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SPATIAL PROPAGATION OF THE ECONOMIC IMPACTS OF BOMBING: THE CASE OF THE 2006 WAR IN LEBANON

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Spatial Propagation of the Economic Impacts of Bombing: The Case of the 2006 War in Lebanon

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Abstract. The event of the Israeli bombing in Lebanon in the summer of 2006 is a unique example of a recent man-made disaster. The bombing actions were concentrated in time – they lasted roughly one month so that the time frame is still considered short in an economic modeling sense; they were also spatially focused – they reached not only various targeted infrastructure points across the country, but also scattered locations in the south of the country. Economic impacts of disasters caused by natural or man-made hazards are complex and difficult to assess and evaluate, due to the features and uniqueness of disasters; however, some methodologies have been utilized to analyze their impacts. This paper aims to evaluate the short run economic effects of the July 2006 War using an interregional CGE model for Lebanon. We look at the economy of the country just before the War and estimate what would be the hypothetical economy-wide impact had the Lebanese regions faced a reduction of physical capital stocks in the same magnitude of the estimated damages associated with the bombing events. In doing that, we are able to derive the estimates of the economic costs of the war related to the structural break in the availability of economic infrastructure in the country. A discussion on resiliency is also introduced.

1. Introduction

On July 12, 2006, the conflict between Israel and Lebanon started and lasted five weeks. By the time the war ended, after the August 14 UN-brokered cease-fire came into effect, Lebanon had sustained enormous economic losses (Darwish et al., 2009; Raphaeli, 2009; Harris, 2012). Not only direct economic damages took place in the form of destruction of the physical capital, but also other severe damages to human and social capitals directly resulted from the conflict, known in Lebanon as the July 2006 War.[1] Damage to the economic infrastructure of the country was perceived mainly in the southern regions, where most of the bombings were concentrated (Figure 1). However, public and private properties were also damaged in other parts of the country, where strategic bombing from Israel took place.

[1] The July 2006 War resulted in more than 1,187 deaths, 4,398 injuries, and large-scale destruction of infrastructure (roads, bridges, water and electricity supplies), disruption of essential services, and displacement of over one million persons. In addition, 27 people were killed and 234 injured by unexploded ordnances (UXOs) after the war ended, as a consequence of the estimated 1.2 million cluster bombs that were scattered over the country during the final days of hostilities (CDR, 2008).

Main targets of the bombings were associated with important links and nodes in the transport infrastructure of the country, as well as key industrial facilities (Figures 2 and 3). Information on the bombed locations in July-August 2006 reveals not only a spatial pattern of localized disruption in infrastructure that covers the entire country, but also a concentration of scattered bombing in the southern governorates of Nabatieh and South Lebanon.

Capital stocks were severely ravaged. Bombing actions by the Israeli forces caused an estimated USD 1.1 billion of direct damage to the economic infrastructure of the country, in addition to USD 1.7 billion of damage in housing. Thus, total reconstruction costs were estimated by the Government to be in the order of USD 2.8 billion (Table 1). However, the overall impacts of the war on the economy, on social indicators and on employment were much greater. Based on the level of various indicators, the economy would have achieved an annual growth of at least 7% and 8% in the years 2006 and 2007, respectively (Council for Development and Reconstruction – CDR, 2008). However, the generated significant higher-order effects were not yet properly estimated.[2]

From a regional perspective, based on the preliminary assessment made by the Government, 117,661 housing and non-housing units, distributed over 354 villages and towns, were partially or severely damaged. The largest number of affected units was in the governorate of Nabatieh (50.5%), followed by South Lebanon (24.3%), Beirut area (20.6%), Bekaa (2.8%), Mount Lebanon (1.3%) and Northern Lebanon (0.6%).

[2] In a pioneering effort, Darwish et al. (2009) calculate that indirect losses may account for additional 80-90 percent of any estimate of direct loss in the agriculture sector.

Table 1. Estimated Reconstruction Costs

Sector	*Estimated direct damages (USD million)*
Economic sectors	*1,105*
Transportation	120
Electricity	160
Telecommunication	135
Water & wastewater	40
Health	15
Education	45
Industrial & commercial	380
Agriculture & irrigation	210
Housing	*1,700*
Total	**2,805**

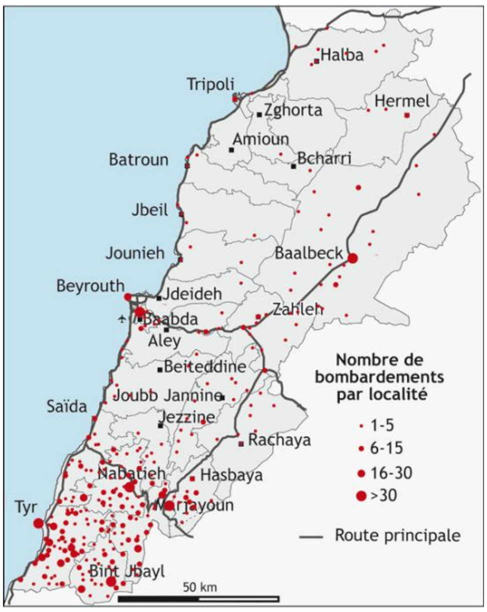
Source: CDR

Such estimates consider only the direct economic damage (value of lost assets) that led to interruptions of economic activities due to the destruction of capital stocks. Immediately after the War, resources for reconstruction were made available by the foreign donors.[3] From an economic perspective, two different driving forces came into play: at first, damage in the economic infrastructure generated a reduction in the capital stock available for production, negatively impacting the potential national GDP and gross regional product (GRP) of Lebanese governorates; secondly, reconstruction efforts operated in the opposite direction, activating investment-oriented activities (e.g. construction sector), starting more vigorously in 2007. This paper aims to evaluate the short run effects of the first of these two driving forces observed in Lebanon. We look at the economy of the country just before the War and estimate what would be the hypothetical economy-wide impact had the Lebanese regions faced a reduction of physical capital stocks in the same magnitude of the estimated damages associated with the bombing events. In doing that, we are able to derive the estimates of the economic costs of the war related to the structural break in the availability of economic infrastructure in the country. By not taking into account the effects of foreign transfers

[3] For further information on the recovery and reconstruction program, initiated in 2007, see CDR (2008).

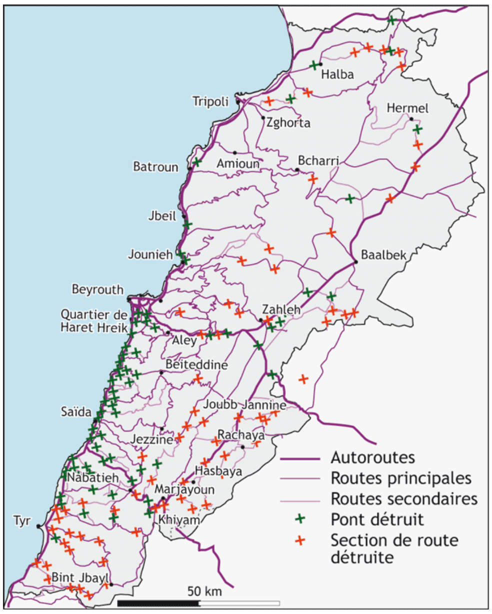
for reconstruction, we are also able to isolate the economic effects of the bombing and its spatial propagation providing a better approximation of the regional consequences of the targeted destruction.

Figure 1. Locations Bombed during July/August 2006



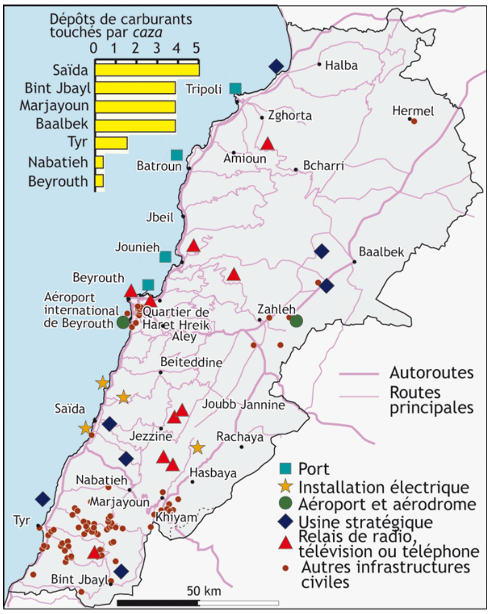
Source: Verdeil, Faour and Velut (2007)

Figure 2. Transport Infrastructure Affected during July/August 2006



Source: Verdeil, Faour and Velut (2007)

Figure 3. Other Vital Infrastructure Affected during July/August 2006



Source: Verdeil, Faour and Velut (2007)

2. Issues in the Modeling of Spatial and Economic Impacts of Bombing

Economic impacts of disasters caused by natural or man-made hazards are complex and difficult to assess and evaluate, due to the features and uniqueness of disasters; however, some methodologies have been utilized to analyze their impacts. There is considerable research addressing the persistent problem of natural disasters, such as floods, storms and earthquakes (Okuyama and Chang, 2012). However, human-induced or man-made disasters, including technological accidents and, especially in the wake of the 9/11 terrorism events, have not received much attention from economic impact analysts until recently.

