

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

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## Abstract

Prohibition of interest rate in Islamic economic framework has 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. Using a Bayesian methodology, this paper makes a first attempt to develop and estimate a New Keynesian small open economy DSGE Model for Iran which 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 there is not actual data available on interest rate and enough data on other possible monetary instruments in Iran, we introduced the nominal 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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# 1 Introduction

Interest rate is the most important instrument for implementation of monetary policy. Prohibition of interest rate in Islamic economic framework, has 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*<sup>1</sup> rules of Islam<sup>2</sup>, 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. It has undergone important socio-economic and institutional changes, been affected by significant economic and political upheavals<sup>3</sup>, and witnessed several changes in policy regimes and numerous exogenous shocks during the past three decades; some of them are external factors including eight years war with Iraq, sanctions<sup>4</sup>, etc. However, major imbalances in the Iranian

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<sup>1</sup>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.

<sup>2</sup>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.

<sup>3</sup>Mazarei (1996) argues 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. For a wide review on economic transformation of Iran in a global context through the twentieth century see Salehi Esfahani and Pesaran (2008).

<sup>4</sup>Torbat (2005) presents a case study of the effectiveness of the US unilateral trade and financial

economy were also internal factors e.g. government deficits and structural regime changes.

Iran has a history of relatively persistence double-digit inflation<sup>5</sup>. 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.

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 mechanisms of domestic and foreign economy are discussed in Section 4. Section 5 describes 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.

## 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*<sup>6</sup> is and whether any prohibition against interest applies to nominal or real rates<sup>7</sup>. Recent developments in this area have revived the ancient controversy concerning the legitimacy of *riba*. The problem is compounded by a tendency

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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.

<sup>5</sup>Alavi and Athawale (2005) show budget deficits, as well as liquidity, do have a significant impact on inflation rates in Iran. Bahmani-Oskooee (1995) employs the monetarist model of inflation, augmented with the exchange rate and import prices to identify the determinant of inflation in Iran.

<sup>6</sup>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.

<sup>7</sup>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.

to interpret *riba*, as both usury<sup>8</sup> and interest<sup>9</sup>. 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<sup>10</sup>.

Although some scholars argue 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 and potentially reduce the pace of economic development.

Islamic banking<sup>11</sup> refers to a system of banking that is based on legally *shariah-compliant financial instruments* and transactions. In particular, conventional transactions based on an *ex ante* promise of a risk-free rate of return are forbidden in Islamic economic jurisprudence. Although in this framework, the central banks have the same functions as an interest-based economy; they should develop innovative types of *shariah-compliant financial instruments* (e.g. *sukuk*) that are also complying with conventional economics<sup>12</sup>.

*Partnership Contracts* in Islamic banking are innovative as well 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

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<sup>8</sup>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.

<sup>9</sup>In an Islamic financial system, interest is a profit sharing system in which risks are shared between lenders and borrowers. 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, not 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.

<sup>10</sup>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.

<sup>11</sup>Errico and Farahbaksh (1998) analyze 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. 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 description of the developments in Islamic banking in Iran.

<sup>12</sup>Imran (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.

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 these plans, starting from 1989, but at much higher levels compared with other countries<sup>13</sup>. 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<sup>14</sup>.

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. *Musharaka*, 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<sup>15</sup>.

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<sup>13</sup>For instance, 12%, for the second FYDP and 15% for the third one. Moreover, 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.

<sup>14</sup>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.

<sup>15</sup>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

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*<sup>16</sup>, *Open Deposit Account*<sup>17</sup>, and *CBI Participation Papers*) that are market-oriented.

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)*<sup>18</sup> 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<sup>19</sup>.

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sector.

<sup>16</sup>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.

<sup>17</sup>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.

<sup>18</sup>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.

<sup>19</sup>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), present 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 and especially in Iran 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

Since there is not actual data available 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 play an important role in the monetary process.

### **3 Exchange Rate as a New Monetary Instrument**

The vast literature on the *Science of Monetary Policy* 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 is quite different. 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. But in most Islamic countries, besides the conceptual problem of interest rate prohibition, we also have institutional problem in sense of underdeveloped financial market.

