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The effects of war and military budget on the fluctuations of macroeconomic variables

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Abstract

Economic conflicts of interest, international agreements, demarcation, ideological beliefs, etc. have led to differences between countries and even regions, to the extent that numerous wars have occurred in the world from the past until now. Evidence in Iran and other parts of the world speaks of the destructive effects of wars. The present study examines the effects of war on macroeconomic variables in Iran, emphasizing both military and non-military expenditures of the government, within the framework of a DSGE model during the time period from 1991 to 2021. According to the results obtained from the variance decomposition of variables in response to a war shock, it was revealed that this shock explains 69.85% of output fluctuations, 67.83% of consumption fluctuations, 65.81% of investment fluctuations, 70.54% of government expenditure fluctuations, 71.28% of employment fluctuations, and approximately 80% of wage fluctuations. The results of instantaneous response functions indicate the negative response of economic variables including production, consumption, investment, employment and wages and the positive response of government expenditures in response to a war shock.

Keywords: government military expenditures, DSGE model, business cycles
2020 MSC: 91B76

1 Introduction

With a general overview of the world map in Figure 1, the differences between many countries or regional disparities are well evident. Economic conflicts of interest, international agreements, demarcation, ideological beliefs, etc. have led to differences between countries and even regions. The history of wars between countries is not limited to the current time period but has existed both in the past, since the emergence of humanity, and likely will exist in the future. In addition to differences between countries, insecurity within countries always potentially exists. In the modern ranking of military power among countries, besides the number of military equipment such as tanks, fighter jets, etc., the military budget, GDP, and population also have a significant impact. Therefore, the economic strength of countries is considered one of the instances of military power. Historical experience in Iran and other countries that have been involved in wars indicates the creation of fluctuations in economic variables, especially in government budgets. Thus, in the present study, an examination and analysis of the effects of war, with an emphasis on government expenditures,

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are conducted on the economic variables of the country. For this purpose, a Bayesian Dynamic Stochastic General Equilibrium (DSGE) model compatible with the economic conditions of Iran is utilized. The continuation of the current paper is explained as follows:

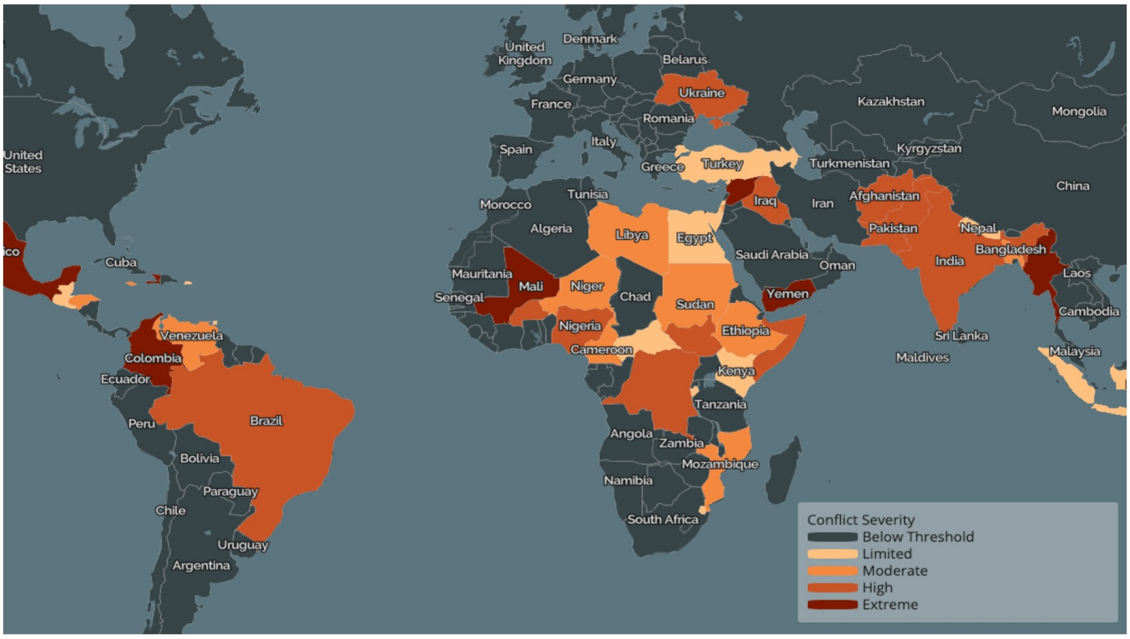

Figure 1: World map based on conflict volume [45].

The research problem is explained in the second section. The importance and necessity of research is mentioned in the third section. The fourth section describes the subject literature in the form of previous studies. In the fifth section, DSGE model research and the theoretical foundations of relationships between variables are explained. The sixth section is dedicated to statistical data, calibration and Bayesian estimation of parameters. In the seventh section, the results of the research are presented, and the last section is dedicated to summarizing and presenting some policy recommendations.