From the perspective of social science, insights are needed into several fundamental questions at the intersection of economics and public policy, particularly in the context of massive bombing events. Carl von Clausewitz claimed that "war is a mere continuation of policy by other means." (Clausewitz, 1832) The consequences of a war would surely become a disaster (the definition of the term, "disaster", please see Okuyama and Chang, 2012); hence the economic impact of the disaster by a war should be considered as the (public) policy's consequences. In this regard, social science research has a critical role to unfold the extent and significance of the economic impact by a war.

As mentioned earlier, the concepts and methodologies for analyzing the economic impact of disasters caused by natural hazards have been progressed considerably in the recent decades. Meanwhile, there had been a limited number of studies on the economic impact of war, due mainly to the confidentiality of war operations. This dearth of research may have been changed since the occurrence of the 9/11 terrorist attacks in the US in 2001. In those researches, the costs of countermeasures against such terrorist attacks are often compared with the economic impacts of such event. Therefore, a series of hypothetical estimations have been performed using the similar methodologies employed for disasters by natural hazards.

Input-output (IO), social accounting matrix (SAM), and computable general equilibrium (CGE) models are the usual tool kits that have been employed more often to estimate the higher-order effects of a disaster.[4] As proposed by Rose (2004), "higher-order effects" should cover all flow losses beyond those associated with the curtailment of output as a result of hazard-induced property damage in the producing facility itself, including input-output linkages and general equilibrium price effects. In an integrated interregional system, it should also cover spatial interdependence effects.

Rose (2004) also observes that the size of higher-order effects can be quite variable depending on the resiliency of the economy, i.e. the ability an economy has to cushion potential losses from a hazard. Resiliency is considered in our modeling exercise in two ways: (i) it is embedded in the possibility of importing more goods and services from other Lebanese regions and also from abroad, in the event a long-standing supplier is temporarily out of business; and (ii) it bears also in the modeling of the optimal mix of inputs in the regional production functions. A sector or region is considered to be more resilient to post-disaster higher-order effects the easier are both the access to alternative suppliers outside the damaged areas and the more flexible are the production functions in terms of input substitution possibilities.

The event of the Israeli bombing in Lebanon in the summer of 2006 is a unique example of a recent man-made disaster. The bombing actions were concentrated in time – they lasted roughly one month so that the time frame is still considered short in an economic modeling sense; they were also spatially focused – they reached not only various targeted infrastructure points across the country, but also scattered locations in the south of the country. Thus, the impact analysis of the July 2006 War provides an opportunity to address some of the issues raised above. It also adds to the literature as regional economic impacts of bombings have received relatively little attention from research communities.[5]

[4] More detailed discussion and empirical applications of different methodologies can be found in Okuyama (2007).

[5] The scarce literature on the regional economic impacts of bombings has focused so far on longer run issues, such as long-run development (Miguel and Roland, 2011); regional distribution of population and city-size (Davis and Weinstein, 2008); and long-run city growth (Brakman et al., 2004).

3. The ARZ Model

In this paper we use the ARZ model, the first fully operational spatial CGE model for Lebanon. We use an approach to incorporate the spatial structure that is similar to Haddad and Hewings (2005). Experimentation with the introduction of Marshallian scale economies and trade costs provide innovative ways of dealing explicitly with theoretical issues related to integrated regional systems. The model used in this research is designed for policy analysis. Agents' behavior is modeled at the regional level, accommodating variations in the structure of regional economies. Regarding the regional setting, the main innovation in the ARZ model is the detailed treatment of interregional trade flows in the Lebanese economy, in which the markets of regional flows are fully specified for each origin and destination. The model recognizes the economies of the six Lebanese governorates. Results are based on a bottom-up approach – i.e. national results are obtained from the aggregation of regional results. The model identifies 8 production/investment sectors in each region producing 8 single commodities (Table 2), one representative household in each region, one government, and a single foreign area that trades with each domestic region. Two local primary factors are used in the production process, according to regional endowments (capital and labor). Special groups of equations define capital accumulation relations. The model is structurally calibrated for 2004-2005; a rather complete data set is available for 2005, which is the year of the publication of the national input-output tables that served as the basis for the estimation of the interregional input-output database. Additional structural data from the period 2004-2005 complemented the database.[6]

The ARZ model qualifies as a Johansen-type model in that the solutions are obtained by solving the system of linearized equations of the model, following the Australian tradition (Dixon et al., 1982). A typical result shows the percentage change in the set of endogenous variables, after a policy is carried out, compared to their values in the absence of such policy, in a given environment. The schematic presentation of Johansen solutions for such models is standard in the literature. More details can be found in Dixon and Parmenter (1996).

[6] See Haddad (2012) for a detailed description of the database.

Table 2. Sectors in the ARZ Model

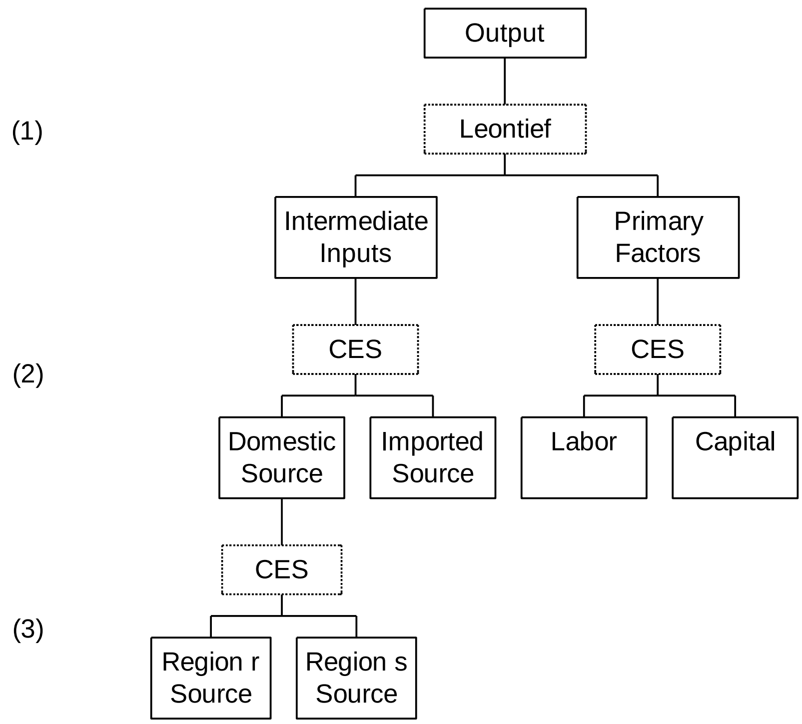
1. Agriculture and livestock
2. Energy and water
3. Manufacturing
4. Construction
5. Transport and communication
6. Other services
7. Trade
8. Administration

3.1. Overview

The basic structure of the ARZ model is very standard and comprises three main blocks of equations determining demand and supply relations, and market clearing conditions. In addition, various regional and national aggregates, such as aggregate employment, aggregate price level, and balance of trade, are defined. Nested production functions and household demand functions are employed.

