



Shiraz University

Journal homepage: ijes.shirazu.ac.ir



A DSGE Analysis of the Effects of Economic Sanctions: Evidence from the Central Bank of Iran

Seyyed Reza Nakhli^a, Monireh Rafat^{a*}, Rasul Bakhshi Dastjerdi^a,
Meysam Rafei^b

a. Department of Economics, University of Isfahan, Isfahan, Iran.

b. Department of Economics, Kharazmi University, Tehran, Iran.

Article History

Received date: 21 January 2020

Revised date: 09 June 2020

Accepted date: 19 October 2020

Available online: 20 October 2020

JEL Classification

E37

F51

Q34

E52

Keyword

Economic Sanctions

Optimal Simple Rule

CPI-PPI Inflation Targeting

DSGE Model

Calibration

Iran

Abstract

Since the nationalization of the oil industry, especially after the 1979 revolution, Iran has always encountered economic sanctions. The oil embargo and international financial sanctions are the most severe sanctions imposed on Iran and have had significant effects on Iran's macroeconomic variables. The current study aimed to analyze the effects of economic sanctions on Iran's macroeconomic variables using a dynamic stochastic general equilibrium (DSGE) model based on the new Keynesian approach. The simulation results showed that the intensification of the oil and international financial sanctions would 1) reduce foreign and government investment, technology innovation, export in the oil sector, and consequently oil production, 2) lead to a higher exchange rate and a decrease in the ratio of the central bank foreign exchange reserves to the monetary base, 3) reduce the GDP and non-oil exports and increase the inflation, which may cause stagflation, 4) increase household consumption and decrease household investment, 5) increase budget deficit, forcing the government to adopt policies to raise current expenditures and maintain housing and urban development budget, which, in turn, will lead to a budget deficit and bond sales. The analysis of various optimal monetary policies in the context of economic sanctions and considering the contingent business interruption (CBI) loss function showed that the optimal simple rule, in the form of the producer price index, targeting monetary policy, could reduce the loss function and increase the importance value of output coefficient in the monetary policy.

Highlights

- This is the first DSGE model in analyzing the effects of Iran's economic sanctions.
- DSGE model is designed by economic sanctions considering the oil and international financial sanctions simultaneously.
- Three kinds of oil sanctions (export, technology, finance) are considered in the model.
- The new form of investment in the oil sector is applied in the model.

* m.rafat@ase.ui.ac.ir

DOI: 10.22099/ijes.2020.36182.1643

© 2020, Shiraz University, All right reserved

1. Introduction

Economic sanctions are one of the most important means used to impose pressure on some countries and their origin dates back to years even before the birth of Christ (Peksen & Drury, 2010). After World War I and the approval of the Covenant of the League of Nations, global convergence was achieved and economic sanctions took international and multilateral formats to maintain international peace and prevent war (Fashandi & Ghaderi, 2017). Since 1990, after the development of public international law, the pattern of sanctions has changed dramatically and the economic sanctions approved by the UN Charter under chapter VII, especially articles 40 and 41, against countries threatening international peace and security are considered “binding” for all the United Nations Member States (De Wet, 2004). Since then, military action against countries that threaten international peace and security has been replaced with sanctions, hence the dramatic rise of sanctions as a more efficient and less costly tool standing between military action and diplomacy (Tayebi & Sadeghi, 2017).

In recent decades, especially after the Islamic revolution of 1979 in Iran, some regional unions, countries, and even international institutions have imposed several sanctions on Iran to apply maximum pressure on it (Katzman, 2019b). These sanctions have been aimed to create a global concession and use the capacity of international organizations, such as international financial institutions, to increase the intensity and scope of sanctions so that they can target the Iranian economy main sectors, including the network of banks and its central bank, the oil sector and oil trades, and foreign direct investment (Lohmann, 2016; Tayebi & Sadeghi, 2017).

These sanctions have had severe negative impacts on Iran’s economy, which, according to 2012-2013 economic sanction data (Central Bank of Iran, Time Series Database), led to a 5.8% decline in GDP, a 40% rise in the consumer price index (CPI), and a 300% rise in the nominal exchange rate.

Over the last 70 years, especially after the Islamic revolution and the US withdrawal from the Joint Comprehensive Plan of Action (JCOPA), which was signed by major international players and achieved after several years of negotiation in August 2018, the possibility of the reimposition of previous sanctions, even at a greater intensity than before, seems stronger than ever, suggesting that the sanctions against Iran are strategic and strict (Ianchovichina et al., 2016) and that they may continue to be there for at least the near future (Kozhanov, 2011). Thus, it is necessary to design a framework for analyzing the impacts of economic sanctions so that the Iranian policy-makers can adopt the most appropriate economic policies to counteract sanctions and reduce their negative effects.

All of the studies conducted on the sanctions imposed on Iran can be classified into three categories: 1) Some of these studies present a theoretical explanation about the incentives, purposes, and fundamentals of the sanctions (e.g., Katzman, 2019a; Zahrani & Dolatkhah, 2010; Hufbauer et al., 1997); 2) some of them emphasize the economic strategies for economic prosperity in the

post-sanction period (e.g., [Mozafari, 2016](#)); 3) a considerable number of studies have focused on evaluating the economic effects of sanctions and their effectiveness in reaching their goals using various quantitative methods (e.g., [Rahmati et al., 2016](#); [Dizaji & Farzanegan, 2019](#); [Tayebi & Sadeghi, 2017](#)). Since the sanctions are stochastic and affect an array of variables of the Iranian economy, it is necessary to design a stochastic and general equilibrium framework to analyze the effects of economic sanctions on macro variables, including different markets, sectors, and other important economic variables that are related to each other in a network considering the dynamics and realities of the economy. Thus, this study sought to develop a DSGE model for the simultaneous analysis of the impacts of oil embargo and international financial sanctions on Iran. The New Keynesian approach was also applied due to the lack of classical assumptions, for example, rigidity, incomplete adjustment process, low speed of adjustment, costs of adjustment, incomplete competition, involuntary unemployment, etc. in the realities of the Iranian economy ([Le et al. 2011](#)). What has been overlooked in research on sanctions imposed on Iran is how the adoption of appropriate policies by policy-makers can reduce the negative effects of economic sanctions. The Central Bank of Iran, as one of the main parties in policy-making concerning the monetary market, can introduce certain monetary policies to mitigate the effects of economic sanctions.

This article is organized as follows. Section 2 provides a review of the literature. The model is presented in Section 3. In Section 4, the data is discussed and the parameters are calibrated. Model fitness is evaluated in Section 5. Section 6 is devoted to the analysis of the consequences of sanction shocks, using impulse response functions (IRFs), and the evaluation of various optimal monetary policies under a condition characterized by sanctions. Finally, some concluding remarks are offered in Section 7.

2. A Review of the Related Literature

Sanctions are generally referred to as tools used to bring about some changes in the political attitudes and behavior of some countries ([Eyler, 2007](#)). Economic sanctions are one of the most important and common types of sanctions aimed at reducing the target country's economic power and hampering its ability to provide its own people with the main requirements ([Peksen, 2009](#)). Sanctions achieve these goals by decreasing the target country's production, devaluing its national currency, and increasing unemployment, level of prices, government budget deficit, and ultimately dissatisfaction among the people, leading to civil unrest in the target country. Economic sanctions can be categorized into two groups: 1) trade sanctions and 2) financial sanctions ([Kittrick, 2008](#)). Trade sanctions are generally selective sanctions intended to restrict the trade (export or import) of certain goods by the target countries. This is achieved by limiting the target country's access to the required import commodities or the foreign exchange incomes earned through export, canceling trade contracts, imposing heavy tariffs, cutting technical and technological assistance, prohibiting export from and import

into the target country, and imposing penalties for any trade relations with the target country (Yavari & Mohseni, 2011). Financial sanctions are often applied with the aim of limiting the target country's international financial relations with other countries and its access to a variety of markets and international financial resources, restricting its foreign investment, increasing its trade costs, and limiting its access to and use of financial and foreign exchange resources (Tayebi & Sadeghi, 2017). A variety of financial sanctions, such as restrictions on foreign investment, bank transactions, the use of bank guarantees (BG) and letters of credit (LC), access to the international insurance market, access to the foreign exchange resource, and the use of international messaging services, can have more powerful and far-reaching effects than just trade sanctions on the target country's economy (Caruso, 2003). Historical evidence shows that although economic sanctions have rarely been successful in achieving their goals (about 34% at maximum), financial sanctions have been more successful (about 41%) than the trade sanctions (about 25%) in this regard (Hufbauer et al., 2009).

There has been a lot of research on oil and international financial sanctions, which can be broadly divided into two categories: 1) studies that have attempted to explain how sanctions work, 2) studies that have focused on evaluating the effects of sanctions on macroeconomic variables. Regarding the first category, Rahmati et al. (2016) noted that the oil embargo reduced Iranian crude oil export and government foreign exchange incomes. Tayebi and Sadeghi (2017) stated that because the Iranian government budget was more than 50% dependent on oil revenues, oil sanctions led to a budget deficit. Due to the ensuing economic recession and inadequate tax revenues, they added, the government had to borrow from the banks or the central banks, which, in turn, would reduce the central bank's ability to manage the exchange market in the form of managed floating, resulting in an increase in the exchange rate. Toghyani and Derakhshan (2014) pointed out that an increase in the exchange rate would increase the import costs, thereby increasing the consumer price and production expenditure, but it may encourage competitiveness among domestic exporters because the foreign exchange earned by the exporters may have more value due to the devaluation of the domestic currency. Eyler (2007) argued that international financial sanctions could increase the risk of any transaction with the financial and banking network of the target country and facilitate the expansion of informal financial activities, which may result in higher exchange transfer and financing costs. Marzban and Ostadzade (2015) opined that the psychological effects of economic sanctions could lead to increased uncertainty among economic agents about the future and have detrimental effects on production, consumption, and, especially, investment. Derakhshan (2014) believed that inadequate internal resources to finance the massive oil industry, high costs of exploration, development, and operation, the need to have advanced technology and equipment for the exploration and exploitation of oil and gas fields, which are often in the second half of their lives, forced the National Iranian Oil Corporation (NIOC) to enter into contracts with international oil companies to be able to finance oil and gas projects and use their

advanced technology. However, international oil companies are risk-averse due to the long-term and significantly costly oil contracts that they sign with other parties. The uncertainty caused by sanctions makes these international companies withdraw from the target country, which may reduce financing and investment in the oil industry, lack of the technology required by the oil industry, and ultimately a reduction in oil production.

Dizaji (2014) examined the impacts of oil shocks on government expenditures and revenues nexus using vector autoregressive (VAR) and vector error correction (VEC) models. The results showed that the main causality was from the revenues to expenditures. Therefore, the oil sanctions were found to significantly affect the government expenditures, as the main source of developing the Iranian economy. Using Autoregressive Distributed Lag (ARDL) and Error Correction Mechanism (ECM) methods in their study, Tayebi and Sadeghi (2017) concluded that the sanctions imposed on Iran before 2012 had a weak effect on the exchange rate, but those sanctions imposed in 2012 had a strong effect on the exchange rate by severely limiting Iran's crude oil exports and causing a huge budget deficit. International financial sanctions have also increased the risk of financial exchanges and enhanced international financing and transaction costs. In an attempt to study the importance of economic shocks in explaining the recession in Iran during 2012-2013, Rahmati et al. (2016) used the business cycle accounting method and concluded that the productivity wedge could play a major role in explaining the business cycles. They also added that when the exchange rate effects were separated, the trade wedge was found to have an important role in explaining the 2013 recession in Iran due to the sanctions. Table 1 summarizes the results of some studies on the effects of sanctions on economic variables.

The behavior of economic policy-makers is very important in obtaining economic equilibrium. As a monetary and exchange policy-maker, the Central Bank (CB) can have significant effects on the equilibrium of economic variables (Blinder et al., 2008). Generally, CB imposes monetary policy rules on the economy, either with interest rates in the form of Taylor rule (Taylor, 1993) or with monetary base in the form of McCallum rule (Mc Callum, 1987). Instead of the current monetary policies, CB may apply an optimal monetary policy by optimizing its objectives or minimizing loss function under a time constraint to secure economic equilibrium (Robert Nobay & Peel, 2003). In fact, CB seeks to minimize its loss function because it reflects the disturbance and disadvantages of the economic system in the optimal monetary policy. For example, the inflation gap, which leads to an inefficient allocation of money, and the output gap, which indicates a lack of optimal use of the country's economic capacities, can be the main factors in the CB loss function (Ruge-Murcia, 2004). The CB can adopt one optimal monetary policy from the several available forms of optimal monetary policy, including the Ramsey approach, the discretionary policy, and the optimal simple rule (OSR), each differing from the other in terms of the loss function (Tavakolian & JalaliNaeni, 2017). According to the variables in the loss function

and their weights in each of the above-mentioned forms of optimal monetary policy, there are many policy options available to the CB to choose from in the face of a given dire economic condition, such as that beset by economic sanctions. Some studies have considered various nominal and real variables in the CB loss function. [Giannoni and Woodford \(2004\)](#), for example, considered inflation, real wages, and output gap. Similarly, [Bernanke et al. \(2018\)](#) considered inflation and output gap. [Guender and Sander \(2011\)](#) and [Tavakolian and JalaliNaeeni \(2017\)](#) considered inflation, output gap, monetary base growth, and exchange rate gap in the CB loss function. Choosing the appropriate optimal monetary policy with less welfare loss by the CB of Iran and evaluating it using the optimal simple rule was the second objective of the present study.

