Iranian Economic Review, 2024, 28(4), 1277-1314
DOI: 10.22059/ier.2024.344202.1007476

RESEARCH PAPER

Macroeconomic Effects of the COVID-19 Pandemic Shock; Implications from a Scenario-Based DSGE Model for Iran

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Article History: Received: 12 June 2022, Revised: 20 January 2023, Accepted: 17 February 2023
Publisher: University of Tehran Press.

Abstract
Given that shocks such as the COVID-19 Pandemic are likely to occur in the future, it is important to understand how they affect macroeconomic variables. In addition to health shock, global oil prices and demand slumped and oil-exporting countries have faced substantial oil shock and budget deficits from the COVID-19 outbreak. Considering the dynamic and stochastic nature of the COVID-19 outbreak, this study mainly aims to evaluate the macroeconomic effects of the current COVID-19 shock through the lens of the micro-founded New Keynesian dynamic stochastic general equilibrium (NK-DSGE) model. Our model has been simulated for Iran's economy, as a major oil exporter and the worst damaged by COVID-19 among oil exporting countries. Since the macroeconomic consequences of pandemics are highly dependent on the length and severity of shock persistency, three scenarios (optimistic, base, and pessimistic) have been considered and compared. The results are considered in four directions: first, the COVID-19 outbreak strongly influenced consumption, labor productivity, production (goods and services), government oil and tax revenues, and caused stagflation. Second, household response to COVID-19 shock is highly affected by shock persistence. Third, the policy response to a budget deficit during COVID-19 is a great concern in oil-exporting developing countries. The policy response could potentially be financed from oil-based sovereign wealth funds (SWFs) in oil-exporting countries. The IRFs analysis of the SWF-funded policy response indicated limited detrimental outcomes in the services and production sector. Fourth, results from implementing a counterfactual tax scenario demonstrated that increasing the government tax base could significantly reduce government budget vulnerabilities during pandemics in oil-exporting developing countries.
Keywords: Budget Vulnerability, COVID-19 Pandemic, DSGE Analysis, Macroeconomic, Persistence of Shock.
JEL Classification: I18, E61, E6, F47.

1. Introduction

The COVID-19 outbreak began in Wuhan, China in December 2019 and has rapidly spread to all continents. Preventive actions such as lockdowns were quickly taken into account in most countries which led to a substantial effect on macroeconomics (Padhan and Prabheesh, 2021; Shafiei, 2020). The coronavirus outbreak has been the biggest macroeconomic shock in recent history. Contrary to previous economic shocks which usually influenced supply or demand, the current pandemic has damaged both sides of economics. The demand shock appears in household demand. Households purchased fewer services such as transport, tourism, restaurants, and recreational activities due to cautionary behavior and also lockdown policy. The supply shock comes from the production and service sector which has been seriously interrupted because of a reduction in intermediate inputs, materials, and workers who get sick and need to be quarantined. The transportation sector also being limited intensely declined petroleum product demand and slowed down economic activities. Global financial market indices have also dropped (Kumar et al., 2021; Maliszewska et al., 2020; Torój, 2013).

The oil-exporting developing countries have faced a dual shock; the COVID-19 shock and the collapses in oil prices. Oil price decline could cause a massive budget deficit in oil-exporting countries. Budget imbalance dwindles preventive action against the virus.

Oil demand has been damaged strongly since the coronavirus outbreak (Chiaramonti and Maniatis, 2020). Global oil demand declined to -5.7% and -16.5% in the first and second quarter of 2020 compared to 2019, respectively. Most oil reduction in 2020 has been due to lockdown restriction policy which reduced air and road travel. These mobility restrictions decreased road and jet fuel demands which account for almost 60% of the global oil demand in the first quarter of 2020. (Arezki and Nguyen, 2020; *EIA- Energy Outlook*, 2020; Rystadenergy, 2020).

Iran has been the first country among oil exporting countries that experience devastating consequences of the COVID-19 crisis. Iranian officials reported the first case of COVID-19 in Qom, a city of 1.2 million residents and close to the capital city, Tehran on February 19, 2020 (Ebrahim and Memish, 2020). By July 20, 2020, the total number of infected people who tested positive for COVID-19 had reached 276,138, and the death toll from the coronavirus had reached 14,188. In addition, Iran's budget in 2020 intensely declined as a matter of oil price shock and US sanctions on oil sales.

Our study contributes to the literature by addressing the impacts of the COVID-19 outbreak shock on macroeconomic variables in Iran one of the main oil-exporting countries. Considering the stochastic nature of pandemics and uncertainty in length and severity and interactions between markets, we have utilized a Micro-funded New Keynesian dynamic stochastic general equilibrium (DSGE) for a small open economy including households, firms (goods and services sectors), government-central bank authorities, and the oil sector in which some nominal rigidities are involved. The DSGE model denotes interactions across decision-makers under a general equilibrium framework. In contrast to the computable general equilibrium (CGE) models, DSGE models are optimized within a stochastic condition (Blake et al., 2003; Yang et al., 2020a).

The persistence of COVID-19 outbreak shock is highly uncertain, so, we have considered three scenarios (base, optimistic, and pessimistic scenarios), and compared the response of macroeconomic variables. Moreover, the effects of implementing a policy response on the production of goods and service sectors are investigated. Policy response potentially can be funded through oil-based sovereign wealth funds (SWFs hereafter). In another scenario, counterfactual circumstances including, an increase in the government tax base (reducing the tax exemptions and tax holidays) to decrease government budget vulnerabilities, compared with a base scenario in response to a COVID-19 shock are studied.

The remainder of the article is organized as follows: A literature review is explained in section two; the COVID-19 Outbreak in oil exporting countries is described in section three; section four considers Model specification; section five provides empirical results and discussion and the conclusion is presented in section six.

2. Literature Review

Consequences of pandemics such as influenza, SARS, and recently COVID-19 are investigated in numerous models. Pandemics have numerous economic, social, and clinical consequences (Goswami et al., 2021; Tisdell, 2020). Panic fear of the disease is a crucial factor in the world's response to pandemics. A society feels at risk of dying at the onset of a pandemic, consequently, a fear of infection has led to a decline in consumer demand (Peiris et al., 2004; Shannon and Willoughby, 2004). In this context, some authors investigate the willingness to pay to avoid death in pandemics (Echazu and Nocetti, 2020). The Spanish flu (1918-19) and COVID-19 share some basic similarities, such as being very contagious with extreme severity of clinical symptoms. Some authors consider influenza and the

COVID-19 pandemic together (Verikios, 2020). Investigations into the impacts of SARS revealed substantial effects on economies through enormous drops in consumption and increases in business costs (Chou et al., 2004; Lee and McKibbin, 2004; Siu and Wong, 2004). Efforts have been made to model the economic consequences of the COVID-19 pandemic by epidemiological models (Susceptible-Infected-Recovered (SIR)). Acemoglu et al. (2020) observe that with a uniform lockdown lasting 434 days, the economic costs reach 24.3 percent of annual GDP (Acemoglu et al., 2020). Chudik et al (2020) found that voluntary isolation taken by an individual's perceived risk has a small impact on flattening the epidemic curve (Chudik et al., 2020). Santos, (2020) graph "flatten the curve" using IO and investigated four scenarios including mitigation and suppression measures (Santos, 2020). The COVID-19 pandemic is predicted to decrease global GDP growth by 4% in 2020 (Boissay and Rungcharoenkitkul, 2020). Organization for Economic Co-operation and Development (OECD) forecasts that the growth rate of world real GDP in 2020 will be 1.4%, which is 1.5% lower than the previous estimation (Coronavirus, 2020).

Several authors investigate the COVID-19 outbreak effect by general equilibrium models. DSGE models on the effect of the COVID-19 outbreak on tourism showed that a one percent increase in health disaster risk could considerably change welfare in sectoral and comprehensive subsidy policy (Yang et al., 2020b). Mckibbin and Fernando (2020) by a global hybrid DSGE/CGE general equilibrium model reported that even a restricted outbreak could notably impact the global economy in the short run (McKibbin and Fernando, 2020). Toròj A. (2013) introduced the idea of indirect influenza cost into a New Keynesian DSGE model in Poland, rather than a framework for exploring the economic effect of influenza. The authors emphasized that the demand-oriented construction of the New Keynesian framework caused a discrepancy in simulated and real indirect costs (Torój, 2013). Asoyan et al. (2020) assessed the effects of the COVID-19 outbreak on economic decisions using standard New Keynesian DSGE for the closed economy (Asoyan et al., 2020). CGE simulation study directed by the World Bank has shown declines in the gross domestic product (GDP) because the pandemic is more devastating in trade-oriented and tourism-oriented countries (Jena et al., 2021; Maliszewska et al., 2020).

Ettayib (2022) examines the impact of COVID-19 and oil Prices on economic policy uncertainty in the US and UK and Brazil by using the panel-ARDL approach. The results show that Economic policy uncertainty is positively correlated with COVID-19. The results also show that the economic policy uncertainty is negatively correlated with the oil prices. Mirneazmi et al. (2022) by using Iran's economy input-output tables try to measure the economy's response to the COVID-19 shock. The scenarios range from the optimistic one with fewer restrictions, resulting in a 2.8% GDP decline, to the pessimistic scenario with major restrictions and barriers leading toward a GDP decrease of 7%. Moreover, the Effect of Health Disaster Risk Shocks on Macroeconomic Variables is investigated by (Keshavarzi et al., 2023). Using a DSGE approach results show that the occurrence of a health disaster risk shock by a standard deviation caused severe fluctuations in macroeconomic and health variables. It is recommended that the government, as a policy-maker, play a stabilizing role under pandemic crisis conditions.

In general, the literature review reveals that few studies have employed the general equilibrium in pandemic modeling, while rarely focusing on oil-exporting countries. Considering the stochastic environment of pandemics, to the best of our knowledge, this work is the first to apply a scenario-based NK-DSGE model for an oil-exporting country in assessing the impact of COVID-19 outbreak on macroeconomic variables. The main contributions of our research are:

1- The National Development Fund (NDF) is included in our model and the effects of implementing a policy response to COVID shock on the production of goods and service sectors are investigated.
2- A budget deficit of government is inserted into the model to better capture Iran's government bottlenecks.
3- In the firm sector the dynamics of producers of goods and services are modeled separately.
4- Health stock specification is different from Keshavarzi et al. (2023).
5- In contrast with Keshavarzi et al. (2023), by using the Ireland (1997) approach, all real variables are substituted in the system of stationary nonlinear equations (Appendix B).
6- A novel counterfactual policy i.e. an increase in the government tax base (reducing the tax exemptions and tax holidays) to decrease government budget vulnerabilities is implemented and results are compared with a base scenario.

