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GEOGRAPHICAL PROPAGATION OF THE ECONOMIC IMPACTS OF THE ISIS CONFLICT IN IRAQ

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Abstract. This study develops a methodology to assess the effects of extreme events. This method measures the geographic propagation of indirect impacts of disasters through supply chains. This modeling framework incorporates an inter-regional input-output system to calibrate a computable general equilibrium model. Our methodological approach includes examining the supply and demand constraints caused by the disruptive event. We also model regional resilience through input substitution possibilities. To illustrate the applicability of the methodology, we analyze the higher-order effects of the regional ISIS-created conflict in Iraq between 2014 and 2017. We also extend the general equilibrium model to downscale Iraq's national economic accounts to the regional level. This strategy projects the post-conflict Iraqi economy at a granular level of spatial aggregation. The model produced for this analysis offers policymakers simulations to identify economic vulnerabilities at the regional and industrial levels and explore alternatives to mitigate the damage caused by extreme events.

Keywords. armed conflict, costs of war, risk analysis, disruptive events, higher-order impacts, CGE model

JEL Codes: R13, C68

1. Introduction

The economic effects of the damage caused by extreme events represent complex modeling challenges. Physical damages and losses may occur across multiple geographic areas in a relatively short time, whereas economic effects can extend even further and persist for a considerable duration (Okuyama et al., 2004; Donaghy et al., 2007). The impact analysis of extreme events also needs to recognize the regional structure of the supply chain because the damage can spread spatially owing to regional and sectoral interdependence (Okuyama, 2007). The systemic effects of extreme events measured in an inter-regional framework provide valuable insights for risk analysis because they incorporate a comprehensive understanding of the economy as a network of integrated supply chains. Therefore, using a model built with regional specifications is critical to ensure that it captures not only the indirect impacts in areas of direct incidence, but also the geographical propagation of these secondary economic impacts.

Previous studies have typically used input-output analysis and computable general equilibrium (CGE) models to estimate the direct and indirect economic impacts of extreme events. These studies highlight how the local impacts caused by natural disasters or human-induced events spread through supply chains and how they affect a country's economy (Li et al., 2013; Koks & Thissen, 2016; Koks et al., 2016; Haddad & Okuyama, 2016; Bier & Cox, 2017; Prager et al., 2018; Xie et al., 2018; Kajitani & Tatano, 2018; Carvalho et al., 2021; Zhou & Chen, 2021; León et al., 2022; Haddad et al., 2023). In this study, we were particularly interested in evaluating extreme events resulting from human-induced risks, such as wars and armed conflicts. Therefore, this study presents a modeling framework for extreme event impact analysis built from an inter-regional CGE model. Our primary contribution involves addressing the challenge of limited information when measuring economic impacts and understanding how regions and sectors respond to such events. We also extend the CGE model to downscale national economic accounts to the regional level by adapting the target-fitting approach initially proposed by Garber and Haddad (2012).

Research on extreme events is still evolving and aims to address the gaps in impact analysis modeling for these events (Dixon et al., 2017; Oosterhaven, 2017; Rose, 2017; Avelino & Hewings, 2019; Okuyama, 2022). Our research involves expanding the CGE framework to address the difficulties of modeling with limited information by integrating targets into model calibration. Additionally, our methodological approach includes disaster-related features in the analysis, such as supply and demand constraints, and resilience in production processes. We also performed a sensitivity analysis of the model parameters and simulation scenarios to propagate uncertainties in the outcomes of the projected economic variables.

To illustrate the applicability of our methodology, we analyzed the direct and indirect effects of the Levant Islamic State of Iraq and Syria (ISIS) conflict in Iraq between 2014 and 2017. The war led to the displacement of five million people in Iraq (World Bank, 2018). Beyond human suffering, the war caused extensive physical destruction. Our assessment focuses on Iraq's economic performance at the national and regional levels. We began the analysis by conducting a damage-and-needs assessment with a specific focus on regional and sectoral estimates of infrastructure destruction. We then calibrated a CGE model to measure the higher-order effects of armed conflict on the Iraqi economy. In this model, the economy is subjected to shocks that partially destroy its capital stock. We combined capital stock destruction shocks with estimates of the overall macroeconomic effects on the Iraqi economy between 2013 and 2017. The CGE model was calibrated using an inter-regional input-output table for Iraq (IIOT-IRQ), which we built for 2013. This table serves as a pre-conflict benchmark of the Iraqi economy. The IIOT-IRQ maps the inter-regional and inter-sectoral linkages, which act as a mechanism for spreading and amplifying damage to regions not directly affected by the ISIS conflict. Our main results provide insights into the effects of conflict by region and identify the sectors most vulnerable to the risks caused by this conflict.

Section two of the paper explains the economic analysis of the disasters. Section three presents the methodological approach and details of the construction of the simulation scenario. Section four presents the results of the study. Finally, we discuss the application of this methodology in evaluating extreme events in a broader context.

2. Economic Analysis of Disasters

The analysis of the economic impacts of extreme events encompasses both direct and indirect effects of the event. The direct impacts include damage to capital stock and losses in production flow for businesses affected by the hazard. Indirect impacts consist of the economic repercussions resulting from the propagation of the consequences of extreme events throughout an economic system. These indirect effects entail losses across supply chains, including both downstream and upstream effects, through interindustry and inter-regional linkages. The indirect impacts include reductions in household income, leading to decreased final consumption. These indirect impacts are often referred to as higher-order effects and can vary depending on the economy's resilience and speed of its recovery (Rose, 2004). Detailed definitions of the direct and indirect impacts as well as their effects on the supply and demand sides in extreme event analysis have been discussed in the literature (Oosterhaven, 2017; Avelino & Hewings, 2019; Okuyama, 2022).

One approach to modeling the higher-order impacts of extreme events is the general equilibrium models. This approach includes higher-order impacts of the supply- and demand-side effects generated by regional and sectorial interdependence and captures responses to price changes in factor and product markets. CGE models offer insights into interconnectedness by conceptualizing the economy as a network of integrated supply chains (Dixon et al., 2017). Therefore, these models are well-suited for examining how the damage caused by extreme events spreads throughout the economy.

CGE models are built on the premise that individual consumers and firms optimize their behavior, subject to resource constraints, in response to external events that disrupt economic equilibrium. In addition to accounting for price changes, this modeling approach incorporates the potential to substitute inputs from various regional sources. Furthermore, inter-regional CGE models are effective in incorporating heterogeneous damage across regions and sectors (Okuyama, 2022). Another benefit of the CGE model is its ability to simultaneously analyze the supply- and demand-side constraints resulting from an extreme event. Supply-side effects encompass constraints arising from physical damage to capital and limited input availability for production owing to disruptions in the production chain. Demand-side effects include income loss, structural changes in expenditure patterns, reduced government spending, and efforts towards reconstruction (Avelino & Hewings, 2019).

One of the challenges in modeling extreme events is the inclusion of regional resilience, which refers to the ability of economic systems to recover from the shock of an extreme event (Rose & Liao, 2005; Prager et al., 2018). Resilience contributes to reducing the negative impacts of disasters and minimizing their propagation across other regions (Rose, 2017; Xie et al., 2018). CGE approaches incorporate economic resilience into the model as part of the economic system during a disaster by inputting substitution possibilities among regions. These spatial substitution effects can reduce the demand-supply gaps in regions affected by the disaster (Okuyama, 2022).

3. Methods

3.1 CGE Model

We built an inter-regional CGE model for Iraq (BMIRAQ) based on the B-MARIA model (Haddad, 1999; Haddad & Hewings, 2005; Haddad & Araújo, 2023) developed following the Australian modeling tradition (Dixon & Parmenter, 1996). The model was solved using the Johansen approach through linearized equations. A typical outcome is the percentage change in endogenous variables after an exogenous shock. In this model, the aggregation of regional results determines national outcomes by employing a bottom-up approach to estimate modeling results.

In the BMIRAQ model, following Dixon and Parmenter (1996), to define the solution of the model, the equilibrium is a vector V, of length n satisfying the following system of equations:

$$\mathrm{F(V)} = 0 \qquad (1)$$

where F denotes a vector function of length m. We assume that F is differentiable and the number of variables n, is greater than the number of equations m. In the linearized version of the model using the Johansen approach, we derived a differential form from Eq. (1):

$$\mathrm{A(V)v} = 0 \tag{2}$$

where A(V) is an $m \, x \, n$ matrix whose components are functions of V. A(V) represents the elasticities of the endogenous variables to changes in exogenous variables. The $n \, x \, 1$ vector v represents the changes in variable V. To determine the extent to which the endogenous variables changed from their initial values owing to specific shifts in the exogenous variables, A(V) was evaluated at $\mathrm{V} = \mathrm{V^I}$. The input-output datasets are the model parameters that define the initial solution. Thus, Eq. (2) can be rewritten as follows:

$$\mathrm{A_\alpha(V^I)v_\alpha} + \mathrm{A_\beta(V^I)v_\beta} = 0 \tag{3}$$

Consider vector v consisting of m endogenous and $n - m$ exogenous components. Let $\mathrm{v_\alpha}$ be the $m \, x \, 1$ subvector of the endogenous components of v, and v_β be the $(n - m)x \, 1$ subvector of the exogenous components. Additionally, let $\mathrm{A_\alpha(V^I)}$ and $\mathrm{A_\beta(V^I)}$ be appropriate submatrices of A(V). We can solve Eq. (3) for $\mathrm{v_\alpha}$ in terms of $\mathrm{v_\beta}$ as follows:

$$\mathrm{v_\alpha} = \mathrm{B(V^I)v_\beta} \tag{4}$$

where $\mathrm{B(V^I)}$ is the elasticity evaluated at $\mathrm{V^I}$. In the following section, we outline the set of exogenous variables in the MBIRAQ model that comprises $\mathrm{v_\beta}$ from Eq. (4).

3.2 Target Fitting

Macroeconomic accounts at the national level are often more readily available than regional-level data. Thus, we use national values to estimate the behavior of other economic variables, specifically those at the regional level. Therefore, we extend the CGE model to downscale the data already available at the national level in Iraq's macroeconomic account to the regional level. This strategy enabled us to project the post-conflict Iraqi economy at a granular level of spatial aggregation. Model adjustment to the targets can help make regional impact projections more precise.

