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Government Expenditure, Risk and Return: A Framework for a New Keynesian Model in the Iranian Economy

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Abstract

According to the studies, capital expenditure shocks are one of the most important factors affecting the capital market (stock market). Since economic modeling based on the Dynamic Stochastic General Equilibrium (DSGE) Modeling is one of the best tools for understanding the mechanisms behind the effect of economic shocks on risk and stock returns, the present study proposed a new Keynesian model to explore the impact of capital expenditure shocks on risk and stock return to the Iranian economy. The results showed that capital expenditure shocks have a negative impact on systematic risk and stock returns, and then by decreasing their impact, such shocks returned to equilibrium very quickly in the next periods.

Keyword: Capital Expenditure; Government; Risk; Return

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1. Introduction

Establishing the inflationary effects of the increased government expenditure from a theoretical point of view and practical experience in various countries has turned government expenditure into one of the most significant topics in studies. Due to the large size of government in the Iranian economy, most of the key economic variables are affected by government presence. According to a report by the Heritage Foundation, Iran's government expenditure index in 2016 grew slightly compared to 2015 and was even above the regional and world average. Therefore, in most domestic studies, the inclusion of government expenditure as a variable in economic models is inevitably evident, implying the difference between Iran's economy and that of other countries.

Since a major part of the ownership of large corporations is governmental or semi-governmental, and given that the relationship between government expenditure and economic growth is one of the most common economic development issues (Hsu & Lee, 2014), capital expenditure, as part of total the public expenditure, can affect the stock market in a number of ways. The stock market may be one of the goals of the government's contraction and expansion policies, and declaring capital expenditure as an information source can create sensitivity for stock demand. Increasing capital expenditure can reduce risks by reducing the heavy costs of industries, increasing their profitability, and thus affecting stock prices as a result of stock return volatility. Stock return volatility is a special interest for investors, analysts and financial regulators (Wang, 2014). Besides, the beta parameter (systematic risk) is one of the most important modern financial concepts (Kurach & Stelmach, 2014), as investors' objectives are usually based on different perspectives on risk orientation or multiple investment horizons, and or perhaps because of the irrational and imitative behavior that follows general market trends (Acatrinei, & Caraiani 2011). Given that there is significant literature on macroeconomics that addresses the consequences of the public expenditure in the economy, identifying an endogenous measure of unexpected projections of the public expenditure is regarded as a major challenge. The reason is that assets that are exposed to the public expenditure shocks are riskier than assets that are affected by household consumption. Therefore, investors demand lower or equivalent prices or higher expected returns for the demand for assets that are positively affected by the public expenditure shocks (Dissanayake, 2016). Capital expenditure is more indicative of the higher risk of private sector investment in the securities market and at the level of enterprises (Belo & Yu, 2012). Changes in public capital expenditure can affect the profitability of industries, corporate financial statements, and stock prices, and as a market risk factor also affect investors' expectations about the future of the market. In their study on financial policy, risk premium, and stock returns to the United States, Da et al. (2018) concluded that government financial policies had an impact on corporate stock returns. The results of a study by Gonzalez et al. (2018) showed that surplus consumption ratio, along with time-variable risk-taking, and default premium, are collective variables that have a statistically significant effect on market beta. In another study, Chung and Chuwonganant (2018) showed that there is a negative relationship between market volatility and stock returns, and in the business period, stock returns are highly sensitive to price volatility shocks. Dissanayake (2016) conducted a study on the public expenditure shocks and asset prices and concluded that financial shocks would increase consumption initially, but reduce it in the long run. The result also showed that assets with high sensitivity to shocks, on average, are expected to yield higher returns than those with low sensitivity. Foresti and Napolitano (2016) explored stock market reactions to taxes and the public expenditure and concluded that fiscal maneuvers affect the stock market and, with the increase in the general shortfall, the stock market index declines and vice versa. Aigheyisi and Edore (2014) investigated whether public debt and spending affect the development of the Nigerian stock market or not. They concluded that capital expenditure would have a negative short-term and long-term effect on the value of stock market transactions. Belo et al. (2013), exploring the public expenditure, political cycles, and cross-sectoral stock returns, found that the firms that experienced public risks during the Democratic Party's presidency had higher cash flows and stock returns companies, while a reverse pattern was observed during the Republicans' presidency. Based on what was mentioned above, the present study aims to propose a new Keynesian model to explore the impact of capital expenditure shocks on risk and stock return to the Iranian economy. Since factors affecting risk and stock returns are considered as one of the essential elements of investment decisions, several models have been used to analyze such factors, the most important of which are linear and non-linear models, artificial neural network model, Fama and French model, generalized autoregressive conditional heteroskedasticity (GARCH) model, and stable optimization model. All these models indicate the application of quantitative methods and models in the investment industry. A reason for using such models is the development of the financial economy. For instance, the GARCH model is one of the most popular models for volatility analysis. The simple GARCH model assumes that positive and negative shocks have the same effect on volatility (Drachal, 2017). Despite the existence of different models, one of the effective models used currently for analyzing the effects of shocks and economic variables on other variables is the DSGE model, which can be modelled in open and closed economies. It should be noted that the use of the DSGE model in open economies was first proposed by Obstfeld and Rogoff (2000) (Caraiani, 2008a). Today, the paradigm prevailing macroeconomics is that DSGE models are dominant (Caraiani, 2008b). However, the impact of the public capital expenditure shocks on systematic risk and corporate returns has not been addressed within the framework of this research model. Therefore, the present paper uses a simulation analysis to investigate the impact of such shocks by proposing a DSGE model for the Iranian economy. The DSGE model was developed based on the Kydland and Prescott methodology (Caraiani, 2008b), in which the behavior of various economic agents is optimized according to their target functions and constraints (Kydland & Prescott, 1996). One of the most widely used models in the analysis of financial and monetary economy variations, as the traditional macroeconomic forecasting models are vulnerable to Lucas's critique that claims that the effects of economic policies cannot be predicted using historical data for a period when that policy (rules of the game) was non-existent. Therefore, DSGE models employ a natural measure to assess the effects of policy changes on welfare (Tovar, 2009). This being so, the present study aims to explore the probable effects of the public capital expenditure shocks on risk and stock returns within the framework of the DSGE model.

2. DSGE Modeling

2.1. Households

Households obtain utility by consuming goods and real money balances and their utility reduces when they do more works. The present value of the utility that the representative household achieves throughout its life is as follows:

$$E_0 \sum_{i=0}^{\infty} \beta^i U_t^i(0) \qquad (1)$$

Where β is the discount factor. The household utility function, which is a function of the total household consumption, the real money balance, and labor supply, is expressed as follows:

$$U_t^i = \left[\frac{1}{1-\sigma_c}\left(c_t^i - hc_{t-1}\right)^{1-\sigma_c} - \frac{1}{1+\sigma_l}\left(L_t^i\right)^{1+\sigma_l} + \frac{1}{1-\sigma_m}\left(\frac{M_t^{c,t}}{P_t^c}\right)^{1-\sigma_m}\right] \tag{2}$$

In Eq. (2), consumer goods are made up of a combination of various domestic and imported goods that are manufactured by domestic producers or are supplied through imports. In the above equation, σ_c is the relative risk aversion which shows the inverted elasticity of substitution between the consumption periods. Besides, σ_1 represents the inverted labor supply elasticity relative to the actual wages and σm is the inverted real money balance elasticity ($m_t^{c,t} = \frac{M_t^{c,t}}{P_t^c}$) relative to the interest rate.

