Model-based planning for post-conflict reconstruction

The case of Yemen

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ABSTRACT

Evidence-based planning for post-conflict reconstruction is often constrained by missing data and the shortcomings of conventional analytical methods. To overcome these constraints, we use economy-wide modeling methods to model the impact of war and reconstruction possibilities for the economy of Yemen. We first calibrate the model to pre-conflict data (2014) and validate it by replicating the most recent available dynamic needs assessments for Yemen that were elaborated by the World Bank. We then report model scenario results for unobserved development indicators, such as estimates for sector-level growth, employment, and poverty. For the post-conflict period, we use the assumptions of a recent dynamic needs assessment and assume gradual reconstruction of the war-induced damages by the target year 2024. Then we focus on uncertain institutional factors and investigate their importance for the country's socio-economic development. Finally, we assess the potential structural characteristics of Yemen's economy in the year 2024 and analyze potential risks and trade-offs associated with government's institutional performance and the implications these have for the pace of post-conflict reconstruction.

Keywords: economy-wide modeling, uncertainty, conflict, reconstruction, Yemen

1 INTRODUCTION

Evidence-based planning for post-conflict reconstruction of national economies is often heavily constrained by missing data and the shortcomings of conventional sector-focused analytical methods. It is well documented that conflicts disrupt trade, service flows, foreign direct investments, and other financial flows (Karam and Zaki 2016; Rifat 2018). An increase in conflict-related expenditures in combination with reduced tax collection and reduced economic activity often increases budget deficits (Rifat 2018). Damage to infrastructure, institutions, and the destruction of assets impacts the real economy by shrinking the agricultural, industrial, and service sectors (Baddeley 2011; Addison 2010; Justino 2010; Justino and Verwimp 2013). These interrelated impacts typically lead to a reduction in economic growth or even a contraction of the economy as a whole, high inflation, depreciating currencies, and a decline in public expenditures on social safety nets, public services, and state salaries (Brinkman and Hendrix 2011; Murdoch et al. 2002, World Bank 2011), all of which affects household welfare and poverty levels adversely. In addition, conflict often limits access to food and increases food prices by reducing agricultural production through the destruction of assets and food-related infrastructure (FAO 2000; Deininger and Castagnini 2006) or by reducing the ability to import food. The household's ability to cope with and respond to economic shocks brought about by the conflict depends on the precise type of shock, their relative exposure to the conflict-induced shock, and on the economic resources on which they can draw (Justino 2010; Justino and Verwimp 2013; Bird et al. 2013).

While such stylized impact channels are well known, timely estimates on how conflict changes economic structures and impacts key development indicators, such as sector-level growth, employment, and poverty, in a specific country or context is scarce. If consistent data is only available from prior to the conflict era, constructing a realistic post-conflict projection and forward-looking assessments to help evaluate reconstruction needs and costs are challenging. Nonetheless, such assessments are critical for governments as countries move from an emergency or conflict mode to an eventual recovery and development mode. It is equally critical for international partners who wish to make informed decision upon their possible financial support for reconstruction. Important post-conflict reconstruction questions usually include:

- How has the structure of the economy and the welfare of the country's citizens changed during conflict? Will support to welfare help stabilize the country, if so how?
- What are the estimated costs for reconstruction?
- What are the expected macroeconomic implications of foreign aid, taking into account the absorptive capacities of the country?

This paper presents an innovative, economy-wide modeling approach to provide answers to these and related questions for Yemen. As hopes are growing for peace in Yemen, the country experiencing the worst contemporary humanitarian crisis in the world (UN 2019a), local, national, regional, and multilateral institutions, such as the United Nations and the World Bank, are trying to estimate war damages – physical, economic, and institutional damage – in their Dynamic Needs Assessments (DNA). This needs assessment process is extremely complicated because it is being done in the midst of the ongoing conflict so that the extent of damages across the country and estimates of recovery needs in most instances can only be roughly approximated (World Bank 2019a). Furthermore, the unavailability of official statistics complicates the derivation of any estimate of war damages even at an aggregated level. Initial estimates of the World Bank (2018a) suggested Yemen's GDP contracted by more than 50 percent during the conflict. However, later the estimate was reduced to 39 percent (World Bank 2019b). With evidence that Yemen's economy began to show signs of stabilization in late-2018, the latest estimates of the aggregate

impact of the conflict on the Yemeni economy are that it contracted overall by about a third (GDP at constant factor prices) between 2014 and 2018 (World Bank 2019c). The worst damage due to the conflict has been seen in the housing sector with 33 percent of units either partially damaged or totally destroyed (World Bank 2019a). The education; health; transport; and water, sanitation, and hygiene (WASH) sectors have also been severely affected, with overall damage levels ranging from 27 to 31 percent.

The destruction of physical infrastructure and the loss of productive factors have severely reduced incentives to pursue productive activities, hampering the effective functioning of economic networks and supply chains (Moyer et al. 2019). Hydrocarbon exports have been much reduced throughout the conflict period, resulting in a severe shortage of foreign exchange and constrained imports of food, fuel, and other goods. Private consumption has been hard hit by the economic decline, foremost through increased food prices, delayed public-sector salary payments (the civil service employs 25 percent of the workforce), and soaring unemployment. Most direct private investments, whether domestic or foreign, have either been halted or withdrawn.

However, such estimates of the effect of the conflict on the economy of Yemen and on the well-being of its citizens are partial and dated – comprehensive and consistent socio-economic datasets, like balance of payments, government accounts, national accounts, and socio-economic household surveys, are only available for the years up to 2014 before the conflict and not for the conflict period between 2015 and 2018. Another challenge is that available estimates of Yemen's reconstruction needs are estimated using a cost assessment approach. The economic repercussions of destroyed assets and value chains are not considered. Based on this method, the World Bank estimates overall needs for reconstruction of the whole country in the medium term of five years to be 32 billion USD (World Bank 2019a).

Furthermore, due to methodological constraints, the DNA reports cannot assess the importance of institutional factors for Yemen's post-conflict development. However, in addition to funds for reconstruction, post-conflict development of the economy will depend significantly on governance quality and institutional factors. In a pre-war study, the World Bank (2015) defined poor governance and institutions as major factors that restrain investment, growth of productivity, and exports. Policy reforms to improve the business environment and labor markets to support productivity growth and labor reallocation were named as important preconditions for creating growth in the Yemeni economy. As the post-conflict quality of Yemeni institutions and governance is highly uncertain, so too is the economic recovery trajectory of the country. Depending on institutional performance, both the quantity and the allocation of production factors across sectors can differ, meaning that the potential structure of the economy at the end of the reconstruction period remains highly uncertain.