3. Stylized Facts and Theoretical Background

In the case of COVID-19, the problem did not occur with only negative demand shock, many problems occurred indeed on the supply side due to the interruption in the supply chains because of travel and transportation restrictions. In a supply shock, global production decreases because of the sudden reduction or stop in factories, which will disturb supply chains and push the global supply curve to the left as we can see from Figure 2. In conclusion, prices will increase (Global Macro Monitor, 2020). However, at the beginning of the economic stagnation, economists tended to explain the situation as a lack of demand and therefore the question of how to stimulate the demand was the focus, but policies to stimulate the demand cannot solve negative supply shock problems such as the reduction of the economic activities, fall in the production, the rise of unemployment and shortages of products which would rise inflation. „Containment policies‟ that reduce production and „stimulus policies‟ that preserve consumption would cause supply-based issues: inflation would rise due to lower production and higher consumption. For this reason, reducing production through containment policies and expanding consumption through stimulus instruments may lead to higher inflation (Baldwin, 2020).

However, even when a lack of supply causes a recession, demand would also be affected which may intensify the recession. A negative supply shock affecting many sectors may have "Keynesian effects" which means job losses and insufficient global demand can extend the first impact and worsen the recession (Guerrieri et al., 2020). For instance, if companies reduce their production or collapse, they will also reduce business opportunities where they get their supplies, and if unemployment rises, households will reduce their spending and start saving. In economic shocks, researchers analyze both the tendency of economic activities and prices. If prices tend to rise during a recession, it is because companies have profitability problems and thus, they increase their prices to gain profitability. However, if prices tend to fall during a recession, this is mainly because companies have difficulties in selling, thus they reduce their prices to stimulate demand and flow out their stocks. In other words, an acceleration of inflation would mean that recession is essentially due to a supply-side problem, whereas disinflation would mean that recession is essentially due to insufficient global demand (Sülün, 2020). However, inflation is more likely in oil-exporting countries.

Iran is highly affected among OPEC countries by the Coronavirus. Death number of COVID-19 in the OPEC countries is shown in Fig.1. The number of deaths due to COVID-19 in Iran has increased extremely in the first weeks of the disease outbreak while there were no significant death rates in other oil exporting countries (WHO statistics, 2020). However, the death trend in Iran declined smoothly at the end of April, due to expensive preventive lockdown policy.

The mortality rate (the number of deaths divided by positive cases) was ~5.1% in COVID-19–positive cases until 20 July while it was ~4.1% in Iraq and about 1% in other OPEC countries (Abdi, 2020).

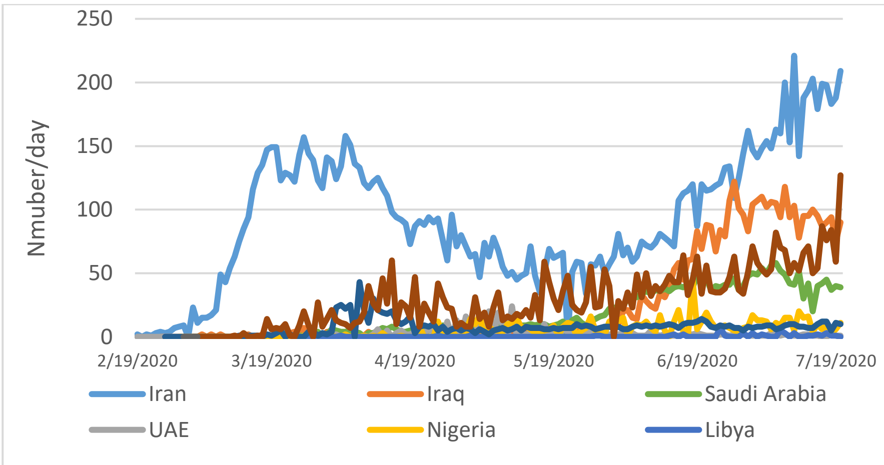

Figure 1. Death Number of COVID-19 in the OPEC Countries
Source: WHO statistics, 2020.

Global oil demand was massively influenced by the COVID-19 outbreak. Due to the reduction in global industrial production, oil and other liquid demands have decreased. Global petroleum and other liquid fuels consumption decreased by around 20% in the first quarter of 2020 due to lower economic growth and less air travel (Dutta et al., 2020; Energy Outlook, 2020; Mensi et al., 2020). Consequently, oil prices sharply declined from 67 $/bbl. In December 2019 to 18 $/bbl. In March 2020 (Figure 2).

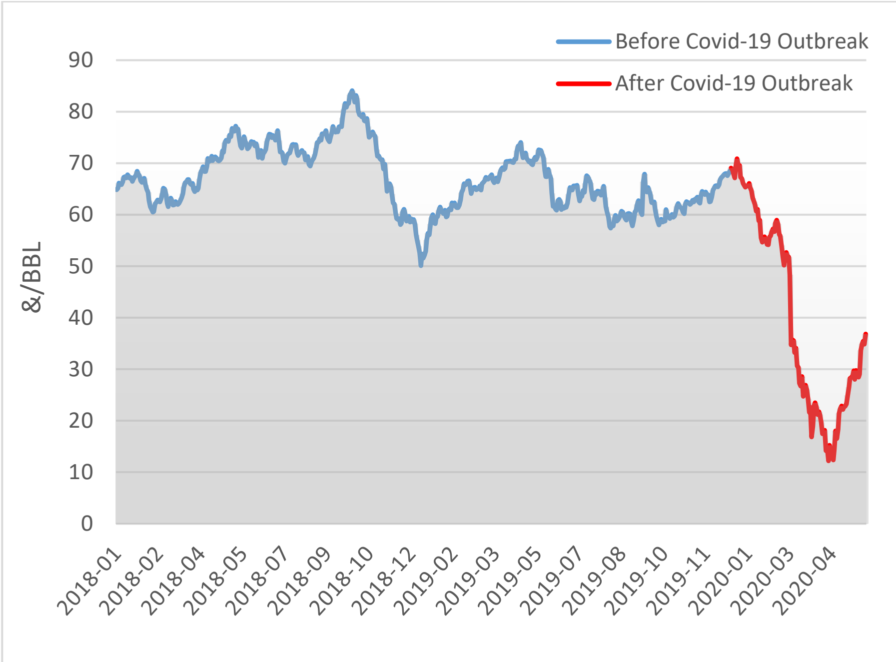

Figure 2. OPEC Reference Basket (ORB) Crude Oil Price
Source: WHO statistics, 2020.

Liquid fuel price slump causes a decline in government revenue and budget deficit. OPEC countries' fiscal budget has a large dependency on oil revenue. The fiscal breakeven oil price for MENAP countries is predicted to be around 77 $/bbl but the current oil price causes a huge budget deficit (IMF, 2019).

Table 1. Fiscal Breakeven Oil Prices

Menap Oil Exporters	**Average**				**Projections**	
	2000-2015	**2016**	**2017**	**2018**	**2019**	**2020**
Algeria	102.6	102.5	91.4	98.9	116.4	92.3
Bahrain	74.1	105.7	112.6	118.4	94.9	93.0
Iran	55.9	58.4	64.8	113.8	125.6	124.4
Iraq	-	46.3	42.3	48.5	64.3	59.0
Kuwait	43.8	43.4	45.2	48.3	48.8	49.7
Libya	70.4	244.5	102.8	77.9	71.3	79.0
Oman	62.4	101.1	91.1	101.1	97	85.9
Qatar	45	54	50.5	50.3	48.7	45.4
Saudi Arabia	78	96.4	83.7	83.9	85.4	78.3
United Arab Emirates	47.6	51.1	60.7	77.6	65.0	68.0
Yemen	197.1	364.0	125.0	-	-	-
Average	75	115.2	79.1	81.8	81.8	77.5

Source: IMF, 2019.

COVID-19 caused high mortality rates and put pressure on Iran's national public healthcare infrastructures. Iranian government imposed fast policy response to control the spread of the virus such as: Issuing a stay-at-home nationwide policy (social isolation policies); Banning public religious activities and closing holy shrines; Temporary release of prisoners from overcrowded prisons, closing all educational institutions, restricting work and mobility of people.

Iranian government imposed financial policies to alleviate the consequences of the pandemic such as financial support to low-income households including a 5 million dollars low-interest loan to small businesses and postponing the load repayment for three months.

Due to sanctions, Iran has extremely struggled to manage the economic consequences of the pandemic spread (Chohan, 2020). The economic loss of COVID-19 in Iran coincides with the ever-toughest sanctions against the country (Takian et al., 2020).

Before the coronavirus pandemic, Iran's economy was significantly damaged as a result of tough economic sanctions as a supply-side shock imposed by the US. As a result of the sanction supply side shock, Iranian currency sharply depreciated by more than 500%, economic growth declined to -7.6, the inflation rate increased to 43% and the unemployment rate increased to 10.6% in 2019 (National Statistic Center, 2020). In this situation, another shock to economics is predicted to make the economy shrink. The job market structure in Iran, similar to many developing countries, is rather a daily working structure that was quickly destroyed by the lockdown policy. Demand for most services and durable goods was affected by decreasing demand due to health provisions and lock-down rules and not having enough income. The service sector accounted for 49% of Iran's economy in the first quarter of 2020 which mostly includes real estate services at 13.8%, public, social, and health services at 12.2%, and wholesale and retail activities (Hotels, Tours, and restaurants) by 11.5 %. (National Statistic Center, 2020). Google trend statistics for selected service searches have dropped significantly (Figure 3). These trends have shown how much service demand declined during the pandemic time. The search trend for train and bus tickets also declined by 83%.

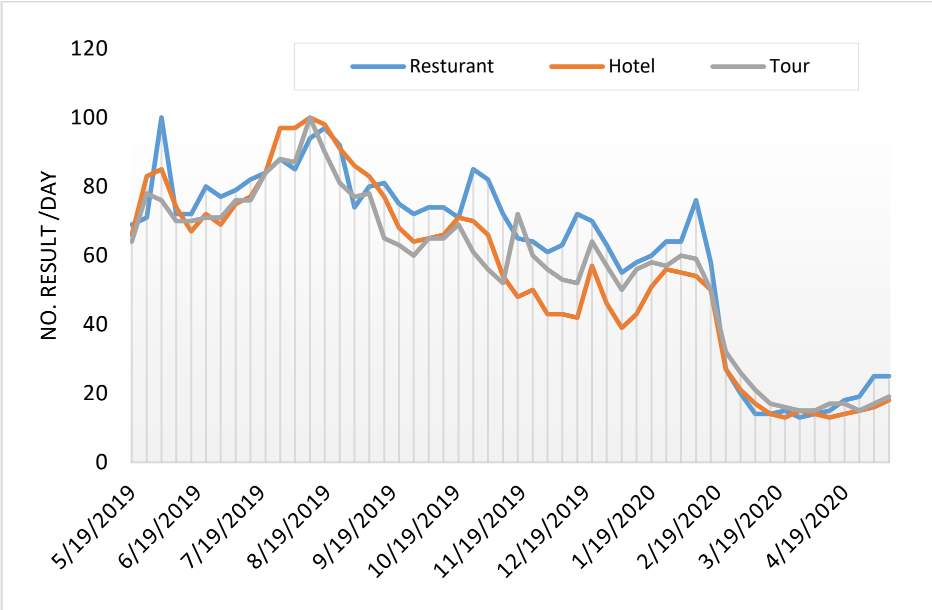

Figure 3. Google Trend for Selected Services in Iran
Source: https://trends.google.com/trends

Another appropriate index for indicating the demand slump in COVID-19 is the Point of sale (POS) transaction. It refers to the place where customers pay for the purchase in store for goods or services. The volume of POS transactions moderately increased over time and reached 16.4 billion dollars in Feb 2020. The trend sharply declined (more than 50%) to 7.2 billion dollars in March 2020 when the first lockdown policy was imposed in Iran. As a result of the COVID-19 pandemic, the government budget in Iran turned out to be more unbalanced due to an increase in the cost of the health sector and a decrease in oil and tax revenue.