The utility function in Eq. (2) reflects the external habits (emulative behaviors) of consumer behavior, and these habits depend on the average per capita economic consumption.

2.1.1 Selecting the Consumption Composition and Obtaining Consumption Demand Functions

In Eq. (2), the total consumption at the real price (c_t^i) is assumed to be a combination of consuming domestic goods (c_t^d) and imported goods (c_t^m) by domestic manufacturing and importing firms, respectively. These goods are combined through Dixit-Stiglitz collectors (1997), as expressed in the following equation:

$$c_t = \left[\xi_c^{\frac{1}{\mu_c}}\left(c_t^d\right)^{\frac{\mu_c-1}{\mu_c}} + (1-\xi_c)^{\frac{1}{\mu_c}}\left(c_t^m\right)^{\frac{\mu_c-1}{\mu_c}}\right]^{\frac{\mu_c}{\mu_c-1}} \tag{3}$$

Where ξ_c and (1-ξ_c) represent the shares of domestic and imported products in the total household consumer basket and η_c is the elasticity of substitution between imported and imported goods.

In general, household decision-making can be considered in two stages: At the first stage, the household decides which consumption composition is chosen to minimize the cost of obtaining a certain level of combined consumption. At this stage, households will minimize the cost of consumption composition (c_t). In the second stage, considering the cost of access at each level of consumption (c_t), the household selects optimal values of $c_t, L_t, \frac{M_t^c}{P_t}$ in a way to maximize its utility.

At the first stage, households minimize the cost of purchasing consumption composition (ct). To choose consumer domestic and imported goods, they solve the following problem:

$$\begin{gathered} \min_{c_t^i} P_t^d c_t^d + P_t^m c_t^m \\ \text{s.t} \\ c_t = \left[\xi_c^{\frac{1}{\mu_c}}\left(c_t^d\right)^{\frac{\mu_c-1}{\mu_c}} + (1-\xi_c)^{\frac{1}{\mu_c}}\left(c_t^m\right)^{\frac{\mu_c-1}{\mu_c}}\right]^{\frac{\mu_c}{\mu_c-1}} \end{gathered} \tag{4}$$

Where c_t^d and c_t^m are the consumption of domestic and imported goods and P_t^d and P_t^m are the price of domestic and imported goods, respectively.

The demand function for domestic and imported goods can be obtained from the solution of the first-order condition in Eq. (4) as follows:

$$c_t^m = (1-\xi_c)\left(\frac{P_t^m}{P_t^c}\right)^{-\mu_c} c_t \tag{5}$$

$$c_t^d = \xi_c \left(\frac{P_t^d}{P_t^c}\right)^{-\mu_c} c_t \tag{6}$$

By substituting the equations (5) and (6) in the household consumer basket, $P_t^d c_t^d + P_t^m c_t^m = P_t^c c_t$, the overall consumer price index (P_t^c) and its components are obtained:

$$P_t^c = \left[\xi_c \left(P_t^d\right)^{1-\eta_c} + (1-\xi_c)(P_t^m)^{1-\eta_c}\right]^{\frac{1}{1-\eta_c}} \tag{7}$$

Where P_t^c represents the overall consumer price index.

After the optimal combination of goods was determined at the first stage, at the third stage, the household's goal is to maximize its expected utility function based on the inter-period budget constraint.

In the second stage, after the optimal combination of goods was determined at the first stage, the household's goal is to choose optimal values of consumption (C_t), labor (L_t), and financial assets in a way that maximizes its utility.

Household financial assets consist of money, bonds, and shares. No interest is assigned to money, but the interest at a rate of r_t^d is assigned to bonds. Dividends (if any) and capital gain are assigned to stocks. The household financial assets at the end of period t include cash, bonds, and the portfolio of stocks Nt(j) issued by intermediary businesses. The par value of each stock of the business j in the period t is shown by $P_t^s(j)$. Therefore, the stock wealth of the household i includes a portfolio of the stocks of intermediary businesses, each having a dividend with a par value of DVt(j). Therefore, the household income at the beginning of each period includes net wages, capital, and a set of financial income from the previous period (including money, bonds, and stocks).

We use Nistico's (2010 and 2012) studies to model stock assets. The stock assets (wealth) of the household i carried from the previous period ($\Omega_{t-1}^{*}(i)$) can be written as follows:

$$\Omega_{t-1}^{*,i} = \int_0^1 (P_t^s(j) + DV_t(j)) N_t(j)\, dj \tag{8}$$

Since the beta coefficient (systematic risk) is defined based on the sensitivity of stock returns (stock price volatility) to market returns (price returns or the stock price index), we will have the following equation:

$$\beta_t^i = \frac{\Delta(P_t^s - P_{t-1}^s)}{\Delta(P_M - P_{M-1})} \tag{9}$$

Also, the household inter-period budget constraint can be expressed in terms of real prices as follows:

$$c_t^i + I_t^i + b_t^i + \frac{1}{P_t^c}\int_0^1 P_t^s(j)\frac{N_t(j)}{\varepsilon_t^s}dj + m_t^{c,i} = \left(1 + r_{t-1}^d\right)\frac{b_{t-1}^i}{\pi_t^c} + \frac{m_{t-1}^{c,i}}{\pi_t^c} + \frac{1}{P_t^c}\Omega_{t-1}^{*,i} + TR_t^i - T_t^i + y_t^i$$
(10)

Where, I_t^i is the investment rate, r_{t-1}^d shows bonds, r_{t-1}^d denotes the nominal interest rate of bonds, T_t^i is the household taxes (direct, indirect, and value-added taxes), TR_t^i is the subsidy paid by the government, P_t^I is the investment price index, in which the household maintains its wealth in the form of the real money balance of $m_t^{c,i}$and bonds b_t^i, π_t^c is the inflation rate based on the consumer price index and ε_t^s is the stock price shocks, which in fact forms the price bubble. Other variables have already been defined in the above sections, and y_t^i represents household income, which is defined as follows:

$$y_t^i = \frac{W_t^i}{P_t^c} L_t^i + R_t^k z_t^i k_{t-1}^i - \psi(z_t^i) k_{t-1}^i + Div_t^i \quad (11)$$

Total household income from labor wages ($\frac{W_t^i}{P_t^c} L_t^i$) is calculated as the capital lease minus the cost associated with changes in utilization of the capital capacity and dividends for the businesses producing intermediary goods Div_t^i. In Eq. (11), W_t^i is the nominal wage, R_t^k is the real rate of return on capital, and z_t^i is the intensity of use (utilization rate) of capital capacity, and $\psi(z_t^i)$ is the cost of capital utilization which represents the cost per unit of physical capital. The following equations are established in long-term equilibrium:

$$\psi'' > 0 \,, \psi' > 0 \,\,, \psi(1) = 0 \,, z = 1$$

2.1.2 Capital Stock and Investment

The capital stock is in the ownership of households and is used as a homogeneous production factor in the production process. Households lease their capital stock at the rate of R_t^k to intermediary businesses. Households can increase their capital in two ways:

By increasing investment It, leading to an increase in capital stock.