In our simulation scenario of the post-conflict Iraqi economy, we first use estimates from the World Bank (2018) for the initial effect of the conflict, which includes damage costs, changes in the unemployment rate, and household disposable income. Subsequently, we calibrate a shock to other exogenous variables to project the already known values of the macroeconomic aggregates, which are the targets of our simulation outcomes. Therefore, based on the 2013 pre-conflict data, the CGE model seeks to generate a corresponding overview of the post-conflict economy in 2017. Our primary emphasis is not on the pre- and post-conflict transitions per se but on the boundary conditions generated by this economic transition. Thus, we aim to identify how regions have adjusted to the macroeconomic scenario based on metrics such as gross regional product (GRP).

Following the target fitting method (Garber & Haddad, 2012), we reduce the model solution to a set of endogenous variables $\hat{v}_\alpha$, targets in our simulations, and a respective set of exogenous variables $\hat{v}_\beta$ that, according to the specification of the BMIRAQ model, are differently related to the target variables. Then, Eq. (4) can be rewritten as follows:

$$\hat{v}_\alpha = \hat{B}\hat{v}_\beta \tag{5}$$

where, the $k \; x \; 1$ vector $\hat{v}_{\alpha}$ has the number of targets variables, k, the $l \; x \; 1$ vector $\hat{v}_{\beta}$ has the number of respect exogenous variables, l, related to the target variables, and the $k \; x \; l$ matrix $\widehat{B}$ is the reduced elasticity matrix in the dimensions of exogenous and endogenous variables. Thus, we built target variable vector t, in which $t = \hat{v}_{\alpha}$. The percentage changes in $\hat{v}_{\beta}$ to reach the target t is defined as follows:

$$\hat{v}^{*}{}_{\beta} = \left(\widehat{B}'\widehat{B}\right)^{-1}\widehat{B}'t \qquad (6)$$

where $\hat{v}^{*}{}_{\beta}$ provides the percentage change in exogenous variables to achieve the known prior values of the target variables.

3.3 Hybrid Closure

Model closure incorporates both short- and long-term elements to capture a comprehensive economic equilibrium. The availability of information for constructing simulation scenarios determines the selection of exogenous variables. On the supply side, we estimate capital stock destruction and changes in the unemployment rate. On the demand side, we have the regional values for the change in household consumption caused by a reduction in disposable income. Thus, the choice of the closure was motivated by the availability of variables to simulate movements away from the initial solution of the model.

In the short term, capital formation reaches an equilibrium as the rate of return adjusts endogenously to maintain predetermined capital stock levels. This process follows the traditional adjustment for exogenous capital stock and endogenous rates of return on capital. Simultaneously, we introduce long-term characteristics by allowing for interregional migration, in which workers are attracted to more competitive sectors in geographically favored areas. Thus, the labor market follows a more traditional long-term closure, featuring an exogenous natural unemployment rate, endogenous real wage, and endogenous inter-regional migration. From a demand perspective, households are endogenous and government consumption is exogenous, while the trade balance adjusts endogenously to satisfy gross domestic product (GDP) identity.

The CGE approach models the behavior of agents to simulate a new equilibrium situation. However, modeling the disruptive characteristics of an extreme event can be challenging because rebuilding capital stock may be difficult, generating a quasi-permanent disequilibrium in the capital, product, and consumer markets. Extreme events cause sudden and intense changes in demand and supply (Rose, 2004). Nevertheless, Johansen's CGE modeling tradition is not concerned with proving the existence of equilibrium because the input-output table provides an initial solution (Dixon et al., 2017). The emphasis of this model is on movements away from the initial solution.

3.4 Incorporating Uncertainty

The uncertainty in modeling extreme events arises from the numerical structure (statistical errors in variable measurements) and the analytical framework of the CGE model (uncertainty about the ability of the model to represent the analyzed economy). In the context of the regional ISIS-created conflict in Iraq, uncertainty may arise from the sparseness of data measuring the level of economic activity in the country and the direct impact of the war. Therefore, we conducted sensitivity analyses of the model parameters and simulation scenarios to incorporate uncertainty into the CGE model outcomes.

We performed a sensitivity analysis on the Armington elasticities, which determine the exchange of inputs in different regions of Iraq and domestic and imported inputs. These elasticities help delineate the role of inter-regional linkages in the context of supply chain disruptions due to wars. These events can affect the spatial substitution possibilities, causing difficulties in exchanging inputs from different sources. In addition to sensitivity tests on the elasticity parameters, we conducted a sensitivity analysis of the simulation scenarios involving supply and demand shocks.

3.5 Calibration

We built the 2013 IIOT-IRQ to calibrate the inter-regional CGE model. The supplementary information file comprehensively describes the methodological details of the data estimation. The CGE model identifies ten production/investment sectors in each region, each producing some of the separate commodities (Table A3 in the Supplementary Information). The model recognizes a single household and consolidated government in each region, in addition to an aggregated foreign area engaged in trade with each domestic region. The model accounts for the economic structures of 18 Iraqi governorates (Table A4 in the Supplementary Information). The structural coefficients of the labor market and population were calibrated using supplementary demographic data from the 2012 Iraq Household Socio-Economic Survey (World Bank, 2015).

3.6 Measuring the Economic Impact of the Conflict in Iraq

We employed an inter-regional CGE model to assess the economic impact of the armed conflict in Iraq. The analysis focused on the period from 2014 to 2017, which aligned with the timeframe covered in the Iraq Damage and Needs Assessment (World Bank, 2018). Thus, we developed an approach that enables us to portray a comprehensive picture of the post-conflict Iraqi economy.

We incorporated three pieces of information to construct our simulation scenario based on the CGE model: damage costs, changes in regional unemployment rates, and household disposable income. These data quantify the supply and demand constraints caused by war. Supply-side effects are captured by physical damage to capital and restrictions in the labor market, which decrease firms' production levels. Another supply-side constraint is disruption in the production chain. This additional negative shock, endogenously simulated in the CGE model, reduces the quantity and variety of goods and services and further dampens demand. These production-side effects also reduce payments to the factors, resulting in a negative shock to household income and decreasing demand. In our simulations, demand-side effects were included through changes in household consumption caused by a reduction in disposable income.

3.7 Defining the Shocks in the CGE Model

The seven governorates directly affected by the conflict are located in eastern Iraq (Figure 1). These governorates were the focus of a report provided by the World Bank, which assessed the socioeconomic costs of the ISIS conflict (World Bank, 2018). The damage cost to capital assets between 2014 and 2017 was estimated at $45 billion (particularly in the seven directly affected governorates)—equivalent to five percent of the national capital stock in 2013 of which Nineveh and Salah al-Din accounted for 60 percent of the total damage costs.[1] These initial costs are used to calculate shocks in the simulation scenarios of the CGE model and to estimate the direct and indirect economic impacts of the war.

[Insert Figure 1 here]

[1] Damage cost refers to the physical and material harm to an asset (buildings, infrastructure, equipment) caused by a risk event. On the contrary, loss cost is a comprehensive measure that accounts not only for the direct damage to infrastructure but also the economic and financial impacts resulting from the risk event, such as business interruption and relocation costs.

Table 1 shows the exogenous shocks in the CGE model for the Iraqi governorates. The primary information in our simulation consists of damage-cost data in governorates directly affected by the conflict. We use damage cost data from the governorate to estimate shocks in capital stock. In our simulations, the change in regional capital stock was quantified as the value of the damage cost between 2014 and 2017 divided by the total capital stock in the Iraqi economy in 2013, as specified in the CGE model.

[Insert Table 1 here]

The change in the unemployment rate was calculated for each directly affected governorate. After the conflict, the unemployment rate in the seven affected governorates increased from 12.6 in 2013 to 17.7 percent by the end of 2017 (World Bank, 2018). These seven governorates directly affected 314,000 newly unemployed individuals. However, the full extent of this impact is likely underestimated as several neighborhoods in these affected areas could not be surveyed due to security concerns according to the World Bank. First, we used microdata from the Iraq Household Socio-Economic Survey (World Bank, 2015) to calculate the pre-conflict unemployment rate in each governorate. We then estimated the contribution of each governorate to the increase in unemployment. Finally, to incorporate this shock into the CGE model, we calculated the variation in percentage points in the unemployment rate.

The shock in consumption was calculated as the change in disposable household income. The loss of livelihood in regions directly affected by the ISIS conflict amounted to USD 2,982 million annually (World Bank, 2018). In our simulations, the percentage shift in household consumption corresponds to livelihood loss in each governorate as a proportion of labor compensation from the 2013 IIOT-IRQ.

4. Results

We evaluated the direct and indirect effects of the war against ISIS in Iraq between 2014 and 2017. This section presents the simulation outcomes of the inter-regional CGE model, focusing on the regional and sectoral effects on GRP, interregional migration, interregional trade flows, and activity levels by sector. Table 2 shows the impact of the ISIS-created conflict on Iraq's macroeconomic aggregates. The table also includes the shock effect of each exogenous variable on national outcomes. Iraq's GDP declined by 4.1 percent, owing to the impact of the shock on current stock capital (-3.2%), changes in the unemployment rate (-1.1%), and household disposable income (0.2%). As a result of the conflict, there was a decrease in household consumption (-12.9%), investment (-6.2%), wages (-3.7%), and employment (-4.4%). The macroeconomic performance indicators stemming from the conflict also exerted pressure on the economy's price indices; there was a 0.4 percent increase in the GDP deflator and a 0.5 percent decrease in the consumer price index.

[Insert Table 2 here]

GDP loss accounted for USD 9,699 million, corresponding to 4.1 percent of the GDP in 2013. All areas directly affected by the conflict recorded a reduction in GRP (Table 3). The directly affected governorates accounted for a loss of USD 10,934 million, corresponding to 11.7 percent of the total GRP of the seven governorates. GRP's loss was concentrated in Nineveh (USD 3391 million). Salah al-Din (47.6%) and Anbar (44.8%) were the most heavily affected governorates. The indirectly affected governorates had GRP gains, with Basra accounting for 40.2 percent (USD 497 million) of the total gain. The results for the indirectly affected governorates are driven by the interdependence of supply chains, measured through input-output linkages in the CGE model. Figure 2 shows a geographic representation of the GRP changes.

