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Original Research Article

Analysis of the Impact of Alternative Method of Financing the Government Budget Deficit through Issuing Treasury Bills on Economic Variables: DSGE Approach

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Financing the government's budget deficit has conventionally taken place in the economy of Iran via borrowing from the Central Bank. However, bonds are the major way to finance the budget deficit in most countries, not admitted due to Shari'ah-compliant financial regulations in the legal system of the Iranian economy. Iranian economy intellectuals have presented an alternative source of funding termed Islamic treasury bills that differ from conventional bills. The present study is set to analyze the impact of Islamic treasury bills as a procedure for covering budget deficits on selected macroeconomic variables, including inflation, investment, gross domestic product, etc. The analysis was performed by applying the Dynamic Stochastic General Equilibrium (DSGE) model for the Iranian economy as an open economy, considering the Islamic treasury bills for reducing the government's budget shortfall. The results revealed that if the DSGE model is employed, the macroeconomic variables under the study will manifest a different and occasionally negative impact in a short-term period; however, in a long-term period, the issuance of treasury bills may positively affect mentioned variables.

Keywords: Islamic Treasury Bills, Budget Deficit, Macroeconomic Variables, Dynamic Stochastic General Equilibrium (DSGE) Model
JEL Classification*:* E12, E44, G32, H62

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1 Introduction

In the current Iranian political economy, financing government expenditures is a recurrent and vital issue, especially when facing a budget shortfall. The main reasons for the budget deficit in Iran are the size of the state, insufficient tax revenues, and fluctuations in oil revenues. The government's expenditure increases and is rapidly financed when oil revenues increase. However, when oil revenues decline, the budget reduction is not accepted from a social-policy perspective (Hajamini et al., 2016). There is no possibility of increasing tax pressure during a recession economy. Also, in underdeveloped and developing countries such as Iran, a large part of the construction and capital activities to build infrastructure is the public sector's responsibility, which must continue in the new conditions.

Various procedures exist to finance the budget deficit, an important of which is borrowing. There are three main methods for borrowing: 1) borrowing from the government body such as the Central Bank, 2) borrowing from foreign countries, and 3) borrowing from people. Borrowing from foreigners is not possibly an appropriate solution for Iran's economy due to foreign debts' repayment problems, the interest rate, and high insurance costs, and also sanctions. The major financing procedure for the budget deficit in Iran has been borrowing from the Central Bank, accompanied with an increase in money supply and inflation rate. The government may compensate for some part of its expenditures via raising money supply through borrowing from the Central Bank. However, increasing the money supply brings about inflation in the society (Nikioskoui et al., 2009).

Borrowing from the private sector and people is also a way to finance the budget deficit, temporarily. Most countries facing a budget deficit apply this method using bonds and treasury bills because of their usurious nature.

Thus, Islamic economics' scholars designed a new instrument for financing the budget deficit, which resembles the conventional treasury bills in terms of functionality; however, it has a different legal and jurisprudential nature, i.e. conventional treasury bills are based on usurious borrowing contracts, but Islamic treasury bills are based on debt purchase contracts. This instrument has been employed in The Iranian economy since 2014, and it has had an increasing share in financing the budget deficit. Accordingly, the current work set to evaluate the effect of this type of budget deficit financing on macroeconomic variables such as gross domestic product (GDP), inflation, consumption, investment, etc. The author sought to assess the effect of the

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government's use of Islamic treasury bills on macroeconomic variables via (DSGE) modeling.

2 Literature Review

2.1 Theoretical Foundations

The evaluation of the government finances in Iran indicates that the budget has been encountering a deficit throughout the years. Figure 1 displays the revenue gap or surplus compared to the total budget. It is depicted that from 1965 to 2021, except for 1994, 1995, 1996, and 2001, there existed an imbalance in other years, the amount of which is so significant in some years; for instance, nearly half of the expenditures faced negative numbers in 1986 and 1988.

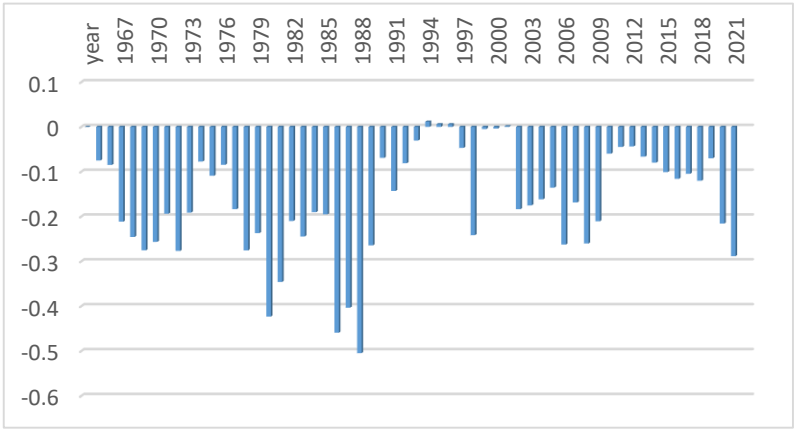

Figure 1. The budget deficit or surplus in comparison with the total budget
Source: Time series of the Central Bank. www.tsd.cbi.ir

Conventional economies have defined different methods for financing the budget hole, such as external and domestic debt. Moreover, each method owns some privileges and shortcomings, each of which can be chosen based on the current status (Khademolhosseini & Mousavian, 2012). Borrowing from foreigners does not appear to be a good solution for Iran's economy because of the problems of repaying foreign debts with high-interest rates, insurance, and sanctions. The main way to finance the budget shortage in Iran is to borrow from the Central Bank, which leads to increase money supply and

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inflation. In this case, the government has taken a surreptitious tax from the people, and there has been a kind of overlap and integration between monetary and fiscal policy (Nikioskoui et al., 2009).

Debt from the people or the private sector is applied in numerous countries to finance the budget deficit via issuing bonds. However, it is forbidden in the Iranian economy because of being usurious. Since 2014, an instrument called an Islamic treasury bill has been announced as compliant with the Shari'ah jurisprudence. Since then, the government has used the Islamic treasury bills to finance the overrun, and its share in paying for the budget overrun has been augmenting annually. However, it is still covering an insignificant share of the burden. Table 1 represents the treasury bills' issuance in the budget from 2015 to 2022, along with other relevant sectors.

Table 1
Treasury bills in the budget of 2015-2022, Iran (million Rials)

Year	Net sales of Islamic treasury bills	Sale and transfer of all types of Islamic Shari'ah financial bills	Transfer of financial assets	Total budget resources
2015	50,000,000	110,000,000	311,833,537	2,243,613,651
2016	75,000,000	275,000,000	453,194,000	3,354,895,145
2017	75,000,000	345,000,002	537,440,002	3,988,531,335
2018	95,000,000	385,000,000	680,850,923	4,249,110,891
2019	130,000,000	440,000,000	510,000,000	4,786,263,828
2020	200,000,000	800,000,000	1,247,000,000	5,638,293,049
2021	500,000,000	1,325,000,000	4,274,749,585	13,737,699,268
2022	360,000,000	1,030,000,000	1,767,899,999	15,273,716,613

Source: 2015-2022 budgets

The following paragraphs introduce and analyze the Islamic treasury bills used for financing the budget deficit.

2.1.1 Islamic Treasury Bills

Among the valuable tools for effectively managing government debt issuance in most countries and delaying the cash settlement of debt when public resources are limited is the issuance of Government Treasury Bills (Dupont & Brian, 1999). These bonds are settled at maturity either by potential revenue or by issuing Treasury bills with new maturities. This type of loan, especially when facing severe financial downturns, allows the governmental body to defer its debt to boom times and redirect its available resources to other areas to reduce vulnerability and facilitate growth (Kubitschch et al., 2013).

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The Islamic economy intellectuals have designed an alternative instrument, i.e., treasury bills that are permissible from the Shari'ah and legal perspective for financing the budget shortfall, considering the budget deficit of Iran's government and the fact that funding the budget gap via debt from the Central Bank has many drawbacks, such as increased liquidity and inflation and the fact that treasury bills cannot be conventionally generalized to the Islamic financial system if they are usurious government bonds (Khademolhoseini & Mousavian, 2012).

Islamic Treasury bills are securities based on the purchase of debt. Debt refers to any general property that one person demands from another. Assuming that the debt has a correct religious basis and the debt is registered and not formal, according to the fatwas of most Shiite jurists like Ayatollah Boroujerdi, Ayatollah Sistani, Ayatollah MakaremShirazi, etc., the creditor can pay all or part of the debt to sell to a third party for less than the face value. With the sale of the debt, the ownership of the debt is transferred to the non-creditor, and the new owner can resell the debt. Therefore, Islamic Treasury bills are a financial instrument based on the country's registered debt to the banking system, stakeholders, and resource providers and are issued by the Ministry of Finance Treasury. (Khademolhoseini & Mousavian, 2012)

The issuance process is such that the first allocation of Treasury bills is fixed in the Treasury of the Ministry of Economy. This amount is allocated to government's creditors, private contractors, commercial banks, and private, and public entities in the primary market. When the creditors need funds, they can sell these bonds in the secondary market to individuals and legal entities as investors who buy to benefit from the discount of the bonds. At the maturity of the Islamic Treasury bills, the government is obliged to refund the cash amount and the face value of the bonds to the creditors who kept the bonds until maturity and to the individuals and legal entities who bought the bonds at a fraction of the face value in the secondary market (Sadraei et al., 2020).

