Research Paper

August 2022

Input-Output Analysis of the Ukraine War: A Tool for Assessing the Internal Territorial Impacts of the Conflict

By Eduardo A. Haddad, Inácio F. Araújo, Ademir Rocha & Karina Sass

RP - 08/22

The Russian invasion of Ukraine on February 24, 2022, scaled up the ongoing conflict in Donbas beyond its regional borders, hindering and halting different aspects of economic life. Considering the internal geography of Ukraine's economic structure, the damages to physical infrastructure and supply chain disruptions are likely to propagate to other parts of the country through an intricate plot of production and income linkages. From a disaggregated analysis of multiregional and multisectoral linkages, this paper offers a systematic, integrated account of the structural linkages that allows modeling spillovers from one Ukrainian region to another. This approach breaks new ground by highlighting the internal economic effects of the conflict in Ukraine. We develop an interregional input-output system for Ukraine, providing the numerical basis for developing analytical frameworks to support knowledge building in the recovery process of distressed territories during the post-war period. We offer this database to the international scientific community to support modeling projects focusing on structural features of the Ukrainian economy. As shown in our illustrative exercises, understanding the structure of intersectoral and interregional linkages is critical to understanding better the propagation of exogenous shocks in the economy.

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1. Introduction

The Russian invasion of Ukraine on February 24, 2022, scaled up the ongoing conflict in Donbas[1] beyond its regional borders, hindering and halting different aspects of economic life. Notwithstanding the loss of life, human suffering, and damage to Ukraine's physical infrastructure, consequences are felt worldwide: different economic indicators suggest a sharp economic contraction. A note from the Board of Governors of the US Federal Reserve System (Caldara *et al*., 2022) concluded that the increased geopolitical risks induced by the Russian invasion of Ukraine would weigh adversely on global economic conditions throughout 2022. Such effects were estimated to reduce GDP and boost inflation significantly, exacerbating the policy trade-offs facing central banks around the world. Moreover, the threat of high inflation intensified by soaring commodity prices increases the risks of stagflation, food security, and social unrest in different parts of the planet affecting post-pandemic recovery.

Countries are expected to face different impacts depending on their access to food and energy supplies (e.g., COFACE, 2022; Lo & Sy, 2022; Carrasco-Muro, 2022; UNCTAD, 2022) and their economic links with Ukraine and Russia (Georgieva, 2022). Similarly, sectors are not evenly affected with implications for within-country impacts. Given the critical participation of the Russian Federation and Ukraine in different global supply chains (e.g., energy, agrifood, metals, automotive, chemicals, and wood industries), sanctions adopted by Western countries add another layer of complexity to the health of the global economy, with direct downturn consequences for the two countries directly involved in the conflict.

There are also concerns about the economic consequences in Ukraine. In a statement on the economic impact of the war in Ukraine (Georgieva, 2022), the IMF recognized that, in addition to the human toll, the economic damage was already substantial in the country. Along with the significant recovery and reconstruction costs the country will face, Ukraine's economic output will likely contract by a

[1] The term Donbas, short for Donets Basin, has historically been an economic as well as a geographic designator. It was coined in the nineteenth century by mining engineers for the Tsarist government to describe a coal-rich area straddling sections of modern-day eastern Ukraine and western Russia (ICG, 2020). Ukraine's Donbas region consists mainly of the Donetsk and Luhansk oblasts.

staggering 45.1% in 2022 as Russia's invasion has shuttered businesses, slashed exports, and rendered economic activity impossible in large swaths of the country, according to the World Bank.[2]

Despite its more widespread reach than during the 2014-2015 armed conflict in Eastern Ukraine that culminated with the annexation of Crimea, 2022 damages are still spatially concentrated in the Donbas region. Donetsk and Luhansk, the two oblasts at the center of the conflict, have suffered the most significant losses. In 2013, the year before the conflict started, Donetsk (11.3%) and Luhansk (3.8%) accounted for 15.1% of the national GDP. In 2019, the benchmark year for the interregional input-output system we develop in this paper, their respective shares in GDP dropped to 5.2% and 1.0%, respectively.[3] Home of more than 6 million people, 9.3% of Ukraine's population in 2019 (Donetsk, 9.4%; Luhansk, 4.9%), both oblasts faced substantial declines in their shares in manufacturing employment. The region has been identified with the manufacturing sector, providing surplus for other parts of the country. According to official statistics, Donetsk experienced a drop in its contribution to national employment in the sector from 15.2% in 2013 to 7.8% in 2019. In the same period, the share of Luhansk in manufacturing employment declined even more sharply, from 7.4% to 2.4%. Despite this decline, the manufacturing sector remains relatively concentrated in Donbas.

Considering the internal geography of Ukraine's economic structure, the damages to physical infrastructure and supply chain disruptions are likely to propagate to other parts of the country through an intricate plot of production and income linkages. From a disaggregated analysis of multiregional and multisectoral linkages, this paper offers a systematic, integrated account of the structural linkages that allows modeling spillovers from one Ukrainian region to another. This approach breaks new ground by highlighting the internal economic effects of the conflict in Ukraine.

The multisectoral and multiregional input-output modeling approach, which has been part of the traditional toolbox of regional scientists for decades, provides a way to wrap up the discussion of the linkages structure of the Ukrainian economy within a methodological anchor. It also provides the opportunity to discuss some of the recent developments associated with these tools in the context of

[2] Lawder (2022): "War to slash Ukraine's GDP output by over 45%, World Bank forecasts", https://www.reuters.com/world/us/war-slash-ukraines-gdp-output-by-over-45-world-bank-forecasts-2022-04-10/

[3] Starting in 2014, data exclude the temporarily occupied territory of the Autonomous Republic of Crimea, the city of Sevastopol and temporarily occupied territories in the Donetsk.

Ukraine, capturing some of the most important channels through which exogenous shocks are transmitted across regions through the country's linkages structure.

This paper presents the main hypotheses and procedures applied to estimate the interregional input-output matrix for Ukraine (IIOM-UKR). It describes the process by which the IIOM-UKR was constructed. A fully specified interregional input-output database is developed under conditions of limited information. The IIOM-UKR provides the opportunity to understand better the spatial linkage structure associated with the Ukrainian economy before the war in the context of its 25 regions and 16 different sectors (Tables 1 and 2, Figure 1).

In what follows, we will summarize the main tasks and working hypotheses involved in the treatment of the initial database used in the construction process of the system. We make available the details of the methodological procedures adopted to generate the interregional system and the database itself to be used by other researchers and practitioners. We will also present illustrative analyses using different indicators from the estimated database, revealing some of the main structural features of the economy of Ukraine, focusing on two of the main regions at risk, Donetsk, and Luhansk.

Table 1. List of Sectors

Sector	Description
S01	Agriculture, forestry and fishing
S02	Manufacturing
S03	Construction
S04	Wholesale and retail trade; repair of motor vehicles and motorcycles
S05	Transportation and storage
S06	Accommodation and food service activities
S07	Information and communication
S08	Financial and insurance activities
S09	Real estate activities
S10	Professional, scientific and technical activities
S11	Administrative and support service activities
S12	Public administration and defense, compulsory social security
S13	Education
S14	Human health and social work activities
S15	Arts, entertainment and recreation
S16	Other types of economic activity

Source: Interregional Input-Output System for Ukraine, 2019.

Table 2. List of Regions

Region	Oblasts	області	GRP[1] (mln.UAH)	GRP (%)
R01	Vinnytsya	Вінницька	129,162	3.2%
R02	Volyn	Волинська	75,660	1.9%
R03	Dnipropetrovsk	Дніпропетровська	390,585	9.8%
R04	Donetsk	Донецька	205,046	5.2%
R05	Zhytomyr	Житомирська	85,294	2.1%
R06	Zakarpattya	Закарпатська	61,335	1.5%
R07	Zaporizhzhya	Запорізька	155,235	3.9%
R08	Ivano-Frankivsk	Івано-Франківська	86,702	2.2%
R09	Kyiv	Київська	218,737	5.5%
R10	Kirovohrad	Кіровоградська	73,093	1.8%
R11	Luhansk	Луганська	40,300	1.0%
R12	Lviv	Львівська	214,453	5.4%
R13	Mykolayiv	Миколаївська	92,459	2.3%
R14	Odesa	Одеська	197,209	5.0%
R15	Poltava	Полтавська	187,381	4.7%
R16	Rivne	Рівненська	67,379	1.7%
R17	Sumy	Сумська	75,855	1.9%
R18	Ternopyl	Тернопільська	57,152	1.4%
R19	Kharkiv	Харківська	247,667	6.2%
R20	Kherson	Херсонська	61,955	1.6%
R21	Khmelnytskiy	Хмельницька	83,034	2.1%
R22	Cherkasy	Черкаська	103,514	2.6%
R23	Chernivtsi	Чернівецька	41,661	1.0%
R24	Chernihiv	Чернігівська	78,001	2.0%
R25	Kyiv City	м.Київ	949,531	23.9%
	Ukraine	**Україна**	**3,978,400**	**100.0%**

Note: [1] Gross Regional Product (GRP), 2019.

Source: State Statistics Service of Ukraine. Multidomain statistical information. Regional statistics.

Figure 1. Gross Regional Product (GRP): Ukraine, 2019

Source: State Statistics Service of Ukraine. Multidomain statistical information. Regional statistics.

2. Interregional Input-Output Matrix for Ukraine

2.1 Initial Data Treatment

The estimation of the IIOM-UKR is based on the Interregional Input-Output Adjustment System (IIOAS) method.[4] The IIOAS method was developed to estimate interregional input-output systems under conditions of limited information. In the case of Ukraine, we have used data from national and regional accounts provided by the State Statistics Service for 2019. The data consist mainly of the

[4] This approach has been applied for distinct interregional systems: interisland model for the Azores (Haddad et al., 2015), interregional models for Brazil (Haddad et al., 2017), Colombia (Haddad et al., 2018), Egypt (Haddad et al., 2016), Greece (Haddad et al., 2020a), Lebanon (Haddad, 2014), Mexico (Haddad et al., 2020b), Morocco (Haddad et al., 2020c), and Paraguay (Haddad et al. 2021).

Supply and Use Tables (SUT) at the national level and regional data on sectoral production and employment.

Step 1. The first step in data treatment was to build the national input-output matrix for Ukraine from the SUT available at the State Statistics Service of Ukraine.[5]

Step 2. The next step was to disaggregate the national data into the 25 regions of Ukraine. Data exclude the temporarily occupied territory of the Autonomous Republic of Crimea, the city of Sevastopol, and a part of temporarily occupied territories in the Donetsk and Luhansk regions. The details of such a procedure are described in Sections 2.2 and 2.3.

We use shares from specific variables to estimate the regional value for household consumption, non-profit institutions serving households (NPIH), government consumption, investment demand, and foreign exports. For each component, the variables used to calculate the shares are presented in Table 3.

Table 3. Data Sources Used to Calculate Regional Shares of Final Demand

Description	Variables used to calculate regional shares	Source (State Statistics Service of Ukraine, Regional statistics)
Households	Disposable income in 2019	Household income and expenditure. Population income in region of Ukraine
Non-profit institutions serving households	Disposable income in 2019	Household income and expenditure. Population income in region of Ukraine
Government	Employment in public administration in 2019	Population and social statistics. Labour Market
Gross fixed capital formation	Capital investment by region in 2019	Economic activity. Investment and capital assets
Export	Regional volumes of foreign trade in goods in 2019. Regional volumes of foreign trade in services in 2020.	Regional volumes of foreign trade in goods and services

Table 4 presents the regional shares for each final demand component. A general result is the spatial concentration of aggregate demand, influenced by the distribution of economic activity and

[5] https://ukrstat.gov.ua/

population across the regions. Economic activity is concentrated in the Kyiv-Donetsk corridor, in blast located on the left bank of the Dnipro river, in Central and Eastern Ukraine, and two regional economic poles, in Lviv and Odesa oblasts.