This paper aims to fill in some of these information gaps and methodological constraints by using a dynamic computable general equilibrium (CGE) model of the Yemen economy to assess the economy-wide repercussions of the conflict and to explore reconstruction possibilities. To estimate the size and structure of the Yemeni economy at the end of the conflict, we use a social accounting matrix (SAM)¹ for Yemen for the year 2014 and then calibrate the CGE model to infer outcomes for unobserved structural variables using economic variables for which data is available. We then utilize available information from various publicly available sources to derive estimates for a variety of structural variables for which estimates are not available of the impact of the conflict. Several studies have used CGE models for assessing the economic impacts of shorter-term external shocks, disasters, and terrorism (Breisinger et al. 2011; Breisinger et al. 2016; Nassios

¹ A social accounting matrix is a snapshot of a country's economy in a given year. The 2014 SAM for Yemen was constructed by Raouf et al (2019) using the latest available data.

and Giesecke 2015; Wiebelt et al. 2013). A global CGE model also was used to assess the significance of mostly trade-related impacts of the Syrian war on the economics of the Mashreq countries of western Asia and eastern North Africa (Ianchovichina and Ivanic 2014). However, this paper is among the first to apply a country-level CGE model in a conflict setting. (For a Syria example, see World Bank (2017a).)

As a base for our post-conflict analysis we use the assumptions and estimates of the most recent Yemen DNA report by the World Bank (2019a). In particular, we assume gradual reconstruction to be completed by 2024, and model the uncertainty of the most important institutional factors that might affect Yemen's economic recovery path. In doing so, we utilize Systematic Sensitivity Analysis (SSA), popularized by Arndt and Pearson (1998), and simulate the uncertainty of important model parameters that represent institutional factors.² Unlike the standard counterfactual CGE approach, SSA allows us to construct interval estimates of critical socio-economic outcomes for Yemen by the target year of 2024 and to analyze the importance of factors that can potentially slow or boost the country's economic recovery.

Furthermore, the application of CGE and SSA methods allows us also to focus on possible welfare outcomes for Yemeni households, providing estimates of the potential needs of the country's social sector. Another significant contribution of our use of these analytical tools is an assessment of structures for the Yemeni economy that may emerge by the end of the reconstruction period.

This paper can be considered complementary to the Yemen DNA report series. In addition to contributing an innovative methodological approach to the conflict literature, it also provides a better understanding of the possible needs and potential challenges that Yemen might face during its reconstruction phase, thereby contributing to the empirical and policy-oriented literature on conflict. Our approach to modeling a country's post-conflict development is in line with recommendations to explicitly communicate uncertainty in policy analyses (Manski 2011; 2018), while also guiding effective aid allocation in support of conflict resolution and the reconstruction that must follow.

The paper is organized as follows. Section 2 describes the main characteristics of the Yemeni economy before the conflict. Section 3 briefly outlines the model and major shock transmission channels during the conflict between 2014 and 2018 and analyzes the state of the economy by the end of the conflict phase. Section 4 considers opportunities for the country's reconstruction and investigates the importance of institutional factors for achieving socio-economic outcomes. In this section possible structural characteristics of the economy by the end of the reconstruction phase are also investigated. Section 5 concludes with a summary of the analysis and policy recommendations.

2 PRE-CONFLICT STRUCTURE OF THE YEMENI ECONOMY

The starting point for the modeling framework used in this analysis is the 2014 and pre-conflict economic data series for Yemen. The key database we use is the SAM for Yemen for 2014 (Raouf et al. 2019). This provides detailed macro- and micro-economic consistent data based on market and financial transactions and the socio-economic characteristics of the economy.³ Tables 1, 2,

² For example, Systematic Sensitivity Analysis is used by Webster et al. (2008) to address the uncertainty in projections of emissions and costs of atmospheric stabilization for five climate scenarios. Phimister and Roberts (2017) investigate the implications of allowing uncertainty in exogenous shocks when modeling a new onshore wind sector in northeast Scotland. Chatzivasileiadis et al. (2019) conduct SSA to address model input uncertainty when analyzing the effects of sea-level rise on the global economy.

³ Because some of the entries of the original SAM represent specific computational limitations for our CGE model, we perform some data adjustments and amendments. (See Appendix 1 for more details.)

and 3 and Table A.1 in the Appendix summarize key characteristics of the pre-conflict Yemeni economy.

Even before the conflict, the economy had many features that characterize least developed countries (Table 1) (Schwab & Sala-i-Martin 2017). The relatively high weight of the primary sector in total GDP (12.6 percent for agriculture, 23.0 percent for the mining sector), the low share of the secondary sector in total GDP (e.g., 1.7 percent for non-food manufacturing with high import intensity), and the relatively high share of the government sector (11.4 percent of GDP) underpin such characteristics. Furthermore, the country is heavily dependent on imports of many essential commodities, while crude oil and gas derivatives dominate exports.

Table 1. Supply, demand, and trade structure, Yemen, 2014

Sector	GDP share, %	Export output share, %	Absorption share, %	Import demand share, %
Cereals	1.0	3.7	2.4	61.2
Vegetables	3.4	4.6	2.9	5.4
Fruits	1.5	28.6	0.8	5.5
Other crops	2.0	6.3	2.3	22.6
Livestock products	3.4	1.8	4.6	1.3
Other agriculture *	1.4	35.1	1.4	2.5
Mining	23.0	56.7	1.5	27.8
Livestock and fishery processing	1.4	28.0	5.1	42.5
Fruit and vegetable processing	2.4	2.2	6.9	13.0
Other food and beverage processing	2.7	9.0	8.7	26.8
Other manufacturing	1.7	10.6	15.2	67.7
Utilities	1.6	-	1.5	-
Construction	3.1	-	8.6	3.7
Wholesale and retail trade	16.7	-	10.7	-
Transportation and storage	8.8	5.5	9.4	27.3
Housing	3.9	39.7	1.9	6.7
Information and communication	1.7	-	1.3	-
Business services	3.0	15.0	3.1	39.5
Other private services	5.9	-	4.4	6.5
Public goods and services	11.4	3.1	7.5	-
Total	100.0	15.3	100.0	22.9

Source: Own calculations based on Raouf et al. (2019).

Note: * "Other agriculture" is primarily capture fisheries (95 percent of sectoral total), with some forestry.

