

The Dynamic Effect of Micro-Structural Shocks on Private Investment Behavior

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Abstract

This paper estimates the dynamic effect of three micro-structural shocks, namely, investment-specific technology, markup and technology shocks to key components of the Iranian economy: private investment behaviour. The identification strategy positions the structural shocks to private investment behaviour in the Dynamics Stochastic General Equilibrium (DSGE) framework with a three-accuracy test estimation: The Brooks and Gelman test, the Metropolis-Hastings jumping distribution acceptance ratio, and the distribution of the deep posteriors parameters are asymptotically normal. The quarter economic data of Iran economy from July 1988 until March 2015 is applied. The findings illustrate that the structural shocks about technology have a similar impact and cause a growth in private investment, and the only difference is, in investment-specific technology shock due to a temporary decrease in the capital expenses installation (Tobin's Q), an investment boom is driven. In contrast, the price markup shock due to inflation causes a decline in all investment indices.

Keywords

private investment behaviour, micro-structural shocks, DSGE framework.



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Introduction

The recent global financial crisis has put financial constraints on governments limiting their capacity to increase public investment and promote economic growth. In addition, in periods of high uncertainty firms tend to postpone the implementation of their projects, which has a negative impact on economic growth. Therefore, in the context of scarce governmental resources, it is necessary to find alternative and viable solutions to promote investment and hence growth. Instead of the traditional direct public investment, governments can stimulate private investment (Barbosa et al., 2016).

Some studies have defined the significance of private investment. A comparison has been made on the public and private company's investment behaviour by Asker et al. (2012), which reveals that private companies are more efficient in investment than the matched sample of public companies. In another study, the vital and essential role of private investment in the processes that generate growth in developing Asian economies was discussed and stressed by Jongwanich and Kohpaiboon (2008). According to Jongwanich and Kohpaiboon (2008), private investment is crucial in enhancing and improving the production capacity of the economy along with long-term economic growth. In addition, Ang (2009) introduce private investment as the main catalyst for generating long-run growth in developing countries.

Despite the aforementioned remarkability of private investment, previous research has neglected to investigate the impact of different variables on investment behaviour, more specifically in response to microstructural shocks. Additionally, most of the studies in private investment have studied the open economies, while our case study, the namely Iranian economy, has been a closed economy and under international sanctions.

There are six different structural shocks in the model, while the present paper has only concentrated on the effects of microstructural shocks. Therefore, in this study using quarterly data from July 1988 until March 2015 of the Iranian economy, we have examined the responsiveness of private investment to three microstructural shocks; investment-specific technology (the shock of households in the business cycle), markup (the shock of final good producer in the business cycle), and technology shocks (the shock of intermediate goods producer) in a Dynamics Stochastic General Equilibrium (DSGE) framework. Figure 1 has depicted the DSGE framework and the contraction between different sections of our model.

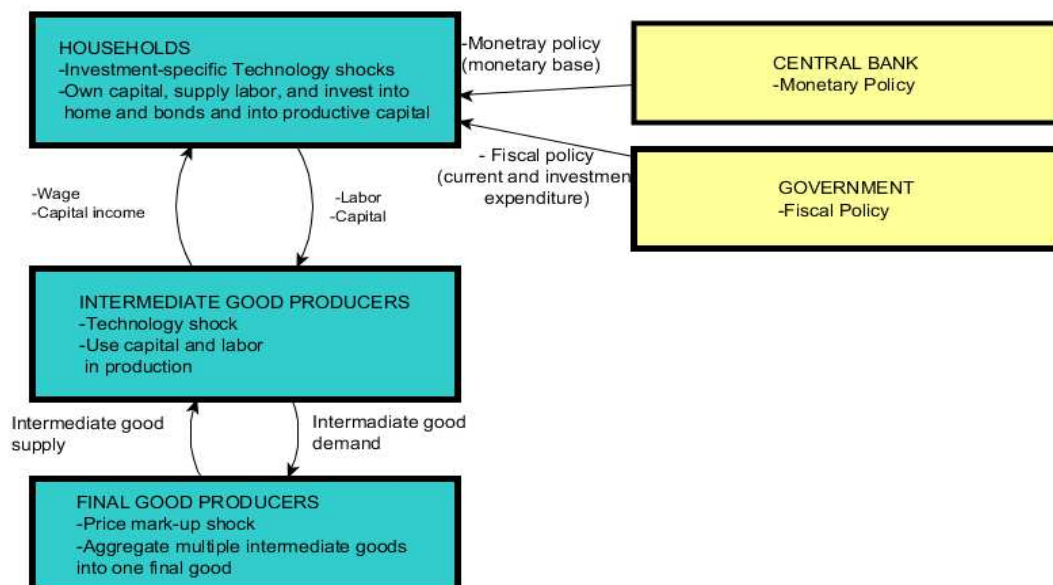


Fig. 1. DSGE framework

The intention of private investment behaviour in this study is; 1- Debt capital (can be obtained through private sources) (K_t^d). 2- Investment (a property or asset that is purchased with the hope that it will appreciate or will generate income in the future) (I_t). 3- The Price of capital dynamics equation (Tobin's Q). 4- Capital return (R_t^k). 5- The cost of capital utilization (z_t). 6- Working hours (L_t) the variable that can be effective on the investment behaviour of households. A novel feature of our model is to incorporate various shocks of the business cycle micro part.

To estimate the parameters, Bayesian statistical methods have been applied, a method that recently gained popularity in applied macro-economic modelling¹. The interpretation of Impulse Response Functions (IRFs)

¹ For a recent overview of the main literature and methods of the Bayesian analysis of DSGE models, refer to An and Schorfheide (2007).

indicates that the structural shocks about technology have a similar impact and cause a growth in private investment. The only difference is that in investment-specific technology shock, because of the temporary decrease of the installing capital expenses (Tobin's Q) an investment boom is driven. In contrast, the price markup shock due to inflation causes a decline in all the investment indices.

The remainder of the paper is organized as follows: Section 2 describes the previous literature related to a problem, the suitable ways to formulate the problem are presented in Section 3, which is followed in Section 4 by a discussion of how to state the main technical result, section 5 provides some final conclusions and directions for future works.

Literature review

A number of studies, starting with the work of Greenwood et al. (2000) and being continued by Fisher (2006) and Justiniano et al. (2011), have emphasized the role of investment-specific productivity shocks as an engine and the main source of business cycles (Schmitt-Grohé and Uribe, 2011). More recent studies even have reached a consensus that technological innovations may not come through increases in Total Factor Productivity (TFP) but rather through the introduction of new and more efficient capital goods triggered by a fall in the relative price of investment the so-called "investment-specific technological (IST henceforth) changes" (Chen and Wemy, 2015). Additionally, In and Yoon (2007) showed that an IST shock enhances the investment's efficiency and increases the expected marginal product of capital during the following period. Also, Araújo (2012) and Chen and Wemy (2015) contend respectively, 30 per cent of output fluctuations and 70 per cent of the price of investment variations could be explained by IST shocks.