4. Model Specification

The structure of the research model and the impact mechanism of COVID-19 shock on the demand and supply of oil-exporting countries are illustrated in Figure 4. The core of the model describes the interlinkage between government, households, the central bank, goods, and service sectors after the COVID-19 shock. The model is extended by the incorporation of the oil sector. It considers expenditure and payment transmission of agents. Current health shock depends on shock persistency and caused a massive drop in consumer spending and the demand for labor forces. Consequently, oil price fall is the second shock to the oil exporting countries which influences payment for oil export transmission channel.

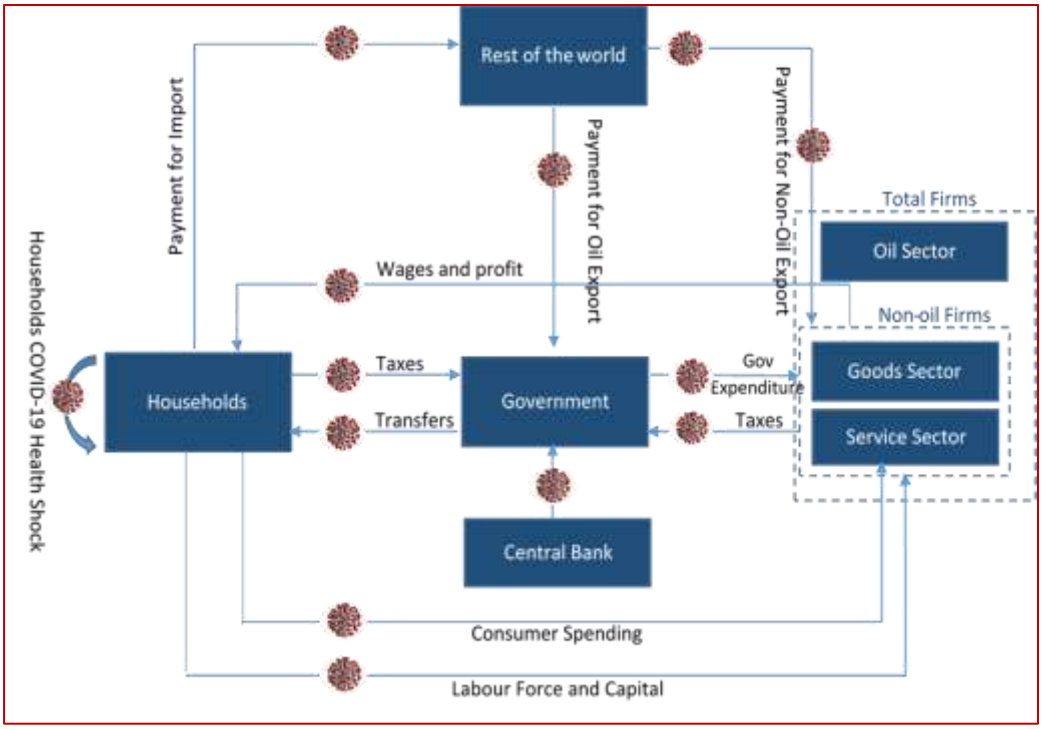

Figure 4. A Schematic Overview of the Model
Source: Research finding.

4.1 Households

We assumed that household goals to maximize the expected utility function; as a function of the amount of consumption, money, and health status (Hall and Jones, 2007; Yang et al., 2020):

$$E_t \sum_0^\infty \beta^t [LnC_t + \varphi_H \frac{H_t^{1-\sigma}}{1-\sigma} + \varphi_m Ln(\frac{M_t}{P_t})] \qquad (1)$$

where E_t is the expectations operator, c_t stands for the real consumption, $\frac{M_t}{P_t} = m_t$ indicates the real money balance, H_t is the health status, and β denotes intertemporal discount factor $(0 < \beta < 1)$.

Health stock is modeled as below:

$$\mathrm{H_{t+1} = (V_t + (1 - \varphi)H_t)e^{s_t \ln(1-\Omega)}} \qquad (2)$$

In this equation, V_t is health increment, φ is the deterioration rate of health status and Ω is the size of the disaster. Health expenditure as a function of leisure time can be expressed as below (Yagihashi and Du, 2015):

$$V_t = (1 - N_t)^{1-\gamma}(Z_t)^{\gamma} \tag{3}$$

in which N_t is the working time, $1 - N_t$ is leisure time, and Z_t is the household expenditure on health. γ and $1 - \gamma$ represents the elasticity of health investment relative to health spending and leisure, respectively. Our model consists of two states of nature, normal and health shock circumstances. s_t is an indicator variable to capture the occurrence of a health disaster. $s_t = 0$ denotes a normal societal period. Otherwise, $s_t = 1$ (with probabilityθ_t), states society is hit by an economy-wide pestilence causing a large share Ω of health to be eliminated.

It is assumed that household consumption is divided into two parts, consumption of goods C_{gt} and services C_{st}:

$$C_t = C_{s,t}^{*\beta} C_{g,t}^{1-\beta} \tag{4}$$

Coronavirus caused harmful effects on the service sector, which can be explained as the following function:

$$C_t = (C_{s,t} e^{s_t ln H_t^{\varsigma}})^{\alpha} C_{g,t}^{1-\alpha} = [\theta_t H_t^{\varsigma} C_{s,t} + (1 - \theta_t) C_{s,t}]^{\alpha} C_{g,t}^{1-\alpha} \tag{5}$$

The budget constraint is explained below:

$$(1 + \tau_c)\mathrm{P_t C_t} + \mathrm{P_t I_t} + \mathrm{P_t} Z_t + M_t \leq (1 - \tau_N) W_t \mathrm{N_t} + R_{k,t} K_t + \mathrm{M_{t-1}} \tag{6}$$

By considering $\pi_t = \frac{P_t}{P_{t-1}}$, the budget constraint could be rewritten as below (Ireland, 2001):

$$(1 + \tau_c)\mathrm{C_t} + \mathrm{I_t} + Z_t + m_t \leq (1 - \tau_N) w_t \mathrm{N_t} + r_{k,t} K_t + \frac{m_{t-1}}{\pi_t} \tag{7}$$

where τ_c denotes the consumption tax rate, τ_N is the wage tax rate, $\mathrm{I_t}$ is the real investment, w_t is the real wages, $r_{k,t}$ is the real return on capital.

The total labor (N_t), capital stock (K_t), and investment (I_t) equals the sum in goods and services sector:

$$\mathrm{N_t} = \mathrm{N}_{g,t} + \mathrm{N}_{s,t} \tag{8}$$

$$\mathrm{K_t} = \mathrm{K_{g,t}} + \mathrm{K_{s,t}} \tag{9}$$

$$\mathrm{I_t} = \mathrm{I_{g,t}} + \mathrm{I_{s,t}} \tag{10}$$

Capital accumulation equations for goods and services can be represented as:

$$\mathrm{K_{g,t+1}} = (1 - \delta_g)\mathrm{K_{g,t}} + \mathrm{I_{g,t}} \tag{11}$$

$$\mathrm{K_{s,t+1}} = (1 - \delta_s)\mathrm{K_{s,t}} + \mathrm{I_{s,t}} \tag{12}$$

4.2 Firms

4.2.1 Goods Sectors

We assume that the final goods producers utilize $Y_{g,t}(j)$ unit of intermediate goods of type j to produce $Y_{g,t}$, in line with the following production function with constant elasticity of substitution (CES)(Portillo et al., 2010):

$$\left[\int_0^1 Y_{g,t}(j)^{\frac{(\theta-1)}{\theta}} dj\right]^{\frac{\theta}{(\theta-1)}} \geq Y_{g,t} \tag{13}$$

where $Y_{g,t}(j)$ denotes the good produced in firm$j$, and $\theta > 0$ is the elasticity of substitution between intermediate goods. The final good producer sells its product with a nominal price P_t and determines $Y_{g,t}(j)$ to maximize its profit.

$$\max P_t Y_{g,t} - P_t\,(j) Y_{g,t}(j) \tag{14}$$

where in $Y_{g,t}$ is substituted from Equation (7). The F.O.C is as follows:

$$Y_{g,t}(j) = \left[\frac{p_t(j)}{P_t}\right]^{-\theta} Y_{g,t}\,, j \in [0,1] \tag{15}$$

$$P_t = \left[\int_0^1 p_t(j)^{1-\theta} dj\right]^{\frac{1}{1-\theta}} \tag{16}$$

We supposed that intermediate goods producers are producing in a monopolistic competition market. The producers of intermediate goods combine $K_{g,t}(j)$ unit of capital with $N_{g,t}H_t(j)$ unit of labor and the technology, A_t, to produce $Y_{g,t}(j)$ unit of heterogeneous goods in line with the following Cobb-Douglas production function:

$$Y_{g,t} = A_t\left(\eta^t N_{g,t} \mathrm{H}_t\right)^{\alpha_g}\left(K_{g,t}\right)^{1-\alpha_g} \tag{17}$$

In this model, it is assumed that intermediate goods producers are facing nominal price rigidity that follows the function below with second-order adjustment cost[1] (Rotemberg, 1982):

$$AC_t(j) = \frac{\phi_{pg}}{2}\left(\frac{P_t(j)}{P_{t-1}(j)}\right)^2 Y_{g,t} \tag{19}$$

where $\phi_p > 0$ denotes the price adjustment cost parameter. In the case of $\phi_p = 0$, the prices are fully flexible, and the price adjustment cost equals zero. Further, A_t follows an AR (1) process as follows:

[1]. The first-order conditions can be seen in Appendix A.

$$log(A_t) = \rho_A \, log(A_{t-1}) + \varepsilon_t^A \qquad \varepsilon_t^A \sim N(0, \sigma_A^2) \tag{20}$$

It is assumed $\emptyset_X$ and $\emptyset_M$ are the percent of produced goods exported and imported, respectively.