Table 4. Regional Shares of Final Demand Components

Region	Oblasts	Households	Non-profit institutions serving households	Government	Gross fixed capital formation	Export
R01	Vinnytsya	3.5%	3.5%	3.9%	2.7%	2.7%
R02	Volyn	1.9%	1.9%	2.5%	2.1%	1.3%
R03	Dnipropetrovsk	9.8%	9.8%	7.7%	11.3%	15.7%
R04	Donetsk	5.7%	5.7%	4.6%	5.2%	7.2%
R05	Zhytomyr	2.6%	2.6%	4.2%	1.4%	1.4%
R06	Zakarpattya	2.1%	2.1%	2.3%	1.6%	2.6%
R07	Zaporizhzhya	4.4%	4.4%	3.5%	2.5%	5.1%
R08	Ivano-Frankivsk	2.7%	2.7%	2.3%	1.5%	1.5%
R09	Kyiv	4.7%	4.7%	5.6%	8.3%	3.8%
R10	Kirovohrad	1.9%	1.9%	2.4%	1.3%	1.1%
R11	Luhansk	1.8%	1.8%	2.3%	0.5%	0.3%
R12	Lviv	5.8%	5.8%	6.8%	4.8%	5.4%
R13	Mykolayiv	2.5%	2.5%	3.7%	2.1%	4.6%
R14	Odesa	6.2%	6.2%	6.7%	3.5%	4.6%
R15	Poltava	3.5%	3.5%	3.3%	3.9%	3.3%
R16	Rivne	2.2%	2.2%	2.3%	1.1%	0.9%
R17	Sumy	2.4%	2.4%	3.2%	1.3%	1.4%
R18	Ternopyl	1.8%	1.8%	1.8%	1.5%	0.9%
R19	Kharkiv	6.1%	6.1%	5.9%	3.9%	3.4%
R20	Kherson	2.1%	2.1%	2.9%	2.1%	0.5%
R21	Khmelnytskiy	2.6%	2.6%	3.4%	1.6%	1.0%
R22	Cherkasy	2.5%	2.5%	2.3%	1.8%	1.4%
R23	Chernivtsi	1.5%	1.5%	1.7%	0.7%	0.4%
R24	Chernihiv	2.1%	2.1%	3.8%	1.5%	1.3%
R25	Kyiv city	17.7%	17.7%	11.0%	31.9%	28.1%
	Ukraine	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

2.2 Estimation of the Interregional Trade Matrices

Step 3. In order to estimate the interregional system, it has been necessary to estimate the trade matrices among the 25 regions of Ukraine. This procedure has been made by calculating three components: (i) the regional demand for domestic products; (ii) the regional demand for imported products; and (iii) the total supply of each region to the domestic and foreign markets by sector.

Step 4. We have assumed that regional demands for domestic and import products follow the national pattern for all users. In other words, economic agents share the same technology and preferences everywhere. However, it is essential to note that we have estimated different trade matrices for each sector, allowing us to have different regional sourcing for intermediate inputs and final products.

Step 5. The regional demand for domestic products is calculated, for each user (intermediate consumption and domestic absorption components), using the information provided in the matrix of demand-generating coefficients (DOMGEN). These coefficients are defined as the ratio of each element of the national use matrix to its respective column total.

For intermediate consumption, we define the ratio as follows:

$$cic_{ij}^{dom} = \frac{z_{ij}^{dom}}{x_j}, \forall\, i,j = 1, \dots, 16 \qquad (1)$$

where cic_{ij}^{dom} is the national coefficient of intermediate consumption of domestic inputs; z_{ij}^{dom} is the intermediate consumption of domestic inputs by sector, and x_j is the total sectoral output. From Equation (1), we can have a matrix of size *16* x *16* (*sector* x *sector*), CIC^{dom}, with all the intermediate consumption ratios (cic_{ij}^{dom}).

Regarding the domestic absorption components (investment, household consumption, NPIH, and government expenditure), we have used the ratio of each *i*-element to its respective column sum:

$$cinv_i^{dom} = \frac{inv_i^{dom}}{invt}, \forall\, i = 1, \dots, 16 \qquad (2)$$

$$chou_i^{dom} = \frac{hou_i^{dom}}{hout}, \forall\ i = 1, \dots, 16 \quad (3)$$

$$cnpih_i^{dom} = \frac{npih_i^{dom}}{npiht}, \forall\ i = 1, \dots, 16 \quad (4)$$

$$cgov_i^{dom} = \frac{gov_i^{dom}}{govt}, \forall\ i = 1, \dots, 16 \quad (5)$$

where inv_i^{dom}, hou_i^{dom}, $niph_i^{dom}$, and gov_i^{dom} are the investment demand, household consumption, NIPH demand, and government expenditure of each *i*-element in the national use matrix; and $invt$, $hout$, $nipht$, and $govt$ are the respective column sums, including tax. Thus, from Equation (2) to (5), we generate vectors of size *25* x *1*, $\mathbf{cinv}^{dom}$, $\mathbf{chou}^{dom}$, $\mathbf{cnpih}^{dom}$, and $\mathbf{cgov}^{dom}$, with all the investment demand, household consumption, NPIH demand, and government expenditure ratios, respectively.

Step 6. The gross regional demand for domestic products is obtained by multiplying these coefficients – Equations (1) to (5) – by (i) a matrix with the total sectoral output of each region (Tables 5 and 6) in the main diagonal and zero elsewhere, $\mathbf{X}^r$; (ii) the total investment demand in each region, $invt^r$; (iii) the total household consumption in each region, $hout^r$; (iii) the total NPIH demand in each region, $npiht^r$; and (v) the total government expenditure in each region, $govt^r$:

$$\mathbf{IC}^{r,\,dom} = \mathbf{CIC}^{dom} * \mathbf{X}^r\ , \forall\ r = 1, \dots, 25, \forall\ i = 1, \dots, 16 \quad (6)$$

$$\mathbf{inv}^{r,\,dom} = \mathbf{cinv}^{dom} * invt^r\ , \forall\ r = 1, \dots, 25 \quad (7)$$

$$\mathbf{hou}^{r,\,dom} = \mathbf{chou}^{dom} * hout^r\ , \forall\ r = 1, \dots, 25 \quad (8)$$

$$\mathbf{npih}^{r,\,dom} = \mathbf{cnpih}^{dom} * npiht^r\ , \forall\ r = 1, \dots, 25 \quad (9)$$

$$\mathbf{gov}^{r,\,dom} = \mathbf{cgov}^{dom} * govt^r\ , \forall\ r = 1, \dots, 25 \quad (10)$$

where $\mathbf{IC}^{r,\,dom}$ is a matrix of intermediate consumption of domestic products, *16* x *16* (*sector* x *sector*) by region; $\mathbf{inv}^{r,\,dom}$ is the consumption vector of capital goods produced domestically; $\mathbf{hou}^{r,\,dom}$ is the household consumption vector of domestic products; $\mathbf{npih}^{r,\,dom}$ is the NPIH demand vector of domestic products; and $\mathbf{gov}^{r,\,dom}$ is the vector of government expenditure on domestic products; all for each region *r*.

Therefore, the (gross) total demand for domestic products in each region is given by

$$\mathbf{demdom}^{r} = \mathbf{IC}^{\mathrm{r,\,dom}}\mathbf{i} + \mathbf{inv}^{\mathrm{r,\,dom}} + \mathbf{hou}^{\mathrm{r,\,dom}} + \mathbf{npih}^{\mathrm{r,\,dom}} + \mathbf{gov}^{\mathrm{r,\,dom}}, \quad \forall\, r = 1, \ldots, 25 \tag{11}$$

where $\mathbf{demdom}^{r}$ is the total demand vector for domestic products of size *16* x *1* for each region *r*. We use **i** to represent a summation vector (dimension 16 x 1).

Table 5. Data Sources Used to Calculate Regional Shares of Sectoral Output

Sector	Description	Variables used to calculate regional shares	Source (State Statistics Service of Ukraine, Regional statistics)
S01	Agriculture, forestry and fishing	Agricultural production in all agricultural holdings by regions in 2019	Economic accounts of agriculture
S02	Industry	Volume of industrial products sold by region in 2019	Economic activity. Industry
S03	Construction	Volume of construction production in 2019	Economic activity. Construction
S04	Wholesale and retail trade	Employment in 2019	Population and social statistics. Labour Market
S05	Transportation and storage	Volume of services sold by regions and types of economic activity in 2019	Economic activity. Service
S06	Accommodation and food service activities	Volume of services sold by regions and types of economic activity in 2019	Economic activity. Service
S07	Information and communication	Volume of services sold by regions and types of economic activity in 2019	Economic activity. Service
S08	Financial and insurance activities	Employment in 2019	Population and social statistics. Labour Market
S09	Real estate activities	Volume of services sold by regions and types of economic activity in 2019	Economic activity. Service
S10	Professional, scientific and technical activities	Volume of services sold by regions and types of economic activity in 2019	Economic activity. Service
S11	Administrative and support service activities	Volume of services sold by regions and types of economic activity in 2019	Economic activity. Service
S12	Public administration and defense	Employment in 2019	Population and social statistics. Labor Market
S13	Education	Volume of services sold by regions and types of economic activity in 2019	Economic activity. Service
S14	Human health and social work activities	Volume of services sold by regions and types of economic activity in 2019	Economic activity. Service
S15	Arts, entertainment and recreation	Volume of services sold by regions and types of economic activity in 2019	Economic activity. Service
S16	Other types of economic activity	Volume of services sold by regions and types of economic activity in 2019	Economic activity. Service

Table 6. Regional Shares of Sectoral Output (%)