The second shock in our study refers to markup shock that previously was called "cost-push" (Clarida et al., 1999). To clarify the significance of this shock in the business cycle, Beetsma and Jensen (2005) understood that markup shocks call for pro-cyclical fiscal policy rules (the gap in government spending has a positive correlation with the output gap) since counter-cyclical fiscal policies are required by productivity shocks. Beetsma and Jensen (2004) showed that with positive markup shock, fiscal and monetary policies are devised and contracted to decrease and lessen the inflationary pressures. The monetary contraction decreases the consumption gap, and thus, both policy reactions are influential in the decrease in the output gap. That is why the optimal fiscal rule has to be pro-cyclical. Notwithstanding its remarkable function in the business cycle, recently scholars have paid less attention to markup shocks.

The third micro-structural shock of our model is technology shock. Following Kydland and Prescott (1982) and Long Jr and Plosser (1983), shocks to total factor productivity (TFP) are initiated in business cycle fluctuations which relatively affect the product inputs' efficiency. In standard RBC models, immediately after an aggregate technology shock, there is a sharp increase in aggregate investment, labour, and the real interest rate. However, Gali (1996) and Basu et al. (2006) realized that in the U.S. economy, the aggregate technology stocks have a contradictory relationship with the real interest rate, labour, and investment in the short-run. In clear contrast to the above observations and on the basis of Michelacci and Lopez-Salido (2007) findings, Wang and Wen (2011) proposed that when the aggregate technology is positively shocked, there is a short-term rise in job creation and destruction and a contraction in aggregate equipment investment, output, and employment. Dave and Dressler (2010) argued that companies want to suppress the exogenous rise in the output (technology shock) by reducing the rate at which existing capital stocks are used. Dave and Dressler (2010) demonstrate that generating an intensive margin through the usage of endogenous capital enables companies to change the productivity of the already existing capital stock. Thus, when capital utilization and labour decrease, the response of output can be offset and even reduced in response to a positive innovation to neutral TFP. Obviously, the literature has not paid serious attention to the plausible impact of these shocks on investment indices; therefore, more investigation will be required to contribute to the science in this subject.

Moreover, the other contributions refer to the illustration of capital (K_t), investment (I_t), the price of capital (Tobin's Q), capital return (R_t^k), cost of capital utilization (z_t), and working hours (L_t) as the endogenous variables of our model. Additionally, the application of investment-specific technology shock is the other key contributions of our model because, according to Araújo (2012) and In and Yoon (2007), the models with investment-specific technology shock outperform those with productivity shock only. The current paper contributes to the existing literature on the topic of "business cycles in Iran" by examining the function of investment-specific shocks in explaining private investment behaviour.

Materials and Methods

The methodology used in this paper is Dynamic Stochastic General Equilibrium (DSGE). The model is a numerical simulation to analyze possible micro and macro shocks effects on private investment behaviour. To simulate using software called "Dynare", which is used to simulating and solving deterministic and stochastic dynamic general equilibrium models (Adjemian et al., 2011; Ali, 2011). DSGE is an effective tool that facilitates

policy discussion and analysis through a coherent framework. In the following, some privileges of this model are defined:

- 1- They are a powerful assistant to identify sources of oscillation, answer questions about structural changes, foresee the effect of policy changes, and accomplish counterfactual experiments (Algozhina, 2012; Tovar, 2009).
- 2- In comparison with econometric models, the DSGE model is based on optimization (Chen, 2010).
- 3- The model is able to track and predict the seven following macroeconomic time series data very well, investment, prices, consumption, GDP, employment, wages, and short-run interest rates (Chen, 2010).
- 4- DSGE models are an undertaking tool to comprehend the consequence of interactions between monetary and fiscal policies (Valli and Carvalho, 2010).
- 5- When the data are not sufficiently informative, a theoretical framework on the structure and model can be provided by the DSGE approach, which might be especially helpful, for example, in regards to the economy's behaviour in the long run or when there has been a change in the regime (Smets and Wouters, 2003).
- 6- A connection between the deeper structural parameters (that is, ones that are less subject to Lucas critique) and the reduced-form parameters must be established to facilitate the utilization of the model for policy authorization since those structural parameters' responding probability is less likely to alter in a policy regime (Smets and Wouters, 2003).
- 7- A more appropriate framework for the analysis of optimality of various policy strategies is provided by micro-founded models like DSGE since using agents in the economy can be regarded as a measure of welfare (Smets and Wouters, 2003).
- 8- The flexibility of these models in entering the different assumptions and economic realities has recently motivated monetary and fiscal policy analysts to employ these models (Komijanej and Tavakolian 2012).
- 9- Some central banks have applied the DSGE model for analyzing and decision-making (Chen, 2010; Walsh, 2010).

The necessary steps for solving the DSGE model are Problem statement, Determination of the equations and constraints of the model, Determination of the First Order Condition (F.O.C), Obtaining of Steady State, Log Linearization of the Constraints and F.O.Cs, Solving the model, Analysis and interpretation of IRFs (Chen 2010, Walsh 2010).

Model Fit

Our model is included of five different parts, households, intermediate good producers, final good producers, Government, and Central Bank. In order to save space, only the dynamics of every part's associated log-linearized equations are presented.

1. Households (Demand Side)

We consider an economy that is populated by a large number of identical households, which maximize their inter-temporal utility function by choosing the amount of consumption (C_t), investment (I_t), labour supply (L_t), capital supply (K_t), the utilization rate of capital (z_t), amount financial wealth in the form of real cash balances (M_t) and bonds (B_t), which are one-period securities.

$$\max_{C_t, L_t, M_t, B_t, z_t, K_t, I_t} E_t \sum_{i=0}^{\infty} \beta^i \left[\frac{(C_t G_t^\gamma)^{1-\sigma}}{1-\sigma} - \chi \frac{L_t^{1+\eta}}{1+\eta} + \frac{k}{1-b} \left(\frac{M_t}{P_t} \right)^{1-b} \right], \quad (1)$$

In this equation β^t defines the discount factor, σ captures the inverse of the inter-temporal elasticity of substitution in consumption ($\frac{1}{\sigma} \geq 0$). η captures the inverse Frisch elasticity of labour (that $\frac{1}{\eta} \geq 0$). b is the inverse of elasticity of real balance ($\frac{1}{b} \geq 0$). $\gamma \in (0,1)$ denotes the impact of public goods on consumer preferences and G_t captures the public goods. To maximize the inter-temporal utility function, there are some restrictions. First, every household faces the following budget constraint expressed in real terms:

$$C_t + I_t + \frac{B_t}{P_t} + \frac{M_t}{P_t} + T_t \leq W_t L_t + R_t^k z_t K_{t-1} - \Omega(z_t) K_{t-1} + (1 + r_{t-1}) \frac{B_{t-1}}{P_t} + \frac{M_{t-1}}{P_t} + D_t, \quad (2)$$

P_t is the Consumer price index, T_t denotes the transfer, D_t are dividends from the final good producers that are assumed to be owned by households, W_t is the nominal wage earned by the household, R_t^k is the return on capital, $\Omega(z_t)$ captures the cost of capital utilization, and r_t is return rate of bonds.