An overview of previous studies shows that although different quantitative methods have been used to analyze the effects of sanctions, to the best of our knowledge, no study has yet utilized the DSGE model to analyze the effects of the sanctions imposed on Iran. The main contribution of the current study is that it attempted to fill this gap in the literature. Moreover, while sanctions have been studied in the form of a dummy variable in the majority of the previous studies, in this study, the sanctions were considered as a stochastic shock with different degrees of impact on various sectors of the economy. Since the effects of oil and international financial sanctions have not been simultaneously investigated in the previous studies, this study was hoped to contribute to the literature by examining the effects of these two types of sanctions at the same time. The analysis of the adoption of different monetary policies by the CB of Iran under the sanction regimes can be considered as another contribution of the present study.

In addition, in the model employed in this study, three kinds of sanctions, including oil sanctions in the form of an embargo on Iranian oil export, technology sanctions, and foreign investment sanctions, were considered, which could be regarded as the main contribution of the current research. Furthermore, this study differs from the previous studies in that it examined two kinds of international financial sanctions, in the form of export and import sanctions, and three kinds of imports, namely, consumption, investment, and intermediate input. Also, in the present study, a new form of investment in the oil sector was developed and domestically produced goods were divided into foreign and domestic markets based on the computable general equilibrium (CGE) model. The above features distinguish the DSGE model developed in this study from those of previous studies.

Table 1. A summary of some studies done on the effects of sanctions

Author(s)	The results of sanctions imposed	Method	Case study
Farzanegan & Hayo (2019)	The negative effects of the shadow economy were more than the formal economy in 2012-2013 and the Iranian households took the brunt of sanctions.	Panel Data	Provinces of Iran (2001-2013)
Sadeghi & Tayebi (2018)	A decrease was reported in the central bank's foreign exchange reserves, leading to an increase in the exchange rate and import costs. As a result, there was inflation in the consumer price index and an increase in the production costs, which resulted in an increase in the budget deficit, forcing the government to borrow from the central bank.	ARDL & ECM	Iran (1981-2014)
Haidar (2017)	The destination of two-thirds of Iran's non-oil exports changed and export costs increased; therefore, exporters made less profit and deadweight loss decreased.	OLS	Iran (2006-2011)
McDonald & Reitano (2016)	The sanctions had a negative effect on economic growth, but the defense expenditure increased, indicating that the sanctions were not effective.	OLS (Growth model)	Iran (1959-2007)
Khabbazan & Farzanegan (2016)	The banking sanction led to a decline in household welfare, had more damaging effects on export than on import and foreign investment, decreased GDP and private consumption, and increased the exchange rate and CPI.	CGE	Iran (SAM table-2001)
Farzanegan et al. (2016)	The oil sanctions reduced GDP, export, import, private consumption, and CPI, had more severe effects on the welfare of the rich than the poor, and increased the exchange rate, wages, and non-oil exports.	CGE	Iran (SAM table-2001)
Petrescu (2016)	The sanctions increased informal economic activities, especially those supported by international agencies and companies.	Panel Data	147 countries, 46 years
Keimasi et al. (2016)	The sanctions imposed on the central bank, the restrictions placed on access to the SWIFT, blocking oil revenues, and rejection of LC negatively affected the profitability of the banks.	Panel Data	22 banks in Iran (2007-2014)
Gurvich & Prilepskiy (2015)	The sanctions decreased foreign direct investment, foreign borrowing, investment in the government debt market, capital withdrawal, GDP, consumption, and government revenues, but increased self-reliance.	OLS	Russia (2014-2017)
Ghazaavi & Mohammadi (2015)	The banking sanctions impeded the transfer of exchange gained through the transactions of imports and exports, limited the bank's international relation and their access to the international financial messengers, increased banking services costs, and decreased public confidence in the banking system.	Delphi and Friedman test	Selected banks from Iran
Toghyani & Derakhshan (2014)	The economic sanctions were found to be effective in limiting access to the international financial system. Multilateral sanctions and permanent sanctions enhanced the negative effects of economic sanctions.	AHP	Iran

Source: Current research.

3. The Study Model

The study model was developed based on two kinds of sanctions, including the oil sanctions and the international financial sanctions, and the reality of Iran's economy, as described by Adolfson et al. (2007), Allegret and Ben Khodja (2015), Balke and Brown (2018), and Tavakolian and JalaliNaeni (2017). Households, labor market, intermediate good producing firm, the trade sector in both non-oil exports and imports, the oil sector, government, the central bank, and clearing conditions were considered in the study model. Figure 2 shows the relationship chart of the model developed for this study.

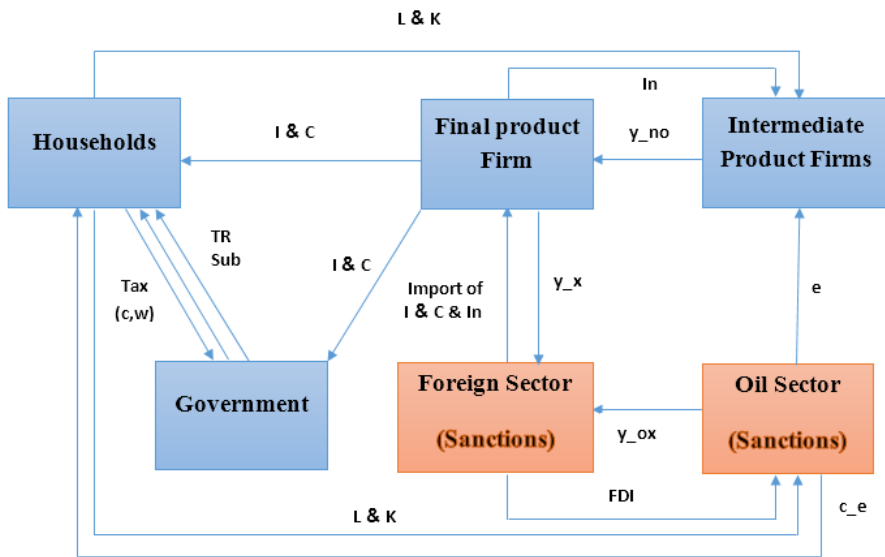


Figure 1. The relationship chart of the developed model.

Source: Current research.

This study aimed to examine the simultaneous effects of sanctions on the oil and international financial sectors. Since the DSGE model was developed to allow the researchers to examine the simultaneous effects of sanctions on the above sectors, it was necessary that the sanctions occurred simultaneously and had different effects on different sectors through different parameters. Therefore, the formulas applied for the oil and international financial sectors facing sanctions were similar, but the sanctions had different effects on each of these two sectors because different parameters were considered for each (Sections 3.4 and 3.5).

3.1 Households

The households derive utility from consumption C_t , and real value of money balances $\frac{M_t}{P_t}$, holding foreign currencies $\frac{M_t^S}{P_t^F}$, and gaining disutility from the labor l_t (Tavakolian & Ghiaie, 2019). The households tend to maximize their utilities

that are discounted by β , as the intertemporal preference subject to constraints in Equations (3) and (7).

$$\text{Max } E_0 \sum_{t=0}^{\infty} \beta^t U_i \left(C_t, \frac{M_t}{P_t}, l_t, \frac{M_t^S}{P_t^f} \right) \tag{1}$$

$$U_i = \frac{c_{t,i}^{1-\sigma_c}}{1-\sigma_c} + \frac{\chi_m}{1-\sigma_m} \left(\frac{M_{t,i}}{P_t} \right)^{1-\sigma_m} - \frac{\chi_l l_t^{1+\sigma_l}}{1+\sigma_l} + \frac{\chi_{ms}}{1-\sigma_{ms}} \left(\frac{M_{t,i}^S}{P_t^f} \right)^{1-\sigma_{ms}} \tag{2}$$

Where σ_c is the consumption substitution elasticity, σ_m is the inverse of the elasticity of money balances, σ_{ms} is the inverse of the elasticity of foreign currencies held, and σ_l is the Frisch elasticity of labor supply.

The households' total income from supplying capital K_t , by the return r_t , and labor, by wage w_t , to the domestic production sector, from the principle and interest of bonds issued by the government $(1 + i_{t-1}) \frac{b_{t-1}}{\pi_t}$, from the transfer payment TP_t , and from the profit of household-own firms D_t should be equal to its total payments_ in the form of investment I_t , bonds issued by the government b_t , consumption c_t , and the domestic money m_t and foreign currencies m_t^S held by the rate of real exchange re_t and the taxes_ in the form of income tax and consumption tax in the rates of t_t^W and t_t^{VA} , respectively:

$$c_t(1 + t_t^{VA}) + \frac{P_t^I}{P_t} I_t + m_t + b_t + re_t \cdot m_t^S = w_t l_t (1 - t_t^W) + (1 + i_{t-1}) \frac{b_{t-1}}{\pi_t} + \frac{m_{t-1}}{\pi_t} + r_t \cdot K_{t-1} + re_{t-1} \cdot \gamma_t \frac{m_{t-1}^S}{\pi_t} + TP_t + D_t \tag{3}$$

Where P_t , P_t^f , s_t , γ_t , and π_t are domestic price index, foreign price index, nominal exchange rate, nominal exchange rate growth, and inflation rate, respectively (Equations 4-6).

$$re_t = \frac{s_t P_t^*}{P_t} \tag{4}$$

$$\gamma_t = \frac{s_t}{s_{t-1}} \tag{5}$$

$$\pi_t = \frac{P_t}{P_{t-1}} \tag{6}$$

According to Rotemberg (1982), the capital accumulated by the households, considering the adjustment cost of investment $j(\frac{I_t}{I_{t-1}})$ and the rate of depreciation δ (as the second constraint on the households) can be calculated as follows:

$$k_t = k_{t-1}(1 - \delta) + \left[1 - j\left(\frac{I_t}{I_{t-1}}\right) \right] I_t \tag{7}$$

$$j_t = \frac{\varphi_I}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \tag{8}$$

By considering q_t as the marginal Tobin's Q^1 , household maximization problem results in the consumption Euler equation, money demand, foreign currency demand, investment Euler equation, supply of labor, and capital pricing dynamics, as shown below, respectively:

¹ Tobin's Q is the ratio of two Lagrangian multipliers ($q_t = \frac{\lambda_t}{\mu_t}$).

$$E_t \frac{c_t^{-\sigma_c}}{c_{t+1}^{-\sigma_c}} = \beta E_t \left(\frac{1+i_t}{\pi_t} \right) \quad (9)$$

$$m_t^{-\sigma_m} = \frac{c_t^{-\sigma_c}}{\chi_m(1+t^{va})} \left(\frac{i_t}{1+i_t} \right) \quad (10)$$

$$m_t^{s-\sigma_{ms}} = \frac{r e_t c_t^{-\sigma_c}}{\chi_{ms}(1+t^{va})} \left[1 - E_t \left(\frac{y_{t+1}}{1+i_t} \right) \right] \quad (11)$$

$$\frac{P_t^l}{P_t} = q_t \left[1 - j_t \left(\frac{l_t}{l_{t-1}} \right) - \left(\frac{l_t}{l_{t-1}} \right) j_t' \left(\frac{l_t}{l_{t-1}} \right) \right] + E_t q_{t+1} \frac{\pi_{t+1}}{1+i_t} \left(\frac{l_{t+1}}{l_t} \right)^2 j_t' \left(\frac{l_{t+1}}{l_t} \right) \quad (12)$$

$$l_t^{\sigma_l} = \frac{c_t^{-\sigma_c}}{\chi_l(1+t^{va})} w_t (1-t^w) \quad (13)$$

$$q_t = E_t \left(\frac{\pi_{t+1}}{1+i_t} \right) [r_{t+1} + (1-\delta)q_{t+1}] \quad (14)$$

A constant elasticity of substitution (CES) function of domestically produced consumption c_t^d and imported consumption c_t^{pm} formed the aggregate consumption with the elasticity of θ_c . The share of domestically produced goods in the consumption was α_c . P_t^{cd} and P_t^{cm} in the total consumption expenditure in Equation (16) denote domestically produced price index and imported consumption goods price index, respectively.