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) assesses 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. Hence, even without Islamic economic framework,

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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.

interest rates could not play a role of reliable monetary policy instrument in these countries.

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) argues 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 other studies e.g. Dueker and Fischer (1996), examine the effects of monetary policy shocks on the exchange rate. Other, so-called *monetary reaction function* literature, addresses 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 is to examine how the foreign exchange intervention affected the exchange rate, while others analyze 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) assess that official intervention can be effective, especially as a signal of policy intentions and when publicly announced and concerted. Kim (2003) develops the structural VAR model to jointly analyze the effects of foreign exchange intervention and conventional monetary policy on the exchange rate. It shows 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) assesses 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<sup>20</sup>.

Within a simple model of monetary policy for an open economy, Vitale (2003) studies 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 reduces 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<sup>21</sup>.

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<sup>20</sup>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.

<sup>21</sup>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 political issues that's mostly the case in a *fixed exchange rate regime* and especially a *multiple exchange rate* one.

The approach of the Iranian authorities to exchange rate policy over the past decades, 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.<sup>22</sup> 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.

## 4 Model and Setting

In this paper, we develop a New Keynesian<sup>23</sup> 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 Nigeria, Liu and Gupta (2007) for the South African, Liu (2006) for New Zealand, Silveira (2006) for Brazil and Medina and Soto (2006) and also Caputo and Liendo (2005) for the Chili. 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 exist not only for Iran but also for all Islamic countries. Moreover, 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

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<sup>22</sup>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.

<sup>23</sup>For a short overview of the new Keynesian theory of optimal monetary policy see Zimmermann (2003).

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.<sup>24</sup> 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,  $N_t$ :

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

where  $\sigma$  is the inverse of intertemporal elasticity of substitution,  $\eta$  is the inverse of elasticity of hours worked with respect to real wage and  $\beta$  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  $\Pi_t$  is the profit from firm. Based on FOC, one could drive Euler equation:

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

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

$$y_t = E_t y_{t+1} - \delta_1 (E_t \Delta s_{t+1} - \pi_{t+1}^*) + \varepsilon_t^y,$$

where  $y_t$  is the output gap,  $\delta_1 := \sigma^{-1}$ , and  $\varepsilon_t^y$  is the white noise IS curve shock. 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),

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<sup>24</sup>See Pagan (2003) for an outline and comparison of various macroeconomic modeling approaches.

we assume that purchasing power parity (PPP) theory holds in Iran<sup>25</sup>. Given that, the IS curve would change to

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

In order to modify this IS curve for open economy, one could add foreign output gap ( $y_t^*$ ) and nominal exchange rate ( $q_t$ ) to (1) as transmission channels of foreign shocks into the domestic economy:

$$y_t = E_t y_{t+1} - \delta_1 (E_t \Delta q_{t+1} - \pi_{t+1}) + \delta_2 y_t^* - \delta_3 q_{t-1} + \varepsilon_t^y. \quad (2)$$

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<sup>26</sup>

$$r_t = \varphi_\pi E_t \pi_{t+1} + \varphi_y y_t, \quad (3)$$

where  $\varphi_\pi$  and  $\varphi_y$  are policy coefficients and  $\varepsilon_t^r$  is the monetary policy white noise shock. To be able to close the model, the evolution of the nominal 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

$$q_t = \delta E_t q_{t+1} + (1 - \delta) q_{t-1} + (r_t - E_t \pi_{t+1}) - (r_t^* - E_t \pi_{t+1}^*) + \varepsilon_t^q, \quad (4)$$

where  $\delta$  has generally a pre-specified value of 0.5 and  $\varepsilon_t^q$  is the white noise error term. Hence from (3) and (4) we have

$$q_t = \delta E_t q_{t+1} + (1 - \delta) q_{t-1} + (\varphi_\pi - 1) E_t \pi_{t+1} + \varphi_y y_t - r_t^* + E_t \pi_{t+1}^* + \varepsilon_t^q. \quad (5)$$

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

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<sup>25</sup>In general, it depends on the period and unit root test. For instance, Bahmani-Oskooee (1998), Shows 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.

