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Financial Sanction, Exchange Rate Volatility and Macroeconomic Variables (Case of Iran)

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Abstract

Financial sanctions have economic consequences for the oil-dependent economies. We examined the impact of financial sanctions on exchange rate fluctuations and macroeconomic variables in Iran. To this end, we employed a new Keynesian DSGE model. The results indicated that with the shock in foreign exchange, production (Y) and imports initially decreased. Oil

production has shown a positive reaction initially and a negative reaction in the medium term, and after 7 periods, the effect of the shock has disappeared. The capital stock (K) also decreased initially, and in two periods, it reacted positively. In the tenth period, its effect disappeared, and in the long term, it became partially negative, and its effect disappeared. The inflation rate has decreased initially, and its effect disappeared over time. Consumption decreased, and after five cycles, the reaction became positive and then disappeared. The interest rate increased initially and then decreased, and in the 10th period, the shock effect disappeared. The exchange rate initially decreased and then increased after one period.

Keywords: Financial Sanction, Exchange Rate, Oil Revenue, Volatility, Macroeconomic Variables.

JEL: F_{51}, $F_{31,}$ E_{12}, D_{25}

Introduction

Since 1914, the world's military and economic powers have resorted to economic sanctions instead of war to advance their objectives. Economic sanctions can be classified into three groups: import sanctions, export sanctions, and financial sanctions (Devarajan et al., 2017). Although a wide range of these sanctions are used, the increase in financial sanctions has been unprecedented.

Financial sanctions targeted the country's financial resources under sanction, which has led to an increase in the interest rate and the costs of medium-term and long-term financing. In general, financial sanctions have had an adverse impact on the financial sector. In this regard, blocking assets and restricting access to financial and foreign exchange resources have reduced investment, exports, and production, resulting in increased inflation and unemployment and ultimately reduced economic growth (Pahlavani et al., 2021). Also, the sanctions affected the foreign exchange market, where currency depreciation occurred, because the financial sanctions restricted foreign exchange transactions, aggravating the Rial's devaluation (Heydarian et al., 2021).

Since 2011, Iran's economy has faced comprehensive financial sanctions (banking system including the central bank). Therefore, financial sanctions and the economic structure dependent on oil revenues have caused Iran's economy to be targeted and face more problems in realizing its development plans (Mirjalili, 2022).

On the other hand, foreign exchange revenue is of great importance due to the dependence of the government's foreign exchange revenue on oil and non-oil exports to finance imports, including raw materials, capital, and intermediate goods. In other words, foreign exchange earnings, access to foreign exchange resources, and their transfer are important issues for trade transactions and foreign exchange needs (Bahadoran & Sofi, 2021).

In Iran's economy, due to the dependence on oil revenue, the government's need for foreign exchange revenues to finance the government budget has led to the economy's vulnerability to oil price volatility and exchange rate fluctuations. Therefore, oil revenue reduction decreased foreign exchange revenues (Heydarian et al., 2021).

The sanctions significantly impact the exchange rate, directly affecting imports, exports, and capital inflow and outflow. The intensification of sanctions, restrictions on export and import, and money transfers directly affect the supply of and demand for currency, leading to exchange rate fluctuations (Eichengreen et al., 2023).

With the imposition of financial sanctions, the exchange rate faces a significant jump (Pourfathi & Kafae, 2020). Both financial sanctions and trade sanctions can seriously affect the foreign exchange market. The sanction of banking transactions and the embargo on oil exports and its proceedings, by limiting foreign exchange earnings (and access to them), create uncertainty in the foreign exchange market, adversely affecting the economy.

Therefore, due to the financial sanctions against Iran, the exchange rate during the past decades was volatile, and the macroeconomic variables were unstable. Exchange rate fluctuations created uncertainty in the economy and, as a result, left adverse effects on the economy's performance (Hastiani et al., 2023).

The exchange rate changes the sanctions, which will affect the performance of the enterprises. Therefore, we need to consider the effects of financial sanctions as a factor in the analysis of exchange rate volatility in Iran. Against this background, in this paper, we explore the impact of financial sanctions on exchange rate fluctuation. Sanctions, especially financial sanctions, directly and indirectly affect macroeconomic variables in Iran's economy.

In this regard, we employ a new Keynesian DSGE model to analyze the effect of financial sanctions on macroeconomic variables, including exchange rates in Iran's economy. To this end, a calibrated and simulated DSGE model

will include the household sector, firms producing final goods in a monopolistic competition producers' market and price stickiness, exporters and importers, and the integration of the government and the central bank. Sanctions, especially financial sanctions, directly and indirectly affect macroeconomic variables in Iran's economy.

The rest of the paper is organized as follows: Section 2 provides the theoretical background. Section 3 is devoted to an empirical literature review. Section 4 provides the details of the model. Section 5 presents the estimation and analysis of the results and calibration of parameters. Section 6 assesses the fit and accuracy of the model. Section 7 analyzes the effect of the sanctions shock in the form of shock (impulse)-response functions (IRFs), and Section 8 deals with the conclusions.

Literature Review

Due to the spread and importance of financial sanctions, these sanctions have extensive and costly effects on the target economy. They are more effective than trade sanctions (41% vs. 25%) (Heydarian et al., 2024).

In recent years, the exchange rate in Iran has experienced severe fluctuations and jumps due to the financial sanctions. Therefore, the first thing that is affected by financial sanctions is the economic situation, which includes the exchange rate at which countries enter the economic war (Pestova & Mamonov, 2022).

Financial sanctions affect the foreign exchange revenues from the oil export. Financial sanctions lead to a depreciation in the target economy's currency's value and increase the target country's exchange rate (Richud et al., 2000; Khajeh Mohamadloo & Mani, 2021).

It also explains the domestic and international situation of the economy in terms of competitiveness, inflation rate, and macro variables that result in the exchange rate volatility (Amrolahi Biuki et al., 2021).

The objective of economic sanctions against Iran, as explicitly mentioned in the "Art of Sanctions," was to damage the ability of the sanctioned economy to obtain and use economic resources, including foreign exchange resources (Mirjalili, 2021, p.87). The dependence on oil revenues has led to high fluctuations in foreign exchange revenues. During the oil boom, the government fixed the exchange rate as a nominal anchor to fight inflation, which decreased the real exchange rate. At the time of the shortage of foreign exchange resources (during the intensification of sanctions from 2012 to 2013),

the floating exchange rate system failed, and governments turned to multi-rate exchange rates (Oskooee & Kandil, 2010).

Oil dependence is one of the most important risky areas in Iran's economy. Oil revenue has two functions in Iran's economy. It provides the central part of the government's revenues and is the primary supplier of foreign exchange revenues. Financial sanctions disrupt the normal flow of transactions related to oil exports and often prevent access to international markets and oil buyers. The disruption can lead to a significant decrease in oil exports and revenues. On the other hand, the US financial sanctions against Iran deteriorated the banking risk (Mohaddes, 2019).

Using the dollar's dominance in the international financial system, the US is trying to utilize financial sanctions to affect the foreign exchange market in Iran (Alavi Razavi et al., 2020). Also, countries may use financial sanctions along with foreign exchange restrictions to put pressure on target countries (Butuzov, 2016).

Financial sanctions on Iran began in 2006. With further restrictions on financial transactions by the US, it peaked in 2011 (Heydarian et al., 2024) and continues. The period in which Iran's economy faced an increase in the exchange rate due to financial sanctions is as follows:

2012-2015: During this period, Iran faced incremental sanctions. These sanctions led to economic challenges and exchange rate fluctuations (European Council, 2012). Over the period, the intensification of financial sanctions against Iran by the European Union and the United States led to a decrease in government revenues, volatility of the exchange rate, an increase in the cost of international transactions, and an increase in the risk of investment in Iran (Pahlavani et al., 2021).

In this regard, in July 2012, the United States imposed severe financial sanctions against banks that deposited revenues of the Iranian government from oil, petroleum products, and petrochemicals. The sanctions embraced entities with financial relationships with the National Iranian Oil Company (NIOC) and Naftiran Intertrade Company (Nakhli et al., 2021).

2018-2020: The United States withdrew from the Iran nuclear deal 2018 and reimposed sanctions on Iran's economy. This has contributed to another period of economic issues, including Iranian rial depreciation. This period was a sign of the renewal and intensification of financial sanctions against Iran (Moeeni et al., 2022). In the aftermath of the United States withdrawal from Iran’s nuclear deal (JCPOA) in 2018, the US administration reimposed

sanctions against Iran. Therefore, Iran's oil exports were once again adversely affected. The sanctions targeted Iran's ability to export oil globally, which decreased Iran's oil revenues (Salavati & Aloosh, 2019).

