pi_t.$$

Where M_t^* is the amount of foreign currency held so as to keep the value of money in the high-inflation economy. P_t^* is the foreign price index, P_t is the domestic price index, $W_t N_t$ is the nominal wage and Π_t is the profit from firm. Based on FOC, one could drive Euler equation:

$$C_t^{-\sigma} + s_t = \beta E_t[C_{t+1}^{-\sigma} + \frac{s_{t+1}}{\pi_{t+1}^*}].$$

Where s_t is the real exchange rate. This would lead us to different IS curve as:

$$y_t = E_t y_{t+1} - \frac{1}{\sigma}(E_t \Delta s_{t+1} - \pi_{t+1}^*) + \varepsilon_t^y.$$

since based on Augmented Dickey-Fuller test and both Schwartz and Akaike information criteria, the null hypothesis of having unit root in real exchange rate series could be rejected (Table 2), we assume that purchasing power parity (PPP) theory holds in Iran[14], it would change to the new IS curve:

$$y_t = E_t y_{t+1} - \frac{1}{\sigma}(E_t \Delta q_{t+1} - \pi_{t+1}) + \varepsilon_t^y.$$

In order to modify this IS curve for open economy, one could add foreign output gap and exchange rate to that:

$$y_t = E_t y_{t+1} - \delta_1(E_t \Delta q_{t+1} - \pi_{t+1}) + \delta_2 y_t^* - \delta_3 q_{t-1} + \varepsilon_t^y. \quad (1)$$

Where y_t is the output gap, r_t is the interest rate, y_t^* the is foreign output gap, q_t the is nominal exchange rate, $\delta_1 \equiv \sigma^{-1}$ and ε_t^y is the white noise IS curve shock. The presence of

[14]In general it depends on the period and unit root test. For instance, Bahmani-Oskooee (1998), Showed that while in most cases the KPSS test supported the stationary of the real effective rates in Middle Eastern countries, thus the PPP, the ADF test did not.

the real exchange rate and the foreign output gap in (1) denotes the transmission channels of foreign shocks into the domestic economy.

In the specification of the monetary policy reaction function, we followed Clarida et al. (1999) and Svensson (2000) arguments that a Taylor-type rule which considers only the domestic output gap and domestic inflation is optimal even for an open economy, and that it is reasonably robust to different model structures. Therefore, we consider a general form of monetary policy rule as below

$$r_t = \varphi_\pi E_t \pi_{t+1} + \varphi_y y_t. \tag{2}$$

where φ_π and φ_y are policy coefficients and ε_t^r is the monetary policy white noise shock. To be able to close the model, the evolution of the real exchange rate in UIP needs to be specified which is the key equation in open economy. We followed IMF approach of Berg et al (2006) for emerging countries which is

$$q_t = \delta E_t q_{t+1} + (1-\delta) q_{t-1} + (r_t - E_t \pi_{t+1}) - (r_t^* - E_t \pi_{t+1}^*) + \varepsilon_t^q. \tag{3}$$

Where δ has generally a pre-specified value of 0.5 and ε_t^q is the white noise error term. Hence from (2) and (3) we have

$$q_t = \delta E_t q_{t+1} + (1-\delta) q_{t-1} + (\varphi_\pi - 1) E_t \pi_{t+1} + \varphi_y y_t - r_t^* + E_t \pi_{t+1}^* + \varepsilon_t^q. \tag{4}$$

The exchange rate affects both inflation and output gap via effects on net exports, on domestic prices through import price pass-through, and on interest rates (through interest rate parity). Kia (2006) found that, over the long run, a higher exchange rate (lower value of domestic currency) leads to a higher price in Iran. So a policy regime that leads to a stronger currency can help to lower inflation. By identifying a long-run equilibrium condition in the money market, Celasun and Goswami (2002) also find a strong impact of money and the exchange rate in the short-run inflation equation in Iran. The equation describing inflation dynamics in the domestic economy is modelled by the following Phillips curve:

$$\pi_t = E_t \pi_{t+1} + \lambda_1 y_t + \lambda_2 q_t + \varepsilon_t^\pi. \tag{5}$$