The structure of factor payments in Yemen is typical for lower income countries (Table 2). The economy is labor-intensive, with labor contributing 60.7 percent of GDP. At the same time, while capital added 34.5 percent to the economy, more than one-half of this (18.9 percent) was capital associated with the mining sector (hydrocarbons). As in most countries, before the war households in urban areas enjoyed higher incomes compared to rural areas (Tables 2 and 3). Urban households consumed 72.6 percent more per capita and the poverty incidence in urban centers was 2.5 times lower than in rural communities. These disparities can be partly explained by different sources of factor income and educational differences between urban and rural households. However, urbanization in Yemen is low with 71 percent of the Yemeni population living in rural areas.

Table 2. Structure of factor payments, Yemen, 2014

Factor	Share of GDP, %	Share of factor income, rural households, %	Share of factor income, urban households, %
Labor			
Rural uneducated	19.4	30.9	11.7
Rural secondary	7.7	11.2	6.4
Rural tertiary	15.1	14.7	24.1
Urban uneducated	2.8	1.3	6.7
Urban secondary	1.5	1.5	2.4
Urban tertiary	14.3	8.2	31.9
Land	4.8	7.3	3.6
Capital			
Crops	0.5	1.0	0.2
Livestock	0.4	0.7	0.0
Mining	18.9	23.3 *	13.1 *
Other	14.8		

Source: Own calculations based on Raouf et al. (2019).

Note: * Capital rents in non-agriculture sectors are through the account of enterprises, not households.

Table 3. Poverty and expenditure indicators

Household	SAM code	Population, millions	Poverty prevalence, %	Per-capita expenditure, '000 YER
Rural	hhd-r	18.5	59.2	194.4
Urban	hhd-u	7.8	23.9	335.4
Total		26.2	48.6	236.0

Source: Household Budget Survey 2014.

In summary, Yemen was already among the poorest countries in the world in 2014, with an annual GDP per-capita of 1,351 USD (290,000 YER), and almost half of the population living below the poverty line.

The next section describes the model and the key conflict transmission channels. It then presents the simulation results for the state of the Yemeni economy in 2018.

3 CONFLICT PHASE, 2014 TO 2018

3.1 The model and its shock transmission channels

We employ the recursive-dynamic CGE model developed by the International Food Research Policy Institute (Lofgren et al. 2002; Diao and Thurlow 2012) and adjust the model to reflect the specific features of the Yemeni economy. (See Appendix 2 for details.) The model allows us to simulate major shocks during the conflict period that are presumed to have direct or indirect effects on the Yemeni economy and to estimate the economic and social repercussions of the shocks suffered.

The specifications of the shocks to the Yemeni economy during the conflict period that are simulated in the CGE model are presented in Table 4. To the extent possible, the assigned shock values are based on the publicly available estimates of most recent damages. However, in certain instances when direct estimates are not available, we use approximations or conventions. (See Appendix 3.)

Table 4. Shocks to the Yemeni economy specified for the conflict period, 2014 to 2018

Shock	Percent change by 2018	Source
Agricultural land	-38.0	FAO (2018)
Capital stock		
Housing	-13.8	World Bank (2019a)
Utilities, Transport, Public sector	-11.6	World Bank (2019a)
Mining	-60.0	Approximation based on World Bank (2018c)
Crude oil prices	-28.0	World Bank (2020a)
Foreign savings (Current account deficit)	-27.7	World Bank (2017b, 2019c)
Production elasticities	-50.0	Calibrated shock

Source: Compilation by authors.

Note: More detailed information on the specification of the shocks is given in Appendix 3.

The scope of all of the economic shocks that we use to characterize the conflict phase can be broadly disaggregated into three types: (i) destruction or underutilization of primary production factors; (ii) shocks associated with trade flows and financial transactions with the rest of the world; and (iii) the deterioration of the government sector and overall economic disorganization (a “level loss” in the productive employment of factors). Each of these is now described in more detail:

Destruction or underutilization of primary production factors: We have sufficient information to approximate the destruction of the capital stock and the underutilization of agricultural land in Yemen. Together with increasing unemployment or underemployment of labor, this category of shocks has direct repercussions on both GDP and the welfare of households. The magnitude of sector-specific GDP losses, besides factor intensities, depends on the trade, production, and demand elasticities of each sector (Table A.2 in Appendix 2). The welfare of households is affected through the change of factor earnings. For labor, this is through increasing unemployment, while for capital and land, this is through wage adjustments.

Shocks associated with transactions with the rest of the world: We have sufficient information to control for the fall in foreign currency earnings due to sharp reductions in exports of hydrocarbons, which constituted about 65 percent of Yemen’s total exports in the years before the conflict. Another major shock related to the conflict and associated with the rest of the world is the observed reduction of foreign savings, as the country did not have enough means to keep a high current account deficit. Together these shocks have three major impacts on the economy: (i) a depreciation of the (real) exchange rate and the repercussions this has on import-dependent consumption; (ii) a fall in investment and a decrease in the demand for investment commodities; and (iii) adverse impacts due to the compounded capital stock shortage in subsequent years.

Deterioration of public sector and overall economic disorganization: A decline in governance quality leads to a “level loss” in productive employment of factors (economic disorganization). We model both direct and indirect channels of the overall deterioration of governance quality and economic organization. As direct impact channels, we model the reduction of capital stock in the public sector. In terms of indirect channels, the economy-wide reduction of production flexibility can be interpreted as a representation of overall economic disorganization and degradation of institutions. In particular, we assume that as a result of the conflict, the flexibility of the economy is reduced by half compared to pre-war levels, i.e., production elasticities decrease by 50 percent. Effectively, this means that the ability of the economy to reallocate factors has halved – a less flexible economy will become more sensitive to the destruction or underutilization of primary production factors. Therefore, this shock can be viewed as complementary to the first category of shocks that stem from the destruction or underutilization of primary production factors.

3.2 Estimating the state of the Yemeni economy in 2018

In this section, we present the results of the model simulation of the shocks on the Yemeni economy during the conflict period up to 2018. In line with the World Bank estimate that total real GDP at constant factor prices contracted by an accumulated 33 percent (Table 5), our model suggests an overall GDP loss of 34.6 percent (Table 6). At aggregated sectoral levels, discrepancies between our model and World Bank estimates also are marginal.