Changing the utilization of capital stock.

The process of capital accumulation is assumed to be carried out through the following equation:

$$k_t^i = (1-\delta) k_{t-1}^i + \left[1 - S\left(\frac{I_t^i}{I_{t-1}^i}\right)\right] I_t^i \quad (12)$$

Where δ is the investment depreciation rate, I_t^i is the gross investment of the private sector, and S(0) is the investment adjustment cost function, which is a positive function of the changes in investment. S(0) represents the resources that are lost when transforming a new investment into capital stock.

In a static equilibrium state where z = 1, S'(1) = S (1) = 0 and S"> 0, so the adjustment cost depends only on the second derivative.

According to the above explanations, the household problem is to maximize the utility function relative to the budget constraint. In the process of optimization, households choose consumption levels, money, investment in stocks, deposits, labor supply, capital stock, investment, and capital utilization rate in a way that to maximize their objective function relative to the budget constraint:

$$\max E_t \sum_{t=0}^{\infty} \left\{ \left[\frac{1}{1-\sigma_c} \left(c_t^i - hc_{t-1}\right)^{1-\sigma_c} - \frac{1}{1+\sigma_l} \left(L_t^i\right)^{1+\sigma_l} + \frac{1}{1-\sigma_m} \left(\frac{M_t^{c,t}}{P_t^c}\right)^{1-\sigma_m} \right] + \lambda_t \left[\left(1 + r_{t-1}^d\right) \frac{b_{t-1}^i}{\pi_t^c} + \frac{m_{t-1}^{c,i}}{\pi_t^c} + \frac{1}{P_t^c} \Omega_{t-1}^{*,i} + TR_t^i - T_t^i + \frac{W_t^i}{P_t^c} L_t^i + R_t^k z_t^i k_{t-1}^i - \psi\left(z_t^i\right) k_{t-1}^i + Div_t^i - c_t^i - I_t^i - b_t^i - m_t^{c,i} - \frac{1}{P_t^c} \int_0^1 P_t^s(j) \frac{N_t(j)}{\varepsilon_t^s} dj \right] + Q_t \left[(1-\delta) k_{t-1}^i + \left[1 - S\left(\frac{I_t^i}{I_{t-1}^i}\right)\right] I_t^i - k_t^i \right] \right\} \quad (13)$$

Where, λt and Qt are the multiple coefficients of the budget constraint and capital stocks, respectively. The first-order conditions for each period t ≥ 0 are as follows:

$$(\partial c_t) \qquad (c_t - hc_{t-1})^{-\sigma_c} = \lambda_t \quad (14)$$

$$(\partial I_t) \quad Q_t \left[1 - S\left(\frac{I_t}{I_{t-1}}\right) - S'\left(\frac{I_t}{I_{t-1}}\right) . \frac{I_t}{I_{t-1}}\right] + \beta E_t Q_{t+1} S'\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2 = \lambda_t \quad (15)$$

$$(\partial z_t) \quad R_t^k = \psi'(z_t) \quad (16)$$

$$(\partial K_t) \quad Q_t = \beta E_t \lambda_{t+1} \left[z_{t+1} R_{t+1}^k - \psi(z_{t+1})\right] + \beta (1-\delta) E_t Q_{t+1} \quad (17)$$

$$(\partial b_t) \quad Q_t = \beta E_t \lambda_{t+1}\left(1 + r_t^d\right)\frac{1}{\pi_{t+1}^c} = \lambda_t \tag{18}$$

$$(\partial m_t^c) \quad \varepsilon_t^M (m_t^c)^{-\sigma_m} = \lambda_t - \beta E_t \lambda_{t+1}\frac{1}{\pi_{t+1}^c} \tag{19}$$

$$(\partial L_t) \quad -L_t^{\sigma_l} + \lambda_t \frac{W_t}{P_t^c} = 0 \tag{20}$$

$$(\partial N_t) \quad \frac{1}{P_t^c \varepsilon_t^s}\lambda_t P_t^s(j) + E\left\{\beta \frac{1}{P_{t+1}^c}\lambda_{t+1}(P_{t+1}^s(j) + DV_{t+1}(j))\right\} = 0 \tag{21}$$

2.1.3 Household Saving and Consumption

Eq. (14) expresses Fuller's consumption equation and is obtained from the ratio of Fuller's equations for periods t and t + 1:

$$E_t \frac{\lambda_t}{\lambda_{t+1}} = E_t \frac{(c_t - hc_{t-1})^{-\sigma_c}}{(c_{t+1} - hc_t)^{-\sigma_c}} \tag{22}$$

The following equation can be obtained from Eq. (15) for periods t and t + 1:

$$E_t \frac{\lambda_t}{\lambda_{t+1}} = \beta E_t \lambda_{t+1}\left(1 + r_t^d\right)\frac{1}{\pi_{t+1}^c} \tag{23}$$

Combining Eq. (14) and Eq. (15), we can obtain the inter-period consumption equilibrium equation between consumption times as follows:

$$\beta E_t \lambda_{t+1}\left(1 + r_t^d\right)\frac{1}{\pi_{t+1}^c} = E_t \frac{(c_t)^{-\sigma_c}}{(c_{t+1})^{-\sigma_c}} \tag{24}$$

Eq. (24) shows the household inter-period consumption optimal allocation performed by households based on the discount rate and interest rate.

2.1.4 Money demand

The household money demand equation can be obtained by combining equations (19), (23), and (24) as follows:

$$(m_t^c)^{-\sigma_m} = (c_t)^{-\sigma_c} \times \frac{r_t^d}{1 + r_t^d} \tag{25}$$

The real money balance has a positive relationship with consumption and its elasticity is calculated as $\frac{\sigma_c}{\sigma_m}$ but it has a negative relationship with the interest rate of the deposits.