Region	Oblasts	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10	S11	S12	S13	S14	S15	S16
1	Vinnytsya	8.4	3.3	5.7	3.3	1.4	1.2	2.7	2.6	0.5	1.0	0.9	3.9	5.4	2.9	0.6	1.5
2	Volyn	2.4	1.3	1.3	2.3	1.1	0.7	0.4	1.7	1.9	0.4	0.4	2.5	1.4	0.9	0.3	0.8
3	Dnipropetrovsk	6.2	18.3	11.0	9.8	10.5	8.2	3.4	10.8	10.1	5.6	9.7	7.7	6.0	8.1	3.8	12.0
4	Donetsk	3.0	11.4	3.8	4.9	1.7	1.2	2.8	1.9	1.9	5.4	1.7	4.6	1.3	1.1	0.5	1.4
5	Zhytomyr	4.0	1.8	1.5	3.5	0.8	1.0	0.7	2.1	0.1	0.4	0.7	4.2	1.2	1.3	0.3	1.4
6	Zakarpattya	1.3	1.0	1.2	2.3	1.5	0.9	0.3	1.4	0.5	0.2	0.5	2.3	1.9	2.6	1.3	1.0
7	Zaporizhzhya	4.0	7.9	2.1	4.3	1.5	2.0	1.2	3.4	2.4	3.0	1.8	3.5	5.0	3.5	1.1	3.5
8	Ivano-Frankivsk	2.0	2.7	2.0	3.0	0.9	2.6	0.5	1.9	1.0	0.5	1.5	2.3	3.6	1.1	0.4	0.9
9	Kyiv	6.0	4.9	5.7	4.7	6.3	5.5	1.2	5.6	5.0	1.6	4.2	5.6	1.3	2.7	1.4	2.4
10	Kirovohrad	5.3	1.3	1.1	1.7	2.1	0.2	0.3	1.0	0.4	0.2	0.8	2.4	0.7	0.8	1.5	0.8
11	Luhansk	2.1	0.9	0.4	2.3	0.2	0.3	0.2	0.6	0.2	0.3	0.3	2.3	0.5	0.4	0.4	0.3
12	Lviv	3.4	4.2	6.0	5.7	4.6	9.2	7.3	5.2	5.5	2.6	4.3	6.8	5.1	7.4	5.3	3.6
13	Mykolayiv	3.8	2.5	2.4	2.5	5.0	1.2	0.6	1.5	0.5	1.2	1.0	3.7	1.4	1.0	1.1	1.2
14	Odesa	4.2	2.5	9.8	6.6	15.2	5.3	2.6	5.5	7.9	3.1	4.2	6.7	9.4	9.2	3.4	5.8
15	Poltava	6.4	6.8	4.2	3.5	1.5	1.4	0.8	2.1	1.6	1.3	2.8	3.3	1.3	3.4	0.8	2.0
16	Rivne	2.5	1.7	1.8	3.5	1.0	0.5	0.2	2.0	0.5	0.2	0.4	2.3	1.5	0.4	0.3	6.2
17	Sumy	4.4	1.9	0.9	2.7	1.1	0.6	0.4	1.5	0.6	0.4	0.7	3.2	2.3	1.4	0.3	1.4
18	Ternopyl	3.6	0.8	1.3	2.1	1.0	0.4	0.5	1.3	0.4	0.2	0.3	1.8	3.7	0.6	0.3	0.9
19	Kharkiv	5.6	7.5	8.2	8.1	2.7	6.3	7.7	4.8	4.5	3.0	3.8	5.9	12.8	4.4	5.1	5.4
20	Kherson	4.2	1.2	1.0	2.8	1.1	0.7	0.3	1.6	0.6	0.2	0.5	2.9	1.3	0.8	0.5	0.6
21	Khmelnytskiy	5.3	1.7	2.1	3.2	0.7	0.5	0.3	1.7	0.8	0.4	1.0	3.4	1.6	0.8	0.4	0.7
22	Cherkasy	5.9	3.0	1.1	2.7	2.1	0.8	1.0	2.5	1.2	0.5	1.0	2.3	1.7	0.9	0.6	1.3
23	Chernivtsi	1.5	0.5	1.2	2.1	0.3	0.5	0.5	1.7	0.5	0.2	0.2	1.7	2.5	1.0	0.3	0.7
24	Chernihiv	4.6	1.4	1.0	2.6	0.9	1.9	0.6	2.4	0.9	0.3	0.9	3.8	0.6	0.5	0.6	1.7
25	Kyiv city	0.0	9.4	23.0	9.9	35.0	47.1	63.3	33.2	50.4	67.9	56.4	11.0	26.6	42.7	69.4	42.8
	Ukraine	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Step 7. The procedure to estimate the demand for imported products is similar. Analogously, we have created a matrix of demand-generating coefficients for imported products (IMPGEN), defined as the ratio of each element of the national matrix of imports over the respective column sum in the use matrix.

For intermediate consumption, the coefficient represents the share of imports in terms of national production as follows:

$$cic_{ij}^{imp} = \frac{z_{ij}^{imp}}{x_j}, \forall\, i,j = 1, \dots, 16 \qquad (12)$$

where cic_{ij}^{imp} is the intermediate consumption coefficient of imported inputs; z_{ij}^{imp} is the intermediate consumption of imported inputs, and x_j is the total sectoral output.

Analogously to domestic ratios, from Equation (12), we can have a matrix of size *16* x *16* (*sector* x *sector*), $\mathbf{CIC}^{\text{imp}}$, with all the intermediate consumption ratios related to imported inputs.

Further, the coefficients for the final demand elements are given by

$$cinv_i^{imp} = \frac{inv_i^{imp}}{invt}, \forall\, i = 1, \dots, 16 \qquad (13)$$

$$chou_i^{imp} = \frac{hou_i^{imp}}{hout}, \forall\, i = 1, \dots, 16 \qquad (14)$$

$$cnpih_i^{imp} = \frac{npih_i^{imp}}{npiht}, \forall\, i = 1, \dots, 16 \qquad (15)$$

$$cgov_i^{imp} = \frac{gov_i^{imp}}{govt}, \forall\, i = 1, \dots, 16 \qquad (16)$$

where inv_i^{imp}, hou_i^{imp}, $niph_i^{imp}$, and gov_i^{imp} are the investment demand, household consumption, NIPH demand, and government expenditure of each *i*-element in the national imported matrix. Thus, $cinv_i^{imp}$, $chou_i^{imp}$, $cnpih_i^{imp}$, and $cgov_i^{imp}$ are the demand shares of imported products related to investment demand, household consumption, NPIH demand, and government expenditure. From Equation (13) to (16), we may have vectors of size *18* x *1*, $\mathbf{cinv}^{\text{imp}}$, $\mathbf{chou}^{\text{imp}}$, $\mathbf{cnpih}^{\text{imp}}$, and $\mathbf{cgov}^{\text{imp}}$,

with all the investment demand, household consumption, NPIH demand, and government expenditure ratios, respectively.

Therefore, the demands for imported products by region are defined as

$$\mathbf{IC}^{\mathrm{r,\,imp}} = \mathbf{CIC}^{\mathrm{imp}} * \mathbf{X}^{r}\ ,\ \forall\ r = 1, \dots, 25 \tag{17}$$

$$\mathbf{inv}^{\mathrm{r,\,imp}} = \mathbf{cinv}^{\mathrm{imp}} * invt^{r}\ ,\ \forall\ r = 1, \dots, 25 \tag{18}$$

$$\mathbf{hou}^{\mathrm{r,\,imp}} = \mathbf{chou}^{\mathrm{imp}} * hout^{r}\ ,\ \forall\ r = 1, \dots, 25 \tag{19}$$

$$\mathbf{npih}^{\mathrm{r,\,imp}} = \mathbf{cnpih}^{\mathrm{imp}} * npiht^{r}\ ,\ \forall\ r = 1, \dots, 25 \tag{20}$$

$$\mathbf{gov}^{\mathrm{r,\,imp}} = \mathbf{cgov}^{\mathrm{imp}} * govt^{r}\ ,\ \forall\ r = 1, \dots, 25 \tag{21}$$

where $\mathbf{IC}^{\mathrm{r,\,imp}}$ is a matrix with imports of intermediate inputs; $\mathbf{inv}^{\mathrm{r,\,imp}}$ is the imports vector of capital goods; $\mathbf{hou}^{\mathrm{r,\,imp}}$ is the vector of imports by household; $\mathbf{npih}^{\mathrm{r,\,imp}}$ is the vector of imports by NPIH; and $\mathbf{gov}^{\mathrm{r,\,imp}}$ is the vector of government expenditure on imports, all for each region *r*.

The total demand for imported products by region is given by

$$\mathbf{demimp}^{r} = \mathbf{IC}^{\mathrm{r,\,imp}}\mathbf{i} + \mathbf{inv}^{\mathrm{r,\,imp}} + \mathbf{hou}^{\mathrm{r,\,imp}} + \mathbf{npih}^{\mathrm{r,\,imp}} + \mathbf{gov}^{\mathrm{r,\,imp}},\quad \forall\ r = 1, \dots, 25 \tag{22}$$

In order to generate a matrix of regional demands for domestic products, we have placed all demand vectors for domestic products ($\mathbf{demdom}^{\mathrm{r}}\ ,\ \forall\ r = 1, \dots, 25$) side by side, which has allowed us to have a matrix of size *16* x 25 (sector x region) – **DEMDOM**, where each row represents the domestic demand for sector *i* by each region *r*. Similarly, we have made the same procedure with the demand vectors for imported products ($\mathbf{demimp}^{\mathrm{r}}\ ,\ \forall\ r = 1, \dots, 25$), which has also allowed us to have a matrix of *16* x *25* (sector x region) – **DEMIMP**, where each row represents the sectoral imports by each region *r*.

Step 8. The next step was to estimate the sectoral domestic supply ($\mathbf{supdom}^{r}$) in each region, which has been done by taking the difference between the sectoral total output ($\mathbf{x}^{\mathrm{r}}$) and the sectoral exports ($\mathbf{exp}^{\mathrm{r}}$) in each region.

$$\mathbf{supdom}^{r} = \mathbf{x}^{r} - \mathbf{exp}^{r}, \forall\, r = 1, \ldots, 25 \qquad (23)$$

Similarly, placing all regional vectors side by side, we have created a 16 x 25 (sector x region) matrix – **SUPDOM**, where each row represents the total regional domestic supply of sector *i*.

Thus, having the sectoral domestic demand and supply by region (**DEMDOM** and **SUPDOM**), we have to ensure the equilibrium between them in aggregate terms. Thus, we have adjusted the aggregate value of (gross) total domestic demand for each sector to have total domestic demand equivalent to total domestic supply.

Step 9. The next step has been to construct, for each sector, matrices with regional trade shares (**SHIN**^{i}). In other words, we have created matrices for each sector representing the regional share of the total domestic trade. Considering *s* origin and *d* destination regions, we have estimated 16 matrices (one for each sector) of *25* x *25* (origin x destination).

These shares have been estimated using Equations (24) and (25), based on previous work by Dixon and Rimmer (2004). Equation (24) has been used to calculate the initial ratio of the intra-regional trade (main diagonal of the trade matrix), while Equation (25) has been used to estimate the interregional trade flows.

Thus, the intra-regional trade share is given by

$$shin_{s,d}^{i} = \text{Min}\left\{\frac{supdom_{s}^{i}}{demdom_{s}^{i}}, 1\right\} * f, \forall\, i = 1, \ldots, 16;\ s, d = 1, \ldots, 25 \text{ and } s = d \qquad (24)$$

where $shin_{s,d}^{i}$ is the share of sector *i* in the national trade within each region. The intra-regional trade flow is defined as the ratio of supply to demand of sector *i* within the region. If supply exceeds demand, we assume that all demand is met internally. However, based on Haddad et al. (2016), we have multiplied the result by a factor (f) which gives us the extent of tradability of a given commodity. For non-tradable sectors, usually services, we have assumed that the local economy typically provides them. Thus, we have used initial f values close to unity 0.9 for non-tradable and 0.5 for tradable sectors.

Otherwise, the interregional trade is given by

$$shin_{s,d}^{i} = \left\{ \frac{1}{imped_{s,d}^{\beta}} * \frac{supdom_{s}^{i}}{\sum_{1}^{25} supdom_{k}^{i}} \right\} * \left\{ \frac{1 - shin_{s,v}^{i}}{\sum_{g=1,g\neq d}^{25} \left[\frac{1}{imped_{s,d}^{\beta}} * \frac{supdom_{s}^{i}}{\sum_{k=1}^{25} supdom_{k}^{i}} \right]} \right\} \quad (25)$$

$\forall\ i = 1, \ldots, 16;\ s, d = 1, \ldots, 25;\ k = s\ ;\ v = s;\ g = s$ and $s \neq d$

where $shin_{s,d}^{i}$ is the share of trade flows of sector *i* with origin in region *s* and destination on region *d*; and $imped_{s,d}$ is given by the average travel time between two trading regions.

Step 10. From Equations (24) and (25), we generate matrices of size *25* x *25* (region x region) for each sector – $\mathbf{SHIN}^{i}$, where the intra-regional trade shares are placed on the main diagonal and the interregional trade shares off-diagonal. Note that the column values add to one.