2 Problem statement

The effects of fiscal policy are fundamental in macroeconomics. In this regard, various macroeconomic models have yielded conflicting results regarding the response of private consumption, gross domestic product, and other variables to government expenditure shocks. The papers by Baxter and King [7], Ambler and Paquet [3], Linnemann and Schabert [30], Forni et al. [20], Leeper et al. [29], Enders et al. [18], Coenen et al. [14], Kormilitsina and Zubairy [28], Beidas and Lorusso [9] are examples of such articles. The inconsistency in the impact of government expenditures on economic variables is not limited to total expenditures, and its constituent elements also encompass a broad classification into military and non-military expenditures. Studies by Pradhan [38], Dunne and Nikolaidou [16], Dada [15], Uçler [47], Lorusso and Pieroni [32], Shaaba Saba and Ngepah [41], Abdel-Khalek et al. [2] are examples of foreign articles and research, while studies by Hasani Sadrabadi and Aziznejad [25], Hasani Sadrabadi and Kashmari [26], Golkhandan [24], Karimi Patanlar and Bajelan [27], Abbasian et al. [1], and Poursadegh and Kashmari [37] constitute some of the domestic studies in this field. Nevertheless, the relationship between government expenditures and its constituent elements with macroeconomic variables has always been a topic of significant discussion in economic forums. On one hand, security is a public good, and ensuring it will have positive effects on investment, economic growth, and private consumption as a result of the growth in societal income. On the other hand, considering the constraints on resources, the growth of government expenditures, especially in the defense sector, will ultimately enhance the efficiency of financial resources in other sectors. This effect, known as the external crowding out effect, will lead to a reduction in consumption, investment, and consequently output through an increase in interest rates.

In this way, the Iranian economy, and especially the consequences arising from the effects of military and non-military components of government expenditures in the country's business cycles, are less understood and have not been extensively examined. Therefore, there are numerous ambiguities regarding the effects of fiscal policy on the economy of Iran. How do military and non-military expenditures impact fluctuations in output and its components? What is the dynamic response of output, household private consumption, and investment to changes in the components of government expenditures resulting from the occurrence of war? And, in general, can shocks arising from the components of government expenditures, assuming the presence of war, influence the business cycle in the Iranian economy?

With this description, the advanced research focuses on the role of the war shock as a stimulus for both military and non-military government expenditures, considering them as drivers of the country's business cycles. For this purpose, a Dynamic Stochastic General Equilibrium (DSGE) model has been developed for the Iranian economy and is estimated using Bayesian methods.

The DSGE model in this study possesses features that make it closely resemble the real world. Similar to the study by Pieroni et al. [36], it is assumed, following the so-called 'military Keynesianism,' that decision-making for two different components of government expenditures is independent. In accordance with proponents of this viewpoint, defense expenditures have two specific conditions: Firstly, military expenditures are independent of other public expenditure items (such as education and health). Secondly, decision-making regarding the defense sector is taken by institutions and entities that are independent of other government sectors (General Staff of the Armed Forces, Ministry of Defense, etc.).

Since the early 1980s, the transmission and impact of fiscal policy shocks on economic variables, especially private consumption, have changed in many economies [11, 19, 21, 35]. Such a change is related to the increase in households' participation in asset markets [10]. The Iranian economy is not an exception to this rule. During the 70s and 80s decades, due to many restrictions, a large part of the households did not have access to the financial markets. From the 90s onwards, financial liberalization expanded private access to financial markets. These structural changes have had a significant impact on the response of private consumption to government expenditure shocks. In this research, the DSGE model tries to describe the possible sources of internal/external crowding of consumption expenditures following government expenditure shocks. To do this, as in the studies of Gali et al. [21] and Lorusso and Pieroni [31, 32], households are considered heterogeneous. Some households do not have access to the financial market and consume their current income in every period of history. On the other hand, some households have access to financial markets and adjust their consumption in a desired way.

In this DSGE model, some firms produce different goods and make decisions regarding the labour input, and according to the Calvo model [13], they will determine the price level. The fiscal policy authority purchases consumer goods, which are divided into military and non-military sectors, and finances these expenditures using lump-sum (uniform) taxes, income taxes, and oil revenues. In this way, the financing structure of government expenditures and its components will be close to the economic structure of Iran.

In this research, the central bank is the monetary policy authority. In Iran, the central bank has various policy-making tools, one of which is the interest rate. It is assumed that the interest rate policymaker adjusts the interest rate of bonds with full discretion to achieve the two goals of reducing the deviation of inflation from the target inflation and reducing the deviation of production from potential production. In addition, it is assumed that the central bank does not have any explicit target for inflation that is announced to the general public. Nevertheless, due to the presence of targeting in development programs, policymakers always strive to pursue an implicit goal. In this way, it is assumed that the monetary policy maker adjusts the nominal interest rate based on the reaction function of the monetary policy and in the form of the following logarithmic-linear equation. In this way, it is possible to analyze the impact of higher nominal interest rates with a more aggressive monetary policy on reinforcing household incentives to delay consumption and negatively affect production. The advanced research model is estimated using Bayesian techniques and Iranian macroeconomic data. The main components of the advanced research, considering the previous literature, include two parts:

Firstly, this research incorporates the disaggregated components of non-military and military expenditures into a theoretical DSGE framework. The war shock affects both the military and non-military budget components, exerting a multiplicative impact on the economy. Secondly, this research utilizes Bayesian methods to assess the impact of fiscal policy shocks on the economy. This approach allows us to address known shortcomings in identifying military shocks associated with neoclassical literature (The view of the neoclassicists regarding the impact of military shocks on the economy is known as the narrative or storytelling approach. For a detailed study on the criticism of the narrative or storytelling approach, see Perotti [35]).