$$X_t = \emptyset_X Y_{g,t} \tag{21}$$

$$M_t = \emptyset_M Y_{g,t} \tag{22}$$

$$NX_t = X_t - M_t \tag{23}$$

4.2.2 Service Sector

We have assumed that a final service is a function of Intermediate services. The final service supply can be expressed as below:

$$\left[\int_0^1 \mathrm{Y}_{\mathrm{s,t}}(j)^{\frac{(\theta-1)}{\theta}} dj\right]^{\frac{\theta}{(\theta-1)}} \geq \mathrm{Y}_{\mathrm{s,t}} \tag{25}$$

where $\mathrm{Y}_{\mathrm{s,t}}(j)$ denote the service produced in firm$j$, $\theta > 0$ is the elasticity of substitution between intermediate services. Consequently, the final service producer sells its service with a nominal price P_t and determines $\mathrm{Y}_{\mathrm{s,t}}(j)$ to maximize its profit:

$$\max P_t \mathrm{Y}_{\mathrm{s,t}} - P_t\,(j) \mathrm{Y}_{\mathrm{s,t}}(j) \tag{26}$$

$$\mathrm{Y}_{\mathrm{s,t}}(j) = \left[\frac{p_t(j)}{P_t}\right]^{-\theta} \mathrm{Y}_{\mathrm{s,t}} \quad , \quad j \in [0,1] \tag{27}$$

The above equation, which is a Dixit-Stiglitz demand function, for intermediate services, has an indirect relationship with relative prices and a direct relationship with the overall production. The final services price index is as follows:

$$P_t = \left[\int_0^1 p_t(j)^{1-\theta} dj\right]^{\frac{1}{1-\theta}} \tag{28}$$

The intermediate producer function is demonstrated as below:

$$\mathrm{Y}_{\mathrm{s,t}} = a_t \left(\eta^t \mathrm{N}_{s,t} \mathrm{H}_{\mathrm{t}}\right)^{\alpha_s} \left(\mathrm{K}_{\mathrm{s,t}}\right)^{1-\alpha_s} \tag{29}$$

Similar to the goods sector, we assumed that intermediate service producers are facing nominal price rigidity with second-order adjustment cost:

$$\mathrm{AC_t(j)} = \frac{\phi_{\mathrm{ps}}}{2} \left(\frac{\mathrm{P_t(j)}}{\mathrm{P_{t-1}(j)}}\right)^2 \mathrm{Y}_{\mathrm{s,t}} \tag{30}$$

4.2.3 Oil Sector

There are several methods to include the oil sector in the model (Finn, 2000; Kim and Loungani, 1992). In some research, oil has been entered into production function as an input (Aba Alkhail, 2007; Mukhamediyev, 2014). Some research takes the oil sector similar to the firm sector and applies the profit maximization assumption (Balke and Brown, 2018; Delpachitra et al., 2020). Contrary to private companies, NOCs (National Oil Companies) do not necessarily follow profit maximization behavior. Constraints such as technical parameters of the reservoir and also a quota of OPEC, curb the amount of NOCs oil production. Other studies utilized an exogenous process to model the oil sector (Richmond et al., 2015; Sayadi and Khosroshahi, 2020). We included the oil sector in the DSGE model as an exogenous variable with the AR (1) process:

$$Y_{oil,t} = e_t q_{oil,t} p_{oil,t} \tag{31}$$

$$Ln\left(Y_{oil,t}\right) = (1-\rho_{Yoil})\, ln(\overline{Y_{oil}}) + \rho_{Yoil} Ln\left(Y_{oil,t-1}\right) - \varepsilon_t^{COV}, \quad \varepsilon_t^{COV} \sim N(0, \sigma^{COV}) \tag{32}$$

which $\overline{Y_{oil}}$ is the real oil revenue, ε_t^{yoil} is oil shock with normal distribution $\rho_{yoil} \in (0,1)$. Change in oil revenue can be as a result of change in oil export (q_t^{oil}), change in the oil price (P_t^{oil}) or change in the exchange rate (e_t).

4.3 Government- Central Bank

We assumed that government-monetary authority is the sole authority in Iran's economy. This assumption is not so implausible regarding the low independence of the central bank in oil-exporting developing countries. Moreover, to a more realistic view, the government budget can be considered by separating oil revenues (Barnett and Ossowski, 2002). Thus, a more pragmatic view of the government budget can be defined as follows:

$$GBT_t = GBNO_t + \left(1-\omega_f\right) Y_{oil,t} \tag{33}$$

$$GBNO_t = T_t - G_t \tag{34}$$

In which GBT_t is the total government budget, $GBNO_t$ denotes the non-oil budget, G_t is government expenditure, $Y_{oil,t}$ is government oil revenue, ω_f is the share of Iran's SWF in oil revenue and T_t is the total tax revenue. G_t consists of capital expenditures ($G_{I,t}$) and current expenditures ($G_{C,t}$):

$$G_t = G_{I,t} + G_{C,t} \tag{35}$$

Tax revenue has three main sources including the consumption tax ($\tau_c \mathrm{C_t}$), wage ($\tau_N w_t \mathrm{N_t}$), and production ($\tau_y Y_{noil,t}$) which can be expressed as below:

$$T_t = \tau_c \mathrm{C_t} + \tau_N w_t \mathrm{N_t} + \tau_y Y_{noil,t} \tag{36}$$

which τ_c is the tax rate on consumption, τ_N is the tax rate on wage, and τ_y is the tax rate on production. In our model, the COVID-19 shock decreased government tax revenue and increased government expenditure:

$$T_t = \rho_{\mathrm{T}} T_{t-1} + (1 - \rho_T)\bar{T} - \varepsilon_t^{COV} \tag{37}$$

$$G_{C,t} = \rho_{GC} G_{C,t-1} + \left(1 - \rho_{GC}\right)\overline{GC} + \varepsilon_t^{COV} \tag{38}$$

which $\bar{T}$ and $\overline{GC}$ demonstrate a steady state of tax and the government budget. ε_t^{COV} stands for the stochastic COVID-19 outbreak shock. One stylized fact about Iran's economy is the central bank's weak independency. The central bank does not have a strong role in monetary policy due to fiscal dominance (Naini and Naderian, 2019). Then, it was considered that borrowing from the central bank was the solution for the government:

$$GBT_t = -\alpha_{GB}\left(\frac{M_t - M_{t-1}}{P_t}\right) = -\alpha_{GB}\left(m_t - \frac{m_{t-1}}{\pi_t}\right), \ \ 0 \leq \alpha_{GB} \leq 1 \tag{39}$$

α_{GB} is the percentage of the money base employed to cover the budget deficit. α_{GB} is a coefficient between 0 and 1, in which 0 demonstrates full independency of the central bank while 1 indicates full dependency of the central bank.

Considering the real money supply ($^{M_t}/_{P_t}$) in each period with the rate of μ_t (Cooley and Hansen, 1989), the liquidity growth rate can be defined as follows:

$$\mu_t = \frac{M_t}{M_{t-1}} = \frac{^{M_t}/_{P_t}}{^{M_{t-1}}/_{P_t}} = \frac{^{M_t}/_{P_t}}{^{M_{t-1}}/_{P_{t-1}}} . \frac{P_t}{P_{t-1}} = \frac{m_t}{m_{t-1}} \pi t \tag{40}$$

5. Empirical Results

5.1 Calibration and Data Analysis

In this research, the calibration method was used to identify the reliable model parameters that have maximum accordance with the real data. To calibrate deep parameters, the steady states of the variables are substituted in the system of stationary nonlinear equations (Appendix B).

In the current study, seasonal time series data from 1990:q1 to 2020:q4 were used. Our data were seasonally adjusted and then the steady-state of the variables was computed. The GDP at a constant price of 2011 was normalized to one, and the ratio of supply and demand variables to GDP was taken into account as the steady state of the variables. Considering the deterministic trend η from the constant rate of technological innovation in the model's real variables, according to (Ireland, 1997), a stationary variable ($\tilde{X}$) can be derived from $\tilde{X} = \frac{X_t}{\eta^t}$. -Hence, the stationary non-linear equations system can be represented as follows:

Households

$$\tilde{C}_{g,t} = \frac{(1-\alpha)\tilde{C}^*_{s,t}}{\alpha[\theta_t H_t^{\varsigma} + (1-\theta_t)]} \qquad \frac{(1-\alpha)}{(1+\tau_c)\tilde{C}_{g,t}} = \tilde{\lambda}_t$$

$$\psi_t \frac{V_t(1-\theta_t\Omega)(1-\gamma)}{(1-N_t)} \frac{(1+\tau_c)\tilde{C}_{g,t}}{(1-\alpha)(1-\tau_N)} = \widetilde{w}_t$$

$$\frac{\eta\tilde{C}_{g,t+1}}{\tilde{C}_{g,t}} = \beta[(1-\delta_s) + r_{kg,t+1}] \qquad \frac{\eta\tilde{C}_{g,t+1}}{C_{g,t}} = \beta[(1-\delta_g) + r_{ks,t+1}]$$

$$\frac{\mathrm{V_t}}{\tilde{Z}_t} = \frac{(1-\alpha)}{\psi_t\gamma(1-\theta_t\Omega)(1+\tau_c)\tilde{C}_{g,t}}$$

$$\psi_t = \beta\alpha\varsigma\frac{\tilde{C}_{s,t+1}}{\tilde{C}^*_{s,t+1}} H_t^{\varsigma-1}\theta_{t+1} + \beta\varphi_{\mathrm{H}} H_t^{-\sigma} + \beta\psi_{t+1}(1-\varphi)(1-\theta_{t+1}\Omega)$$

$$\frac{\psi_m}{\widetilde{m}_t} = \frac{(1-\alpha)}{(1+\tau_c)}\left[\frac{1}{\tilde{C}_{g,t}} - E_t\left(\frac{\beta}{\pi_{t+1}\eta\tilde{C}_{g,t+1}}\right)\right]$$

$$\tilde{C}_t = [\tilde{C}^*_{s,t}]^{\alpha}\tilde{C}_{g,t}^{1-\alpha} \qquad \tilde{C}^*_{s,t} = \theta_t H_t^{\varsigma}\tilde{C}_{s,t} + (1-\theta_t)\tilde{C}_{s,t}$$

$$\mathrm{N_t} = \mathrm{N}_{g,t} + \mathrm{N}_{s,t}$$

Firms

$$\eta\widetilde{\mathrm{K}}_{\mathrm{g,t+1}} = (1-\delta_g)\widetilde{\mathrm{K}}_{\mathrm{g,t}} + \tilde{\mathrm{I}}_{\mathrm{g,t}} \qquad \eta\mathrm{K}_{\mathrm{s,t+1}} = (1-\delta_s)\mathrm{K}_{\mathrm{s,t}} + \mathrm{I}_{\mathrm{s,t}}$$

$$\tilde{I}_t = \tilde{\mathrm{I}}_{\mathrm{g,t}} + \tilde{\mathrm{I}}_{\mathrm{s,t}} \qquad \widetilde{\mathrm{Y}}_{\mathrm{g,t}} = a_t(\mathrm{N}_{g,t}\mathrm{H_t})^{\alpha_g}(\widetilde{\mathrm{K}}_{\mathrm{g,t}})^{1-\alpha_g}$$