2.1.5 Capital Accumulation and Investment

Combining equations (20) and (22), we can write the marginal Tobin's Q equation calculated as $q_t = \frac{Q_t}{\lambda_t}$, which represents the investment value in terms of the capital replacement cost. Taking into account the definition of the marginal Tobin's Q equation, we can rewrite the equations (20) and (22) through algebraic operations as follows:

$$1 = q_t\left[1 - S\left(\frac{I_t}{I_{t-1}}\right) - S'\left(\frac{I_t}{I_{t-1}}\right).\frac{I_t}{I_{t-1}}\right] + \beta E_t q_{t+1}\frac{\lambda_{t+1}}{\lambda_t} S'\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2 \tag{26}$$

$$q_t = \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left[q_{t+1}(1 - \delta) + z_{t+1}R_{t+1}^k - \psi(z_{t+1})\right] \tag{27}$$

Eq. (26) can be interpreted as an investment Euler equation, which represents the path of investment optimization. Eq. (26) applies when there is no investment adjustment, i.e. $S\left(\frac{I_t}{I_{t-1}}\right)$.

2.1.6 Households Decision to Supply Labor and the Wage-Setting Equation

Households offer their labor at a very competitive price. Therefore, the household labor supply equation is expressed as follows:

$$L_t^{\sigma_l} + (c_t - hc_{t-1})^{-\sigma_c}\frac{W_t}{P_t^c} = 0 \tag{28}$$

2.1.7 Stock Price Dynamics

Eq. (28) shows the stock return dynamics. By combining equations (20) and (14), the stock return dynamics (including dividends and capital gains) can be written as follows:

$$P_t^s(j) = \varepsilon_t^s E\left\{\beta\frac{\varepsilon_{t+1}^{\beta}(c_{t+1}-hc_t)^{-\sigma_c}}{\varepsilon_t^{\beta}(c_t-hc_{t-1})^{-\sigma_c}}\left(P_{t+1}^s(j) + DV_{t+1}(j)\right)\frac{P_t^c}{P_{t+1}^c}\right\} \tag{29}$$

The above equation can be written as follows using Eq. (24):

$$P_t^s(j) = \varepsilon_t^s E\left\{\frac{\pi_{t+1}^c}{(1+r_t^d)}\left(P_t^s(j) + DV_{t+1}(j)\right)\frac{P_t^c}{P_{t+1}^c}\right\} \qquad (29)'$$

The same equation can be also rewritten as following based on real prices:

$$\gamma_t^{sc}(j) = \varepsilon_t^s E\left\{\frac{\pi_{t+1}^c}{(1+r_t^d)}\left(\gamma_{t+1}^{sc}(j) + dv_{t+1}(j)\right)\right\} \qquad (29)'$$

In the above equation, $\gamma_t^{sc}(j) = \frac{\pi_t^s(j)}{p_t^c}$ represents the ratio of return on stock j to the consumer price index.

According to Eq. (30), the return on each stock of the business j is equal to the present value of all future earnings of that stock (including dividends and capital gains).

2.2. Businesses

2.2.1. The behavior of marginal goods-producing businesses

A typical business, as assumed in Ireland (2004), produces marginal goods Yt from intermediate goods units Y_{jt} by purchasing j∈ [0,1] at the nominal price Pjt . According to the following equation, which is a collector according to Dixit-Stiglitz (1977), one can write:

$$\left[\int_0^1 Y_{jt}^{(\theta-1)/\theta} dj\right]^{\theta/(\theta-1)} \geq Y_t \tag{30}$$

Where, θ > 1 and intermediary goods are distinct and inadequate substitutes, and the constant elasticity of substitution θ is established between them. Therefore, during the period t = 0, 1,..., n, a marginal goods-producing business chooses Yjt for all j∈ [0,1] in such a way to maximize its profit:

$$\max_{Y_{jt}}\left\{P_t Y_t - \int_0^1 P_{jt} Y_{jt} dj\right\} \tag{31}$$

The first-order condition of this demand function a distinct good produced by the business j is as follows:

$$Y_{jt} = \left[\frac{P_{jt}}{P_t}\right]^{-\theta} Y_t \tag{32}$$

Where -θ is the demand price elasticity for the intermediary goods j. In competitive markets, the profit of marginal goods-producing businesses is zero. The zero-profit condition Pt is defined as follows:

$$P_t = \left[\int_0^1 P_{jt}{}^{1-\theta} dj\right]^{\frac{1}{(1-\theta)}} \quad \text{for t = 0, 1, …, n} \tag{33}$$

2.2.2. Intermediate Goods Producing Businesses

An economy is composed of a chain of exclusive competition businesses in the intermediate goods-producing sector, which is indexed in the range of [1, 0]. Each of the businesses produces distinct goods. These businesses produce intermediate goods j by employing labor, capital, and other inputs. They use labor and capital as inputs in the production process. Because of the government's dominance on the economy, there are significant developmental budgets in the private sector's productivity, thus it is necessary to consider the formation of public capital in the production function of the businesses producing intermediate goods. The production function of the enterprises producing intermediate goods based on the Cobb-Douglas model is expressed as follows:

$$y_t^j = A_t\left(z_t k_{t-1}^j\right)^{\alpha}\left(L_{t-1}^j\right)^{1-\alpha}(K_{t-1}^G)^{\kappa} \tag{34}$$

Where, $z_t k_{t-1}^j = \tilde{k}_{t-1}$is the effective capital stock and K_{t-1}^G is the public capital formation5 and is assumed to be common to all firms in this sector. Besides, At represents productivity.

The intermediary goods producing business j is looking to minimize its costs based on a given production level. Therefore, the objective function of the business j is as follows:

$$\min_{\tilde{k}_{t-1}, L_t} \frac{W_t}{P_t^d} L_t^j + R_t^k z_t k_{t-1}^j \tag{35}$$

s.t.

$$y_t^j = A_t\left(z_t k_{t-1}^j\right)^{\alpha}\left(L_{t-1}^j\right)^{1-\alpha}(K_{t-1}^G)^{\kappa}$$

Where Wt is the nominal wage, R_t^k is the rate of return on investment, and y_t^j is the demand for goods j.

If we obtain the first-order condition of the business optimization problem, then the marginal cost of the business in terms of real prices can be written as follows:

$$mc_t = \frac{Mc_t}{P_t} = \frac{1}{A_t}\left(\frac{1}{1-\alpha}\right)^{1-\alpha}\left(\frac{1}{\alpha}\right)^{\alpha}\left(\frac{w_t}{P_t}\right)^{1-\alpha}(R_t^k)^{\alpha}(k_{t-1}^G) \tag{36}$$

In this study, we use Calvo's (1983) method to adjust prices. That is, in each period only (1 - θP)% of the businesses will be able to optimally adjust their product prices, while other firms (θP%) that cannot determine prices optimally in the current period, use the following to partially adjust prices based on historical prices:

$$P_{t+1}^i = \left(\pi_t^i\right)^{\tau_p} P_t^i \tag{37}$$

Where $\pi_t^i = \frac{P_t^i}{P_{t-1}^i}$ represents the inflation rate of the products in sector i and τ_p is a parameter that shows the price indexation degree.