Step 11. Using the $\mathbf{SHIN}^{i}$ matrices, we have estimated initial values for the trade matrices by multiplying each $\mathbf{SHIN}^{i}$ by its respective reference value in **DEMDOM**:

$$\mathbf{TRADE}^{i} = \mathbf{SHIN}^{i} * \mathbf{DEMDOM}^{*i},\ \forall\ i = 1, \ldots, 16 \text{ and } s, d = 1, \ldots, 25 \quad (26)$$

where $\mathbf{TRADE}^{i}$ is the trade matrix for sector *i* with origin in region *s* and destination in region *d*; and $\mathbf{DEMDOM}^{*i}$ is a diagonal matrix where values related to sector *i* from **DEMDOM** have been placed on the main diagonal and zero elsewhere.

This procedure ensures that the column sums of each $\mathbf{TRADE}_{s,d}^{i}$ matrix is equivalent to the demand of the respective region *d* for the products of region *s* (for each sector *i*). However, the row sum is not necessarily equivalent to the supply of each sector *i* from region *s* to region *d*. Thus, we have used a

RAS procedure[6] to ensure supply and demand balance. Table 7 illustrates the estimated trade flows for groups of sectors, identifying supplying and demanding regions and the main trade flows.

Step 12. After the RAS procedure, we have included in each $\mathbf{TRADE}^{i}_{s,d}$ matrix the respective row from **DEMIMP**. In other words, we added the Rest of the World as one of the origins. Thus, now *s* is equal to 26 since it represents the 25 Ukrainian regions plus the Rest of the World.

[6] For more details, see Miller and Blair (2009).

Table 7. Estimated Interregional Trade Flows in 2019 (mln. UAH)

Origin	Destination																									Total
	R01	R02	R03	R04	R05	R06	R07	R08	R09	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22	R23	R24	R25	
R01 - Vinnytsya	130.3	1.9	7.7	4.6	5.8	2.2	3.1	2.6	9.2	2.2	0.8	6.0	2.9	6.4	2.8	2.1	1.4	2.3	2.5	1.6	5.8	2.8	1.4	2.0	30.3	**240.8**
R02 - Volyn	1.9	78.0	3.1	2.2	1.6	1.6	1.3	1.9	2.3	0.6	0.4	7.0	0.9	1.9	1.5	3.9	0.6	1.7	1.4	0.5	1.6	0.8	0.7	0.8	12.7	**130.9**
R03 - Dnipropetrovsk	6.0	2.3	418.5	29.9	3.5	3.3	39.9	3.3	10.3	5.7	3.7	7.0	7.2	11.3	20.5	2.5	5.2	2.1	23.9	5.8	3.3	6.2	1.8	3.5	47.0	**673.7**
R04 - Donetsk	4.4	1.9	34.3	228.0	2.7	3.0	14.5	2.7	7.9	2.9	6.2	6.2	5.5	10.5	10.1	2.0	3.5	1.6	14.8	3.6	2.5	3.9	1.4	2.6	34.7	**411.6**
R05 - Zhytomyr	4.9	1.3	3.9	2.5	80.7	1.1	1.5	1.1	5.4	0.8	0.4	3.2	1.2	2.8	2.1	1.9	0.8	0.9	1.8	0.6	1.9	1.4	0.6	1.3	29.8	**153.7**
R06 - Zakarpattya	0.9	0.5	1.9	1.4	0.4	55.8	0.7	1.0	0.8	0.3	0.2	2.3	0.5	0.9	0.7	0.5	0.3	0.5	0.6	0.3	0.6	0.3	0.4	0.3	5.5	**77.5**
R07 - Zaporizhzhya	2.7	1.0	46.7	14.3	1.5	1.5	146.5	1.5	4.9	2.4	1.6	3.3	3.8	6.1	7.0	1.1	2.0	0.9	7.5	2.9	1.5	2.7	0.8	1.6	19.5	**285.3**
R08 - Ivano-Frankivsk	2.8	2.0	3.9	2.7	1.5	3.5	1.5	97.3	3.1	0.8	0.5	12.3	1.4	3.0	1.6	1.9	0.7	3.0	1.4	0.8	2.8	1.1	2.6	0.9	12.9	**166.0**
R09 - Kyiv	8.1	2.2	10.1	6.9	5.8	2.6	4.8	2.8	218.3	3.1	1.4	6.0	4.0	9.8	5.9	2.8	2.6	2.1	5.7	2.1	3.8	5.2	1.6	4.0	91.7	**413.3**
R10 - Kirovohrad	2.5	0.6	9.9	4.7	1.1	1.0	4.2	1.0	3.9	69.6	0.7	2.2	1.9	3.8	3.9	0.7	1.0	0.7	3.3	1.4	1.2	3.5	0.5	1.1	11.0	**135.5**
R11 - Luhansk	0.6	0.2	4.3	7.8	0.3	0.4	1.8	0.3	0.9	0.4	44.7	0.8	0.7	1.1	1.6	0.2	0.6	0.2	2.3	0.4	0.3	0.5	0.1	0.4	4.6	**75.6**
R12 - Lviv	4.5	5.7	6.0	4.4	2.8	5.9	2.6	8.5	4.5	1.3	1.0	241.3	2.2	4.5	2.8	4.3	1.4	5.4	2.8	1.4	4.6	1.6	2.3	1.6	24.2	**347.7**
R13 - Mykolayiv	1.1	0.4	3.7	2.5	0.6	0.6	1.7	0.6	1.9	0.6	0.4	1.2	85.9	7.9	1.1	0.4	0.4	0.4	1.3	2.8	0.6	0.7	0.3	0.5	7.1	**124.7**
R14 - Odesa	4.1	1.4	7.4	7.5	2.0	2.0	4.5	2.0	5.4	1.9	1.6	3.6	10.8	203.1	3.3	1.4	1.6	1.4	3.8	5.3	2.4	2.4	1.2	1.7	22.4	**304.4**
R15 - Poltava	4.7	2.3	36.4	15.1	3.7	3.0	10.5	2.7	11.2	4.1	2.4	6.8	4.1	8.8	184.7	2.4	6.7	1.7	25.7	2.8	2.7	6.4	1.4	4.1	54.3	**408.6**
R16 - Rivne	2.4	3.8	3.3	2.3	2.3	1.4	1.3	1.8	3.0	0.6	0.3	5.6	0.9	2.0	1.7	69.1	0.6	1.7	1.4	0.5	1.8	1.0	0.7	0.9	17.4	**127.8**
R17 - Sumy	1.3	0.6	6.9	4.2	0.9	0.8	2.4	0.7	2.6	0.8	0.8	1.7	1.0	2.1	4.7	0.6	79.7	0.4	5.5	0.7	0.7	1.4	0.3	1.3	12.2	**134.4**
R18 - Ternopyl	2.2	1.5	2.7	1.9	1.1	1.3	1.1	2.5	1.9	0.7	0.3	6.4	1.0	1.6	1.1	1.6	0.5	53.9	0.9	0.5	3.2	0.7	0.9	0.7	6.8	**97.0**
R19 - Kharkiv	3.8	2.0	41.2	22.9	3.1	2.5	11.3	2.3	8.6	3.4	4.8	5.8	4.6	7.1	23.8	2.1	8.1	1.4	263.1	3.7	2.4	4.6	1.2	3.5	41.9	**479.3**
R20 - Kherson	1.2	0.4	8.0	4.8	0.6	0.6	3.8	0.6	1.8	1.1	0.6	1.3	6.0	5.0	2.0	0.4	0.7	0.4	2.1	66.3	0.6	1.1	0.3	0.6	6.4	**116.6**
R21 - Khmelnytskiy	6.4	1.6	4.8	3.1	2.3	1.8	2.0	2.6	4.1	1.1	0.4	6.0	1.6	3.4	2.0	1.8	0.8	3.1	1.7	0.8	85.6	1.4	1.5	1.1	15.7	**157.0**
R22 - Cherkasy	3.4	1.1	10.6	5.3	2.1	1.4	4.2	1.4	8.6	3.7	0.8	3.3	2.5	5.9	5.6	1.3	1.9	1.0	4.4	1.4	1.6	100.0	0.7	2.4	30.3	**205.0**
R23 - Chernivtsi	1.4	0.6	2.2	1.6	0.7	0.8	0.9	1.8	1.3	0.4	0.2	2.2	0.7	1.1	0.8	0.6	0.3	0.8	0.7	0.4	1.3	0.5	43.3	0.4	6.4	**71.3**
R24 - Chernihiv	1.7	0.7	4.4	2.9	1.3	0.8	1.9	0.8	3.9	0.8	0.5	1.9	1.2	2.5	2.6	0.8	1.3	0.5	2.2	0.6	0.9	1.6	0.4	75.2	23.3	**134.5**
R25 - Kyiv city	30.1	13.5	44.3	37.1	32.8	13.9	24.1	15.9	50.1	14.8	13.5	25.8	19.6	26.9	31.6	19.0	19.4	12.3	35.8	14.3	21.2	20.4	9.7	25.2	698.2	**1,269.5**
Total	**233.3**	**127.7**	**726.0**	**420.7**	**161.4**	**113.0**	**292.2**	**159.8**	**376.0**	**124.2**	**88.1**	**369.3**	**172.1**	**339.3**	**325.4**	**125.4**	**142.1**	**100.3**	**416.3**	**121.4**	**154.9**	**172.3**	**76.4**	**137.7**	**1,266.4**	**6,741.6**

Source: Interregional Input-Output System for Ukraine, 2019. The University of Sao Paulo Regional and Urban Economics Lab (NEREUS).

3. Regionalization Procedure

Step 13. The 16 trade matrices estimated are consistent with the national supply and demand in each sector. The trade matrices, after the inclusion of the import row, $\mathbf{TRADE}^{*i}_{s,d}$, consider the sales of each Ukrainian region to the other Ukrainian regions and the purchases of each of them both from domestic and foreign supply regions. However, from these matrices, we cannot know if the sales were purchased by industries (intermediate consumption) or by final users in the other regions.

In order to deal with this issue, we have used a regionalization strategy proposed originally by Chenery (1956) and Moses (1955). We have applied the same regional proportion in acquiring inputs for all sectors and final products by all final users within a given region. In other words, we have used the same trade coefficients for all sectors or final users in the destination. The idea behind this procedure is that users in a specific region face the supply of a "pool good" composed of fixed shares of related goods from the different sourcing regions.

The following steps may describe the regionalization procedure. The first step is given by the calculation of a new matrix for each sector with the trade shares, $\mathbf{SHIN\_N}^{i}$. This matrix is estimated based on the $\mathbf{TRADE}^{*i}_{s,d}$ matrices as follows:

$$\mathbf{SHIN\_N}^{i} = \mathbf{TRADE}^{*i}_{s,d} * [\mathbf{TRADE}^{*i}]^{-1} \quad (27)$$

$$\forall\ i = 1, \ldots, 16;\ s = 1, \ldots, 26; \text{ and } d = 1, \ldots, 25$$

where $\mathbf{TRADE}^{*i}$ is a matrix diagonal whose ($\sum_{s=1}^{25} \text{trade}^{i}_{s,d}$) are placed on the main diagonal and zero elsewhere, being $trade^{i}_{s,d}$ each element of $\mathbf{TRADE}^{*i}_{s,d}$ matrix; s represents the 26 origin regions (25 regions of Ukraine plus the Rest of the World), and d represents the 25 destination regions (regions of Ukraine).

Subsequently, we have used elements from the national use matrix to estimate the national coefficients (domestic plus imports) of intermediate consumption, investment demand, household consumption, NPIH demand, and government expenditure.