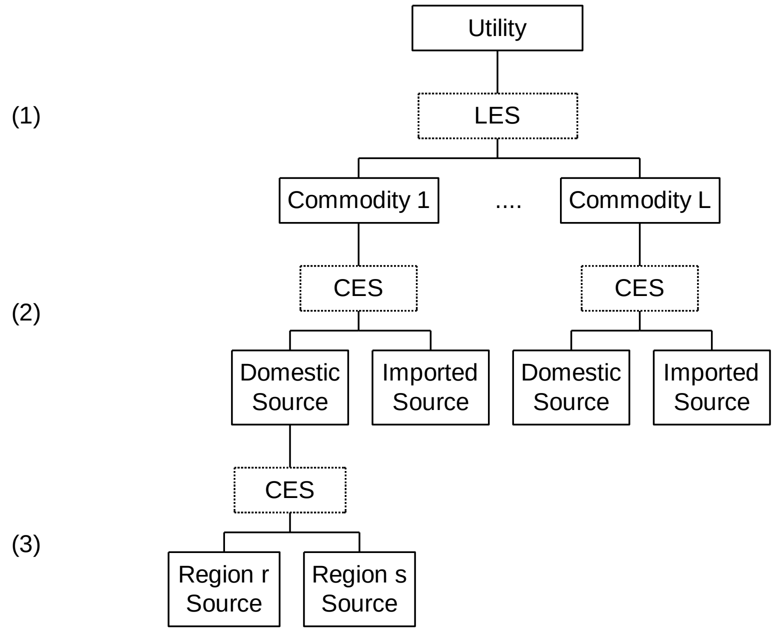
Firms are assumed to use fixed proportion combinations of intermediate inputs and primary factors in the first level while, in the second level, substitution is possible between domestically produced and imported intermediate inputs, on the one hand, and between capital and labor, on the other. At the third level, bundles of domestically produced inputs are formed as combinations of inputs from different regional sources (Figure 4). The modeling procedure adopted in the ARZ model uses a constant elasticity of substitution (CES) specification in the lower levels to combine goods from different sources. Given the property of standard CES functions, non-constant returns are ruled out. One can modify assumptions on the parameters values in order to introduce external scale economies of the Marshallian type. Changes in the sectoral production functions are easily implemented in order to incorporate non-constant returns to scale, a fundamental assumption for the analysis of integrated interregional systems. To do so, we keep the hierarchy of the nested CES structure of production, which is very convenient for the purpose of calibration (Bröcker, 1998), but we modify the hypotheses on parameters values, leading to a more general form. Non-constant returns to scale can be introduced in the group of equations associated with primary factor demands within the nested structure of production. The sectoral demand for the primary factor composite (in region r), y, relates to the total output, z, in the following way: $y = Az^{\rho}$, with the technical coefficient A, and the parameter ρ specific to sector j in region r. This modeling procedure allows for the introduction of Marshallian agglomeration (external) economies, by exploring local properties of the CES function.

Figure 4. Nesting Structure of Regional Production Technology



The treatment of the household demand structure is based on a nested CES/linear expenditure system (LES) preference function (Figure 5). Demand equations are derived from a utility maximization problem, whose solution follows hierarchical steps. The structure of household demand follows a nesting pattern that enables different elasticities of substitution to be used. At the bottom level, substitution occurs across different domestic sources of supply. Utility derived from the consumption of domestic composite goods is maximized. In the subsequent upper-level, substitution occurs between domestic composite and imported goods.

Figure 5. Nesting Structure of Regional Household Demand



Equations for other final demand for commodities include the specification of export demand and government demand. Exports face downward sloping demand curves, indicating a negative relationship with their prices in the world market. The nature of the input-output data enables the isolation of the consumption of public goods by the government. However, productive activities carried out by the public sector cannot be isolated from those by the private sector. Thus, government entrepreneurial behavior is dictated by the same cost minimization assumptions adopted by the private sector.

A unique feature of the ARZ model is the explicit modeling of the costs of moving products based on origin-destination pairs according to the allocation of trade margins. The model is calibrated taking into account the specific trade structure cost of each commodity flow, providing spatial price differentiation, which indirectly addresses the issue related to regional transportation infrastructure efficiency. Such structure is physically constrained by the available transportation network, modeled in a stylized geo-coded transportation module.[7]

[7] Spatial friction was approximated by distance measures, calculated for each pair of origin-destination using Google Maps.

The set of equations that specify purchasers' prices in the ARZ model imposes zero pure profits in the *distribution* of commodities to different users. Prices paid for commodity *i* from source *s* in region *q* by each user equate to the sum of its basic value and the trade costs associated with the use of the relevant margin-commodity. The role of the margin-commodity is to facilitate flows of commodities from points of production or points of entry to either domestic users or ports of exit. The margin-commodity, or, simply, margin, includes trade services, which take account of transfer costs in a broad sense.[8] The margin demand equations in the model show that the demands for margins are proportional to the commodity flows with which the margins are associated; moreover, a technical change component is also included in the specification in order to allow for changes in the implicit trade rate.[9]

Other definitions in the CGE core module include: basic and purchase prices of commodities, components of real and nominal GRP/GDP, regional and national price indices, money wage settings, factor prices, employment aggregates, and capital accumulation relations.[10]

3.2. Structural Database

The CGE database requires detailed sectoral and regional information about the Lebanese economy. Haddad (2012) reports on the recent developments in the construction of the interregional input-output system for Lebanon (IIOM-LIBAN) used in the process of calibration of the structural coefficients of the ARZ model. A fully specified interregional input-output database was developed, under conditions of limited information, as part of an initiative involving researchers from the Regional and Urban Economics Lab at the University of São Paulo (NEREUS).

3.3. Behavioral Parameters

Empirical estimates of the key behavioral parameters of the ARZ model are not available in the literature. We have thus relied on "best guesstimates" based on usual

[8] Hereafter, trade services and margins will be used interchangeably.
[9] In the case of international imported goods, the implicit trade margin may be interpreted as the costs at the port of entry, while for foreign exports it would refer to costs at the port of exit.
[10] The detailed system of equations of the ARZ model is available in an appendix.

values used in similar models. Parameter values for international trade elasticities, σ's in equation (A2) in the appendix, were set to 1.5; regional trade elasticities, σ's in equation (A1), were set at the same values as the corresponding international trade elasticities. Substitution elasticity between primary factors, σ's in equation (A3), was set to 0.5. Scale economies parameters, μ's in equation (A4), were set to one in all sectors and regions, denoting constant returns to scale. The marginal budget share in regional household consumption, β's in equation (A5), were calibrated from the input-output data, assuming the average budget share to be equal to the marginal budget share. We have set to -2.0 the export demand elasticities, η's in equation (A7).

4. Simulation

The ARZ model is used to simulate the short run impacts of the July 2006 War in Lebanon. The model is applied to analyze the effects of reductions in sectoral capital stocks in the regions according to official information on direct damages.[11] All exogenous variables are set equal to zero, except the changes in the affected capital stocks (Figure 6). South Lebanon and Nabatieh were the most affected governorates, with considerable damages in agriculture, manufacturing, transportation & communication and public facilities. Beirut also presented significant damages, especially in the manufacturing, and transportation & communication sectors. The energy sector in South Lebanon and, to a lesser extent, in Bekaa, also suffered damages.

Results of the simulation were computed via a 2-4-6 Gragg procedure with extrapolation, under a short-run closure (exogenous capital stocks). Uncertainty about key trade elasticities was also considered through qualitative sensitivity analysis, in an attempt to look at the potential range of the total costs under different degrees of resilience (both technological and spatial). It was assumed a fixed low degree of technological resiliency (low values for the elasticities of substitution of primary inputs) – consistent with a less complex and diversified economy – together with a spectrum of spatial resiliency (substitution of suppliers). We have altered the regional and international substitution elasticities to model the economy under different (unknown)

[11] Declines in regional sectoral capital stocks were computed based on information provided by CDR (2008) on the estimated damages in sectoral economic infrastructure, and the regional distribution of damaged transport and other vital infrastructure units.

scenarios of adjustment following the bombings. Departing from the initial set of substitution elasticities used to calibrate the benchmark Lebanese economy – described in the previous section –, we have exogenously introduced different sets of elasticities to evaluate substitution possibilities for the regional economies in different resiliency settings. As suggested by Rose and Guha (2004), this procedure mimics the reaction of the economy with the assumption that resiliency is built in the adjustment process.

We imposed the same reduction in capital stocks to reflect the supply losses under different sets of substitution elasticities. For the base case with the initial set of parameter values in the ARZ model, national GDP decreases by 6.26% (Table 3).[12] In regional terms, the Nabatieh region is the most affected, with a GRP decrease over -50%. South Lebanon region is second, with total losses accounting for a little over -14% of GRP. The least affected regions are Mount Lebanon, Northern Lebanon and Bekaa, with GRP losses in the rough magnitude of of -2%. Finally, total impact in the capital area is estimated in -4.61% of its 2005 GRP.

In money values, the total impact in the Lebanese economy is estimated to be USD 1,644 million in the base case simulation, for a direct damage of USD million 1,105, so that the associated total impact-damage ratio is 1.49 in the short run.

The results presented in Table 4 indicate the simulated sectoral impacts. The largest impacts occurred in the production of the energy and water sector, whose producing facilities and distribution lines were targeted by the bombings.[13] Manufacturing and agriculture presented also great losses, not only because of direct damages to factories and farms, but also because of disruption in the transportation infrastructure – modeled as increasing trade costs in the country due to damage in the available infrastructure (bridges and roads). As tradable goods, increasing transaction costs in space hampered

[12] As a reference for heuristic validation of our aggregate results, we can look at the indirect costs reported by Raphaeli (2009) in terms of the real GDP growth rate in 2006, the year of the war. Accordingly, Lebanese real GDP growth, which had achieved a rate of 5-6 percent in the first half of 2006 ended the year on the negative side with a decline of 5 percent, representing a loss of output in 2006 in the order of USD 2.2 billion (at 2005 prices). However, no estimate at the regional and sectoral levels was provided.