$$\widetilde{\mathrm{Y}}_{\mathrm{s,t}} = a_t(\mathrm{N}_{s,t}\mathrm{H_t})^{\alpha_s}(\widetilde{\mathrm{K}}_{\mathrm{s,t}})^{1-\alpha_s} \qquad \widetilde{w}_t = (1-\tau_y)\alpha_g(\frac{\widetilde{\mathrm{Y}}_{\mathrm{g,t}}}{\mathrm{N}_{g,t}})(\frac{1}{q_{g,t}})$$

$$\widetilde{w}_t = (1-\tau_y)\alpha_s(\frac{\widetilde{\mathrm{Y}}_{\mathrm{s,t}}}{\mathrm{N}_{s,t}})(\frac{1}{q_{s,t}}) \qquad r_{kg,t} = (1-\tau_y)(1-\alpha_g)(\frac{\widetilde{\mathrm{Y}}_{\mathrm{g,t}}}{\widetilde{\mathrm{K}}_{g,t}})(\frac{1}{q_{g,t}})$$

$$r_{ks,t} = (1-\tau_y)(1-\alpha_s)(\frac{\widetilde{\mathrm{Y}}_{\mathrm{s,t}}}{\widetilde{\mathrm{K}}_{s,t}})(\frac{1}{q_{s,t}})$$

$$\left(\frac{1}{q_{g,t}}\right) = \frac{\theta-1}{\theta} + \frac{\phi_{pg}}{\theta}.\pi_t(\pi_t - 1) - \beta\frac{\phi_{pg}}{\theta}E_t\left[\pi_{t+1}(\pi_{t+1} - 1)\frac{\tilde{\Lambda}_{t+1}}{\tilde{\Lambda}_t}\frac{\tilde{Y}_{g,t+1}}{\tilde{Y}_{g,t}}\right]$$

$$\left(\frac{1}{q_{s,t}}\right) = \frac{\theta-1}{\theta} + \frac{\phi_{ps}}{\theta}.\pi_t(\pi_t - 1) - \beta\frac{\phi_{ps}}{\theta}E_t\left[\pi_{t+1}(\pi_{t+1} - 1)\frac{\tilde{\Lambda}_{t+1}}{\tilde{\Lambda}_t}\frac{\tilde{Y}_{s,t+1}}{\tilde{Y}_{s,t}}\right]$$

Government -Central Bank

$$\widetilde{GBT}_t = \widetilde{GBNO}_t + \left(1 - \omega_f\right)\tilde{Y}_{oil,t}$$

$$\widetilde{GBNO}_t = \tilde{T}_t - \tilde{G}_t$$

$$\widetilde{GBT}_t^{total} = -\alpha_{GB}\left(\frac{M_t - M_{t-1}}{P_t}\right) = -\alpha_{GB}\left(\tilde{m}_t - \frac{\widetilde{m_{t-1}}}{\eta\pi_t}\right)$$

$$\tilde{\mu}_t = \frac{M_t}{M_{t-1}} = \eta\frac{\tilde{m}_t}{\tilde{m}_{t-1}}\pi_t \qquad \tilde{G}_t = \tilde{G}_{I,t} + \tilde{G}_{C,t}$$

$$\tilde{G}_{I,t} = \alpha_{GI}\tilde{G}_t \qquad \tilde{T}_t = \tau_c\tilde{C}_t + \tau_N\tilde{w}_t N_t + \tau_y\tilde{Y}_{noil,t}$$

Market Clearing Condition

$$\tilde{Y}_{s,t} = \tilde{C}_{s,t} \qquad \tilde{Y}_{noil,t} = \tilde{Y}_{s,t} + \tilde{Y}_{g,t}$$

$$\tilde{Y}_t = \tilde{Y}_{noil,t} + \tilde{Y}_{oil,t} \qquad \tilde{Y}_t = \tilde{C}_t + \tilde{I}_t + \tilde{G}_t + +\widetilde{NX}_t$$

Shocks

$$Ln\left(Y_{oil,t}\right) = (1 - \rho_{Yoil})\, ln(\overline{Y_{oil}}) + \rho_{Yoil}Ln\left(Y_{oil,t-1}\right) - \varepsilon_t^{COV}$$

$$Ln(GC_t) = (1 - \rho_{GC})\, ln(\overline{GC}) + \rho_{GC}Ln(GC_{t-1}) + \varepsilon_t^{COV}$$

$$Ln(T_t) = (1 - \rho_T)\, ln(\bar{T}) + \rho_T Ln(T_{t-1}) - \varepsilon_t^{COV}$$

$$Ln\left(C_{s,t}\right) = (1 - \rho_{CS})\, ln(\overline{CS}) + \rho_{CS}Ln\left(C_{s,t-1}\right) - \varepsilon_t^{COV}$$

$$Ln(H_t) = (1 - \rho_H)\, ln(\bar{H}) + \rho_{\theta H}Ln(H_{t-1}) - \varepsilon_t^{COV}$$

The values were taken from the numerical solution of the system of nonlinear equations regarded as the initial values for other parameters. Furthermore, in the baseline scenario, quarterly disaster probability (θ) is calibrated to 5%, representing that disaster appears every 5 years on average. The set of the main calibrated parameters is summarized in Table 2.

Table 2. Main Calibrated Parameters

Parameters	Definition	Value	Source
β	discount factor	0.987	Research calibration
δ_s	depreciation rate for service sector capital	0.029	Research calibration
δ_g	depreciation rate for goods sector capital	0.030	Research calibration
η	economic seasonal growth rate	1.013	Research calibration
θ	Probability of disaster (mean)	0.05	Research calibration
φ_H	Weight of health	0.7	Research calibration
φ	Health deterioration rate	0.08	Yang et al. (2020)
γ	Elasticity of health spending	0.27	Yang et al. (2020)
σ	Risk aversion coefficient	3	Yang et al. (2020)
Ω	Size of disaster	0.10	Yang et al. (2020)
α	share of service in consumption	0.40	Research calibration
α_s	share of labor in service sector production	0.60	Research calibration
α_g	share of labor in goods sector production	0.55	Research calibration
α_{GB}	central bank dependency	0.62	Research calibration
ψ_m	elasticity of money in the utility function	0.21	Research calibration
ϕ_F	Share of the SWF in oil revenues	0.20	Research calibration
$r_{ks,t}$	Capital return in the service sector	0.06	Research calibration
$r_{kg,t}$	Capital return in the goods sector	0.04	Research calibration
ρ_{yoil}	AR(1) coefficient in Oil revenue shock	0.50	Research calibration (base scenario)
ρ_{GC}	AR(1) coefficient in government expenditure shock	0.50	Research calibration (base scenario)
ρ_T	AR(1) coefficient in government tax shock	0.50	Research calibration (base scenario)
ρ_{CS}	AR(1) coefficient in service consumption	0.50	Research calibration (base scenario)
ρ_H	AR(1) coefficient in Health shock	0.50	Research calibration (base scenario)
τ_c	the tax rate on consumption	0.09	Research calibration
τ_N	the tax rate on wage	0.10	Research calibration
τ_y	the tax rate on production	0.05	Research calibration

5.2 Model Validation

In this study, the first and second-order moments of the model are compared with the real-world moments to assess the goodness of fit for the calibrated model. For this purpose, the mean and standard deviation of the calibrated model and real data of the five variables, including total production (Y_t), oil production (Y_t^{oil}), non-oil production (Y_t^{noil}), consumption (C_t), and government expenditures (G_t^C), were compared. (Table 3). Comparing the moments (simulated model and the real world) reflects the success of the model in simulating the state of Iran's economy.

Table 3. The Comparison of Moments (Simulated and Real-World Variables)

Variable	Mean		Standard Deviation	
	Model	Real World	Model	Real World
Y_t	1.008	1	0.2134	0.1941
Y_t^{oil}	0.2694	0.2500	0.0687	0.0791
Y_t^{noil}	0.7523	0.7501	0.1953	0.2139
I	0.1823	0.1702	0.0932	0.0789
C_t	0.5823	0.5986	0.0925	0.0632

Source: Research finding.

5.3 Impulse-Response Functions (IRFs)

We have considered three scenarios including Base, optimistic, and pessimistic scenarios in this paper according to the high uncertainty of current shock. The base scenario assumed that $\rho_{yoil} = \rho_{GC} = \rho_T = \rho_{CS} = \rho_H$ is 0.5 which means 5 quarter persistency of COVID-19 outbreak. This criterion in the optimistic and pessimistic scenarios are 0.3 and 0.7, respectively which are interpreted as three and seven-quarter persistency. Greater persistence means that the increase in health disaster risk is tolerated. These scenarios help us to capture and compare the impulse response functions (IRFs) considering various persistency. Our results have shown that household response to COVID-19 shock is highly affected by the persistence of COVID-19 shock (Figure 5). This finding is in line with (Keshavarzi et al., 2023) and Mirneazmi et al. (2022).

The first IRFs criteria in our analysis is health status (H) which is shown at the top and left side of Figure 5. As health disaster risk increased, the H criteria gradually deteriorated. Different health status scenarios also influence labor productivity (A). Consequently, declining health status leads to lower service (YS) and goods (YG) output. Apart from the supply side, service demand (CS) and goods demand (CG) sharply declined especially in the pessimistic scenarios given its relationship with health risk. To rebuild health, households would increase their health spending (V) and leisure time while cutting their working time in service (NS) and goods sectors (NG). More resources spent in the health sector improved health status over time and eventually reverted to the pre-shock level.

The government's response to COVID-19 shock due to the persistence of COVID-19 is the same as the household's response (Figure 6). Government tax revenue (T) would decrease as a result of lower consumption and production. Government expenditure (GC) would jump because of higher health expenditure. Therefore, the deficit in the non-oil budget is inevitable but the overall deficit is worse because of the reduction in oil revenue (yoil). The lack of independence of the central bank is an important stylized fact (Moshiri et al., 2012) of Iran's economy. The government always borrows from the central bank in fiscal deficit situations which leads to an increase in the liquidity growth rate (MU), and inflation (PI).