Concerning the probable impacts of issuance of Islamic treasury bills on macroeconomic variables, there will not be an increase in inflation rate, as such, since the monetary base and liquidity will not rise through this way. Moreover, since the resources obtained through Islamic treasury bills may settle the debts of the government creditors, such as the government projects' contractors, the contractors may also access cash resources via the discount and sale of these bills in the secondary market, the re-injection of which increases the implementation of new contract plans. Therefore, private sector investment rises and economic growth is promoted (Sadraei et al., 2020). However, increasing the supply of Islamic treasury bills in the secondary

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market may augment the discount rate in the secondary market, resulting in an investment decline, hence, negatively affecting the economic growth. The mere impact of the issuance of Islamic treasury bills is of interest regarding economic growth. Large scale issuance of these bonds may bring about Ponzi scheme and financial crisis in the government. Thus, there is no unity of opinions with regard to the economic influences of Islamic treasury bills. Accordingly, the present article aims to identify the impacts of issuance of Islamic treasury bills on economic variables against economic shocks.

2.2 Research Background

The following reviews the studies on the budget deficit, financing methods for the budget deficit, and the Islamic treasury bills. The studies assessing the government budget deficit have primarily evaluated the impact of the government budget deficit on economic variables. Sill (2005) evaluated the association of inflation and budget deficit in different statuses from 1950 to 2002 and whether the budget deficit causes inflation or not. Accordingly, in the case of debt from the Central Bank, the budget deficit induces inflation. He also revealed a weak correlation between the budget deficit and inflation in the American economy. However, this relationship is stronger in developing countries. Komijani and Varhrami (2012) using the OLS method for 1979 to 2008 data concluded that there was a negative relationship between oil revenue, tax revenue and economic growth on budget deficit and a positive impact of subsidies and general government expenditure on budget deficit. Samsami et al. (2014) using simultaneous equations method and time series data from 1978 to 2009 concluded that financing the budget by increasing exchange rate in comparison with borrowing from the Central Bank has resulted in further reduction in output and has had more inflationary effects. Khrawish et al. (2012), using co-integration method and vector error correction model between 1992 and 2010 in Greece, concluded that there was a long-run positive significant relationship between real money demand and real budget deficit. Hossinipour (2018) used the Granger causality test in his study and found that money supply causes inflation and budget deficit, and the ongoing increase of the budget deficit results in more money supply, leading to the arising of inflation. Tayebi et al. (2019) applied the matching approach and reported that globalization increases the budget deficit, one of the causes of which is compelling the governments to decrease taxes, such as capital gains tax. Kopeledi (2020) carried out a long-term study of triple deficits of the budget deficit, current account deficit, and savings gap through conducting co-integration tests and yearly data of 1996-2018,

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finding a positive significant correlation between the budget deficit and the current account deficit and also a negative negligible correlation between the savings gap and the budget deficit in the long run. Montazeri et al. (2021) assessed the causal relationship between the inflation and government budget deficit in Iran's economy by the Granger causality and revealed a one-way causal relationship between the government budget deficit and inflation rate.

Until now, the studies that have been conducted in the field of Islamic Treasury bills and other Islamic bonds are mostly related to the nature of these instruments and the related issues regarding the legal and juridical aspects, secondary market transactions and the functions of these bonds. Mousavian et al. (2012) stated that due to the prohibition of usury in Islam, conventional Treasury bills are not valid in the Islamic financial system, and only when the issuance of Islamic Treasury bills to pay government debt to banks, companies and private and public institutions is due to the purchase of real goods and services, their purchase and sale is allowed according to the views of the most Islamic religions and Iranian law. Hajidolabi (2018) addressed the need to develop the debt market in the Iranian economy and state the requirements for this development based on the experiences of developed and successful countries in this field. Sadraei et al. (2020) using the DSGE model and Iranian economic data from 1990 to 2017, investigated the index of financial stability (debt to output ratio) at the time of issuance of Islamic Treasury bills. They concluded that in a situation where the government used Islamic Treasury bills along with other debt securities, the long-run financial stability index in times of productivity shocks, monetary shocks and oil shocks showed the financial instability of the government budget and in times of private sector investment shocks, currency shocks, and civil and consumption expenditure shocks showed budget stability. Srebrny (2021) studied the correlation between bonds rate and budget deficits by panel regression using the data of 31 European countries from 1990 to 2019, demonstrating that a higher budget deficit reduces bond yields merely due to more government investment. Hadian and Dargahi (2021) evaluated the macroeconomic impacts of the current and construction expenditures of the government and its financing approach in Iran using the DSGE model and concluded that the construction expenditures of the government versus its consumption expenditures has lower inflationary effects and higher production growth. Furthermore, increasing the contribution of issuing bonds for financing the government expenditures may decrease the inflation fluctuations and improve production.

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No study has ever been performed on the influence of issuing Islamic treasury bills on macroeconomic variables, including production, inflation, consumption, investment, etc. The current study is the first that evaluates the impact of budget deficit financing through issuing Islamic treasury bills on economic variables.

3 Design of a Dynamic Stochastic General Equilibrium Model

This paper, using the framework of the New Keynesian model for an open economy, studies the impact of Islamic Treasury bills issuance on the Iranian economy. The main framework of the DSGE model of this study is the articles of Gelain and Kulikov (2009) for the household sector and Escude (2012) for the government and the Central Bank. Accordingly, the model has five general sections: Households, Firms, Government and Central Bank, the foreign sector and oil sector. The foreign sector enters the model through the government and households as consumers of imported goods and through firms as exporters of some of the products. In the Iranian economy, the Central Bank acts in correspondence with government policies.

The DSGE model has limitations as any other model in economics, which are caused by the method assumptions, including the assumption of rational expectations in the model; however, rational expectations are occasionally violated in reality and complying with financial and behavioral economics. The present study also suffers from some limiting assumptions, such as the way Islamic treasury bills resources can be used. Applying Islamic treasury bills is based on the assumption that financial resources gained from Islamic treasury bills should only be employed for economic projects and entrepreneurial corporations and real debts should be covered by these resources. Nevertheless, the government may use these resources for other purposes such as current payments, which is in contrary to the objectives of Islamic treasury bills.

3.1 Households

The household seeks to maximize its discounted expected utility. This utility is directly related to the consumption of goods (domestic and imported) and money balances and inversely related to the supply of labor; in a way that gains utility through consumption of goods and increase in stock and loses utility through labor. How money enters the utility function follows the MIU model, and money enters the utility function directly. The economy is assumed to comprise the same households that live indefinitely and use a

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domestic and foreign consumption and investment goods basket with a constant elasticity of substitution (CES).

The discounted utility function of the household in this model is defined as follows, and the household seeks to maximize this utility function:

$$U. = E_t \sum_{t=.}^{\infty} \beta^t \left\{ \frac{1}{1-\delta_c} (C_t)^{1-\delta_c} - \frac{\varphi}{1+\delta_N} (N_t)^{1+\delta_N} + \frac{\kappa_M}{1-\delta_m} (m_t)^{1-\delta_m} \right\} \quad (1)$$

Utility function (1) states that in period t, the household sector tries to make optimal decisions in terms of consumption (C_t), labor supply (N_t), and the amount of money actually available (m_t). $\delta_c \succ 0$ is the inverse elasticity of inter-temporal consumption, $\delta_N \succ 0$ is the inverse elasticity of labor supply, $\delta_m \succ 0$ is the inverse elasticity of demand for money, and κ_M is the preference coefficient of real money left over.

On the other hand, the real budget inter-temporal of the household sector is as follows:

$$C_t + \frac{P_t^I I_t}{P_t} + \frac{M_t}{P_t} + \frac{B_t}{P_t} + T_t = \frac{W_t N_t}{P_t} + \frac{M_{t-1}}{\pi_t} + \frac{R_{t-1}^b B_{t-1}}{P_t} + R_t u_t K_{t-1} - \psi(u_t) K_{t-1} + \frac{D_t}{P_t} + \frac{TA_t}{P_t} \quad (2)$$

Where households are assumed to sell their labor power, N_t, and lease the capital stock that accrued to them from the previous period, i.e., K_{t-1}, in each period t. $w_t$and $r_t$are real wages and rental rates. After paying taxes and receiving interest on Treasury bonds from the previous period, households consume and invest this leftover and also form their own portfolio of financial assets, which includes the monetary balance and the government's Treasury bills.

In this formula, I_t is the amount of direct investment expenditures in the production sector during the current period, T_t represents the household's tax expenditure in the current period, K_t represents the capital stock in the current period at the interest rate r_t^k, B_t stands for the demand for Treasury bills at the interest rate r_t^b, and $R_{t-1}^b = (1 + r_t^b)$ represents the Treasury's capital and interest, W_t is the wage rate of labor, and P_t is the price index. The household is also subject to capital constraints as follows:

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$$K_t = (1-\delta)K_{t-1} + [1 - s\left(\frac{I_t}{I_{t-1}}\right)]I_t \quad (3)$$

Where δ is the depreciation rate of fixed capital and $s\left(\frac{I_t}{I_{t-1}}\right)$ is a function of the capital adjustment cost.