$$c_t = \left[\alpha_c^{\frac{1}{\theta_c}} c_t^d \frac{\theta_c-1}{\theta_c} + (1-\alpha_c)^{\frac{1}{\theta_c}} c_t^{pm} \frac{\theta_c-1}{\theta_c} \right]^{\frac{\theta_c}{\theta_c-1}} \quad (15)$$

$$P_t c_t = P_t^{cd} c_t^d + P_t^{cm} c_t^{pm} \quad (16)$$

The households tend to minimize their expenditure; therefore, their demands for domestic consumption, imported consumption, and consumption price index will be as follows:

$$c_t^d = \alpha_c \left(\frac{P_t^{cd}}{P_t} \right)^{-\theta_c} c_t \quad (17)$$

$$c_t^{pm} = (1-\alpha_c) \left(\frac{P_t^{cm}}{P_t} \right)^{-\theta_c} c_t \quad (18)$$

$$P_t^{1-\theta_c} = \alpha_c P_t^{cd 1-\theta_c} + (1-\alpha_c) P_t^{cm 1-\theta_c} \quad (19)$$

A CES function was used to break up the domestic productions into energy and non-energy products by considering θ_e and α_e as their elasticity of substitution and the share of each one in the domestic products:

$$c_t^d = \left[\alpha_e^{\frac{1}{\theta_e}} c_t^e \frac{\theta_e-1}{\theta_e} + (1-\alpha_e)^{\frac{1}{\theta_e}} c_t^{ne} \frac{\theta_e-1}{\theta_e} \right]^{\frac{\theta_e}{\theta_e-1}} \quad (20)$$

Based on the households' intention to minimize the expenditures, the households' demands for the consuming energy and non-energy goods and domestic consumption goods price can be shown as follows:

$$c_t^e = \alpha_e \left(\frac{P_t^e}{P_t^{cd}} \right)^{-\theta_e} c_t \quad (21)$$

$$c_t^{ne} = (1-\alpha_e) \left(\frac{P_t^{ne}}{P_t^{cd}} \right)^{-\theta_e} c_t \quad (22)$$

$$P_t^{cd 1-\theta_e} = \alpha_e P_t^{e 1-\theta_e} + (1-\alpha_e) P_t^{ne 1-\theta_e} \quad (23)$$

According to Algret and Bin Khodja (2015), due to the subsidy, the price of energy is equal to the weighted combination of the previous price of energy and

the world oil price P_t^{of} , in which α_s ($0 \leq \alpha_s \leq 1$) is the share of world oil price in the subsidized price of energy.

$$P_t^e = (1 - \alpha_s) P_{t-1}^e + \alpha_s S_t P_t^{of} \tag{24}$$

The households gain their total investment from domestic I_t^d and imported investment goods I_t^{pm} in the form of a CES function, in which θ_I and α_I are the elasticity of substitution and the share of each one in the total investment:

$$I_t = \left[\alpha_I^{\frac{1}{\theta_I}} I_t^d^{\frac{\theta_I-1}{\theta_I}} + (1 - \alpha_I)^{\frac{1}{\theta_I}} I_t^{pm}^{\frac{\theta_I-1}{\theta_I}} \right]^{\frac{\theta_I}{\theta_I-1}} \tag{25}$$

$$P_t^I I_t = P_t^{Id} I_t^d + P_t^{Im} I_t^m \tag{26}$$

In Equation (26), which represents the total investment expenditure, P_t^I , P_t^{Id} , and P_t^{Im} denote investment price index, the price of domestic investment goods, and the price of imported investment goods, respectively. The households' demands investment from domestic and imported goods by minimizing the expenditures can be calculated as follows:

$$I_t^d = \alpha_I \left(\frac{P_t^{Id}}{P_t^I} \right)^{-\theta_I} I_t \tag{27}$$

$$I_t^{pm} = (1 - \alpha_I) \left(\frac{P_t^{Im}}{P_t^I} \right)^{-\theta_I} I_t \tag{28}$$

In which the investment price can be shown as follows:

$$P_t^{I1-\theta_I} = \alpha_I P_t^{Id1-\theta_I} + (1 - \alpha_I) P_t^{Im1-\theta_I} \tag{29}$$

3.2 Labor Market

Following Erceg et al. (2000), in this study, the competitive market was assumed to be monopolistic, in which the household supplies a heterogeneous labor force to the intermediate goods and the oil-producing firms determine the wages and the amount of labor. In such a market, one aggregator buys all of the services provided by the labor forces (Dixit & Stiglitz, 1983) and combines them by the elasticity of θ_l .

$$l_t = \left[\int_0^1 l_t(i)^{\frac{\theta_l-1}{\theta_l}} di \right]^{\frac{\theta_l}{\theta_l-1}} \tag{30}$$

The aggregator determines the labor demand from each household by maximizing its profit:

$$Max_{l_t(i)} w_t l_t - \int_0^1 l_t(i) w_t(i) di \tag{31}$$

$$l_t(i) = \left[\frac{w_t(i)}{w_t} \right]^{-\theta_l} l_t \tag{32}$$

By substituting Equation (32) into Equation (30), the wage can be shown as follows:

$$w_t = \left[\int_0^1 w_t(i)^{1-\theta_l} di \right]^{\frac{1}{1-\theta_l}} \tag{33}$$

According to Calvo (1983), households cannot determine the optimum wage in a monopolistic competitive market due to price rigidity. Thus, the households

can only adjust the optimum wage w_t^* in the probability of $1 - v_w$ and follow the rule of thumbs and adjust the inflation rates by wage indexation in the degree τ_w (Equation 34) to be able to determine the wage with the probability of v_w in each period:

$$w_{t+1}(i) = (\pi_t)^{\tau_w} w_t(i) \tag{34}$$

The representative household determines the wage in the way that minimizes its labor disutility by considering v_w as the probability of not readjusting the wage up to s periods:

$$Min E_0 \sum_{s=0}^{\infty} (\beta v_w)^s \left(-\frac{\chi l_{t+s}^{1+\sigma_l}(i)}{1+\sigma_l} + \lambda_{t+s} \frac{w_{t+s}(i)}{P_{t+s}} l_{t+s}(i)(1 - t^w) \right) \tag{35}$$

Where, in each period, v_w percentage of the households cannot adjust their wages to the optimum level and just $1 - v_w$ percentage of the households will be able to adjust the nominal wage:

$$w_t^{1-\theta_l} = v_w [(\pi_{t-1})^{\tau_w} w_{t-1}]^{1-\theta_l} + (1 - v_w) w_t^*{}^{1-\theta_l} \tag{36}$$

Determining the wage process resulted in the log-linearized New Keynesian Phillips curve for the wage:

$$\begin{aligned} \left(\frac{A}{1-v_w} - \sigma_l \theta_l \right) \widehat{w}_t &= \frac{A v_w}{1-v_w} \widehat{w}_{t-1} + \frac{A v_w \tau_w}{1-v_w} \widehat{\pi}_{t-1} + \beta \sigma_l \theta_l v_w E(\widehat{w}_{t+1}) \\ &+ \beta v_w (1 + \sigma_l \theta_l) E(\widehat{\pi}_{t+1}) - \left[\frac{A v_w}{1-v_w} + \beta v_w \tau_w (1 + \sigma_l \theta_l) \right] \widehat{\pi}_t \tag{37} \\ &+ \sigma_c [\widehat{c}_t + \beta v_w \sigma_l E(\widehat{c}_{t+1})] + \sigma_l [\widehat{l}_t + \beta v_w \sigma_l E(\widehat{l}_{t+1})] \end{aligned}$$

$$\text{Where } A = \frac{1+\sigma_l \theta_l}{(1-\beta v_w)}.$$

3.3 Intermediate Good Producing Firms

According to Balke and Brown (2018), the intermediate-good-producing firms use the labor force l_t^y , capital services Ksc_t , and inputs In_t by the price P_t^{In} , and produce the intermediate products y_t^{no} in a Cobb-Douglas form. Capital services are the function of capital accumulation, energy, and government capital accumulation as follows:

$$y_t^{no}(j) = A_t Ksc_t(j)^\alpha l_t^y(i)^\omega In_t(j)^{1-\alpha-\omega} \tag{38}$$

$$Ksc(j) = k_{t-1}^y(j)^\varepsilon e_t(j)^{1-\varepsilon} k_{t-1}^G \tag{39}$$

The demands of the producing firm for labor, capital, intermediate goods, and energy and its marginal cost were obtained by minimizing its expenditure:

$$l_t^y(i) = \omega mc_t \frac{y_t^{no}(i)}{w_t} \tag{40}$$

$$k_{t-1}^y(i) = \alpha \varepsilon mc_t \frac{y_t^{no}(i)}{r_t} \tag{41}$$

$$e_t(i) = \alpha (1 - \varepsilon) mc_t y_t^{no}(i) \frac{P_t}{P_t^\varepsilon} \tag{42}$$

$$In_t(i) = (1 - \alpha - \omega) mc_t y_t^{no}(i) \frac{P_t}{P_t^{In}} \tag{43}$$

$$mc_t = \frac{r_t^{\alpha \varepsilon} \left(\frac{P_t^\varepsilon}{P_t} \right)^{\alpha(1-\varepsilon)} w_t \omega \left(\frac{P_t^{In}}{P_t} \right)^{(1-\alpha-\omega)} A_t k_{t-1}^G}{\alpha \varepsilon^{\alpha \varepsilon} \alpha (1-\varepsilon)^{\alpha(1-\varepsilon)} \omega^\omega (1-\alpha-\omega)^{(1-\alpha-\omega)} A_t k_{t-1}^G} \tag{44}$$

Producing firms separate their products to supply the domestic and foreign markets with non-oil exports in the amount of y_t^d and y_t^x and the prices of P_t^d and $s_t P_t^x$, respectively, and in the form of a constant elasticity of transformation (CET) function following the CGE model.

$$y_t^{no}(i) = \left[\alpha_y \frac{1}{\theta_y} y_t^d(i)^{\frac{\theta_y+1}{\theta_y}} + (1 - \alpha_y) \frac{1}{\theta_y} y_t^x(i)^{\frac{\theta_y+1}{\theta_y}} \right]^{\frac{\theta_y}{\theta_y+1}} \tag{45}$$

Producing firms maximize their profits to determine supply to the foreign and domestic markets:

$$y_t^x(i) = (1 - \alpha_y) \left(\frac{s_t P_t^x}{P_t^y} \right)^{\theta_y} y_t^{no}(i) \tag{46}$$

$$y_t^d(i) = \alpha_y \left(\frac{P_t^d}{P_t^y} \right)^{\theta_y} y_t^{no}(i) \tag{47}$$

Where the intermediate goods price index P_t^y , is as follows:

$$P_t^y(i)^{1+\theta_y} = \alpha_c P_t^d(i)^{1+\theta_y} + (1 - \alpha_c) [s_t P_t^x(i)]^{1+\theta_y} \tag{48}$$

According to the Walras's law, the price of domestic products P_t^d , is equal to the price of domestically produced goods demanded by households, government, and intermediate firms (P_t^{cd} , P_t^{id} , and P_t^{ind}). Monopolistic competitive markets were assumed to be responsible for supplying producing firm products to the foreign and domestic markets. Here, the domestic monopolistic competitive market is presented and the foreign market is presented later in Section 3.4.1. According to [Dixit and Stiglitz \(1983\)](#), one aggregator buys all of the goods supplied by the producing firms in a domestic monopolistic competitive market by the substitution elasticity of θ_d :

$$y_t^d = \left[\int_0^1 y_t^d(i)^{\frac{\theta_d-1}{\theta_d}} di \right]^{\frac{\theta_d}{\theta_d-1}} \tag{49}$$

Where the demand from each supplier and the domestic products price index considering the minimum profit are, respectively, as follows:

$$y_t^d(i) = \left[\frac{P_t^d(i)}{P_t^d} \right]^{-\theta_d} y_t^d \tag{50}$$

$$P_t^d = \left[\int_0^1 P_t^d(i)^{1-\theta_d} di \right]^{\frac{1}{1-\theta_d}} \tag{51}$$

Assuming the price rigidity proposed by [Calvo \(1983\)](#), only $1 - v_d$ percentage of the firms can determine their optimal prices in the price P_t^{d*} . For the rest of the firms, the prices are determined according to the inflation of the previous periods adjusted by the degree of domestic price indexation τ_d , as shown below:

$$P_{t+1}^d(i) = (\pi_t^d)^{\tau_d} P_t^d(i) \tag{52}$$

Where, according to Equation (51), the domestically produced goods price index is as follows:

$$P_t^{d^{1-\theta_d}} = v_d [(\pi_{t-1}^d)^{\tau_d} P_{t-1}^d]^{1-\theta_d} + (1 - v_d) P_t^{d*^{1-\theta_d}} \tag{53}$$

The firms maximize their expected discounted profits, which are subject to Equations 50 and 53, to determine the price in the way that they cannot adjust their prices in the probability of v_d up to s periods:

$$\text{Max } E_0 \sum_{s=0}^{\infty} (\beta v_d)^s \left(\frac{\lambda_{t+s}}{\lambda_t} \right) \left(\frac{P_{t+s}^d(i)}{P_{t+s}^d} - m c_{t+s} \right) y_{t+s}^d(i) \quad (54)$$