Table 5. GDP losses relative to 2014, World Bank estimates

Sector	2015	2016	2017	2018
Real GDP at constant factor prices	-17.6	-29.4	-33.5	-32.9
Agriculture	-12.5	-21.7	-26.9	-26.3
Industry	-27.8	-44.8	-46.8	-46.1
Services	-12.5	-21.7	-26.9	-26.3

Source: Authors calculations based on World Bank 2018a; 2018b

Table 6. GDP losses for the Yemeni economy by 2018 due to conflict, model simulation estimates

Sector	% by 2018	Sector	% by 2018
Total	-34.6		
Agriculture	-26.7	Services	-28.7
Crops	-33.0	Private services	-37.0
Cereals	-35.0	Wholesale and retail trade	-27.5
Vegetables	-19.2	Transportation and storage	-41.3
Fruits	-32.4	Housing	-34.9
Other crops	-56.4	Information and communication	-59.4
Livestock products	-22.4	Business services	-28.4
Other agriculture	-1.2	Other private services	-56.3
Industry	-45.9	Public goods and services	0.0
Mining	-60.0		
Manufacturing	-3.4		
Food and beverage processing	-3.2		
Livestock and fishery	5.5		
Fruit and vegetables	-7.8		
Other food and beverages	-3.8		
Other manufacturing	-4.0		
Utilities	-27.7		
Construction	-62.5		

Source: CGE model simulations of the Yemeni economy by the authors.

The comparability of these macro-level simulation outcomes to the most recent publicly available estimates of the World Bank validates the specified set of input shocks. This allows us to consider simulation results for other economic variables of interest for which estimates of the impact of the conflict on them are not available. Model results at the sector level (Table 6) suggest that the most severe economic losses were experienced by the industrial sector, mostly due to the collapse of the mining sector, while the agricultural and services sectors demonstrated relative resilience. Besides the direct loss of production factors (Table 4), foreign and domestic demand characteristics are important determinants for production losses in each sector. In this light, the agricultural sector demonstrated relative resilience due its importance for domestic consumption, as is evident in the low income elasticities for agricultural sub-sectors presented in Table A.2 in Appendix 2. Furthermore, trade-intensive agricultural sub-sectors, like fishery (part of the 'Other agriculture' sub-sector) fishery processing, and livestock (Table 1), benefited from a depreciating exchange rate and expanded exports. Fishery processing even demonstrated moderate growth overall. At the same time, sub-sectors that are less important for domestic consumption and those

that could not compensate for the fall in domestic demand by expanding exports experienced the most severe GDP losses. Non-tradable goods, like information and communication or other private services, lost nearly 60 percent in terms of their share of GDP. However, according to our estimates, the most severely affected sector was construction, which lost 62.5 percent of its relative share in GDP. This was because investment demand in Yemen, which expands construction activities, was dramatically reduced.

Our estimates suggest that nearly three out of ten previously employed persons lost their jobs (Table 7). Job losses in rural areas were relatively higher than those in the cities because agricultural production technologies are both labor intensive and less flexible with regard to factor substitution. This is evident in the agricultural sub-sector production elasticities presented in Table A.2 in Appendix 2. As a result, large shocks of agricultural land losses (–38 percent) forced these sub-sectors to release labor factors at almost a proportional rate.

Table 7. Employment losses for Yemen due to conflict

Type	% by 2018
National	-26.9
Rural	-34.0
Uneducated	-33.6
Secondary	-34.0
Tertiary	-36.3
Urban	-10.0
Uneducated	-9.5
Secondary	-9.3
Tertiary	-30.4

Source: CGE model simulations of the Yemeni economy by the authors.

In terms of distributional impacts, the model results indicate that rural residents experienced lower relative losses to their consumption and expenditure than did those living in urban centers (Table 8). In part, this is because rural residents rely less on labor and more on land for their consumption (Table 2). In addition, agricultural land is mostly owned by rural residents.

Table 8. Per-capita expenditure decline in Yemen due to conflict

Type	% by 2018
National	-35.9
Rural	-35.8
Urban	-38.0

Source: CGE model simulations of the Yemeni economy by the authors.

According to our estimates, the national poverty level increased from 48.6 percent in 2014 to 75.0 percent by 2018 (Table 9). This is similar to the World Bank estimate of the poor making up between 71 and 78 percent of the total population in 2018 (World Bank 2019a: 4). The urban population experienced a greater relative increase in the prevalence of poverty than did the rural population – the poverty headcount rose by half for the rural population from 59.2 percent in 2014 to 85.9 percent in 2018, while for the urban population, it doubled from 23.9 to 52.5 percent. As the level of poverty in rural areas was much higher than in cities before the conflict, almost nine out of ten rural Yemenis now have a level of consumption below the poverty line.

Table 9. Poverty prevalence in Yemen, 2018

Type	% by 2018
National	75.0
Rural	85.9
Urban	52.2

Source: CGE model simulations of the Yemeni economy by the authors.

Despite the reduction of cultivated areas, rural residents realized increased total factor payments from their land due to significant price increases as a result of land scarcity (Table 10). Besides factor payments, consumption indicators of urban and rural residents are also affected by different population growth rates.⁴

Table 10. Miscellaneous changes in the Yemeni economy due to conflict

Variable	% by 2018
Investment	-70.5
Exchange rate *	8.7
Total factor payments	
Harvested cropland (flnd)	35.5
Capital for agricultural crops (fcap-c)	0.0
Capital for livestock (fcap-l)	0.0
Capital for mining (fcap-m)	-60.0
Capital for all other sectors (fcap-o)	-3.7

Source: CGE model simulations of the Yemeni economy by the authors.

Note: * The simulations do not take into account currency devaluation caused by the Central Bank's monetary policy actions.

Having established a scenario that reflects the impact mechanisms of the conflict on Yemen's economy, the next section assesses alternative recovery and reconstruction scenarios.

4 POST CONFLICT RECOVERY AND RECONSTRUCTION PHASE, 2019 TO 2024

4.1 Incorporating the uncertainty of institutional factors for Yemen's economic recovery

The dynamic needs assessment (DNA) report of the World Bank serves as a starting point for our examination of the country's potential reconstruction trajectories. The DNA report, written in collaboration with Yemeni authorities, was a multiphase, in-conflict assessment that relied primarily on remote data sources, including satellite imagery and social media analytics (World Bank. 2019a). To the extent possible, the information was verified using information available from the World Bank's partners on the ground. However, the country's medium term reconstruction needs are not fully understood. The DNA study was solely concentrated on the largest 16 urban centers, for which the five-year reconstruction needs are estimated to cost 14 billion USD. Extrapolated to the entire country, total reconstruction needs over five years are projected by the World Bank to cost 32 billion USD (World Bank. 2019a: 7).