Secondly, the households own the capital stock in the economy, and every household faces the following capital accumulation equation in each time:

$$K_t = (1 - \delta)K_{t-1} + \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] I_t \varepsilon_t^x, \quad (3)$$

δ is the depreciation rate of capital and $S\left(\frac{I_t}{I_{t-1}}\right)$ is the investment adjustment cost function, and

$$\begin{aligned} \log \varepsilon_t^x &= \rho_x \log \varepsilon_{t-1}^x + u_t^x, \\ u_t^x &\approx WN(0, \sigma_x^2), \end{aligned} \quad (4)$$

is a stationary investment-specific technology shock common across all households in the economy, that its log-linearized form is as follow,

$$\begin{aligned} \hat{\varepsilon}_t^x &= \rho_x \hat{\varepsilon}_{t-1}^x + u_t^x, \\ u_t^x &\approx WN(0, \sigma_x^2), \end{aligned} \quad (5)$$

The log-linearized of equation (3) is the following,

$$\hat{K}_t = (1 - \delta)\hat{K}_{t-1} + \delta(\hat{i}_t + \varphi \hat{\varepsilon}_t^x). \quad (6)$$

From the first-order conditions of the Lagrangian equation of households, labour supply, money demand, Euler' equation, cost of capital, investment decision, and Tobin's Q equations will be earned, respectively.

$$\hat{w}_t = \eta \hat{l}_t + \sigma \hat{c}_t + \gamma(\sigma - 1)\hat{c}g_t, \quad (7)$$

$$\hat{m}_t = \frac{\sigma}{b} \hat{c}_t + \frac{\gamma(\sigma-1)}{b} \hat{c}g_t - \frac{1}{b} \hat{r}_t, \quad (8)$$

$$\hat{c}_t = E_t \hat{c}_{t+1} - \frac{1}{\sigma} \{ \hat{r}_t - E_t \hat{r}_{t+1} - \gamma(\sigma - 1)[E_t \hat{c}g_{t+1} - \hat{c}g_t] \}, \quad (9)$$

$$\hat{z}_t = \frac{\Omega(1)}{\hat{\Omega}(1)} \hat{r}_t^k = \mu \hat{r}_t^k, \quad (10)$$

$$\hat{i}_t = \frac{1}{1+\beta} \hat{i}_{t-1} + \frac{\beta}{1+\beta} E_t \hat{i}_{t+1} + \frac{1}{1+\beta} \frac{1}{\varphi} \hat{q}_t + \hat{\varepsilon}_t^x, \quad (11)$$

$$\hat{q}_t = -\hat{r}_t + \frac{1-\delta}{1-\delta+R} E_t \hat{q}_{t+1} + \frac{R}{1-\delta+R} E_t \hat{r}_{t+1}^k. \quad (12)$$

2. Firms (Supply Side)

The supply side of the economy consists of two main sectors of limitless lived agents: a retail sector acting in perfect competition to produce the final consumption good and a wholesale sector hiring labour and capital from the households to produce a sequence of different intermediate goods.

3. Final Good Producers

The final good is produced using the following aggregation technology, where intermediate goods $Y_t(j)$ are indexed by $j \in (0,1)$:

$$Y_t = \left[\int_0^1 Y_t^\theta(j) \right]^{\frac{\theta}{\theta-1}} \quad \theta > 1, \quad (13)$$

in this equation, θ is the markup shock:

$$\begin{aligned} \log \theta_t &= (1 - \rho_\theta) \log \theta + \rho_\theta \log \theta_{t-1} + \varepsilon_t^\theta, \\ \varepsilon_t^\theta &\sim i. i. d. N(0, \sigma_\theta^2). \end{aligned} \quad (14)$$

The log-linearized of this shock is as follow:

$$\begin{aligned} \hat{\theta}_t &= \rho^\theta \hat{\theta}_{t-1} + \varepsilon_t^\theta, \\ \varepsilon_t^\theta &\approx i. i. d. N(0, \sigma_\theta^2). \end{aligned} \quad (15)$$

The aim of the final goods producer is to maximize the profit, hence:

$$\max_{Y_t(j)} P_t \left[\int_0^1 Y_t^\theta(j) \right]^{\frac{\theta}{\theta-1}} - \int_0^1 P_t(j) Y_t(j) dj. \quad (16)$$

The first-order condition by $Y_t(j)$, is as follow:

$$\begin{aligned} \frac{\partial \mathcal{L}_t}{\partial Y_t(j)} &= \\ P_t \frac{\theta-1}{\theta} \frac{\theta}{\theta-1} Y_t^{\frac{1}{\theta}}(j) \left[\int_0^1 Y_t^{\frac{\theta-1}{\theta}}(j) \right]^{\frac{1}{\theta-1}} - \\ P_t(j) &= \\ \mathbf{0}, \end{aligned} \quad (17)$$

therefore,

$$Y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\theta} y_t, \quad (18)$$

which is the demand equation for $Y_t(j)$. Combining $Y_t(j)$ with Y_t capture consumer price index equation (CPI), which is the weighted sum of all produced goods in the economy

$$P_t = \left[\int_0^1 P_t^{1-\theta}(j) di \right]^{\frac{1}{1-\theta}}. \quad (19)$$

4. Intermediate Good Producers

Intermediate good producers operate and function within a monopolistically competitive market. They pay W_t salary to labourers and borrow capital from households with R_t^k capital return. Differentiated output units of $Y_t(j)$ are produced by every company indexed by $j \in (0,1)$ through the utilization of Cobb-Douglas production technology:

$$Y_t(j) \leq a_t [K_{t-1}(j) K G_{t-1}^\psi]^\alpha L_t(j)^{1-\alpha}, \quad (20)$$

The log-linearized of this equation is as follow:

$$\hat{y}_t = \alpha \psi \widehat{kg}_{t-1} + \alpha \hat{k}_{t-1} + (1-\alpha) \hat{l}_t + \hat{a}_t, \quad (21)$$

in which α is the share of capital in the production, a_t is the technology shock,

$$\begin{aligned} \log(a_t) &= \rho_a \log(a_{t-1}) + \varepsilon_t^a, \\ \varepsilon_t^a &\approx i. i. d. N(0, \sigma_a^2), \end{aligned} \quad (22)$$

the log-linearized of this shock is

$$\begin{aligned} \hat{a}_t &= \rho_a \hat{a}_{t-1} + \varepsilon_t^a, \\ \varepsilon_t^a &\approx i. i. d. N(0, \sigma_a^2). \end{aligned} \quad (23)$$

The aim of intermediate good producers is to minimize the cost of producing,

$$\min_{K_{t-1}, L_t} \mathcal{E}_t = w_t L_t(j) + R_{t-1}^k K_{t-1}(j) + \phi_t(j) \left[y_t(j) - a_t [K_{t-1}(j) K G_{t-1}^\psi]^\alpha L_t(j)^{1-\alpha} \right], \quad (24)$$

that its first-order condition is

$$\begin{aligned} \frac{\partial \mathcal{L}_t}{\partial K_t} &= \\ -R_t^k - \\ E_t \beta \phi_{t+1} a_{t+1} \alpha K G_t^\psi [K_t(j) K G_t^\psi]^{\alpha-1} L_{t+1}(j)^{1-\alpha} &= \\ \mathbf{0}, \end{aligned} \quad (25)$$

in which,

$$R_t^k = -E_t \beta \phi_{t+1} a_{t+1} \alpha K G_t^\psi [K_t(j) K G_t^\psi]^{\alpha-1} L_{t+1}(j)^{1-\alpha}. \quad (26)$$