[Insert Table 3 here]

[Insert Figure 2 here]

Inter-sectoral and inter-regional interdependence can amplify the effects of conflicts by spreading losses or generating economic growth in other regions through supply chains. Table 4 shows the economic impact of the conflict on the performance of the sectoral and regional indicators. Household consumption, inter-regional trade, and foreign imports declined across all Iraqi governorates. The rise in exports in Baghdad and the governorates not directly affected by the ISIS conflict partially mitigated the decrease in foreign exports from the conflict areas. The cost of capital and labor increased in Nineveh, Diyala, Anbar, and Salah al-Din—the governorates that suffered the most significant losses in capital stock.

[Insert Table 4 here]

Table 5 shows the impact of the conflict on sectoral activity levels across ten Iraqi industries. The activity level in the oil sector was the least affected, with a 2.0 percent reduction in value added and a 5.6 percent increase in employment. The model outcomes also indicate that pressure leads to a reduction in international trade across all sectors, except for trade and financial services exports. Additionally, there was pressure on capital prices compared with the pre-crisis situation in most sectors, followed by decreased labor prices.

[Insert Table 5 here]

In Iraq 4.7 million people were displaced between 2005 and 2015, with 94 percent being internally displaced Iraqis (Connor, 2016). Our results also reveal the consequences of the war on inter-regional migration flows (Figure 3). The numerical structure of the population module in the CGE model, calibrated for the pre-conflict period, illustrates the tendency of the regions to lose (or gain) population according to the shocks specified in our simulation. A previous study found that households forced to leave their residences due to violent conflict relocated to more distant and populated regions (Lozano-Gracia et al., 2010). The journey to safety often does not result in moving to a “safer” place, as the presence of family or friends plays an important role in relocation decisions. Similarly, in Iraq, some regions directly affected by the ISIS conflict, such as Baghdad, Kirkuk, and Babil, recorded positive migration flows, highlighting the complexity of displacement patterns and migration decisions.

[Insert Figure 3 here]

Our migration flow results align with the statistics compiled by the International Organization for Migration of the United Nations (IOM, 2023). After the ISIS conflict, the number of internally displaced Iraqis increased from 443,124 in February 2014 to over 3.3 million at the peak of the displacement crisis in June 2016, representing approximately nine percent of Iraq’s population. The governorates with the highest numbers of internally displaced persons were Anbar (1,408,842), Nineveh (1,150,908), Salah al-Din (415,638), and Diyala (129,462). In 2023, Iraq had 1.1 million internally displaced persons, with Nineveh (242 thousand), Dohuk (240 thousand), and Erbil (229 thousand) being the governorates with the highest number of displaced individuals (IOM, 2023).

The ISIS conflict impacted the production of firms in directly affected regions, and firms located in indirectly affected regions could replace these production losses. Consequently, the affected regions may experience a reduction in exports to other regions and inter-regional imports exhibit two effects. One effect is a reduction in imports owing to a decrease in production and household income in the affected region. This effect was followed by another trend of increasing imports of intermediate and final goods to compensate for local production losses. The change in trade resulting from these effects establishes a new equilibrium in the economy. Figure 4 shows that the reduction in imports exceeded the effect of the increase in inter-regional imports. Therefore, the decrease in trade flow is mainly attributed to a reduction in inter-regional imports in governorates that were directly affected by the conflict. This finding underlines the importance of regional interdependence in the supply chain for amplifying the economic impacts of the conflict in the Iraqi regions.

[Insert Figure 4 here]

We employed a hybrid closure with mixed short- and long-term characteristics in our simulations, in which capital formation is modeled with short-term characteristics; thus, capital cannot move across regions. Consequently, the change in inter-regional trade is relatively small in areas not directly affected by the conflict because the substitution effects are closer to zero than their long-term equivalents. However, because of spatial substitution possibilities, some regions that were not directly affected by the conflict experienced a slight increase in trade flows, such as Sulaymaniyah, Erbil, Najaf, Qadessiyah, Muthanna, Thi-Qar, and Basra. Therefore, supply chain disruption significantly affected local economies, including regions not directly affected by the conflict. Section 4.1 examines the sensitivity of outcomes to trade substitution elasticities since these elasticities impact spatial substitution effects.

4.1 Parameters Sensitivity Analysis

The ISIS conflict disrupted Iraq's logistics system, affecting its ability to substitute similar inputs produced in different Iraqi regions and the rest of the world. In the CGE model, Armington elasticities reflect the exchange of goods between regions in the modeling framework, specifying the degree of substitution between foreign/domestic and inter-regional trade. We assume that the substitution between imported and domestic commodities in foreign and inter-regional trade is imperfect, defining the elasticity parameter as 0.5 for both Armington elasticities.

The sectoral and spatial extent of the propagation of the effects of extreme events depends on the input-output linkages in the economic system, which in turn depend on the substitution elasticities in the production and consumption functions. Thus, regional and sectoral responses to a change in the equilibrium of the initial solution result from many factors that involve trade substitution elasticities. Smaller trade elasticities imply weaker substitution among similar inputs produced in different locations, thereby reducing the potential strength of the linkage structure in post-shock adjustments. Through trade substitution possibilities, firms and households can substitute the origin of inputs between regions within Iraq and foreign/domestic sources. These substitution possibilities also allow for the modeling of economic resilience to the occurrence of an extreme event.[2]

In case of the CGE model for the Iraqi economy, formal econometric estimation of many model parameters is not possible because of the unavailability of data. Hence, it is necessary to make assumptions regarding the values of certain parameters. Therefore, it is essential to investigate the sensitivity of the model to the values assumed for key parameters. Thus, we tested how the

[2] Regions' resilience to extreme events could also be modeled in the general equilibrium approach through technical substitution possibilities; however, in this study, we are modeling only spatial substitution possibilities since they are far more likely to occur in the short-run. Dixon et al. (2017) discuss how resilience can be incorporated into CGE models.

Armington parameters changed the simulation results, especially in the context of disruptions to the country's transportation network during wartime. The sensitivity tests addressed the uncertainties associated with these elasticities.

We assessed the sensitivity of our GRP outcomes to extreme values of Armington elasticities, focusing on seven directly affected governorates. Our simulations test extreme values of Armington elasticities, ranging between 0.1 and 2.0 in both foreign/domestic and inter-regional trade. Figure 5 shows that the choice of Armington elasticities can affect the GRP results.

[Insert Figure 5 here]

The contribution of the seven directly affected governorates to the national GDP was -4.7 percent. These seven governorates account for approximately 39.7 percent of the national GDP, distributed among Baghdad (16.7%), Kirkuk (7.8%), Nineveh (5.6%), Babil (3.1%), Salah al-Din (2.8%), Anbar (2.1%), and Diyala (2.1%). The aggregate results for the seven directly affected governorates appear consistent, even for extreme values of this parameter. However, the effects of the seven directly affected governorates on national GDP (last box in the bottom left corner) are more significant for an elasticity equal to 2.0, for both foreign/domestic and interregional elasticities of substitution. Therefore, Figure 5 indicates that the results remain robust to the choice of this parameter, mainly because of the model closure without allowing the movement of capital to a new region, in which the value of supply-side shocks determines the impact on GDP, as shown in Table 2.

4.2 Shock Sensitivity Analysis

We also conducted a sensitivity analysis of the magnitude of shocks to capital stock and household disposable income due to uncertainty regarding the initial effects on these variables.

Change in capital stock (*curcap*) is the primary determinant of GDP. To understand how potential uncertainty of shocks in *curcap* (Table 1) affects the model's key outcomes, we tested a set of alternative values for the variation in *curcap*. We do not have an estimate of variance for this variable; thus, we constructed scenarios in which the value of *curcap* varies by ±25 percent from its initial value. We then considered all possible combinations of values, such as simulating *curcap* variation in only one region or jointly changing *curcap* across all regions. We randomly drew 10,000 shock possibilities to run the CGE model simulations. For the draw, we did not specify any distribution function over the values of *curcap*; we restricted the values to the established range.

The results of the sensitivity analysis of the GDP are shown in Figure 6. The variation in GDP across the 10,000 simulations ranged from approximately -4.7 to -3.5 percent, with a mean value of -4.1 percent, which is consistent with the values presented in Table 2. The GRP results of the Iraqi governorates are presented in Figure 7a.

[Insert Figure 6 here]

Household consumption is the primary demand component. In Iraq, households account for 35 percent of the final demand. Considering the importance of this component, we conducted sensitivity tests for this variable. Variations in household demand are driven by income loss, followed by reductions in the quantity and variety of goods and services offered due to decreases in production resulting from capital stock damage. Therefore, we analyzed the sensitivity of the results to variations in the shock applied to disposable household income (*c_shift*) as shown in Table 1. We constructed simulation scenarios for *c_shift* using the same strategy as in *curcap*, with *c_shift* values varying by ±25 percent from its initial value. We then randomly drew 10,000 shocks to run CGE model simulations. The results for real household consumption by governorate are shown in Figure 7b.

[Insert Figure 7 here]

4.3 Macro Results as the Target

We projected the impact of war on Iraq's regions by adjusting the CGE model to national-level data for 2013 and 2017 provided by the World Bank (2023). Iraq's real GDP grew by 15.9 percent from 2013 to 17. The World Bank database also provides projections for other macroeconomic aggregates, such as household consumption (45.0%), government consumption (23.7%), investment (-9.7%), and exports (60.5%). These high growth rates, although unexpected given the situation of a country at war, are accompanied by high negative rates of nominal growth, for example, GDP (-16.7%), household consumption (-12.0%), government consumption (0.9%), investment (-48.2%), and exports (-20.3%). Despite the consumer price index registering a cumulative increase of 4.4 percent during this period, the GDP deflator had significantly negative rates, for example, -2.8 percent in 2014, -30.0 percent in 2015, and -11.0 percent in 2016. Therefore, given the uncertainty regarding macroeconomic aggregates, we use only real GDP growth as the target for the model to project the governorate's GRP. Table 6 presents the GRP results corresponding to a GDP growth rate of 15.9%.