The countries sanctioned by the United States are North Korea in 1950, Cuba in 1962, Iran in 1979, Syria in 1986, Burma in 1997, and Sudan in 2002. It should be mentioned that the exchange rate fluctuations in none of the mentioned countries were as severe as the exchange rate volatility in Iran (Rosulyar et al., 2015).

In Iran, oil exports are the primary source of foreign exchange supply. The value of oil exports determines the exchange rate in the market. Decreasing oil revenue will limit foreign exchange resources and thereby depreciate the exchange rate, increasing the costs of importing raw materials and capital goods for producers (Hastiani et al., 2023).

Increasing non-oil exports could mitigate some cost pressures on the producers. The promotion of non-oil exports is motivated by the exchange rate increase. However, due to the high share of the oil export revenues in the foreign exchange resources, the growth of non-oil exports cannot compensate for the decrease in oil revenues (Shuleska et al., 2024).

The importance of oil in Iran's economy is such that the changes in its production and revenue affect the economic developments positively and negatively and bring prosperity or stagnation. The foreign exchange and fiscal role of oil revenue in Iran is more important than its role as a supplier of petrochemicals and oil products (Abonouri et al., 2013). Put differently, oil revenues are the most important source of foreign exchange in Iran's economy and play a significant role in financing government expenditures. Due to the impact of US financial sanctions since 2018– both in reducing exports and freezing accounts– Iran has had limited access to its oil export earnings. For example, Iran had 41 billion dollars in oil revenue in 2016 and 53 billion in 2017. However, from March 2019 to March 2020, Iran earned only 8 to 9 billion dollars in oil revenue (Rome, 2021).

When shocks such as sanctions and export earnings decrease, the economy easily slips into a crisis. Government spending continues, albeit with more significant fiscal deficits, but more importantly, the value of the national currency will decrease alongside domestic inflation. This has been a standard feature in Iran and other oil-exporting countries such as Saudi Arabia (Sivramkrishna, 2016) and Venezuela (Kautilya & Bhavish, 2019).

When the sender country deprives the target economy of its financial

resources, it reduces the supply of funds. It leads to an increase in the financial costs for the target economy. Another type of financial sanctions will reduce or cut off the revenue from the assets of the target country, which are currently in the sender country, which is known as asset blocking (Besedeš et al., 2024).

Freezing the assets of the central bank is another aspect of the sanctions. The assets in the accounts of Iranian banks or deposited in other banks are blocked because they are ultimately related to the central bank and, thereby, will be subject to sanctions. The possibility of disruption in the foreign exchange policy can be another result of the central bank's sanction because, in this situation, the central bank does not have enough reserves to intervene in the market to maintain the value of the national currency (Hilgenstock et al., 2023).

Due to the lack of full access to foreign exchange resources, government expenses will increase, and in practice, part of the government revenues will not be accessible (Pahlavani et al., 2021).

The contagion of the negative impulses of oil to the foreign exchange market has caused significant fluctuations in the exchange rate due to the major share of foreign exchange receipts of oil in foreign exchange revenues. Due to the low share of non-oil export foreign exchange receipts, the impact of oil shocks on the exchange rate has become more apparent. Therefore, Iran's economy is affected by events related to oil exports, including economic sanctions (Tayebi & Sadeghi, 2018).

Sanctions led to uncertainty by restricting the oil export and foreign exchange earnings. Consequently, the exchange rate pushed upwards, leading to increased production costs due to the increase in raw materials and imported capital goods, which resulted in limiting non-oil exports (Hadad et al., 2020).

Exports are the most important source of foreign exchange earnings. Then, economic sanctions can adversely affect foreign exchange earnings, and the imports will be disrupted. When export diversification in the target country is low, sanctions can be risky (Garshasbi & Yusofi, 2016).

Financial sanctions affect the monetary and foreign exchange systems (Drezner, 1999). Economic sanctions affect the foreign exchange market and the economy's reserves. It also affects other markets and speculation attacks (Purshahabi, 2014). In fact, economic sanctions have direct effects on the foreign exchange market, which include increasing the real exchange rate, increasing the gap between the official exchange rate and the free market, and intensifying the exchange rate volatility (Nademi et al., 2017).

It is the foreign exchange sanctions that give rise to an increase in the gap between the nominal and the actual variables because when the foreign exchange transactions do not happen on the date of their contract, they must be transacted through mechanisms other than SWIFT or other currencies, which has the possibility of delays in carrying out the transactions or making the transactions more expensive (Eichengreen et al., 2023).

The exchange rate gap strengthens the rent-seeking process in the foreign exchange market, and this phenomenon can lead liquidity to speculation in the foreign exchange market to benefit from the rent of multiple exchange rates instead of production activities. This phenomenon helps to increase the exchange rate and inflationary expectations in the foreign exchange market. Another mechanism of the effect of sanctions on the foreign exchange market is the increase in the exchange rate due to the reduction of foreign exchange reserves and lower supply in the market (Nademi et al., 2017).

Keshtgar et al. (2020) explored the impact of exchange rate volatility on banking performance in Iran. As banks play an important role in Iran's economy, which has a bank-based financial system, they examined the impact of exchange rate volatility as a determinant of banks' performance. The exchange rate has been volatile in Iran's economy due to sanctions, among others, and has had an adverse effect on banking performance. They investigated the issue from 2007-2017 for 14 Iranian banks. Exchange rate fluctuations are derived by the GARCH method, and the effect of its fluctuations on bank performance is examined using panel data. To evaluate banks' performance, they utilized liquidity and profitability. Estimating the econometric model using panel data by random effects indicated that exchange rate volatility has a negative and statistically significant effect on banks' capital return ratio. Exchange rate volatility is also a determinant in increasing the lending ratio to total bank deposits, as it increases the financial gap and creates the credit risk that the gap entails.

Empirical literature review

Eichengreen et al. (2023) examined the economic sanctions and exchange rates over the period 1914-1945. The results indicated that import and export restrictions, asset freezing, and trade sanctions led to exchange rate effects consistent with the theory. However, the effects vary based on the types of sanctions. The direction of the exchange rate movement is not a suitable measure of the success or failure of sanctions but rather a reflection of the type and scale of measures taken.

Zamani et al. (2022) explored the impact of economic sanctions on exchange rate movement in Iran using the Markov switching method from 1985 to 2021. The findings suggest that sanctions have a positive effect on the exchange rate. Also, the effect of inflation on the exchange rate is positive.

Moeeni et al. (2021) investigated the impact of sanctions on Iran's oil exports on the exchange rate based on internet search data. Google Trends has provided an analytical tool to measure and monitor people's expectations based on their internet search data. This study analyzed and modeled Iran's exchange rate trend using sanctions-related expectations extracted from Google Trends. Google Search Index (GSI) on sanctions indicates the expectations. Estimation is conducted using monthly data and the autoregressive distributed lag method (ARDL). The results indicated a positive and significant effect of GSI on the exchange rate in the market and only a positive effect on the real exchange rate. The effects of sanctions appear partly through changes in people's expectations, which can be extracted using GSI.

Laudati and Pesaran (2021) explored the impact of sanctions on Iran's economy using a time series index based on the newspapers' data that covered the daily sanctions from 1989-2020. Their findings suggest that sanctions impacted Iran's exchange rate, inflation, and growth.

Nakhli et al. (2021) investigated the oil embargo and its transmission channels in Iran's economy using the New Keynesian DSGE model from 2000-2017. The results indicated that sanctions reduced the ratio of the central bank's foreign reserves to the monetary base, leading to an increase in the nominal exchange rate.

Wang et al. (2019) investigated the effect of economic sanctions on the exchange rate fluctuations. They estimated exchange rate fluctuations using panel data of 23 target countries, including Iran, from 1996 to 2015 using the least squares dummy variable corrected model (LSDVC). The results indicated that economic sanctions affect the instability of the exchange rate of the target countries. Also, different sanctions (trade, financial, etc.) affect the exchange rate fluctuations differently.

Barkhordari and Abolhasani (2019) examined the determinants of the exchange rate in Iran and the role of economic sanctions over the period 2016-2018 using the Auto Regressive Distributed Lag (ARDL) model and vector error correction mechanism (ECM). The findings suggest that economic sanctions in 2013 had a decisive impact on the exchange rate in Iran.

Ghorbani Dastgerdi et al. (2018) developed an index for trade-financial

sanctions (TF index) from 1970-2011. They examined the effect of sanctions on Iran's economy through the index variation. Their results suggest severe sanctions led to instability in the market exchange rate and increased the gap between market and official exchange rates.