Therefore,

$$R_t^k = \alpha \frac{y_t(j)}{K_{t-1}(j)}, \quad (27)$$

The second first-order condition is as follow,

$$\frac{\partial L_t}{\partial L_t} = -w_t - \phi_t a_t [K_{t-1}(j) K G_{t-1}^\psi]^\alpha (1 - \alpha) L_t(j)^{-\alpha} = 0, \quad (28)$$

in which,

$$w_t = -\phi_t a_t [K_{t-1}(j) K G_{t-1}^\psi]^\alpha (1 - \alpha) L_t(j)^{-\alpha}, \quad (29)$$

so,

$$w_t = (1 - \alpha) \frac{y_t(j)}{L_t(j)}, \quad (30)$$

dividing $\frac{R_t^k}{w_t}$, and simplifying capture labour demanding equation,

$$\frac{R_t^k}{w_t} = \frac{\alpha}{1 - \alpha} \frac{L_t(j)}{K_{t-1}(j)}, \quad (31)$$

therefore,

$$\alpha w_t L_t(j) = (1 - \alpha) R_t^k K_{t-1}(j). \quad (32)$$

The log-linearized of equation (30) is

$$\hat{l}_t = \hat{r}_t^k - \hat{w}_t + \hat{k}_{t-1}. \quad (33)$$

In addition, the marginal cost equation is obtained from equation (29),

$$mc_t = \phi_t = \alpha^{-\alpha} (1 - \alpha)^{-(1-\alpha)} a_t^{-1} R_t^k w_t^{1-\alpha}, \quad (34)$$

which, in the log-linearized form, is as follow,

$$\widehat{mc}_t = \alpha(\hat{r}_t^k - \psi k \hat{g}_{t-1}) + (1 - \alpha)\hat{w}_t - \hat{a}_t. \quad (35)$$

The other challenge that intermediate good producers face each period is only a fraction (ξ) of them can optimally re-adjust their prices (Calvo, 1983). For producers who cannot re-optimize, prices are indexed to past inflation as follow,

$$P_t(j) = \pi_{t-1}^\tau P_{t-1}(j), \quad (36)$$

in which $\pi_t = \frac{P_t}{P_{t-1}}$ is the inflation rate.

On the other hand, the aim of firms that can re-adjust their prices (ξ) is to maximize their profit, which is operated through optimizing the $P_t^*(j)$. Considering the equations (30) and (31), and the problem of the firms, which can re-adjust their price will have

$$\max_{P_t(j)} E_t \sum_{i=0}^{\infty} (\xi \beta)^i \left[\left(\frac{P_t(j)}{P_t} \right)^{-\theta} - mc_t \right] Y_t(j). \quad (37)$$

The new Keynesian Philips Carve in the form of log-linearized is achieved from the maximization of the last equation state to the $P_t(j)$,

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \frac{(1-\xi)(1-\xi\beta)}{\xi} \widehat{mc}_t + \varepsilon_t^\pi \quad \varepsilon_t^\pi \approx i. i. d. N(0, \sigma_\pi^2). \quad (38)$$

3.1.3. Government and Central Bank

In this study, the economy is closed, and the governmental constraint resource equation is as follows,

$$CG_t + IG_t + (1 + i_{t-1}) \frac{B_{t-1}}{P_t} = T_t + \frac{B_t}{P_t} + \frac{M_t - M_{t-1}}{P_t}. \quad (39)$$

In this equation CG_t represents the current government expenditure, IG_t is the government investment expenditure, which together forms the total government consumption, also $\frac{M_t - M_{t-1}}{P_t}$ denotes the monetary base.

$$G_t = CG_t + IG_t. \quad (40)$$

The log-linearized of this equation is as follow:

$$\hat{g}_t = \frac{\bar{c}g}{\bar{y}} \hat{c}g_t + \frac{\bar{i}g}{\bar{y}} \hat{i}g_t, \quad (41)$$

Combining the government resource constraint (39) and household resource constraint (2) direct to the market-clearing equation,

$$Y_t = C_t + I_t + G_t. \quad (42)$$

On the other hand, the sum of private investment (I_t) and government investment expenditure (IG_t) represent the total investment in the economy.

$$IT_t = I_t + IG_t. \quad (43)$$

The log-linearized of these two last equations is as follow, respectively,

$$\hat{y}_t = \frac{\bar{c}}{\bar{y}} \hat{c}_t + \frac{\bar{i}}{\bar{y}} \hat{i}_t + \frac{\bar{g}}{\bar{y}} \hat{g}_t, \quad (44)$$

$$\hat{it}_t = \frac{\bar{i}}{\bar{i}} \hat{i}_t + \frac{\bar{i}g}{\bar{i}} \hat{i}g_t. \quad (45)$$

In addition, it is supposed that the government capital motion follows the subsequent equation,

$$KG_t = (1 - \delta_g)KG_t + IG_t, \quad (46)$$

That in log-linearized form is as follow,

$$\widehat{kg}_t = (1 - \delta_g)\widehat{kg}_t + \delta_g \widehat{i}g_t, \quad (47)$$

The two-next equation represent the log-linearized form of government investment and current expenditures shocks, respectively,

$$\widehat{IG}_t = \rho_{IG} \widehat{IG}_{t-1} + \varepsilon_t^{IG}, \quad (48)$$

$$\widehat{CG}_t = \rho_{CG} \widehat{CG}_{t-1} + \varepsilon_t^{CG}. \quad (49)$$

The monetary shock of the central bank in log-linearized form is the following equation:

$$\widehat{m}_t = \rho_m \widehat{m}_{t+1} + \varepsilon_t^m. \quad (50)$$

Furthermore, the definition of the monetary base in the Iranian economy is as follow

$$\dot{m}_t = \frac{M_t}{M_{t-1}} = \frac{m_t}{m_{t-1}} \pi_t, \quad (51)$$

which its log-linearized form is

$$\widehat{m}_t = \widehat{m}_t - \widehat{m}_{t-1} + \widehat{\pi}_t. \quad (52)$$

Therefore, the equations number, 5, 6, 7, 8, 9, 10, 11, 12, 15, 21, 23, 33, 35, 38, 41, 44, 45, 47, 48, 49, 50, 52 organize our System of Equations.

This model contains 22 endogenous variables, which are equal to the number of equations in our System of Equations. This is one of the most significant conditions in the Dynamic Stochastic General Equilibrium (DSGE) that must be observed; therefore, the model meets the condition from this point of view. In Table 1, the endogenous variables are presented.