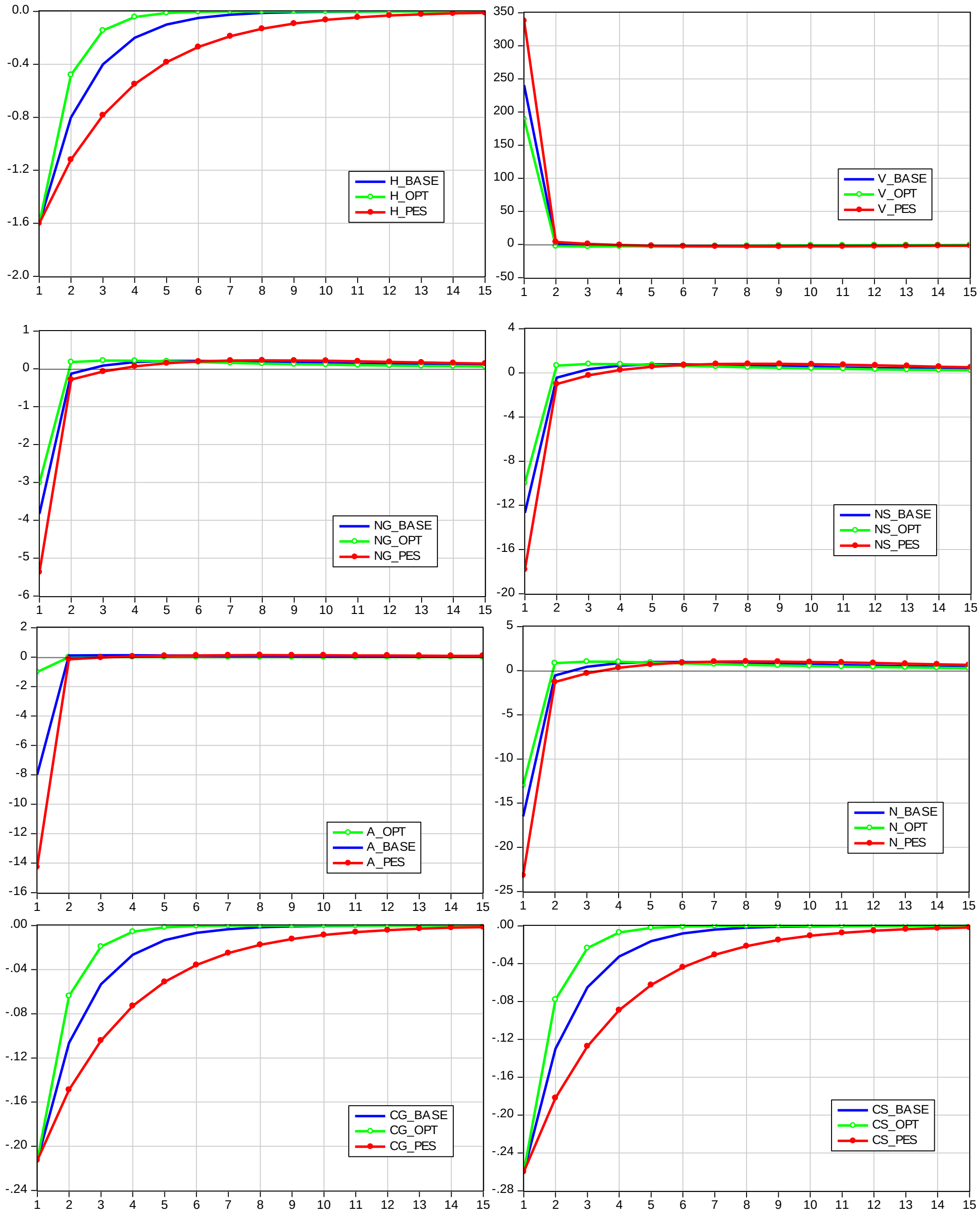

Figure 5. The Household's Response to a COVID-19 Shock in Various Scenarios (OPT: Optimistic, PES: Pessimistic Scenario)

Source: Research finding.

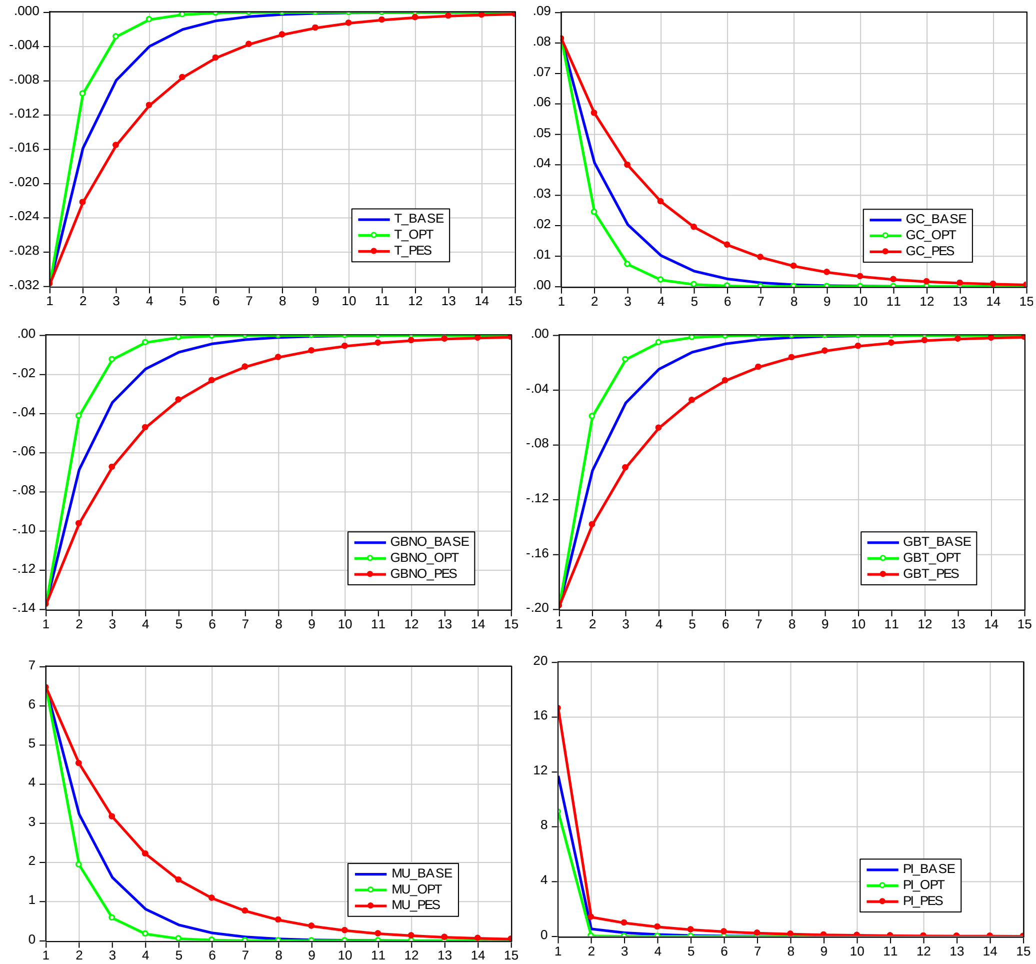

Figure 6. The Government's Response to a COVID-19 Shock in Various Scenarios
Source: Research finding.

The lockdown policy caused a huge reduction in the service sector (YS) and good sector production (YG). Non-oil production (YNOIL) which is the sum of YS and YG also reduced (Figure 7). Oil revenue (YOIL) also declined due to oil price fall. Therefore, aggregate production (Y) dropped and inflation increased which caused stagflation its deepness differs from the persistence of shock.

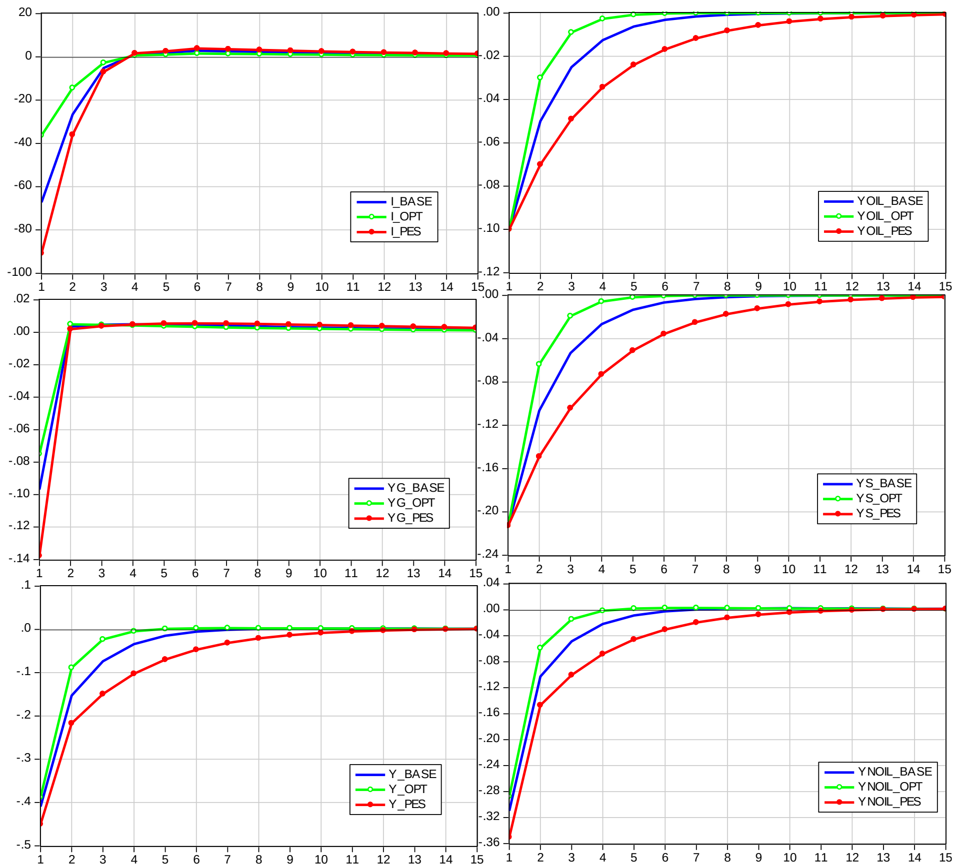

Figure 7. Production's Response to COVID-19 Shock in Various Scenarios

Source: Research finding.

5.4 SWFs-funded Policy Response Scenario

In this part, we evaluated the effect of supportive policy response to facilitate the current crisis recovery. Limited policy responses can be implemented due to fiscal imbalance in many countries (Makin and Layton, 2021). This limitation is more critical in oil-exporting countries but the most prevalent finance source is oil-based SWFs.

Oil-based SWFs not only save for future generations but also peruse current development goals (Mahmoudi et al., 2020; Steigum, 2012). SWFs also face the most severe shock due to the reduction of oil prices (Bortolotti and Fotak, 2020) but accumulated assets of oil-based SWFs in most oil exporting countries such as Norway, Iran, and Qatar have permitted them to manage pandemics (Says, 2020; Ursin et al., 2020).

In this proposed policy, we assumed that the government borrows from SWF to support the goods and service sector.

Gaspar et al. (2019) estimated that emerging economies would need to spend, on average, an additional 4% of gross domestic product (GDP) to fill their SDG (Sustainable Development Goals) spending gaps. The aforementioned 4% of Iran's GDP is equal to 18.32 billion dollars which is about 27% of the Iranian oil-based sovereign wealth fund (namely NDF)[1]. To assess the response of policy response through SWF, we considered a 27% increase in SWFs sources to finance the crisis (as a result of the immense disruption of the service sector, we considered 2/3 of SWF funded to the service sector and 1/3 to the goods sector).