Where the New Keynesian Philips curve for the domestic price in the log-linearized form can be shown as follows:

$$\hat{\pi}_t^d = \frac{v_d}{1+\beta v_d} \hat{\pi}_{t-1}^d + \frac{\beta}{1+\beta v_d} \hat{\pi}_{t+1}^d + \frac{(1-v_d)(1-\beta v_d)}{v_d(1+\beta v_d)} \widehat{m\bar{c}}_t \quad (55)$$

On other hand, the intermediate firms receive their intermediate input from the domestic market In_t^d and import In_t^m , which combine together in the CES process with the substitution elasticity of θ_{In} :

$$In_t = \left[\alpha_{In} \frac{1}{\theta_{In}} In_t^d \frac{\theta_{In}-1}{\theta_{In}} + (1 - \alpha_{In}) \frac{1}{\theta_{In}} In_t^m \frac{\theta_{In}-1}{\theta_{In}} \right]^{\frac{\theta_{In}}{\theta_{In}-1}} \quad (56)$$

On the basis of the optimization behavior, the intermediate firm demands domestic input In_t^d by the price of P_t^{Ind} and imported inputs In_t^m by the price of P_t^{Inm} :

$$In_t^d = \alpha_{In} \left(\frac{P_t^{Ind}}{P_t^{In}} \right)^{-\theta_{In}} In_t \quad (57)$$

$$In_t^m = (1 - \alpha_{In}) \left(\frac{P_t^{Inm}}{P_t^{In}} \right)^{-\theta_{In}} In_t \quad (58)$$

Where the input price index can be calculated by substituting Equations (57) and (58) into Equation (56):

$$P_t^{In} 1^{-\theta_{In}} = \alpha_{In} P_t^{Ind} 1^{-\theta_{In}} + (1 - \alpha_{In}) P_t^{Inm} 1^{-\theta_{In}} \quad (59)$$

3.4 Trade Sector

In this study, the trade sector was divided into two sections, i.e. export and import, to analyze the effects of international financial sanctions, as one of the two sanctions considered in the study.

3.4.1 Exports

The intermediate goods firms sell some of their products to foreign markets as exports in a manner that reflects monopolistic competition. Similar to what was mentioned earlier, there is one aggregator that purchases and aggregates the supplied export products to sell them to the foreign markets:

$$y_t^x = \left[\int_0^1 y_t^x(i) \frac{\theta_x-1}{\theta_x} di \right]^{\frac{\theta_x}{\theta_x-1}} \quad (60)$$

Where θ_x is the substitution elasticity of the exporting products of the intermediate firm. The aggregator demand from each exporter is shown below:

$$y_t^x(i) = \left[\frac{P_t^x(i)}{P_t^x} \right]^{-\theta_x} y_t^x \quad (61)$$

And the export price index is as follows:

$$P_t^x = \left[\int_0^1 P_t^x(i)^{1-\theta_x} di \right]^{\frac{1}{1-\theta_x}} \tag{62}$$

Assuming the price rigidity proposed by Calvo (1983), only $1 - v_x$ percentage of the exporters can determine their optimal prices in the price P_t^{x*} . For the rest of the exporters, the prices are determined according to the inflation of the previous periods adjusted by the degree of export price indexation τ_x , as shown below:

$$P_{t+1}^x(i) = (\pi_t^x)^{\tau_x} P_t^x(i) \tag{63}$$

Where, according to Equation (62), the export price index can be calculated as follows:

$$P_t^{x^{1-\theta_x}} = v_x [(\pi_{t-1}^x)^{\tau_x} P_{t-1}^x]^{1-\theta_x} + (1 - v_x) P_t^{x*^{1-\theta_x}} \tag{64}$$

The problem is that each exporter chooses P_t^{x*} to maximize the expected discounted sum of profits, which is subject to Equations (61) and (64), in a way that it cannot adjust its prices in the probability of v_x up to s periods:

$$Max E_0 \sum_{s=0}^{\infty} (\beta v_x)^s \left(\frac{\lambda_{t+s}}{\lambda_t} \right) \left(\frac{P_{t+s}^{x*}(i)}{P_{t+s}^x} - mc_{t+s}^x \right) y_{t+s}^x(i) \tag{65}$$

Where ultimately log-linearized New Keynesian Philips curve of the export price is:

$$\hat{\pi}_t^x = \frac{v_x}{1+\beta v_x} \hat{\pi}_{t-1}^x + \frac{\beta}{1+\beta v_x} \hat{\pi}_{t+1}^x + \frac{(1-v_x)(1-\beta v_x)}{v_x(1+\beta v_x)} \widehat{mc}_t^x \tag{66}$$

On the one hand, the exporter purchases the intermediate producing firm products at the price of P_t^d to sell them to foreign customers at the exchange price of P_t^x . On the other hand, the international financial sanctions increase the export financial costs S_t^x , through by raising transportation charges in shipping, insurance, etc. Thus, the marginal cost for each exporter can be shown as follows:

$$mc_t^x = \frac{P_t^d}{s_t P_t^x} S_t^x \tag{67}$$

Export financial costs follow an autoregressive process degree 1 (AR (1)). The sanctions increase these costs through parameter ssx , which is the elasticity of S_t^x following the intensification of economic sanctions, as shown below:

$$\ln S_t^x = (1 - \rho_x) \ln \bar{S}^x + \rho_x \ln S_{t-1}^x + ssx \cdot sanc_t + \varepsilon_t^x \varepsilon_t^x \sim i. i. d. N(0, \sigma_{ssx}^2) \tag{68}$$

Where \bar{S}^x is the value of the steady-state of the export financial cost.

3.4.2 Imports

Importing firms can be active in three areas: consumption goods, investment goods, and intermediate inputs.

The firms importing consumption goods purchase their needed goods from foreign and sell them to domestic consumers, such as households and government, in a monopolistic competitive market. Indeed, one aggregator buys the imported consumption goods from importers to sell them to the domestic markets in the substitution elasticity of θ_{cm} :

$$c_t^M = \left[\int_0^1 c_t^M(i)^{\frac{\theta_{cm}-1}{\theta_{cm}}} di \right]^{\frac{\theta_{cm}}{\theta_{cm}-1}} \tag{69}$$

The aggregator minimizes its profit to determine both the demand from each of the consumption goods importers and the imported consumption goods price:

$$c_t^M(i) = \left[\frac{P_t^{cm}(i)}{P_t^{cm}} \right]^{-\theta_{cm}} c_t^M \quad (70)$$

$$P_t^{cm} = \left[\int_0^1 P_t^{cm}(i)^{1-\theta_{cm}} di \right]^{\frac{1}{1-\theta_{cm}}} \quad (71)$$

Following Calvo (1983), only $1 - v_{cm}$ percentage of the importers of consumption goods can determine their optimal prices at the price of P_t^{cm*} . For the rest of the importers, the prices are determined according to the inflation of the previous periods adjusted by the degree of imported consumption goods prices indexation τ_{cm} , as shown below:

$$P_{t+1}^{cm}(i) = (\pi_t^{cm})^{\tau_{cm}} P_t^{cm}(i) \quad (72)$$

Where, according to Equation (71), the imported consumption price index can be calculated as follows:

$$P_t^{cm^{1-\theta_{cm}}} = v_{cm} [(\pi_{t-1}^{cm})^{\tau_{cm}} P_{t-1}^{cm}]^{1-\theta_{cm}} + (1 - v_{cm}) P_t^{cm*^{1-\theta_{cm}}} \quad (73)$$

Each importer of the consumption goods decides to choose P_t^{cm*} to maximize the sum of its expected profits, which is subject to Equations (70) and (73), in the discounted form in a way that it cannot adjust its prices in the probability of v_{cm} up to s periods:

$$\text{Max } E_0 \sum_{s=0}^{\infty} (\beta v_{cm})^s \left(\frac{\lambda_{t+s}}{\lambda_t} \right) \left(\frac{P_{t+s}^{cm*}(i)}{P_{t+s}^{cm}} - m c_{t+s}^{cm} \right) c_{t+s}^M(i) \quad (74)$$

Eventually, the New Keynesian Philips curve of the imported consumption goods price in the log-linearized form can be shown as follows:

$$\hat{\pi}_t^{cm} = \frac{v_{cm}}{1+\beta v_{cm}} \hat{\pi}_{t-1}^{cm} + \frac{\beta}{1+\beta v_{cm}} \hat{\pi}_{t+1}^{cm} + \frac{(1-v_{cm})(1-\beta v_{cm})}{v_{cm}(1+\beta v_{cm})} \hat{m} c_t^{cm} \quad (75)$$

On the one hand, importers buy the consumption goods needed from the foreign markets at the price of P_t^f and sell them to domestic customers at the price of P_t^{cm} . On the other hand, the international financial sanctions increase the import financial costs S_t^{cm} , by raising transportation charges in shipping, insurance, etc. Thus, the marginal cost for the importers of consumption goods can be measured based on the following equation:

$$m c_t^{cm} = \frac{s_t P_t^f}{P_t^{cm}} S_t^{cm} \quad (76)$$

The import financial costs follow an AR (1). Sanctions increase these costs through parameter scm , which is the elasticity of S_t^{cm} following the intensification of economic sanctions, as shown below:

$$\ln S_t^{cm} = (1 - \rho_{scm}) \ln S_{t-1}^{cm} + \rho_{scm} \ln S_{t-1}^{cm} + scm \cdot sanc_t + \varepsilon_t^{cm} \quad (77)$$

$\varepsilon_t^{cm} \sim i. i. d. N(0, \sigma_{scm}^2)$

The second kind of import firms is referred to as importers of investment goods. They purchase the needed investment goods from the foreign market and sell them to domestic investors, such as households and government. Importers of investment goods operate as monopolistic competitive firms. One aggregator buys the imported goods from the importers by the substitution elasticity of θ_{Im} and aggregates them to sell them in the domestic markets:

$$I_t^M = \left[\int_0^1 I_t^M(i)^{\frac{\theta_{Im}-1}{\theta_{Im}}} di \right]^{\frac{\theta_{Im}}{\theta_{Im}-1}} \tag{78}$$

The aggregator demand from each importer of the investment goods can be shown as follows:

$$I_t^M(i) = \left[\frac{P_t^{Im}(i)}{P_t^{Im}} \right]^{-\theta_{Im}} I_t^M \tag{79}$$

Where the imported investment goods price is:

$$P_t^{Im} = \left[\int_0^1 P_t^{Im}(i)^{1-\theta_{Im}} di \right]^{\frac{1}{1-\theta_{Im}}} \tag{80}$$

Following Calvo (1983), only $1 - v_{im}$ percentage of the importers of investment goods can determine their optimal prices at the price of P_t^{Im*} . For the rest of the importers, the prices are determined according to the inflation of the previous periods adjusted by the degree of imported investments prices indexation τ_{im} , as shown below:

$$P_{t+1}^{Im}(i) = (\pi_t^{Im})^{\tau_{im}} P_t^{Im}(i) \tag{81}$$

Where, according to Equation (80), the imported investment price index can be calculated as follows:

$$P_t^{Im^{1-\theta_{Im}}} = v_{Im} [(\pi_{t-1}^{Im})^{\tau_{im}} P_{t-1}^{Im}]^{1-\theta_{Im}} + (1 - v_{Im}) P_t^{Im*^{1-\theta_{Im}}} \tag{82}$$

Each importer of investment goods decides to set P_t^{Im*} to maximize the expected discounted sum of its profits, which is subject to Equations (79) and (82), in the way that it cannot adjust its prices in the probability of v_{Im} up to s periods:

$$Max E_0 \sum_{s=0}^{\infty} (\beta v_{Im})^s \left(\frac{\lambda_{t+s}}{\lambda_t} \right) \left(\frac{P_{t+s}^{Im*}(i)}{P_{t+s}^{Im}} - mc_{t+s}^{Im} \right) I_{t+s}^M(i) \tag{83}$$

Where the log-linearized New Keynesian Philips curve of the imported investment goods price is as follows:

$$\hat{\pi}_t^{Im} = \frac{v_{Im}}{1+\beta v_{Im}} \hat{\pi}_{t-1}^{Im} + \frac{\beta}{1+\beta v_{Im}} \hat{\pi}_{t+1}^{Im} + \frac{(1-v_{Im})(1-\beta v_{Im})}{v_{Im}(1+\beta v_{Im})} \widehat{mc}_t^{Im} \tag{84}$$

Similar to the importers of consumption goods, the marginal cost for the importers of the investment goods can be calculated as follows:

$$mc_t^{Im} = \frac{s_t P_t^f}{P_t^{Im}} S_t^{Im} \tag{85}$$

The financial costs of importing investment goods follow an AR (1) process. Sanctions affect these costs through parameter sim , which is the elasticity of S_t^{Im} following the intensification of economic sanctions, as shown in the following equation:

$$\ln S_t^{Im} = (1 - \rho_{Im}) \ln \overline{S^{Im}} + \rho_{Im} \ln S_{t-1}^{Im} + s sim . sanc_t + \varepsilon_t^{Im} \tag{86}$$