The price set by business i at time t is a function of the expected future marginal costs and is equal to the markup value of the weighted marginal costs. If the prices are completely flexible ($\theta_P = 0$), the markup value at time t is equal to $(\frac{\zeta}{\zeta-1})$, in which case; $\overline{\mathrm{P}} = \left(\frac{\zeta}{\zeta-1}\right)\mathrm{mc}_t^i$,

5 *The public capital formation is complementary to the private sector inputs, suggesting that increasing KG will increase the marginal productivity of labour and private sector capital.*

which is the same condition of exclusive competition in the total price flexibility, where the price is equal to the markup value plus the nominal marginal cost.

But when prices are sticking ($\theta_P > 0$), the markup value changes over time when the economy faces an exogenous shock.

Given that in each period, only 1 - θ_P% of the businesses can adjust their prices optimally, and the rest of the businesses index their prices based on those of the previous periods. Therefore, using Eq. (33), the total price index at time t is based on the average weighted equation stated as follows:

$$\left[P_t^d\right]^{1-\zeta} = \theta_P\left[\left(\pi_{t-1}^d\right)^{\tau_P} P_{t-1}^d\right]^{1-\zeta} + (1-\theta_P)[\overline{P}_t]^{1-\zeta} \tag{38}$$

2.3. Government and Central Bank

2.3.1. Government

Similar to the study conducted by Portillo et al. (2010) for low-income and oil-rich developing countries, and the study conducted by Dagher et al. (2010) for Ghana, the public budget constraint a real price can be expressed through the following equation:

$$g_t + \frac{\left(1+r_{t-1}^d\right)b_{t-1}}{\pi_t^c} = \frac{\omega.EX_t.o_t}{P_t^c} + T_t + \text{other}_t + fa_t + \frac{GBD_t}{P_t^c} \tag{39}$$

Where gt is the total the public expenditure, EXt is the nominal exchange rate, ot is oil revenues in foreign currency, bt is bonds, Tt is tax revenues, othert shows other revenues, fat is the acquisition of state-owned companies, GBDt is the public budget deficit. As is evident, the government ω spends a percentage of oil revenue through the budget.

The public expenditures are defined in terms of current expenditures C_t^g and capital expenditures I_t^g:

$$g_t = c_t^g + I_t^g \tag{40}$$

Public investment (in the form of log-linear) follows a first-order auto-regressive process in which public investment comes from oil shocks and the government independent decision-making:

$$u_t^{I^g} \sim N\left(0.\sigma_{I^g}^2\right) \tag{41}$$
$$\log I_t^g = \rho_I \log I_{t-1}^g + u_t^{I^g}$$

2.3.2. Budget Deficit and Financing methods

When faced with a budget deficit, the government will compensate it partly through selling bonds. The process of issuing bonds is assumed to follow Eq. (42):

$$b_t = \alpha^{gbd}.gbd_t + \frac{b_{t-1}}{\pi_t^c} \tag{42}$$

A part of the budget deficit can be financed through borrowing from banks, which is, in fact, a type of loan granted to the public sector l_t^g reflected in the financial intermediary sector. It is obvious that in financing through deposits, the resources needed to grant loans to the private sector are reduced.

$$L_t^g = \beta^{gbd}.GBD_t + L_{t-1}^g - LB_t^g \tag{43}$$

In the above equation, LB_t^g shows the payback from the previous loans. By dividing both sides of the above equation by the price index, the following equation is obtained in terms of real prices:

$$l_t^g = \beta^{gbd}.gbd_t + \frac{l_{t-1}^g}{\pi_t^c} - lb_t^g \quad (44)$$

Borrowing from the central bank is another way to finance the budget deficit. Therefore, we have:

$$dc_t^g = (1 - \alpha^{gbd} - \beta^{gbd})gbd_t + \frac{dc_{t-1}^g}{\pi_t^c} \quad (45)$$

2.3.3. Monetary Policy

The monetary policy response function (log-linear) is expressed as follows:

$$\widehat{\Theta}_t = \rho_\Theta \widehat{\Theta}_{t-1} + \theta_\pi \widehat{\pi}_t^c + \theta_y \widehat{y}_t + \theta_{rer} \widehat{rer}_t + \theta_{\pi^s} \widehat{\pi}_t^s + \varepsilon_t^\Theta \quad (46)$$

$$\widehat{\Theta}_t = \widehat{m}_t^c - \widehat{m}_{t-1}^c + \widehat{\pi}_t^c \quad (47)$$

$$\varepsilon_t^\Theta = \rho_\Theta \varepsilon_{t-1}^\Theta + u_t^\Theta \qquad u_t^\Theta \sim N(0, \sigma_\Theta^2) \quad (48)$$

Where, $\widehat{\theta}_t$is the nominal growth rate of the monetary base6, $\hat{\pi}_t$, $\hat{y}_t$, and $\widehat{rer}_t$ are the standard deviation of interest rate, production logarithm, and the real exchange rate from their stable position values, θ_π, θ_y, θ_{rer}, and θ_{π^s} are significance attached through policymaking to inflation gap, production, exchange rate, and total stock price index. Besides, ε_t^θ is the monetary policy shock that itself follows a random process AR(1).

2.3.4. Market Equilibrium

The goods market is in equilibrium when production is equal to the household demand for consumption and investment, the public expenditures, and imports minus exports:

$$y_t = c_t + i_t + g_t \quad (49)$$

The total production is equal to non-oil and oil production as follows:

$$Y_t = \left[\alpha_\mu^{\frac{1}{\mu_o}} (Y_t^{no})^{\frac{\mu_o - 1}{\mu_o}} + (1 - \alpha_\mu)^{\frac{1}{\mu_o}} (Y_t^o)^{\frac{\mu_o - 1}{\mu_o}} \right]^{\frac{\mu_o}{\mu_o - 1}} \quad (50)$$

3. Model Solution and Approximation

By optimizing the objective functions of each of the above agents, the result of the obtained economic equations shows that the non-linear differential equations' system is based on rational expectations so that the model can be solved practically within the approximation limits using perturbation. In this paper, the proposed equations are linearly logarithmic[7] using Uhlig's (1999) method. In the next step, by determining the input values of and calibration of the parameters, as shown in Tables 1 and 2, the model is simulated. As shown in Table 2, first the data are extracted from the database of the Central Bank of Iran (CBI) and then the corresponding values for each parameter are calculated.

In this paper, the introduced shocks indicate the impact of capital expenditure shocks and the output gap is defined as the logarithm of the deviation of the actual output from the potential output. Potential output was also calculated using the Hodrick-Prescott (HP) filter. Also, based on the definition of growth rate in the new Keynesian literature, the growth rate

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[6] *Of course, this instrument can also be liquidity growth rate that will be tested in calibration and estimation stage of the parameters.*

[7] *See appendix for details.*

is defined as the ratio of growth in period t to the growth at period t-1 and since all variables in the model have been defined the logarithm of deviation of the variable in question from the steady-state, using the HP filter with $\lambda = 677$, the logarithmic ratio of each variable to its previous value was obtained. It should be noted that before estimating the parameters, the parameters that did not need to be estimated (Table 1) were specified and calibrated.