For intermediate consumption, the matrix of coefficients is given by

$$\mathbf{CIC}^{\mathrm{N}} = \mathbf{Z}^{\mathrm{DOM+IMP}} * (\mathbf{ICT}^{*\mathrm{N}})^{-1} \quad (28)$$

where $\mathbf{Z}^{\mathrm{DOM+IMP}}$ is the intermediate consumption matrix (domestic + imported); and $\mathbf{ICT}^{*\mathrm{N}}$ is a diagonal matrix with the values from the vector of total intermediate consumption for each sector of destination *j* ($\mathbf{ict}^{\mathrm{N}}$) in the main diagonal. This vector, $\mathbf{ict}^{\mathrm{N}}$, is defined as

$$\mathbf{ict}^{\mathrm{N}} = \mathbf{x}^{\mathrm{N}} - \mathbf{va}^{\mathrm{N}} \quad (29)$$

where $\mathbf{x}^{\mathrm{N}}$ is the vector with all national total sectoral output; and $\mathbf{va}^{\mathrm{N}}$ is the vector with all national sectoral value-added.

For the final demand elements, we have taken each vector element over its respective total (including indirect taxes). Thus, the investment demand, household consumption, NPIH demand, and government expenditure coefficients are defined as follows:

$$cinv_i^N = \frac{inv_i^{DOM+IMP}}{invt^N}, \forall\, i = 1, \dots, 16 \quad (30)$$

$$chou_i^N = \frac{hou_i^{DOM+IMP}}{hout^N}, \forall\, i = 1, \dots, 16 \quad (31)$$

$$cnpih_i^N = \frac{npih_i^{DOM+IMP}}{npiht^N}, \forall\, i = 1, \dots, 16 \quad (32)$$

$$cgov_i^N = \frac{gov_i^{DOM+IMP}}{govt^N}, \forall\, i = 1, \dots, 16 \quad (33)$$

where $inv_i^{DOM+IMP}$, $hou_i^{DOM+IMP}$, $npih_i^{DOM+IMP}$, and $gov_i^{DOM+IMP}$ represent each element in the investment demand, household consumption, NPIH demand, and government expenditure vectors, respectively (including domestic and imported sources); $invt^N$, $hout^N$, $npiht^N$, and $govt^N$ are the respective column sum, including also indirect taxes.

From Equations (30) to (33), we can generate vectors with coefficients of investment demand ($\mathbf{cinv}^{\mathrm{N}}$), household consumption ($\mathbf{chou}^{\mathrm{N}}$), NPIH demand ($\mathbf{cnpih}^{\mathrm{N}}$), and government expenditure ($\mathbf{cgov}^{\mathrm{N}}$).

The next step has been to estimate the regional coefficients. In order to obtain the intermediate consumption shares, **RICC**, we have transformed the 16 **SHIN_N** matrices into 26 **SHIN_S** matrices of size *16* x 25, which represent, for each origin, foreign region inclusive, the consumption share of each sector in each destination region. Thus, each **SHIN_S** matrix represents one origin trade region, where rows show the sectors and columns the destination regions.

Therefore, using Vinnytsya (the first region) as an example, the **SHIN_S** for this region is composed of all the first rows of each of the 16 **SHIN_N**. For the second region, Volyn, the **SHIN_S** includes all the second rows of each of the 16 **SHIN_N**, and so on. Further, in order to estimate **RICC**, each column of each **SHIN_S** matrix is diagonalized and multiplied by $\mathbf{CIC}^{\boldsymbol{N}}$:

$$\mathbf{RICC}^{\mathrm{sd}} = \mathbf{SHIN\_S}^{*} * \mathbf{CIC}^{\mathrm{N}} \qquad (34)$$

where $\mathbf{SHIN\_S}^{*}$ is a diagonal matrix whose non-zero elements come from the **SHIN_S**; *s* represents the 26 origin regions, and *d* represents the 25 destination regions.

From Equation (34), we estimated 25 destination matrices of size 16 x 16 (sector x sector) for each origin region. These matrices contain the shares of each sector in the intermediate consumption in each destination region.

Similarly, for each of the final demand components, we estimated, for each origin region, 26 vectors of size *16* x *1*, **shin_s**, which represents the shares of each destination region *d* in the acquisition of the output from each of the 16 sectors.

The final demand for capital goods (investment demand) for each region is given by

$$\mathbf{rcinv}^{\mathrm{sd}} = \mathbf{SHIN\_S}^{**} * \mathbf{cinv}^{\mathrm{N}}, \forall\, s = 1, \ldots, 26; \text{ and } d = 1, \ldots, 25 \qquad (35)$$

where $\mathbf{SHIN\_S}^{**}$ is a diagonal matrix of the vector **shin_s**.

For household consumption:

$$\mathbf{rchou}^{\mathrm{sd}} = \mathbf{SHIN\_S}^{**} * \mathbf{chou}^{\mathrm{N}}, \forall\, s = 1, \ldots, 26; \text{ and } d = 1, \ldots, 125 \qquad (36)$$

For NPIH demand:

$$\mathbf{rcnpih}^{\mathrm{sd}} = \mathbf{SHIN\_S}^{**} * \mathbf{cnpih}^{\mathrm{N}}, \forall\, s = 1, \ldots, 26; \text{ and } d = 1, \ldots, 25 \qquad (37)$$

and for government expenditure:

$$\mathbf{rcgov}^{\mathrm{sd}} = \mathbf{SHIN\_S}^{**} * \mathbf{cgov}^{\mathrm{N}}, \forall\, s = 1, \ldots, 26; \text{ and } d = 1, \ldots, 25 \qquad (38)$$

In order to obtain the regional share for the indirect tax paid by each user, we have calculated some coefficients from the national tax matrix. These coefficients are calculated for intermediate consumption, investment, household consumption, NPIH demand, and government expenditure as follows.

The matrix with the national indirect tax coefficients related to intermediate consumption ($\mathbf{TCIC}^{\mathrm{N}}$) is given by

$$\mathbf{TCIC}^{\mathrm{N}} = \mathbf{TIC}^{\mathrm{N}} * (\mathbf{ICT}^{\mathrm{N}})^{-1} \qquad (39)$$

where $\mathbf{TIC}^{\mathrm{N}}$ is a matrix of size *16* x *16* (*sector* x *sector*) with the indirect taxes related to intermediate consumption in the national tax matrix; and $\mathbf{ICT}^{\mathrm{N}}$ is a diagonal matrix with the sectorial total intermediate consumption.

The vector with national indirect tax coefficients related to investment ($\boldsymbol{tcinv}^{\mathrm{N}}$) is

$$\mathbf{tcinv}^{\mathrm{N}} = \mathbf{tinv}^{\mathrm{N}} * (invt^{N})^{-1} \qquad (40)$$

where $\mathbf{tinv}^{\mathrm{N}}$ is the vector with tax related to investment, and $invt^N$ is the total demand for investment from the national use matrix.

The vector with national tax coefficients related to household consumption ($\mathbf{tchou}^{\mathrm{N}}$) is given by

$$\mathbf{tchou}^{\mathrm{N}} = \mathbf{thou}^{\mathrm{N}} * (hout^N)^{-1} \quad (41)$$

where $\mathbf{thou}^{\mathrm{N}}$ is the vector with tax related to household consumption, and $hout^N$ is the total demand for households from the national use matrix.

The vector with national tax coefficients related to NPIH demand ($\mathbf{tcnpih}^{\mathrm{N}}$) is given by

$$\mathbf{tcnpih}^{\mathrm{N}} = \mathbf{tnpih}^{\mathrm{N}} * (npiht^N)^{-1} \quad (42)$$

where $\mathbf{tnpih}^{\mathrm{N}}$ is the vector with tax related to NPIH demand, and $npiht^N$ is the total demand for NPIH from the national use matrix.

Finally, the vector with national tax related to government expenditure ($\mathbf{tcgov}^{\mathrm{N}}$) is

$$\mathbf{tcgov}^{\mathrm{N}} = \mathbf{tgov}^{\mathrm{N}} * (govt^N)^{-1} \quad (43)$$

where $\mathbf{tgov}^{\mathrm{N}}$ is the vector with tax related to government consumption, and $govt^N$ is the total demand for the government from the national use matrix.

The regional coefficients are obtained by multiplying each column of **SHIN_S** by the national tax coefficient. Thus, the regional coefficient for indirect tax related to intermediate consumption is given by

$$\mathbf{RTCIC}^{\mathrm{sd}} = \mathbf{SHIN\_S}^{*} * \mathbf{TCIC}^{\mathrm{N}}, \forall\, s = 1, \ldots, 26; \text{ and } d = 1, \ldots, 25 \quad (44)$$

which generates 256 matrices of size *16* x *16* (sector x sector). These matrices represent the regional indirect tax coefficients for each pair of regions *s* x *d* (origin x destination).

For investment demand:

$$\mathbf{rtcinv}^{sd} = \mathbf{SHIN\_S}^{*} * \mathbf{tcinv}^{N}, \forall\, s = 1, \ldots, 26; \text{ and } d = 1, \ldots, 25 \qquad (45)$$

which gives us 256 vectors of size 16 x *1* representing the proportion paid in tax related to the acquisition of products for investment in each pair of regions *s* x *d.*

Similarly, we have the regional coefficient for household consumption:

$$\mathbf{rtchou}^{sd} = \mathbf{SHIN\_S}^{*} * \mathbf{tchou}^{N}, \forall\, s = 1, \ldots, 26; \text{ and } d = 1, \ldots, 25 \qquad (46)$$

for NPIH demand:

$$\mathbf{rtcnpih}^{sd} = \mathbf{SHIN\_S}^{**} * \mathbf{tcnpih}^{N}, \forall\, s = 1, \ldots, 26; \text{ and } d = 1, \ldots, 25 \qquad (47)$$

and for government expenditure:

$$\mathbf{rtcgov}^{sd} = \mathbf{SHIN\_S}^{*} * \mathbf{tcgov}^{N}, \forall\, s = 1, \ldots, 14; \text{ and } d = 1, \ldots, 13 \qquad (48)$$

In order to have all regional coefficients in monetary flows, we have multiplied the coefficients defined above by the regional values presented in Section 2.2.

Intermediate consumption:

$$\mathbf{RIC}^{sd} = \mathbf{RICC}^{sd} * \mathbf{RICT}^{d}, \forall\, s = 1, \ldots, 26; \text{ and } d = 1, \ldots, 25 \qquad (49)$$

where $\mathbf{RIC}^{sd}$ is the regional intermediate consumption matrix for each pair of regions (*s x d*), and $\mathbf{RICT}^{d}$ is a matrix with the total regional intermediate consumption in the main diagonal and zero elsewhere.

Investment demand:

$$\mathbf{rinv}^{sd} = \mathbf{rcinv}^{sd} * rinvt^{d}, \forall\, s = 1, \ldots, 26; \text{ and } d = 1, \ldots, 25 \qquad (50)$$

where $\mathbf{rinv}^{sd}$ is the vector of demand for regional investment for each pair of regions (*s x d*), and $rinvt^{d}$ is the total regional for investment.

Household consumption:

$$\mathbf{rhou}^{sd} = \mathbf{rchou}^{sd} * rhout^{d}, \forall\, s = 1, \ldots, 26; \text{ and } d = 1, \ldots, 25 \qquad (51)$$

where $\mathbf{rhou}^{sd}$ is the vector of regional household consumption for each pair of regions (*s x d*), and $rhout^{d}$ is the total regional household consumption.

NPIH demand:

$$\mathbf{rnpih}^{sd} = \mathbf{rcnpih}^{sd} * rnpiht^{d}, \forall\, s = 1, \ldots, 26; \text{ and } d = 1, \ldots, 25 \qquad (52)$$

where $\mathbf{rnpih}^{sd}$ is the vector of regional NPIH demand for each pair of regions (*s x d*), and $rnpiht^{d}$ is the total regional NPIH demand.