$\varepsilon_t^{Im} \sim i. i. d. N(0, \sigma_{sIm}^2)$

The third kind of import firms is referred to as the importers of intermediate inputs. There is one aggregator in a monopolistic competitive market that purchases the imported intermediate inputs from the importers by the substitution elasticity of θ_{Im} and aggregates them to sell them in the domestic market:

$$In_t^m = \left[\int_0^1 In_t^m(i)^{\frac{\theta_{Inm}-1}{\theta_{Inm}}} di \right]^{\frac{\theta_{Inm}}{\theta_{Inm}-1}} \quad (87)$$

The aggregator demand from each importer of the intermediate inputs and the imported intermediate input price can be shown as follow, respectively:

$$In_t^m(i) = \left[\frac{P_t^{Inm}(i)}{P_t^{Inm}} \right]^{-\theta_{Inm}} In_t^m \quad (88)$$

$$P_t^{Inm} = \left[\int_0^1 P_t^{Inm}(i)^{1-\theta_{Inm}} di \right]^{\frac{1}{1-\theta_{Inm}}} \quad (89)$$

Following Calvo (1983), only $1 - v_{Inm}$ percentage of the importers of the intermediate goods can determine their optimal prices at the price P_t^{Inm*} . For the rest of the importers, the prices are determined according to the inflation of the previous periods adjusted by the degree of imported input prices indexation τ_{Inm} , as shown in the following equation:

$$P_{t+1}^{Inm}(i) = (\pi_t^{Inm})^{\tau_{Inm}} P_t^{Inm}(i) \quad (90)$$

Where, according to Equation (89), the imported intermediate input price index is as follows:

$$P_t^{Inm} = v_{Inm} [(\pi_{t-1}^{Inm})^{\tau_{Inm}} P_{t-1}^{Inm}]^{1-\theta_{Inm}} + (1 - v_{Inm}) P_t^{Inm*} \quad (91)$$

Each importer of intermediate inputs decides to set P_t^{Inm*} to maximize the expected discounted sum of its profits, which is subject to Equations (88) and (91), in the way that it cannot adjust its prices in the probability of v_{Inm} up to s periods:

$$Max E_0 \sum_{s=0}^{\infty} (\beta v_{Inm})^s \left(\frac{\lambda_{t+s}}{\lambda_t} \right) \left(\frac{P_{t+s}^{Inm}(i)}{P_{t+s}^{Inm}} - mc_{t+s}^{Inm} \right) In_{t+s}^m(i) \quad (92)$$

Where the log-linearized New Keynesian Philips curve of the imported intermediate inputs price is as follows:

$$\hat{\pi}_t^{Inm} = \frac{v_{Inm}}{1+\beta v_{Inm}} \hat{\pi}_{t-1}^{Inm} + \frac{\beta}{1+\beta v_{Inm}} \hat{\pi}_{t+1}^{Inm} + \frac{(1-v_{Inm})(1-\beta v_{Inm})}{v_{Inm}(1+\beta v_{Inm})} \widehat{mc}_t^{Inm} \quad (93)$$

Similar to what was mentioned before, the marginal cost for the importers of intermediate inputs can be calculated as follows:

$$mc_t^{Inm} = \frac{s_t P_t^f}{P_t^{Inm}} S_t^{Inm} \quad (94)$$

The financial costs for importing intermediate inputs follow a AR (1) process. Sanctions affect these costs through parameter $sinm$, which is the elasticity of S_t^{Inm} following the intensification of sanctions, as shown below:

$$\ln S_t^{Inm} = (1 - \rho_{Inm}) \ln \overline{S_t^{Inm}} + \rho_{Inm} \ln S_{t-1}^{Inm} + s sinm \cdot sanc_t + \varepsilon_t^{Inm} \quad (95)$$

$\varepsilon_t^{Inm} \sim i. i. d. N(0, \sigma_{sinm}^2)$

3.5 Oil Sector

The oil industry is one of the main sectors almost always affected by the sanctions. The government-owned oil-producing firm uses labor l_t^o , capital k_t^o , and technology A_t^o to produce the oil y_t^o in a Cobb-Douglas form, as captured in the following equation:

$$y_t^o = A_t^o k_{t-1}^o \xi l_t^o \quad (96)$$

The firm tends to maximize its profit; thus, the demands for its inputs in the form of first-order conditions can be expressed as follows:

$$k_{t-1}^o = \xi \frac{P_t^o y_t^o}{r_t} \tag{97}$$

$$l_t^o = (1 - \xi) \frac{P_t^o y_t^o}{w_t} \tag{98}$$

Where P_t^o is the oil price and can be calculated by the following equation:

$$P_t^o = s_t P_t^{ox} \frac{y_t^{ox}}{y_t^o} + P_t^e \frac{e_t}{y_t^o} + P_t^c \frac{c_t^e}{y_t^o} \tag{99}$$

Based on the economic realities of Iran, three kinds of sanctions were considered in this study: Sanctions on oil exports y_t^{ox} , technology, and foreign investment. The sanctions affected the export of oil, technology, and foreign direct investment in the oil industry fdi_t^o in the form of an AR (1) process. The parameters $ssyox$, $ssoa$, and $ssfdio$ are the elasticity of y_t^{ox} , A_t^o , and fdi_t^o due following the intensification of oil sanctions, respectively, as shown below:

$$\ln y_t^{ox} = (1 - \rho_{ox}) \ln \bar{y}^{ox} + \rho_{ox} \ln y_{t-1}^{ox} + ssyox \cdot sanc_t + \varepsilon_t^{ox} \tag{100}$$

$$\ln A_t^o = \rho_{oa} \ln A_{t-1}^o + ssoa \cdot sanc_t + \varepsilon_t^{oa} \tag{101}$$

$$\ln fdi_t^o = (1 - \rho_{fdio}) \ln \bar{f}^{dio} + \rho_{fdio} \ln fdi_{t-1}^o + ssfdio \cdot sanc_t + \varepsilon_t^{fdio} \tag{102}$$

The government-owned oil-producing firm combines the foreign investment I_t^{of} and the government investment I_t^{oG} in a CES function with the substitution elasticity of θ_o to provide total investment I_t^o . Based on the economic realities of Iran (The Sixth Development Plan and the National Iranian Oil Company (NIOC) Statute), γ_o percentage of the exchange revenues gained from oil export should be attributed to the oil-producing firm for investment in the oil industry (Equation (104)). Foreign investment I_t^{oF} in domestic currency is another source of investment in the oil industry (Equation (105)), in which s_t is the nominal exchange rate, as shown below:

$$I_t^o = \left[\alpha_o \frac{1}{\theta_o} I_t^{oG} \frac{\theta_o - 1}{\theta_o} + (1 - \alpha_o) \frac{1}{\theta_o} I_t^{oF} \frac{\theta_o - 1}{\theta_o} \right] \frac{\theta_o}{\theta_o - 1} \tag{103}$$

$$I_t^{oG} = \gamma_o s_t P_t^{of} y_t^{ox} \tag{104}$$

$$I_t^{oF} = s_t fdi_t^o \tag{105}$$

The accumulation of capital in the oil sector by considering the rate of depreciation δ^o can be calculated as follows:

$$k_t^o = k_{t-1}^o (1 - \delta^o) + I_t^o \tag{106}$$

The oil market-clearing condition is as follows:

$$y_t^o = y_t^{ox} + e_t + c_t^e \tag{107}$$

Sanctions on the Iranian oil export leads to an increase in the world price of oil because Iran is one of the key oil-producing countries, but the effect is little because other oil-exporting countries usually increase their oil production to

cancel out the rise in the price of oil. Thus, the world oil price inflation π_t^{of} is affected by the amount of oil exported with the elasticity of ρ_{poff} :

$$\ln \pi_t^{of} = (1 - \rho_{pof}) \ln \overline{\pi^{of}} + \rho_{pof} \ln \pi_{t-1}^{of} + \rho_{poff} y_t^{ox} + \varepsilon_t^{of} \tag{108}$$

$$\varepsilon_t^{of} \sim i. i. d. N(0, \sigma_{of}^2)$$

3.6 Government

Government total revenues from consumption and income taxes, issuing bond sb_t , exchanges earned from $(1 - \gamma_o)$ percentage of oil export, selling oil to households and intermediate firms in the form of energy, and ultimately seigniorage $d_t^G - d_{t-1}^G$ should be equal to its transfer payments TP_t , consumption c_t^G at the price of P_t^{cG} , investment I_t^G at the price of P_t^{IG} , the resources necessary for clearing previous bonds b_{t-1} , and the labor and the capital used in the oil sector.

$$\frac{P_t^{cG}}{P_t} c_t^G + \frac{P_t^{IG}}{P_t} I_t^G + b_{t-1} \frac{(1+i_{t-1})}{\pi_t} + TP_t + w_t l_t^o + r_t k_t^o = t^w w_t l_t \tag{109}$$

$$+ t_t^{VA} \left(c_t + \frac{P_t^{cG}}{P_t} c_t^G \right) + b_t + (1 - \gamma_o) \frac{s_t P_t^{of} y_t^o}{P_t^f} + \frac{P_t^e}{P_t} (c_t^e + e_t) + (d_t^G - d_{t-1}^G)$$

Capital accumulation by government investment and depreciation rate δ^G is shown below:

$$k_{t+1}^G = k_t^G (1 - \delta^G) + I_t^G \tag{110}$$

Government provides its consumption and investment goods from the domestic (c_t^{Gd} and I_t^{Gd}) and imported goods (c_t^{Gm} and I_t^{Gm}), combined in a CES function by the elasticity of substituting θ_{cG} and θ_{IG} , respectively:

$$c_t^G = \left[\alpha_{cG} \frac{1}{\theta_{cG}} c_t^{Gd} \frac{\theta_{cG}-1}{\theta_{cG}} + (1 - \alpha_{cG}) \frac{1}{\theta_{cG}} c_t^{Gm} \frac{\theta_{cG}-1}{\theta_{cG}} \right]^{\frac{\theta_{cG}}{\theta_{cG}-1}} \tag{111}$$

$$I_t^G = \left[\alpha_{IG} \frac{1}{\theta_{IG}} I_t^{Gd} \frac{\theta_{IG}-1}{\theta_{IG}} + (1 - \alpha_{IG}) \frac{1}{\theta_{IG}} I_t^{Gm} \frac{\theta_{IG}-1}{\theta_{IG}} \right]^{\frac{\theta_{IG}}{\theta_{IG}-1}} \tag{112}$$

Demands for domestic and imported consumption and investment goods can be measured based on the government optimization, as shown below, respectively:

$$c_t^{Gd} = \alpha_{cG} \left(\frac{P_t^{cd}}{P_t^{cG}} \right)^{-\theta_{cG}} c_t^G \tag{113}$$

$$c_t^{Gm} = (1 - \alpha_{cG}) \left(\frac{P_t^{cm}}{P_t^{cG}} \right)^{-\theta_{cG}} c_t^G \tag{114}$$

$$I_t^{Gd} = \alpha_{IG} \left(\frac{P_t^{Id}}{P_t^{IG}} \right)^{-\theta_{IG}} I_t^G \tag{115}$$

$$I_t^{Gm} = (1 - \alpha_{IG}) \left(\frac{P_t^{Im}}{P_t^{IG}} \right)^{-\theta_{IG}} I_t^G \tag{116}$$

Where the price indices of the government consumption and investment goods are as follows:

$$P_t^{cG^{1-\theta_{cG}}} = \alpha_{cG} P_t^{cd^{1-\theta_{cG}}} + (1 - \alpha_{cG}) P_t^{cm^{1-\theta_{cG}}} \tag{117}$$

$$P_t^{IG^{1-\theta_{IG}}} = \alpha_{IG} P_t^{IG^{1-\theta_{IG}}} + (1 - \alpha_{IG}) P_t^{IG^{1-\theta_{IG}}} \tag{118}$$

For simplicity, the fiscal policies adopted by the government concerning the consumption and investment goods were considered exogenous in the form of an AR (1):

$$lnc_t^G = (1 - \rho_{cG})lnc_t^G + \rho_{cG}lnc_{t-1}^G + \varepsilon_t^{cG} \quad \varepsilon_t^{cG} \sim i.i.d. N(0, \sigma_{cG}^2) \tag{119}$$

$$lnI_t^G = (1 - \rho_{IG})lnI_t^G + \rho_{IG}lnI_{t-1}^G + \rho_{IGg}ln d_t^G + \varepsilon_t^{IG} \tag{120}$$

$$\varepsilon_t^{IG} \sim i.i.d. N(0, \sigma_{IG}^2)$$

3.7 Central Bank

The combination of government debt to the CB of Iran d_t^G and the net foreign reserves held by the CB of Iran fr_t form monetary base m_t can be shown as follows:

$$m_t = re_t fr_t + d_t^G \tag{121}$$

While the oil export, oil foreign direct investment, and the non-oil exports increase the accumulation of foreign reserves by the CB of Iran, the foreign currencies held by the households and total imports decrease the accumulation of foreign reserves by the CB of Iran, as manifested below:

$$fr_t - \frac{fr_{t-1}}{P_t^f} = \frac{P_t^{of}}{P_t^f} y_t^{ox} + fdi_t^o + \frac{P_t^x}{P_t^f} y_t^x - m_t^s - \frac{(P_t^{cm}c_t^M + P_t^{lm}l_t^M + P_t^{lnm}ln_t^m)}{s_t P_t^f} \tag{122}$$