Following (Sayadi and Khosroshahi, 2020), by some modification, the accumulated oil revenue in Iranian oil-based SWF (NDF_t) in each period can be represented as follows:

$$NDF_t = NDF_{t-1} + \omega_f Y_{oil,t} + F_t \quad (37)$$

$$I_{s,t}^{a} = I_{s,t} + \frac{2}{3} F_t \quad (38)$$

$$I_{g,t}^{a} = I_{g,t} + \frac{1}{3} F_t \quad (39)$$

which F_t is the portion of oil revenues assigned from Iran SWF to the service sector to enhance its capital accumulation. Given the long-run production model (Esfahani et al., 2013), when a portion of oil revenues is invested, oil revenues can have an efficient role in the capital accumulation equation which could be represented as the following for the service sector:

$$\mathrm{K}_{s,t+1} = (1 - \delta_s)\mathrm{K}_{s,t} + I_{s,t}^{a} \quad (40)$$

$$\mathrm{K}_{g,t+1} = (1 - \delta_g)\mathrm{K}_{g,t} + I_{g,t}^{a} \quad (41)$$

Here $I_{s,t}^{a}$ and $I_{g,t}^{a}$ denote services and goods investment, respectively, which to some extent are financed by the SWFs.

IRFs analysis shows a lower inflation (PI) in the SWFs-funded policy response which is the result of increasing the supply of goods and services. The result of implementing this policy also showed that the negative effect of COVID-19 shock significantly curtailed services production (YS), goods production (YG), and total production (Y) (Figure 8). Furthermore, the full recovery of economics not only

[1]. NDF, established in 2011, is an oil-based developmental fund pursuing the development targets through fortifying the private capital.

depends on the response policy but is also dependent on the health situation and preventive measures of households.

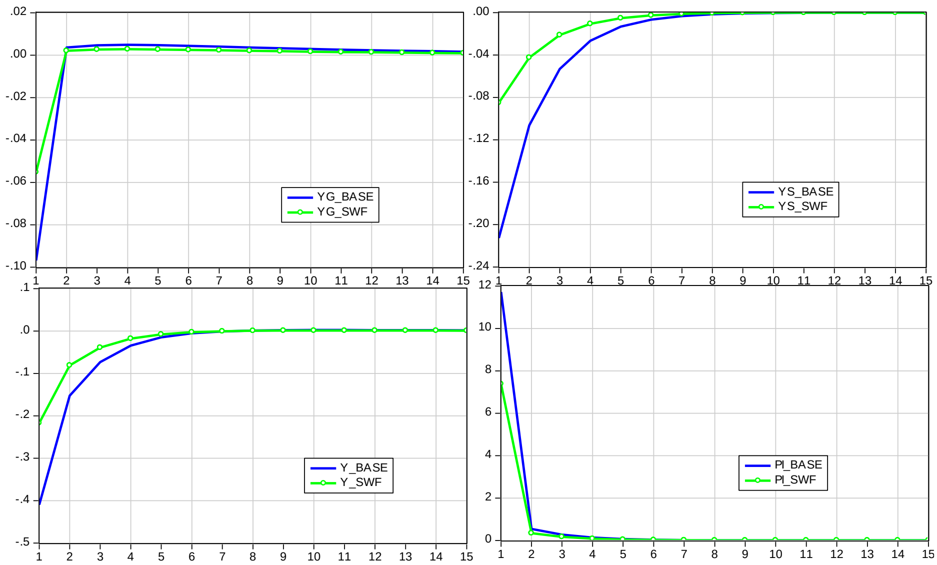

Figure 8. The Effects of Implementing a Swfs-Funded Response Policy on Production and Consumption

Source: Research finding.

5.5 Counterfactual Tax Scenario

We developed a counterfactual scenario for the COVID-19 response to quantify how tax evasion reform would have helped to restrict undesirable macroeconomic effects such as liquidity rate, budget deficit, and inflation. Currently, tax revenue accounts for 38% of government revenue in Iran (CBI Economic Time Series Database; Iran., 2018). According to (World Bank data, 2020), the world's average tax-to-GDP ratio is 15%, this ratio represents about 6% in Iran. Raising tax revenues can effectively balance the government budget deficit. In Iran, this could be attained by reducing tax exemptions and expansion of the tax base. About 40% of Iran's economic activity is always tax-exempt or involved in substantial tax holidays due to taxation law. Furthermore, reducing tax evasion and increasing the efficiency of the tax system can also increase the tax revenue base. The government could avoid 40% of current tax evasion and employ the tax revenue to meet the budget deficit. Current findings showed that the proposed counterfactual scenario has better outcomes including Non-oil government budget (GBNO), liquidity growth rate (MU), and inflation (PI) than the base scenario (Figure 9).

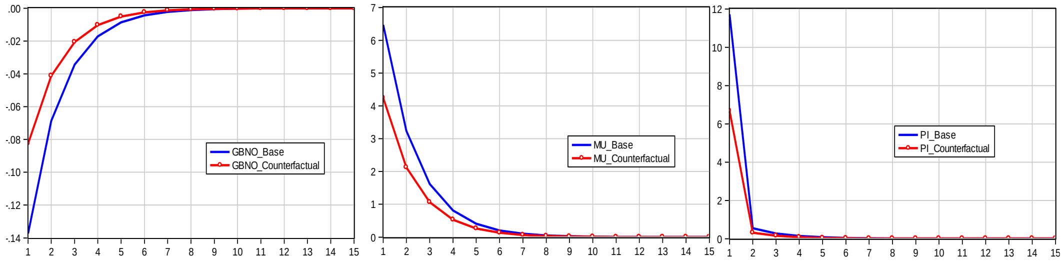

Figure 9. Comparison of Counterfactual Tax Scenario and the Base Scenario Due to the COVID-19 Shock

Source: Research finding.

6. Conclusion and Policy Implications

Considering that shocks such as the COVID-19 Pandemic are likely to occur in the future, it is important to understand how they affect macroeconomic variables. The Coronavirus pandemic has created massive economic supply and demand shock since the end of 2019. Oil prices crashed in March 2020 and subsequently, petroleum product prices and demand plunged in this period. Therefore, oil exporting countries have faced multiple shocks which have increased their vulnerability to external shocks and widened budget deficit.

This paper investigated the effect of COVID-19 shock by the NK-DSGE model on the Iranian economy as the worth affected by the disease outbreak in oil-exporting countries. We have outlined three scenarios for how the uncertainty of pandemic persistence can affect macroeconomics. These scenarios include optimistic, base, and pessimistic scenarios according to the tree, five, and the seven-quarter persistency length. Our model highlighted that a decline in the supply side (service and goods output) occurred through deterioration in labor productivity. Apart from the supply side, service demand also dropped given its relationship with health risk.

The findings indicated that, first, service and goods output and demand sharply declined especially in the pessimistic scenarios. Second, government tax revenue would decrease as a result of lower consumption and production and government expenditure would increase because of higher health expenditure. Hence deficit in the non-oil budget is expected. Oil revenue was also reduced which together caused an immense budget deficit. As an important stylized fact of Iran's economy, the government borrows from the central bank which has led to an increase in the liquidity growth rate, and inflation.

Third, household response to COVID-19 shock is highly affected by shock persistence. In other words, households inevitably raise their health expenditure and leisure time while cutting their working time in the service and goods sectors.

Government budget deficit analysis is imperative in the pandemic analysis. In our model, the two main sources of the budget deficit are oil and non-oil budget. The non-oil part has been affected by the reduction of tax revenue and an increase in health expenditure and the oil part has been disrupted due to the oil price slump. The fiscal budget of oil-exporting countries is highly dependent on oil revenue. Oil price plummet associated with macroeconomic vulnerability and budget deficit. This implies a borrowing of the central bank and expansion in the monetary base which results in an increase in money supply and inflation in oil-exporting developing countries. The policy response to a huge budget deficit in the time of COVID-19 is a great concern in oil-exporting developing countries that should cope with oil price reduction as an extra shock. We have evaluated the effect of two different types of responses. Firstly, oil-based SWFs-funded policy response, and secondly counterfactual tax scenario. In the SWFs-funded policy, the response restricted the undesirable impact of COVID-19 shock has been observed in its IRFs analysis. Meanwhile, a reduction in the stock of SWFs is a limitation of this policy in times of prolonged health shock.

Reducing tax evasion as a counterfactual scenario has been considered as a second policy option. The result of implementing the current counterfactual policy response has led to stability in the monetary base and consequently lower inflation. It is worth noting that as long as the budget is dependent on oil price, vulnerability remains a contentious issue and oil exporting countries should pursue stable solutions such as reforming the tax system as a counterfactual scenario[1].

[1]. This work was supported by the Iran National Science Foundation [grant number 99004069].

Appendix A

Derivation of first-order conditions (F.O.C)

- Households

$$\zeta = \mathrm{E_t}\sum_{0}^{\infty} \beta^t[\mathrm{Ln}((\theta_t H_t^{\varsigma} C_{s,t} + (1-\theta_t)C_{s,t})^{\alpha} C_{g,t}^{1-\alpha}) + \varphi_{\mathrm{H}} \frac{H_t^{1-\sigma}}{1-\sigma} + \varphi_{\mathrm{m}}\mathrm{Ln}(m_t)]$$
$$- \beta^t \lambda_t \{(1+\tau_c)[C_{g,t} + C_{s,t}] + \mathrm{I_{g,t}} + \mathrm{I_{s,t}} + m_t + \mathrm{Z}_t$$
$$- w_t(1-\tau_N)[N_{g,t} + N_{s,t}] - r_{k,t}(K_{g,t} + K_{s,t}) - \frac{m_{t-1}}{\pi_t}\}$$

- F.O.C

$$C_t = (C_{s,t} e^{s_t ln H_t^{\varsigma}})^{\alpha} C_{g,t}^{1-\alpha} = [\theta_t H_t^{\varsigma} C_{s,t} + (1-\theta_t)C_{s,t}]^{\alpha} C_{g,t}^{1-\alpha}$$

$$\mathrm{H_{t+1}} = (\mathrm{V_t} + (1-\varphi)\mathrm{H_t})\mathrm{e}^{\mathrm{s_t}\ln(1-\Omega)} = (\mathrm{V_t} + (1-\varphi)\mathrm{H_t})(1-\theta_t\Omega)$$

$$V_t = (1-N_t)^{1-\gamma}(Z_t)^{\gamma} \qquad \mathrm{K_{g,t+1}} = (1-\delta)\mathrm{K_{g,t}} + \mathrm{I_{g,t}}$$

$$\mathrm{K_{s,t+1}} = (1-\delta)\mathrm{K_{s,t}} + \mathrm{I_{s,t}}$$

$$\frac{\partial\zeta}{\partial C_{s,t}} : \frac{\alpha[\theta_t H_t^{\varsigma} + (1-\theta_t)]}{[\theta_t H_t^{\varsigma} C_{s,t} + (1-\theta_t)C_{s,t}]^{\alpha}(1+\tau_c)} = \lambda_t \qquad \frac{\partial\zeta}{\partial C_{g,t}} : \frac{(1-\alpha)}{(1+\tau_c)C_{g,t}} = \lambda_t$$

$$\frac{\partial\zeta}{\partial N_t}: \ \psi_t(1-\gamma)\frac{V_t}{(1-N_t)}(1-\theta_t\Omega) = \lambda_t w_t(1-\tau_N)$$

$$\frac{\partial\zeta}{\partial \mathrm{K_{t+1}}}: \lambda_t = \beta\lambda_{t+1}[(\delta-1) + r_{k,t+1}] \qquad \frac{\partial\zeta}{\partial Z_t}: \ \psi_t\gamma\frac{\mathrm{V_t}}{Z_t}(1-\theta_t\Omega) = \lambda_t$$

$$\psi_t = \beta\alpha\varsigma\frac{C_{s,t+1}}{(\theta_t H_t^{\varsigma} C_{s,t+1} + (1-\theta_t)C_{s,t+1})^{\alpha}} H_t^{\varsigma-1}\theta_{t+1} + \beta\varphi_{\mathrm{H}} H_t^{-\sigma} + \beta\psi_{t+1}(1$$
$$-\varphi)(1-\theta_{t+1}\Omega)$$

$$\frac{1}{C_t} = \beta E_t(\frac{1}{C_{t+1}})(r_{k,t} + 1 - \delta_p) \qquad \frac{\psi_m}{m_t} = \left(\frac{1}{1+\tau_c}\right)\left[\frac{1}{C_t} - E_t(\frac{1}{C_{t+1}})\left(\frac{\beta}{\pi_{t+1}}\right)\right]$$