3 Significance of the study

Iran is situated in a sensitive and strategic region of the world, where a significant portion of the Middle East is embroiled in conflict, and the most crucial issue for many countries in this region is the lack of security; For this reason, attention to the military budget is a matter of great importance. On the other hand, the Iranian economy, in addition to facing internal structural issues, is confronted with compounded challenges due to the imposition of sanctions; Therefore, in such conditions, both the overall government budget and its financing are subjects of discussion, and the impact of military expenditures on economic variables is of paramount importance.

Over the past years, numerous studies have been conducted in various regions around the world regarding the impact of government expenditures, including its military components, on economic variables. These studies have yielded different results, and there is no consensus regarding the impact of military and defense budgets on economic variables in them. While some studies have assessed the positive impact of military expenditures on economic growth, the results of other studies indicate a negative effect of military expenditures on economic growth and other key macroeconomic variables. It is evident that the analysis of the results of each study depends on the conditions prevailing in that region, its specific time period, and the model and assumptions used in analyzing the data, which, in turn, provides the groundwork for further studies.

In order to fill the research gap, the advanced study adjusts and estimates a Dynamic Stochastic General Equilibrium (DSGE) model for the Iranian economy. This model includes two distinct components of government expenditures, namely non-military and military expenses. The reason for using the DSGE method in this research is that, despite efforts made in previous studies, there are still areas where they can be complemented, and the application of this method somewhat addresses many of the challenges in previous research:

Firstly, the model used in the conducted research, especially domestic studies, includes only a few variables and tends to be overly general. In other words, they examine the impact of military expenditures on a limited number of variables, such as economic growth and private consumption, within the framework of a single regression equation. Many variables affected by military expenditures, such as nominal interest rates, inflation, wage levels, and employment, which themselves are demand and production drivers, have been excluded from economic studies. Secondly, they have a non-structural nature and, especially in the case of estimating models with constant coefficients, face criticism from the Lucas [33] critique [34]. In other words, over time, they lose their credibility and only explain the period under consideration. Thirdly, the Iranian economy is an oil-based economy. Unlike many studies where the role of oil income and its resulting shocks in studies related to the effects of military expenditures on economic variables is ignored, the structural feature of the DSGE model allows for analyzing the effects of the military budget on the Iranian economy, taking into account shocks to oil income. Fourthly, the structural feature of the DSGE model in this research provides the role of monetary policies, with the nominal interest rate as a driver, in creating fluctuations in economic variables in Iran.

In this way, the designed pattern is challenged in different situations mentioned below:

In the first stage, the relative importance of shocks in creating fluctuations in macroeconomic variables in Iran is examined. For this purpose, in an estimation, the variance decomposition of the prediction error of model variables, including Gross Domestic Product (GDP), private consumption, employment, nominal interest rate, and inflation rate, is measured concerning the occurrence of shocks to government expenditures and military and non-military components resulting from war and shocks to oil income. It is assumed that other government expenditures and military expenditures depend on their previous period levels. On the other hand, the inverse function of a negative productivity shock, such as war or insecurity, will be negative. In other words, due to a negative productivity shock (such as war or insecurity), other government expenditures and military expenditures will increase. In this scenario, assuming the reality that during the occurrence of a phenomenon like war, on the one hand, the production is reduced due to the decline in productivity resulting from the transfer of some of the human resources from productive activities to non-productive activities, and some industrial enterprises partially shut down due to restrictions announced in special conditions, the productivity variable is modelled with a negative coefficient in the production function. On the other hand, according to historical evidence, due to such a shock, government expenditures in the military sector increase to prevent further damages caused by war and insecurity. Additionally, due to the loss of a significant portion of jobs and activities, the government strives to compensate for the incurred losses and elevate its expenditures to address the economic situation of the society. In the second stage, the impulse response functions of the variables obtained from the model will be estimated in response to the occurrence of structural shocks. This way, the dynamics and predictions of each variable can be observed and examined in response to the occurrence of structural shocks, especially war shock.

4 Literature review

The majority of studies conducted in domestic and foreign research have been based on a single equation and estimated the effects of military expenditures on one of the macroeconomic variables. Some categories of research have examined the effects of military expenditures on economic growth, and some studies have considered the effects of military expenditures on variables such as consumption and investment. In addition, there are rarely articles in economics that have investigated the effects of uncertainty or war as an unforeseen shock on economic variables. Despite the challenges in today's world and witnessing numerous conflicts in various parts of the globe.

5 Research methodology

The advanced research method is based on Correlation-Causal and utilizes both observable and unobservable time series data from the Iranian economy. In this study, the effects of government expenditure shocks on the dynamics of business cycles are analyzed using a Dynamic Stochastic General Equilibrium (DSGE) model. For this purpose, quarterly data from the period 1991 to 2021 is used to capture the business cycle patterns. The relationships between the research variables will be estimated using Bayesian econometric methods.

In this section, a DSGE model is designed for Iran's economy, which includes households, firms, and the government, by adapting Bilbiie et al. [10] and Lorusso and Pieroni [32].

5.1 Households

A spectrum of heterogeneous households with infinite lifespan is considered, divided into two segments: households participating in the asset market and households not participating in the asset market. Households holding assets are considered as a fraction of the total households, denoted by $1-\lambda$. They exchange riskless bonds for one period and own shares of firms. In this model, the fraction of households not holding assets is denoted by λ. They do not participate in asset markets and are solely consumers of their limited income.