Tab. 1. Endogenous variables

Endogenous Variables	Definition	Endogenous Variables	Definition
K_t	Debt capital	IT_t	The total amount of investment by government and private sector
W_t	Nominal wage earned by a household	q_t	Price of capital dynamics equation or Tobin's Q
M_t	Amount of money to hold in cash	Y_t	Output
C_t	Amount of consumption	a_t	The technology shock
r_t	The rate of return of bonds	L_t	The working hours of household
I_t	Amount to investment	mc_t	Marginal cost
IG_t	Government investment expenditure	G_t	Total government consumption
CG_t	Government current expenditure	KG_t	Governmental capital

Additionally, in DSGE models, the number of exogenous variables and shocks must be equal. In this study, the number of exogenous variables and Structural Shocks both is six; therefore, in this point of view also the equilibrium is established. In Table 2, the exogenous variables are presented.

Tab. 2. Exogenous variables

Exogenous Variables	Definition
u_t^x	Stationary investment-specific technology shock
ε_t^θ	Markup shock
ε_t^a	Technology shock
ε_t^{IG}	Government investment expenditure shock
ε_t^{CG}	Government current expenditure shock
ε_t^m	Monetary shocks of the central bank

Results and Discussion

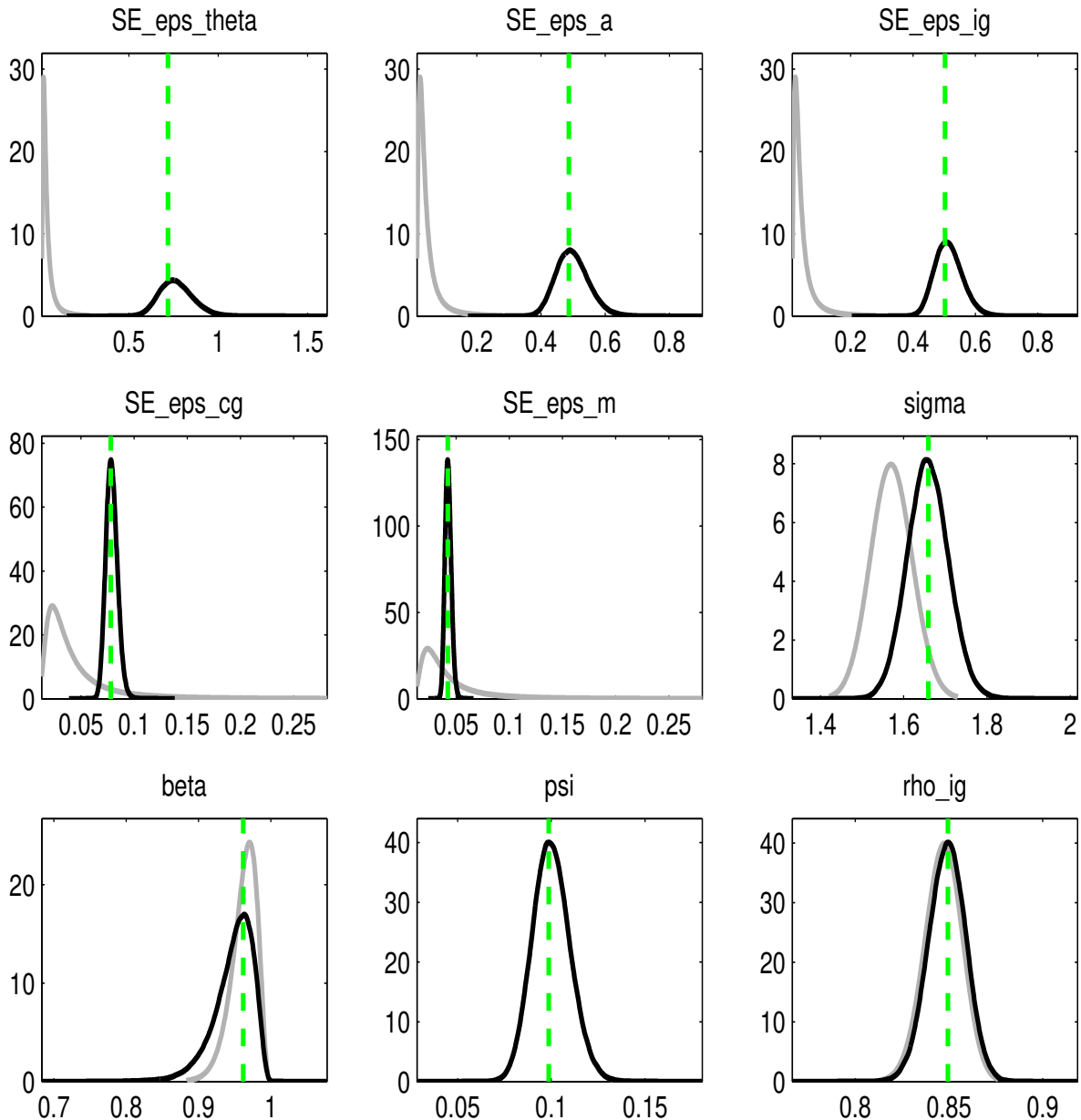
In Table 3, the estimated parameters are represented.

Tab. 3. Estimated parameters

Parameter	Definition	Distribution	Prior Mean (prior SD)	Source	Posterior Mean (posterior SD)
β	Discount factor	Beta	0.9622 (0.018)	Tavakolian (2012)	0.9618 (0.02)
α	Share of capital in the production	Beta	0.428 (0.02)	Komijanei, and Tavakolian (2012)	0.4147 (0.0174)
ψ	Impact of governmental capital on output	Beta	0.1 (0.01)	Komijanei, and Tavakolian (2012)	2.4390 (0.0692)
ξ	Fraction of firms that can optimally re-adjust their prices	Beta	0.58 (0.0196)	Komijanei, and Tavakolian (2012)	0.5669 (0.0182)
γ	Impact of public goods on consumer preferences	Beta	0.198 (0.001)	Komijanei, and Tavakolian (2012)	0.1980 (0.0010)
σ	Inverse of the inter-temporal elasticity of substitution in consumption	Gamma	1.571 (0.05)	Tavakolian (2011)	1.6594 (0.0317)
η	Inverse Frisch elasticity of labor	Gamma	2.216 (0.0499)	Komijanei, and Tavakolian (2012)	2.2003 (0.0516)
b	Inverse of elasticity of real balance	Gamma	2.24 (0.0944)	Komijanei, and Tavakolian (2012)	2.4390 (0.0692)
ρ^a	Coefficient of technology shock AR1	Beta	0.85 (0.1)	Authors' calculation	0.0829 (0.0112)
ρ^θ	Coefficient of mark-up shocks AR1	Beta	0.8 (0.26)	Authors' calculation	0.7168 (0.0245)
φ	Elasticity of the investment adjustment cost function	Normal	3 (0.5)	Authors' calculation	0.0986 (0.0074)
μ	Capital utilization	Normal	0.2 (0.05)	Authors' calculation	0.2007 (0.0501)
ρ_x	Coefficient of investment-specific technology shock AR1	Beta	0.850 (0.1)	Authors' calculation	0.9345 (0.0367)

Due to the volatility of data series in the Iranian economy, we prefer to concentrate on the Hodrick–Prescott (HP) filter to remove the trend of a time series from raw data. The results are based on 500,000 Markov chain Monte Carlo (MCMC) draws. There are three different ways to determine the accuracy of the estimation: the first is Hodrick–Prescott (HP) acceptance ratio that must be between 0.2 and 0.4 per cent, which ours have been 0.31, averagely. Second is the employment of Brooks and Gelman (1998) diagnostics to assess if the Markov chain has converged to the stationary distribution, which in this study is convergence after about 100000 draws according to the Metropolis-Hastings sampling algorithm. However, for all parameters, the Metropolis-Hastings sampling algorithm convergences after about 100000 draws.