The household seeks to maximize its utility function over time according to Constraints (2) and (3), which is shown in Equation 4.

$$\mathcal{L}_t = E_t \sum_{t=}^{\infty}. \beta^t \left\{\frac{1}{1-\delta_c}(C_t)^{1-\delta_c} - \frac{\varphi}{1-\delta_N}(N_t)^{1+\delta_N} + \frac{\kappa_M}{1+\delta_M}(M_t)^{1+\delta_M}\right\} -$$
$$\lambda_t\left(C_t + \frac{P_t^I I_t}{P_t} + \frac{M_t}{P_t} + \frac{B_t}{P_t} + T_t - \frac{W_t N_t}{P_t} - \frac{M_{t-1}}{\pi_t} - \frac{R_{t-1}^b B_{t-1}}{P_t} - R_t u_t K_{t-1} +\right.$$
$$\left.\psi(u_t)K_{t-1} - \frac{D_t}{P_t} - \frac{TA_t}{P_t}\right) - u_t(K_t - (1-\delta)K_{t-1} - \left[1 - s\left(\frac{I_t}{I_{t-1}}\right)\right]I_t \quad (4)$$

According to the above optimization problem, the first-order conditions for the decision variables of the household, i.e., C_t, N_t, M_t, K_t, and B_t, can be obtained, leading to the following equations:

$$W_t = \frac{\varphi N_t^{\sigma_N}}{C_t^{-\sigma_c}} \quad (5)$$

$$\lambda_t(m_t)^{\sigma_m} = \frac{r_t^b}{1+r_t^b} C_t^{-\sigma_c} \quad (6)$$

$$C_t^{-\sigma_c} = (1 - r_t^b)\beta E_t\left(\frac{C_{t-1}^{-\sigma_c}}{\pi_{t+1}}\right) \quad (7)$$

$$P_t^i = q_t\left[1 - s\left(\frac{I_t}{I_{t-1}}\right) - S'\left(\frac{I_t}{I_{t-1}}\right)\left(\frac{I_t}{I_{t-1}}\right)\right]\beta E_t q_{t+1}\varepsilon_{t+1}^i S'\left(\frac{I_t}{I_{t-1}}\right)\left(\frac{I_t}{I_{t-1}}\right)^2 \quad (8)$$

$$q_t = \beta E_t \frac{\lambda_{t+1}}{\lambda_t}[q_{t+1}(1-\delta) + u_{t+1}R_{t+1} - \psi(u_{t+1})] \quad (9)$$

In the above equations, $\lambda_t$is the Lagrange coefficient corresponding to the budget constraint in period *t* and u_t is the Lagrange coefficient corresponding to the investment constraint.

Equation 5 is labor supply, Equation 6 is real money demand, Equation 7 is the Euler equation of consumption, Equation 8 is the Euler equation of investment, and Equation 9 is the dynamic equation of capital pricing, in which $q_t = \frac{\lambda_t}{Q_t}$ is the ratio of the market value of a unit of capital to the replacement value of a unit of capital.

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3.2 Domestic and Imported Consumption

As explained in the previous section, since the model is designed for an open economy and there are exports and imports in this economy, consumption of goods also consists of two parts: domestically produced goods and imported goods. Accordingly, the household consumption index is expressed as follows:

$$C_t = [\gamma_c^{\frac{1}{\upsilon_c}}\left(C_{H,t}\right)^{\frac{\upsilon_c-1}{\upsilon_c}} + (1-\gamma_c)^{\frac{1}{\upsilon_c}}\left(C_{F,t}\right)^{\frac{\upsilon_c-1}{\upsilon_c}}]^{\frac{\upsilon_c}{\upsilon_c-1}} \quad (10)$$

Where $C_{H,t}$ is the consumption index of domestic goods, $C_{F,t}$ is the consumption index of foreign goods, $\gamma_c$is the share of domestic goods in the household consumption index, and $\upsilon_c > 0$ is the elasticity of substitution between domestic and foreign goods. Equation 10 shows that the consumption index is a linear combination of domestic and foreign goods whose share in current household consumption is a function of the elasticity of substitution (υ_c) and the share of goods (γ_c).

Household final consumption expenditure consists of total final consumption expenditure on domestically produced goods and final consumption expenditure on imported goods. As a result:

$$P_t C_t = P_t^H C_{H,t} + P_t^F\ C_{F,t} \quad (11)$$

$$P_t^F = S_t P_t^* \quad (12)$$

Where $P_t^H$is the price index for domestic goods and P_t^F is the price index for imported goods, defined as Equation 12. S_t is the exchange rate and P_t^* is the price index for foreign goods, and P_t is the price index for consumer goods. To choose a combination of domestic and imported goods, the household minimizes the cost of its basket of goods relative to the consumption constraint in Equation 10:

$$\text{Min } P_t C_t = P_t^H C_{H,t} + P_t^F\ C_{F,t}$$

$$\text{s.t} \quad C_t = [\gamma_c^{\frac{1}{\upsilon_c}}\left(C_{H,t}\right)^{\frac{\upsilon_c-1}{\upsilon_c}} + (1-\gamma_c)^{\frac{1}{\upsilon_c}}\left(C_{F,t}\right)^{\frac{\upsilon_c-1}{\upsilon_c}}]^{\frac{\upsilon_c}{\upsilon_c-1}}$$

$$P_t C_t - P_t^H C_{H,t} + P_t^F\ C_{F,t} = 0$$

$$P_t[\gamma_c^{\frac{1}{\upsilon_c}}\left(C_{H,t}\right)^{\frac{\upsilon_c-1}{\upsilon_c}} + (1-\gamma_c)^{\frac{1}{\upsilon_c}}\left(C_{F,t}\right)^{\frac{\upsilon_c-1}{\upsilon_c}}]^{\frac{\upsilon_c}{\upsilon_c-1}} - P_t^H C_{H,t} + P_t^F\ C_{F,t} = 0$$

By deriving $C_{H,t}$ and $C_{F,t}$, the level of domestic and imported consumption can be shown in terms of domestic and foreign prices and the overall price index.

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$$C_t^H = \gamma_c C_t (\frac{P_t^H}{P_t})^{-\upsilon_c} = \gamma_c (\eta_t^H)^{-\upsilon_c} \; C_t \quad (13)$$

$$C_t^F = (1-\gamma)_c C_t (\frac{P_t^F}{P_t})^{-\upsilon_c} = (1-\gamma_c)(\eta_t^F)^{-\upsilon_c} \; C_t \quad (14)$$

$$\eta_t^H = \frac{P_t^H}{P_t} \quad (15)$$

$$\eta_t^F = \frac{P_t^F}{P_t} = \frac{S_t P_t^*}{P_t} = e_t \quad (16)$$

Equation 15 is the relative domestic price and Equation 16 is the relative import price.

Inserting Equations 13 and 14 into Equation 10 gives the consumer price index.

$$P_t = [\gamma_c (P_t^H)^{1-\upsilon_c} + (1-\gamma_c)(P_t^F)^{1-\upsilon_c}]^{\frac{1}{1-\upsilon_c}} \quad (17)$$

Like consumption, the decision of households to invest in each period is a function of domestic and imported capital goods.

3.3 Firms

It is assumed that there is a final good firm in the economy that buys Y_t^J units from the output of monopolistic competition firms producing intermediate goods j∈ [0.1] at the price of P_t^J to produce Y_t final goods using the productivity with constant returns on the following scale:

$$Y_t = \int_0^1 [Y_t^{j\frac{1}{1+\theta_t^p}} dj]^{1+\theta_t^p} \quad (18)$$

Where θ_t^p is the random shock of the mark-up price producer following the below AR(1) process.

$$\text{Log}\,\theta_t^p - \theta^p = \rho_p \left(Log\theta_t^p - \theta^p\right) + u_t^p \qquad u_t^p \sim i,i,d.N\left(0,\sigma_p^2\right) \quad (19)$$

The final producer's objective is to maximize their profit.

$$\max \int_0^1 P_t^J \, Y_t^J dj - P_t^H (\int_0^1 Y_t^{j\frac{1}{1+\theta_t^p}} dj)^{1+\theta_t^p} \quad (20)$$

Thus, the demand function for j^{th} intermediate goods is as follows:

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$$Y_t^J = \left(\frac{P_t^J}{P_t^H}\right)^{-\frac{1+\theta_t^p}{\theta_t^p}} \tag{21}$$

Inserting Equation21 into Equation 19 and simplifying it, the price index for domestically produced goods is obtained as follows.

$$P_t^H = \left[\int_0^1 \left(P_t^J\right)^{-\frac{1}{\theta_t^p}}\right]^{-\theta_t^p} \tag{22}$$