Table 1

Value of the calibrated parameters

Parameter Name	Description	Value	Resource
β	The discount factor	0.97	Fakhrhosseini (2014)
h	The parameter that controls habit persistence	0.30	Fakhrhosseini (2014)
σ_c	The coefficient of relative risk aversion of households or the inverse of the intertemporal elasticity of substitution	0.80	Kavand (2009)
σ_m	The inverse of the elasticity of money holdings with respect to the interest rate	1.315	Fakhrhosseini (2014)
φ	Elasticity of investment adjustment cost	3.943	Fakhrhosseini (2014)
σ_l	The inverse of the elasticity of work effort with respect to the real wage	2.92	Fakhrhosseini (2014)
α	The capital-output ratio	0.42	Shahmordi & Ebrahimi (2010)
ψ	The inverse of the elasticity of the capital utilization cost function	0.21	Manzoor & Taghipour (2016)
τ_p	The degree of partial indexation of price	0.511	Manzoor & Taghipour (2016)
θ_p	The percentage of firms that do not adjust their prices	0.20	Manzoor & Taghipour (2016)
η_c	The elasticity of substitution between imports and domestic goods	1.05	Parsa & et al (2015)
μ^0	The elasticity of substitution between Oil and non-oil production	0.15	Manzoor & Taghipour (2016)
ρ_0	Oil revenue shocks, AR	0.249	Parsa & et al (2015)
ϖ_π	The reaction coefficient of the monetary policy with respect to inflation	-1.548	Shahhosseini & Bahrami (2012)
ϖ_y	the reaction coefficient the monetary policy with respect to production	-1.70	Shahhosseini & Bahrami (2012)
ϖ_s	reaction coefficient of the monetary policy with respect to stock price index	0.90	Shahhosseini & Bahrami (2012)
ϖ_{rer}	The reaction coefficient of the monetary policy with respect to real exchange rate	0.80	Manzoor & Taghipour (2016)

Note: The table reports the value of the calibrated parameters. These values are drawn from Iranian research.

Table 2

Calibrated Parameters

Parameter Name	Description	Value	Resource
$\bar{\gamma}_t^{dc}$	producer price index to consumer price index Ratio	0.9849	Research findings
$\bar{\gamma}_t^{mc}$	import price index to consumer price index Ratio	0.9357	Research findings
δ	The depreciation rate of capital	0.0139	Research findings
$\bar{R}_t^k$	The real rate of return on capital	0.046	Research findings
$\bar{C}/\bar{Y}$	consumption to production Ratio	0.510	Research findings
$\bar{I}/\bar{Y}$	total investment to production Ratio	0.321	Research findings
$\bar{g}_t/\bar{Y}$	government expenditure to production ratio	0.123	Research findings
$\bar{X}_t^o/\bar{Y}$	oil exports to production Ratio	0.175	Research findings
$\bar{X}_t^{no}/\bar{Y}$	non - oil exports to production Ratio	0.105	Research findings
$\bar{m}_t/\bar{Y}$	total imports to production Ratio	0.234	Research findings
$\bar{C}_t^d/\bar{C}_t$	goods of domestic consumption to consumption ratio	0.97	Research findings
$\bar{I}_t^l/\bar{I}$	private investment to total investment ratio	0.728	Research findings
$\bar{I}_g^l/\bar{I}$	government investment to total investment ratio	0.272	Research findings
$\bar{C}_t^g/\bar{g}_t$	current expenditure to government expenditure Ratio	0.7313	Research findings
$\bar{I}_t^g/\bar{g}_t$	capital expenditure to government expenditure ratio	0.2687	Research findings
$\bar{o}_t^g$	The share of oil revenues in the budget	0.3942	Research findings
$\bar{o}/\bar{y}$	The value-added ratio in the oil sector to production	0.2066	Research findings

Note: Seasonal value of parameters are reported (2002 to 2016). The calibration is based on the data available over the sample period.

4. Simulation Results and Discussion

In this paper, using the calculated parameters and ratios, the time series of variables are simulated in the proposed model. Comparing the moments obtained from the model with the moments in the seasonal data for the variables during the period from 2002 to 2016 indicates the success of the model in simulating the variables' data in the Iranian economy. The results shown in Figure 1 indicate that the public capital expenditure leads to an increase in public capital through increasing public investment, and since public capital enters the production function in the form of an investment product, it influences variables such as investment, employment, consumption, and production. In addition, the public capital expenditure shocks initially decrease the money supply, and then with the completion of public investment and the increase in total the public expenditure, they increase the money supply. One of the reasons for the increase in the f money supply as a result of the increase in public investment is that the source of investment finance is mainly from oil revenues. The effects of the public capital expenditure on production are positive, resulting in non-oil production growth.

Inflation initially slightly increases but declines very rapidly. The reason is that it will take some time for the capital budget to turn into investment and show its effects.

Since the public expenditure affects household consumption, it also affects the increase or decrease in the consumer marginal utility, so if the public expenditure is suitable for individuals in the future and the public expenditure is complementary to consumer goods and services in the private sector, then the increase in the public expenditure will increase the consumption of the private sector. Therefore, individuals' investment in financial markets including stocks decreases, and stock prices initially decrease due to lower demand for investment in stocks, which leads to a decrease in stock return. Also, according to Friedman (1981), since the public expenditure is partly financed by the sale of bonds to people or through taxes, the public expenditure directly affects inflation. Therefore, part of these funds in Iran are financed through the sale of bonds, given the low risk (risk-free) bonds in the individuals' investment portfolio, investors tend to prefer bonds overstocks, and as a result of the decreased demand for stocks, their price falls, and hence the stock return or the replacement of bonds instead of stocks in the investment portfolio and the sale of the stocks lead to a reduction in stock prices. As the results of this study suggest, the stock return first drops by 0.7 percent, and then with the reduction of the shock and the finance of necessary funds for the government, the stock price and return increase in the next periods and return to equilibrium very quickly.

Figure 1

Capital Expenditures shock.