<sup>26</sup>The fact that there is not any official interest rate does not mean that it does not really exist in the economy. 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.

interest rate parity). Kia (2006) finds that, over the long run, a higher exchange rate (lower value of domestic currency) leads to a higher price in Iran. Hence, 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 modeled as

$$\pi_t = E_t\pi_{t+1} + \lambda_1 y_t + \lambda_2 q_t + \varepsilon_t^\pi, \quad (6)$$

where  $\pi_t$  is the CPI inflation rate and  $\varepsilon_t^\pi$  is the Phillips curve white noise shock. Equations (2), (5) and (6) 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:

$$y_t^* = E_t y_{t+1}^* - \delta^*(r_t^* - E_t \pi_{t+1}^*) + \varepsilon_t^{y*}, \quad (7)$$

$$\pi_t^* = E_t \pi_{t+1}^* + \lambda^* y_t^* + \varepsilon_t^{\pi*}, \quad (8)$$

$$r_t^* = \varphi_\pi^* E_t \pi_{t+1}^* + \varphi_y^* y_t^* + \varepsilon_t^{r*}. \quad (9)$$

The model described by Equations (2), (??) and (6) to (9), 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) shows 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.

I used Dynare 4.2<sup>27</sup> 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 underlying the *New Area Wide Model* (NAWM) of the European Central Bank, which is described in detail in Fagan et al. (2005). Domestic CPI<sup>28</sup> inflation and GDP for this period stem from *CBI Economic Time Series Databae*<sup>29</sup>. 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. It has been authorized in government at November 2006 that all international trades should be done using Euro instead of Dollar. Now more than half of revenue from oil export is earned via Euro. Since exchange rate data for Euro is not available, I used build-in *Kalman Filter* feature of Dynare estimation to generate measure of exchange rate.

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* ensures that the average acceptance rate within each chain is around the

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<sup>27</sup>Dynare estimation codes are available upon request.

<sup>28</sup>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. Moreover, measured inflation is likely to underestimate true inflation owing to price controls and direct and indirect government subsidies. 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.

<sup>29</sup>This data is available online at <http://tsd.cbi.ir/>

value of 0.25 (which is the value often recommended to be achieved), should be set to 0.013. In addition, the acceptance rate of two chains is 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 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 ( $\varphi_\pi$ ) or the coefficient on real interest rate in foreign IS curve ( $\delta^*$ ). 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  $\varepsilon_t^y$ ,  $\varepsilon_t^\pi$ , and  $\varepsilon_t^q$  and multivariate diagnostic in figure 5, we confirm the convergence of most of the parameters and the model as whole. 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 confirms 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. Positive exchange rate shock, as expected, leads to a fall in real activity

and inflation that reverts to their initial steady states in about 2 years.

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<sup>30</sup>. 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 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<sup>31</sup>. There are also a number of variant approaches to modeling 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 a 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

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<sup>30</sup>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.

<sup>31</sup>For instance, Adolfson et al. (2008) estimates and tests a new Keynesian small open economy model using Bayesian estimation techniques on Swedish data which explores 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.



openness, as well as the strength of the response of monetary policy authority to the inflation.