On the one hand, the CB of Iran adopts some new policies to control the exchange market with a managed floating system in response to the foreign reserves fraction to the monetary base and the differentiation of domestic inflation from foreign inflation π_t^f . Therefore, the log-linearized exchange rate policy can be written as follows:

$$\hat{y}_t = \rho_s \hat{y}_{t-1} + \rho_{ss}(\widehat{re}_t + \widehat{fr}_t - \widehat{m}_t) + \rho_{sss}(\widehat{\pi}_t - \widehat{\pi}_t^f) + \varepsilon_t^s \tag{123}$$

$$\varepsilon_t^s \sim i.i.d. N(0, \sigma_s^2)$$

Where the rate of foreign inflation considered in the form of an AR (1) can be shown as follows:

$$ln\pi_t^f = (1 - \rho_{pf})ln\pi_t^f + \rho_{pf}ln\pi_{t-1}^f + \varepsilon_t^{pf} \quad \varepsilon_t^{pf} \sim i.i.d. N(0, \sigma_{pf}^2) \tag{124}$$

On the other hand, the CB of Iran adopts some new monetary policies, by determining monetary growth \hat{m}_t , in response to the gap between inflation and the inflation target π_t^* , and the gap between the GDP y_t and its steady-state. Accordingly, the current monetary policies in the form of CPI or producer price index (PPI) targeting can be performed with the following log-linearized rules:

$$\widehat{m}_t = \rho_m \widehat{m}_{t-1} + \rho_\pi(\widehat{\pi}_t - \widehat{\pi}_t^*) + \rho_y \widehat{y}_t + \varepsilon_t^m \quad \varepsilon_t^m \sim i.i.d. N(0, \sigma_m^2) \tag{125}$$

$$\widehat{m}_t = \rho_m \widehat{m}_{t-1} + \rho_\pi(\widehat{\pi}_t^d - \widehat{\pi}_t^*) + \rho_y \widehat{y}_t + \varepsilon_t^m \quad \varepsilon_t^m \sim i.i.d. N(0, \sigma_m^2) \tag{126}$$

Where the growth of the monetary base and the rate of target inflation are as follows:

$$\hat{m}_t = \frac{m_t}{m_{t-1}} - \pi_t \tag{127}$$

$$\ln \pi_t^* = (1 - \rho_{p^*}) \ln \bar{\pi}^* + \rho_{p^*} \ln \pi_{t-1}^* + \varepsilon_t^{p^*} \quad \varepsilon_t^{p^*} \sim i. i. d. N(0, \sigma_{p^*}^2) \quad (128)$$

Instead of the current monetary policies mentioned in Equations (125) and (126), the CB of Iran can use optimal monetary policies by optimizing its loss function. In the present study, the optimal simple rule (OSR) was considered to analyze various optimal monetary policies with CPI and PPI inflation targeting to chooses the appropriate policy with less loss function. Therefore, the loss function presented below was considered by the CB of Iran.

$$L = \lambda_1 var(\widehat{\pi}_t) + \lambda_2 var(\widehat{y}_t) \quad (129)$$

Where λ_1 and λ_2 are the weights of inflation and output gaps in the loss function.

3.8 Clearing Conditions

Some more equations had to be added to the model to complete and close the model and clear the total economy (Equations (130-134)), the labor market (Equation (135)), and the market for domestic goods (Equation (136)). These equations are presented below:

$$y_t = c_t + \frac{P_t^{cG} c_t^G}{P_t} + \frac{P_t^I I_t + P_t^{IG} I_t^G}{P_t} + \frac{X_t}{P_t} - \frac{M_t}{P_t} \quad (130)$$

$$X_t = P_t^x y_t^x + S_t P_t^{of} y_t^{ox} \quad (131)$$

$$M_t = P_t^{cm} c_t^M + P_t^{Im} I_t^M + P_t^{Inm} I_n^m \quad (132)$$

$$c_t^M = c_t^{pm} + c_t^{Gm} \quad (133)$$

$$I_t^M = I_t^{pm} + I_t^{Gm} \quad (134)$$

$$l_t = l_t^y + l_t^o \quad (135)$$

$$y_t^d = c_t^{ne} + c_t^{gd} + I_t^d + I_t^{gd} + I_n^d \quad (136)$$

4. Calibration of Parameters

Before simulating the shocks caused by the imposition of sanctions, a calibration method was used to calibrate the model parameters, as suggested by Chen et al. (2012) and Angelopoulos et al. (2010). The time series of all macroeconomic variables extracted from economic databases, such as CB of Iran (www.tsd.cbi.ir) and the Statistical Center of Iran (SCI; www.amar.org.ir), and their geometric means were calculated as the steady-state values according to the available data. Some of these values are shown in Table 2.

Table 2. Steady-state values of the main variables

Variable	\bar{y}	$\frac{\bar{c}}{\bar{y}}$	$\frac{\bar{i}}{\bar{y}}$	$\frac{\bar{c}_g}{\bar{y}}$	$\frac{\bar{i}_g}{\bar{y}}$	$\frac{\bar{y}_x}{\bar{y}}$	$\frac{\bar{y}_o}{\bar{y}}$	$\frac{\bar{y}_{ox}}{\bar{y}}$	$\frac{\bar{m}}{\bar{y}}$	$\frac{\bar{p}_l}{\bar{p}}$	$\frac{\bar{p}_d}{\bar{p}}$	$\frac{\bar{p}_x}{\bar{p}}$
Steady-state value	1	0.45	0.23	0.12	0.09	0.086	0.22	0.179	0.12	1.131	0.999	1.25

Source: Current research.

Most of the parameters were calculated by considering the steady-state values of the variables in the static nonlinear equations of the model using Maple

software. The rest of the parameters were estimated using Eviews software or taken from other studies, as shown in Table 3.

Table 3. Calibrated parameters

Parameter	Description	value	Source
β	Intertemporal discount factor	0.965	Current research
α	The share of capital services in the production of intermediate goods	0.4	Current research
ε	The share of capital in capital services	0.9	Current research
ω	The share of labor in the production of intermediate goods	0.3	Current research
ξ	The share of capital in the production of oil	0.9	Current research
σ_c	The elasticity of the intertemporal substitution of consumption	1.2	Current research
σ_m	The inverse of the interest elasticity of real balances	1.25	Current research
σ_{ms}	The inverse of the interest elasticity of real foreign currencies held by different agents	1.3	Current research
σ_l	Frisch labor elasticity	2.9	Current research
φ_I	The elasticity of investment adjustment costs	0.25	Current research
δ	The depreciation rate of private capital	0.0103	Current research
δ^G	The depreciation rate of government capital	0.0233	Current research
δ^o	The depreciation rate of capital in the oil sector	0.0137	Current research
θ_c	The substitution elasticity of domestic and imported consumption by the households	2.16	Current research
θ_e	The substitution elasticity of oil and non-oil consumption by the households	0.103	Current research
θ_I	The substitution elasticity of domestic and imported investment by the households	1.54	Current research
θ_{In}	The substitution elasticity of domestic and imported production of inputs	1.39	Current research
θ_l	The substitution elasticity of aggregator's demand from labor	6	Current research
θ_y	The substitution elasticity of goods produced domestically or exported	2.27	Current research
θ_o	The substitution elasticity of government and foreign oil investment	0.01	Current research
θ_{cG}	The substitution elasticity of domestic and imported consumption by the government	2.816	Current research
θ_{IG}	The substitution elasticity of domestic and imported investment by the government	2.108	Current research
α_c	The share of domestic consumption in household consumption	0.9	Current research
α_e	The share of energy in household domestic consumption	0.075	Current research
α_s	The share of world oil price in domestic oil price index	0.4	Current research
α_I	The share of domestic investment in household investment	0.84	Current research

Table 3 (Continued). Calibrated parameters

Parameter	Description	value	Source
α_I	The share of domestic investment in household investment	0.84	Current research
α_{Im}	The share of domestic input in the production of intermediate inputs	0.7	Current research
α_y	The share of domestically supplied goods in the total production of a firm	0.9	Current research
α_o	The share of domestic oil investment in the total oil investment	0.82	Current research
α_{CG}	The share of domestic consumption in government consumption	0.9	Current research
α_{IG}	The share of domestic investment in government investment	0.83	Current research
τ_w	The degree of wage indexation	0.6	Current research
v_w	The percentage of the labors not able to adjust their wages	0.7	Current research
τ_d	The degree of price indexation in domestically produced goods	0.3	Current research
v_d	The percentage of the domestic firms not able to adjust their prices	0.5	Current research
τ_x	The degree of price indexation in goods exported	0.2	Current research
v_x	The percentage of the export firms not able to adjust their prices	0.5	Current research
τ_{cm}	The degree of price indexation in consumption goods imported	0.35	Current research
v_{cm}	The percentage of the consumption import firms not able to adjust their prices	0.5	Current research
τ_{Im}	The degree of price indexation in the investment goods imported	0.15	Current research
v_{Im}	The percentage of the investment import firms not able to adjust their prices	0.5	Current research
τ_{Inm}	The degree of price indexation in the production inputs imported	0.15	Current research
v_{Inm}	The percentage of the input import firms not able to adjust their prices	0.5	Current research
γ^o	The share of NIOC from crude oil export devoted to investment	0.145	The Sixth Development Plan of Iran
t^w	The income tax rate	0.0237	Current research
t^{va}	The consumption (value-added) tax rate	0.0212	Current research
ρ_{pof}	AR (1) coefficient of world oil inflation rate	0.05	Current research
ρ_{poff}	The elasticity of world oil inflation due to Iran oil export	0.005	Current research
ρ_{pf}	AR (1) coefficient of world inflation rate	0.05	Current research
ρ_a	AR (1) coefficient of intermediate production technology	0.8	Tavakolian & Ghiaie (2019)
ρ_m	AR (1) coefficient of the monetary policy rule	0.4	Tavakolian & Ghiaie (2019)

Table 3 (Continued). Calibrated parameters

Parameter	Description	value	Source
ρ_y	The coefficient of output gap in the monetary policy rule	-1.7	Manzoor & Taghipur (2016)
ρ_π	The coefficient of inflation gap in the monetary policy rule	-1.54	Manzoor & Taghipur (2016)
ρ_{π^*}	AR (1) coefficient of target inflation rate	0.6	Manzoor & Taghipur (2016)
ρ_s	AR (1) coefficient of the exchange policy rule	0.7	Tavakolian & Ghiaie (2019)
ρ_{ss}	The coefficient of foreign reserves ratio to the monetary base in the exchange policy rule	-1.55	Tavakolian & JalaliNaeni (2017)
ρ_{sss}	The coefficient of inflation gap in the exchange policy rule	-1.9	Tavakolian & JalaliNaeni (2017)
ρ_{cG}	AR (1) coefficient of government consumption expenditures (fiscal policy rule)	0.188	Current research
ρ_{iG}	AR(1) coefficient of government investment expenditures (fiscal policy rule)	0.336	Current research
ρ_{iGG}	The elasticity of government investment due to government debt to the CB	-0.419	Current research
ρ_x	AR (1) coefficient of financial costs of export	0.4	Current research
ρ_{cm}	AR (1) coefficient of financial costs of the consumption goods imported	0.4	Current research
ρ_{Im}	AR (1) coefficient of financial costs of the investment goods imported	0.4	Current research
ρ_{Imm}	AR (1) coefficient of financial costs of the intermediate inputs imported	0.4	Current research
ρ_{fdio}	AR (1) coefficient of foreign direct investment	0.406	Current research
ρ_{oa}	AR (1) coefficient of oil production technology	0.8	Current research
ρ_{ox}	AR (1) coefficient of crude oil export	0.33	Current research

Source: Current research.

5. Performance of the Model

Following Khosravi and Mehrabi Boshrabadi (2020), we compared various moments of the real data and the simulated values of the variables in the model to evaluate the model fitness and precision. The moments of the real data were selected from the 1997-2017 data, which were deseasonalized and detrended using Hodrick-Prescott filter. The model was found to be suitable for simulation, as shown in Table 4.

Table 4. Second-order moments and the correlation of the variables GDP.

variable	Description	Correlation with GDP		Variance	
		Real data	Simulated data	Real data	Simulated data
y	GDP	1	1	0.0043	0.0051
C	Private consumption	0.897	0.888	0.0035	0.0038
I	Private investment	0.647	0.550	0.0129	0.0231
c_g	Government consumption	-0.222	-0.387	0.0036	0.0044
y_o	Oil production	-0.299	-0.251	0.021	0.019
y_ox	Oil export	-0.472	-0.334	0.0514	0.0491
y_x	Non-oil exports	0.295	0.321	0.0685	0.0563
π	Inflation rate	0.584	0.513	0.0057	0.0061

Source: Current research.