5.1.1 Households holding assets

These households face the following inter-period decision making problem:

$$\max_{\{C_{A,t},L_{A,t},B_{A,t+1}\}} E_t \sum_{t=0}^{\infty} \beta^t \frac{(C_{A,t}L_{A,t}^{\varphi})^{1-\sigma}}{1-\sigma} \tag{5.1}$$

where, $\beta \in (0,1)$ represents the subjective discount rate. φ denotes the inverse of the Frisch labor supply elasticity, and σ represents the inverse of the intertemporal elasticity of substitution. In addition, $C_{A,t}, L_{A,t}$, and $B_{A,t+1}$ represent, respectively, the consumption, leisure, and the nominal holding of bonds for this category of households in each period. The intertemporal budget constraint for asset-holding households is formulated as follows:

$$R_t^{-1}B_{A,t+1} + P_tC_{A,t} + P_tT_t = B_{A,t} + (1-\tau)(W_tN_{A,t} + P_tD_{A,t}) \tag{5.2}$$

where τ represents the fixed assumed income tax rate, and T_t is the lump-sum taxes, which are adjusted based on a pre-determined rule. In addition, R_t represents the nominal gross return on purchased bonds in period t, where P_t is the price level, W_t is nominal wages, and $D_{A,t}$ is the payment of real dividends to households holding shares in competitive (firm) companies. Finally, $N_{A,t}$ denotes working hours for asset-holding households. It is assumed that the total available time endowment is normalized to one, so $N_{A,t} = 1 - L_{A,t}$.

5.1.2 Households without assets

In each period such as t, these households face the following inter-period decision problem:

$$\max_{\{C_{N,t},L_{N,t}\}} \frac{(C_{N,t}L_{N,t}^{\varphi})^{1-\sigma}}{1-\sigma} \tag{5.3}$$

and their budget limit will be as follows:

$$P_tC_{N,t} = (1-\tau)W_tN_{N,t} - P_tT_t \tag{5.4}$$

where $C_{N,t}$ and $N_{N,t}$ represent the consumption and working hours, respectively, for asset-less households. Equation (5.4) indicates that the consumption of asset-less households is equal to their net income.

5.2 Firms

A spectrum of firms producing final goods is considered to be homogeneous. An imaginary firm $j \in [0, 1]$ combines capital K_t^j and labor N_t^j to produce final goods Y_t^j using the following production function:

$$Y_t^j = (u_t^j K_t^j)^\alpha (A_t N_t^j)^{1-\alpha}, \tag{5.5}$$

where $\alpha \in (0, 1)$ denotes the capital share in production, u_t^j is the utilization rate of capacity, and A_t represents the technology shock. Also, depending on the Cobb-Douglas production function, A_t may be referred to as a total factor productivity (TFP) shock. For a new firm entering at time t, $K_t^j = K_{0t}$ is assumed. The technology shock process is given by:

$$\ln A_t = \rho_a \ln A_{t-1} + \epsilon_t^A. \tag{5.6}$$

The parameter $\rho_a \in (-1, 1)$ measures the persistence of the shock. Also, ϵ_t^A is an independently and identically distributed (IID) natural variable with a mean of zero and a given variance σ_a^2. It is assumed that, according to Fig. 2, a negative shock to productivity, such as a military war, reduces the production level.

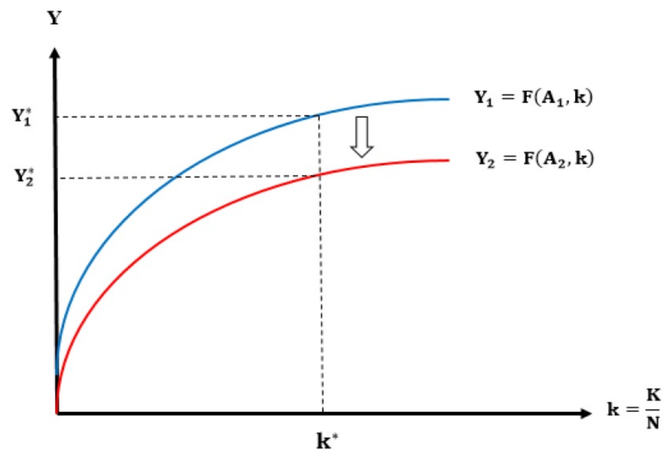

Figure 2: The effect of negative productivity shock on production level following military insecurity

It is assumed that the capital depreciation rate between periods t and t+1 is given by the relationship $\delta_t^j = \delta(u_t^j)$, where δ is a second-order differentiable function and represents a positive number in the range [0,1]. For simplicity, the rate of capacity utilization is considered constant and equal to 1 in the stable state. In this case, the capital accumulation will be as follows:

$$K_{t+1}^j = (1 - \delta_t^j) K_t^j + \varepsilon_t^j I_t^j \tag{5.7}$$

where I_t^j is the investment, and ε_t^j measures the efficiency of investment. It is assumed that ε_t^j is firm-specific and IID over time, drawn from the cumulative distribution function Φ in the range $[\varepsilon_{\min}, \varepsilon_{\max}] \subset (0, \infty)$, with a mean of 1 and probability density function $\emptyset$. This shock induces heterogeneity in the firm in this model.