Duval and Vogel (2008) also study monetary policy in a small open economy New Keynesian DSGE model including oil as a production input and a component of final demand. They investigate the performance of alternative price level definitions, notably 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
$\delta_1$	$\mathbb{N}(0.15, 0.1)$	0.2988	[0.2553 , 0.3382]
$\delta_2$	$\mathbb{N}(0.25, 0.05)$	0.2576	[0.2061 , 0.3148]
$\delta_3$	$\mathbb{N}(0.1, 0.1)$	0.0209	[0.0171 , 0.0240]
$\lambda_1$	$\mathbb{N}(0.1, 0.1)$	0.0526	[-0.0655 , 0.1748]
$\lambda_2$	$\mathbb{N}(0.01, 0.01)$	-0.0534	[-0.0535 , -0.0534]
$\lambda^*$	$\mathbb{N}(0.1, 0.05)$	0.1316	[0.0598 , 0.1983]
$\varphi_\pi$	$\mathbb{N}(0.75, 0.3)$	0.6354	[0.6225 , 0.6440]
$\varphi_y$	$\mathbb{N}(0.25, 0.1)$	0.2382	[0.1315 , 0.3583]
$\delta^*$	$\mathbb{N}(0.1, 0.1)$	0.0008	[0.0000 , 0.0017]
$\varphi_\pi^*$	$\mathbb{N}(1.75, 0.3)$	1.9217	[1.5205 , 2.2802]
$\varphi_y^*$	$\mathbb{N}(0.15, 0.1)$	0.1582	[0.0413 , 0.2687]
$\delta$	$\mathbb{N}(0.5, 0.25)$	0.3909	[0.3897 , 0.3920]
$\varepsilon_t^e$	<i>inv</i> $\Gamma(1, 1)$	2.1252	[1.6858 , 2.5348]
$\varepsilon_t^y$	<i>inv</i> $\Gamma(0.01, 1)$	0.0292	[0.0119 , 0.0470]
$\varepsilon_t^\pi$	<i>inv</i> $\Gamma(1, 1)$	1.6756	[1.6287 , 1.7340]
$\varepsilon_t^{y^*}$	<i>inv</i> $\Gamma(0.01, \infty)$	0.0067	[0.0055 , 0.0077]
$\varepsilon_t^{\pi^*}$	<i>inv</i> $\Gamma(0.1, \infty)$	0.8056	[0.7142 , 0.9192]
$\varepsilon_t^{r^*}$	<i>inv</i> $\Gamma(0.1, \infty)$	0.8511	[0.7972 , 0.9097]

Table 1) Bayesian Estimation of Model Parameters

Variables	$\varepsilon_t^y$	$\varepsilon_t^\pi$	$\varepsilon_t^e$	$\varepsilon_t^{y^*}$	$\varepsilon_t^{\pi^*}$	$\varepsilon_t^{r^*}$
$e$	0.00	0.00	86.48	0.00	0.00	13.52
$\pi$	0.02	2.40	85.05	0.00	0.00	12.53
$\pi^*$	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	$e$	$\pi$	$\pi^*$	$y$	$y^*$	$r^*$
$e$	1.0000	-0.9734	0.0044	-0.9322	0.2821	-0.2825
$\pi$	-0.9734	1.0000	-0.0034	0.9685	-0.2209	0.2213
$\pi^*$	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