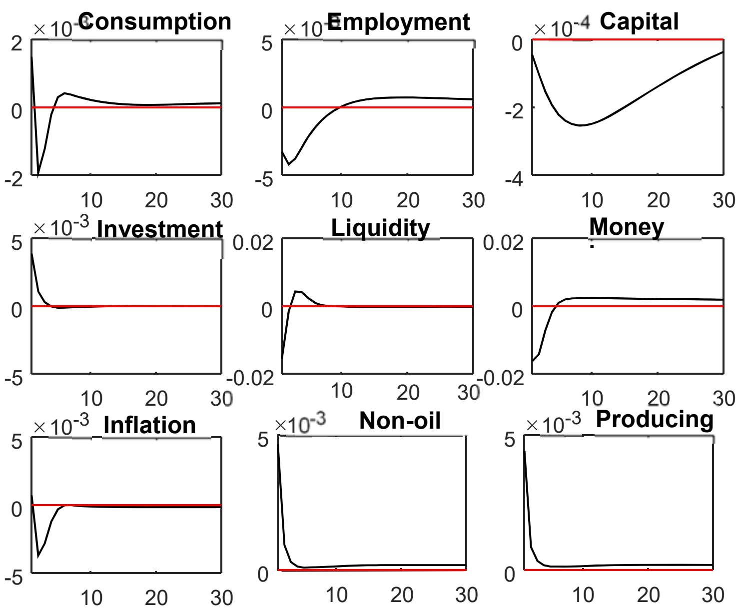
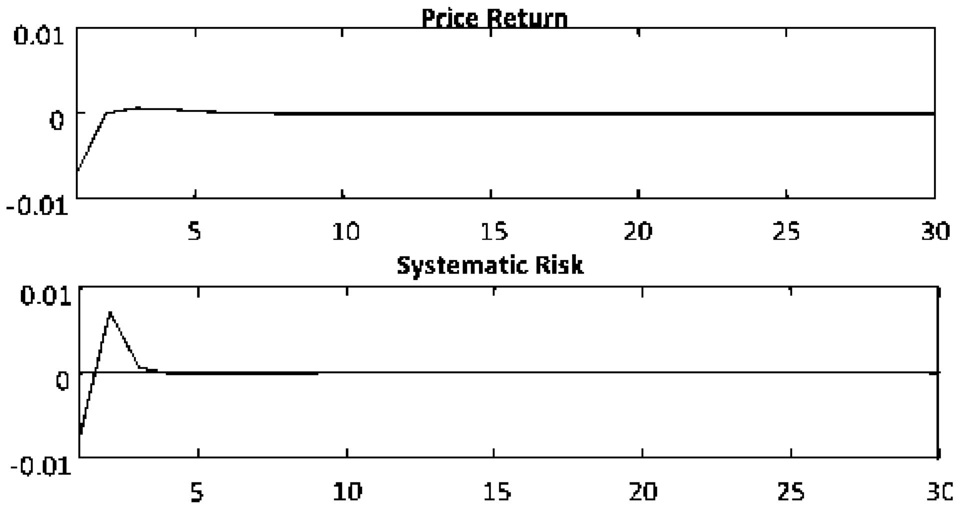


Figure 1 (Cont.)



Besides, financing part of the public expenditure through bonds and increasing the overall demand will increase inflation in the society, and as a result of the increased inflation, the interest rate of the economy increases and thus the private sector's incentive for investment and savings is reduced (Friedman, 1981). Therefore, companies do not enter into risk investment opportunities and the systematic risk of their stocks is not increased. However, when the shocks are reduced and shareholders become interested in investing in stocks, the systematic risk of stocks will start to decline after an increase in the short term and when stock prices return to equilibrium.

5. Conclusion

Undoubtedly, investors interested in investing in the stock exchange are seeking to obtain appropriate returns for the risks they undergo. Besides, one of the most important issues is the amount of capital expenditure and government policies to support economic and infrastructural activities, which play an inevitable role in decisions taken by financial market participants, including governmental, institutional, and potential investors, and individual shareholders. Hence, various groups of market participants, investors and financial experts, as well as policymakers and economic planners are interested in studying the effects of financial policies on capital markets under various circumstances and also in different policy-making programs t create a framework to show that changes in capital expenditure as part of public spending in the economy affect stock risk and returns. Accordingly, the present study used DSGE modeling and the data related to the Iranian economy from 2002 to 2016 to analyze and analyze the effects of this shock on systematic risk and stock return. After developing the research model, the optimization of the economic agents' behavior, the linear logarithm of the behavioral functions of the agents and the initialization of the model were performed. The results show that, firstly, a comparison of the moments from the simulated data with real data indicates the success of the model in simulating the economic reality of Iran. Second, of the two variables related to the stock market namely, i.e. risk and return, the most volatility was due to systematic risk. Thirdly, the effects of capital expenditure shock on the risk and returns of companies can be indirectly analyzed through other important economic variables. Hence, based on the above results, since capital spending as part of government expenditure is influenced by financial variables, especially stock returns, and because government expenditure variations are also a tool for imposing fiscal policy, the finding of the present study are consistent with the observations made by other researchers (e.g., Da et al., 2018; Dissanayake, 2016, Foresti & Napolitano, 2016; Aigheyisi & Edore, 2014; Belo et al., 2013).

It active investors in the capital market are suggested to be aware of the effects of capital expenditure shocks on risk and stock return and do not consider the sudden fluctuations in stock returns as the only criterion for assessing the profitability and choosing new stocks. Besides, as the effects of capital expenditure shocks can vary from industry to industry, investors are advised to pay attention to industry type in their portfolios when investing in the stock market.

Finally, we faced a number of limitations in conducting the present study, most notably the high complexity of modelling, which is due to the differences in the economic structure of Iran due to the high influence of the government on business and firms, which in turn impedes the application of models used in other countries.

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Appendix:

Log-linearized System

Some expected linear differential equations systems are summarized as follows:

1. Total consumption components:

$\hat{c}_t^m = \hat{c}_t - \eta_c \hat{\gamma}_t^{mc}$

$\hat{\gamma}_t^{mc} = \hat{\pi}_t^m - \hat{\pi}_t^c + \hat{\gamma}_{t-1}^{mc}$

$\hat{c}_t^d = \hat{c}_t - \eta_c \hat{\gamma}_t^{dc}$

$\hat{\gamma}_t^{dc} = \hat{\pi}_t^d - \hat{\pi}_t^c + \hat{\gamma}_{t-1}^{dc}$

2. Prices index:

$\hat{\pi}_t^c = \xi_c \left(\bar{\gamma}^{dc}\right)^{1-\eta_c} \hat{\pi}_t^d + (1-\xi_c)(\bar{\gamma}^{mc})^{1-\eta_c} \hat{\pi}_t^m$

3. Consumption Euler equation:

$$\hat{c}_t = \frac{h}{1+h}\hat{c}_{t-1} + \frac{1}{1+h}E_t\hat{c}_{t+1} - \frac{1-h}{\sigma_c(1+h)}\left(\hat{r}_t^d - \hat{\pi}_{t+1}^c\right)$$

4. Capital accumulation:

$\hat{k}_t = (1-\delta)\hat{k}_{t-1} + \delta \hat{\imath}_t$

5. Capital cost dynamic equation:

$$\hat{q}_t = \frac{1-\delta}{1-\delta+\bar{R}^k}\hat{q}_{t+1} + \frac{1-\bar{R}^k}{1-\delta+\bar{R}^k}\hat{R}_{t+1}^k - \left(\hat{r}_t^d - \hat{\pi}_{t+1}^c\right)$$

In the long run equilibrium due to zero inflation rate, $\bar{R}^k$ is equal to $\bar{R}^k = \beta^{-1} + \delta$.