The third subject that confirms the accuracy of our estimation refers to the distribution of posteriors that must be normal, and the mode line must be coincident to the mode of posterior. Figure 2 represents this reality, the grey line is prior, and the black line is posterior, and the green line is the mod of posterior.



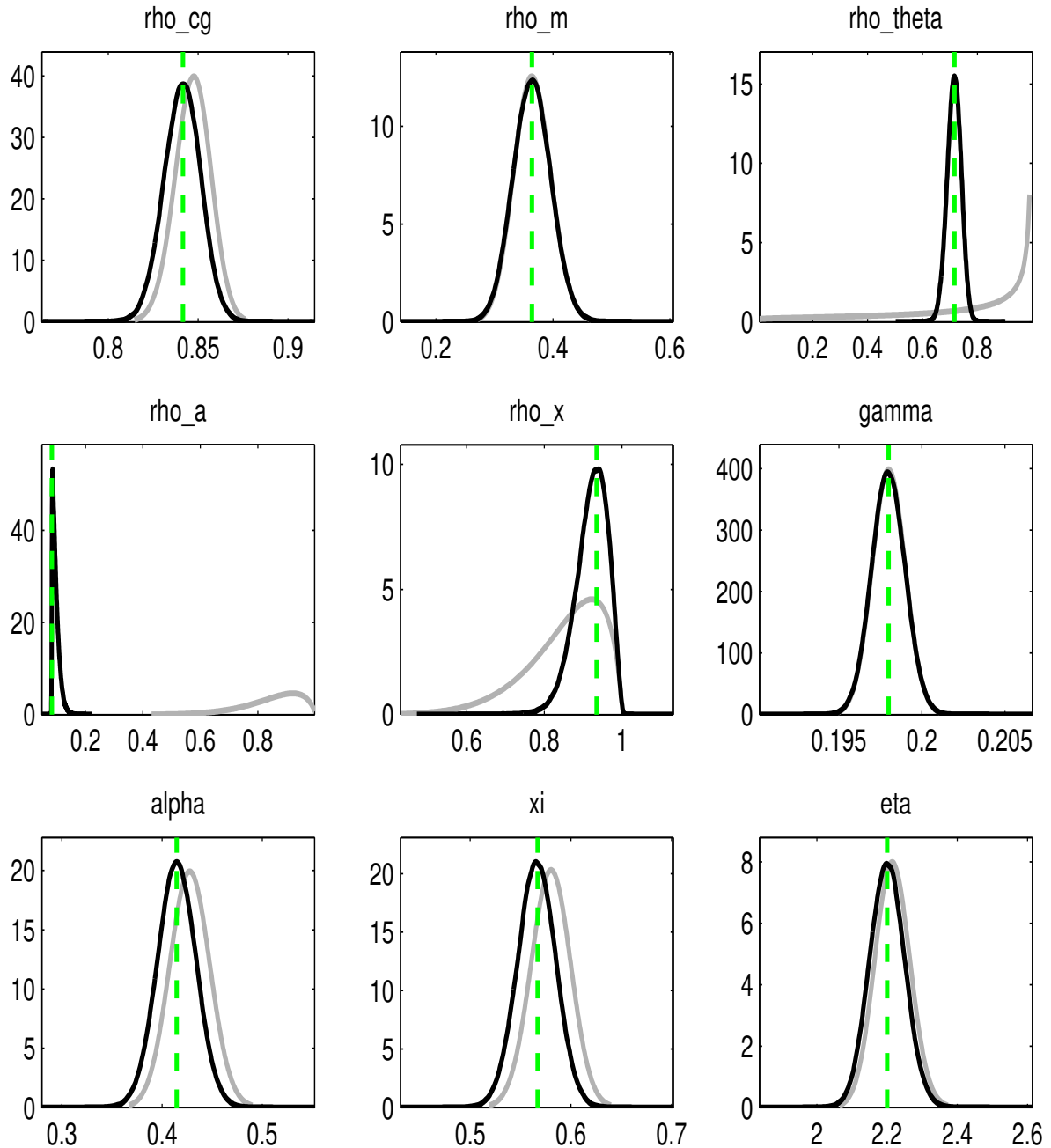


Fig. 2. The prior and posterior distribution

The effect of structural shocks on endogenous variables is analyzed by Impulse Response Functions (IRFs) analysis. A number of studies used the coefficients from VEC or VAR model in quantifying a relationship where signs of Granger causality could be found (Dunne and Vougas, 1999; Kollias et al., 2004). However, variables are usually highly correlated because of lags, which is not the best way to quantify a significant relationship. The utilization of an impulse response function is a better way due to two main reasons. The first reason is that the dynamic behaviour is better captured by an impulse response function since it can trace the impact of an exogenous shock to a variable on another variable's current as well as future values. The second reason is that the common component possessed by variables is taken into account in an impulse response function. In the following, Figures 3, 4 and 5, illustrate the impulse response functions of different investment behaviour indices to the micro-structural shocks of this model.

Figure 3 represents the Impulse response functions (expressed in percentage deviations from the steady states) to one standard deviation to an investment-specific technology shock (u_t^x). A positive shock of investment-specific technology requires satisfying increased demand by an increase in the utilization of installed capital and an increase in employment (Smets and Wouters, 2003). Therefore, the demand for investment will rise. This increase has last

for about ten periods and then decline. The cost of capital utilization raised for five periods then plummeted; therefore, the household will be motivated to lend more capital to the firms. Tobin introduced q as the market value of firms when q index is high (more than 1), the market value of the firm is higher than substitution cost of capital, and new plant and capital is more advantageous compared to the market value of firms. As a result, spending on investment will increase. On the other hand, when Q is small (lower than 1), businesses do not buy new capital goods; due to the market value of firms is a lower cost of capital (Mishkin, 1995). Nevertheless, in this model, the IST shock draws the inverse relationship between Tobin's Q and investment; while Tobin's Q is descending, the investment is ascending and vice versa.

The hypothesis of Mundell (1963) and Tobin (1965) negatively related the real return component to the expected inflation, while the empirical results of our study illustrate the positive relationship and are in line with D'Acunto et al. (2016), which resulted in inflation expectations incentivize households to purchase durable goods, to prevent their purchasing power from fallen. Therefore, they invest more (Fama and Gibbons, 1982). Hence, inflation movement caused by IST shocks can justify the households' investment and consumption behaviour, which district inflation cause an increase in investment and a decline in consumption.