Tayebi and Sadeghi (2018) investigated "the effects of international sanctions on the exchange rate in Iran" over the period 1981 to 2015 using the auto-regressive distributed lag (ARDL) model. The results indicated that the revenue from oil exports, the consumer price index (CPI), and GDP positively and significantly affected the exchange rate.

Nademi et al. (2017) investigated the impact of sanctions on the foreign exchange market and its transmission mechanism to macroeconomic variables such as inflation and unemployment in Iran. To this end, they employed econometric models, including ARMAX, GARCH, and the Markov switching model. The results suggest that sanctions have had three direct effects on the foreign exchange market: an increase in the exchange rate, an increase in the gap between the official exchange rate and market exchange rate, and exchange rate volatility.

Tyll et al. (2018) investigated the impact of US sanctions on the Russian economy and the exchange rate from 02/01/2012 to 07/11/2015. As Russia's economy depends on oil exports, sanctions affected the ruble exchange rate against the US dollar, impacting the price level and the overall economic environment.

Amini (2016) explored the impact of sanctions on oil exports and exchange rate fluctuations in Iran. The findings suggest that the sanctions imposed on oil exports have intensified the exchange rate fluctuations.

Garshasbi and Yousefi (2016) investigated the impact of international sanctions on macroeconomic variables in Iran. They identified twelve variables severely affected by sanctions and included them in the indexation process of sanctions. The variables include the official exchange rate, the market exchange rate, and the price index of export and import goods. According to the findings, the direct effects of sanctions are significant only in terms of economic growth and trade. There is a direct relationship between the severity of sanctions and their effects on economic variables, especially the foreign exchange rate.

Eyler (2015) investigated the effects of economic sanctions on the official exchange rate stability using the ARDL model and a sanction indicator. A change in the exchange rate helps save the target economy from the adverse

effects of sanctions. The results show that the exchange rate could be used as a signal for the effectiveness of sanctions.

Rasulyar et al. (2015) explored the impact of economic sanctions on the exchange rate in Iran, Burma, Cuba, North Korea, Sudan, and Syria from 1974 to 2011 using the GMM method. In the first scenario for six countries, the results indicated that the relationship between sanctions and exchange rate fluctuations is positive, and a 1 percent increase in sanctions increases exchange rate fluctuations by 0.38. In the second scenario for Iran, which is the impact of sanctions on the exchange rate, the results indicated that the relationship between sanctions and exchange rate fluctuations is positive, and a one percent increase in the sanctions led to an increase in exchange rate fluctuations.

Mirjalili and Karimzadeh (2021) examined the negative oil revenue shock for depositing in the National Development Fund of Iran as a fiscal policy using the DSGE model. The impact of a negative oil revenue shock, such as a sanction, not only affects the aggregate product but also leads to the reduction of aggregate consumption and investment. The rise of the exchange rate leads to the reduction of imports. Also, counter-cyclical fiscal policy is practically impossible without the foreign exchange resources of the National Development Fund to absorb the negative shock of sanctions (Mirjalili & Karimzadeh, 2021, pp. 671–673).

Pourshahabi and Dehmardeh (2015) investigated the impact of economic sanctions on speculative attacks and the foreign exchange crisis. They employed a model of the foreign exchange crisis based on the New-Keynesian framework. Iran's assets in US dollars are estimated using the DOLS method. MRSGARCH is utilized to record the dynamics of speculative attacks, and the Beta-Skew-t-EGARCH model is employed to generate the economic uncertainty variable using the exchange rate, interest rate, inflation, and economic growth. The results indicated that economic sanctions and speculative attacks positively and significantly affect the foreign exchange crisis.

Shirvan and Sufi (1400) explored the determinants of exchange rate volatility using thematic analysis and the MICMAC technique. The findings show that in addition to very effective sanctions, foreign exchange reserves, the psychological atmosphere governing the foreign exchange market, and the central bank's managerial efficiency are the most effective on exchange rate volatility. Imposed sanctions have the most significant effect on other variables, including the exchange rate.

Keshavarz et al. (2018) examined the impact of sanctions and uncertainty of oil revenues on the fluctuations of macroeconomic variables over the period 1991-2017 using the BEKK Asymmetric Mean-in-GARCH VARMAX model in terms of a structural break in conditional variance. The results indicated that oil revenue impulse (shock) or sanction index would affect production, exchange rate, and the stock market. Also, the intensification of sanctions leads to a spillover of uncertainty to macroeconomic variables and pushes the exchange rate upwards.

Keshtgar et al. (2020) examined the impact of exchange rate fluctuations on financial cycles in Iran. They studied the exchange rate as an effective variable in the financial cycles, and its fluctuations are extracted by the TGARCH method. The result of the VAR model shows the relationship between the Granger causality of the exchange rate fluctuations towards the financial cycle, which suggests that exchange rate fluctuations lead to instability in the financial cycle in Iran.

Dehghan Khavari et al. (2021) explored the impact of news, such as sanctions, on the fluctuations of the banking group index in the Tehran Stock Exchange. They examined the effectiveness of news as one of the most important factors in the formation of volatility on the banking group index using 1460 daily records during 2018-2019 and the GARCH family's method. The results indicated that political and economic news, such as news on sanctions, significantly impacts banking index fluctuations. Good and bad news on exchange rate volatility (new sanctions) and unexpected news can be considered factors impacting the Stock Exchange's total index (pp. 401–402). Exchange rate fluctuations affect the stock price index in two ways. First, trade company revenue is directly affected by the exchange rate. Second, foreign exchange as a competing asset in the portfolio of economic entities influences their decisions on buying and selling stocks. Many activities rely on imports; therefore, exchange rate fluctuations affect companies' profits and change the competitive position of domestic producers (p. 402). Negative news such as "sanctions" adversely affected Iran's economic environment. Negative news, such as sanctions on banks and the central bank, has intensified the reactions of the banking index (p. 413).

Contributions

As can be seen from the aforementioned studies, they explored the effect of economic sanctions on the exchange rate; however, we narrowed the topic and focused on the impact of financial sanctions on the exchange rate. Knowing this topic is a novel academic study in this field. We employed a DSGE model

to explore the issue. A contribution of the study is to fill this gap in the literature.

Another contribution to the DSGE model is modeling the effect of financial sanctions through changes in oil exports, capital flow, and international transactions. We also considered the effect of financial sanctions on the economy through the behavior of households and firms affected by the reduction of oil revenues. Finally, another contribution is designing a model based on Iran's economic circumstances. The above characteristics distinguish the DSGE model developed in this paper from previous studies.

Research Methodology

We employed a new Keynesian DSGE model, which includes households, firms, policymaking departments, the government, and the central bank. On the other hand, in the new Keynesian approach that we followed, the economic shocks and different policies can affect actual variables and, therefore, economic equilibrium. In this structure, financial sanctions are modeled as stochastic shocks, and we studied the dynamic path of macro variables.

The model includes the household sector, the firms producing final goods in a monopolistic competition producers' market and capital goods, price stickiness, and other features provided in the New Keynesian approach (Mirjalili, 2015, pp. 433-439). In the following, the behavior of each economic unit and sector will be analyzed separately.

Household

This model's economy consists of identical households with an infinite horizon. They use a basket with constant elasticity of substitution (CES) for domestic and imported consumer and capital goods and financial assets in cash m_t‘, one-year government bonds $_{but}$ with nominal interest rate (Felices & Tuesta, 2010; Tavakolian & Jalali, 2017). The household gains utility from private consumption goods C_t, maintains the balance of money ($m_t = \frac{M_t}{P_t}$), and loses utility due to labor supply (N_t). The utility function of a household is as follows:

$$Max\ E_0 \sum_{t=0}^{\infty} \beta^t\ U_i(C_t, \frac{M_t}{P_t}, N_t) \quad (1)$$

$$U_t = \frac{C_t^{1-\sigma_c}}{1-\sigma_c} + \frac{\chi_m}{1-\sigma_m}(\frac{M_t}{P_t})^{1-\sigma_m} - \chi_{ir}\frac{N_t}{1+\sigma_{ir}} \quad (2)$$

Where $\beta \in (0,1)$ is the inter-period discount factor, σ_c is the inter-period elasticity of substitution of consumption, σ_m is the elasticity of substitution of the actual balance of money, and σ_{ir} is the opposite of Frisch's labor elasticity for labor. The household maximizes its preferences according to the budget constraint and the capital movement rule (K_{t+1}), and it is assumed that the households own the capital stock rented to the representative firm in each period. In the above relationship, the right side is the household income, which includes the supply of capital K_t through the rate of return of capital r_t‘, and the wages of the labor force W_t in Iran, which are deducted from his salary at the wage tax rate t^w—also, transfer payments (Tr_t) and deflated domestic money $\frac{m_{t-1}}{\pi_t}$.