Where π_t is the CPI inflation rate and ε_t^π is the Phillips curve white noise shock. Equations (1), (4) and (5) represent the domestic side of the model. The specification of

the Euro area is analogous to the one employed for the domestic economy, with the impact of foreign variables completely removed:

$$y_t^* = E_t y_{t+1}^* - \delta^*(r_t^* - E_t \pi_{t+1}^*) + \varepsilon_t^{y*}. \tag{6}$$

$$\pi_t^* = E_t \pi_{t+1}^* + \lambda^* y_t^* + \varepsilon_t^{\pi*}. \tag{7}$$

$$r_t^* = \varphi_\pi^* E_t \pi_{t+1}^* + \varphi_y^* y_t^* + \varepsilon_t^{r*}. \tag{8}$$

The model described by Equations (1), (4) and (5) to (8), specifies the complete two-block structure.

5 Methodology and Result

There exist several estimation methods in the literature to fit New Keynesian models to the data. One method that is often employed is the *Generalized Method of Moments (GMM)*. However, Lind´e (2005) showed recently that GMM estimates of the parameters of a simple New Keynesian model are likely to be estimated imprecisely and with a bias. It has thus become common practice to estimate New Keynesian models using either a *Full Information Maximum Likelihood (FIML)* or Bayesian approach. it is more natural to add a probabilistic statement, or a prior belief, on the parameter space of the estimated model, rather than imposing constraints on the parameter space in ML estimation. This can be done easily within a Bayesian estimation approach which combines theoretical constraints and prior beliefs on the parameter space with the information contained in the data. Our preferred approach to obtain parameter estimates and draw inferences on the model is therefore Bayesian approach.

The Bayesian approach to estimating a NKPM with nominal rigidities consists of the following steps. Combining the likelihood function of the solved model with the prior densities on the parameters then defines the posterior density. The values of the parameters at the posterior mode, together with the corresponding Hessian matrix are then used to start the random walk Metropolis-Hastings sampling algorithm to obtain draws from the entire posterior distribution. Metropolis-Hastings algorithm used to generate a sequence of samples from a distribution. In order to find the mean and variance of the estimators (posterior distribution) based on the posterior mode; the algorithm constructs a Gaussian

approximation around the posterior mode and uses a J-scaled version of the asymptotic covariance matrix as the covariance matrix for the proposal distribution.

Priors are described by a density function and could be seen as weights on the likelihood function in order to give more importance to certain areas of the parameter subspace. More technically, priors and likelihood functions are tied together by Bayes' Rule. Given the model, its parameters priors' distributions and the observed variables that are declared on *varobs* command in the code; Dynare uses *Kalman Filter* to calculate the recursive likelihood function that describes the density of the observed data. Having estimated the likelihood and the priors, Dynare construct the posterior density by using twice the Bayes Theorem. Finally, the posterior kernel (un-normalized posterior density) corresponds to the numerator of the posterior density.

In order to estimate the posterior mode, Dynare simply maximize the log posterior kernel with respect to model parameters using numerical methods. The posterior distribution of parameters will be given by the kernel equation that is a nonlinear function of the deep parameters of model. Thus instead of obtaining an explicit form, Dynare resorts to *sampling-like methods* and particularly *Metropolis-Hastings Algorithm.*

Based on the fact that under general conditions, the distribution of the deep parameters will be asymptotically normal; Dynare picks a random new candidate for the current draw from normal distribution with the mean equal to last period value of parameter vector and variance equal to the J-scale multiplied by the inverse of Hessian matrix evaluated at the above posterior mode. Then it compares the ratio between the value of posterior kernel at the new candidate and at the old value. For the value of this ratio above or equal one, Dynare sets the current value equal to the new candidate. For values below one, Dynare sets the current value as a linear weighted average of new candidate (with the computed acceptance rate as its weight) and the old one (with one minus the computed acceptance rate as the weight). For the next draw, it would set again the mean of drawing distribution to be equal to the updated value. Based on all draws, Dynare construct the histogram of these results which is actually our posterior distributions.