[Insert Table 6 here]

To achieve the known GDP variation in Table 6, we applied a shock to the factor-saving technical changes in the oil sector across all regions. The oil sector accounted for 48.6 percent of the value-added and 95 percent of Iraqi exports in 2013. The increase in the revenue of this sector led to a 15.9 percent increase in GDP and 60.5 percent increase in exports from 2013 to 2017. Thus, using Eq. (6), we calculated the corresponding variation in the factor-saving technical changes in the oil sector to achieve the national target. Subsequently, we calculated the new impacts on the GRP, including the initial shocks from Table 1, and added the shock to the factor-saving technical changes.

5. Conclusions

This study proposes a methodology to evaluate the higher-order effects of disruptive events, such as armed conflicts, using a general equilibrium model. Thus, we developed an economic model to measure the geographic propagation of the indirect effects of disasters through supply chains. This model conceptualizes the economy as a network of integrated supply chains, highlighting their interconnectedness. Therefore, it is well-suited for examining how the damage caused by extreme events spreads throughout the economy.

Our primary contribution to the economic analysis of disasters involves addressing the challenge of limited information when measuring economic impacts and understanding how regions and sectors respond to such events. The analysis incorporates economic resilience into the CGE model as part of the economic system during a disaster by inputting substitution possibilities among regions. We also extend the CGE model to downscale national economic accounts to the regional level by adapting the target-fitting approach. Thus, the study expands the CGE framework to address the difficulties of modeling in the presence of limited information by integrating targets into model calibration.

To illustrate how this methodology can be applied to impact analysis, we evaluated the economic effects of the regional ISIS-created conflict in Iraq between 2014 and 2017. We departed from an assessment of the conflict's damage and needs, and focused on the estimates of regional and sectoral infrastructure destruction. We then calibrated a CGE model to estimate the higher-order effects of the armed conflict on the Iraqi economy. Our results provide a detailed analysis of the costs of war, highlighting its impacts on regional and sectoral economic activity, domestic and foreign trade, price levels, employment, wages, and inter-regional migration caused by internally displaced people. We also explored the potential uncertainties in the results by conducting a sensitivity analysis of the model parameters and simulation scenarios, highlighting the uncertainties arising from limited information about the analyzed economy.

The methodological approach developed in this study improves the precision of local-level impact analysis, enabling the analysis of economic impacts resulting from extreme events, such as wars or natural disasters. Assessing the economic impacts of extreme events is crucial for risk management and devising strategies for economic recovery. Therefore, the proposed methodology can serve as a decision-making tool, such as for identifying industries and regions to prioritize support.

References

Avelino, A. F., & Hewings, G. J. (2019). The Challenge of Estimating the Impact of Disasters: Many Approaches, Many Limitations and a Compromise. In: Okuyama, Y., & Rose, A. (Eds.) *Advances in Spatial and Economic Modeling of Disaster Impacts*. Cham: Springer International Publishing.

Bier, V., & Cox, T. (2017). Coping with Uncertainty in Adversarial Risk Analysis. Abbas, A. E., Tambe, M., & Von Winterfeldt, D. (Eds.) *Improving Homeland Security Decisions*. Cambridge University Press.

Carvalho, V. M., Nirei, M., Saito, Y. U., & Tahbaz-Salehi, A. (2021). Supply Chain Disruptions: Evidence from the Great East Japan Earthquake. *The Quarterly Journal of Economics*, 136(2), 1255-1321.

Connor, P. (2016). *Middle East's Migrant Population More Than Doubles Since 2005.* Pew Research Center, October. Available at https://www.pewresearch.org.

Dixon, P. B., Rimmer, M. T., Wittwer, G., Rose, A., & Heatwole, N. (2017). Economic Consequences of Terrorism and Natural Disasters: The Computable General Equilibrium

Approach. Abbas, A. E., Tambe, M., & Von Winterfeldt, D. (Eds.) *Improving Homeland Security Decisions*. Cambridge University Press.

Dixon, P. B., & Parmenter, B. R. (1996). Computable General Equilibrium Modelling for Policy Analysis and Forecasting. *Handbook of Computational Economics*, vol. 1, 3-85.

Donaghy, K. P., Balta-Ozkan, N., & Hewings, G. J. D. (2007). Modeling Unexpected Events in Temporally Disaggregated Econometric Input-Output Models of Regional Economies. *Economic Systems Research*, 19(2), 125-145.

Garber, G., & Haddad, E. (2012). *Target Fitting and Robustness Analysis in CGE Models*. Working Paper Series, N. 2012-14, Department of Economics, USP.

Haddad, E. A. (1999). *Regional Inequality and Structural Changes: Lessons from the Brazilian Experience*. Aldershot; Brookfield USA: Ashgate.

Haddad, E. A., & Araújo, I. F. (2023). *The Interregional Computable General Equilibrium Model for Colombia*. In: Haddad, E. A., Bonet, J., & Hewings, G. J. (Eds.). The Colombian Economy and its regional structural challenges: A linkages approach. Springer Nature.

Haddad, E. A., Araújo, I. F., Rocha, A., & Sass, K. S. (2023). Input–Output Analysis of the Ukraine War: A Tool for Assessing the Internal Territorial Impacts of the Conflict. *Regional Science Policy & Practice*, 15(1), 8-55.

Haddad, E. A., & Okuyama, Y. (2016). Spatial Propagation of the Economic Impacts of Bombing: The Case of the 2006 War in Lebanon. *Review of Middle East Economics and Finance*, 12(3), 225-256.

Haddad, E. A., & Hewings, G. J. D. (2005). Market Imperfections in a Spatial Economy: Some Experimental Results. *Quarterly Review of Economics and Finance*, 45(2–3), 476-496.

IOM (2023). *Displacement Tracking Matrix: Iraq*. International Organization for Migration. Available at: https://iraqdtm.iom.int/.

Kajitani, Y., & Tatano, H. (2018). Applicability of a Spatial Computable General Equilibrium Model to Assess the Short-Term Economic Impact of Natural Disasters. *Economic Systems Research*, *30*(3), 289-312.

Koks, E. E., & Thissen, M. (2016). A Multiregional Impact Assessment Model for Disaster Analysis. *Economic Systems Research*, *28*(4), 429-449.

Koks, E. E., Carrera, L., Jonkeren, O., Aerts, J. C., Husby, T. G., Thissen, M., & Mysiak, J. (2016). Regional Disaster Impact Analysis: Comparing Input–Output and Computable General Equilibrium Models. *Natural Hazards and Earth System Sciences*, *16*(8), 1911-1924.

León, J. A., Ordaz, M., Haddad, E., & Araújo, I. F. (2022). Risk Caused by the Propagation of Earthquake Losses through the Economy. *Nature Communications*, 13(1), 2908.

Li, J., Crawford-Brown, D., Syddall, M., & Guan, D. (2013). Modeling Imbalanced Economic Recovery Following a Natural Disaster using Input-Output Analysis. *Risk Analysis*, *33*(10), 1908-1923.

Lozano-Gracia, N., Piras, G., Ibáñez, A. M., & Hewings, G. J. (2010). The journey to safety: conflict-driven migration flows in Colombia. *International Regional Science Review*, 33(2), 157-180.

Okuyama, Y. (2007). Economic Modeling for Disaster Impact Analysis: Past, Present, and Future. *Economic Systems Research*, *19*(2), 115-124.

Okuyama, Y. (2022). A few good models for economic analysis of disasters: can your model handle the truth?. In: Skidmore, M. (Ed.). *Handbook on the Economics of Disasters*. Cheltenham: Edward Elgar Publishing.

Okuyama, Y., Hewings, G. J., & Sonis, M. (2004). Measuring Economic Impacts of Disasters: Interregional Input-Output Analysis using Sequential Interindustry Model. In: Okuyama, Y.; Chang, S. E. (Ed.). *Modeling Spatial and Economic Impacts of Disasters*. Advances in Spatial Science. Berlin, Heidelberg: Springer Berlin Heidelberg.

Oosterhaven, J. (2017). On the Limited Usability of the Inoperability IO Model. *Economic Systems Research*, 29(3), 452-461.

Prager, F., Chen, Z., & Rose, A. (2018). Estimating and comparing economic consequences of multiple threats: A reduced-form computable general equilibrium approach. *International Journal of Disaster Risk Reduction*, 31, 45-57.

Rose, A. (2004). Economic principles, issues, and research priorities in hazard loss estimation. In: Okuyama, Y., & Chang, S. E. (Eds.). *Modeling Spatial and Economic Impacts of Disasters*. Berlin, Heidelberg: Springer Berlin Heidelberg.

Rose, A. (2017). Economic Resilience to Terrorism and Natural Hazards. Abbas, A. E., Tambe, M., & Von Winterfeldt, D. (Eds.) *Improving Homeland Security Decisions*. Cambridge University Press.

Rose, A., & Liao, S. Y. (2005). Modeling Regional Economic Resilience to Disasters: A Computable General Equilibrium Analysis of Water Service Disruptions. *Journal of Regional Science*, 45(1), 75-112.

World Bank (2015). *Iraq Household Socio-Economic Survey 2012*. Produced by the World Bank Group and Ministry of Planning, Government of Iraq. Available at https://microdata.worldbank.org/index.php/catalog/2334

World Bank (2018). *Iraq, Reconstruction and Investment*. Part 2: Damage and Needs Assessment of Affected Governorates. The World Bank Group.