[13] Power plants and fuel tanks have been targeted: the supply of the South was totally disrupted and the rest of the country experienced rationing. Several water reservoirs and pipes were affected, and, in the absence of electricity, water supply in the South was cut. Deficiencies of these two services are the main cause of deterioration of the material situation in the localities in the South (Verdeil, Faour and Velut, 2007).

sectoral competitiveness. Additionally, non-tradable sectors (i.e. services sectors) were also negatively affected due to a reduction in real income caused by the general increase in prices, that also hampered Lebanese competitiveness in foreign markets.

Figure 6. Estimated Damage of Capital Stocks, by Sector and Region (in percentage change from pre-War estimates)

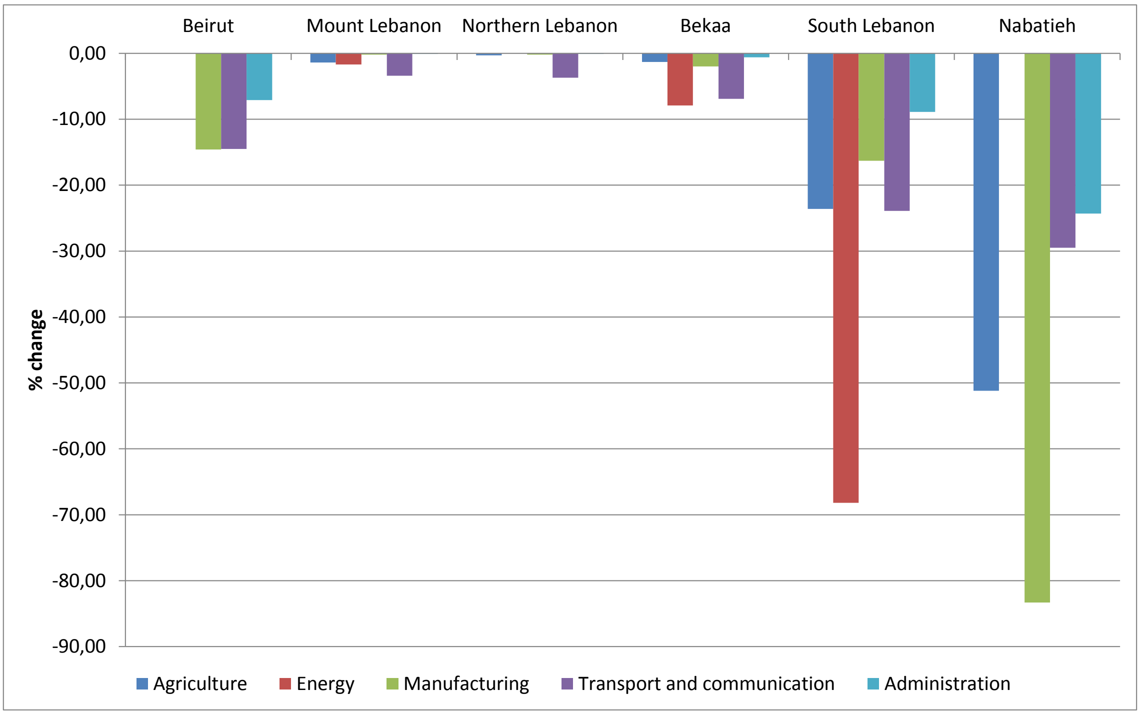


Table 3. Macro-regional Effects: GDP/GRP effects (in percentage change)

Beirut	-4.61
Mount Lebanon	-2.44
Northern Lebanon	-2.05
Bekaa	-2.21
South Lebanon	-14.43
Nabatieh	-50.15
Lebanon	**-6.26**

Table 4. Sectoral Effects: Activity level (in percentage change)

1. Agriculture and livestock	-17.89
2. Energy and water	-44.15
3. Manufacturing	-30.51
4. Construction	-4.48
5. Transport and communication	-7.81
6. Other services	-2.84
7. Trade	-1.81
8. Administration	-5.14

Figure 7 presents the surface of total damage in terms of national GDP, considering different scenarios of resiliency. Similar surfaces are presented for regional (Figure 8) and sectoral (Figure 9) damage surfaces. GDP impacts range from -17.8% to -4.2%, with increasing levels of resiliency generating lower GDP losses. Noteworthy is that, given its high external dependency and its low internal complexity, the Lebanese economy is more sensitive to lower levels of substitutability with foreign products. In the scenarios with better access to international suppliers, the post-bombing adjustment process is favored, suggesting smaller losses with greater international responses to the production shortages in the country. The shape of the surface also suggests a non-linearity as the scenarios approach a "Leontief world", in which less flexible substitutability alternatives prevail. At the regional level, Nabatieh, the governorate that was more severely damaged by the bombing attacks, seems to be also pretty much sensitive to regional trade elasticities scenarios (Figure 8), given its relatively high dependence upon the core regions of the country. In sectoral terms, access to regional markets of final manufactured goods produced in Lebanon is responsible for a greater sensitivity of the manufacturing sector to lower degrees of resiliency also at the regional level (Figure 9).

Finally, Figure 10 presents the total impact, in USD terms, and Figure 11 presents the total impact-damage ratio, both under different assumptions of regional resiliency. Given the different sets of regional and international trade elasticities, total impact of bombing was in the range of USD million 1,138 to 5,521. With the estimated direct damage equivalent to USD million 1.105, total impact-damage ratio ranges from 1.03 to 5.00.

The main shock absorbers are related to access to alternative suppliers and markets. The impact of different scenarios of resiliency can also be perceived in Figure 12, which illustrates the impacts of both interregional and international trade flows in the post-bombing equilibrium. The information is presented in arrows that indicate (i) the direction of flows, for each pair of origin-destination; (ii) the direction of changes – blue relates to increases in the flows while red indicates decreases; and (iii) the intensity of the changes in the flows, given by the thickness of the arrows. In the two resiliency cases that were considered, it is clear the role played by the interactions with the international markets in the higher degree of resilience case, acting as a mechanism to minimize the negative impacts associated with regional production disruptions in the bombed areas. As the possibilities of substitution diminish, the regional Lebanese economies become less prone to mitigate the economic losses through trade deviation.

Figure 7. Total Damage Surface under Different Assumptions of Regional Resiliency, Lebanon (in percentage change in GDP)

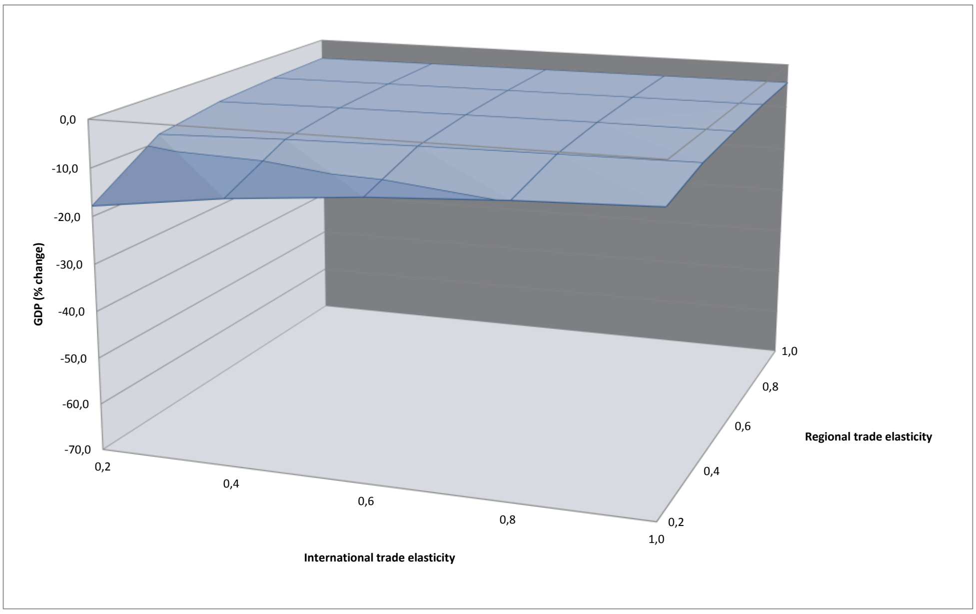
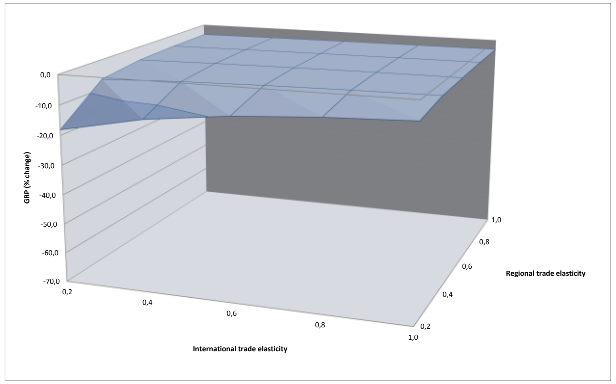
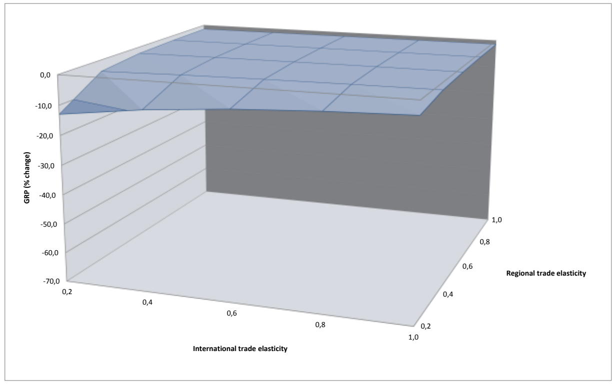