I used Dynare 4.2[15] which is a convenient and common tool for conducting Bayesian Estimation in DSGE framework. The estimation procedure uses Euro Area data on CPI inflation, GDP and interest rate for the period 1990Q3–2002Q2 from the database un-

[15]Dynare estimation codes is available upon request.

derlying the *New Area Wide Model* (NAWM) of the European Central Bank, which is described in detail in Fagan et al. (2005). Domestic CPI[16] inflation and GDP for this period stem from CBI Economic Time Series Databae[17]. Figure 1 depicts historical and smoothed graphs of these variables. The domestic and foreign output gaps are constructed by subtracting the Hodrick-Prescott filtered permanent component from quarterly GDP data. Since exchange rate data for the most of this period is constant and therefore uninformative, I used build-in *Kalman Filter* feature of Dynare estimation to generate measure of exchange rate from system.

Choosing the appropriate prior for parameters is a tricky task. One should think not only about the domain of prior over each parameter but also the shape of prior distribution (Symmetric, Skewed, etc.). In the case of Iran, micro-level studies were relatively scarce and could not be used to choose the priors distribution and their parameters. Therefore, Our choices of priors, have been based on widely accepted priors' distribution in the literature, namely for the standard deviation of exogenous shocks the inverted gamma has been chosen while non-informative normal distributions are chosen for the rest of the parameters. The marginal prior distributions for the model's parameters are summarized in table 1.

We ran 2 chains of 300000 draws, where the first 20% of each chain were discarded as a burn-in sample to eliminate the influence of initial values. Hence, finally I kept 240000 draws. j-scale that ensures that the average acceptation rate within each chain is around the value of 0.25 (which is the value often recommended to be achieved), should be set to 0.013. In addition, the acceptation rate of two chains are almost the same (0.3266 and 0.3271) which indicates robustness of the model.

In Figures 2 and 3, the thick and thin curves indicate the posterior and prior distributions respectively. Vertical lines represent their mode obtained by a maximum likelihood method. The plots of prior and posterior distributions indicate that there is a significant amount of information contained in the data that can be used to update our prior beliefs about the model's parameters. In other words, for most of estimated parameters, we have

[16]The Iranian CPI covered 346 items from 1990/91-1996/97, 344 items from 1997/98 - 2001/02 and 359 items nowadays; with slightly different weights in the sub-periods and also between administered and non-administered prices within each period. The prices of bread, sugar, vegetable oil, medicines, water, fuel, electricity, interurban bus transport, and inter-city air transport, which have a total weight of about 5.5 percent in the CPI, are subsidized and administered by the government.

[17]This data is available online at http://tsd.cbi.ir/

informative data in the sense that the posterior distributions visibly differ to assumed priors, implying that the used dataset contains more information than what was assumed in prior distributions. for all cases in which no further information gain have less estimated value than what assumed which is almost calibrated. For instance, the parameter on inflation in the domestic policy function (φ_π) or the coefficient on real interest rate in foreign IS curve (δ^*). comparing policy function estimation implied that the central bank in the euro zone, care significantly more about inflation than CBI.

The priors on the model's parameters are assumed to be independent of each other, which allows for easier construction of the joint prior density used in the MCMC algorithm. Using potential scale reduction statistics developed by Brooks and Gelman (1998) as MCMC univariate diagnostic in figure 4 for ε_t^y, ε_t^π, and ε_t^q and multivariate diagnostic in figure 5, We confirm the convergence of most of the parameters and the model as whole is achieved. This is further strengthened by the generated graphs of smoothed exogenous shocks. A rule of thumb for the presence of sensible estimation is that these should be centered around zero. This is very much achieved for domestic economy confirm also the assumption of white noise error terms.