Government expenditure:

$$\mathbf{rgov}^{sd} = \mathbf{rcgov}^{sd} * rgovt^{d}, \forall\, s = 1, \ldots, 26; \text{ and } d = 1, \ldots, 25 \qquad (53)$$

where $\mathbf{rgov}^{sd}$ is the vector of regional government expenditures for each pair of regions (*s x d*), and rgovt^{d} is the total regional government expenditures.

Given the estimates of sectoral foreign exports by region ($\exp^{r}$), the values are allocated directly in the relevant column of the inter-regional system. For sectors where regionally disaggregated foreign exports were not available, we assumed the same ratio of sectoral foreign exports to sectoral gross output to allocate foreign exports across regions.

A similar procedure has been used to transform indirect tax coefficients in monetary flows as follows:

For tax related to intermediate consumption:

$$\mathbf{RTIC}^{\mathrm{sd}} = \mathbf{RTCIC}^{\mathrm{sd}} * \mathbf{RICT}^{\mathrm{d}}, \forall\, s = 1, \dots, 26; \text{ and } d = 1, \dots, 25 \qquad (54)$$

Investment:

$$\mathbf{rtinv}^{\mathrm{sd}} = \mathbf{rtcinv}^{\mathrm{sd}} * rinvt^{d}, \forall\, s = 1, \dots, 26; \text{ and } d = 1, \dots, 25 \qquad (55)$$

Household consumption:

$$\mathbf{rthou}^{\mathrm{sd}} = \mathbf{rtchou}^{\mathrm{sd}} * rhout^{d}, \forall\, s = 1, \dots, 26; \text{ and } d = 1, \dots, 25 \qquad (56)$$

NPIH demand:

$$\mathbf{rtnpih}^{\mathrm{sd}} = \mathbf{rtcnpih}^{\mathrm{sd}} * rnpiht^{d}, \forall\, s = 1, \dots, 26; \text{ and } d = 1, \dots, 25 \qquad (57)$$

and government expenditure:

$$\mathbf{rtgov}^{\mathbf{sd}} = \mathbf{rtcgov}^{\mathbf{sd}} * rgovt^{d}, \forall\, s = 1, \dots, 14; \text{ and } d = 1, \dots, 13 \qquad (58)$$

In order to have the completed inter-regional system, we need the regional value-added components (VA^R). In the interregional input-output system, the total regional output (x^R) should be equivalent to the total demand of each region (DT^R). This balance checking can be done using the following identities.

Total regional output:

$$\mathbf{x}^{\mathrm{R}} = \sum_{i=1}^{16} \mathbf{RIC}^{\mathrm{sd}} + \sum_{i=1}^{16} \mathbf{RTIC}^{\mathrm{sd}} + \mathbf{rva}^{\mathrm{sd}} \tag{59}$$

where $\mathbf{x}^{\mathrm{R}}$ is the vector of sectorial regional total output; $\mathbf{RIC}^{\mathrm{sd}}$ is the regional intermediate consumption matrix; $\mathbf{RTIC}^{\mathrm{sd}}$ is the indirect tax matrix related to intermediate consumption, and $\mathbf{rva}^{\mathrm{sd}}$ is the vector of regional value-added.

Total demand:

$$\mathbf{dt}^{\mathrm{R}} = \sum_{j=1}^{16} \mathbf{RIC^{sd}} + \mathbf{rinv^{sd}} + \mathbf{rhou^{sd}} + \mathbf{rnpih^{sd}} + \mathbf{expr^{sd}} + \mathbf{rgov^{sd}} \tag{60}$$

where $\mathbf{dt}^{\mathrm{R}}$ is the total demand vector; $\mathbf{rinv}^{\mathrm{sd}}$ is the demand for investment; $\mathbf{rhou}^{\mathrm{sd}}$ is the household consumption; $\mathbf{rnpih^{sd}}$ is the NPIH demand; $\mathbf{expr}^{\mathrm{sd}}$ is the export vector; and $\mathbf{rgov}^{\mathrm{sd}}$ is the government expenditure.

Finally, an adjustment in stocks ($\mathbf{stock}^{\mathrm{R}}$) has to be done to complete the interregional system:

$$\mathbf{stock}^{\mathrm{R}} = \mathbf{x}^{\mathrm{R}'} - \mathbf{dt}^{\mathrm{R}} \tag{61}$$

Figure 2. Structure of the Interregional Flows Database

		Processing sectors							*Final demand*					*Total output*
		11	$\cdots$	rn	…	$r1$	$\cdots$	rn						
Processing sectors	11	z_{11}^{11}	$\cdots$	z_{1n}^{11}		z_{11}^{1r}	$\cdots$	z_{1n}^{1r}	$\mathbf{c}_1^{1\bullet}$	$\mathbf{np}_1^{1\bullet}$	$\mathbf{i}_1^{1\bullet}$	$\mathbf{g}_1^{1\bullet}$	$\mathbf{e}_1^{1\bullet}$	x_1^1
	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\cdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
	$1n$	z_{n1}^{11}	$\cdots$	z_{nn}^{11}		z_{n1}^{1r}	$\cdots$	z_{nn}^{1r}	$\mathbf{c}_n^{1\bullet}$	$\mathbf{np}_n^{1\bullet}$	$\mathbf{i}_n^{1\bullet}$	$\mathbf{g}_n^{1\bullet}$	$\mathbf{e}_n^{1\bullet}$	x_n^1
	$\vdots$		$\vdots$		$\ddots$		$\vdots$		$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
	$r1$	z_{11}^{r1}	$\cdots$	z_{1n}^{r1}		z_{11}^{rr}	$\cdots$	z_{1n}^{rr}	$\mathbf{c}_1^{r\bullet}$	$\mathbf{np}_1^{r\bullet}$	$\mathbf{i}_1^{r\bullet}$	$\mathbf{g}_1^{r\bullet}$	$\mathbf{e}_1^{r\bullet}$	x_1^r
	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\cdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
	rn	z_{n1}^{r1}	$\cdots$	z_{nn}^{r1}		z_{n1}^{rr}	$\cdots$	z_{nn}^{rr}	$\mathbf{c}_n^{r\bullet}$	$\mathbf{np}_n^{r\bullet}$	$\mathbf{i}_n^{r\bullet}$	$\mathbf{g}_n^{r\bullet}$	$\mathbf{e}_n^{r\bullet}$	x_n^r
Imports		m_1^1	$\cdots$	m_n^1	…	m_1^r	$\cdots$	m_n^r	$m_c^\bullet$	$m_{np}^\bullet$	$m_c^\bullet$	$m_g^\bullet$	$m_e^\bullet$	m
Indirect taxes		t_1^1	$\cdots$	t_n^1	…	t_1^r	$\cdots$	t_n^r	$t_c^\bullet$	$t_{np}^\bullet$	$t_c^\bullet$	$t_g^\bullet$	$t_e^\bullet$	t
Labor payments		l_1^1	$\cdots$	l_n^1	…	l_1^r	$\cdots$	l_n^r						
Other payments		n_1^1	$\cdots$	n_n^1	…	n_1^r	$\cdots$	n_n^r						n
Outlays		x_1^1	$\cdots$	x_n^1	…	x_1^r	$\cdots$	x_n^r	c	np	i	g	e	
Employment		L_1^1	$\cdots$	L_n^1	…	L_1^r	$\cdots$	L_n^r						

z_{ij}^{rs}, with $i, j = 1, \dots, n$ and $r, s = 1, \dots, r$ represents interindustry sales from industry *i* in region *r* to industry *j* in region *s*

m_i^s and t_i^s with $i = 1, \dots, n, c, i, g, e$ represent, respectively, imports and indirect taxes payments in region *s*

l_i^s and L_i^s with $i = 1, \dots, n$ and $s = 1, \dots, r$ represent, respectively, payments by sectors for labor services, and the total number of workers in region *s*

n_j^s, with $j = 1, \dots, n$ and $s = 1, \dots, r$ represents payments by sectors for all other value-added items in region *s*

$c_i^{r\bullet}$, $np_i^{r\bullet}$, $i_i^{r\bullet}$, $g_i^{r\bullet}$, and $e_i^{r\bullet}$ with $i = 1, \dots, n$ and $r = 1, \dots, r$ represent the regional components of final demand, $f_i^{r\bullet}$, respectively, household purchases, NPIH purchases, investment purchases, government purchases, and exports from region *r*

x_i^r, with $i = 1, \dots, n$ and $r = 1, \dots, r$ is the total sectoral output in region *r*

4. Structural Analysis: Regions at Risk

To illustrate the potential use of the IIOM-UKR, we provide a few examples of input-output techniques that focus on understanding the role played by the main border regions at risk: Donetsk and Luhansk.

4.1. Linkages Structure

The conventional input-output model is given by

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{f} \tag{62}$$

and

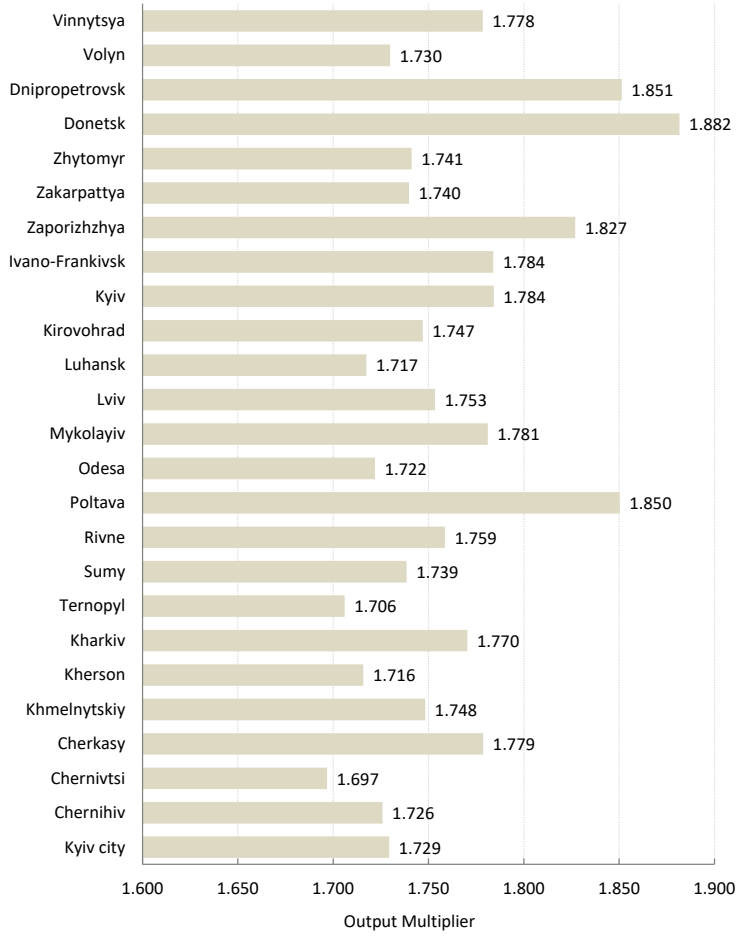
$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} = \mathbf{B}\mathbf{f} \tag{63}$$

where **x** and **f** are respectively the vectors of gross output and final demand; **A** is a matrix with the input-output coefficients a_{ij} defined as the amount of product *i* required per unit of product *j* (in monetary terms) – $i, j = 1, \ldots, n$; and **B** is known as the Leontief inverse.

The column multipliers derived from **B** were computed (Miller and Blair, 2009). An output multiplier is defined for each sector *j*, in each region *r*, as the total value of production in all sectors and in all regions of the economy that is necessary to satisfy a currency unit of final demand for sector *j*'s output. Figure 3 shows the output multiplier for the Ukrainian regions.