However, the methodology used in the DNA has two major drawbacks. First, the cost estimation method cannot take into account economy-wide spillovers. Consequently, the overall economic impact of the restoration of destroyed assets remains unknown. Second, the DNA cannot consider the importance of institutional factors for Yemen's economic recovery, such as the capacity of the Yemeni government to implement efficiency-enhancing policies. Depending on institutional quality, the allocation of production factors can be different across sectors, which means that the potential structure of the economy by the end of the reconstruction period is uncertain. To address both problems, we apply Systematic Sensitivity Analysis (SSA) (Arndt and Pearson 1998) to our CGE model to analyze the importance of the uncertain institutional performance of the Yemeni government for the country's socio-economic development during the reconstruction period.

⁴ Yemen's urban population is growing on average 4 percent per year, which is more than three times faster than the growth rate of the rural population of 1.25 percent per year (Table A.3 in Appendix 2).

In our model simulation scenarios for the post-war era, we assume that all war-related destruction will be restored to pre-war levels by 2024 as a result of joint efforts of Yemeni authorities and the international community.⁵ While this is a somewhat optimistic assumption, it is justified since the country's long-term reconstruction needs are not yet fully estimated. Consequently, in our study we exclude from the analysis uncertainty associated with the reconstruction of damaged assets. Rather, we concentrate on uncertain institutional factors that can hamper or boost the recovery and influence the allocation of production factors across economic sectors. In this regard, the paper provides important additional insights and recommendations for planning the recovery and reconstruction process in Yemen.

In our CGE model we select model parameters that represent institutional restraints on productivity, investment, and factors allocation, as highlighted in the pre-war study on Yemen's economic growth (World Bank 2015):

- Growth in total factor productivity (tfp) – This parameter defines the effectiveness of utilization of all primary factors of production and is positively associated with both production and welfare outcomes.
- Effectiveness of investment (inv) – This parameter defines the country's capacity for capital accumulation – that is, the transformation of capital investment into new capital stock.
- Production elasticities of substitution of all sectors (prod) – This parameter defines the production flexibility of the economy and the possibilities of economic sectors to substitute capital, labor, and land.

We follow Webster et al. (2008) and use Latin Hypercube Sampling from a multivariate Gaussian distribution to cover the potential space of these parameters. Due to their unobserved nature and to specify potential variations for each parameter, we use assumptions and expert views. As shown in Figure 1, we assume that during the post conflict phase:

- Total factor productivity growth (tfp) can vary between 0 percent (stagnation) and 2 percent (boom);
- The effectiveness of investment (inv) can increase by 100 percent (boom) from its 2018 value (stagnation);
- Production elasticities (prod) can increase from 2018 values (stagnation) by 100 percent to their pre-war values (boom).

To emphasize the dependency of institutional factors on overall governance quality, we impose a perfect correlation between them. In this case, each sampled reconstruction scenario can have a distinct qualitative interpretation of the country's institutional performance. In particular, the worst-case institutional performance scenario assumes zero productivity growth, stagnant capacity for capital accumulation, and the conflict-phase production flexibility of the economy ($\text{tfp} = 0$, $\text{inv} = 1$, $\text{prod} = 1$). The best-case institutional performance scenario assumes 2 percent annual productivity growth, two-fold capacity for capital accumulation, and pre-war production flexibility of the economy ($\text{tfp} = 2$, $\text{inv} = 2$, $\text{prod} = 2$).

⁵ In running our model scenarios, two assumptions related to reconstruction are imposed. First, capital and land assets of foreign investors are assumed to be directly restored by 2024 without repatriating profits. Second, foreign savings (current account deficit) are restored to pre-war levels by 2024.

Figure 1. Marginal distributions of the economic impact of uncertain institutional change

Source: CGE model simulations of the Yemeni economy by the authors.

Following the guidance of the World Bank’s pre-war study on Yemen’s economic growth (World Bank 2015), we are conservative as to the future institutional performance of the Yemeni government. Consequently, we sample the parameters from truncated multivariate Gaussian distributions where the lower bounds are the medians of the respective marginal distributions. Thus, the skewed distributions shown in Figure 1 reflect our conservative assumption of slow institutional change, as we consider the likelihood of poor performance to be higher than the likelihood of good performance in the post-conflict period.

4.2 Recovery and reconstruction trajectories and socio-economic implications

Here we describe potential reconstruction trajectories under the main assumption that the destroyed assets will be restored and funded according to the DNA estimates in the amount of 32 billion USD. Figures 2, 3, and 4 present the model results associated with potential recovery trajectories for selected development indicators. The graphs on the left side of each figure represent potential dynamics driven by the sampled model parameters that represent institutional restraints on productivity, investment, and factors allocation. In order to identify the contribution of these parameters to the total variation of the endogenous variables considered, we define three scenarios: (1) only the tfp parameter varies; (2) only the tfp and inv parameters vary; and (3) all three parameters vary.⁶ The graphs on the right side represent estimates of each endogenous variable’s potential distribution in 2024.

Under the CGE model scenarios, economic growth rates are expected to be high (Figure 2). Compared to the estimated 2018 GDP level of 5 trillion YER (2014), by 2024 GDP is expected to reach between 7.9 trillion and 9.6 trillion YER (2014), which corresponds to an average 9.4 percent of real growth per year over the period 2019 to 2024. The fast recovery pace is driven by our assumption that all destroyed assets will be gradually restored to pre-war levels by 2024. These results are in line with the World Bank’s latest projections of double-digit growth rates in coming years in Yemen (World Bank 2018b; 2019b).

⁶.For each of the defined conditions, we sample parameters from respective dimensions of specified multivariate Gaussian distribution, each with 100 simulations. To technically perform the sampling, we apply the R-package ‘EnvStats’ by Millard (2013).

Figure 2. Real GDP trends between 2014 and 2024 and distribution in 2024

Source: CGE model simulations of the Yemeni economy by the authors.

The restoration of infrastructure leads to a rapid increase in employment of, on average, 7 percent per year (Figure 3). By the end of the reconstruction period, the supply of labor will begin to be restricted by population growth rates (Table A.1 in Appendix 2). Consequently, it can be expected that the welfare of households will increase and the overall poverty level in the country will have dropped significantly by 2024 (Figure 4).

Figure 3. National employment trends between 2014 and 2024 and distribution in 2024

Source: CGE model simulations of the Yemeni economy by the authors.

Figure 4. Poverty headcount trends between 2014 and 2024 and distribution in 2024

Source: CGE model simulations of the Yemeni economy by the authors.