The jth firm, the producer of intermediate goods in a monopolistic competitive market, employs its capital (K_{t-1}^j) as a function of Cobb-Douglas at the rental rate of capital R_t^K and labor L_t^j at the wage w_t of the intermediate goods unit.

$$Y_t^{no^j} = A_t\left(K_{t-1}^j\right)^{\alpha}(kg_{t-1})^{\chi}{L_t^j}^{1-\alpha} - \Phi^j \tag{23}$$

Where $\alpha(0,1)$ determines the share of capital in output, Φ^j is the fixed cost, kg_{t-1} is the volume of public capital, and χ determines the impact of the volume of public capital on the output of private goods. A_t is the efficiency shock assumed to follow an AR(1) process, as follows.

$$\text{Log}\,(A_t) = \rho_a \log(A_{t-1}) + u_t^a \qquad u_t^a \sim i,i,d.N(0,\sigma_u^2) \tag{24}$$

The objective of the producer of intermediate goods is to minimize costs relative to their production function. Therefore, the Lagrangian function and the first-order optimization conditions are as follows:

$$X_t = w_t(l_t) + R_t K_{t-1} + \emptyset_t\left[Y_t^{no^j} - A_t\left(K_{t-1}^j\right)^{\alpha}(kg_{t-1})^{\chi}{L_t^j}^{1-\alpha} + \Phi^j\right] \tag{25}$$

$$\left(\frac{\partial X_t}{\partial K_{t-1}^j}\right) = 0 \;\rightarrow w_t - \emptyset_t A_t(\alpha)\left(K_{t-1}^j\right)^{\alpha-1}(kg_{t-1})^{\chi}{L_t^j}^{1-\alpha} = 0 \tag{26}$$

$$\left(\frac{\partial X_t}{\partial l_{t-1}^j}\right) = 0 \;\rightarrow R_t - \emptyset_t A_t(1-\alpha)\left(K_{t-1}^j\right)^{\alpha}(kg_{t-1})^{\chi}{L_t^j}^{-\alpha} = 0 \tag{27}$$

$$\left(\frac{\partial X_t}{\partial \emptyset_t}\right) = 0 \;\rightarrow Y_t^{no^j} - A_t\left(K_{t-1}^j\right)^{\alpha}(kg_{t-1})^{\chi}{L_t^j}^{1-\alpha} + \Phi^j = 0 \tag{28}$$

Using the above equations and simplifying them, we have:

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$$l_t = \frac{1-\alpha}{\alpha}\frac{R_t}{W_t}\ K_{t-1} \tag{29}$$

$$mc_t = \frac{1}{A_t}\ \frac{\alpha^{-\alpha}}{(1-\alpha)^{\alpha-1}}\frac{R_t^{\alpha}}{W_t^{\alpha-1}} Kg_{t-1}^{-\chi} \tag{30}$$

Equations 35 and 36 show the final cost of production at constant prices and the function of labor demand, respectively.

Given the structure of the Iranian economy, price stickiness in the economy is assumed to be of the Calvo (1983) type, i.e. a random $(1-\omega)$ percent of firms are able to adjust their prices, while ω percent of firms are unable to adjust their prices. For the firms that are unable to optimize their prices, prices in that period are indexed to inflation in the previous period as follows.

$$P_t^j = (\pi_{t-1}^H)^{\tau_p} \tag{31}$$

Where $\pi_t^H = \frac{P_t^H}{P_{t-1}^H}$ is the internal inflation rate, and τ_p is the degree of adjustment relative to the previous period's inflation ($0 < \tau_p < 1$).

In each period, the intermediate producer maximizes its expected discounted profits relative to a sequence of the final producer's demand function for intermediate goods demand function. Firm profits are collected and returned to households as shareholders in the form of discounted profits. In this equation, mu_{t+k} is the final utility of household income and mc_{t+k} is the final cost of the household.

$$\max E_t\ \sum_{k=0}^{\infty}(\beta\omega)^k \frac{mu_{t+k}}{mu_t}[\prod_{s=1}^{k}(\pi_{t+s-1}^H)^{\tau_p}\frac{P_t^j}{P_{t+k}^H} - mc_{t+k}]Y_{t+k}^j \tag{32}$$

Equation 32 is maximized according to the following demand constraint function:

$$Y_{t+k}^j = (\prod_{s=1}^{k}(\pi_{t+s-1}^H)^{\tau_p}\frac{P_t^j}{P_{t+k}^H})\frac{1-\theta_{t+k}^p}{\theta_t^p}Y_{t+k} \tag{33}$$

Given that in each period, ω percent of firms optimize their price using Equation 32 and the remaining $(1-\omega)$ percent optimize their price ($P_t^{H^*}$) using Equation 31, thus Equation 22 can be formulated as follows:

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$$P_t^H = [\omega((\pi_{t-1}^H)^{\tau_p} P_{t-1}^H)^{\frac{1}{1-\theta_t^p}} + (1-\omega)(P_t^{H^*})^{\frac{1}{1-\theta_t^p}}]^{1-\theta_t^p} \quad (34)$$

Defining the relative domestic price as $p_t^{H^*} = \frac{P_t^{H^*}}{P_t}$, the first-order condition of the problem can be expressed as follows:

$$\frac{P_t^{H^*}}{P_t^H} = \frac{\left(E_t \sum_{k=0}^{\infty} (\beta\omega)^k \frac{mu_{t+k}}{mu_t} \left(\frac{1+\theta_{t+k}^p}{\theta_{t+k}^p}\right) \left(\prod_{s=1}^{k} \frac{(\pi_{t+s-1}^H)^{\tau_p}}{\pi_{t+s}^H}\right) \left(\frac{1+\theta_{t+k}^p}{\theta_{t+k}^p}\right) mc_{t+k} Y_{t+k} \right)}{\left(E_t \sum_{k=0}^{\infty} (\beta\omega)^k \frac{mu_{t+k}}{mu_t} \left(\frac{1+\theta_{t+k}^p}{\theta_{t+k}^p}\right) \left(\prod_{s=0}^{k} \frac{(\pi_{t+s-1}^H)^{\tau_p}}{\pi_{t+s}^H}\right) \left(\frac{1+\theta_{t+k}^p}{\theta_{t+k}^p - 1}\right) Y_{t+k} \right)} \quad (35)$$

Solving the problem and applying Equation 34, the New-Keynesian Phillips Curve is obtained in terms of the following linear logarithm:

$$\pi_t^H = \frac{\beta}{1+\beta\tau_p} E_t \pi_{t+1}^H + \frac{\tau_p}{1+\beta\tau_p} \pi_{t-1}^H + \frac{(1-\omega)(1-\omega\beta)}{\omega(1+\beta\tau_p)} \left(mc_t + \theta_t^p\right) \quad (36)$$

3.4 Oil Sector

Given the nature of Iran's economy based on the existence of revenues from crude oil production, the inclusion of the oil sector in the model to consider the shocks of this sector seems necessary. Oil in terms of domestic currency can be shown in the following relation:

$$XO_t = S_t * P_t^o * Y_t^o \quad (37)$$

Where P_t^o is the price oil, Y_t^o is oil production and S_t is the exchange rate. Oil prices and production follow the AR (1) process as follows.

$$\log P_t^o = \rho_{po} log P_{t-1}^o + u_t^{po} \quad (38)$$

$$\log Y_t^o = \rho_{yo} log Y_{t-1}^o + u_t^{yo} \quad (39)$$

3.5 Government and Central Bank

The Central Bank in Iran is not independent of the government. So, they cannot be modeled in two separate parts. It is assumed that the government's goal is to keep its budget balanced, and that the Central Bank helps the government to do this by maintaining price stability and increasing economic growth. The government seeks to offset its recurrent and civil expenditures

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through tax revenues and the sale of treasury bills and oil revenues. When the budget is balanced, the central bank can conduct its monetary policy without budget restrictions. However, if there is a deficit despite these three sources of revenue, the government finances it by borrowing money from the central bank or withdrawing its deposits from the central bank, which means money creation, and that means financial domination. It is worth noting that the sale of foreign exchange from oil revenues to the central bank appears as a change in foreign reserves. Mathematically, the government's budget constraint consists of the three balances of net operating, net acquisition of non-financial assets, and net financial worth as follows:

$$T_t - P_t^{cg} C_t^g : \text{Net Operating Balance} \tag{40}$$

$$\xi Xo_t - P_t^{ig} I_t^g : \text{Net Acquisition of non} - \text{financial assets} \tag{41}$$

$$\frac{B_t}{P_t} + \frac{(M_t - M_{t-1})}{P_t} - \left(1 + r_{t-1}^b\right)\frac{B_{t-1}}{P_t} : \text{Net Ainancial Aorth} \tag{42}$$

In equation 41, the government sells $\xi \in (0,1)$ percent of its oil revenues in dollars directly to the central bank, and converts them into rial. On the other hand, it keeps $1 - \xi$ percent on deposit with the central bank in the National Development Fund NOF_t and spends it over time.

$$NOF_t = NOF_{t-1} + (1 - \xi)Xo_t \tag{43}$$

Government budget constraint consists of a combination of the above three balances as follows:

$$P_t^{cg} C_t^g + P_t^{ig} I_t^g + \left(1 + r_{t-1}^b\right)\frac{B_{t-1}}{P_t} = T_t + \frac{B_t}{P_t} + \frac{(M_t - M_{t-1})}{P_t} + \xi Xo_t \tag{44}$$

$$G_t = \eta_t^{cg} C_t^g + \eta_t^{ig} I_t^g \tag{45}$$

Where $P_t^{cg} C_t^g$ and $P_t^{ig} I_t^g$ are government consumption expenditure and government investment expenditure, and $\frac{RCB_t}{P_t}$ are the changes in foreign exchange reserves. G_t is government expenditure, which is defined as the sum of current expenditure and civil expenditure.