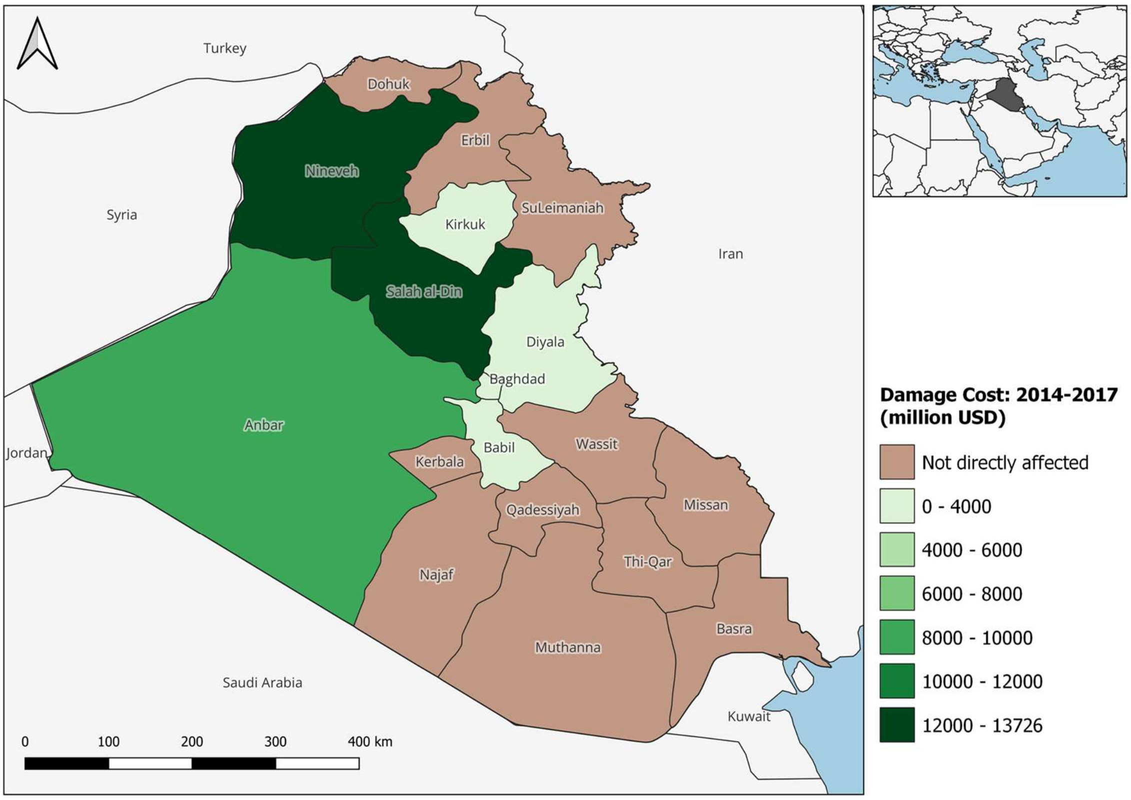
World Bank (2023). World Development Indicators. Updated data: 05/25/2021. The World Bank Group. Available at https://databank.worldbank.org/source/world-development-indicators.

Xie, W., Rose, A., Li, S., He, J., Li, N., & Ali, T. (2018). Dynamic economic resilience and economic recovery from disasters: A quantitative assessment. *Risk Analysis*, 38(6), 1306-1318.

Zhou, L., & Chen, Z. (2021). Are CGE Models Reliable for Disaster Impact Analyses? *Economic Systems Research*, *33*(1), 20-46.

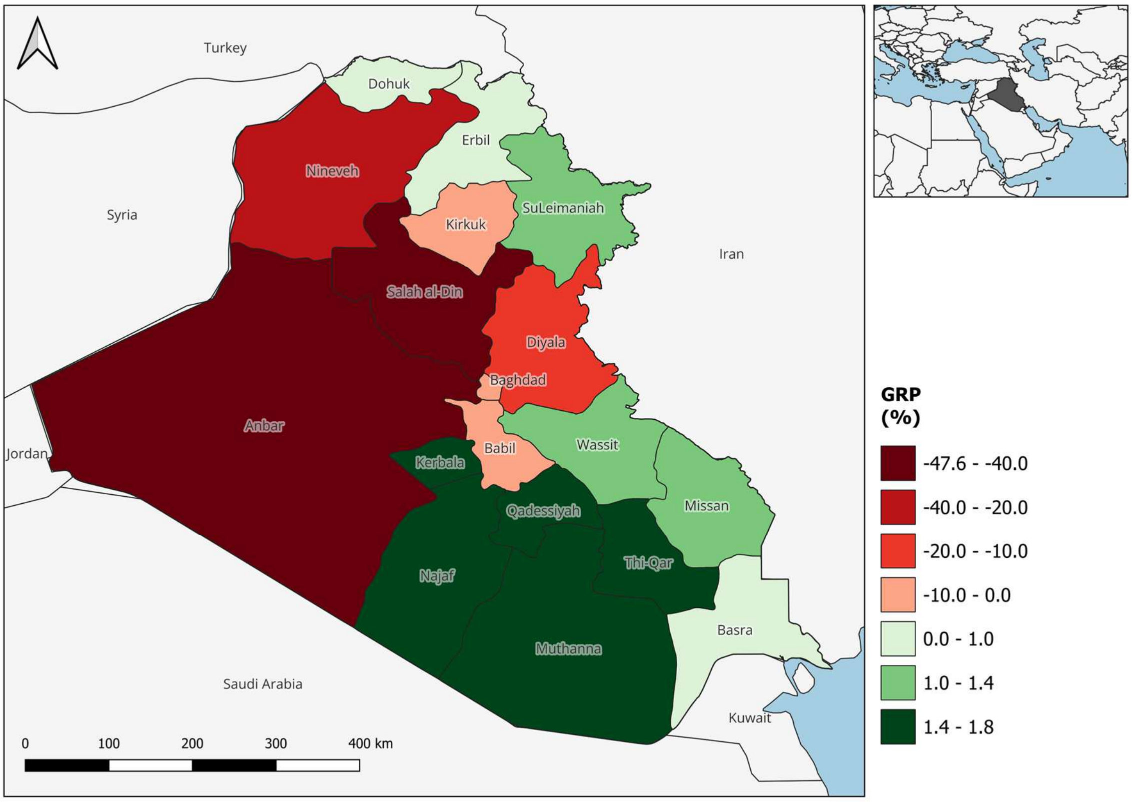
Figures

Figure 1. Damage cost in the Iraqi governorates directly affected by the regional ISIS-created conflict: 2014-2017 (million, USD)



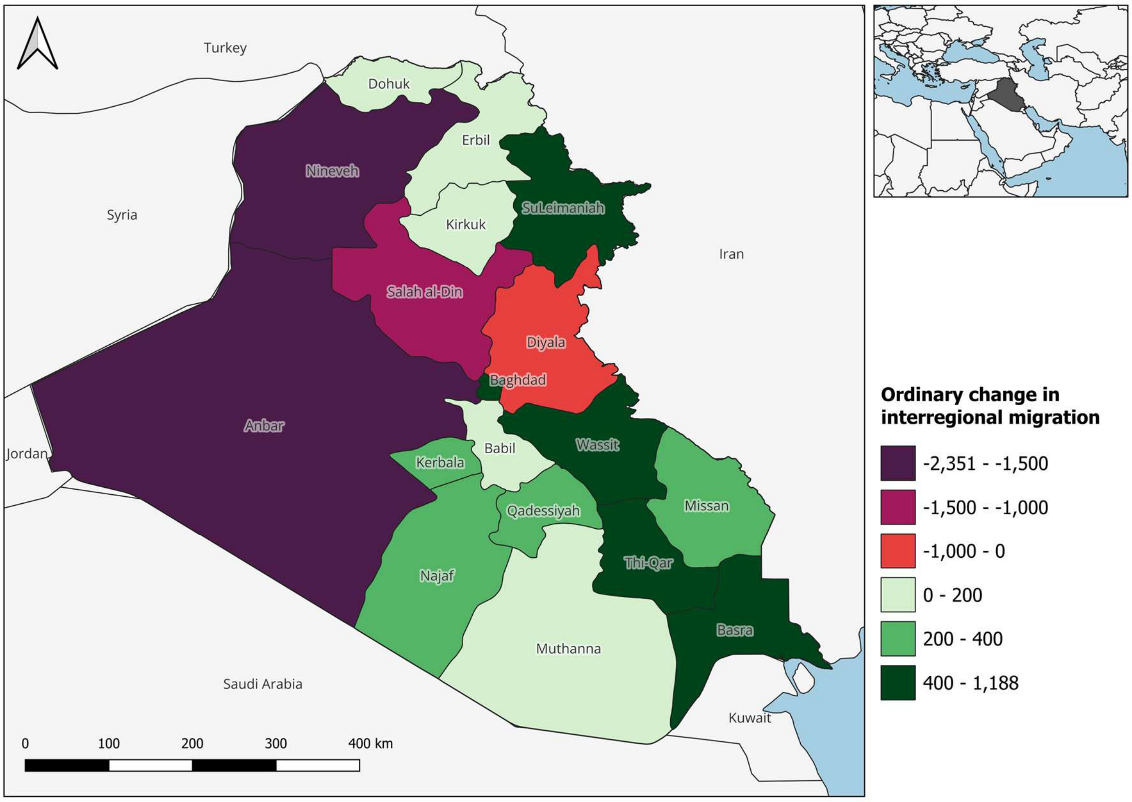
Source: Iraq Damage and Needs Assessment (World Bank, 2018).

Figure 2. Change in the GRP by governorate (in percent change)



Source: Own simulation.

Figure 3. Ordinary change in interregional migration



Source: Own simulation.