Next, it is assumed that the decision regarding capacity utilization is made before observing the efficiency shock ε_t^j. Therefore, the optimal capacity utilization is independent of the specific shock ε_t^j. Considering the wage rate W_t and the capacity utilization rate u_t^j, the firm chooses the optimal labor demand by solving the following problem:

$$R_t u_t^j K_t^j = \max_{N_t^j} (u_t^j K_t^j)^\alpha (A_t N_t^j)^{1-\alpha} - W_t N_t^j \tag{5.8}$$

So that the optimal labor demand is equal to:

$$N_t^j = \left[\frac{(1-\alpha) A_t^{1-\alpha}}{W_t} \right]^{\frac{1}{\alpha}} u_t^j K_t^j \tag{5.9}$$

And the capital rental rate can also be obtained from the following relationship:

$$R_t = \alpha \left[\frac{(1-\alpha) A_t}{W_t} \right]^{\frac{1-\alpha}{\alpha}} \tag{5.10}$$

In each period, such as t, firm j can invest by purchasing investment goods from capital producers at the price P_t.

5.3 Government and financial policy

In the desired DSGE model, the government budget limit will be as follows:

$$R_t^{-1}B_{t+1} = B_t + P_t[G_t - \tau Y_t - T_t - OIL_t] \tag{5.11}$$

where τ and T_t represent respectively production-dependent taxes and uniform taxes (lamp-sum). Also, B_t denotes one-period discounted bonds, and OIL_t indicates oil income.

It is assumed that government expenditures and military expenditures of the government follow the equations below. In these equations, it is assumed that other government expenditures and military expenditures depend on their previous period's values, and, on the other hand, the inverse function of the negative productivity shock due to military insecurity will affect other government and military expenditures. In other words, in the event of a negative shock to productivity (such as war or military insecurity), other government expenditures and military expenditures increase. In this scenario, assuming the reality that at the time of the occurrence of a phenomenon, such as the reduction in productivity due to the transfer of labor from productive activities to non-productive activities, the partial shutdown of some production firms due to announced constraints in special conditions decreases. The productivity variable becomes negative in the production function model (equations (5.5) and (5.6)), and, according to historical evidence, government expenditures in the military sector increase due to such shocks to prevent further damage caused by war and insecurity. Additionally, due to the loss of a significant portion of jobs and activities, the government attempts to compensate for the incurred losses and elevates its expenditures. Equations (5.12) and (5.13) are also specified in a way that government expenditures, both in the military sector and in other sectors, increase following a war shock.

$$\log(NM_t) = \rho_{nm}\log(NM_{t-1}) + A_t \tag{5.12}$$

$$\log(M_t) = \rho_m\log(M_{t-1}) + A_t \tag{5.13}$$

The government's primary budget deficit is defined as follows:

$$D_t = G_t - \tau Y_t - T_t \tag{5.14}$$

Given the economic conditions in Iran and the financing of part of the budget through oil revenues, the above equation changes as follows, and therefore Equation (5.15) is considered in the DSGE system of the research:

$$D_t = G_t - \tau Y_t - T_t - OIL_t \tag{5.15}$$

where OIL_t represents oil income and follows an AR(1) stochastic process as an exogenous variable:

$$\begin{gathered} \log(OIL_t) = \rho^{OIL}\log(OIL_{t-1}) + \epsilon_t^{OIL} \\ \epsilon_t^{OIL} \sim N(0, \sigma_{OIL}^2) \end{gathered} \tag{5.16}$$

in this relation, ρ^{OIL} represents the persistence parameter of the oil income shock, and ϵ_t^{OIL} indicates the exogenous shock to this variable, which is distributed as I.I.D.

Equations (5.14) and (5.15) indicate that the total initial budget deficit of the government is generated from the difference between total expenditures and total revenues. Additionally, it is assumed that the government bears a structural deficit, $D_{s,t}$, which is adjusted by the automatic responses of tax revenues due to deviations of output from its steady-state value (Y):

$$D_{t,s} = D_t - \tau(Y_t - Y) = G_t - T_t - \tau Y_t \tag{5.17}$$

It is assumed that the structural budget deficit will be adjusted based on the following logarithmic-linear rule:

$$d_{s,t} = \eta d_{s,t-1} + \emptyset_g G_Y g_t \tag{5.18}$$

This rule is in line with the studies of Bohn [12] and Gali and Perotti [22]. The parameter η allows for budget decisions to be endogenous. The parameters $\emptyset_g$ also measure the response of the structural budget deficit to changes in government expenditures.

5.4 Central bank and monetary policy

The central bank is the monetary policy authority in this study. In Iran, the central bank has various tools for policy-making, and one of them is the interest rate. It is assumed that the policy-maker adjusts the interest rate on securities with full discretion to achieve two goals: reducing the deviation of inflation from the target inflation and reducing the deviation of output from potential output. Additionally, it is assumed that the central bank does not have any explicit targeting for inflation announced to the general public. However, due to the existence of targeting in development plans, policymakers always attempt to pursue an implicit goal. Thus, it is assumed that the monetary policy-maker adjusts the nominal interest rate based on the reaction function of monetary policy and in the form of the following logarithmic-linear equation.

$$r_t = \rho^R r_{t-1} + (1-\rho^R)\{\overline{\pi}_t + r_\pi(\pi_{t-1} - \overline{\pi}_t) + r_y(y_t - y)\} \tag{5.19}$$

where ρ^R is the smoothed parameter for the interest rate, and π_t refers to the inflation rate. Equation (5.19) indicates that the central bank responds to inflation deviations with a lag from the implicit inflation and the output gap. The output gap in this model is defined as the difference between real output and output in the steady state [**?**].