$\eta_t^{cg} = \frac{P_t^{cg}}{P_t}$ and $\eta_t^{ig} = \frac{P_t^{ig}}{P_t}$ are the relative prices of current government spending and civil spending, respectively. It is assumed that government current and civil expenditures, such as consumption and private investment, are a function of the CES functions of goods produced domestically and abroad. In other words:

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$$C_t^g = \left[\gamma_{cg}^{\frac{1}{\upsilon_{cg}}}\left((C_{H,t})^g\right)^{\frac{\upsilon_{cg}-1}{\upsilon_{cg}}} + (1-\gamma_{cg})^{\frac{1}{\upsilon_{cg}}}\left((C_{F,t})^g\right)^{\frac{\upsilon_{cg}-1}{\upsilon_{cg}}}\right]^{\frac{\upsilon_{cg}}{\upsilon_{cg}-1}} \quad (46)$$

$$I_t^g = \left[\gamma_{ig}^{\frac{1}{\upsilon_{ig}}}\left((I_{H,t})^g\right)^{\frac{\upsilon_{ig}-1}{\upsilon_{ig}}} + (1-\gamma_{ig})^{\frac{1}{\upsilon_{ig}}}\left((I_{F,t})^g\right)^{\frac{\upsilon_{ig}-1}{\upsilon_{ig}}}\right]^{\frac{\upsilon_{ig}}{\upsilon_{ig}-1}} \quad (47)$$

Where $(C_{H,t})^g$, $(C_{F,t})^g$, $(I_{H,t})^g$ and $(I_{F,t})^g$ are the demand for domestically produced and imported consumer goods and the demand for domestically produced and imported capital goods consumed by the government, respectively. γ_{cg} and γ_{ig} are the share of domestically produced consumption and investment goods in total government consumption and total government investment, respectively, and υ_{cg} and υ_{ig} are the elasticity of substitution between domestically produced and imported consumer goods and between domestically produced and imported government capital goods, respectively.

In the public sector, as in the household sector, the investment follows the below capital rule:

$$K_t^g = I_t^g + (1-\delta_g)K_{t-1}^g \quad (48)$$

The fiscal policymaker is assumed to follow a first-order self-regression process as follows when there is a change in current government spending:

$$\log cg_t - \log\ cg\ = \rho_{cg}(\log cg_{t-1} - \log cg) + u_t^{cg}\ \ u_t^{cg} \sim i,i,d.N(0,\sigma_{cg}^2) \quad (49)$$

The monetary base is the central bank's balance sheet, written as follows:

$$M_t = DC_t + S_t FR_t \quad (50)$$

That its changes are as follows:

$$M_t - M_{t-1} = DC_t - DC_{t-1} + S_t FR_t - S_{t-1} FR_{t-1} \quad (51)$$

Where DC_t is domestic credit, S_t is nominal exchange rate, FR_t is foreign reserves, that is, the net foreign assets of the central bank converted into domestic currency at the S_t exchange rate. Equation 51 is as follows:

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$$m_t = dc_t + e_t fr_t \quad (52)$$

Where m_t and dc_t are adjusted relative to the domestic price index P_t and fr_t are adjusted relative to the foreign price index P_t^*.

Together with the government, the central bank seeks to achieve its twin objectives of controlling inflation and controlling the exchange rate by applying Taylor's rules of conduct (in which the growth rate of the monetary base is used to determine interest rates), the mechanism of a managed floating exchange rate system, and participating in the money and foreign exchange markets. This is done by changing the growth rate of the monetary base. Namely, when the central bank detects an increase in the deviation of output from its stable position, it tries to minimize this deviation by changing the monetary base. This procedure of the central bank is also applied to the deviations of inflation from its stable rate and the deviations of the exchange rate from its stable position. Therefore, changes in the growth rate of the domestic credit are an equation of deviations in output, inflation and the exchange rate. This equation is as follows.

$$\frac{\dot{dc}_t}{dc} = (\frac{\dot{dc}_{t-1}}{dc})^{n_0} + (\frac{\pi_t}{\pi^T})^{n_1} + (\frac{Y_t}{Y})^{n_2} + (\frac{e_t}{e})^{n_3} \quad (53)$$

Where $\dot{dc}_t$ the growth rate of the domestic credit, π_t is inflation, π^T is target inflation, Y_t is output and e_t is the real exchange rate. *Y* and *e* are the output and the exchange rate in steady state. n_0, n_1, n_2, and n_3 are the central bank's commitment to maintain constant money growth, achieve target inflation, maintain the output level, and maintain the exchange rate, respectively.

3.6 Foreign Sector

The model in this study is a small open economy. The AR (1) process is considered π_t^* and y_t^* as follows for external inflation and external production:

$$\log \pi_t^* - log\pi^* = \rho_{\pi^*}(\log \pi_{t-1}^* - log\pi^*) + u_t^{\pi^*} \quad u_t^{\pi^*} \sim i,i,d.N(0,\sigma_{\pi^*}^2) \quad (54)$$

$$\log y_t^* - logy^* = \rho_{y^*}\left(\log y_{t-1}^* - logy^*\right) + u_t^{y^*} \quad u_t^{y^*} \sim i,i,d.N(0,\sigma_{y^*}^2) \quad (55)$$

3.7 Market Clearing and Equilibrium

In market clearing, aggregate supply and aggregate demand are equal. That is, by combining the consumer and government budget constraints and the central bank balance sheet, markets are unwound as follows:

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$$C_t + \frac{P_t^I I_t}{P_t} + \frac{M_t - M_{t-1}}{P_t} + \frac{B_t}{P_t} + T_t + P_t^{cg} C_t^g + P_t^{ig} I_t^g + \left(1 + r_{t-1}^b\right) \frac{B_{t-1}}{P_t} + TA_t =$$
$$R_t u_t K_{t-1} - \psi(u_t) K_{t-1} + \frac{W_t N_t}{P_t} + \frac{M_t - M_{t-1}}{P_t} + \frac{R_{t-1}^b B_{t-1}}{P_t} + \frac{D_t}{P_t} + TA_t + T_t + \frac{B_t}{P_t} \quad (56)$$

In other words, the sum of oil and non-oil production equals the sum of consumption, investment, government spending, and net exports.

$$C_t + \frac{P_t^I I_t}{P_t} + P_t^{cg} C_t^g + P_t^{ig} I_t^g = R_t u_t K_{t-1} - \psi(u_t) K_{t-1} + \frac{W_t N_t}{P_t} + \frac{D_t}{P_t} \quad (57)$$

Thus, we obtain the following definition of GDP:

$$Y_t = C_t + I_t + G_t + \psi(u_t) k_{t-1} + X_t - IM_t \quad (58)$$

Where IM_t is the amount of import since there is investment and import consumption in the model, the clearing condition is simplified as follows:

$$IM_t = C_{F,t} + I_{F,t} + (C_{F,t})^g + (I_{F,t})^g \quad (59)$$

Total exports are the sum of oil exports and non-oil exports and are as follows, where υ_* is the elasticity between consumer and capital goods for foreigners. Y_t^* and P_t^* are the revenue and foreign price, respectively, and $\eta_t^x = \frac{P_t^x}{P_t^*}$ is the relative export price.

$$Xno_t = \left(\frac{P_t^x}{P_t^*}\right)^{-\upsilon_*} Y_t^* = (\eta_t^x)^{-\upsilon_*} Y_t^* \quad (60)$$

$$X_t = Xo_t + Xno_t \quad (61)$$

Substituting exports and consumption, investment and government expenditure, where $\eta_t^c = \frac{P_t^c}{P_t^H}$, the GDP equation is obtained as follows:

$$Y_t = \gamma_c (\eta_t^c)^{-\upsilon_c} C_t + \gamma_{cg} ((\eta_t^{cg})^H)^{-\upsilon_{cg}} C_t^g + \gamma_i (\eta_t^{I^H})^{-\upsilon_i} I_t +$$
$$\gamma_{ig} ((\eta_t^{ig})^H)^{-\upsilon_{ig}} I_t^g + \psi(u_t) K_{t-1} + (\eta_t^x)^{-\upsilon_*} Y_t^* + Xo_t \quad (62)$$

The accumulation of foreign assets of the central bank is assumed to follow the below process:

$$FR_t = FR_{t-1} + \xi Xo_t + Xno_t - P_t^* IM_t \quad (63)$$

Converting this equation into the foreign price index P_t^* yields the accumulation of real foreign exchange reserves:

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$$fr_t = \frac{fr_t}{\pi_t^*} + \frac{\xi Xo_t + Xno_t}{P_t^*} - IM_t \quad (64)$$

3.8 Islamic Treasury Documents in the Model

By using Islamic T-Bills, it is assumed that there would be contracting enterprise for state projects along with that two already mentioned enterprises in the first pattern (the final commodities and the intermediate commodities enterprise). According to Chen and Columba (2016), this contracting enterprise gains utility from demand for money and consumption, being as an investor, demands for labor force as well as selling its commodities to the state. This enterprise receives Islamic T-Bills from the state towards selling own products, while they are considered as the capital goods and the state demands them, and might dispose the bills in the discounted form or might wait until the due date of bills and then receive the principal debt.