On the household payment side (left side) is consumption of goods (C_t), value-added tax (t^{VA}), investment (I_t), and domestic money (m_t).

$$C_t(1+t^{VA}) + m_t + I_t^{Pa} = W_t N_t(1-t^w) + \frac{m_{t-1}}{\pi_t} + Tr_t + r_t K_t \quad (3)$$

The important issue for the oil-exporting country is that if a part of the oil revenues is invested, the oil revenues will play an effective role in capital accumulation. In this case, a part of the country's oil revenues is saved in the National Development Fund and allocated to non-governmental private and public sector investment projects. Therefore, the capital accumulation process for the private sector can be presented as follows (Sayadi & Bahrami, 2015; Mirjalili & Karimadeh, 2021):

$$K_{t+1} = (1-\delta)K_t + I_t^{Pa} \quad (4)$$

$$I_t^{Pa} = I_t^P + F_t \quad (5)$$

In this regard, I_t^{Pa} is an augmented investment, part of which is provided by the private sector firm I_t^P and part of which is provided by the National Development Fund F_t . In fact, F_t is from the oil revenues that are allocated to the private sector in each period to enhance its capital accumulation. By maximizing the utility function subject to the constraints, we will have the following equations:

$$N_t^{\sigma_{ir}} = \frac{\lambda_t w_t^{ir}(1-t^w)}{\chi_{ir}} \quad (6)$$

$$\lambda_t = m_t^{-\sigma_m} + \beta E_t \frac{\lambda_{t+1}}{\pi_{t+1}} \quad (7)$$

$$\frac{C_t^{-\sigma_c}}{1-t^{VA}} = \beta E_t\left[\frac{C_{t+1}^{-\sigma_c}}{1-t^{VA}}(r_{t+1} + (1-\delta)\right] \quad (8)$$

Also, the aggregate consumption C_t is divided into consumption of domestic goods (C_t^d) and consumption of imported goods (C_t^{pm}) based on the constant elasticity of substitution (CES) (Tavakolian & Jalali, 2017). In the above relationship, θ_c is the elasticity of substitution between domestic and imported consumer goods, and α_c is the share of domestically produced consumer goods in total consumption.

$$C_t = [\alpha_c^{\frac{1}{\theta_c}} C_t^{d\frac{\theta_c-1}{\theta_c}} + (1-\alpha_c) C_t^{pm\frac{\theta_c-1}{\theta_c}}]^{\frac{\theta_c}{\theta_c-1}} \quad (9)$$

In addition, like consumer goods, it is assumed that private investment also follows the CES and is divided into domestic production investment (I_t^d) and import goods investment (I_t^{pm}). In the above relationship, θ_I is the elasticity of substitution between domestic and imported investment, and α_I is the share of investment in domestic production from the aggregate investment.

$$I_t^P = [\alpha_I^{\frac{1}{\theta_I}} I_t^{d\frac{\theta_I-1}{\theta_I}} + (1-\alpha_I) I_t^{pm\frac{\theta_I-1}{\theta_I}}]^{\frac{\theta_I}{\theta_I-1}} \quad (10)$$

Labor market

Each household is assumed to be a monopolistically competitive supplier of differentiated labor services, which producers require of intermediate goods. Households can determine their wages according to the substitution between different labor services. After determining the wage rate, each household supplies the labor enterprises need with this wage without flexibility (Igityan, 2016). The analytical framework explaining the wage adjustment process in the economy is similar to price adjustment. Suppose a labor aggregator (for example, an employment agency) rents different labor services from households and transforms them into a homogeneous factor of production N_t^{ir} using the following technology:

$$N_t = [\int_0^1 N(i)_t^{1-\frac{1}{\theta_w^{ir}}} di]^{\frac{\theta_w^{ir}}{\theta_w^{ir}-1}} \quad (11)$$

Where $N(i)_t$ represents the workforce of the ith household, assuming that w_t is the index of the aggregate wage, from solving the problem, the demand function for the labor force of the ith household is obtained from the labor force aggregator as follows:

$$N(i)_t = (\frac{W(i)_t^{ir}}{W_t^{ir}})^{-\theta_w^{ir}} N_t \quad (12)$$

The aggregator of labor supplies the homogeneous labor force to the intermediary firms in perfect competition. To model the wage adjustment process, households are assumed to determine their wages in the labor market. They supply their labor in monopolistic competition, but it is not possible for them to adjust their wages optimally in every period.

According to Calvo's pricing (1983), it is assumed that only $(1-\vartheta_w^{ir})$ percent of households can optimally adjust their nominal wages in each period. The household sets the optimal wage at W_t^* so that they cannot change it in the future. Based on a similar equation, optimization is conducted as follows:

$$\sum_{j=0}^{\infty}(\beta v_w^{ir})^j E_t\left[\Lambda_{t,t+j}^{ir}\left(\frac{W_t^{*ir}}{P_{t+j}^{ir}}-M_w^{ir}MRS_{t+j}^{ir}\right)N_{t+j}\right]=0 \quad (13)$$

By defining wage inflation $\pi_{w,t}$ and inserting W_t^* in the last two equations, the Phillips Keynesian curve for wage inflation is as follows:

$$\pi_{w,t}=\beta\pi_{w,t+1}+\lambda_w^{ir}[mrs_t^{ir}-(W_t-P_t^{ir})] \quad (14)$$

Where

$\lambda_w^{ir}=\frac{(1-\vartheta_w^{ir})(1-\beta\vartheta_w^{ir})}{\vartheta_w^{ir}(1+\theta_w^{ir}\sigma_{ir})}$

and $mrs_t^{ir}=\frac{\chi_{ir}N_t^{ir^{\sigma_{ir}}}}{C_t^{-\sigma_c}}$

This equation shows that when the real wage is lower than expected, the household increases the wage by putting pressure on wage inflation. Therefore, the real wage can be defined as follows:

$$w_t=w_{t-1}+\pi_{w,t}-\pi_t \quad (15)$$

Firms:

The model includes two types of domestic firms, i.e., producers of intermediate goods and producers of final goods (Tavakolian & Jalali, 2017). Regarding the firms that produce final goods, it is assumed that there is a firm that buys differentiated goods produced by firms that produce intermediate goods and produces final goods and sells them to final buyers. Intermediate goods are distinct and imperfect substitutes of each other, which the producer of the final product combines based on the logic of the Dixit-Stiglitz aggregator as follows:

$$y_t^d=[\int_0^1 y_t^d(i)^{\frac{\theta_d-1}{\theta_d}}di]^{\frac{\theta_d}{\theta_d-1}} \quad (16)$$

The firm producing the final product in perfect competition and considering the prices of the differentiated intermediate goods tries to determine the purchase of these goods to maximize its profit or minimize its cost. By solving the first-order condition of the equation, the demand function for the differentiated product produced by each intermediate firm is provided as follows, which is a function of the ratio of its price to the price of the domestic final product:

$$y_t^d(i) = [\frac{P_t^d(i)}{P_t^d}]^{-\theta_d} y_t^d \quad (17)$$

Here, $P_t^d(i)$ is the price of the intermediate goods, and P_t^d is the price index of domestically produced goods. By replacing equation (21) in equation (20), the relation between the price index of the domestically produced final product and the price of intermediate goods can be derived as follows:

$$P_t^d = [\int_0^1 {P_t^d}^{1-\theta_d} di]^{\frac{1}{1-\theta_d}} \quad (18)$$

Intermediate firms employ labor and capital as inputs in the production process. Each firm producing intermediate goods produces the goods using the Cobb-Douglas function in a monopolistic competition structure, and due to the fact that the oil sector is considered separately in the model, the production of this sector includes the production of non-oil goods (Nakhli et al., 2020):

$$y_t(j) = A_t K(j)_t^{\alpha} {N(i)_t}^{\omega} In_t^{1-\alpha-\omega}(j) \quad (19)$$

The firm's demand for labor, capital (K_t) and intermediate goods (In_t) and the marginal cost could be derived through cost minimization. In these equations, i is omitted from the MC subscript because all firms are assumed to have identical marginal costs.

$$N(i)_t = \omega \frac{y_t(i)}{w_t^{ir}} mc_t \quad (20)$$

$$K_t(j) = \frac{\alpha y_t(i)}{r_t} mc_t \quad (21)$$

$$In_t(j) = (1-\alpha-\omega) \frac{y_t(i)}{P_t^{In}} mc_t \quad (22)$$

$$mc_t = (\frac{1}{\omega})^{\omega} (\frac{1}{\alpha})^{\alpha} (\frac{1}{1-\alpha-\omega})^{1-\alpha-\omega} {w_t^{ir}}^{\omega} r_t^{\alpha} {P_t^{In}}^{1-\alpha-\omega} \quad (23)$$