The estimated posterior means of the parameters of the model at hand can be used further in order to examine the inherent dynamics of economy and the relative importance of different shocks. For that purpose, a separate code in Dynare is written which computes responses of the endogenous variables to one standard deviation impulse of exogenous shocks of the model for 12 periods (3 years) in the future. Figure 6 depicts Impulse Responses of endogenous domestic variables to exchange rate shock in which the horizontal axis represents time on a quarterly scale and vertical axis represents percentage deviations from equilibrium. findings here are hardly surprising. Positive exchange rate shock, as expected, leads to a fall in real activity and inflation that revert to their initial steady states in about 2 years.

In addition to examining the IRFs of the endogenous variables another interesting aspect of the analysis concerns the importance of the exogenous shocks in determining the variability of the endogenous variables. table 2 provides a Dynare generated variance decomposition. One striking result is the very prominent role that shock to exchange rate plays in the overall variability of inflation and output gap. It is of course interesting to examine how the variance decomposition of the endogenous variables at hand evolves as

the time horizon changes. This would allow one to disentangle the purely temporary from the more long-lasting shocks that hit the economy. The fact that exchange rate difference could be used to decrease the loss function could be also observed from correlation matrix in table 3.

6 Concluding Remarks and Model Extensions

The main contribution of this paper is introducing the difference of nominal exchange rate as an alternative monetary policy instrument for Iran as a typical Islamic economy. Indeed our model here is the simplest one that could be imagined. There are plenty of rooms to enrich the model and build more realistic but complicated model. One could think of different evolution procedure for shocks in the models or even other specification for UIP[18]. There are also a number of variant approaches to modelling the world economy in the literature. Furthermore the fact that riba is prohibited it does not mean that it does not really exist. As far as econometric work is concerned, people have used some proxies for the interest rate in Iran such as rate of return on housing industry, that could be also used as an monetary policy instrument.

One other important issue that we didn't take into account in this basic model is oil price which plays a significant role in Iranian economy. In fact, the strong and sustained rise in oil prices observed in recent years poses a challenge to monetary policy and its ability to simultaneously achieve low inflation and stable output. Unalmis et al. (2008) model the price of oil endogenously within a DSGE framework. Specifically, using a new Keynesian small open economy model, they analyze the effects of an increase in the price of oil caused by an oil supply shock and an oil demand shock. In addition, they investigate the sensitivity of the general equilibrium outcomes to the degrees of oil dependence and openness, as well as the strength of the response of monetary policy authority to the inflation.

Duval and Vogel (2008) also studies monetary policy in a small open economy New Keynesian DSGE model including oil as a production input and a component of final demand. It investigates the performance of alternative price level definitions, notably

[18]For instance, Adolfson at al. (2008) estimates and tests a new Keynesian small open economy model using Bayesian estimation techniques on Swedish data. It explore the consequences of modifying the UIP condition to allow for a negative correlation between the risk premium and the expected change in the nominal exchange rate.

headline and core CPI, in standard interest rate rules with respect to output and inflation stabilization. The analysis puts special emphasis on the impact of price and real wage rigidity and their interaction on the policy trade-off induced by the oil price shock.