Considering subjects mentioned above, this enterprise, same as other economic agents, looks for maximizing the agent utility comparing to its constraint.

$$E_t \sum_{t=}^{\infty}. \beta_e^t \left\{ \frac{1}{1-\delta_{cE}} (C_t^E)^{1-\delta_{cE}} + \frac{\kappa_{ME}}{1+\delta_{mE}} (m_t^E)^{1+\delta_{mE}} \right\} \quad (65)$$

In which case, [the letter] E indicates the contracting enterprise. This enterprise faces two Constraints; the budget Constraint and the capital formation Constraint. The budget constraint explains as below:

$$W_t N_t^E + b_t^E - (1 + r_{t-1}) \frac{b_{t-1}^E}{\pi_t} + m_t^E - \frac{m_{t-1}^E}{\pi_t} + C_t^E + I_t^E \leq P_t^E A_t (K_{t-1}^E)^{\alpha_E} (N_t^E)^{1-\alpha_E} \quad (66)$$

Also, the capital formation constraint explains as below:

$$K_t^E = (1 - \delta_K) K_{t-1}^E + I_t^E \quad (67)$$

By optimizing the above-mentioned expression and simplifying it, the following solutions are found; they are considered as equation of demand for the labor force, equation of demand for the contracting enterprise money, the demand for capital and the Euler equation respectively.

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$$W_t = P_t^E A_t (1-\alpha_E)\left(\frac{N_t^E}{K_t^E}\right)^{-\alpha_E} \quad (68)$$

$$\frac{\left(m_t^E\right)^{1-\delta_{mE}}}{\left(c_t^E\right)^{-\delta_{cE}}} = \frac{r_t}{1+r_t} \quad (69)$$

$$1 = \beta_E^t E_t \left(\frac{c_{t+1}^E}{\left(c_t^E\right)^{-\delta_{cE}}}\right)\left[P_{t+1}^E A_{t+1}\alpha_E \left(\frac{N_t^E}{K_t^E}\right)^{\alpha_{E-1}} - \delta_K\right] \quad (70)$$

$$\left(c_t^E\right)^{-\delta_{cE}} = \beta_E^t E_t \frac{1+r_t\left(c_{t+1}^E\right)^{-\delta_{cE}}}{\pi_{t+1}} \quad (71)$$

Having the settlement conditions needs to consider the demand for money in the new provided pattern equals to that total demand for money, in addition to the demand for contracting enterprise in the former pattern. Besides, the total demand for the labor force equals to the total demand for labor force in former pattern, in addition to demand for the labor force of the contracting enterprise. This [procedure] is also same in the production investment. Also, the total provided bills by the state for financing the securities with fixed income is (B_t) which is received from the state by the interest (r) and the Islamic T-Bills (B_t^E) by the contracting enterprise.

In this model, it is assumed that the government budget deficit is financed through the use of Islamic treasury bills. Therefore, the amount of publication of Islamic treasury bills depends on the amount of government budget deficit. Therefore, if the government uses treasury bills to compensate for its budget deficit, the amount will be as follows:

$$B_t = P_t^{cg} C_t^g - T_t + P_t^{ig} I_t^g - \xi Xo_t \quad (72)$$

On the other hand, Treasury bills are expressed as a function of past values and the main macro variables that affect them, such as output, inflation, exchange rate and oil revenues, in the form of a linear logarithm (Khiabani and Amiri, 2014):

$$\log(B_t) = b_1 \log(er_t) + b_2\, log(\pi_t) + b_3 \log(Y_{t-1}) + b_4 \log(B_{t-1}) + \varepsilon_t^B \quad (73)$$

4 Calibration

One of the most important methods in computing DSGEs is to assign values to the model parameters. In this study, we took two steps to solve the model using the calibration method. First, we calibrated some parameters using quarterly data on real consumption, consumer inflation, money growth,

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government current and civil expenditure, and GDP between 1991 and 2019, and quarterly data on Islamic Treasury bills from 2014 to 2019. (Table 2)

Table 2
Calibrated values of the parameters using research

Parameter	Description	Value	Parameter	Description	Value
$\frac{\bar{\imath}^{\bar{h}}}{\bar{y}}$	Ratio of domestic investment to total output	0.1	$\frac{\overline{efr}}{\bar{m}}$	Ratio of foreign reserve to money supply	0.59
$\frac{\overline{c^{fg}}}{\bar{y}}$	Ratio of imported consumer goods by government to total output	0.05	$\frac{\overline{c^{f}}}{\bar{y}}$	Ratio of consumption of imported goods to total production	0.02
$\frac{\overline{\imath^{fg}}}{\bar{y}}$	Ratio of government investment by imported capital goods to total output	0.01	$\frac{\bar{\imath}^{\bar{f}}}{\bar{y}}$	Ratio of imported investment to total output	0.01
$\frac{\overline{c^{hg}}}{\bar{y}}$	Ratio of government domestic consumer goods to total output	0.15	$\frac{\overline{c^{h}}}{\bar{y}}$	Ratio of consumption of domestic goods to total output	0.51
$\bar{r}$	Quarterly average interest rates	1.03	$\frac{\overline{\imath^{hg}}}{\bar{y}}$	Ratio of government investment by domestic capital goods to total output	0.1
$\frac{\bar{c}_g}{\bar{g}}$	Ratio of current expenditure to government expenditure	0.8	$\frac{\bar{x}}{\bar{y}}$	Ratio of exports to total output	0.23
$\frac{\bar{\imath}_g}{\bar{g}}$	Ratio of capital expenditure to government expenditure	0.2	$\frac{\overline{imt}}{\bar{y}}$	Ratio of imports to total output	0.18
ρ_{cg}	Autoregressive coefficient of government consumption expenditure	0.42	$\frac{\bar{c}^{\bar{f}}}{\overline{imt}}$	Ratio of imported consumption to imports	0.14
$\frac{\overline{xo}}{\overline{nof}}$	Ratio of oil sales to development fund reserves	4	$\frac{\bar{\imath}^{\bar{f}}}{\overline{imt}}$	Ratio of imported capital goods to imports	0.50
$\frac{\overline{xo}}{\overline{fr}}$	Ratio of oil exports to foreign assets of the central bank	1.7	$\frac{\overline{c^{fg}}}{\overline{imt}}$	Ratio of imported goods consumption to imports in the public sector	0.11
$\frac{\overline{xno}}{\overline{fr}}$	Ratio of non-oil exports to the central bank's foreign assets	0.3	$\frac{\overline{\imath^{fg}}}{\overline{imt}}$	Ratio of capital goods consumption to imports in the public sector	0.25
$\frac{\overline{imt}}{\overline{fr}}$	Ratio of imports to the central bank's foreign assets	1.59	$\frac{\overline{xo}}{\bar{x}}$	Ratio of oil exports to exports	0.83
$\frac{\overline{dc}}{\overline{\bar{m}}}$	Ratio of domestic credits to money supply	0.41	$\frac{\overline{xno}}{\bar{x}}$	Ratio of non-oil exports to exports	0.16

Source: Research Findings

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Then, we calibrated a number of other parameters using studies whose assumptions are close to the model assumptions of this paper, such as the openness of the economy, the existence of the oil sector in the economy, the lack of independence of the central bank, and etc. (Table 3)

Table 3
Calibrated values of the parameters using previous studies

Parameter	Description	Value	Source	Parameter	Description	Value	Source
υ_c	Elasticity of substitution between domestic and imported consumption	6.17	Tavakkolian & Afzali (2016)	ε	Percentage of oil revenues converted into rials	0.78	Tavakkolian & Afzali (2016)
$\bar{\eta}^h$	Ratio of the price of domestic goods to the price index	0.97	Sadraaei (2020)	σ_m	Inverse money supply elasticity	2.09	Tavakkolian & Afzali (2016)
γ_c	Share of domestic consumption to total consumption	0.85	Tavakkolian & Afzali (2016)	δ_g	Depreciation rate of state fixed capital	0.032	Tavakkolian & Afzali (2016)
$\bar{\eta}^f$	Ratio of the price of imported goods to the price index	1.28	Sadraaei (2020)	n_0	Commitment to maintaining a constant level of money growth rate in monetary policy	0.35	Sadraaei (2020)
σ_c	Inverse intertemporal elasticity of substitution of consumption	1.19	Tavakkolian & Afzali (2016)	n_1	Commitment to inflation targets in monetary policy	-2.9	Sadraaei (2020)
υ_i	Elasticity of substitution between domestic and imported investment	0.64	Tavakkolian & Afzali (2016)	n_2	Commitment to deviation from output in monetary policy	-2.8	Sadraaei (2020)
γ_i	Ratio of domestic investment to total investment	0.97	Tavakkolian & Afzali (2016)	n_3	Commitment to maintain a fixed level of the exchange rate in monetary policy	-0.1	Sadraaei (2020)