Figure 4. Change in the interregional trade flows between each origin and destination pair (in percent change)

Origin	Destination																	
	Dohuk	Nineveh	Suleima-niah	Kirkuk	Erbil	Diyala	Anbar	Baghdad	Babil	Kerbala	Wassit	Salah al-Din	Najaf	Qadessi-yah	Muthanna	Thi-Qar	Missan	Basra
Dohuk	-1.77	-14.89	-3.44	-4.41	-4.76	-6.71	-23.75	-3.52	-2.74	-0.98	-0.79	-13.71	-0.95	-0.98	-0.49	-0.52	-0.35	0.44
Nineveh	-14.15	-26.65	-16.16	-17.51	-18.56	-20.65	-39.53	-16.92	-13.79	-10.51	-9.61	-28.74	-13.65	-14.34	-14.74	-6.88	-12.18	-10.62
Suleimaniah	-2.32	-14.67	-1.34	-3.50	-4.43	-6.49	-24.25	-2.35	-1.97	0.19	0.02	-16.66	0.45	0.31	0.84	0.15	1.27	2.19
Kirkuk	-4.20	-20.16	-4.80	-5.99	-6.82	-9.54	-28.57	-5.95	-4.63	-2.52	-2.24	-17.54	-3.06	-3.29	-3.39	-1.50	-2.36	-1.52
Erbil	-1.68	-14.08	-2.33	-3.53	-2.09	-6.22	-24.81	-1.96	-1.81	-0.09	-0.20	-13.58	0.31	0.14	0.55	-0.06	0.72	1.55
Diyala	-9.11	-25.02	-11.19	-13.13	-12.39	-13.36	-35.59	-11.80	-9.57	-7.18	-6.58	-27.36	-10.07	-9.90	-9.94	-4.35	-7.57	-6.56
Anbar	-20.06	-34.96	-25.66	-26.77	-28.39	-26.72	-42.69	-25.35	-16.48	-12.47	-12.45	-27.41	-22.56	-21.71	-22.95	-7.43	-14.48	-12.07
Baghdad	-2.62	-17.61	-2.90	-4.56	-4.34	-7.54	-27.41	-2.65	-3.29	-1.39	-1.24	-20.63	-1.23	-1.39	-1.10	-0.86	-0.94	0.01
Babil	-5.98	-18.07	-6.41	-7.44	-7.85	-9.72	-25.35	-7.37	-5.52	-4.68	-3.86	-22.13	-4.85	-4.68	-4.38	-3.21	-3.92	-2.97
Kerbala	-1.61	-15.27	-1.94	-3.40	-3.23	-5.78	-25.12	-2.56	-2.19	-0.68	-0.70	-19.70	-0.62	-0.77	-0.55	-0.49	-0.39	0.38
Wassit	-2.05	-18.48	-1.92	-3.97	-3.76	-7.42	-27.83	-3.46	-3.25	-1.29	-0.35	-23.65	-0.66	-0.95	-0.97	-1.01	-0.75	0.14
Salah al-Din	-21.46	-37.04	-25.28	-26.12	-28.59	-28.54	-46.10	-26.53	-20.87	-15.97	-14.91	-35.29	-22.52	-22.54	-23.09	-10.19	-17.49	-16.20
Najaf	-2.03	-14.86	-2.35	-3.57	-3.65	-6.14	-24.28	-2.84	-2.46	-0.71	-0.65	-19.56	-0.22	-0.72	-0.40	-0.45	0.00	0.98
Qadessiyah	-2.73	-14.49	-3.05	-3.97	-4.53	-6.56	-23.71	-3.93	-3.39	-1.62	-1.23	-18.71	-1.48	-0.38	-1.06	-1.00	-0.81	0.06
Muthanna	-0.53	-15.31	-1.12	-2.97	-2.52	-5.22	-26.44	-2.35	-1.85	-0.95	-0.78	-25.67	-0.59	-0.74	-0.36	-0.69	-0.53	0.14
Thi-Qar	-1.71	-15.96	-1.96	-3.62	-3.56	-6.22	-26.53	-3.00	-2.53	-1.14	-0.98	-21.64	-0.86	-1.00	-0.84	-0.41	-0.68	0.10
Missan	-2.21	-20.26	-1.80	-4.26	-3.85	-8.56	-31.41	-3.58	-3.68	-1.40	-1.37	-25.49	-0.52	-0.86	-1.11	-1.21	-0.62	-0.30
Basra	-1.24	-23.21	-0.10	-4.01	-2.29	-10.45	-40.67	-1.79	-3.29	0.13	-0.52	-33.70	0.92	0.78	0.15	-0.41	-0.66	-0.03

Source: Our simulation.

Figure 5. Effect of different values of Armington elasticities on the GRP in the seven directly affected governorates (in percent change)

Rows: Elasticity of Substitution: Domestic/ Foreign Armington. Columns: Elasticity of Substitution: Interregional Armington.

Nineveh

	0.10	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00
0.10	-26.19	-26.66	-27.25	-27.70	-28.06	-28.36	-28.62	-28.84	-29.04
0.25	-26.28	-26.74	-27.31	-27.75	-28.11	-28.41	-28.66	-28.88	-29.07
0.50	-26.43	-26.86	-27.41	-27.84	-28.19	-28.47	-28.72	-28.93	-29.12
0.75	-26.56	-26.97	-27.51	-27.92	-28.26	-28.54	-28.78	-28.99	-29.17
1.00	-26.68	-27.08	-27.60	-28.00	-28.33	-28.60	-28.83	-29.04	-29.22
1.25	-26.79	-27.18	-27.69	-28.08	-28.39	-28.66	-28.89	-29.09	-29.27
1.50	-26.90	-27.28	-27.77	-28.15	-28.46	-28.72	-28.94	-29.14	-29.31
1.75	-27.00	-27.37	-27.85	-28.21	-28.52	-28.77	-28.99	-29.18	-29.35
2.00	-27.10	-27.46	-27.92	-28.28	-28.57	-28.82	-29.04	-29.22	-29.39

Kirkuk

	0.10	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00
0.10	-5.19	-5.16	-5.11	-5.08	-5.05	-5.03	-5.01	-4.99	-4.97
0.25	-5.19	-5.16	-5.12	-5.08	-5.05	-5.03	-5.01	-4.99	-4.98
0.50	-5.19	-5.16	-5.12	-5.09	-5.06	-5.04	-5.02	-5.00	-4.98
0.75	-5.19	-5.16	-5.12	-5.09	-5.06	-5.04	-5.02	-5.00	-4.99
1.00	-5.19	-5.16	-5.12	-5.09	-5.06	-5.04	-5.02	-5.00	-4.99
1.25	-5.19	-5.16	-5.12	-5.09	-5.06	-5.04	-5.02	-5.01	-4.99
1.50	-5.18	-5.16	-5.12	-5.09	-5.06	-5.04	-5.02	-5.01	-4.99
1.75	-5.18	-5.16	-5.12	-5.09	-5.07	-5.04	-5.03	-5.01	-4.99
2.00	-5.18	-5.16	-5.12	-5.09	-5.07	-5.04	-5.03	-5.01	-5.00

Diyala

	0.10	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00
0.10	-14.03	-14.52	-15.16	-15.64	-16.03	-16.35	-16.63	-16.87	-17.09
0.25	-14.07	-14.56	-15.19	-15.67	-16.05	-16.38	-16.65	-16.89	-17.11
0.50	-14.14	-14.62	-15.24	-15.71	-16.09	-16.41	-16.69	-16.92	-17.14
0.75	-14.20	-14.68	-15.28	-15.75	-16.13	-16.45	-16.72	-16.95	-17.17
1.00	-14.26	-14.73	-15.33	-15.79	-16.17	-16.48	-16.75	-16.98	-17.19
1.25	-14.32	-14.78	-15.37	-15.83	-16.20	-16.51	-16.78	-17.01	-17.22
1.50	-14.38	-14.83	-15.42	-15.87	-16.24	-16.54	-16.81	-17.04	-17.25
1.75	-14.44	-14.88	-15.46	-15.91	-16.27	-16.57	-16.84	-17.07	-17.27
2.00	-14.49	-14.93	-15.50	-15.94	-16.30	-16.60	-16.87	-17.09	-17.30

Anbar

	0.10	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00
0.10	-41.68	-42.88	-44.46	-45.69	-46.68	-47.51	-48.22	-48.85	-49.40
0.25	-41.84	-43.02	-44.58	-45.79	-46.77	-47.59	-48.29	-48.91	-49.46
0.50	-42.11	-43.25	-44.76	-45.95	-46.91	-47.71	-48.41	-49.01	-49.55
0.75	-42.36	-43.47	-44.94	-46.10	-47.04	-47.83	-48.52	-49.11	-49.65
1.00	-42.60	-43.68	-45.12	-46.25	-47.17	-47.95	-48.62	-49.21	-49.74
1.25	-42.83	-43.88	-45.28	-46.39	-47.30	-48.07	-48.73	-49.31	-49.83
1.50	-43.05	-44.07	-45.45	-46.53	-47.42	-48.18	-48.83	-49.40	-49.91
1.75	-43.26	-44.26	-45.60	-46.67	-47.54	-48.29	-48.93	-49.49	-50.00
2.00	-43.47	-44.44	-45.75	-46.80	-47.66	-48.39	-49.03	-49.59	-50.08

Baghdad

	0.10	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00
0.10	-1.28	-1.03	-0.73	-0.50	-0.32	-0.17	-0.05	0.06	0.15
0.25	-1.26	-1.02	-0.71	-0.49	-0.31	-0.16	-0.04	0.07	0.16
0.50	-1.22	-0.99	-0.69	-0.47	-0.29	-0.15	-0.03	0.08	0.17
0.75	-1.19	-0.96	-0.67	-0.45	-0.28	-0.13	-0.01	0.09	0.18
1.00	-1.16	-0.93	-0.65	-0.43	-0.26	-0.12	0.00	0.10	0.19
1.25	-1.13	-0.91	-0.63	-0.41	-0.25	-0.11	0.01	0.11	0.20
1.50	-1.10	-0.88	-0.61	-0.40	-0.23	-0.09	0.02	0.12	0.21
1.75	-1.07	-0.86	-0.59	-0.38	-0.22	-0.08	0.03	0.13	0.22
2.00	-1.05	-0.84	-0.57	-0.37	-0.20	-0.07	0.04	0.14	0.23