Manufacturing firms supply their products to domestic and foreign markets, where $y_t^d(i)$ and P_t^d are the supply and price of the produced goods to the domestic market. Also, $y_t^x(i)$ is the supply of manufactured goods to the

foreign market at the price $Ex_t P_t^x$. The production function with constant elasticity of substitution is as follows:

$$y_t(i) = [\alpha_y^{\frac{1}{\theta_y}} y_t^{d\frac{\theta_y+1}{\theta_y}}(i) + (1-\alpha_y)^{\frac{1}{\theta}} y_t^{x}(i)^{\frac{\theta_y+1}{\theta_y}}]^{\frac{\theta_y}{\theta_y+1}} \quad (24)$$

Manufacturing firms maximize their profits to determine supply to domestic and foreign markets.

$$y_t^x = (1-\alpha_y)\left(\frac{Ex_t P_t^x}{P_t^y}\right)^{\theta_y} y_t(i) \quad (25)$$

$$y_t^d = \alpha_y\left(\frac{P_t^d}{P_t^y}\right)^{\theta_y} y_t(i) \quad (26)$$

According to the first-order conditions and their combination with the rule of changes in the price index of domestically produced goods, finally, the relationship between the dynamics of the inflation rate of domestically produced goods (the new Keynesian Phillips curve) can be derived in the following linear-logarithmic form:

$$\hat{\pi}_t^d = \frac{v_d}{1+\beta v_d}\hat{\pi}_{t-1}^d + \frac{\beta}{1+\beta v_d}\hat{\pi}_{t+1}^d + \frac{(1-v_d)(1-\beta v_d)}{\beta v_d(1+\beta v_d)}\widehat{mc}_t \quad (27)$$

Also, the demand for intermediate goods could be divided into domestic and imported intermediate goods. Therefore, the form of demand for intermediate goods for the CES function will be as follows:

$$In_t = [\alpha_{In}^{\frac{1}{\theta_{In}}} In_t^{d\frac{\theta_{In}-1}{\theta_{In}}} + (1-\alpha_{In})^{\frac{1}{\theta_{In}}} In_t^{m\frac{\theta_{In}-1}{\theta_{In}}}]^{\frac{\theta_{In}}{\theta_{In}-1}} \quad (28)$$

By optimizing the behavior, the demand for each of the domestic and imported intermediate goods can be derived as follows, where P_t^{In} is the price of the intermediate goods in the domestic market and P_t^{Inm} is the price of imported intermediate goods.

$$In_t^m = (1-\alpha_{In})\left(\frac{P_t^{Inm}}{P_t^{In}}\right)^{-\theta_{In}} In_t \quad (29)$$

$$In_t^d = \alpha_y\left(\frac{P_t^{Ind}}{P_t^{In}}\right)^{-\theta_{In}} In_t \quad (30)$$

Foreign trade

The foreign trade sector is divided into export and import so that the effects of financial sanctions can be examined. Firms producing intermediate goods sell a part of their products in the foreign market. As before, an aggregator (for

example, an exporting company) collects domestically produced goods and sells them to the foreign market. The goods exported by each supplier depend on the total price of the export goods and the price of each export goods by each firm $P_t^x(i)$.

$$y_t^x = [\int_0^1 y_t^x(i)^{\frac{\theta y-1}{\theta y}} di]^{\frac{\theta_x}{\theta_x-1}} \quad (31)$$

Therefore, the demand and export price index of each aggregator for export is as follows:

$$y_t^x(i) = [\frac{P_t^x(i)}{P_t^x}]^{-\theta_x} y_t^x \quad (32)$$

$$P_t^x = [\int_0^1 P_t^{x\,1-\theta_x} di]^{\frac{1}{1-\theta_x}} \quad (33)$$

Now, according to Calvo's model, only $1-\vartheta_x$ % of the exporters can determine their prices optimally for other exporters. In that case, the prices will be adjusted based on the inflation of the previous period, which, based on export price indexation, is as follows:

$$P_{t+1}^x(i) = (\pi_t^x)^{\tau_x} P_t^x(i) \quad (34)$$

In this way, the linear-logarithmic Phillips-Keynesian curve for export is as follows:

$$\hat{\pi}_t^x = \frac{v_x}{1+\beta v_x}\hat{\pi}_{t-1}^x + \frac{\beta}{1+\beta v_x}\hat{\pi}_{t+1}^x + \frac{(1-v_x)(1-\beta v_x)}{\beta v_x(1+\beta v_x)}\widehat{mc}_t^x \quad (35)$$

Exporters buy domestic intermediate goods at the price of P_t^d and sell to foreign consumers at the price of P_t^x. International sanctions increase the price of export goods by S_t^x. As a result, the marginal cost of each exporter will be as follows:

$$mc_t^x = \frac{P_t^d}{Ex_t P_t^x} S_t^x \quad (36)$$

Export costs follow the $AR(1)$ process, and sanctions increase costs through the ss_x parameter. In this regard, $\overline{S^x}$ represents the value of the steady state resulting from the financial costs of exports.

$$lnS_t^x = (1-\rho_x)ln\overline{S^x} + \rho_x \ln S_{t-1}^x + ssx.sanc_t + \varepsilon_t^x \quad ; \quad \varepsilon_t^x \sim i.i.d.N(0,\sigma_{sx}^2) \quad (37)$$

However, importing firms can be considered in the model in three ways (Manzoor & Taghipour, 2016; Nakhli et al., 2020): consumer goods (C_t^M), capital goods (I_t^M), and intermediate goods (In_t^M). To this end, in each of the three mentioned cases, according to Nakhli et al. (2021), the importer in each sector is considered an aggregator to import the desired product and then make it available to those who request it, including the private sector or the government in a monopolistic competition market. C_t^M is the supply of imported goods, a function of the goods purchased from each importer (i).

$$C_t^M = [\int_0^1 C_t^x(i)^{\frac{\theta_{cm}-1}{\theta_{cm}}} di]^{\frac{\theta_{cm}}{\theta_{cm}-1}} \quad (38)$$

The aggregator minimizes his cost to determine the demand from each importer and the price of imported goods. In fact, the aggregator chooses the combination of goods to minimize the cost of the imported goods according to the specified import price P_t^{cm}. By solving the first-order conditions, we can determine the demand function faced by each importer i and the price of the export goods.

$$C_t^M(i) = [\frac{P_t^{cm}(i)}{P_t^{cm}}]^{-\theta_{cm}} C_t^M \quad (39)$$

$$P_t^{cm} = [\int_0^1 P_t^{cm\,1-\theta_{cm}} di]^{\frac{1}{1-\theta_{cm}}} \quad (40)$$

Again, according to Calvo's method, only$1-\vartheta_{cm}$ percent of the importing firms can determine their prices optimally, and the rest of the firms adjust the prices of their imported goods based on the following indexation.

$$P_{t+1}^{cm}(i) = (\pi_t^{cm})^{\tau_{cm}} P_t^{cm}(i) \quad (41)$$

Therefore, the import price index is:

$$P_t^{cm\,1-\theta_{cm}} = \vartheta_{cm}[(\pi_{t-1}^{cm})^{\tau_{cm}} P_{t-1}^{cm}]^{1-\theta_{cm}} + (1-\vartheta_{cm}) P_t^{cm*\,1-\theta_{cm}} \quad (42)$$

Each consumer goods importer decides to get the optimal price P_t^{cm*} to maximize his profit. Now, companies that have the opportunity to adjust the price should maximize their expected future profit flow in order to determine the optimal price of the present value. Therefore, the linear-logarithmic Phillips-Keynesian curve for imported goods will be as follows:

$$\hat{\pi}_t^{cm} = \frac{v_{cm}}{1+\beta v_{cm}} \hat{\pi}_{t-1}^{cm} + \frac{\beta}{1+\beta v_{cm}} \hat{\pi}_{t+1}^{cm} + \frac{(1-v_{cm})(1-\beta v_{cm})}{\beta v_{cm}\,1+\beta v_{cm}} \widehat{mc}_t^{cm} \quad (43)$$

In fact, importers buy the required goods from foreign markets at the price of P_t^f and sell them to the domestic market at the price of P_t^{cm}. The marginal

costs for importers can be measured based on the following equation:

$$mc_t^{cm} = \frac{Ex_t P_t^f}{P_t^{cm}} S_t^{cm} \quad (44)$$

Import costs follow the $AR(1)$ process, and the sanctions increase the costs through the scm parameter.