Figure 4 represents the Impulse response functions of the model (expressed in percentage deviations from the steady states) to one standard deviation to markup shocks (ε_t^θ). A positive shock reduces substitutability between the variety of differentiated produced intermediate goods and drives up the markups charged by the intermediate good producers. As a result, inflation jumps up and cause pronounced effects on the inter-temporal allocation decisions by households. In particular, consumption and capital accumulation activity of the households decrease in favour of investing in bonds. This generates a demand-driven downturn in the economy, with an associated decrease in the labour effort, the price of capital, capital return, the cost of capital utilization, and Tobin's Q .

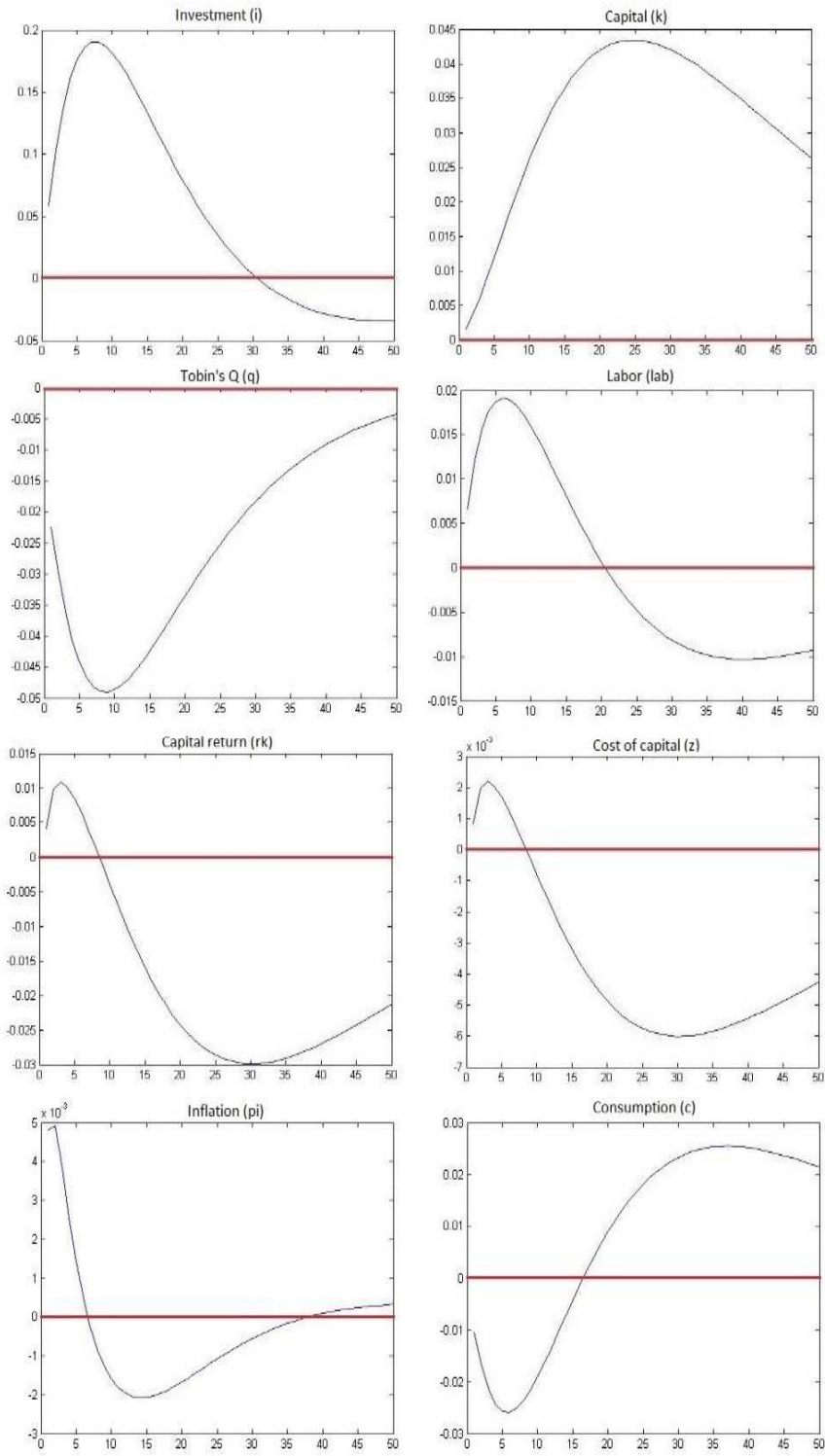


Fig. 3. Impulse response functions to one standard deviation to investment-specific technology shock (u_t^x)