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7 Appendix

Parameters	Prior Distributions	Posterior Mean	95% Confidential Interval
δ_1	$\mathbb{N}(0.15, 0.1)$	0.2988	[0.2553 , 0.3382]
δ_2	$\mathbb{N}(0.25, 0.05)$	0.2576	[0.2061 , 0.3148]
δ_3	$\mathbb{N}(0.1, 0.1)$	0.0209	[0.0171 , 0.0240]
λ_1	$\mathbb{N}(0.1, 0.1)$	0.0526	[−0.0655 , 0.1748]
λ_2	$\mathbb{N}(0.01, 0.01)$	−0.0534	[−0.0535 , −0.0534]
λ^*	$\mathbb{N}(0.1, 0.05)$	0.1316	[0.0598 , 0.1983]
φ_π	$\mathbb{N}(0.75, 0.3)$	0.6354	[0.6225 , 0.6440]
φ_y	$\mathbb{N}(0.25, 0.1)$	0.2382	[0.1315 , 0.3583]
δ^*	$\mathbb{N}(0.1, 0.1)$	0.0008	[0.0000 , 0.0017]
φ_π^*	$\mathbb{N}(1.75, 0.3)$	1.9217	[1.5205 , 2.2802]
φ_y^*	$\mathbb{N}(0.15, 0.1)$	0.1582	[0.0413 , 0.2687]
δ	$\mathbb{N}(0.5, 0.25)$	0.3909	[0.3897 , 0.3920]
ε_t^e	$inv\ \Gamma(1, 1)$	2.1252	[1.6858 , 2.5348]
ε_t^y	$inv\ \Gamma(0.01, 1)$	0.0292	[0.0119 , 0.0470]
ε_t^π	$inv\ \Gamma(1, 1)$	1.6756	[1.6287 , 1.7340]
ε_t^{y*}	$inv\ \Gamma(0.01, \infty)$	0.0067	[0.0055 , 0.0077]
$\varepsilon_t^{\pi*}$	$inv\ \Gamma(0.1, \infty)$	0.8056	[0.7142 , 0.9192]
ε_t^{r*}	$inv\ \Gamma(0.1, \infty)$	0.8511	[0.7972 , 0.9097]

Table 1) Bayesian Estimation of Model Parameters

Variables	ε_t^y	ε_t^π	ε_t^e	ε_t^{y*}	$\varepsilon_t^{\pi*}$	ε_t^{r*}
e	0.00	0.00	86.48	0.00	0.00	13.52
π	0.02	2.40	85.05	0.00	0.00	12.53
π^*	0.00	0.00	0.00	0.00	99.98	0.02
y	0.10	0.00	87.42	0.00	0.00	12.48
y^*	0.00	0.00	0.00	0.27	0.00	99.73
r^*	0.00	0.00	0.00	0.00	0.00	100.00

Table 2) Variance Decomposition (in present)

Variables	e	π	π^*	y	y^*	r^*
e	1.0000	−0.9734	0.0044	−0.9322	0.2821	−0.2825
π	−0.9734	1.0000	−0.0034	0.9685	−0.2209	0.2213
π^*	0.0044	−0.0034	1.0000	−0.0023	0.0155	−0.0155
y	−0.9322	0.9685	−0.0023	1.0000	−0.1479	0.1482
y^*	0.2821	−0.2209	0.0155	−0.1479	1.0000	−0.9986
r^*	−0.2825	0.2213	−0.0155	0.1482	−0.9986	1.0000