6. Empirical Results

Before evaluating and comparing the monetary policies of the CB of Iran, the IRFs of the shocks related to the imposition of oil and international financial sanctions need to be presented in the form of the base model.

6.1 IRF Analysis

The IRFs in the base model were analyzed under the context of sanctions. All equations were log-linearized and entered in MATLAB and DYNARE software using calibrated parameters and the steady-state values of the variables (Tables 3 and 4)

A sanction condition was considered, based on which the sanctions raised the costs of export and import operation by 30% due to the point that inflation in the import price index in the foreign currency (dollar) increased about 30% in 2012 and 2013 (CB of Iran, Time Series Database). Since we aimed to analyze the simultaneous effects of sanction on the oil and trade sectors, we supposed that the sanctions would decrease export, technology, and foreign investment in the oil sector by 80% due to a reduction of about 80% in the amount of crude oil export in 2012-2013 (CB of Iran, Time Series Database).

According to Figure 2, Oil sanctions reduced the export of oil, hampered the transfer of technology that can be employed in the oil industry, and reduced foreign investment by 80%. The decrease in the oil export caused by the sanctions, in turn, decreased government investment in the oil sector by decreasing the share of oil export revenues allocated to domestic investment in the oil industry. In addition, foreign investment in the oil sector decreased. Thus, the total investment dropped by about 35% and converged to a steady state after 30 periods, which resulted in a reduction in capital accumulation. Decreased technology, investment, and capital in the oil sector eventually led to a reduction of about 70% in oil production. Given that Iran plays a pivotal role in the world oil market, the above-mentioned negative effects led to an initial increase of about 35% in oil prices, which was in line with the oil price data in 2011-2013. A decrease in the export of oil decreased the foreign reserves of the CB of Iran and due to the discretionary policies adopted by the CB of Iran regarding the exchange market

during the sanctions period, the exchange rate initially increased by 48%, which was in conformity with the rise in the exchange rate in 2012-2013, and returned to a steady state after 14 periods.

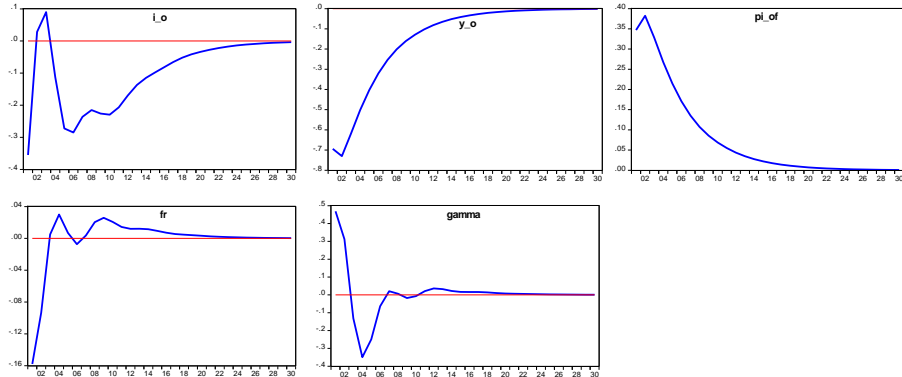


Figure 2. The IRF effects of sanctions on the oil sector and exchange rate.

Although a rise in the exchange rate and export price index increased competitiveness between the domestically produced goods versus foreign goods and encouraged export firms to develop their markets, international financial sanction increased export transaction costs and trade friction, leading to an increase in the marginal cost of non-oil exporting goods. Accordingly, the inflation in the export price index initially rose 28% and the non-oil exports decreased by about 80% and returned to a steady state after 20 periods (Figure 3). This is in line with the real non-oil export data in 2012-2013. In the import sector, there were two factors that caused an increase in the marginal costs of importing: 1) the international financial sanctions, which increased transaction costs and 2) the rising exchange rate, which disappointed the importers because it increased the import prices for domestic demanders. Therefore, the inflation rates of the price index for the consumption goods, investment goods, and intermediate inputs imported for the firms producing intermediate goods increased 34%, 44%, and 17%, respectively, and returned to their steady state after 20 periods. This is in agreement with the positive growth observed in the imported goods price index data in the winter of 2012 to the winter of 2014.

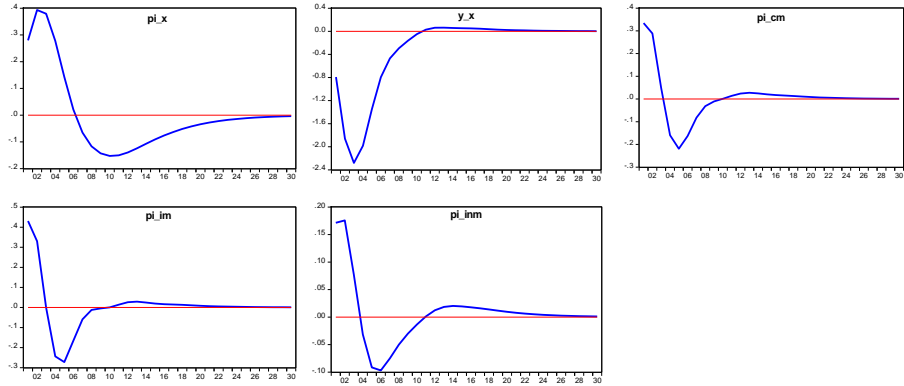


Figure 3. *The IRF effects of sanctions on non-oil exports and imports.*

As shown in Figure 4, the marginal costs of domestic production increased the inflation of domestically produced price index by 55% due to inflationary conditions and uncertainty in the national economy, which, in turn, decreased households' and government's demand for domestic products by 18%. That is in line with the data in 2012-2013. The decline in the domestic products and non-oil exports due to the oil and international financial sanctions eventually decreased gross domestic products (GDP) by about 18%. On the other hand, the growth in the price index of domestic production and imported consumption goods increased the growth in the consumer price index and inflation rate. However, the real monetary base declined significantly due to a decrease in the foreign reserves held by the CB of Iran and the pressure of issuing currency by purchasing oil export revenues. Stagflation in Iran, as manifested in the macroeconomic data in 2012-2013, confirms the simulation results. A drop in the real monetary base shows that the CB of Iran's priority was to control the inflation rate rather than recession.

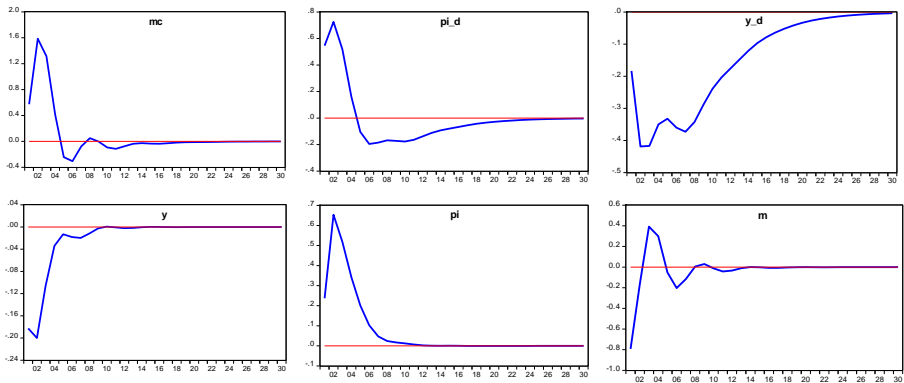


Figure 4. *The IRF effects of sanctions on domestic products, GDP, and inflation.*

According to Figure 5, the marginal utility of the households for saving decreased. Therefore, household consumption increased by 12% while their investment decreased by 4%. According to the statistics released by the CB of Iran, private consumption and investment in 2012-2013 decreased, which is in line with the simulation results of investment but not with those of consumption. The government fiscal policy, despite the budget deficit caused by the decline in oil exports, concentrated on increasing the government current expenditures and preserving government investment expenditures to prevent recession and the reduction of total household consumption. Thus, government consumption increased by more than 6%, which is in line with data in 2012-2013. However, government investment did not change, which is not in agreement with the 2012-2013 data. Since the growth of nominal government debt was equal to the inflation rate; thus, the real government debt to the CB of Iran did not change and the government tried to finance the budget deficit by increasing the issuing of bonds by about 22% and raising the nominal interest rate.

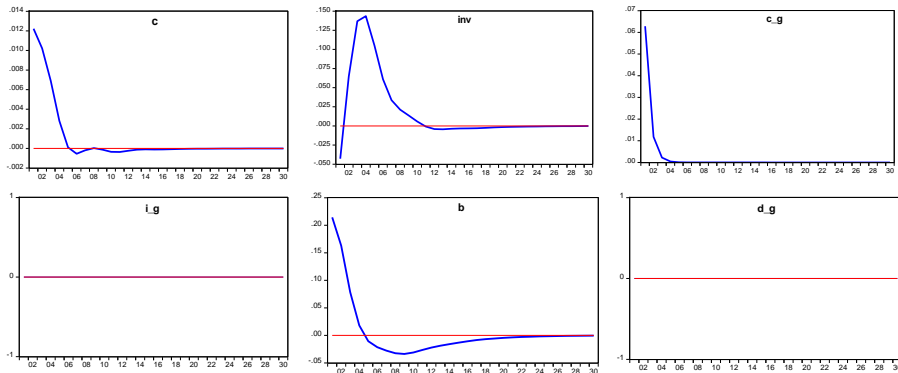


Figure 5. The IRF effects of sanctions on households and government.

6.2 The CB of Iran Optimal Monetary Policies

The CB of Iran can adopt different optimal monetary policies in the form of optimal simple rule (OSR) instead of the current monetary policy. Thus, the CB can choose between CPI-inflation targeting and PPI-inflation targeting monetary policy in an optimal simple rule. Finally, three kinds of monetary policies will remain to be adopted by the CB of Iran, including current monetary policy (CMP), optimal simple rule with CPI-inflation targeting (OSR (CPI)), and optimal simple rule with PPI-inflation targeting (OSR (PPI)). The CB of Iran can choose different appropriate monetary policies that lead to less loss function value and implement each of these policies at different stages during the economic sanctions period. Based on the value of loss function in each of the monetary policies developed for the economic sanctions period, as presented in Table 5, implementing an optimal monetary policy could decrease the value of loss function significantly due to the sharp drop in the variance of the simulation output while OSR could only have

little effect on inflation. On the other hand, OSR with PPI-inflation targeting seems to have a lower loss function than CPI, indicating that OSR (PPI) can be the most appropriate monetary policy with the lowest loss function in the face of economic sanctions shocks. This suggestion can be supported by the optimal values of the parameters in the monetary policy adopted by the CB of Iran.

Table 5. Different monetary policies based on the values of the loss function

Monetary policy	Variance				Value of loss function
	$\widehat{\pi}_t$	\widehat{y}_t	$\widehat{\pi}_t^d$	$\widehat{r}e_t$	
CMP	0.000101	0.093944	1.447166	0.013995	0.094045
OSR(CPI)	0.000108	0.014336	1.940028	0.030620	0.013608
OSR(PPI)	0.000109	0.012770	2.234046	0.033313	0.012753

Source: Current research.

There are two parameters in the monetary policy function of the CB of Iran that show the importance of inflation and output in monetary policy-making. In the current monetary policy, the values of -1.54 and -1.7 were considered for the importance coefficient of inflation and output, reflecting a countercyclical monetary policy. In fact, the CB of Iran was found to increase the growth rate of the monetary base when the inflation rate and output increased during a period of economic prosperity; also, the CB of Iran was found to decrease the growth rate of the monetary base when the inflation rate and output decreased during economic recession as to push inflation rate and output toward a steady state. According to Table 6, in an OSR (CPI) monetary policy, the CB of Iran should consider -0.79 and -11.9 as the optimal values of the importance coefficient of inflation and output. This means that the CB of Iran should concentrate more on the output than on the CPI inflation fluctuations because economic sanctions have greater effects on output than on the variance of inflation. In an OSR (PPI) monetary policy, the CB of Iran should concentrate more on the variance of output than on the variance of inflation. The value of the importance coefficient of inflation and output is -2.3 and -30.8, respectively (Table 6).

Table 6. The optimal value of parameters in the monetary policy

Monetary policy	ρ_π	ρ_y
	coefficient of inflation	coefficient of output
Current	-1.54	-1.7
OSR(CPI)	-0.79	-11.9
OSR(PPI)	-2.3	-30.8

Source: Current research.