Figure 8. Regional Damage Surfaces under Different Assumptions of Regional Resiliency, by Governorate (in percentage change in GRP)

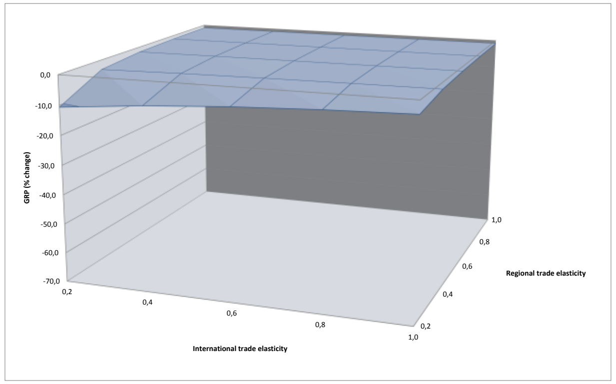
Beirut



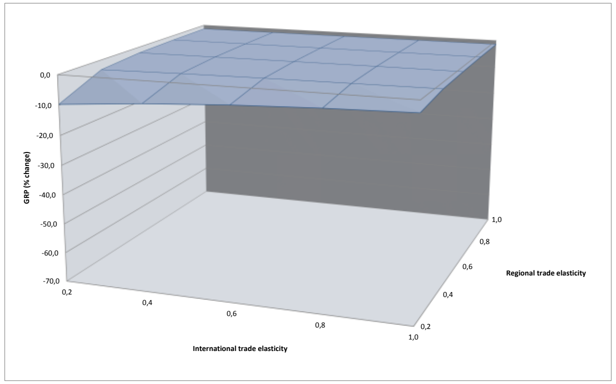
Mount Lebanon



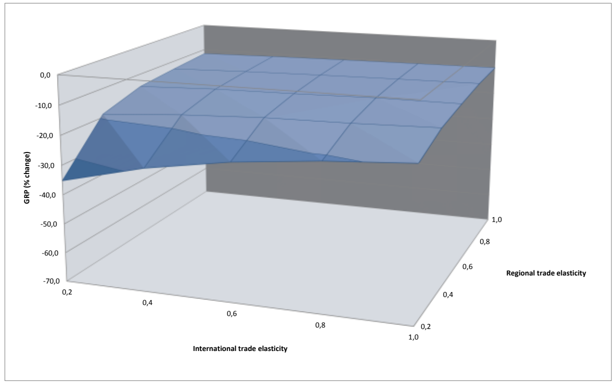
Northern Lebanon



Bekaa



South Lebanon



Nabatieh

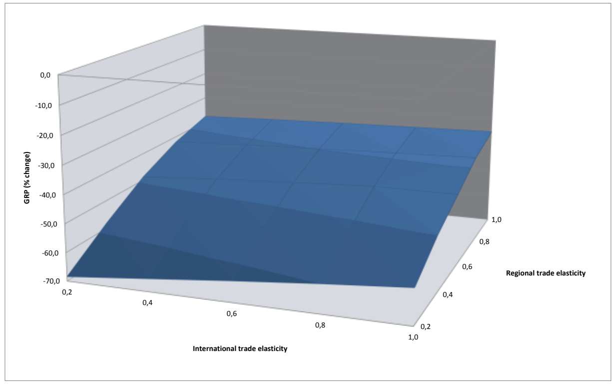
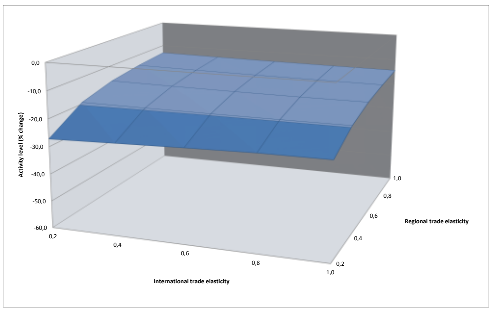
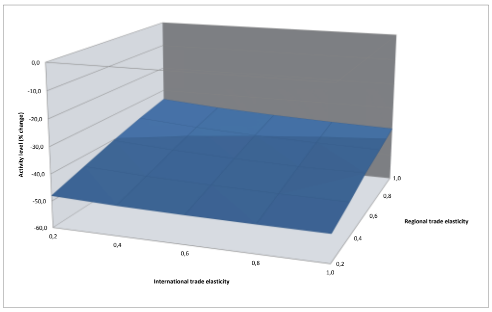


Figure 9. Sectoral Damage Surfaces under Different Assumptions of Regional Resiliency, by Governorate (in percentage change in activity level)

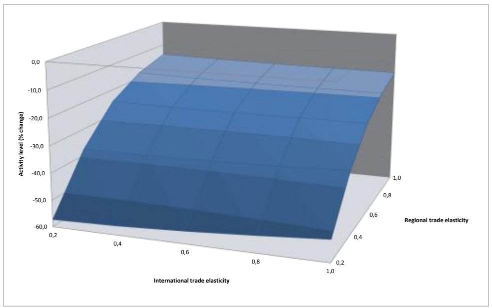
Agriculture



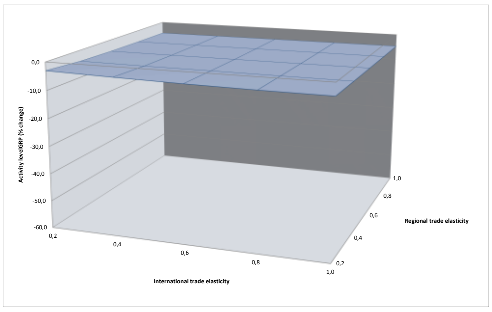
Energy and Water



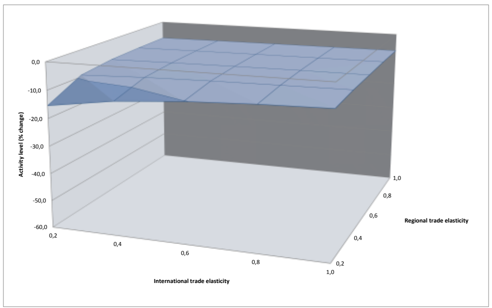
Manufacturing



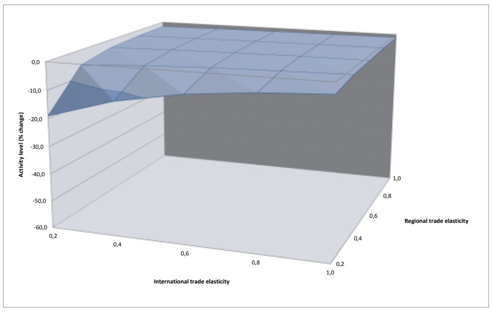
Construction



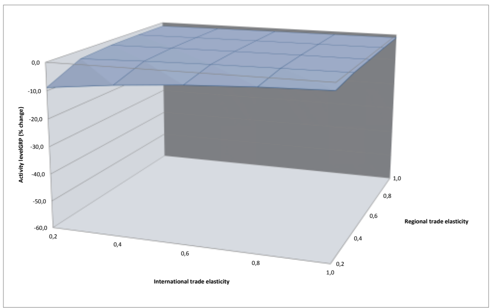
Transport and Communication



Other Services



Trade



Administration

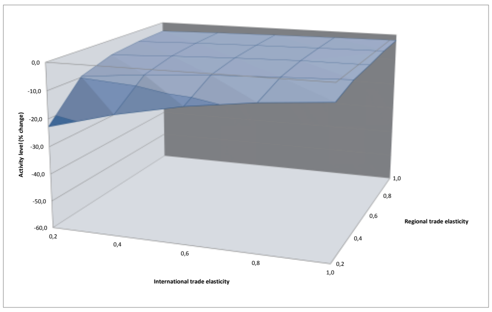


Figure 10. Total Impact under Different Assumptions of Regional Resiliency (in USD million)