5.5 General balance and aggregation

The market clearing condition for final goods is expressed as the following equation:

$$Y_t = C_t + I_t + G_t \tag{5.20}$$

The above relation indicates that total production is equal to total demand, and total demand is obtained by summing up household consumption expenditures, investment expenditures, and total government expenditures.

In this model, the total consumption is explained as follows:

$$C_t = \lambda C_{N,t} + (1-\lambda) C_{A,t} \tag{5.21}$$

The balance in the labor market is also expressed as the following relationship:

$$N_t = \lambda N_{N,t} + (1-\lambda) N_{A,t} \tag{5.22}$$

In the above relation, the wage rate is such that the demand of firms for labor equals the total labor supply. Finally, the equilibrium in the stock market of companies (firms) will be represented by equation (5.23):

$$B_{t+1} = (1-\lambda) B_{A,t+1} \tag{5.23}$$

This means that households own all preferred stocks and all government debt is settled by asset holders.

Finally, given that working hours data are not available for Iran, this study utilizes employment data. Following Smets and Wouters [43], Zagaglia [48], and Asadi et al. [4, 5, 6], it is assumed that in response to macroeconomic shocks, employment data exhibit less volatility compared to working hours due to rigidities and contracts. However, it is further assumed that only a fraction of firms can adjust their workforce in each period. Thus, the following equation is added to the system of logarithmic-linear equations of the research model:

$$\widehat{EMP}_t = \beta \widehat{EMP}_{t+1} + \frac{(1-\beta\xi_e)(1-\xi_e)}{\xi_e}(\widehat{N}_t - \widehat{EMP}_t) \tag{5.24}$$

where $\widehat{N}_t$ is working hours and $\widehat{EMP}_t$ is the number of employees. ξ_e represents the fraction of firms that can adjust their workforce. Since ξ_e follows a beta distribution with values between zero and one, the above equation ensures that fluctuations in working hours will be greater than fluctuations in employment.

In the process of DSGE model calibration, the objective functions of each sector and economic agents are optimized with respect to their constraints. Typically, the equations derived from the first-order conditions and market clearing constraints are transformed into logarithmic-linear equations using mathematical techniques. Linear-logarithmic equations resulting from the DSGE model are estimated using Bayesian econometric methods. The impact of shocks to government public expenditures, healthcare, and other public expenditures, alongside other introduced shocks, is examined on macroeconomic variables in Iran through instantaneous response functions and variance decomposition. It is evident that, given the characteristics of the Iranian economy, these functions and equations may encounter variations. The approach of this research regarding the parameters is also to estimate them, but under conditions where their estimation involves numerous constraints or extensive computational operations that may deviate from the main research path, the method of calibration based on the consensus of previous major studies will be employed.

6 Statistical data, quantification and estimation of parameters

The data used in this study are presented in Table 1 and have been collected in the time span from 1978.4 to 2021.4. All the data are seasonally adjusted and, after taking logarithms, trend-stationary using the Hodrick-Prescott filter ($\lambda = 677$) (The value of $\lambda = 677$ is considered based on the study by Einiyan and Barkchian [17]).

Before estimating the model parameters and after initializing them, it is necessary to perform sensitivity analysis and identification based on the prior values set for the model parameters. The results of this operation indicate a unique and identifiable solution for the parameters. In other words, all model parameters are identifiable, allowing for the simultaneous estimation of all considered parameters. Furthermore, according to the sensitivity analysis results, all parameters individually have a significant impact on the model's behavior, implying that the chosen values for the prior distribution lead to a unique and identifiable solution.

Table 1: Research data in the period from 1978 to 2021

Variable	Symbol	Source
Gross domestic product	Y	World Bank
Private consumption	c	World Bank
Formation of fixed gross capital	I	World Bank
Government expenses	G	World Bank
Government military expenditure	M	World Bank
Working population	EMP	Statistics Center
Oil revenue	OIL	Central Bank

The model parameters are determined using three methods: initialization based on previous studies, calculations from the research, and Bayesian estimation. Thus, parameter initialization in the DSGE model in this study is categorized into three groups: The first category of parameters, as presented in Table 2, is initialized using two methods based on previous studies and also calculations from the research. Initialization based on research calculations refers to values for parameters that are consistent with the economic literature of DSGE models and are derived from real variables.

Table 2: Initialization of model parameters

Parameter	Description	Source	Value
τ	Tax rate	Research calculations	0.096
α	Capital's share of production	[4, 5, 6]	0.412
δ	Capital depreciation rate	[42]	0.042
η	Autocorrelation coefficient of government budget deficit	[23]	0.82
$\emptyset_g$	The ratio of budget deficit to total government expenditure	Research calculations	0.26
β	Mental discount rate	[49]	0.985
φ	Inverse of labor supply elasticity	[46]	0.46
σ	Inverse intertemporal substitution between periods	[40]	1.63
N	Hours of work in the stable state	[4, 5, 6]	0.28
r_π	Weight of inflation in the monetary policy rule	[8]	1.09
r_y	Weight of output in the monetary policy rule	[8]	0.04
ρ_r	Autoregressive coefficient of the interest rate in monetary policy	[8]	0.50
ρ_m	Parameter of government military expenditure shock	Research calculations	0.5634
ρ_{nm}	Parameter of government non-military expenditure shock	Research calculations	0.5549
λ	Share of non-Ricardian households	[46]	0.52
ξ_e	Surplus of firms that can adjust their workforce	[4, 5, 6]	0.7

The second category of parameters are a part of economic ratios that are obtained by dividing two variables in a steady state. To calculate these ratios, real data has been used in the period from 1978 to 2021. These ratios are shown in table 3:

Table 3: Relative parameters (The last two symbols are considered separately in the two scenarios, in the whole period and the war period.)