Table 3) Correlation Matrix

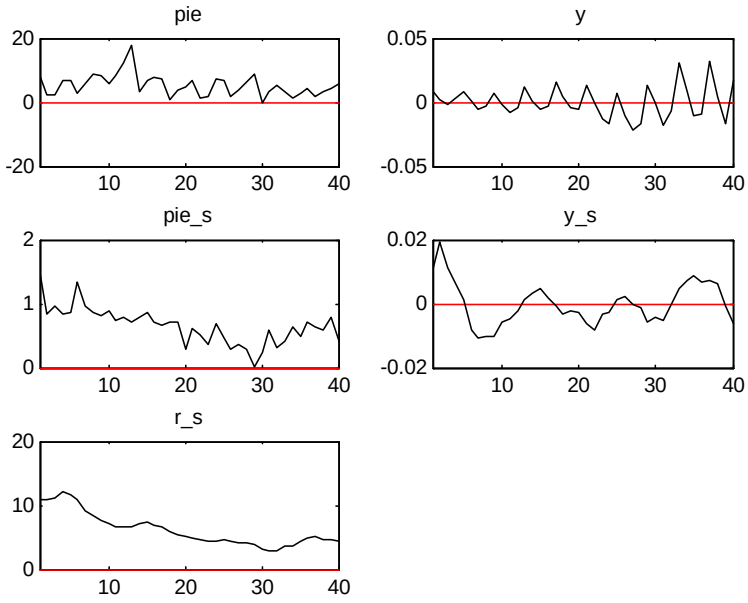

Figure 1) Historical and Smoothed Variables

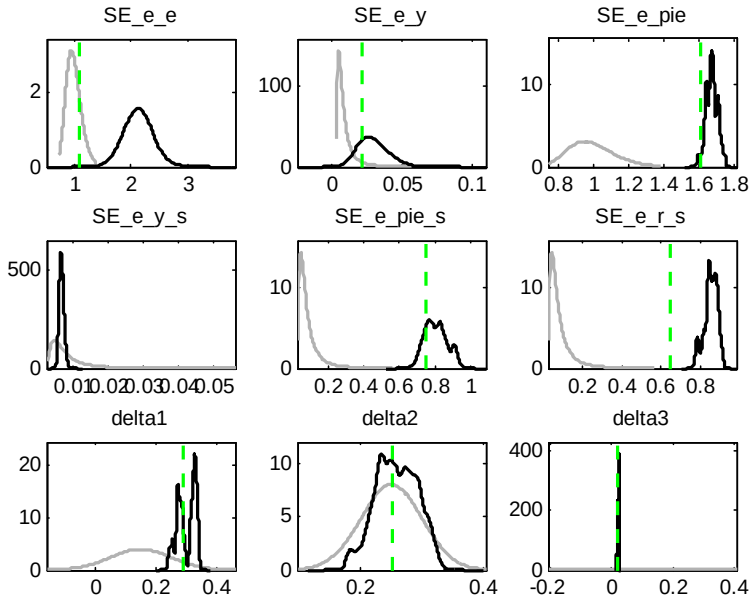

Figure 2) Prior and Posterior Distributions

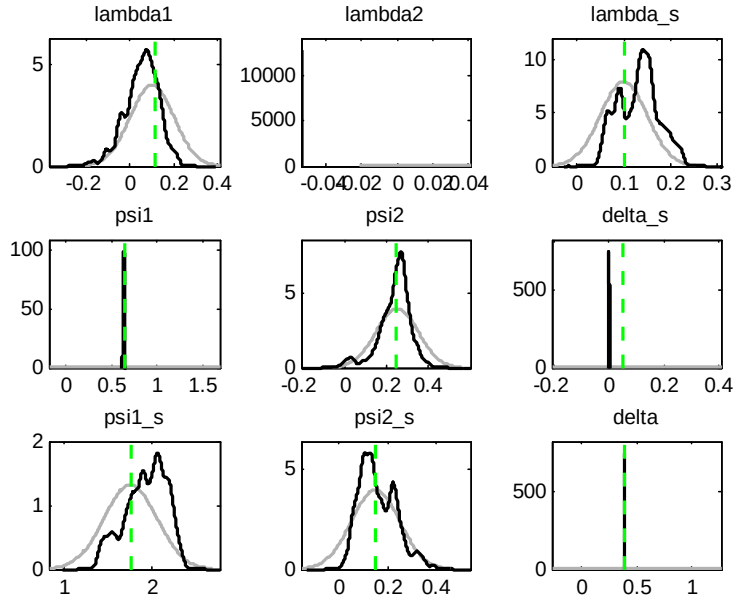

Figure 3) Prior and Posterior Distributions