$$lnS_t^{cm} = (1-\rho_{cm})ln\overline{S^{cm}} + \rho_{cm} \ln S_{t-1}^{cm} + sscm.sanc_t + \varepsilon_t^{cm};$$
$$\varepsilon_t^{cm} \sim i.i.d.N(0, \sigma_{scm}^2) \quad (45)$$

Oil revenue

There are different ways to enter the oil revenue in the model. In general, some studies consider the oil sector like other economic activities, but other studies use the exogenous process to model the oil sector. In their modeling, the oil shock is considered through the application of international sanctions against oil exports. It is also assumed that all oil extracted in the economy is exported at world prices, and the foreign exchange revenues will be available to the government. Oil proceeds are considered a first-order AR(1) auto-regressive process, which is affected by the sanctions through the ss. oil parameter (Nakhli et al., 2021).

$$lnOil_t = (1-\rho_{oil})ln\overline{Oil} + \rho_{oil} \ln Oil_{t-1} + ssoil.sanc_t +$$
$$\varepsilon_t^{oil}; \varepsilon_t^{oil} \sim i.i.d.N(0, \sigma_{soil}^2) \quad (46)$$

In addition, it is assumed that the accumulation of National Development Fund (NDF_t) reserves in each period follows the following process (Sayadi & Bahrami, 2015; Manzoor & Taghipour, 2016; Mirjalili & Karimzadeh, 2021):

$$NDF_t = NDF_{t-1} + \emptyset_F Oil_t - F_t + \alpha_{nd} ND_t + Z_t \quad (47)$$

Where NDF_{t-1} is the balance of National Development Fund reserves from the previous period that is transferred to the current period. $\emptyset_F$ is the fund's share of oil revenues; F_t is the facility granted by the fund to the private sector, ND_t is the net debt of the private sector to the fund, α_{nd} is the percentage of the net debt of the private sector to the fund that is repaid to the fund in each period. Z_t is the profit deposited into the fund from the fund's resources that has not been lent to the private sector.

A better interpretation of the dynamics of the National Development Fund reserves is that the fund's resources are mainly from the oil revenues, so that$\emptyset_F$ percent of the oil revenues are deposited into the fund. In each period, the fund lends F_t percent of resources to the private sector (more precisely, private,

cooperative, and non-governmental public sectors) through commercial banks (Mirjalili & Karimzadeh, 2021). If we assume that α_F percent of the fund's resources are given to the private sector in each period, we have:

$$F_t = \alpha_F \, NDF_t \tag{48}$$

Also, the net debt of the private sector to the fund can be considered as follows:

$$ND_t = ND_{t-1} + (1 + rd)F_t - \alpha_{nd} ND_t \tag{49}$$

The net debt of the private sector to the fund also includes the accumulated balance of the net debt of the previous period ND_{t-1}, which is transferred to the current period; in addition, the principal and interest of the fund's lending $((1 + rd)F_t)$ minus the repayment of the loan to the fund in each period is $\alpha_{nd} ND_t$. In this regard, rd is the services of the loan granted to the private sector. It is also assumed that r percent profit is also assigned to the fund reserve balance in each period as follows:

$$Z_t = r \, NDF_t \tag{50}$$

The country is small and cannot influence global oil prices. It has no other transactions with the outside world except oil exports, and it exports all the produced oil.

Government

The government finances its expenses by issuing a partnership with Sukuk, borrowing from the central bank, and taxing and exporting oil. In this way, the government's revenue is provided from tax revenues, foreign exchange revenue, oil exports, and monetization of deficits $d_t^G - d_{t-1}^G$ (Khosravi, 2017).

Also, government expenditures include transfer payments (Tr_t), government consumption ($C^G{}_t$) at the price of P_t^{cG}, and government investment I_t^G at the price of P_t^{IG}. In this way, the government budget deficit of GBD_t at real prices can be expressed through the following equation:

$$GBD_t = \frac{P_t^{cG}}{P_t} C^G{}_t + \frac{P_t^{IG}}{P_t} I^G{}_t + TR_t - [\frac{(1-\emptyset_f-\emptyset_{NIOC}-\emptyset_{Dep})Oil_t}{P_t} + \frac{(d_t^G - d_{t-1}^G)}{P_t} + t^w w_t N_t + +t_t^{VA}\left(c_t + \frac{P_t^{cG}}{P_t} C^G{}_t\right) \tag{51}$$

The government procures consumer and capital goods from the domestic market (C_t^{Gd} and I_t^{Gd}) and imported goods (C_t^{Gm} and I_t^{Gm}) through the CES function with substitution elasticity θ_{cG} and θ_{IG} as follows (Tavakolian and

Jalali; 2017):

$$c_t^G = [\alpha_{cG}^{\frac{1}{\theta_{cG}}} C_t^{Gd\frac{\theta_{cG}+1}{\theta_{cG}}} + (1-\alpha_{cG})^{\frac{1}{\theta_{cG}}} c_t^{Gm}(i)^{\frac{\theta_{cG}+1}{\theta_{cG}}}]^{\frac{\theta_{cG}}{\theta_{cG}-1}} \quad (52)$$

$$I_t^G = [\alpha_{IG}^{\frac{1}{\theta_{IG}}} I_t^{Gd\frac{\theta_{IG}+1}{\theta_{IG}}} + (1-\alpha_{IG})^{\frac{1}{\theta_{IG}}} I_t^{Gm}(i)^{\frac{\theta_{IG}+1}{\theta_{IG}}}]^{\frac{\theta_{IG}}{\theta_{IG}-1}} \quad (53)$$

Also, it is assumed that the central bank uses the money growth rate as its monetary policy tool. The reaction function of monetary policy in Iran's economy follows Manzoor and Taghipour (2016) in that the growth rate of the monetary base is determined based on the deviation of production, inflation, and the real exchange rate from their stable values.

Also, according to Khosravi (2017) and considering the importance of the government budget deficit (and the impact of the National Development Fund on the government budget), the deviation from the government budget deficit also affects the growth rate of the monetary base. Therefore, the growth rate of money follows the following rule:

$$\dot{m}_t = \rho_p \dot{m_{t-1}} + \rho_\pi \pi_t + \rho_y y_t + \rho_{re} Re_t + \rho_{Gbd} GBD_t \quad (54)$$

Where $\dot{m}_t = \frac{m_t}{m_{t-1}} \pi_t$

Market settlement conditions

Finally, in the market settlement condition, some unities are added to the model to complete the model and establish the Walras condition. These equations are as follows:

$$y_t \equiv C_t + \frac{P_t^{cG} C_t^G}{P_t} + \frac{P_t^I Ipa_t + P_t^{IG} I_t^G}{P_t} + \frac{X_t}{P_t} - \frac{M_t}{P_t} \quad (55)$$

$$X_t \equiv P_t^x y_t^x + Ex_t Oil_t \quad (56)$$

$$M_t \equiv P_t^{cm} C_t^M + P_t^{Im} I_t^M + P_t^{Inm} In_t^m \quad (57)$$

$$C_t^M \equiv C_t^{pm} + C_t^{Gm} \quad (58)$$

$$I_t^M \equiv I_t^{pm} + I_t^{Gm} \quad (59)$$

$$y_t^d \equiv C_t + C_t^{gd} + I_t^d + I_t^{gd} + In_t^d \quad (60)$$

Results

In the following, we simulated the shock of financial sanctions and the reaction of macroeconomic variables to this shock. We estimated model parameters using the Bayesian method.

Model parameters

The prior density of the parameters is estimated with the posterior density based on the Metropolis-Hastings algorithm. Using this algorithm, two parallel chains with a volume of one million have been extracted to obtain the posterior density of the parameters. The seasonal data of GDP, private investment, private consumption, and government consumption have been used throughout 1990-2021 to estimate the model. All mentioned variables have been deseasonalized using the Hodrick-Prescott filter.

Their geometric mean is considered a stable value according to the available data. Also, the new Keynesian school's growth rate is defined as the variable's ratio in period t to period t-1. As all the variables in the model are defined as the deviation of the logarithm of the variable from the value of the steady state, the growth rate of the variables has been derived from extracting the HP filter with a value of 677 for the parameter related to the logarithm of the ratio of each variable to its previous period value. In addition, the values of the parameters for which there is no data are estimated based on the values of similar parameters.

It has been determined and calibrated in previous studies or based on information and indicators related to Iran's economy (with econometric or mathematical methods). The Table below shows the values of the calibrated parameters.