Variable	Symbol	Value
c/y	Consumption to product ratio	0.642
i/y	Investment to product ratio	0.117
g/y	The ratio of government expenditure to output	0.241
γ_M	The ratio of military expenditure to total government expenditure	0.139
γ_{NM}	The ratio of non-military expenditure to total government expenditure	0.861
γ_M	Ratio of military expenditure to total government expenditure (during war)	0.191
γ_{NM}	The ratio of non-military expenditures to total government expenditures (during wartime)	0.809

The parameters of the third category in this research are estimated using the Bayesian method. The Bayesian approach requires specifying prior information for the parameters to be estimated. Usually, in this case, prior information about the model parameters and their distribution is also derived from previous studies and economic literature. Prior information reflects the researcher's opinions and hypotheses before examining the information embedded in the sample data, essentially providing additional information for estimating the model parameters. Prior information is elucidated through the prior probability density function, and the information embedded in sample observations is explicated through the likelihood function. The product of these two distributions, according to Bayes' theorem, yields a new distribution called the posterior probability distribution. Subsequent judgments and decision-making in the modeling process are based on this distribution [42]. With these explanations, the posterior distribution of model parameters in the present study has been calculated using the Metropolis-Hastings algorithm with 200,000 iterations under the Dynare software. The posterior distribution of parameters, along with their prior mean and standard deviation taken from previous studies, is reported in Table 4.

Table 4: The results of Bayesian estimation for parameters related to structural shocks

Parameter	**Distribution type**	**Description**	**Prior mean and standard deviation**	**Source**	**Posterior estimate**
ρ_a	Beta	Productivity shock parameter or TFP	(0.2 and 0.50)	[44]	0.6295
ρ_{oil}	Beta	The oil income shock parameter	(0.2 and 0.42)	[39]	0.6239
σ_a	Inverse Gamma	Standard deviation of productivity shock or TFP	(INF and 0.01)	[44]	0.0228
σ_{oil}	Inverse Gamma	Standard deviation of oil income shock	(INF and 0.01)	Research calculations	0.0741

7 Results

7.1 Evaluation of estimation results

An important part of estimating a model is evaluating its results. In the case of a DSGE model estimated using a Bayesian approach, this can be done through various methods, using techniques common to other conventional estimation methods, as well as techniques specifically used in the Bayesian econometrics framework. In this study, aspects that can be examined to assess the quality of the estimated model include:

1. validation of estimation methods;
2. the ability of the model to adapt to the characteristics of real data;

To evaluate and ensure the credibility of this model in terms of parameter estimation, the acceptance rate of the Metropolis-Hastings algorithm is used. The ideal acceptance rate for the Metropolis-Hastings algorithm in the estimation process is typically in the range of 25% to 33%. The estimation results obtained in this study indicate that this rate falls within the ideal range in all three research scenarios across the three algorithm chains. These results are presented in Table 5:

Table 5: Acceptance rate values in 3 chains of Metropolis-Hastings algorithm

Metropolis-Hastings algorithm	**The first chain**	**The second chain**	**The third chain**
Acceptance rate	28.4532	31.2390	32.1873

After examining the strength and reasonableness of the estimation results, what the empirical researcher is interested in seeing is the ability of the estimated model to match the empirical properties of the data.

Next, a set of statistics related to real data is compared with the same set of statistics generated by the model's simulated data. These typically include sample torques such as the mean, variance, standard deviation relative to the mean, correlation with the mean, and autocorrelation coefficient. After estimating some parameters, they, along with the specified parameters, are used to solve and simulate the model for the Iranian economy. To evaluate the performance of this model in simulating variables, the predicted moments of the model are compared with the moments of the actual variables, and a summary is presented in Table 6.

For this purpose, standard deviation, correlation with output, and autocorrelation of variables such as consumption, investment, government spending, and employment are compared with each other. Both simulated and real data are seasonally adjusted, logarithmized, and filtered using the Hodrick–Prescott filter. The results of the comparison of torques in Table 6 indicate the relative success of the model in simulating real data.

Table 6: Comparing the torques of the simulated variables of the model against the real data (Symbols y, c, i, g and emp represent product, consumption, investment, government expenditure and employment, respectively.)

Data	y	c	i	g	emp
Standard deviation					
Real data	0.0378	0.0399	0.1051	0.0258	0.0093
Simulated data	0.0486	0.0412	0.1142	0.0269	0.0089
Data correlation with Y product					
Real data	1.000	0.8597	0.9079	0.3599	0.0343
Simulated data	1.000	0.8824	0.8259	0.3742	0.0924
First-order autocorrelation coefficient					
Real data	0.9466	0.9125	0.9350	0.8997	0.9121
Simulated data	0.9022	0.8882	0.8685	0.9120	0.9246

7.2 Analysis of the results

After estimating and ensuring the model's ability to simulate data, it is necessary to explain and analyze the results of each shock's occurrence based on the definition. For this purpose, two tools, namely variance decomposition and impulse response functions, which are widely used in DSGE models, will be employed.