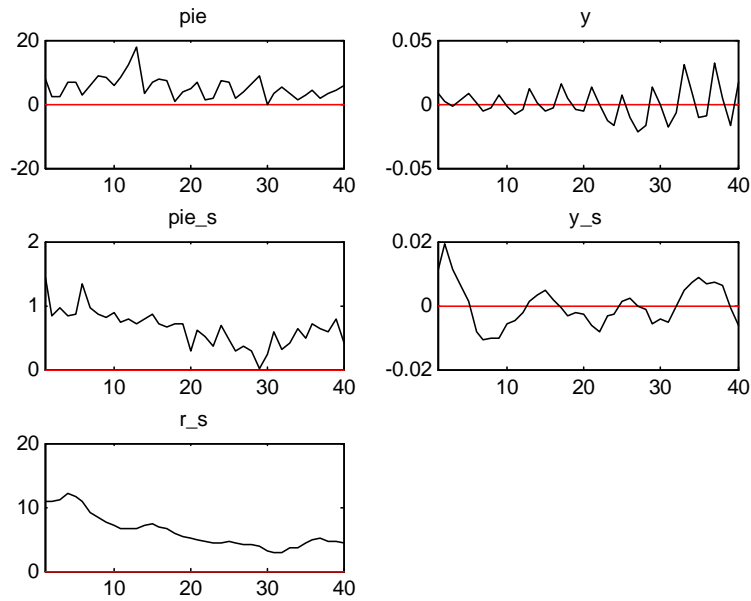


Figure 1) Historical and Smoothed Variables

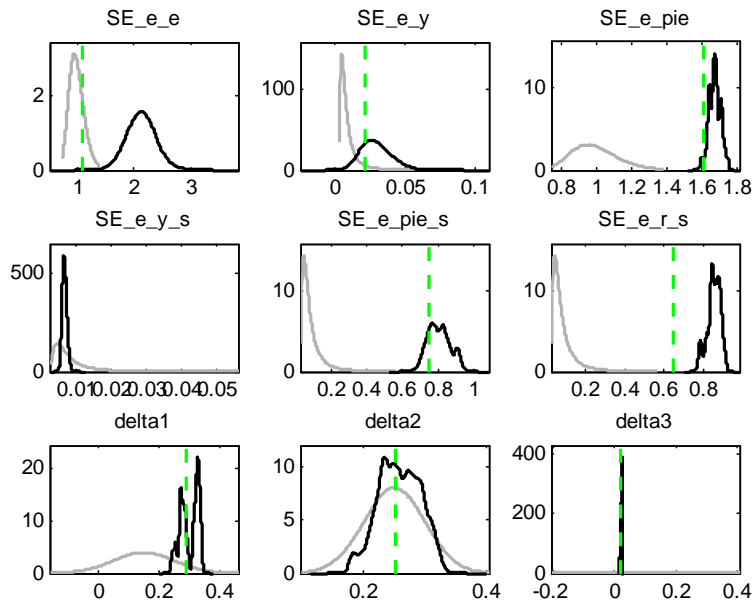


Figure 2) Prior and Posterior Distributions

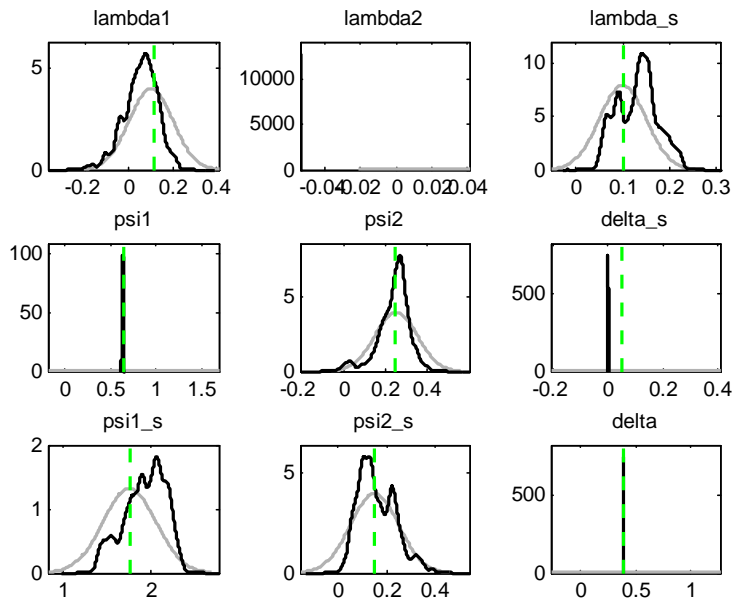


Figure 3) Prior and Posterior Distributions

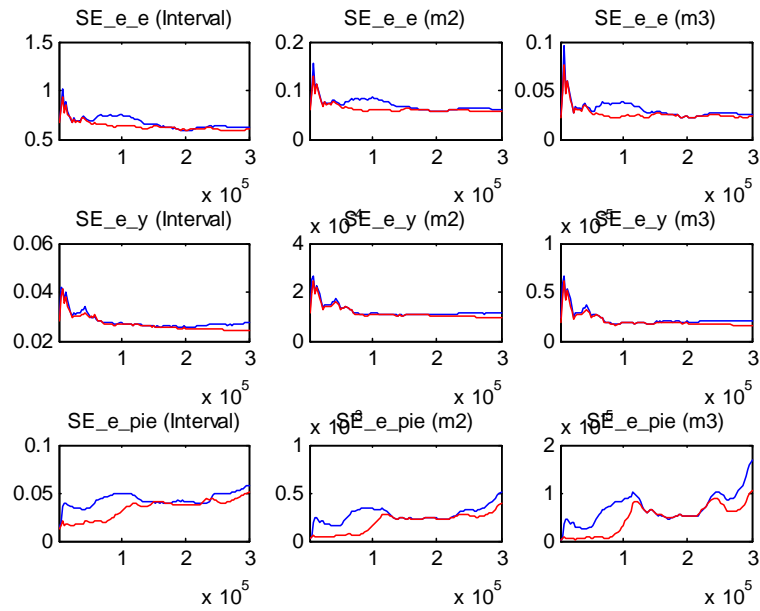