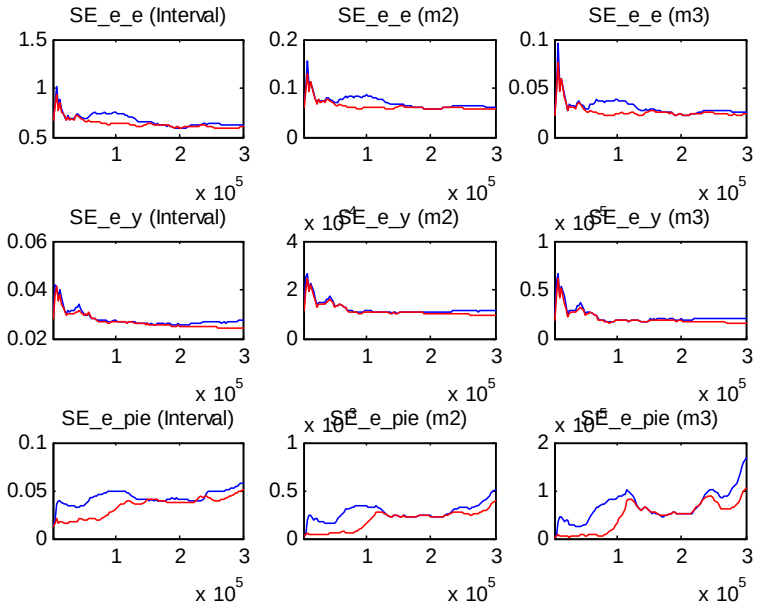

Figure 4) MCMC Univariate Diagnostics for ε_t^y, ε_t^π, and ε_t^q Brooks and Gelman (1998)

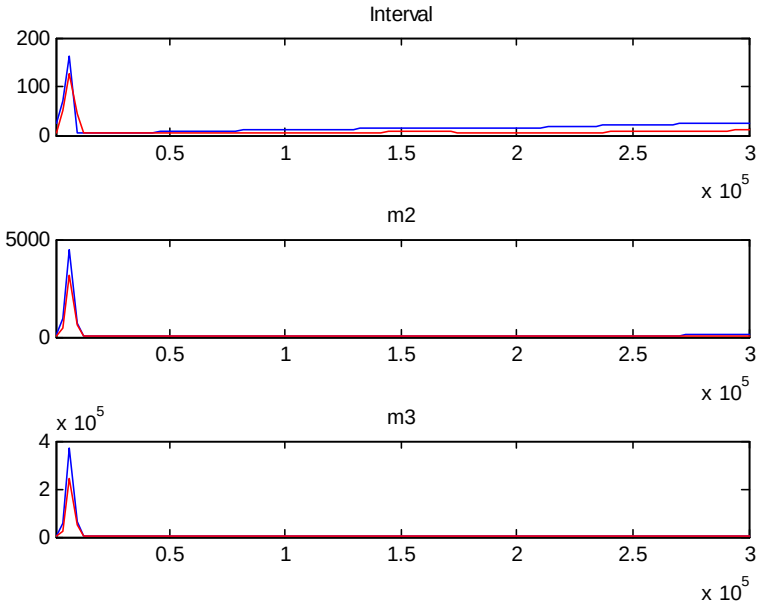

Figure 5) Multivariate Diagnostics

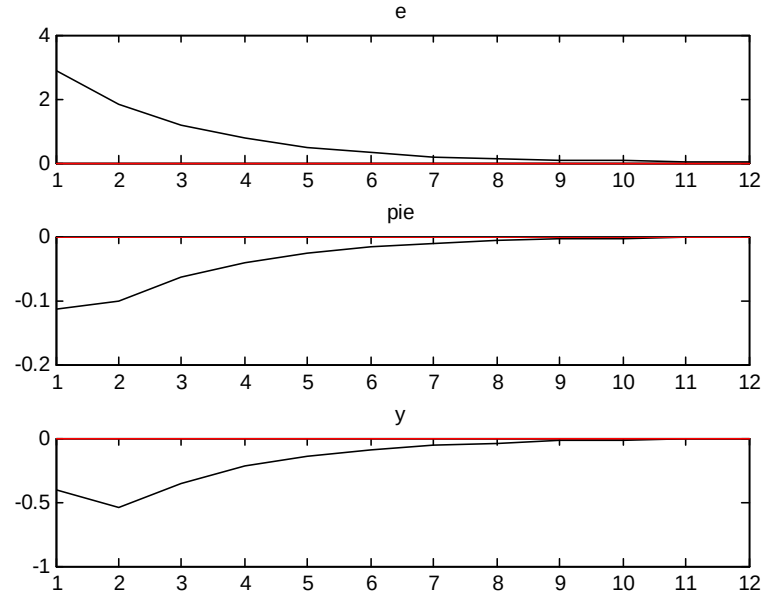

Figure 6) Responses of Domestics variables to ε_t^q