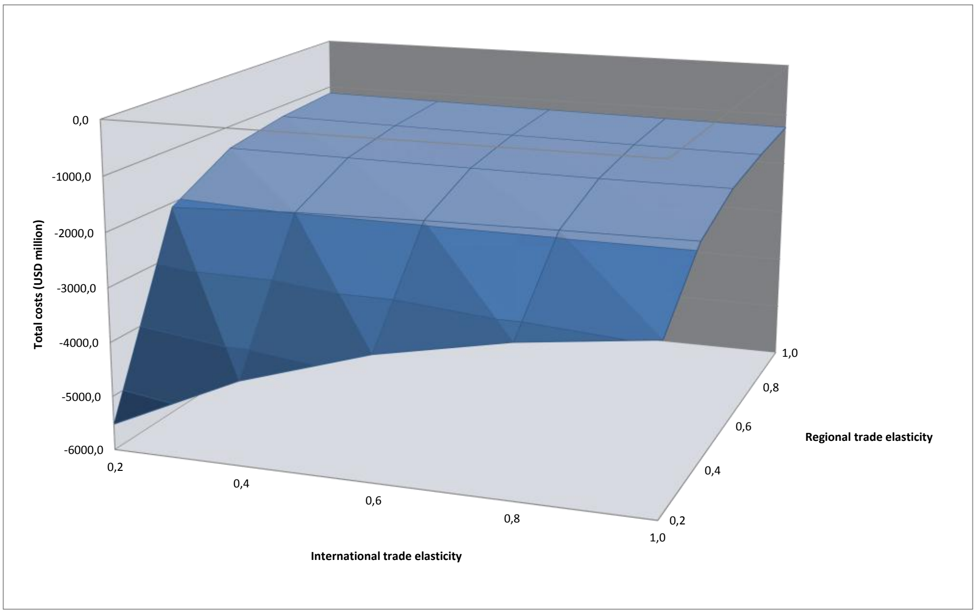


Figure 11. Total Impact-Damage Ratio under Different Assumptions of Regional Resiliency

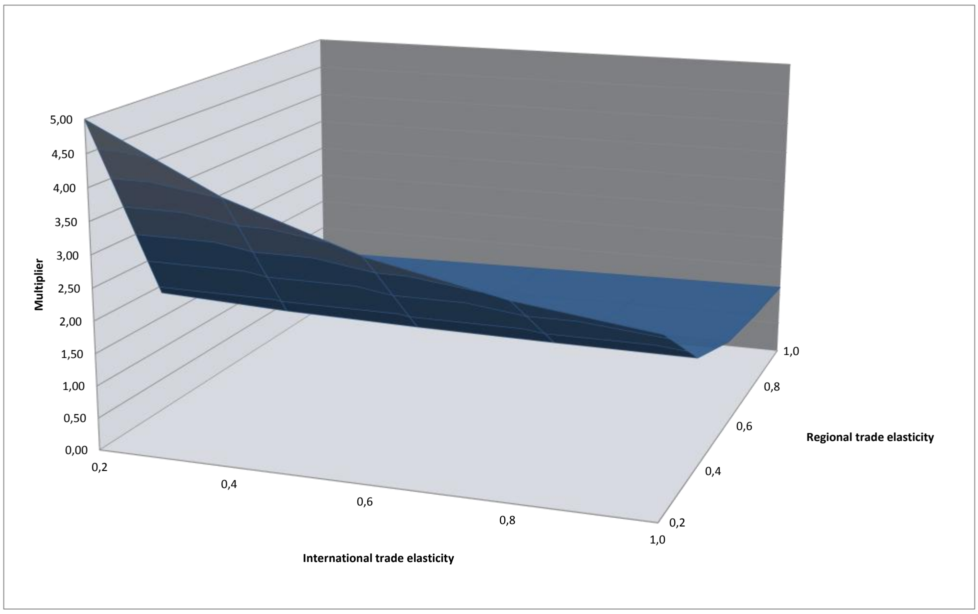
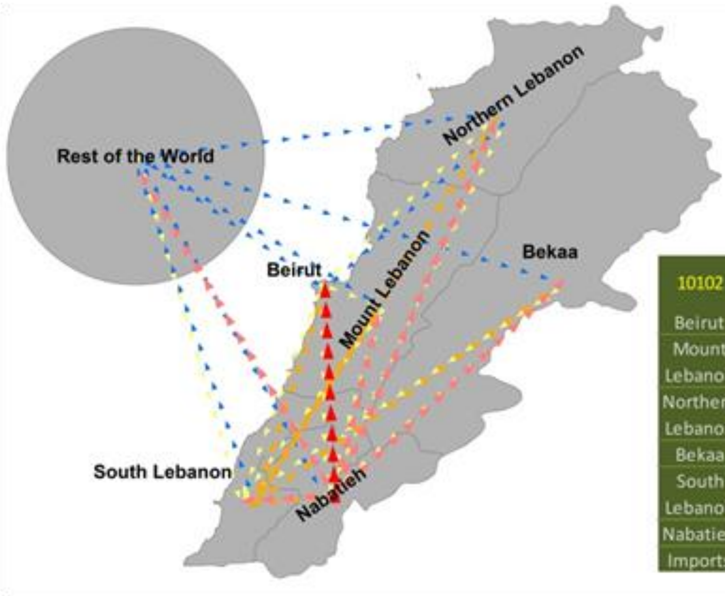


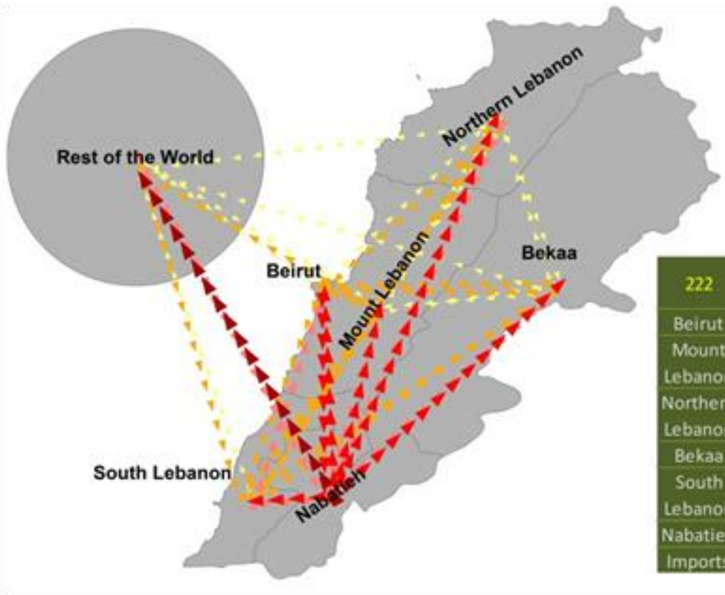
Figure 12. Impacts on International and Interregional Trade Flows

Higher degree of resilience



10102	Beirut	Mount Lebanon	Northern Lebanon	Bekaa	South Lebanon
Beirut	-4,2	-5,6	-5,2	-3,8	-7,2
Mount Lebanon	-0,2	-1,3	-0,9	-1,3	-5,5
Northern Lebanon	0,4	-0,3	-1,4	-1,0	-0,6
Bekaa	-0,4	-0,8	-1,2	-2,0	-6,7
South Lebanon	-23,7	-19,5	-24,0	-21,0	-11,3
Nabatieh	-55,8	-54,9	-53,2	-49,1	-54,8
Imports	1,2	2,1	1,6	0,8	-7,9

Lower degree of resilience



222	Beirut	Mount Lebanon	Northern Lebanon	Bekaa	South Lebanon
Beirut	-16,6	-11,1	-9,4	-10,2	-18,1
Mount Lebanon	-15,5	-11,8	-7,1	-8,4	-15,7
Northern Lebanon	-14,6	-8,0	-10,3	-7,7	-13,5
Bekaa	-14,2	-8,4	-7,4	-9,7	-19,9
South Lebanon	-31,5	-26,8	-29,1	-26,0	-35,4
Nabatieh	-63,0	-61,6	-59,6	-55,1	-65,1
Imports	-7,0	-7,8	-5,7	-5,6	-20,6

5. Concluding Remarks

The economic infrastructure in Lebanon presents low capacity to easily absorb an exogenous shock that destroys linkages in the production chain, creating an environment of uncertainty for those dependent on local suppliers and local markets. Moreover, because it can be considered as a developing economy due to the lack of redundancy in its economic infrastructure, i.e. the inability to have alternatives to solve the given problem of logistics, communications or energy, Lebanon tended to suffer more severely the impacts of the War. In our modeling exercise, given the conditions of limited information that prevail in Lebanon, the lack of behavioral parameters to properly calibrate the model brings further uncertainty for the simulation results. The default value used for the Armington elasticities in the ARZ model – identified as the analytically most important parameters in generating the model outcomes was in accordance with the estimates in the prevailing literature. Nonetheless, it denotes stronger substitution possibilities than a small, specialized economy such as Lebanon would potentially face. Resilience, in the form of substitution possibilities, is intrinsically related to the complexity and diversity of an economy's production structure. It seems to us that the "right" magnitude of such set of parameters for Lebanon would be much lower than that used in the benchmark, leading to an approximate value of the economic costs of the July War closer to the upper bound of our estimates.