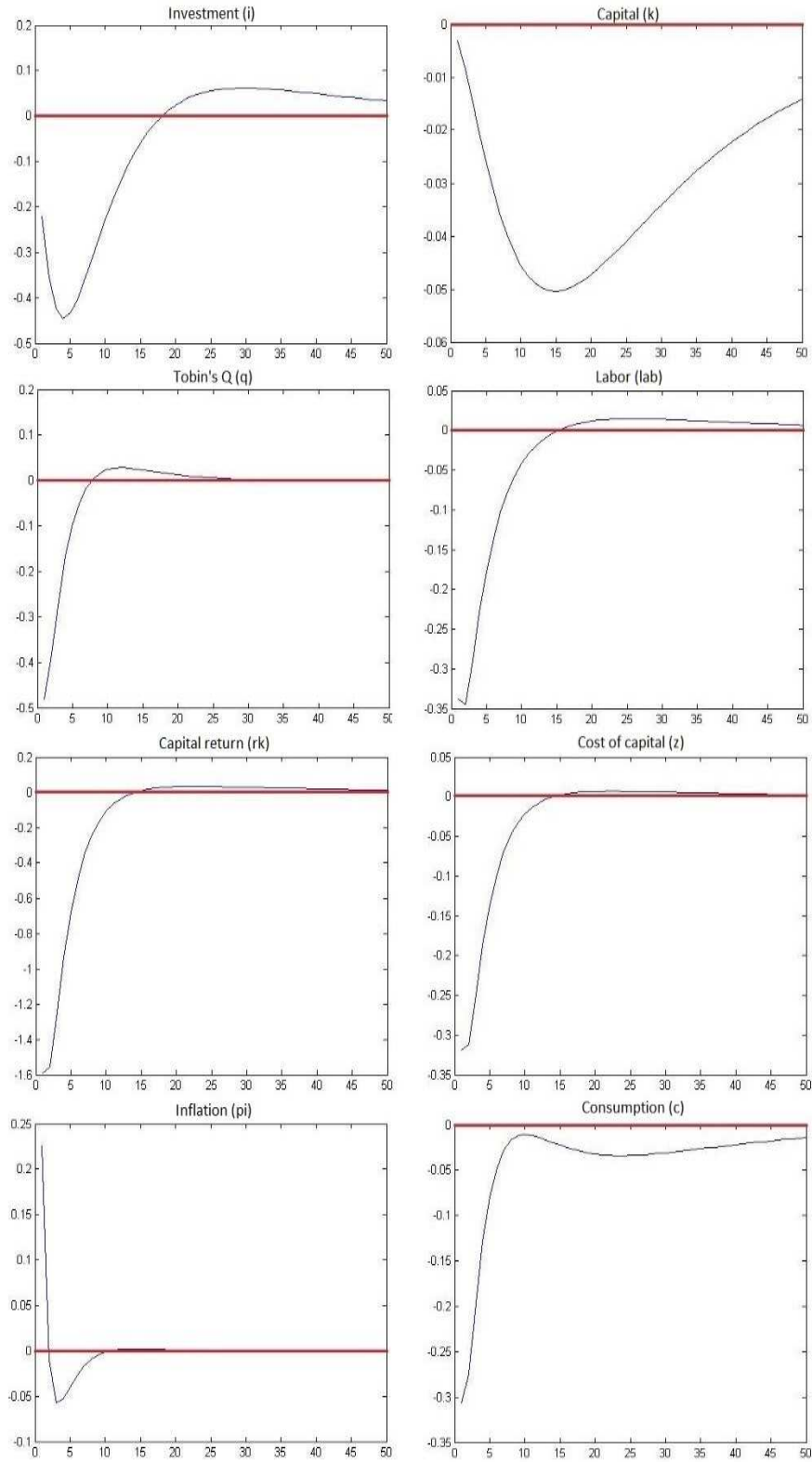


Fig. 4. Impulse response functions to one standard deviation to the markup shocks (ε_t^θ)

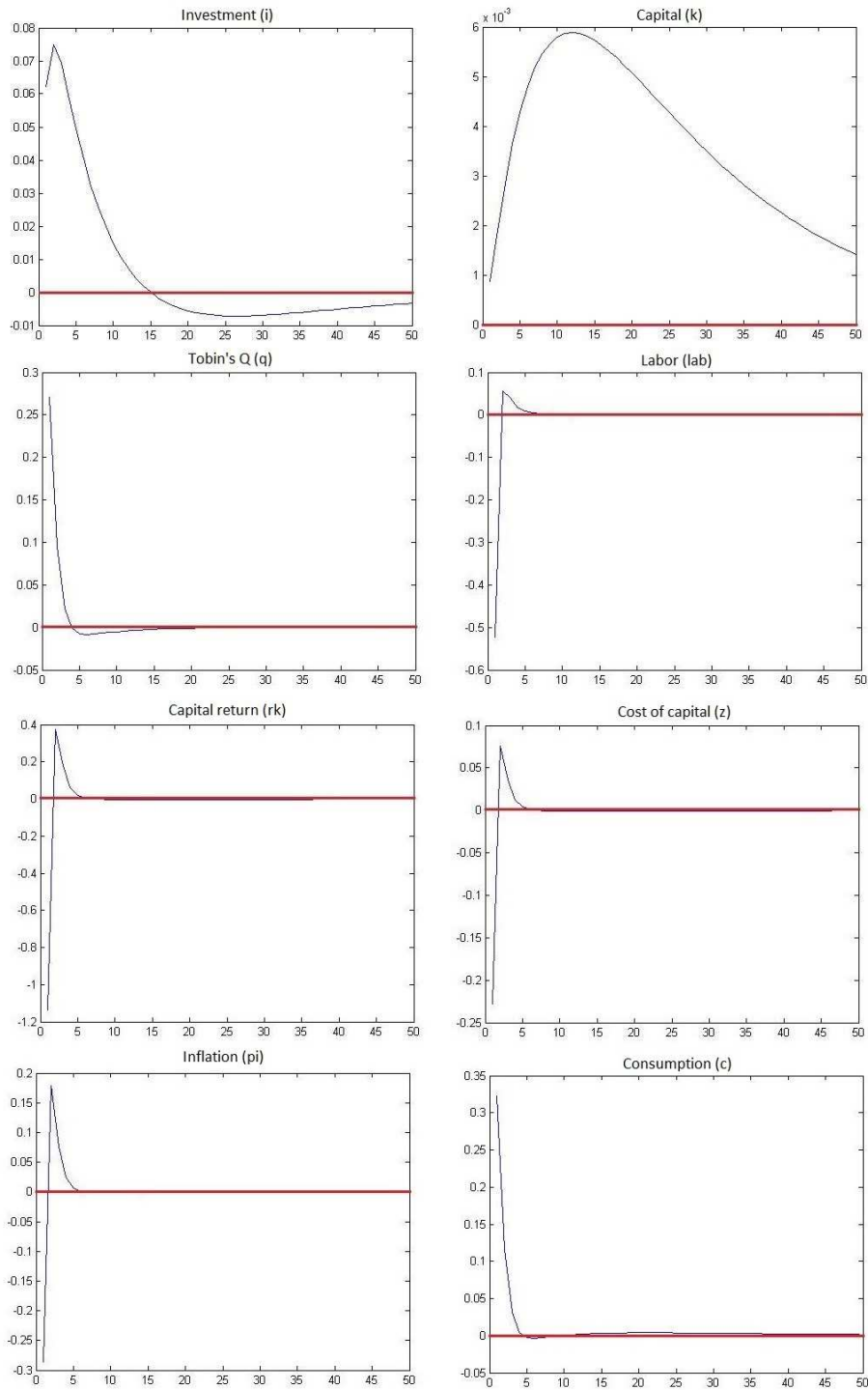


Fig. 5. Impulse response functions to one standard deviation to the technology shock (ϵ_t^a)

Figure 5 depicts the model response to one standard deviation of the technology shock. The gained result of this shock is in accordance with the result of Smets and Wouters (2003) to some extent. This shock hits the production side of the domestic economy: productivity of labour and capital rises uniformly for all intermediate good producers, leading to a decrease in marginal cost. A gradual process of producer price reduction ensues, and inflation falls. As a result, households move from saving to consumption and capital accumulation. Therefore, the investment, capital accumulation, and Tobin's Q arise. Note that the labour effort initially falls because of a positive technological innovation, a finding that is emphasized by Galí (1996) and later corroborated by Smets and Wouters (2005) and Adolfson et al. (2007). According to Smets and Wouters (2003), a combination of sticky wages and prices drives the substitution from labour to capital at the point of the initial impact of the technology

shock, generating this result. The subsequent upturn in the economic activity drives up both the labour effort and the capital accumulation.

Conclusion

This paper works out the theoretical foundations and reports Bayesian estimations results of three micro-structural shocks namely investment-specific technology, price markup, and technology on private investment behaviors in the Iranian economy. The investment-specific technology shock arising from households' capital accumulation equation, the price markup arising from final good producers' aggregation technology equation, and technology shock originated from Cobb-Douglas production technology. The private investment behaviours including, the amount of capital that households lend to the firms, the amount of investment, the Price of capital dynamics equation or Tobin's, capital return, the cost of capital utilization. The main empirical findings are largely in line with previous studies such as Smets and Wouters (2003). It is worth mentioning that the structural shocks about technology have a similar impact on investment, and the difference is that the investment-specific technology shock, due to a temporary reduction in the cost of installing capital, an investment boom was driven. In contrast, the price markup shock due to inflation causes a decline in all the investment indices. Investigating the impact of these microstructural shocks on financial markets, especially the stock market, would be very welcome. Furthermore, the analysis in this paper needs to be improved in a number of dimensions and various structural shocks.

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