6. Investment equation:

$$\hat{\imath}_t = \frac{1}{1+\beta}\hat{\imath}_{t-1} + \frac{\beta}{1+\beta}E_t\hat{\imath}_{t+1} + \frac{1}{\varphi(1+\beta)}\hat{q}_t$$

Where $S''(1) = \varphi$ is elasticity of Investment adjustment cost function.

7. Money demand equation:

$$\sigma_m . \hat{m}_t^c = \sigma_c[\hat{c}_t - h\hat{c}_{t-1}] - \frac{\hat{r}_t^d}{\bar{r}^d}$$

8. Stock market equation:

$\hat{\gamma}_t^{sc} = \frac{1}{1+\bar{r}^d}\hat{\gamma}_{t+1}^{sc} + \frac{\bar{r}^d}{1+\bar{r}^d}\widehat{dv}_{t+1} - \hat{r}_t^d + \hat{\pi}_{t+1}^c + \varepsilon_t^s$

$\hat{\gamma}_t^{sc} = \hat{\pi}_t^s - \hat{\pi}_t^c + \hat{\gamma}_{t-1}^{sc}$

$\hat{\beta}_t^{rs} = \hat{\pi}_t^s - \hat{\pi}_{t-1}^s - \hat{\pi}_t^m + \hat{\pi}_{t-1}^m$

9. Real wage equation:

$$\hat{w}_t = \sigma_l \hat{l}_t + \frac{\sigma_c}{1-h}(\hat{c}_t - h\hat{c}_{t-1}) + \hat{\varepsilon}_t^l$$

10. Economic production function:

$\hat{y}_t = \hat{a}_t + \alpha\hat{k}_{t-1} + \alpha\psi\hat{R}_t^K + (1-\alpha)\hat{l}_t$

11. Productivity Process of Production factor:

$\hat{a}_t = \rho_a \hat{a}_{t-1} + u_t^a$

12. Labor demand equation: $\hat{l}_t = -\hat{w}_t + \hat{R}_t^K + \hat{k}_{t-1}$

13. Philips Curve:

$$\hat{\pi}_t^d = \frac{\beta}{1+\beta\tau_p} E_t\hat{\pi}_{t+1}^d + \frac{\tau_p}{1+\beta\tau_p}\hat{\pi}_{t-1}^d + \frac{1}{1+\beta\tau_p} . \frac{(1-\theta_P)(1-\beta\theta_P)}{\theta_P}\widehat{mc}_t$$

14. Production marginal cost:

$$\widehat{mc}_t = \hat{w}_t + \hat{l}_t - \hat{y}_t$$

15. Philips Curve of consumption Imports:

For simplicity, we assume $\pi_t^{m_c} = \pi_t^{m_I}$, so we have an equation of imports Philips curve:

$$\hat{\pi}_t^m = \frac{\beta}{1+\beta\tau_m} + \frac{\tau_m}{1+\beta\tau_m}\hat{\pi}_{t-1}^m + \frac{1}{1+\beta\tau_m} . \frac{(1-\theta_m)(1-\beta\theta_m)}{\theta_m}\widehat{mc}_t^m$$

16. Imports marginal cost:

$$\widehat{mc}_t^m = \widehat{rer}_t - \hat{\gamma}_t^{mc}$$

$$\hat{\gamma}_t^{mc} = \hat{\pi}_t^m - \hat{\pi}_t^c + \hat{\gamma}_{t-1}^{mc}$$

17. Real exchange rate:

$$\widehat{rer}_t = \hat{\delta}_t^{EX} + \hat{\pi}_t^* \text{-} \hat{\pi}_t^c + \widehat{rer}_{t-1}$$

18. Demand for non-oil exports:

$$\hat{x}_t = \hat{y}_t^* - \eta^* \hat{\gamma}_t^{e^*} + \eta_y \hat{y}_t$$

$$\hat{\gamma}_t^{e^*} = \hat{\pi}_t^e - \hat{\pi}_t^* + \hat{\gamma}_{t-1}^{e^*}$$

$$\hat{\pi}_t^e = \hat{\pi}_t^d - \hat{\delta}_t^{EX}$$

19. Government Expenditure:

$$\bar{g}\hat{g}_t = \bar{c}^g \hat{c}_t^g + \bar{I}^g \hat{I}_t^g$$

$$\varepsilon_t^{cg} = \rho_{cg}\varepsilon_{t-1}^{cg} + u_t^{cg} \qquad u_t^{cg} \sim N(0, \sigma_{cg}^2)$$

$$\varepsilon_t^{Ig} = \rho_{Ig}\varepsilon_{t-1}^{Ig} + u_t^{Ig} \qquad u_t^{Ig} \sim N(0, \sigma_{Ig}^2)$$

$$\varepsilon_t^{o} = \rho_{o}\varepsilon_{t-1}^{o} + u_t^{o} \qquad u_t^{o} \sim N(0, \sigma_{o}^2)$$

20. The monetary policy response function:

$$\hat{\Theta}_t = \rho_\Theta \hat{\Theta}_{t-1} + \theta_\pi \hat{\pi}_t^c + \theta_y \hat{y}_t + \theta_{rer}\widehat{rer}_t + \theta_{sc}\hat{\pi}_t^s + \varepsilon_t^\Theta$$

$$\hat{\Theta}_t = \hat{m}_t^c - \hat{m}_{t-1}^c + \hat{\pi}_t^c$$

$$\varepsilon_t^\Theta = \rho_\Theta \varepsilon_{t-1}^\Theta + u_t^\Theta \qquad u_t^\Theta \sim N(0, \sigma_\Theta^2)$$

21. Market clearing:

$$\hat{y}_t = \bar{c}\hat{c}_t + \bar{\imath}\hat{\imath}_t + \bar{g}\hat{g}_t + \frac{\bar{o} \times \overline{rer}}{\bar{y}}(\widehat{rer}_t + \hat{o}_t) + \frac{\bar{o} \times \overline{rer} \times \bar{\gamma}^{e^*}}{\bar{y}}(\widehat{rer}_t + \hat{x}_t + \hat{\gamma}_t^{e^*}) - \frac{(\bar{\imath}^{im} + \bar{c}^{im})\bar{\gamma}^{imc}}{\bar{y}}(\hat{c}_t^{imc} + \hat{\imath}_t^{imc} + \hat{\gamma}_t^{imc})$$

22. Total Production:

$$\hat{y}_t = \alpha_\mu^{\frac{1}{\mu_o}} \left(\frac{\bar{Y}^o}{\bar{Y}}\right)^{\frac{\mu_o - 1}{\mu_o}} \hat{y}_t^o + (1-\alpha_\mu)^{\frac{1}{\mu_o}} \left(\frac{\bar{Y}^o}{\bar{Y}}\right)^{\frac{\mu_o - 1}{\mu_o}} \hat{y}_t^{no}$$

23. Oil production: $\hat{y}_t^o = \widehat{rer}_t + \hat{o}_t - \hat{\gamma}_t^{dc}$