As discussed in Section 2, the economic impacts from man-made hazards, such as this 2006 bombing may appear similar to natural hazards', thus the similar methodologies and analytical framework can be employed, since wars and natural hazards share some common features, such as physical destructions, uneven damages over space, human casualties, among others. What may become different between them are: 1) the occurrence of a man-made hazard can be avoided via diplomatic and/or international efforts; 2) location of damages can be determined strategically, rather than unexpectedly by natural hazards; and 3) the consequences of a hazard, thus the disaster, can be premeditatedly determined. Subsequently, the use of the results from such research may well be different: analysis of disaster's economic impact by a natural hazard has been used to evaluate the countermeasures for mitigating such economic impacts; on the other hand, studies of economic impacts of a war, like this paper, to investigate the cost of such war, deriving the opportunity cost (benefit) to avoid such event. This is one of the objectives in this paper and our hope for the future.

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Appendix. The Equation System of the ARZ Model

The functional forms of the main groups of equations of the spatial CGE core are presented in this Appendix together with the definition of the main groups of variables, parameters and coefficients.

The notational convention uses uppercase letters to represent the levels of the variables and lowercase for their percentage-change representation. Superscripts *(u), u = 0, 1j, 2j, 3, 4, 5*, refer, respectively, to output *(0)* and to the five different regional-specific users of the products identified in the model: producers in sector *j (1j)*, investors in sector *j (2j)*, households *(3)*, purchasers of exports *(4)*, and government *(5)*; the second superscript identifies the domestic region where the user is located. Inputs are identified by two subscripts: the first takes the values *1, ..., g*, for commodities, *g + 1*, for primary factors, and *g + 2*, for "other costs" (basically, taxes and subsidies on production); the second subscript identifies the source of the input, being it from domestic region *b (1b)* or imported *(2)*, or coming from labor *(1)* or capital *(2)*. The symbol (•) is employed to indicate a sum over an index.

Equations

(A1) Substitution between products from different regional domestic sources

$$x_{(i(1b))}^{(u)r} = x_{(i(1\bullet))}^{(u)r} - \sigma_{(i)}^{(u)r}\,(p_{(i(1b))}^{(u)r} - \sum_{l \in S^*}(V(i,1l,(u),r)/V(i,1\bullet,(u),r)(p_{(i(1l))}^{(u)r}))$$

$i = 1,...,g;\ b = 1,...,q;\ (u) = 3$ and (kj) for $k = 1$ and 2 and $j = 1,...,h; r = 1,...,R$

(A2) Substitution between domestic and imported products

$$x_{(is)}^{(u)r} = x_{(i\bullet)}^{(u)r} - \sigma_{(i)}^{(u)r}\,(p_{(is)}^{(u)r} - \sum_{l=1\bullet,2}(V(i,l,(u),r)/V(i,\bullet,(u),r)(p_{(il)}^{(u)r}))$$

$i = 1,...,g;\ s = 1\bullet$ and $2;\ (u) = 3$ and (kj) for $k = 1$ e 2 and $j = 1,...,h; r = 1,...,R$

(A3) Substitution between labor and capital

$$x^{(1j)r}_{(g+1,s)} - a^{(1j)r}_{(g+1,s)} = \alpha^{(1j)r}_{(g+1,s)} x^{(1j)r}_{(g+1\bullet)} - \sigma^{(1j)r}_{(g+1)} \{ p^{(1j)r}_{(g+1,s)} + a^{(1j)r}_{(g+1,s)}$$
$$- \sum_{l=1,2} (V(g+1,l,(1j),r)/V(g+1,\bullet,(1j),r))(p^{(1j)r}_{(g+1,l)} + a^{(1j)r}_{(g+1,l)})\}$$

$j = 1,...,h;\ \ s = 1$ and $2;\ r = 1,..., R$

(A4) Intermediate and investment demands for composites commodities and primary factors

$$x^{(u)r}_{(i\bullet)} = \mu^{(u)r}_{(i\bullet)} z^{(u)r} + a^{(u)r}_{(i)}$$

$u = (kj)$ for $k = 1, 2$ and $j = 1,..., h$
if $u = (1j)$ then $i = 1,..., g+2$
if $u = (2j)$ then $i = 1,..., g;$
$r = 1,..., R$

(A5) Household demands for composite commodities

$$V(i,\bullet,(3),r)(p^{(3)r}_{(i\bullet)} + x^{(3)r}_{(i\bullet)}) =$$
$$\gamma^{r}_{(i)} P^{(3)r}_{(i\bullet)} Q^{r} (p^{(3)r}_{(i\bullet)} + x^{(3)r}_{(i\bullet)}) + \beta^{r}_{(i)} (C^{r} - \sum_{j\in G} \gamma^{r}_{(j)} P^{(3)r}_{(i\bullet)} Q^{r} (p^{(3)r}_{(i\bullet)} + x^{(3)r}_{(i\bullet)}))$$

$i = 1,\ldots, g;\ r = 1,..., R$

(A6) Purchasers' prices related to basic prices and margins (trade costs)

$$V(i,s,(u),r)\, p^{(u)r}_{(is)} = (B(i,s,(u),r) + \sum_{m\in G} M(m,i,s,(u),r) p^{(0)r}_{(m1)},$$

$i = 1,..., g;\ (u) = (3), (4), (5)$
and (kj) for $k = 1, 2$ and $j = 1,..., h;\ s = 1b, 2$ for $b = 1,..., q$
$r = 1,..., R$

(A7) Foreign demands (exports) for domestic goods

$$(x^{(4)r}_{(is)} - fq^{(4)r}_{(is)}) = \eta^{r}_{(is)} (p^{(4)r}_{(is)} - e - fp^{(4)r}_{(is)}) \ , \qquad i = 1,...,g;\ s = 1b, 2 \text{ for } b = 1,..., q;\ r = 1,..., R$$

(A8) Government demands

$$x^{(5)r}_{(is)} = x^{(3)r}_{(\bullet\bullet)} + f^{(5)r}_{(is)} + f^{(5)r} + f^{(5)} \qquad i = 1,...,g;\; s = 1b,2 \text{ for } b = 1,...,q; \text{r} = 1,..., \text{R}$$

(A9) Margins demands for domestic goods

$$x^{(is)(u)r}_{(m1)} = x^{(u)r}_{(is)} + a^{(is)(u)r}_{(m1)} \qquad \begin{array}{l} m, i = 1,...,g; \\ (u) = (3), (4b) \text{ for } b = 1,...,r, (5) \text{ and } (kj) \text{ for } k = 1, 2; \\ j = 1,...,h;\; s = 1b, 2 \text{ for } b = 1,...,r; \\ r = 1,...,R \end{array}$$

(A10) Demand equals supply for regional domestic commodities

$$\sum_{j\in H} Y(l, j, r) x^{(0j)r}_{(l1)} = \sum_{u\in U} B(l,1,(u),r) x^{(u)r}_{(l1)} + \sum_{i\in G}\sum_{s\in S}\sum_{u\in U} M(l,i,s,(u),r) x^{(is)(u)r}_{(l1)} \qquad l = 1,...,g; r = 1,...,R$$

(A11) Regional industry revenue equals industry costs

$$\sum_{l\in G} Y(l, j, r)(p^{(0)r}_{(l1)} + a^{(0)r}_{(l1)}) = \sum_{l\in G^*}\sum_{s\in S} V(l, s, (1j), r)(p^{(1j)r}_{(ls)}), \quad j = 1,...,h; r = 1,...,R$$