At the same time, the model results suggest that the pace of recovery will also significantly depend on the institutional factors represented by the sampled model parameters. The difference in the results in 2024 under the best and the worst institutional performance scenarios is 21 percent of total GDP. The uncertainty decomposition analysis suggests that the most important contributors to potential variation in the outcome variables are the growth of total factor productivity (tfp) and the production elasticities (prod). These two variables can be viewed as complementary to each other as increased factor substitution possibilities strongly reinforce the effects of increased total factor productivity (direct growth component). The lower importance of the parameter on the effectiveness of investment (inv) is explained by the small share of capital value-added in the pre-war economy and to the halt in investment because of the conflict, which further weakened this variable in terms of its impact on reconstruction.

From a policy perspective, this analysis of institutional factors complements the World Bank's DNA report by providing a proxy for a costed assessment of governance quality (World Bank 2019a). In particular, the difference in GDP of 1.66 trillion in 2014 YER (approximately 7 billion USD) between the best and the worst reconstruction scenario in 2024 can be interpreted as the potential cost of poor institutional performance.

Furthermore, our findings highlight particularly important areas of governance requiring attention and strengthening during the reconstruction phase. Post-conflict reconstruction can be effectively boosted by reducing overall economic disorganization, which is represented by the production elasticities. Institutional improvements directed at productivity growth will also be important. As highlighted in the World Bank's pre-war study on Yemen's economic growth, (World Bank 2015), such efforts might include improving the business environment, creating conditions for effective labor reallocation, possible autonomy at regional level with federalization, and other structural reforms aimed at increasing both efficiency and flexibility with Yemen's economy.

4.3 Estimating poverty reduction under post-conflict reconstruction

Our application of CGE and SSA methods allows us to estimate the potential needs of the country's social sector. The delivery of services and cash transfers to the poor and vulnerable in Yemen has been tremendously complicated as the on-going conflict and political instability has made it nearly impossible for international organizations to operate on the ground (World Bank 2018d). However, such efforts can be expected to intensify as the development community is increasingly realizing that social protection measures are just as important and vital for post-conflict development as are efforts aimed at economic reconstruction (World Bank 2018d).

Of several possible target variables, we follow the World Bank (2018d) and focus on the poverty prevalence rate as a critical indicator of Yemen's social development. Using this measure of development, the simulated trajectories of economic recovery account for all factor income changes that affect the welfare of households, including labor,. Consequently, the range of possible poverty outcomes (Figure 4) can be used to estimate the potential needs of Yemen's social sector to restore welfare levels to pre-war levels. Despite expecting a significant increase in household factor income, the best-case scenario only restores 17 percent of the population to its pre-war poverty level by 2024 (right side graph in Figure 4, 'pre-war' percentile). In the other scenarios with poorer institutional performance, the mobilization of additional financing for social spending is required to restore all Yemeni's household to their pre-war welfare levels.

Figure 5. Yearly transfers to Yemeni households required to reach pre-war welfare levels

Source: CGE model simulations of the Yemeni economy by the authors.

Note: First quartile lies wholly at zero.

In order to estimate the funding required to restore for all households in Yemen their pre-war levels of welfare, for each potential recovery trajectory we calculate the minimum amount of transfers to households⁷ that would be necessary to reduce the national poverty headcount to 48.6 percent, the pre-war level. The set of estimates obtained then is used to construct interval estimates (Figure 5). Costs increase with deficits in institutional performance. Summarizing our findings:

- Under the 25 percent best institutional performance scenarios ($tfp > 1$, $inv > 1.5$, $prod > 1.5$, corresponding to quartile 3 in Figure 1), the amount of transfers required to reach the pre-war poverty level by end 2024 are projected to not exceed 0.4 billion USD annually.
- With median institutional performance ($tfp=0.6$, $inv=1.3$, $prod=1.3$), the amount of transfers required is estimated at about 1.3 billion USD annually.
- In the case of poor institutional performance, the country will need between 1.3 and 2.1 billion USD per year (3rd quartile).
- Finally, in the case of absolutely stagnant institutions ($tfp=0$, $inv=1$, $prod=1$), Yemeni households are estimated to require 3.2 billion USD per year to enable their consumption levels to be at pre-war levels.

4.4 Estimate of post-reconstruction economic structure by 2024

These uncertainties in the trajectories for the reconstruction of the economy of Yemen and the associated aid or financial inflows necessary to reach pre-war welfare levels will result in different structural characteristics for the Yemeni economy in 2024. The factors responsible for institutional performance can play a significant role in determining these structural outcomes. To analyze the potential structure of the Yemeni economy in 2024 (Table 11), we consider the following institutional performance scenarios:

- Best institutional performance ($tfp=2$, $inv=2$, $prod=2$, see Figure 1);
- Median institutional performance ($tfp=0.6$, $inv=1.3$, $prod=1.3$) that requires 1.3 billion USD of yearly transfers to households to improve welfare to their pre-war levels; and
- Worst institutional performance ($tfp=0$, $inv=1$, $prod=1$) that requires 3.2 billion USD of yearly transfers to households to improve welfare to their pre-war levels.

⁷ This is operationalized in the model through direct transfers from the Rest of the World to households. The distribution between urban and rural is proportional to their population shares.

In addition to institutional performance, the recovery trajectory also can be driven by different sectoral levels of performance. Moreover, similar to what was observed during the conflict period, characteristics of domestic and external demand can play an important role in defining the potential structure of Yemen's economy in 2024.

Table 11. Possible sectoral GDP outcomes for Yemen's post-reconstruction economic structure in 2024