The multiplier effect can be decomposed into intraregional (internal multiplier) and interregional (external multiplier) effects, the former representing the impacts on the outputs of sectors within the region where the final demand change was generated, and the latter showing the impacts on the other regions of the system (interregional spillover effects). Figure 4 shows the intraregional and interregional shares for the average total output multipliers of the 25 regions of Ukraine (the total output multiplier effect net of the initial change). The entries are shown in percentage terms, providing insights into the degree of dependence of each region on the other regions.

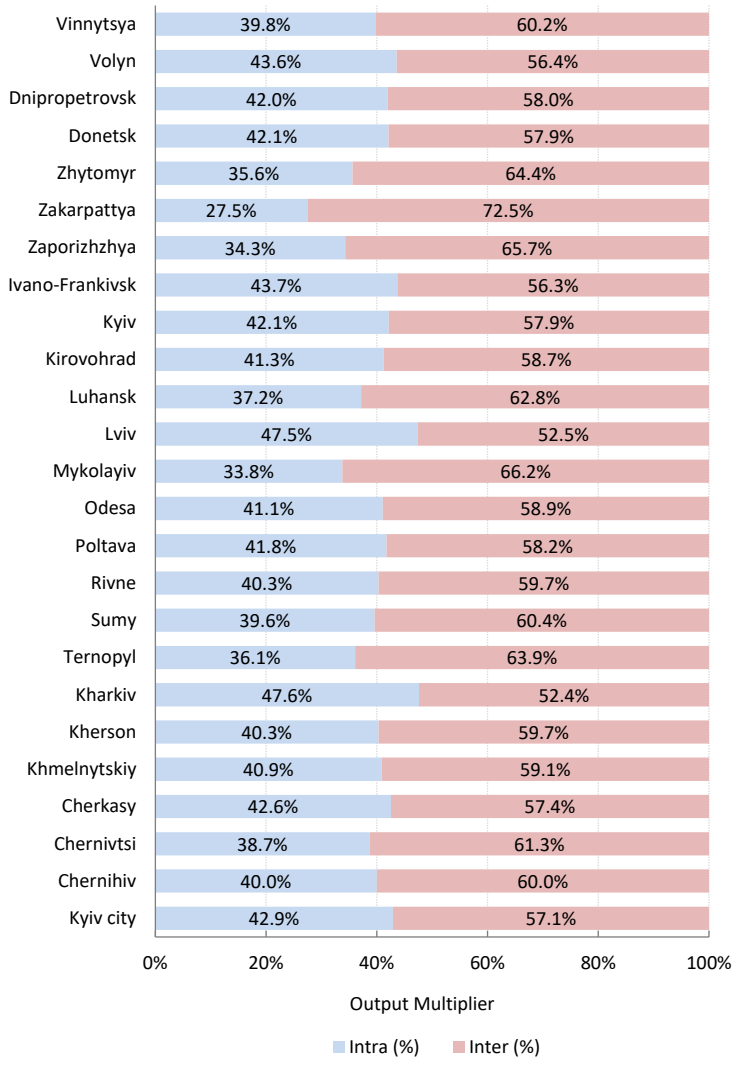
Figure 3. Output Multiplier: Ukraine, 2019



Note: The regional output multiplier is obtained by weighting region-sectoral multipliers by final demand.

Source: Interregional Input-Output System for Ukraine, 2019.

Figure 4. Regional Percentage Distribution of the Net Output Multipliers: Ukraine, 2019



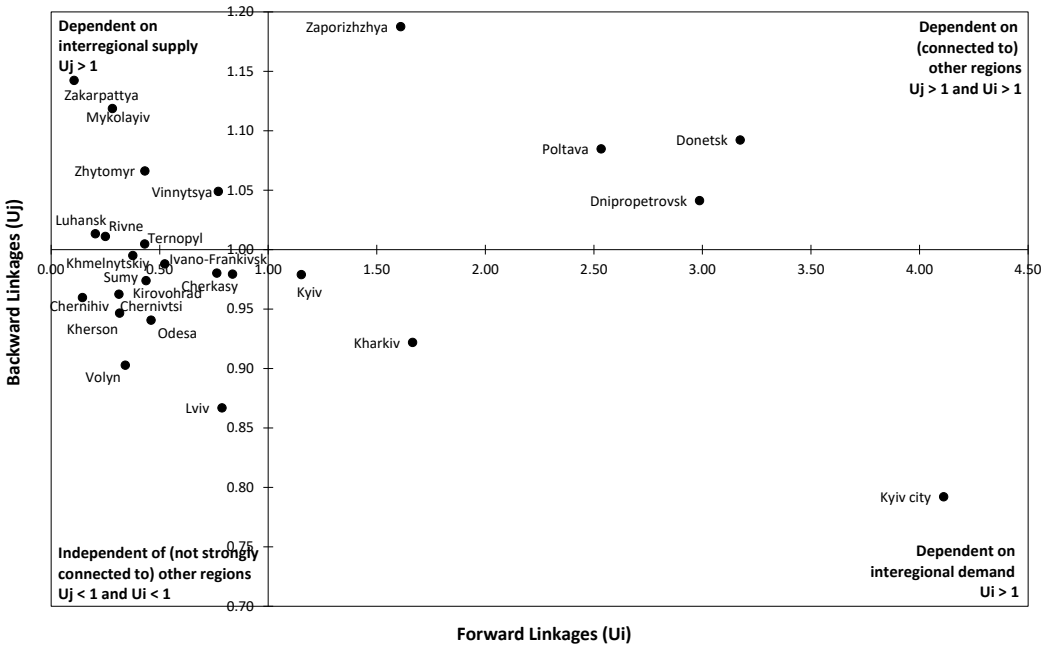
Source: Interregional Input-Output System for Ukraine, 2019.

We also calculate the forward and backward linkages associated with the Ukrainian regions. We calculate these multipliers using only interregional effects. Departing from $\mathbf{B} = \begin{bmatrix} \mathbf{B}^{11} & \cdots & \mathbf{B}^{1R} \\ \vdots & \ddots & \vdots \\ \mathbf{B}^{R1} & \cdots & \mathbf{B}^{RR} \end{bmatrix}$, intraregional effects are associated with the block matrices in the main diagonal, and interregional effects with the off-diagonal block matrices. Forward linkages are calculated as a row multiplier from **B**. While backward linkages are calculated as a column multiplier from **B**. Multipliers are aggregated regionally weighted by gross output. Then, we normalized the multiplier for each region by the national multiplier (simple average of the multipliers of all regions). In normalized form, the regions with both backward linkages (U_j) and forward linkages (U_i) greater than one are the most connected regions along interregional supply chains.

Our approach is similar to the traditional Rasmussen-Hirschman index to identify key sectors in the input-output model. If the backward linkage of the region *r* is larger than other regions, one might conclude that an expansion of region *r* output would be more beneficial to the economy than would an equal expansion in the other regions' output in terms of the productive activity throughout the economy that would be generated by it. Similarly, if the forward linkage of region *r* is larger than that of the other regions, it could be said that an expansion of the output of region *r* is more essential to the economy than a similar expansion in the output of the other regions, from the point of view of the overall productive activity that it could support.

Figure 5 shows the classification of the Ukrainian regions according to backward and forward linkages. Comparisons of the backward and forward linkages for the regions provide one mechanism for identifying "leading" regions in Ukraine's economy – those regions that are most connected and, therefore, in some sense, most "important". Figure 6 plots the typology of Ukrainian regions on a map according to the classification shown in Figure 5. The regions are distributed over a four-way classification as: dependent on (connected to) other regions ($U_i > 1$ and $U_j > 1$), dependent on interregional demand ($U_i > 1$), dependent on interregional supply ($U_j > 1$), and independent of (not strongly connected to) other regions ($U_i < 1$ and $U_j < 1$). Notice that regions in the northeast quadrant are located in the direct area of influence of the Kyiv-Donetsk corridor. Moreover, the two other oblasts in this area of influence, Kyiv and Kharkiv, and Kyiv city, are shown to be relatively more dependent on interregional demand (southeast quadrant).

Figure 5. Backward and forward linkages for Ukrainian regions



Source: Interregional Input-Output System for Ukraine, 2019.

Figure 6. Typology of Ukrainian regions based on backward and forward linkages

Source: Interregional Input-Output System for Ukraine, 2019.

4.2. Regional Propagation of Final Demand Shocks

Considering the systems Equations (62) and (63) in an interregional context, with *r* different regions, so that:

$$\mathbf{x} = \begin{bmatrix} \mathbf{x}^1 \\ \vdots \\ \mathbf{x}^R \end{bmatrix}; \mathbf{A} = \begin{bmatrix} \mathbf{A}^{11} & \cdots & \mathbf{A}^{1R} \\ \vdots & \ddots & \vdots \\ \mathbf{A}^{R1} & \cdots & \mathbf{A}^{RR} \end{bmatrix}; \mathbf{f} = \begin{bmatrix} \mathbf{f}^1 \\ \vdots \\ \mathbf{f}^R \end{bmatrix}; \text{ and } \mathbf{B} = \begin{bmatrix} \mathbf{B}^{11} & \cdots & \mathbf{B}^{1R} \\ \vdots & \ddots & \vdots \\ \mathbf{B}^{R1} & \cdots & \mathbf{B}^{RR} \end{bmatrix} \tag{64}$$

and

$$\begin{aligned} \mathbf{x}^1 &= \mathbf{B}^{11}\mathbf{f}^1 + \cdots + \mathbf{B}^{1R}\mathbf{f}^R \\ &\vdots \\ \mathbf{x}^R &= \mathbf{B}^{R1}\mathbf{f}^1 + \cdots + \mathbf{B}^{RR}\mathbf{f}^R \end{aligned} \tag{65}$$

Furthermore, we may consider different components of **f**, which include demands originating in the specific regions, *V,* and abroad, *e*. We obtain information on final demand from origin *s* in the IIOM-UKR, allowing us to treat **V** as a matrix that provides the monetary values of final demand expenditures from the domestic regions in Ukraine and the foreign region.

$$\mathbf{V} = \begin{bmatrix} \mathbf{V}^{11} & \cdots & \mathbf{V}^{1R} \\ \vdots & \ddots & \vdots \\ \mathbf{V}^{R1} & \cdots & \mathbf{V}^{RR} \end{bmatrix}; \text{ and } \mathbf{e} = \begin{bmatrix} \mathbf{e}^1 \\ \vdots \\ \mathbf{e}^R \end{bmatrix} \tag{66}$$

Thus, we can re-write Equation (65) as:

$$\begin{aligned} \mathbf{x^1} &= \mathbf{B^{11}}(\mathbf{V^{11}} + \cdots + \mathbf{V^{R1}} + \mathbf{e^1}) + \cdots + \mathbf{B^{1R}}(\mathbf{V^{1R}} + \cdots + \mathbf{V^{RR}} + \mathbf{e^R}) \\ &\vdots \\ \mathbf{x^R} &= \mathbf{B^{R1}}(\mathbf{V^{11}} + \cdots + \mathbf{V^{R1}} + \mathbf{e^1}) + \cdots + \mathbf{B^{RR}}(\mathbf{V^{1R}} + \cdots + \mathbf{V^{RR}} + \mathbf{e^R}) \end{aligned} \tag{67}$$

From Equation (67), we can compute the contribution of final demand from different origins on regional output. It is clear from (67) that regional output depends, among others, on demand originating in the region and on the degree of interregional integration, also on demand from outside the region.

In what follows, interdependence among sectors in different regions is considered through the analysis of the complete intermediate input portion of the interregional input-output table. Based on

the system (65), the Leontief inverse matrix will be considered, and some summary interpretations of the economy's structure derived from it will be provided. To illustrate the nature of interregional linkages in Ukraine, we analyze the structure of the Ukrainian economy derived from the Leontief inverse (multipliers) matrix, focusing on the database for 2019.