Figure 4) MCMC Univariate Diagnostics for  $\varepsilon_t^y$ ,  $\varepsilon_t^\pi$ , and  $\varepsilon_t^q$  Brooks and Gelman (1998)

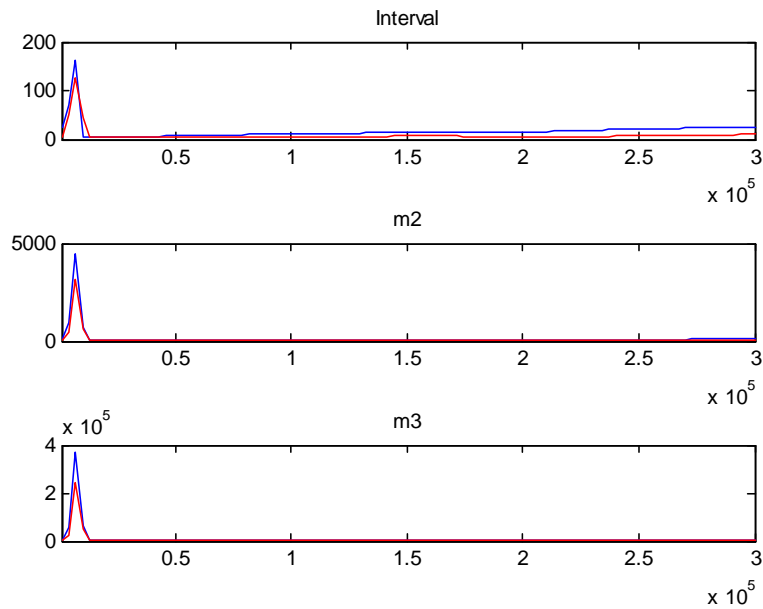


Figure 5) Multivariate Diagnostics

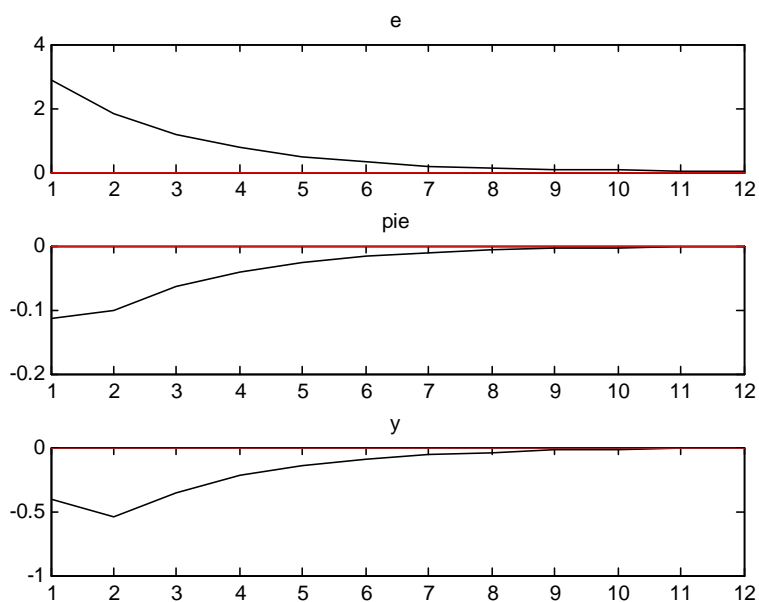


Figure 6) Responses of Domestic variables to  $\varepsilon_t^q$