Sectors	2014 pre-war, billions 2014 YER	2024, billions 2014 YER			Change between 2024 and 2014, %		
		best	median	worst	best	median	worst
Total	7,624	9,567	8,763	8,303	25.5	14.9	8.9
Agriculture	959	1,176	1,074	1,017	22.6	12.0	6.0
Crops	596	676	631	606	13.3	5.9	1.6
Cereals	80	102	88	76	28.0	11.2	-4.4
Vegetables	257	285	276	275	10.8	7.4	6.7
Fruits	111	116	110	108	5.0	-1.1	-2.8
Other crops	149	172	157	148	15.8	5.5	-0.6
Livestock products	258	315	297	291	22.2	15.5	13.1
Other agriculture	105	186	146	120	76.3	38.2	13.5
Industry	2,742	3,115	2,943	2,841	13.6	7.3	3.6
Mining *	1,756	1,756	1,756	1,756	0.0	0.0	0.0
Manufacturing	623	954	807	718	53.0	29.5	15.2
Food and beverages processing	493	717	624	565	45.3	26.4	14.5
Livestock and fishery	107	197	152	125	84.2	41.9	17.0
Fruit and vegetables	180	231	216	205	28.2	19.9	13.8
Other food and beverages	206	288	256	235	40.0	24.2	13.9
Other manufacturing	130	238	184	154	82.5	41.2	18.0
Utilities	123	151	139	133	22.6	12.7	7.6
Construction	240	254	241	234	6.1	0.5	-2.2
Services	3,923	5,276	4,745	4,445	34.5	21.0	13.3
Private services	3,056	4,279	3,760	3,466	40.0	23.0	13.4
Wholesale and retail trade	1,271	1,610	1,481	1,421	26.7	16.6	11.8
Transportation and storage	669	873	794	735	30.4	18.7	9.9
Housing	301	492	397	338	63.6	32.0	12.2
Information and communication	133	196	172	158	46.6	28.7	18.8
Business services	230	378	301	256	64.7	30.8	11.6
Other private services	452	731	615	557	61.6	36.1	23.3
Public goods and services	867	997	986	978	15.0	13.7	12.8
Real investment	1,469	1,473	1,411	1,389	0.3	-3.9	-5.4
Exchange rate (2014 YER per 1 USD)	215	243	231	213	13.3	7.3	-0.9

Source: CGE model simulations of the Yemeni economy by the authors.

Note: * Mining GDP is fixed across all scenarios due to the use of a Leontief production function (see Appendix 2).

In the case of best institutional performance, the country does not need additional external resources. In this low transfer scenario, the exchange rate is likely to stay depreciated as part of the macroeconomic recovery process. Consequently, export-oriented sectors, such as fishery (part of "Other agriculture"), livestock, fishery processing, and housing (including hotels), expand sales abroad. A weakened currency provides expanding opportunities for import-substitution in sectors such as cereals and non-food manufacturing. Furthermore, increasing household incomes expand the demand for non-tradable superior goods, such as information and communication technologies or other private services (Table A.2 in Appendix 2).

A deterioration of institutional performance implies a need for a higher level of aid transferred to households, potentially creating the risk of a countervailing appreciating exchange rate. This could adversely affect export expansion and import substitution opportunities, underpinning the need for

prioritizing investment in building institutional capacity during the recovery and reconstruction phase.⁸ However, not all economic sectors require the same level of institutional capacity to recover and grow. Agriculture is expected to be relatively resilient, while the performance of the industrial and services sectors is much more susceptible to the institutional performance of the country.

5 CONCLUSION

An economy-wide modeling approach was applied to simulate the impact of the conflict in Yemen between 2014 and 2018 and possible post-conflict development paths for the Yemeni economy. Using this approach, we analyzed in detail the repercussions of the conflict at the economic sector and household levels and investigated the potentially important challenges and opportunities for reconstruction planning. Several policy recommendations arise from this model-based analysis:

- The impact of the conflict devastated an already impoverished country. As a result of asset destruction, a sharp drop in oil exports, a halt to investment, and significant deterioration in institutional capacity, the recovery and the economy are best served by leveraging transformative reforms that are able to boost productivity.
- Prospects for Yemen's economic recovery are most optimistic if the Yemeni authorities and their international partners concentrate on improving the institutional factors associated with productivity growth and enhancing economic organization and value chain operations (private investment).
- To reach pre-conflict welfare (poverty) levels by 2024, if the institutional performance of the country remains poor, the need for foreign aid will remain high. Up to 3.2 billion USD yearly are estimated to be required alone for restoring the pre-conflict welfare level of Yemen's population. These costs are additional to those required for the reconstruction of economic assets.
- Investing in strengthening institutional factors can significantly and positively affect the structure of the Yemeni economy and its recovery trajectory. Poor governance and institutions restrain the development of the industrial and services sectors, while improved institutions will result in a more diversified economy, reducing its dependence on the hydrocarbon industry in the post-conflict period.

⁸ This finding is in line with the theory of a country's competitiveness, according to which poor institutional quality particularly restrains development of non-primary sectors in the economy (Schwab and Sala-i-Martin 2017).

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APPENDICES

Appendix 1: Adjustments to the social accounting matrix for Yemen

The original social accounting matrix (SAM) for Yemen by Raouf et al. (2019) has 159 accounts for 60 production activities or sectors, 64 commodities, 11 factors of production, 15 household types, and nine other institutional, tax, and savings or investment accounts. However, some accounts in the SAM for Yemen were incompatible with our theoretical, empirical, or computational approach. In particular:

- Certain commodities are reexported (export > domestic production);
- Certain commodities are pure import goods;
- Some specific sectors are tiny; and
- Public goods and services are produced and consumed by both private and public entities.

In order to avoid solving problems due to these incompatibilities, we perform the following adjustments:

- For commodities with the reexport problem, we net out imports;
- Sectors or commodities that are less than 1 percent of GDP or absorption are aggregated with the closest matching sectors or commodities; and
- Public goods and services are consumed and produced only by the public sector. This amendment allows us to emphasize that public goods and services should be outside of the consumers' demand system and that the prices of these specific goods are determined by production costs only.

The resulting SAM has 60 accounts – 20 representing activities, 20 representing commodities, 11 representing primary production factors, two representing households, and seven for other entries.⁹

⁹ The SAM is available from the authors upon request.

Appendix 2: Functional forms, closures, and parameterization of the CGE model

Production. We assume two-stage nested production functions with a constant elasticity of substitution (CES) for primary factors and a Leontief function for intermediate inputs at the bottom technology nests. For aggregate primary and aggregate intermediates at the top nest, Leontief functions are used.¹⁰

Trade. To model the degree of homogeneity of Yemeni products versus similar goods produced by the Rest of the World, we use the CES functions for import and constant elasticity of transformation (CET) functions for export products.¹¹

Consumption. We model the consumption side of the model via Linear Expenditure System (LES) functions. Most importantly, this functional form highlights the importance of subsistence consumption and, therefore, restricts the demand adjustment possibilities of the households. This factor is especially crucial for Yemen, where, according to pre-war estimates, over 48 percent of the population was below the national poverty line (World Bank 2017c).

Closure rules. The model closure rules are based on the closures defined in Diao and Thurlow (2012) and are tailored to adequately reflect the adjustment mechanisms of the Yemeni economy.

Terms of trade:

- The current account balance is fixed and given exogenously.
- The exchange rate of the Yemeni Rial is flexible.
- The consumer price index is fixed and chosen as model numeraire.

Consequently, terms of trade (real exchange rate) are mostly defined through the nominal exchange rate, domestic producers' prices, and world market prices.