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$\bar{\eta}^{ih}$	Ratio of the price of domestic capital goods to the price index	0.89	Tavakkolian & Afzali (2016)	$\bar{\eta}^{igf}$	Ratio of the price of imported capital goods in the public sector to the price index	1.26	Sadraaei (2020)
$\bar{\eta}^{if}$	Ratio of the price of imported capital goods to the price index	0.69	Sadraaei (2020)	ρ_{dc}	Autoregressive coefficient of growth of monetary base	0.78	Heidari & Molabahrami (2017)
σ_n	Inverse elasticity of labor supply	2.89	Sadraaei (2020)	ρ_{xo}	Autoregressive coefficient of oil exports	0.27	Sadraaei (2020)
χ	The share of public capital in production	0.21	Tavakkolian & Afzali (2016)	ρ_e	Autoregressive coefficient of the exchange rate	0.91	Sadraaei (2020)
α	Share of capital in production	0.64	Sadraaei (2020)	υ_{cg}	Alternative elasticity between domestic and imported public sector consumption	5.46	Tavakkolian & Afzali (2016)
β	Discount factor	0.96	Tavakkolian & Afzali (2016)	γ_{cg}	Share of domestic consumption in total public sector consumption	0.41	Sadraaei (2020)
τ_p	Benchmark for inflation	0.86	Tavakkolian & Afzali (2016)	υ_{ig}	Elasticity of substitution between domestic and imported public sector investment	1.85	Sadraaei (2020)
ω	Degree of price stickiness	0.37	Sadraaei (2020)	γ_{ig}	Share of domestic investment in total investment in the public sector	0.87	Sadraaei (2020)
δ	Depreciation rate of fixed capital	0.04	Shahmoradi & Naseri (2011)	$\bar{\eta}^{cgh}$	Ratio of the price of domestic consumer goods in the public sector to the price index	1.11	Sadraaei (2020)

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ρ_a	Self-regression coefficient of efficiency	0.9	Tavakkolian & Afzali (2016)	$\bar{\eta}^{cgf}$	Ratio of the price of imported public sector consumer goods to the price index	0.94	Sadraaei (2020)
ρ_{tr}	Autoregressive coefficient of transfer payments	0.8	Pirahmadi et al. (2019)	$\bar{\eta}^{igh}$	Ratio of the price of domestic capital goods in the public sector to the price index	2.03	Sadraaei (2020)
b_4	Impact coefficient of the Treasury bills of the previous period on the issuance of the	0.283	Heidari & Molabahrami (2017)	b_2	Inflation on the issuance of Treasury bills	0.47	Heidari & Molabahrami (2017)
b_1	Impact coefficient of the exchange rate on the issuance of Treasury bills	0.12	Heidari & Molabahrami (2017)	b_3	Impact coefficient of the production factor on the issuance of Treasury bills	0.39	Heidari & Molabahrami (2017)

In addition to calibrating the parameters, it is necessary to calibrate the variance of the shocks to obtain the magnitude of the torques of the key variables. The values of the variance of the shocks are determined so that the second-order moments of the key variables are maximally similar to the real-world values. The value of these shocks is given in the table 4.

Table 4
Calibrated values of standard deviation of shocks

shock	**Monetary base growth**	**Oil revenue**	**Exchange rate**	**Efficiency**	**Treasury bills**
Standard deviation	0.15	0.03	0.025	0.1	0.01

Source: Research Findings

Based on Table 5, the second-order moments of the simulated variables of the model and the actual estimated values of the Iranian economy based on the Central Bank's quarterly data from 1991 to 2019 are given. These

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variables are first quarterly classified. Since the model variables are linear, the real variables are then logarithmized and the Hodrick - Prescott filter is used to remove the trend from the variables. It can be seen that the values of the moments obtained from the model and the actual data are very close, which is an indication of the validity of the results obtained in the model simulation.

Table 5
Comparison of the estimated moments in the model and the actual data

		GDP	Private sector consumption	Capital stock	Government expenditure	Inflation	Money supply growth
Average	Model	0.002723	0.004080	0.000759	0.0016	-0.00271	0.0027
	Real data	0.00	0.00	0.00	0.00	0.00	0.0046
Standard deviation	Model	0.242195	0.4237	0.407	0.4141	0.211	0.2049
	Real data	0.22	0. 315	0. 5	0.٤18	0.٢3	0. 33

Source: Research Findings

5 Simulated Impulse-Response Functions

Instantaneous response function graphs depict the response of the values when an impulse occurs. To put it differently, these graphs represent the dynamic behavior of the simulated quantities when an impulse takes place identical to the specified standard deviations. In all graphs, the horizontal axis indicates 30 periods of time. The vertical axis indicates the percentage of the factors' variations against the impulses since the variables are displayed as logarithmic deviations from the equilibrium values. Figures 2 to 5 show the impacts of government expenditure impulse, the Islamic treasury bills impulse, oil income impulse, and monetary impulse on the economic indicators: consumption (c), consumer inflation (panic), capital stock (K), gross domestic product (GDP) (Y), monetary base (m), and governmental expenditures (g) when Islamic treasury bills are used for financing the state's budget deficit.

5.1 Government Expenditure Impulse

Figure 2 shows the impact of fiscal expenditure impulse on the macroeconomic parameters due to Islamic treasury bills. The positive impulse of government expenditure refers to the expansionary fiscal policy. As expected, this positive shock immediately influences consumption, gross national product, and national expenditures, losing its effect in the long run. These variables return towards equilibrium in less than ten periods of time.

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Moreover, this impulse effectively affects the money volume and inflation, which decreases in the long term.

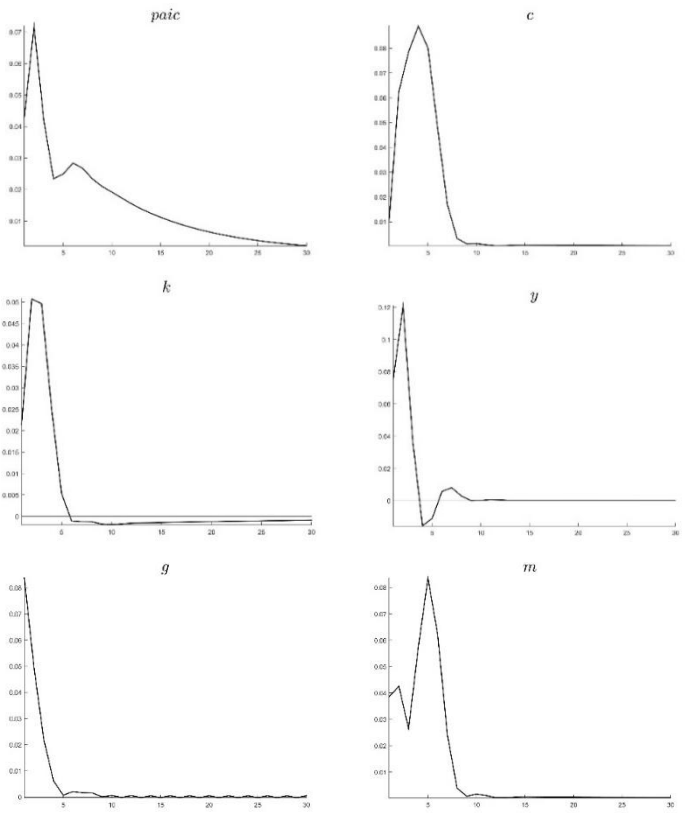

Figure 2. Instantaneous response functions for the government expenditure impulse
Source: Research Findings

5.2 Oil Revenue Shocks

The present study evaluates the negative impulse of oil revenues since a cause for the budget deficit in Iran reduces oil revenues; thus, the oil revenues of the government decline and the state faces further economic problems. The government uses Islamic treasury bills to finance its budget deficiencies. The negative impact of oil revenues increases inflation, as is expected because an increase in the exchange rate accompanies the reduction of oil revenues.

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However, inflation returns to equilibrium since the debt has been financed with no money printing and borrowing from the Central Bank. Due to reduced oil revenues, consumption, GDP, government expenditure, and capital stock numbers also decrease in the early stages. However, in the long term, this shock decreases, and these indices return to equilibrium.