Table 1. Calibrated parameters of the model

value	Parameter Description	Parameter
0/965	inter-temporal discount factor	β
1/5	inter-temporal elasticity of substitution for consumption	σ_c
0/048	capital depreciation rate	δ
0/24	wage tax rate	t^w
0/27	Value Added Tax Rate	t^{VA}
2/9	The inverse of Frisch's 'labor elasticity for the labor force in Iran	σ_{ir}
0/81	share of investment in domestic production from total investment	α_I
0/4	share of capital services in the production of domestic goods	α
0/9	share of domestically produced consumer goods in total consumption	α_c
0/34	share of the labor force in the production of domestic goods	ω
0/7	share of domestic inputs in the production of domestic goods	α_{In}

0/68	percentage of workers who are unable to adjust their wages	ϑ_w^{ir}
0/15	share of lending to the private sector by the NDFI	α_F
0/15	net share of private sector debt to the NDFI	α_{nd}
0/2	NDFI's share of oil revenues	$\emptyset_F$
0/015	profit share of loans granted to the private sector	rd
0/35	AR(1) coefficient of oil export	ρ_{oil}
0/29	coefficient of importance of lag in money growth	ρ_m
0/7	coefficient of importance of the budget deficit in determining the growth of money	ρ_{Gbd}
0/62	coefficient of the importance of the real exchange rate in determining money growth	ρ_{re}
-1.54	coefficient of importance of inflation in monetary policy reaction function	ρ_π
-1.7	coefficient of the importance of production in monetary policy reaction function	ρ_y
0/42	AR(1) coefficient of financial sanction	ρ_{sanc}

Source: research findings

Other parameters were estimated using the Bayesian method. The results are provided with a 90% confidence interval in Table (2).

Table 2. Estimation of model parameters

90% confidence interval	posterior mean	prior mean	prior distribution	definition	Parameter
1/1402 1/2946	1/21	1/25	gamma	relative preferences of the workforce	χ_{ir}
0/5125 0/6754	0/59	0/6	beta	wage indexation degree	τ_w
0/9992 1/1551	1/07	1/16	Gamma	elasticity of substitution between domestic and imported consumer goods	θ_c
1/3324 1/4781	1/4	1/54	Gamma	elasticity of substitution between domestic investment and import	θ_I
0/4553 0/6117	0/53	0/45	beta	elasticity of substitution between types of labor supplied	θ_w^{ir}
0/5906 0/7284	0/65	0/9	beta	share of manufactured goods supplied to the domestic market	α_y
1/1091 1/2499	1/18	1/27	gamma	elasticity of substitution between goods supplied inside and abroad	θ_y
0/4278 0/5768	0/5	0/39	beta	elasticity of substitution of domestic and imported production inputs	θ_{In}

0/3612 0/4834	0/42	0/35	beta	percentage of companies importing consumer goods that are unable to adjust their prices	ϑ_{cm}
0/2438 0/3936	0/31	0/35	beta	coefficient of AR(1) financial costs of imported consumer goods	ρ_{cm}
0/3153 0/4768	0/39	0/43	Beta	coefficient AR(1) financial costs of imported investment goods	ρ_{Im}
0/0527 0/1796	0/11	0/15	beta	percentage of import companies that are unable to adjust their prices	ϑ_{inm}
0/2368 0/3624	0/3	0/36	beta	coefficient of financial costs of imported intermediate inputs	ρ_{Inm}
0/7082 0/7957	0/75	0/9	Beta	share of domestic goods in government consumption	α_{cG}
0/7904 0/9163	0/85	0/81	Beta	elasticity of substitution of domestic and imported consumer goods by the government	θ_{cG}
p 0/8832 0/9620	0/92	0/83	Beta	share of domestic goods in government investment	α_{IG}
0/0404 0/1262	0/08	0/108	Beta	elasticity of substitution of domestic and imported investment by the government	θ_{IG}
0/3089 0/4248	0/36	0/5	Beta	percentage of export companies that are unable to adjust their prices	ϑ_x
0/2850 0/4230	0/35	0/4	beta	coefficient of AR(1) financial costs of export	ρ_x
0/4459 1/0938	0/78	0/1	Gamma-inverse	stability coefficient of non-oil export shock	ε_x
0/1634 0/3119	0/23	0/1	Gamma-inverse	coefficient of stability of import shock of consumer goods	ε_{cm}
π 0/1266 0/2355	0/18	0/1	Gamma-inverse	stability coefficient of capital goods import shock	ε_{im}
0/4805 0/8732	0/68	0/1	Gamma-inverse	coefficient of stability of intermediate goods import shock	ε_{inm}
0/0023 0/0156	0/008	0/1	gamma-inverse	coefficient of stability of oil export shock	ε_{oil}

Source: research findings

In order to check the accuracy of the estimates obtained from the MCMC1 method, we conducted Brooks and Gelman's (1998) univariate and multivariate diagnostic tests. The result of the multivariate mode is shown in Diagram (2).

Based on the results, the univariate test of intra-sample and inter-sample variance of all parameters is close to each other and eventually converges to a constant value. Therefore, the Bayesian estimation results using the MCMC method are accurate.

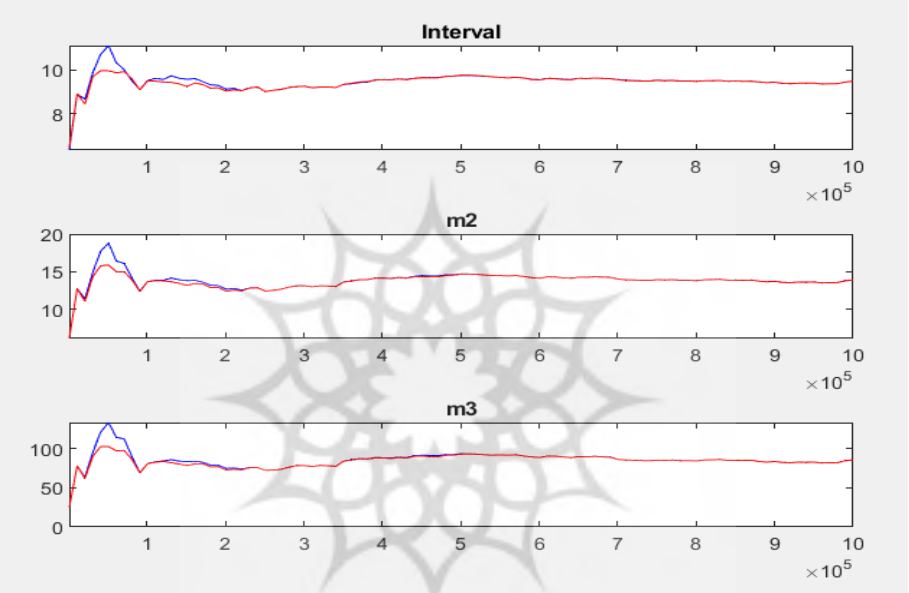

Diagram 1. Diagnostic test for the accuracy of model parameter estimation

The pre-and post-estimated density of the parameters of the model is presented in Diagram (1). The posterior and prior distribution curves are different in some cases, indicating that these parameters can be identified, and the data can contribute to determining the parameters. However, for several parameters, two charts are superimposed on each other, which indicates that the initial information of the previous density is the main factor in determining the parameter values, and the parameters are practically calibrated. The prior and posterior functions of the estimated model indicate that the time series used in the model has a significant role in determining the values of the model's structural parameters.

[1] Markov Chain Monte Carlo

Simulation of simultaneous equations

Financial sanctions are an external shock affecting household budgets, government spending, and economic sectors. Also, financial sanction shock is considered as oil exports, import costs, and investment based on the AR (1) shock. In addition, we explore the impact of financial sanctions on the macroeconomic variables in the model. To this end, we employed a New Keynesian DSGE model, which included the characteristics of Iran's economy as an open oil-exporting economy, emphasizing the role of the National Development Fund and financial sanctions on Iran's economy. In this model, we analyze the sanction impact on income distribution and inequality through the total income channel.

Foreign investment flows through the capital channel. We analyze the impact of foreign exchange through the exchange rate channel. In the DSGE model, the central bank and the government try to reduce the effects of economic sanctions and maintain economic growth through fiscal and monetary policies. We examined the imports of capital and intermediate goods through the foreign trade channel and the production and import costs. In the DSGE model, an increase in the price of imported goods due to sanctions increases production costs and reduces firms' output. This can affect economic growth by reducing production and investment.

The instantaneous response functions depict the dynamic behavior of the variables over time. These functions explain how the economy responds to shocks from exogenous variables. The response of a variable to an incoming shock is expressed as the logarithmic deviation of that variable from its stable value and as a percentage. Here, the results of two shocks of financial sanctions and the exchange rate shock are provided.