Babil

	0.10	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00
0.10	-4.08	-4.16	-4.25	-4.31	-4.36	-4.39	-4.41	-4.43	-4.45
0.25	-4.07	-4.15	-4.25	-4.31	-4.35	-4.38	-4.41	-4.43	-4.45
0.50	-4.06	-4.14	-4.24	-4.30	-4.34	-4.38	-4.40	-4.42	-4.44
0.75	-4.05	-4.13	-4.23	-4.29	-4.33	-4.37	-4.39	-4.42	-4.43
1.00	-4.05	-4.12	-4.22	-4.28	-4.33	-4.36	-4.39	-4.41	-4.43
1.25	-4.04	-4.12	-4.21	-4.27	-4.32	-4.35	-4.38	-4.40	-4.42
1.50	-4.03	-4.11	-4.20	-4.26	-4.31	-4.35	-4.38	-4.40	-4.42
1.75	-4.03	-4.10	-4.19	-4.26	-4.30	-4.34	-4.37	-4.39	-4.41
2.00	-4.02	-4.10	-4.19	-4.25	-4.30	-4.33	-4.36	-4.39	-4.41

Salah al-Din

	0.10	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00
0.10	-46.09	-46.68	-47.44	-48.03	-48.50	-48.89	-49.23	-49.52	-49.77
0.25	-46.18	-46.75	-47.50	-48.08	-48.54	-48.93	-49.26	-49.55	-49.80
0.50	-46.32	-46.87	-47.59	-48.16	-48.61	-48.99	-49.31	-49.59	-49.84
0.75	-46.45	-46.98	-47.68	-48.23	-48.67	-49.04	-49.36	-49.64	-49.88
1.00	-46.57	-47.09	-47.77	-48.30	-48.73	-49.10	-49.41	-49.68	-49.92
1.25	-46.69	-47.19	-47.85	-48.37	-48.79	-49.15	-49.46	-49.72	-49.96
1.50	-46.80	-47.28	-47.93	-48.43	-48.85	-49.20	-49.50	-49.76	-50.00
1.75	-46.91	-47.38	-48.00	-48.50	-48.90	-49.25	-49.54	-49.80	-50.04
2.00	-47.01	-47.47	-48.08	-48.56	-48.96	-49.29	-49.59	-49.84	-50.07

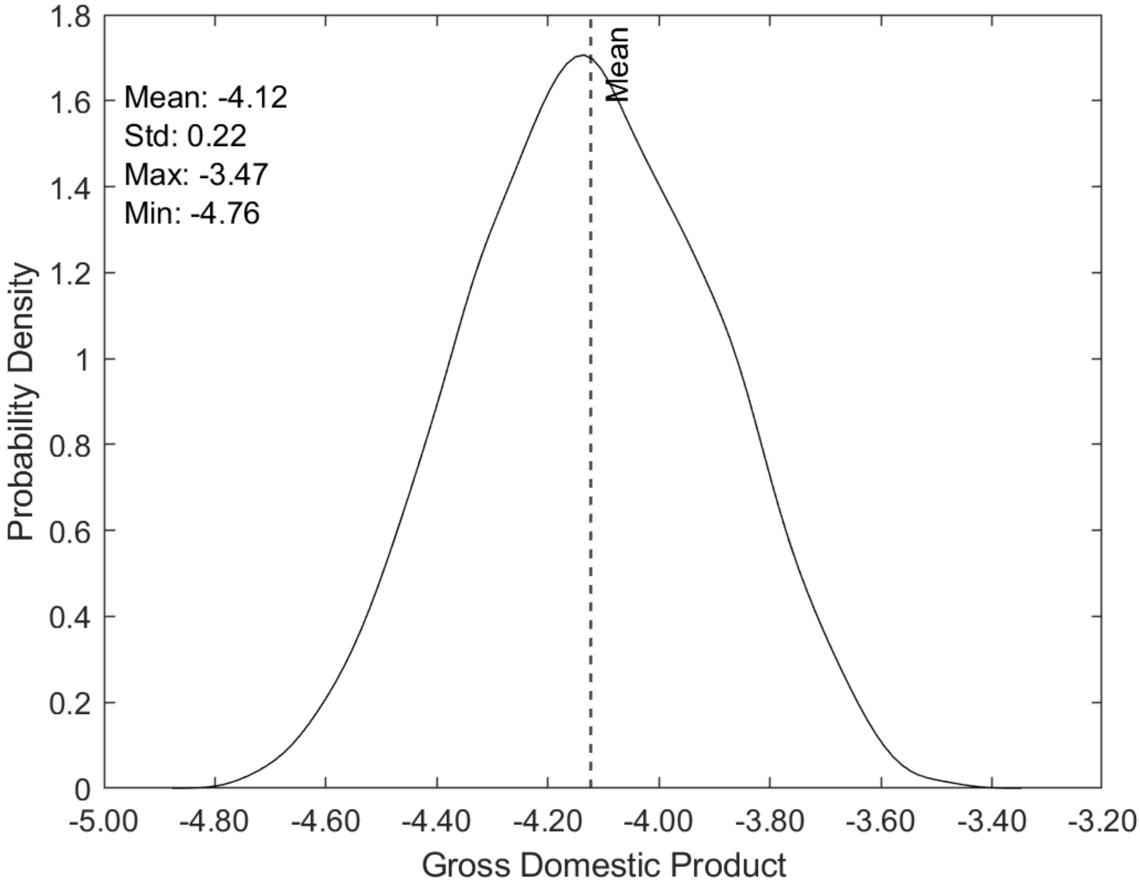
Seven directly affected governorates

	0.10	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00
0.10	-4.55	-4.59	-4.64	-4.67	-4.70	-4.73	-4.75	-4.77	-4.79
0.25	-4.56	-4.60	-4.64	-4.68	-4.71	-4.73	-4.76	-4.77	-4.79
0.50	-4.57	-4.61	-4.65	-4.69	-4.72	-4.74	-4.76	-4.78	-4.80
0.75	-4.59	-4.62	-4.66	-4.69	-4.72	-4.75	-4.77	-4.78	-4.80
1.00	-4.60	-4.63	-4.67	-4.70	-4.73	-4.75	-4.77	-4.79	-4.80
1.25	-4.61	-4.64	-4.68	-4.71	-4.73	-4.76	-4.78	-4.79	-4.81
1.50	-4.62	-4.64	-4.68	-4.71	-4.74	-4.76	-4.78	-4.80	-4.81
1.75	-4.63	-4.65	-4.69	-4.72	-4.74	-4.77	-4.79	-4.80	-4.82
2.00	-4.63	-4.66	-4.70	-4.73	-4.75	-4.77	-4.79	-4.81	-4.82

Note: Results from 81 simulations (one simulation for each combination of elasticities of substitution between foreign and domestic trade and interregional trade).

Source: Our simulation.

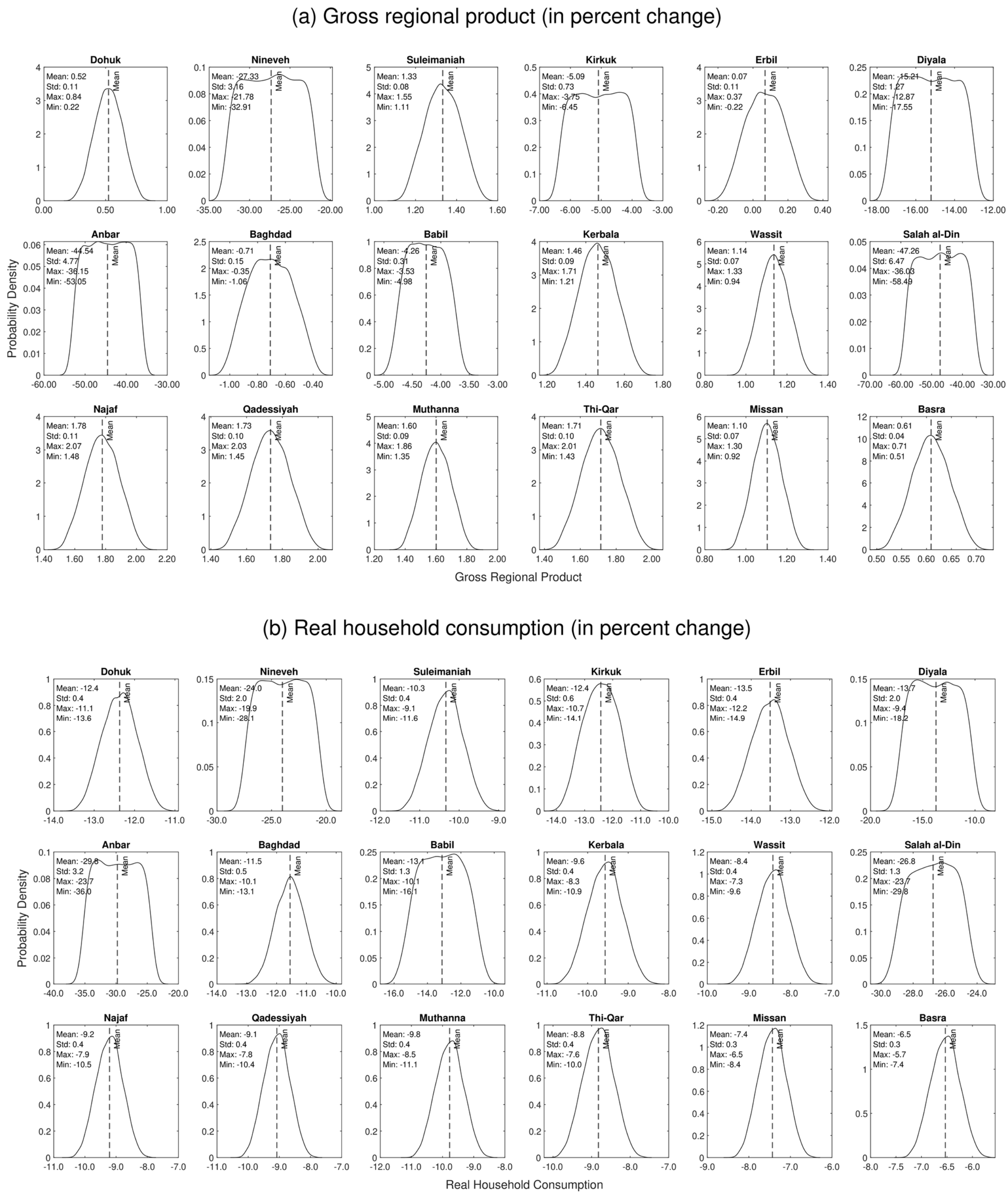
Figure 6. Gross domestic product: sensitivity analysis (in percent change)



Note: Results from 10,000 simulations.