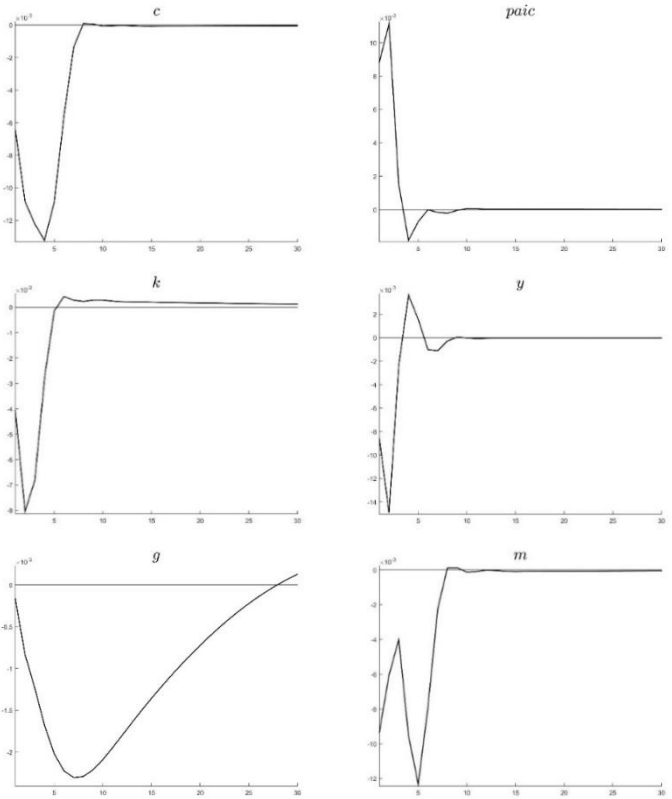

Figure 3. Instantaneous response functions for the negative impulse of oil revenues
Source: Research Findings

5.3 Monetary Base Shock

Figure 4 displays the behavior of macroeconomic variables versus a positive monetary shock. A positive monetary response is achieved by adopting an expansionary monetary policy. At the same time, issuing Islamic treasury bills

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is a contractionary process and can cool an overheated effect of the expansionary monetary policy. Inflation logically increases by positive monetary pressure but declines and returns to equilibrium after a few periods; inflation decreases because of the contractionary policy of issuing Islamic treasury bills. The outcomes of the monetary crisis and issuing Islamic treasury bills involve a reduction in investment and capital stock via a discount rate increase. Production initially increases by an increase in the consumption of the private sector; nevertheless, it may encounter a decline in consumption and investment after a few periods.

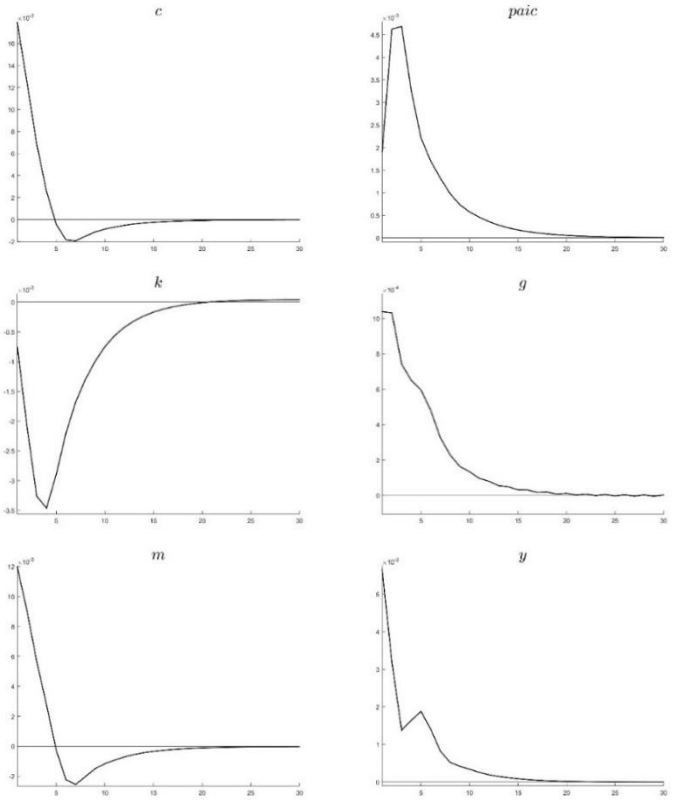

Figure 4. Instantaneous response functions for the monetary base shock
Source: Research Findings

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5.4 Islamic Treasury Bills Shock

Figure (5) is the instant response function to the increase in Islamic treasury bills. Islamic Treasury bills initially increase the government's spending, but then spending decreases, thus reaching equilibrium after several periods. The reason is that with the positive reaction of treasury bills, a new source is created to finance government expenditures and projects. Therefore, direct spending increases. Then, with the discharge of this jolt, governmental expenditures return to an equilibrium state. Also, the GDP initially reacted positively to the shock of Islamic treasury bills due to the increased public sector spending.

With the publication of Treasury bills, inflation will initially decrease due to the lack of monetization of the budget deficit and the creation of an alternative method of borrowing from the central bank. However, it will return to its equilibrium state after a few periods.

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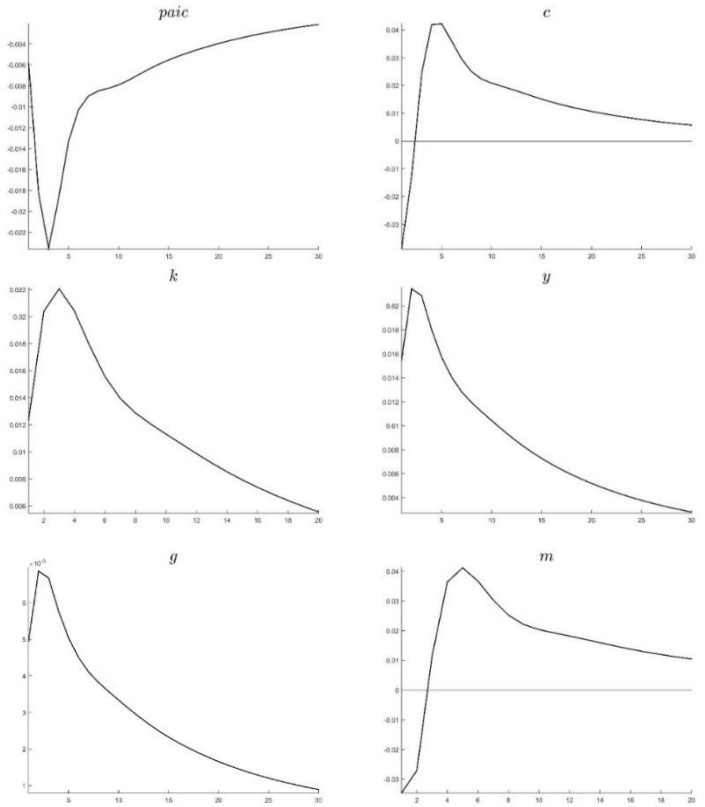

Figure 5. Response functions to the shock of Islamic treasury bills.
Source: Research Findings

Considering the Treasury bill's impact, consumption initially deviates negatively. This can be attributed to the improvement in economic investment during this initial downturn. Still, increased income increases consumption after several periods, and as the effect dissipates, consumption converges to its equilibrium value. Investment initially responds positively to the Treasury bills shock, but after about five periods, the positive effect of this event disappears. This negative effect can be due to the private sector crowding out due to the accumulation of resources by the government through the issuance of Treasury bills.

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6 Conclusion

To analyze the influence of issuing Islamic treasury bills for financing the public sector's deficit on macroeconomic data, the budget shortfall and different models for covering the funding gap were initially evaluated. Afterward, Islamic treasury bills were presented to finance the government's deficit-ridden budget. The DSGE model was designed and solved for the Iranian economy to assess the impact of this method on economic factors. After optimization and linearization of the equations, the parameters were calibrated. Comparing the torques, the model variables, and accurate data were compared, approving the capability of the research model. After model stipulation and optimization, the results manifested that the impulses on the macroeconomy induced some effects in compliance with the theoretical expectations.

Four primary shocks were assessed to investigate the impact of Islamic treasury bills on economic variables: government expenditures, growth in the monetary base, negative oil revenues shock, and the shock of issuance of Islamic treasury bills. At government expenditures shock, first, the economic variables increase because of its expansionary policy. However, the economic variables decline after a few periods and reach equilibrium through the issuance of Islamic treasury bills, which is a contractionary policy.

The negative oil revenues shock is crucial in Iran's economy and is created by oil price decline or the reduction of oil exports due to factors like sanctions. Initially, this shock has a negative impact on economic variables; for instance, inflation rate rises and production decreases. But the variables return to equilibrium after around five time periods if the government can compensate the budget deficit through Islamic treasury bills. Economic variables primarily show different and sometimes negative effects due to the shock of the monetary base growth, which is an expansionary policy. However, the impact of this expansionary monetary policy become neutralized and the variables reach equilibrium through Islamic treasury bills.

The response functions results: The Inflation decreases with the increase in Treasury bills, only to return to equilibrium after a while. Consumption initially decreases but increases over time and converges to equilibrium. The shock of Islamic treasury bills also positively affects investment, GDP, and government spending. Overall, the results of this study confirmed the positive effect of issuing Islamic treasury bills on macroeconomic indicators.

As a suggestion for future studies based on the results of the current model and modeling in the space of the DSGE model, the researchers propose to

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determine the optimal ratio of Treasury bills issuance to national output or other economic variables such as government spending.

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