Table 7: Variance analysis of model variables in relation to structural shocks in the third scenario

Shock	y	c	i	g	emp	w
Negative shock of TFP productivity (war)	69.85	67.83	65.81	70.54	71.28	79.86
Oil income shock	30.15	32.17	34.19	29.46	28.72	20.14

In the current study, two shocks, a negative Total Factor Productivity (TFP) shock representing war, and an oil income shock, are present in the model. According to the specified equations, war affects the production function on the level of output and wages (due to changes in labor demand) and, in response to a war shock, both military expenditures and other government expenditures are influenced. Based on the results presented in Table 7, the war shock contributes more to generating fluctuations in economic variables compared to the oil income shock. The war shock explains 69.85% of output fluctuations, 67.83% of consumption fluctuations, 65.81% of investment fluctuations, 70.54% of government expenditure fluctuations, 71.28% of employment fluctuations, and approximately 80% of wage fluctuations.

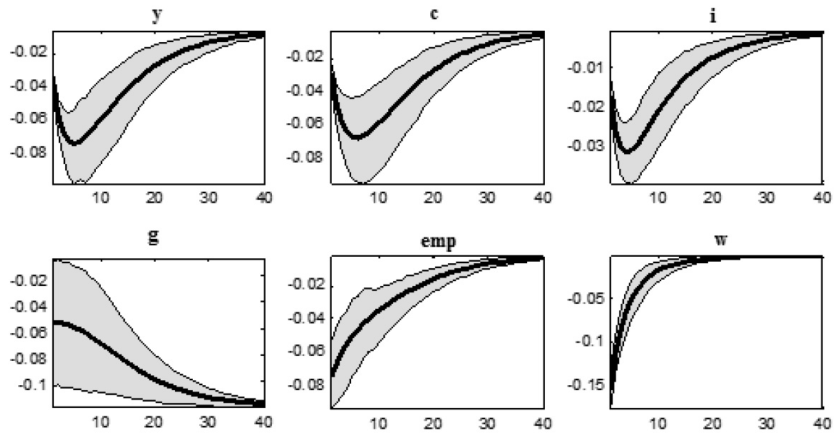

Figure 3: Instant reaction graphs of model variables in response to negative TFP shock (war)

For a better understanding of the structural effects of the war shock on macroeconomic variables in Iran, the impulse response functions of this shock are illustrated in Figure 3. In these figures, the symbols y, c, i, g, emp, and w represent output, consumption, investment, government expenditure, employment, and wages, respectively. The vertical axis in each of the graphs in Figure 3 indicates the percentage changes in variables from their steady-state (stable) conditions, and the horizontal axis represents the periods (where each period corresponds to one quarter in this context).

The results show that the product decreases in response to a negative productivity shock. This shock is directly included in the production function of the research DSGE model. In modelling this study, it is assumed that during the war, production decreases due to a reduction in productivity caused by the depletion of capital stock, a reluctance to invest due to the lack of investment security, and the partial shutdown of production firms due to restrictions imposed by the General Staff of the Armed Forces; Productivity shock with a negative sign has affected the product. The reduction in output due to this shock, following Okun's law and the profit optimization equation of the firm in the DSGE model, decreases the demand for labour, leading to a decline in employment. Consequently, with the decrease in labour demand, wages also decrease. On the other hand, according to recorded evidence due to such shocks, government expenditures in the military sector increase to prevent further damages and losses. This includes raising the level of deterrence, purchasing military equipment, etc. Additionally, government expenditures in other sectors, especially in transfer payments, increase to mitigate the economic impact resulting from the war. In such a situation, the increase in government expenditures due to budget deficits will lead to an increase in interest rates and capital outflows, resulting in a decline in existing capital investment. Consequently, the level of output will decline. Following the reduction in the output level from the stable state, the demand for labour will decrease, resulting in surplus effects on employment and wages. Ultimately, the reduction in wage levels through household budgets will lead to a decrease in household consumption. Consumption, compared to investment, is less affected by the shock due to higher stickiness and receiving a portion of government expenditures under transfer payments such as subsidies and coupons. On the other hand, with the reduction in the shock effect, despite having a stability coefficient smaller than one, the model transfers macroeconomic variables to their equilibrium levels in the stable state.

8 Conclusion

Economic conflicts of interest, international treaties, border issues, ideology-centric beliefs, and other factors have led to differences between countries and even regions, resulting in numerous wars worldwide from the past until now. Evidence in Iran and other parts of the world attests to the destructive effects of wars. Besides the loss of life, wars also impact various economic variables. Iran is located in a region that is surrounded by conflict and strife. Afghanistan to the east, Armenia and Azerbaijan to the north, and Iraq and Syria to the west of Iran all experience insecurity. The present study examines the effects of war on economic variables, emphasizing both military and non-military government expenditures, within the framework of a DSGE model over the period from 1991 to 2021. The results indicate a negative response of economic variables such as output, consumption, investment, employment, and wages to a war shock. As an additional effect, government budget increases due to the war and can exacerbate adverse economic impacts due to budget deficits. Furthermore, this DSGE model in the current study incorporates an oil income shock, which has positive effects on economic variables. The results of this research provide the following two policy suggestions:

1. Increasing deterrence by maintaining the current levels of government military expenditures because the effects of increasing the military budget on economic variables are less than the shock of war.
2. Increasing interactions through the country's foreign policies to create restraint, promote peace, and increase oil sales.

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