To investigate financial sanctions, exchange rates, and macroeconomic variables, we addressed the questions raised in this article by simulating the shock of financial sanctions and the response of macroeconomic variables to this shock and the shock of the exchange rate. The following variables have been used to examine the impact of financial sanctions on macroeconomic variables, which are related to the question: What is the impact of financial sanctions on the exchange rate? What is the impact of financial sanctions on economic growth? What is the impact of financial sanctions on oil revenues? What is the impact of financial sanctions on foreign capital inflows into Iran? What is the impact of financial sanctions on income inequality in Iran? What is the impact of financial sanctions on foreign direct investment in Iran? How do financial sanctions impact the imports of capital and intermediate goods? What

is the impact of financial sanctions on the exchange rate?

Analysis of shock reaction functions

Financial sanctions shock

Chart (1) shows the instantaneous response functions of a financial sanctions shock of one standard deviation. With the implementation of financial sanctions, inflation, consumption, and interest rate variables indicated a positive response. However, production, foreign investment, imports, exchange rate, and oil sales variables indicated a negative response to the fiscal policy shock. Also, from examining the instantaneous response functions of the financial sanctions shock, it can be concluded that the shock of financial sanctions leads to an increase in the real exchange rate and marginal export costs, and ultimately results in an increase in inflation.

A reason could be the impact of the laws related to the return of foreign exchange to the country for exporters, which has led to many problems with the supply of foreign exchange in the domestic market. However, due to the depreciation of the country's currency, despite the increase in the marginal cost of exports, the exports to neighboring countries and trade partners increase. Therefore, due to the increase in exports, the net debt of the private sector to the National Development Fund slightly decreased, but it is not sustainable. In addition, the facilities granted to the private sector by the National Development Fund have decreased, so the NDF's resources have not been able to meet the needs of the private sector. In addition, the shock caused by the financial sanctions has led to decreased economic growth through increased production costs.

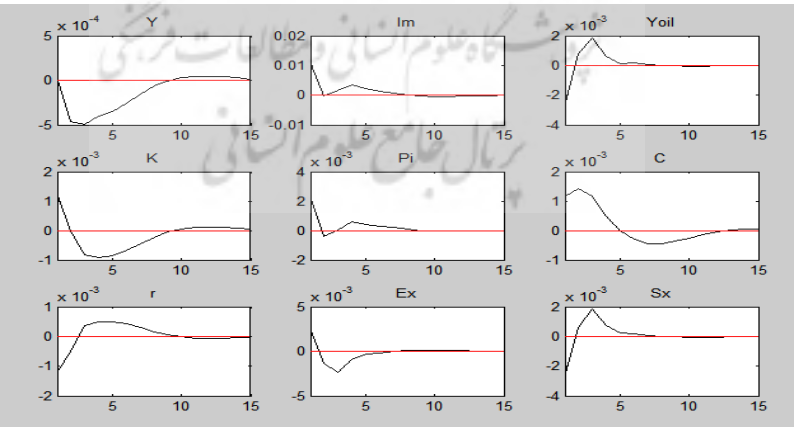

Diagram 2. Instantaneous reaction functions of financial sanctions shock on economic variables

The financial sanctions' shock has led to a decrease in foreign investment due to increased uncertainty and a decrease in investment returns (Heydarian et al., 2022). The results indicated that the financial sanctions resulted in a decrease in oil exports and foreign exchange earnings. Regarding the reaction of income inequality to the shock of financial sanctions, households' average income level decreased with the shock, and the effect of the shock disappeared in the long run. Accordingly, the shock of financial sanctions has increased income inequality (Heydarian et al., 2021). Finally, it should be noted that the increase in financial sanctions due to the increase in financial cost has led to a decrease in the import of intermediate and capital goods in Iran (Heydarian et al., 2023).

Foreign exchange policy shock

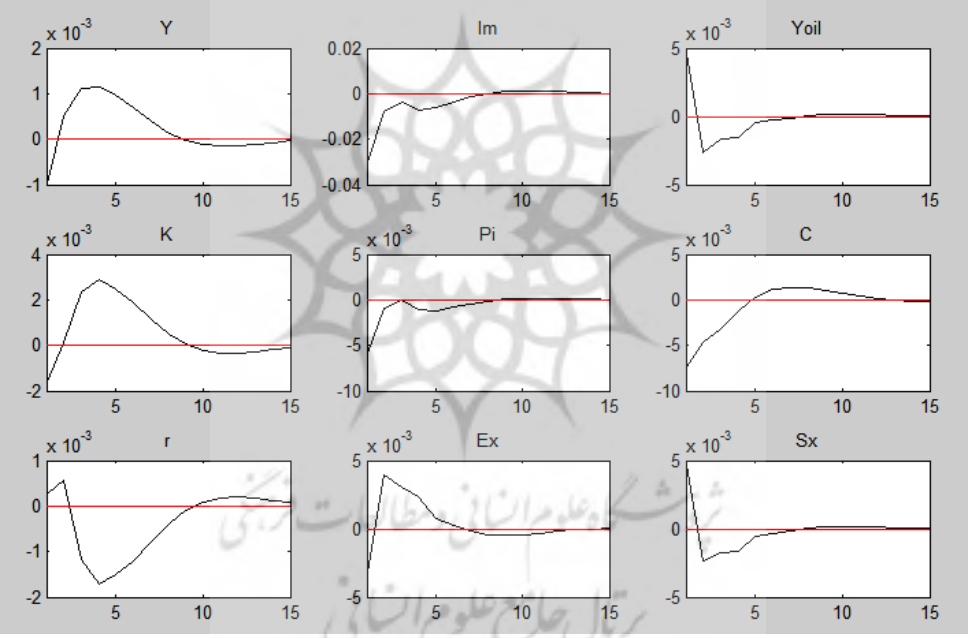

Diagram 3. The effect of foreign exchange shock on economic variables and financial sanctions

The red line shows the zero line. The line below the zero line is an adverse reaction, and above the zero line is a positive reaction. In the case of a foreign exchange shock, the production (Y) decreases initially. However, after a while, the effect of the shock gradually decreases and becomes negative in the medium term. Finally, its effect disappears in the long term.

Also, because of the shock in foreign exchange, the imports decreased initially; that is, they reacted negatively, and the effect of the shock disappeared in the long term. Oil production has shown a positive reaction initially and a negative reaction in the medium term, and after 7 periods, the effect of the shock has disappeared. The capital stock (K) decreased initially; however, in two periods, it reacted positively, and again, in the tenth period, the effect disappeared. In the long term, it became partially negative, and its effect disappeared.

The prices indicate that inflation has decreased initially, and its effect has disappeared over time. Consumption decreased, and again, in 5 periods, the reaction became positive and then disappeared. The interest rate initially increased and then decreased, and in the 10th period, the shock effect disappeared.

With the introduction of an exchange rate shock, it can be concluded that financial sanctions' impact initially decreases in the short run and then increases and gradually returns to an equilibrium in the long run. Therefore, it can be concluded that an exchange rate shock affects the impact of financial sanctions with a lag.

Discussion and Conclusion

The current literature on sanctions examines the evolution of sanctions and trade sanctions against Iran, which exposed the economy to limitations in policymaking. The policy space of the sanctioned country is limited, and third countries also face restrictions. In the case of Iran, the sanctions have a greater financial dimension and are more effective on the policy environment of the economy. Even financial sanctions were more effective than conventional trade sanctions to isolate the economy and could drive the economy out of the international economic system. The sanctions intensified in recent years. As oil export revenue plays a crucial role in Iran's economy, it is considered one of the vulnerable areas of financial sanctions. In this study, we employed a DSGE model for Iran's economy.

By optimizing and making equations log-linear, we calibrated the values of the parameters, and then, using the Bayesian method, we estimated the equations. In the next step, the model was confirmed using the MCMC diagnostic test of Brooks and Gelman (1998) and comparing the prior and posterior density diagrams of the estimated parameters. Then, we interpreted the reaction functions of the macro variables. The results indicated that the

shock caused by the financial sanctions was due to the reduction of oil exports and the decrease of oil revenues. Also, the shock increased the consumption expenditures of the government. This suggests that a more significant part of the oil revenue is spent on the government's consumption expenses instead of being deposited into the National Development Fund. Moreover, the financial shock caused by sanctions led to a decrease in the value of the Iranian Rial. The financial shock caused by increasing production costs has led to a decrease in economic growth and foreign investment, which in turn is affected by an increase in uncertainty and a decrease in the return on investment.

Also, the exchange rate shock initially caused a decrease in financial sanctions and then increased, and in the long run, its effects disappeared. The results also indicated that the shock caused by financial sanctions, which came through the channel of a decrease in oil sales and a decrease in foreign exchange earnings, led to a decrease in the country's oil revenues, and the effect of this shock on oil revenues was negative.

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