Primary factors:

- During the conflict phase, we assume that:
 - Capital and land quantities are immobile across sectors and given exogenously, as discussed in Section 3.1;
 - Part of the labor force is unemployed.¹²
- For the post-conflict phase, we assume that:
 - Between years, new capital is mobile across sectors, and its distribution depends on the patterns of capital rent distribution paid by each sector – the 'putty-clay' assumption;
 - Land is fully-employed and immobile across sectors;
 - Until reaching the upper threshold of the available labor force (Table A.1), labor factors are unemployed. However, after reaching respective threshold levels, labor factors are fully-employed and mobile across sectors.

¹⁰ In order to explicitly control the export quantity of the mining (crude oil) sector, we assume Leontief technology for all nests. See Appendix 3.

¹¹ Export supply of mining (crude oil) is determined exogenously (by contract). See Appendix 3.

¹² This is in line with concerns expressed by the World Bank about job losses and growing unemployment during the conflict period (2019a).

Table A.1. Labor supply by skill level upper thresholds, thousands of workers, 2014 to 2024

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Rural uneducated	964	979	994	1,008	1,022	1,035	1,048	1,060	1,071	1,082	1,092
Rural secondary	2,870	2,916	2,960	3,002	3,043	3,082	3,119	3,155	3,189	3,222	3,252
Rural tertiary	129	131	133	135	136	138	140	141	143	144	146
Urban uneducated	404	422	440	459	478	497	517	537	558	579	600
Urban secondary	1,203	1,256	1,310	1,365	1,422	1,479	1,538	1,599	1,660	1,723	1,787
Urban tertiary	54	56	59	61	64	66	69	72	74	77	80

Source: World Bank 2020a (labor force by skill), and UN 2019b (rural and urban population growth projections)

Government budget:

- We assume exogenously determined government tax and subsidy rates, while government savings or investments adjust to available net revenues.

Savings and investment:

- We assume a neoclassical closure rule with the sum of private, government, and foreign savings defining total savings and investment.

Model parameters

We use external sources and approximations to assign initial model parameters (Table A.2):

- To assign production and trade elasticities, we use the GTAP 9 database (Aguiar et al. 2016);
- To assign income elasticities, we use estimates by Breisinger et al. (2011);
- To assign Frisch parameters, we use the method described by Lluch et al. (1977);

Table A.2. Initial production, trade, and income elasticity parameters, by sector

Sector	Production elasticities	Trade elasticities	Income elasticities	
			Rural households	Urban households
Cereals	0.2	3.6	0.3	0.4
Vegetables	0.2	1.9	0.5	0.7
Fruits	0.2	1.9	0.5	0.7
Other crops	0.2	3.3	1.1	1.1
Livestock products	0.2	1.3	1.0	0.6
Other agriculture	0.2	1.3	1.0	0.6
Mining	Leontief	5.2	1.8	2.3
Livestock and fishery production and processing	1.1	3.7	0.6	0.5
Fruit and vegetable processing	1.1	3.3	0.6	0.5
Other food and beverage processing	1.1	2.4	0.6	0.5
Other manufacturing	1.3	3.1	1.5	1.7
Utilities	1.3	-	0.9	0.7
Construction	1.7	1.9	1.0	0.8
Wholesale and retail trade	1.3	-	2.1	2.0
Transportation and storage	1.3	1.9	2.1	2.0
Housing	1.3	1.9	2.4	1.9
Information and communication	1.3	-	2.4	1.9
Business services	1.3	1.9	2.4	1.9
Other private services	1.3	1.9	2.4	1.9
Public goods and services	1.3	1.9	-	-
Frisch parameter (LES)	--	--	-5.5	-4.5

Source: Aguiar et al. 2016; Breisinger et al. 2011; Lluch et al. 1977.

- To assign population growth projections, we use the World Urbanization Prospects of the Population Division of the Department of Economic and Social Affairs of the United Nations (Table A.3).

Table A.3. Annual population growth projections for Yemen, rural and urban, 2015 to 2024, percent

Type	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Rural	1.60	1.51	1.43	1.35	1.28	1.21	1.15	1.08	1.02	0.96
Urban	4.39	4.30	4.22	4.13	4.06	3.99	3.92	3.85	3.78	3.71

Source: UN 2019b.

Appendix 3: Specification of shock parameters for the conflict period

Agricultural land. A direct estimate of cultivated land loss is provided by the FAO (2018: 9).

Capital stock. The most important parts of the Dynamic Needs Assessment report conducted by the World Bank in 2017/18 are stated in the Country Engagement note (World Bank 2019a: 7). In particular, the note states that:

- The housing sector suffered the worst damage, with 32 percent of houses partially damaged and 1 percent fully destroyed;
- Education, health, transport, and water supply, sanitation, and hygiene (WASH) sectors experienced damage ranging from 27 to 31 percent.

We then use the methodological conventions of standard Dynamic Needs Assessments of the World Bank according to which the costs of replacing destroyed assets are assessed at 100 percent, while those for partially damaged assets are assessed at 40 percent (World Bank 2017e: 5). Thus, we assume that the capital stock of the housing sector was reduced by $(32 \times 0.40) + (1 \times 1.00) = 13.8$ percent. For the costs of replacing destroyed assets for utilities, in the transport sector, and in the public sector, we use the median of the disclosed range of damage (27 to 31 percent), so assume that 29 percent of the capital of these sectors was damaged, resulting in an 11.6 percent capital loss (29×0.40) .

For the mining sector, we use the 90 percent estimate of the reduction of oil export earnings since 2014 (World Bank 2018c, Policy Note 2: 8). In order to achieve a similar reduction, we assume residual export function and control for the decrease of Leontief production through a reduction in the capital stock. Together with the reduction of world market prices, a 60 percent reduction in the capital stock leads to an 87 percent loss of export earnings in the mining sector in USD terms.

Foreign savings (current account deficit): We use the World Bank estimates (2017b, 2019c) on the Current Account Balance (percent of GDP) and calculate the change of the current account deficit from 2014 to 2018.

Multiplier for the economy-wide reduction of production elasticities. This parameter represents reduced functionality of the economy and institutional capacity. To specify it, we used the principle of a 'residual parameter'. In particular, we calibrated its value (–50 percent) such that all shocks together allow us to replicate the macroeconomic estimates of the World Bank. The main outcomes that were taken into account when calibrating this parameter are overall and sector-level GDP loss estimates given in the Economic Outlook for Yemen series published by the World Bank (see Section 3.2 for more details).

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