- Firms

$$Max\Pi t = (1-\tau_y)\mathrm{Y_{n,t}} - w_t \mathrm{N}_{n,t} - r_{k,t}\mathrm{K}_{n,t} - \frac{\phi_p}{2}\left(\frac{P_t(j)}{P_{t-1}(j)}\right)^2 \mathrm{Y_{n,t}}$$

$n = s, g$ s.t: $\mathrm{Y_{n,t}} = a_t(\eta^t \mathrm{N}_{n,t}\mathrm{H_t})^{\alpha_1}(\mathrm{K_{n,t}})^{\alpha_2}$

- FOC:

$$w_t = (1-\tau_y)\alpha_1(\frac{\mathrm{Y_{n,t}}}{\mathrm{N}_{n,t}})(\frac{1}{q_{n,t}}) \qquad r_{k,t} = (1-\tau_y)\alpha_2(\frac{\mathrm{Y_{n,t}}}{\mathrm{K_{n,t}}})(\frac{1}{q_{n,t}})$$

$$\left(\frac{1}{q_{n,t}}\right) = \frac{\theta-1}{\theta} + \frac{\phi_p}{\theta}.\pi_t(\pi_t - 1) - \beta\frac{\phi_p}{\theta}E_t\left[\pi_{t+1}(\pi_{t+1}-1)\frac{\lambda_{t+1}}{\lambda_t}\frac{\mathrm{Y_{n,t+1}}}{\mathrm{Y_{n,t}}}\right]$$

- Market clearing conditions:

$Y_{s,t} = C_{s,t}$ $\qquad$ $Y_{noil,t} = Y_{s,t} + Y_{g,t}$

$Y_t = Y_{noil,t} + Y_{oil,t}$ $\qquad$ $Y_t = C_t + I_t + G_t + NX_t$

Appendix B

Considering the deterministic trend η from the constant rate of technological innovation in the model's real variables, according to Ireland (1997), a stationary variable ($\tilde{X}$) can be derived from $\tilde{X} = \frac{X_t}{\eta^t}$. Hence, the stationary non-linear equations system can be represented as follows:

- Households

$$\tilde{C}_{g,t} = \frac{(1-\alpha)\tilde{C}^*_{s,t}}{\alpha[\theta_t H_t^{\varsigma} + (1-\theta_t)]} \qquad \frac{(1-\alpha)}{(1+\tau_c)\tilde{C}_{g,t}} = \tilde{\lambda}_t$$

$$\psi_t \frac{V_t(1-\theta_t\Omega)(1-\gamma)}{(1-N_t)} \frac{(1+\tau_c)\tilde{C}_{g,t}}{(1-\alpha)(1-\tau_N)} = \widetilde{w}_t \qquad \frac{\eta\tilde{C}_{g,t+1}}{\tilde{C}_{g,t}} = \beta[(1-\delta_s) + r_{kg,t+1}]$$

$$\frac{\eta\tilde{C}_{g,t+1}}{C_{g,t}} = \beta[\left(1-\delta_g\right) + r_{ks,t+1}] \qquad \frac{V_t}{\tilde{Z}_t} = \frac{(1-\alpha)}{\psi_t\gamma(1-\theta_t\Omega)(1+\tau_c)\tilde{C}_{g,t}}$$

$$\psi_t = \beta\alpha\varsigma\frac{\tilde{C}_{s,t+1}}{\tilde{C}^*_{s,t+1}} H_t^{\varsigma-1}\theta_{t+1} + \beta\varphi_H H_t^{-\sigma} + \beta\psi_{t+1}(1-\varphi)(1-\theta_{t+1}\Omega)$$

$$\frac{\psi_m}{\widetilde{m}_t} = \frac{(1-\alpha)}{(1+\tau_c)}\left[\frac{1}{\tilde{C}_{g,t}} - E_t\left(\frac{\beta}{\pi_{t+1}\eta\tilde{C}_{g,t+1}}\right)\right] \qquad \tilde{C}_t = [\tilde{C}^*_{s,t}]^{\alpha}\tilde{C}_{g,t}^{1-\alpha}$$

$$\tilde{C}^*_{s,t} = \theta_t H_t^{\varsigma}\tilde{C}_{s,t} + (1-\theta_t)\tilde{C}_{s,t} \qquad N_t = N_{g,t} + N_{s,t}$$

- Firms

$$\eta\widetilde{K}_{g,t+1} = \left(1-\delta_g\right)\widetilde{K}_{g,t} + \tilde{I}_{g,t} \qquad \eta K_{s,t+1} = (1-\delta_s)K_{s,t} + I_{s,t}$$

$$\tilde{I}_t = \tilde{I}_{g,t} + \tilde{I}_{s,t} \qquad \widetilde{Y}_{g,t} = a_t\left(N_{g,t}H_t\right)^{\alpha_g}\left(\widetilde{K}_{g,t}\right)^{1-\alpha_g}$$

$$\widetilde{Y}_{s,t} = a_t\left(N_{s,t}H_t\right)^{\alpha_s}\left(\widetilde{K}_{s,t}\right)^{1-\alpha_s} \qquad \widetilde{w}_t = (1-\tau_y)\alpha_g\left(\frac{\widetilde{Y}_{g,t}}{N_{g,t}}\right)\left(\frac{1}{q_{g,t}}\right)$$

$$\widetilde{w}_t = (1-\tau_y)\alpha_s\left(\frac{\widetilde{Y}_{s,t}}{N_{s,t}}\right)\left(\frac{1}{q_{s,t}}\right) \qquad r_{kg,t} = (1-\tau_y)(1-\alpha_g)\left(\frac{\widetilde{Y}_{g,t}}{\widetilde{K}_{g,t}}\right)\left(\frac{1}{q_{g,t}}\right)$$

$$r_{ks,t} = (1-\tau_y)(1-\alpha_s)\left(\frac{\widetilde{Y}_{s,t}}{\widetilde{K}_{s,t}}\right)\left(\frac{1}{q_{s,t}}\right)$$

$$\left(\frac{1}{q_{g,t}}\right)=\frac{\theta-1}{\theta}+\frac{\phi_{pg}}{\theta}.\pi_t(\pi_t-1)-\beta\frac{\phi_{pg}}{\theta}E_t\left[\pi_{t+1}(\pi_{t+1}-1)\frac{\tilde{\Lambda}_{t+1}}{\tilde{\Lambda}_t}\frac{\tilde{Y}_{g,t+1}}{\tilde{Y}_{g,t}}\right]$$

$$\left(\frac{1}{q_{s,t}}\right)=\frac{\theta-1}{\theta}+\frac{\phi_{ps}}{\theta}.\pi_t(\pi_t-1)-\beta\frac{\phi_{ps}}{\theta}E_t\left[\pi_{t+1}(\pi_{t+1}-1)\frac{\tilde{\Lambda}_{t+1}}{\tilde{\Lambda}_t}\frac{\tilde{Y}_{s,t+1}}{\tilde{Y}_{s,t}}\right]$$

$$\tilde{X}_t=\emptyset_X\tilde{Y}_{g,t} \qquad \tilde{M}_t=\emptyset_M\tilde{Y}_{g,t} \qquad \widetilde{NX}_t=\tilde{X}_t-\tilde{M}_t$$

- Government -Central Bank

$$\widetilde{GBT}_t=\widetilde{GBNO}_t+(1-\omega_f)\tilde{Y}_{oil,t} \qquad \widetilde{GBNO}_t=\tilde{T}_t-\tilde{G}_t$$

$$\widetilde{GBT}_t^{total}=-\alpha_{GB}(\frac{M_t-M_{t-1}}{P_t})=-\alpha_{GB}(\tilde{m}_t-\frac{\widetilde{m_{t-1}}}{\eta\pi_t})$$

$$\tilde{\mu}_t=\frac{M_t}{M_{t-1}}=\eta\frac{\tilde{m}_t}{\tilde{m}_{t-1}}\pi_t \qquad \tilde{G}_t=\tilde{G}_{I,t}+\tilde{G}_{C,t}$$

$$\tilde{G}_{I,t}=\alpha_{GI}\tilde{G}_t \qquad \tilde{T}_t=\tau_c\tilde{C}_t+\tau_N\tilde{w}_t N_t+\tau_y\tilde{Y}_{noil,t}$$

- Market Clearing Condition

$$\tilde{Y}_{s,t}=\tilde{C}_{s,t} \qquad \tilde{Y}_{noil,t}=\tilde{Y}_{s,t}+\tilde{Y}_{g,t}$$

$$\tilde{Y}_t=\tilde{Y}_{noil,t}+\tilde{Y}_{oil,t} \qquad \tilde{Y}_t=\tilde{C}_t+\tilde{I}_t+\tilde{G}_t++\widetilde{NX}_t$$

- Shocks

$$Ln(Y_{oil,t})=(1-\rho_{Yoil})\,ln(\overline{Y_{oil}})+\rho_{Yoil}Ln(Y_{oil,t-1})-\varepsilon_t^{COV}$$

$$Ln(GC_t)=(1-\rho_{GC})\,ln(\overline{GC})+\rho_{GC}Ln(GC_{t-1})+\varepsilon_t^{COV}$$

$$Ln(T_t)=(1-\rho_T)\,ln(\overline{T})+\rho_T Ln(T_{t-1})-\varepsilon_t^{COV}$$

$$Ln(C_{s,t})=(1-\rho_{CS})\,ln(\overline{CS})+\rho_{CS}Ln(C_{s,t-1})-\varepsilon_t^{COV}$$

$$Ln(H_t)=(1-\rho_H)\,ln(\overline{H})+\rho_{\theta H}Ln(H_{t-1})-\varepsilon_t^{COV}$$

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Cite this article: Sayadi, M., & Ghorbani Pashakolaei, V. (2024). Macroeconomic Effects of the COVID-19 Pandemic Shock; Implications from a Scenario-Based DSGE Model for Iran. *Iranian Economic Review, 28*(4), 1277-1314.