Source: Own simulation.

Figure 7. Shock sensitivity analysis (in percent change)



Note: Results from 10,000 simulations.

Source: Our simulation.

Tables

Table 1. Exogenous shocks in the CGE model (in percent change)

Variable	Change
Current capital stock (curcap)	
Nineveh	-28.22
Kirkuk	-5.52
Diyala	-12.26
Anbar	-48.03
Baghdad	-1.21
Babil	-2.68
Salah al-Din	-57.17
Percentage-point changes in unemployment rate (del_unr)	
Nineveh	13.11
Kirkuk	3.96
Diyala	16.45
Anbar	20.65
Baghdad	1.41
Babil	6.79
Salah al-Din	8.76
Shift term in household disposable income (c_shift)	
Nineveh	-20.02
Kirkuk	-5.62
Diyala	-26.41
Anbar	-34.61
Baghdad	-2.02
Babil	-13.34
Salah al-Din	-14.86

Source: Our simulation.

Table 2. Macroeconomic impacts of the regional ISIS-created conflict in Iraq between 2013 and 2017 (in percent change)

	Real GDP	Household Consumption	Investment Expenditure	GDP Price Index	Consumer Price Index	Real wages	Employment
National result	-4.13	-12.90	-6.19	0.37	-0.54	-3.72	-4.43
*Subtotal**							
Current capital stock							
Nineveh	-0.89	-3.64	-2.44	-0.65	-0.60	-3.86	0.17
Kirkuk	-0.36	-0.44	-0.23	0.04	-0.09	-0.42	-0.03
Diyala	-0.14	-0.55	-0.75	-0.12	-0.19	-0.56	0.01
Anbar	-0.54	-2.50	-1.39	-0.25	-0.12	-2.57	0.03
Baghdad	-0.14	-0.39	-0.27	-0.04	-0.05	-0.38	0.00
Babil	-0.05	-0.21	-0.12	-0.03	-0.02	-0.22	-0.01
Salah al-Din	-1.09	-2.45	-1.00	0.03	-0.20	-2.55	0.03
Percentage-point changes in unemployment rate							
Nineveh	-0.35	1.75	0.00	1.65	1.59	3.28	-1.47
Kirkuk	-0.05	0.20	0.00	0.19	0.18	0.44	-0.20
Diyala	-0.19	1.19	0.00	1.06	0.94	2.03	-0.82
Anbar	-0.25	1.31	0.00	1.22	1.18	2.38	-1.11
Baghdad	-0.09	0.65	0.00	0.52	0.52	0.91	-0.37
Babil	-0.10	0.50	0.00	0.46	0.44	0.92	-0.45
Salah al-Din	-0.09	0.59	0.00	0.48	0.46	0.91	-0.40
Change in household disposable income							
Nineveh	0.07	-2.50	0.00	-1.22	-1.29	-1.30	0.18
Kirkuk	-0.01	-0.33	0.00	-0.14	-0.16	-0.05	-0.03
Diyala	0.03	-1.23	0.00	-0.54	-0.66	-0.46	0.05
Anbar	0.06	-2.19	0.00	-1.06	-1.12	-1.10	0.05
Baghdad	0.00	-0.79	0.00	-0.34	-0.37	-0.25	-0.01
Babil	0.02	-0.97	0.00	-0.45	-0.48	-0.44	-0.07
Salah al-Din	0.02	-0.90	0.00	-0.45	-0.49	-0.43	0.02

Note: *The subtotal is the contribution of the shock in each exogenous variable of the CGE model (current capital stock, percentage-point changes in unemployment rate, and shift in household disposable income) to the result in the endogenous variables.

Source: Our simulation.

Table 3. Effect of the regional ISIS-created conflict on the gross regional product by Iraqi Governorate between 2013 and 2017

Governorate	Directly affected?	GRP (2013)		GRP (change: 2013-17)	
		Million, USD	GRP share (%)	Million, USD	%
Dohuk	No	3,889.8	1.7	21.9	0.6
Nineveh	Yes	12,369.7	5.3	-3,391.2	-27.4
Suleimaniah	No	10,209.1	4.3	139.9	1.4
Kirkuk	Yes	18,246.5	7.8	-933.9	-5.1
Erbil	No	6,900.5	2.9	8.1	0.1
Diyala	Yes	4,829.4	2.1	-735.9	-15.2
Anbar	Yes	4,940.9	2.1	-2,211.7	-44.8
Baghdad	Yes	39,205.4	16.7	-270.7	-0.7
Babil	Yes	7,268.3	3.1	-307.8	-4.2
Kerbala	No	4,445.5	1.9	66.2	1.5
Wassit	No	8,888.7	3.8	101.8	1.1
Salah al-Din	Yes	6,477.9	2.8	-3,083.0	-47.6
Najaf	No	5,753.1	2.4	104.2	1.8
Qadessiyah	No	3,827.3	1.6	67.5	1.8
Muthanna	No	2,210.1	0.9	36.0	1.6
Thi-Qar	No	6,397.3	2.7	111.1	1.7
Missan	No	7,400.2	3.1	82.0	1.1
Basra	No	81,788.9	34.8	496.6	0.6
Iraq	-	**235,048.4**	**100.0**	**-9,698.9**	**-4.1**

Source: Our simulation.

Table 4. Economic impact of the regional ISIS-created conflict by Iraqi governorate between 2013 and 2017 (in percent change)

Governorate	Household consumption	Interregional exports	Interregional imports	Foreign export	Foreign import	Capital price	Labor price
Dohuk	-12.2	-9.4	-9.1	15.8	-6.8	-13.7	-14.2
Nineveh	-23.8	-17.0	-18.0	-39.7	-21.1	28.4	34.4
Suleimaniah	-10.2	-4.6	-6.4	17.7	-6.5	-11.9	-19.1
Kirkuk	-12.3	-8.5	-7.7	-4.0	-7.8	1.8	-4.9
Erbil	-13.3	-6.3	-11.8	17.3	-7.9	-15.7	-14.5
Diyala	-13.7	-12.5	-9.1	-24.2	-11.7	14.1	36.9
Anbar	-29.7	-22.3	-29.7	-92.2	-29.7	71.1	69.3
Baghdad	-11.3	-7.1	-8.8	5.0	-6.7	-5.8	-12.5
Babil	-13.0	-6.7	-3.8	2.6	-7.0	-5.0	5.7
Kerbala	-9.4	-3.0	-2.7	9.9	-4.1	-8.2	-18.4
Wassit	-8.3	-3.4	-2.3	3.8	-3.8	-2.9	-18.5
Salah al-Din	-26.6	-26.1	-21.3	-70.2	-24.7	60.2	29.4
Najaf	-9.1	-2.3	-2.5	15.8	-3.8	-9.8	-19.3
Qadessiyah	-8.9	-3.1	-2.0	14.6	-3.8	-8.8	-19.1
Muthanna	-9.6	-2.1	-1.9	14.7	-3.1	-10.1	-18.8
Thi-Qar	-8.7	-2.0	-1.5	8.8	-3.3	-6.4	-18.4
Missan	-7.4	-2.3	-1.6	2.8	-4.0	-1.3	-18.4
Basra	-6.5	-4.6	-1.1	1.1	-2.5	0.1	-18.0

Source: Our simulation.

Table 5. Economic impact of the regional ISIS-created conflict in Iraq by sector between 2013 and 2017 (in percent change)

Sector	Value Added	Foreign Import	Foreign Export	Capital Price	Labor Price	Employment
Agriculture	-8.6	-11.2	-3.2	3.4	-1.3	-6.6
Extraction of crude petroleum	-2.0	-6.4	-1.8	1.8	-14.0	5.6
Other mining and quarrying	-10.7	-5.7	-12.2	10.9	0.4	-6.1
Manufacturing industry	-6.8	-9.1	-1.8	4.4	-2.9	-4.0
Electricity and water	-8.2	0.0	0.0	-3.0	-2.8	-8.3
Construction	-6.4	0.0	0.0	-4.8	-3.9	-6.6
Transport and communications	-6.7	-8.2	-1.8	4.0	-2.3	-4.4
Trade	-8.2	0.0	6.0	-5.0	-2.4	-9.1
Finance and insurance	-5.7	-9.1	10.7	-5.7	-6.3	-5.5
Services	-3.8	-2.8	-5.8	14.1	-1.8	-0.6

Source: Our simulation.

Table 6. Value added and gross regional product by Iraqi governorate

Governorate	Value added 2013 (million, USD)			GRP (% change: 2013-17)
	Total	Oil sector	Oil sector (%)	
Dohuk	3,875.7	0.0	0.0	0.1
Nineveh	12,338.8	1,836.6	14.9	-21.4
Suleimaniah	10,177.0	0.0	0.0	1.0
Kirkuk	18,229.6	12,371.6	67.9	23.3
Erbil	6,874.0	0.0	0.0	-0.3
Diyala	4,814.7	459.1	9.5	-11.6
Anbar	4,927.4	0.0	0.0	-44.9
Baghdad	39,109.6	11,937.7	30.5	11.8
Babil	7,247.5	0.0	0.0	-4.5
Kerbala	4,432.5	688.7	15.5	7.6
Wassit	8,874.6	4,591.4	51.7	22.5
Salah al-Din	6,464.2	2,295.7	35.5	-32.7
Najaf	5,736.3	0.0	0.0	1.5
Qadessiyah	3,816.0	0.0	0.0	1.5
Muthanna	2,202.6	0.0	0.0	1.3
Thi-Qar	6,378.7	1,147.9	18.0	8.9
Missan	7,390.9	4,706.2	63.7	27.5
Basra	81,758.3	73,922.1	90.4	38.4
Iraq	**234,648.4**	**113,957.1**	**48.6**	**15.9**

Source: Our simulation.