7. Concluding Remarks

The present study aimed to analyze the effects of international financial and oil sanctions in a New Keynesian DSGE model. The parameters were calibrated by geometric means of macroeconomic data and estimation information. All equations were log-linearized. The empirical results indicated that the tightening

of economic sanctions, including oil and international financial sanctions, could have detrimental effects on export, technology, foreign investment, and ultimately production in the oil sector. This finding is in line with those of [Derakhshan's \(2014\)](#) study. The results also showed that the ratio of foreign reserves held by the CB of Iran to the monetary base decreased; thus, the exchange rate increased due to the decline in the oil export. This finding is consistent with those reported by [Rahmati et al. \(2016\)](#) and [Tayebi and Sadeghi \(2017\)](#). On the one hand, international financial sanctions raised the export costs and decreased non-oil export, which is in agreement with what [Farzanegan et al. \(2016\)](#) and [Khabbazan and Farzanegan \(2016\)](#) observed in their studies. On the other hand, the increase in the import costs and the inflation of imported goods decreased importing consumption and investment, which is consistent with the results of [Eyler's \(2007\)](#) and [Toghyani and Derakhshan's \(2014\)](#) studies. GDP dropped due to the decrease in non-oil domestic production and export, oil production, and oil export, which signifies an increase in the inflation rate and stagflation. This is in line with what was reported by [Rahmati et al. \(2016\)](#) and [Dizaji \(2014\)](#). In order to cut the budget deficit, the government endeavored to generate more revenues by issuing more bonds, a finding which is not confirmed by what was suggested by [Sadeghi and Tayebi \(2018\)](#), who emphasized on government debt than bonds. The government raised consumption expenditures and held the investment expenditures constant by focusing on domestic products, which is in line with what [Gurvich and Prilepskiy \(2015\)](#) and [Marzban and Ostadzad \(2015\)](#) reported in their studies.

Although the implementation of optimal instead of current monetary policy in the form of OSR by minimizing CBI loss function means focused attention on the inflation and output gap during the economic sanctions period, such a policy decreases the value of loss function dramatically both in the CPI and PPI monetary policies. Following the shocks caused by economic sanctions, the CB of Iran should implement the OSR (PPI) monetary policy due to higher fluctuation in the output than in the inflation gap. Accordingly, the CB of Iran is recommended to increase the optimal value of the importance coefficient of output in the monetary policy reaction function, which is in line with was suggested by [Faraji et al. \(2015\)](#).

Based on the evidence presented in the current study, the following recommendations are made:

- During the sanctions period, investment, which is necessary for the manufacturing sectors and growth in the long-run, is reduced due to a decrease in the household and oil investment. Therefore, the policy-makers should develop some policies and strategies to confront this lack of investment;
- The decline in the government and foreign investment in the oil sector can have destructive effects on the process of oil production, especially for the

Iranian oil fields which face pressure depletion. The policy-makers should go toward domestic resources and the capacities of the political partners;

- The government should concentrate on the downstream sector of the oil industry, especially by developing refineries, during the oil sanctions period; otherwise, it will not be able to export a large amount of oil produced;
- The government should pay more attention to the households in the stagflation period by redistributing income policies;

The CB of Iran should focus more on the output to decrease its loss function during the economic sanctions period.

References

- Adolfson, M., Laséen, S., Lindé, J., & Villani, M. (2007). Bayesian estimation of an open economy DSGE model with incomplete pass-through. *Journal of International Economics*, 72(2), 481-511. doi: <https://doi.org/10.1016/j.jinteco.2007.01.003>.
- Allegret, J. P., & Benkhodja, M. T. (2015). External shocks and monetary policy in an oil-exporting economy (Algeria). *Journal of Policy Modeling*, 37(4), 652-667.
- Angelopoulos, K., Dimeli, S., Philippopoulos, A., & Vassilatos, V. (2010). *Rent-seeking competition from state coffers in Greece: A calibrated DSGE model* (No. 120).
- Balke, N. S., & Brown, S. P. (2018). Oil supply shocks and the US economy: An estimated DSGE model. *Energy Policy*, 116, 357-372.
- Bernanke, B. S., Laubach, T., Mishkin, F. S., & Posen, A. S. (2018). *Inflation targeting: Lessons from the international experience*. Princeton University Press.
- Blinder, A. S., Ehrmann, M., Fratzscher, M., De Haan, J., & Jansen, D. J. (2008). Central bank communication and monetary policy: A survey of theory and evidence. *Journal of Economic Literature*, 46(4), 910-45.
- Calvo, G. A. (1983). Staggered prices in a utility-maximizing framework. *Journal of Monetary Economics*, 12(3):983-998.
- Caruso, R. (2003). The impact of international economic sanctions on trade: An empirical analysis. *Peace economics, peace science and public policy*, 9(2).
- Central Bank of Iran, time series information banks (www.tsd.cbi.ir).
- Chen, Q., Funke, M., & Paetz, M. (2012). Market and non-market monetary policy tools in a calibrated DSGE model for mainland China.
- De Wet, E. (2004). *The chapter VII powers of the United Nations security council* (Vol. 3). Hart Publishing.
- Derakhshan, M. (2014). Oil contracts from the perspective of conservation and harvesting: Resilience economy approach *Islamic economics studies*, 6(2), 7-52.
- Dixit, A. K., & Stiglitz, J. E. (1977). Monopolistic competition and optimum product diversity. *The American Economic Review*, 67(3), 297-308.
- Dizaji, S. & Farzanegan, M. R. (2019): Do sanctions constrain military spending of Iran?, *defence and peace economics*, doi: 10.1080/10242694.2019.1622059.
- Dizaji, S. F. (2014). The effects of oil shocks on government expenditures and government revenues nexus (with an application to Iran's sanctions). *Economic Modelling*, 40, 299-313.
- Ercog, C. J., Henderson, D. W., & Levin, A. T. (2000). Optimal monetary policy with staggered wage and price contracts. *Journal of Monetary Economics*, 46(2), 281-313.

- Eyler, R. (2007). *Economic sanctions: International policy and political economy at work*. Springer.
- Faraji, M., Afshari, Z., & Ebrahimi, I. (2015). Oil price shocks and monetary policy in Iran: The new Keynesian approach. *Journal of Monetary & Banking Research*, 7(22), 533-568.
- Farzanegan, M. R., & Hayo, B. (2019). Sanctions and the shadow economy: Empirical evidence from Iranian provinces. *Applied Economics Letters*, 26(6), 501-505.
- Farzanegan, M. R., Khabbazan, M. M., & Sadeghi, H. (2016). *Effects of oil sanctions on Iran's economy and household welfare: New evidence from a CGE model*. In *Economic Welfare and Inequality in Iran* (pp. 185-211). Palgrave Macmillan, New York.
- Fashandi, N., & Ghaderi, H. (2017). Reviewing the legal foundations of the imposition of smart sanctions on Iran and the impact of JCOPA on the sanctions. *Ghanoonyar*, 2(2), 135-172.
- Ghazaavi, H., & Mohammadi, M. h. (2015). Model of managing challenges facing banking system in sanction. *Financial Research Journal*, 17(2), 341-356.
- Giannoni, M., & Woodford, M. (2004). *Optimal inflation-targeting rules*. In *The Inflation-Targeting Debate* (pp. 93-172). University of Chicago Press.
- Guender, A., & Sander, N. (2011), (Re) Introducing money into the new Keynesian framework: Does it matter?. *Reserve Bank of New Zealand Working Paper*.
- Gurvich, E., & Prilepskiy, I. (2015). The impact of financial sanctions on the Russian economy. *Russian Journal of Economics*, 1(4), 359-385.
- Haidar, J. I. (2017). Sanctions and export deflection: Evidence from Iran. *Economic Policy*, 32(90), 319-355.
- Hufbauer, G. C., Elliott, K. A., Cyrus, T., & Winston, E. (1997). *US economic sanctions: Their impact on trade, jobs, and wages* (No. Working Paper Special (2)).
- Hufbauer, G., Schott, J., & Elliott, K. (2009). *Economic Sanctions Reconsidered*. Peterson Institute for International Economics.
- Ianchovichina, E., Devarajan, S., & Lakatos, C. (2016). *Lifting economic sanctions on Iran: Global effects and strategic responses*. The World Bank.
- Katzman, K. (2019a). Iran sanctions. *Congressional Research Service*, RS20871 (www.crs.gov).
- Katzman, K. (2019b). Iran: Internal politics and US policy and options. *Congressional Report*. Congressional Research Service.
- Keimasi, M., Ghafarnejad, A., & Rezaei, S. (2016). Effects of sanctions of the Iranian banking system on profitability. *Journal of Monetary and Banking Research*, 9(28), 171-197.
- Khabbazan, M. M., & Farzanegan, M. R. (2016). *Household welfare in Iran under banking sanctions: From open economy toward autarchy*. In *Economic Welfare and Inequality in Iran* (pp. 213-232). Palgrave Macmillan, New York.

- Khosravi, M., & MehrabiBoshrabadi, H. (2020). Agricultural economic dynamics in a Bayesian DSGE model for Iran. *Iranian Economic Review*, 24(1), 267-297.
- Kittrie, O. F. (2008). New sanctions for a new century: Treasury's innovative use of financial sanctions. *U. Pa. J. Int'l L.*, 30, 789.
- Kozhanov, N. A. (2011). US economic sanctions against Iran: Undermined by external factors. *Middle East Policy*, 18(3), 144.
- Le, V. P. M., Meenagh, D., Minford, P., & Wickens, M. (2011). How much nominal rigidity is there in the US economy? Testing a new Keynesian DSGE model using indirect inference. *Journal of Economic Dynamics and Control*, 35(12), 2078-2104.
- Lohmann, S. (2016). The convergence of transatlantic sanction policy against Iran. *Cambridge Review of International Affairs*, 29(3), 930-951.
- Manzoor, D., & Taghipour, A. (2016). A dynamic stochastic general equilibrium model for an oil-exporting and small open economy: The case of Iran. *IJNAA*, 23(75), 7-44. Retrieved from <http://qjerp.ir/article-1-1156-en.html>.
- Marzban, H., & Ostadzad, A. H. (2015). The impact of economic sanctions on gross domestic product and social welfare for Iran: Generalized stochastic growth model. *Iranian Journal of Economic Research*, 20(63), 37-69.
- McCallum, B. T. (1988). *Robustness properties of a rule for monetary policy*. Paper Presented at The Carnegie-Rochester Conference Series on Public Policy.
- McDonald III, B. D., & Reitano, V. (2016). Sanction failure: Economic growth, defense expenditures, and the Islamic Republic of Iran. *Armed Forces & Society*, 42(4), 635-654.
- Mozafari, M. (2016). Iran and science publishing in the post-sanctions era. *The Lancet*, 387(10029), 1721-1722.
- Peksen, D. (2009). Better or worse? The effect of economic sanctions on human rights. *Journal of Peace Research*, 46(1), 59-77.
- Peksen, D., & Drury, A. C. (2010). Coercive or corrosive: The negative impact of economic sanctions on democracy. *International Interactions*, 36(3), 240-264.
- Petrescu, I. (2016). The effects of economic sanctions on the informal economy. *Management Dynamics in the Knowledge Economy*, 4(4), 623-648
- Rahmati, M. H., Karimi Rad, A., & Madanizadeh, S. A. (2016). Studying the impact of sanctions on Iran's economy in a 2012-2013 recession. *Economic Research*, 51(3), 569-594.
- Robert Nobay, A., & Peel, D. A. (2003). Optimal discretionary monetary policy in a model of asymmetric central bank preferences. *The Economic Journal*, 113(489), 657-665.
- Rotemberg, J. J. (1982). Monopolistic price adjustment and aggregate output. *The Review of Economic Studies*, 49(4), 517-531.
- Ruge-Murcia, F. J. (2004). The inflation bias when the central bank targets the natural rate of unemployment. *European Economic Review*, 48(1), 91-107.

- Sadeghi, A., & Tayebi, S. K. (2018). Effects of international sanctions and other determinants on Iran's inflation rate (1981-2014). *Iranian Journal of Economic Research*, 23(74), 33-57.
- Tavakolian, H., & Ghiaie, H. (2019). *Optimal inflation targeting in a dual-exchange rate oil economy* (No. 2019-09). THEMA (THéorieEconomiq ue, Modélisation et Applications), Université de Cergy-Pontoise.
- Tavakolian, H., & JalaliNaeeni, A. (2017). Optimal and discretionary monetary and exchange policies in Iran: A DSGE approach. *Iran Economic Research*, 22(70), 33-98.
- Tayebi, S. K., & Sadeghi, A. (2017). The impacts of international sanctions and other factors affecting exchange rate in Iran. *Journal of Economic Research*, 52(3), 641-661.
- Toghyani, M., & Derakhshan, M. (2014). Analysis of the factors of impact of economic sanctions on Iran and solutions to cope with it. *Journal of Rahbord*, 23(73), 115-146.
- Yavari, K., & Mohseni, R. (2011). The effects of trade and financial sanction on Iran: Historical analysis. *Parliament and Strategy Journal*, 61, 10-53.
- Zahrani, M., & Dolatkah, Z. (2010). Comparing the Security Council's sanctions against Iran and North Korea. *Rahbord Journal*, 19(55), 139-170.