(A12) Basic price of imported commodities

$$p^{(0)}_{(i(2))} = p^{(w)}_{(i(2))} - e + t^{(0)}_{(i(2))}, \qquad i = 1,...,g$$

(A13) Cost of constructing units of capital for regional industries

$$V(\bullet,\bullet,(2j),r)(p^{(1j)r}_{(k)} - a^{(1j)r}_{(k)}) = \sum_{i\in G}\sum_{s\in S} V(i, s, (2j), r)(p^{(2j)r}_{(is)} + a^{(2j)r}_{(is)}), \quad j = 1,...,h; r = 1,...,R$$

(A14) Investment behavior

$$z^{(2j)r} = x^{(1j)r}_{(g+1,2)} + 100 f^{(2j)r}_{(k)}, \qquad j = 1,...,h; r = 1,...,R$$

(A15) Capital stock in period T+1 – comparative statics

$$x_{(g+1,2)}^{(1j)r}(1) = x_{(g+1,2)}^{(1j)r} \qquad j = 1,\ldots,h; r = 1,\ldots,R$$

(A16) Definition of rates of return to capital

$$r_{(j)}^{r} = Q_{(j)}^{r}(p_{(g+1,2)}^{(1j)r} - p_{(k)}^{(1j)r}), \qquad j = 1,\ldots,h; r = 1,\ldots,R$$

(A17) Relation between capital growth and rates of return

$$r_{(j)}^{r} - \omega = \varepsilon_{(j)}^{r}(x_{(g+1,2)}^{(1j)r} - x_{(g+1,2)}^{(\bullet)r}) + f_{(k)}^{r}, \qquad j = 1,\ldots,h; r = 1,\ldots,R$$

Other definitions in the CGE core include: revenue from indirect taxes, import volume of commodities, components of regional/national GDP, regional/national price indices, wage settings, definitions of factor prices, and employment aggregates.

Variables

Variable	*Index ranges*	*Description*

$x_{(is)}^{(u)r}$	(u) = (3), (4), (5), (6) and
	(kj) for k = 1, 2 and j = 1,…,h;
	if (u) = (1j) then i = 1,…,g + 2;
	if (u) ≠ (1j) then i = 1,…,g;
	s = 1b, 2 for b = 1,…,q; and i = 1,…,g and
	s = 1, 2, 3 for i = g+1
	r = 1,…,R
		Demand by user (u) in region r for good or primary factor (is)

$p_{(is)}^{(u)r}$	(u) = (3), (4), (5), (6) and
	(kj) for k = 1, 2 and j = 1,…,h;
	if (u) = (1j) then i = 1,…,g + 2;
	if (u) ≠ (1j) then i = 1,…,g;
	s = 1b, 2 for b = 1,…,q; and i = 1,…,g and
	s = 1, 2, 3 for i = g+1
	r = 1,…,R
		Price paid by user (u) in region r for good or primary factor (is)

$x_{(i\bullet)}^{(u)r}$	(u) = (3) and (kj) for k = 1, 2 and
	j = 1, …,h.
	if (u) = (1j) then i = 1, …,g + 1;
	if (u) ≠ (1j) then i = 1, …,g
	r = 1,…,R
		Demand for composite good or primary factor i by user (u) in region r

$a_{(g+1,s)}^{(1j)r}$	j = 1, …,h and s = 1, 2, 3 r = 1,…,R	Primary factor saving technological change in region r
$a_{(i)}^{(u)r}$	i = 1,...,g, (u) = (3) and (kj) for k = 1, 2 and j = 1,..., h r = 1,…,R	Technical change related to the use of good i by user (u) in region r
C^r		Total expenditure by regional household in region r
Q^r		Number of households
$z^{(u)r}$	(u) = (kj) for k = 1, 2 and j = 1, …,h r = 1,…,R	Activity levels: current production and investment by industry in region r

Variable	*Index ranges*	*Description*
$fq_{(is)}^{(4)r}$	i = 1, …,g; s = 1b, 2 for b = 1, …,q r = 1,…,R	Shift (quantity) in foreign demand curves for regional exports
$fp_{(is)}^{(4)r}$	i = 1, …,g; s = 1b, 2 for b = 1, …,q r = 1,…,R	Shift (price) in foreign demand curves for regional exports
e		Exchange rate
$x_{(m1)}^{(is)(u)r}$	m, i = 1,…,g; s = 1b, 2 for b = 1,…,q (u) = (3), (4), (5) and (kj) for k = 1, 2 and j = 1, …,h r = 1,…,R	Demand for commodity (m1) to be used as a margin to facilitate the flow of (is) to (u) in region r
$a_{(m1)}^{(is)(u)r}$	m, i = 1,…,g; s = 1b, 2 for b = 1,…,q (u) = (3), (4), (5) and (kj) for k = 1, 2 and j = 1, …,h r = 1,…,R	Technical change related to the demand for commodity (m1) to be used as a margin to facilitate the flow of (is) to (u) in region r
$x_{(i1)}^{(0j)r}$	i = 1,…,g; j = 1,…,h r = 1,...,R	Output of domestic good i by industry j
$p_{(is)}^{(0)r}$	i = 1,…,g; s = 1b, 2 for b = 1,…,q r = 1,...,R	Basic price of good i in region r from source s
$p_{(i(2))}^{(w)}$	i = 1,…,g	USD c.i.f. price of imported commodity i
$f_{(k)}^{(2j)r}$	j = 1,…,h r = 1,...,R	Regional-industry-specific capital shift terms
$f_{(k)}^{r}$	r = 1,...,R	Capital shift term in region r
$x_{(g+1,2)}^{(1j)r}(1)$	j = 1,…, h r = 1,...,R	Capital stock in industry j in region r at the end of the year, i.e., capital stock available for use in the next year
$p_{(k)}^{(1j)r}$	j = 1,…, h r = 1,...,R	Cost of constructing a unit of capital for industry j in region r

Variable	*Index ranges*	*Description*
$f_{(is)}^{(5)r}$	i = 1, …,g; s = 1b, 2 for b = 1,…,q r = 1,…,R	Commodity and source-specific shift term for government expenditures in region r
$f^{(5)r}$	r = 1,…,R	Shift term for government expenditures in region r
$f^{(5)}$		Shift term for government expenditures
ω		Overall rate of return on capital (short-run)
$r_{(j)}^{r}$	j = 1,...,h r = 1,…,R	Regional-industry-specific rate of return

Parameters, Coefficients and Sets

Symbol	*Description*
$\sigma_{(i)}^{(u)r}$	Parameter: elasticity of substitution between alternative sources of commodity or factor i for user (u) in region r
$\sigma^{(0j)r}$	Parameter: elasticity of transformation between outputs of different commodities in industry j in region r
$\alpha_{(g+1,s)}^{(1j)r}$	Parameter: returns to scale to individual primary factors in industry j in region r
$\beta_{(i)}^{r}$	Parameter: marginal budget shares in linear expenditure system for commodity i in region r
$\gamma_{(i)}^{r}$	Parameter: subsistence parameter in linear expenditure system for commodity i in region r
$\varepsilon_{(j)}^{r}$	Parameter: sensitivity of capital growth to rates of return of industry j in region r
$\eta_{(is)}^{r}$	Parameter: foreign elasticity of demand for commodity i from region r
$\mu_{(i\bullet)}^{(u)r}$	Parameter: returns to scale to primary factors (i = g+1 and u = 1j); otherwise, $\mu_{(i\bullet)}^{(u)r}=1$
$B(i,s,(u),r)$	Input-output flow: basic value of (is) used by (u) in region r
$M(m,i,s,(u),r$	Input-output flow: basic value of domestic good m used as a margin to facilitate the flow of (is) to (u) in region r
$V(i,s,(u),r)$	Input-output flow: purchasers' value of good or factor i from source s used by user (u) in region r
$Y(i,j,r)$	Input-output flow: basic value of output of domestic good i by industry j from region r
$Q_{(j)}^{r}$	Coefficient: ratio, gross to net rate of return

Symbol	Description
G	Set: {1,2, …, g}, g is the number of composite goods
G*	Set: {1,2, …, g+1}, g+1 is the number of composite goods and primary factors
H	Set: {1,2, …, h}, h is the number of industries
U	Set: {(3), (4), (5), (6), (k j) for k = 1, 2 and j = 1, …, h}
U*	Set: {(3), (k j) for k = 1, 2 and j = 1, …, h}
S	Set: {1, 2, …, r+1}, r+1 is the number of regions (including foreign)
S*	Set: {1, 2, …,r}, r is the number of domestic regions