Following Equation (67), regional output (for each region) was decomposed, and the contributions of the components of final demand from different areas were calculated. The results are presented in Table 8. As expected, the main contributions to the final demand of a region are given by itself, so the highest values in the table are on the diagonal. In addition, the importance of Kyiv City (R25), Dnipropetrovsk (R03), and Donetsk (R04) for the Ukrainian economy is verified, with the final demand originating in these regions generating the largest contribution to the output of the other regions. The final demand for Kyiv City (R25) contributes to 12.36% of the Ukrainian output, and, at the regional level, it contributes mainly to the regions Kyiv (R09), Zhytomyr (R05), and Cherkasy (22). Final demand originating in Dnipropetrovsk (R03) contributes to 6.34% of total national output, and final demand originating in Donetsk (R04) contributes to 3.54% of the final output. The importance of the rest of the world's demand for Ukrainian production is worth noting, with a contribution of 35.47%.

A more systematic approach to visualize the influence of final demand from different regions is to map the original column estimates that generated Table 8. The results, shown in Table 9 for oblasts of Donetsk (R04) and Luhansk (R11), besides foreign exports, provide an attempt to reveal the spatial patterns of income dependence upon specific sources of final demand. The 25 regions are grouped in five different categories on each map so that darker colors represent higher values (Figure 7).

Table 8. Components of Decomposition of Regional Output Based on the Sources of Final Demand: Ukraine, 2019 (in %)

Regional Output		Origin of Final Demand																									Total
		R01	R02	R03	R04	R05	R06	R07	R08	R09	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22	R23	R24	R25	EXP	
R01	Vinnytsya	28.52	0.77	2.67	1.61	1.81	0.85	1.07	0.88	2.92	0.69	0.40	2.23	0.97	2.46	0.79	0.79	0.59	0.83	1.05	0.71	1.76	0.86	0.59	0.77	11.85	31.53	100.0
R02	Volyn	1.26	35.25	2.15	1.44	1.13	1.11	0.90	1.21	1.60	0.41	0.37	4.38	0.68	1.60	0.80	2.32	0.52	1.12	1.06	0.47	1.10	0.56	0.60	0.59	9.17	28.18	100.0
R03	Dnipropetrovsk	0.72	0.35	27.41	2.59	0.51	0.47	3.13	0.42	1.25	0.61	0.55	1.00	0.80	1.54	1.43	0.36	0.67	0.33	2.26	0.79	0.47	0.63	0.28	0.49	6.08	44.87	100.0
R04	Donetsk	0.91	0.49	5.14	22.78	0.66	0.70	2.15	0.59	1.63	0.58	1.30	1.46	1.03	2.33	1.31	0.49	0.78	0.44	2.47	0.87	0.60	0.70	0.39	0.62	7.78	41.78	100.0
R05	Zhytomyr	2.18	0.78	2.25	1.40	30.83	0.70	0.91	0.67	2.62	0.48	0.36	1.97	0.74	1.89	0.88	1.05	0.58	0.57	1.14	0.48	1.05	0.69	0.45	0.79	15.79	28.73	100.0
R06	Zakarpattya	0.69	0.46	1.47	1.04	0.42	35.82	0.60	0.78	0.73	0.27	0.25	1.79	0.45	0.86	0.46	0.42	0.30	0.45	0.58	0.33	0.56	0.30	0.34	0.31	4.50	45.81	100.0
R07	Zaporizhzhya	0.80	0.39	8.73	2.97	0.57	0.54	22.87	0.48	1.45	0.66	0.59	1.18	1.01	1.99	1.30	0.41	0.66	0.36	1.97	0.94	0.53	0.69	0.32	0.54	6.53	41.52	100.0
R08	Ivano-Frankivsk	1.42	1.18	2.16	1.43	0.93	1.85	0.84	33.33	1.76	0.49	0.37	6.06	0.80	1.89	0.73	1.04	0.50	1.60	0.92	0.58	1.52	0.59	1.46	0.62	7.98	27.93	100.0
R09	Kyiv	1.58	0.58	2.29	1.51	1.28	0.67	1.06	0.67	28.90	0.64	0.46	1.52	0.89	2.32	0.97	0.70	0.68	0.56	1.34	0.62	0.90	0.95	0.46	0.91	17.63	29.89	100.0
R10	Kirovohrad	1.36	0.51	5.18	2.49	0.81	0.77	2.17	0.72	2.22	27.64	0.58	1.68	1.12	2.83	1.53	0.55	0.73	0.52	2.06	0.96	0.80	1.48	0.45	0.72	8.91	31.21	100.0
R11	Luhansk	0.76	0.39	4.64	6.42	0.55	0.58	1.93	0.49	1.33	0.48	41.69	1.27	0.86	1.80	1.34	0.41	0.77	0.33	2.53	0.66	0.47	0.60	0.29	0.53	7.07	21.84	100.0
R12	Lviv	1.05	1.38	1.58	1.11	0.76	1.38	0.68	1.74	1.20	0.36	0.33	39.58	0.58	1.27	0.56	1.04	0.43	1.32	0.76	0.46	1.13	0.43	0.64	0.47	6.37	33.39	100.0
R13	Mykolayiv	0.56	0.25	1.70	1.09	0.35	0.34	0.76	0.30	0.96	0.30	0.26	0.73	28.04	3.62	0.44	0.25	0.27	0.24	0.68	1.44	0.36	0.35	0.21	0.30	4.06	52.15	100.0
R14	Odesa	1.05	0.45	2.19	1.90	0.63	0.57	1.16	0.55	1.63	0.56	0.53	1.11	2.55	39.52	0.73	0.44	0.54	0.46	1.05	1.64	0.71	0.68	0.37	0.56	7.05	31.36	100.0
R15	Poltava	1.12	0.63	6.30	2.79	0.96	0.81	2.01	0.70	2.43	0.84	0.72	1.82	0.98	2.41	19.59	0.66	1.45	0.52	4.45	0.85	0.75	1.16	0.45	0.97	12.74	31.89	100.0
R16	Rivne	1.57	2.43	2.44	1.63	1.57	1.08	1.00	1.20	2.13	0.47	0.39	3.88	0.74	1.82	0.93	32.34	0.58	1.22	1.14	0.52	1.30	0.69	0.63	0.71	12.74	24.87	100.0
R17	Sumy	0.83	0.45	3.84	2.25	0.70	0.60	1.37	0.52	1.64	0.49	0.61	1.35	0.71	1.71	1.78	0.48	34.59	0.37	2.92	0.58	0.56	0.75	0.32	0.84	8.63	31.08	100.0
R18	Ternopyl	1.58	1.29	2.32	1.55	1.05	1.17	0.91	1.79	1.69	0.55	0.40	5.14	0.86	1.75	0.75	1.33	0.49	34.37	0.92	0.58	2.43	0.57	0.86	0.64	7.17	27.85	100.0
R19	Kharkiv	0.86	0.54	6.76	3.79	0.78	0.65	2.00	0.54	1.89	0.72	1.13	1.43	0.99	1.82	2.91	0.53	1.62	0.41	30.40	0.97	0.63	0.88	0.35	0.83	9.48	27.10	100.0
R20	Kherson	0.93	0.40	5.16	2.99	0.58	0.62	2.33	0.54	1.49	0.70	0.56	1.34	3.44	4.15	1.12	0.42	0.60	0.38	1.70	38.08	0.56	0.71	0.33	0.51	6.72	23.64	100.0
R21	Khmelnytskiy	2.73	0.94	2.73	1.65	1.29	1.10	1.12	1.35	2.22	0.57	0.37	3.42	0.89	2.32	0.85	1.03	0.56	1.57	1.15	0.59	32.91	0.71	0.94	0.67	10.30	26.02	100.0
R22	Cherkasy	1.39	0.60	4.07	2.11	1.03	0.78	1.63	0.72	3.19	1.23	0.53	1.79	1.06	2.97	1.55	0.67	0.90	0.54	1.94	0.78	0.83	24.40	0.46	1.02	13.84	29.97	100.0
R23	Chernivtsi	1.58	0.85	2.75	1.86	0.94	1.04	1.09	1.90	1.76	0.57	0.42	2.85	0.87	1.71	0.86	0.78	0.54	1.07	0.99	0.63	1.64	0.63	41.84	0.64	8.93	21.24	100.0
R24	Chernihiv	1.05	0.50	2.71	1.69	0.92	0.63	1.15	0.57	2.17	0.50	0.43	1.45	0.77	1.92	1.10	0.57	0.83	0.41	1.45	0.51	0.65	0.82	0.35	31.91	14.34	30.61	100.0
R25	Kyiv City	1.76	0.87	2.90	2.34	1.99	0.88	1.48	0.98	2.98	0.95	0.97	1.66	1.27	1.84	1.51	1.16	1.28	0.81	2.00	1.04	1.38	1.19	0.65	1.59	24.13	40.39	100.0
	Total	2.18	1.32	6.34	3.54	1.71	1.29	2.55	1.54	3.56	1.18	1.08	3.75	1.71	3.70	2.30	1.29	1.51	1.11	3.68	1.41	1.61	1.48	0.89	1.44	12.36	35.47	100.0

Source: Interregional Input-Output System for Ukraine, 2019.

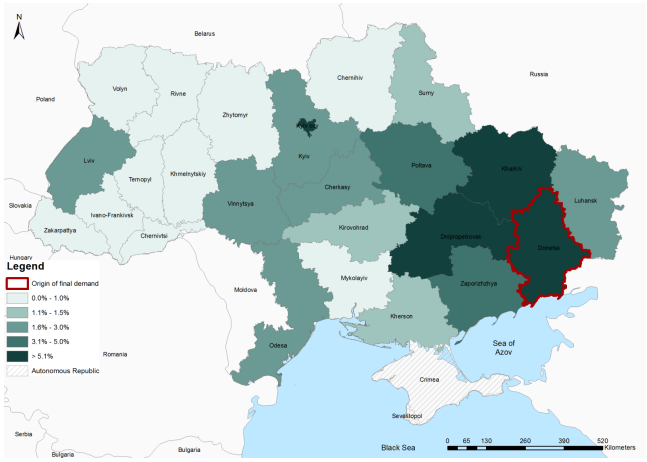
Table 9. Regions Relatively More Affected by a Specific Regional Demand

	Origin of Final Demand								
	R04 – Donetsk			R11 – Luhansk			Foreign Exports		
	Tradables	Services	Total	Tradables	Services	Total	Tradables	Services	Total
R01 Vinnytsya	1.97	1.29	1.55	1.54	1.12	1.27	3.28	2.22	3.04
R02 Volyn	0.76	0.73	0.74	0.66	0.59	0.62	1.57	1.01	1.44
R03 Dnipropetrovsk	10.16	6.89	8.12	7.13	4.83	5.63	17.14	3.73	14.04
R04 Donetsk	39.57	41.60	40.83	14.49	4.07	7.70	9.11	2.05	7.48
R05 Zhytomyr	1.01	0.72	0.83	0.86	0.62	0.70	1.83	1.32	1.71
R06 Zakarpattya	0.21	0.55	0.42	0.18	0.41	0.33	1.75	2.13	1.84
R07 Zaporizhzhya	5.58	2.56	3.70	3.64	1.76	2.42	6.10	2.10	5.17
R08 Ivano-Frankivsk	0.98	0.90	0.93	0.85	0.77	0.80	2.04	1.03	1.81
R09 Kyiv	2.52	2.37	2.43	2.25	2.51	2.42	4.94	4.29	4.79
R10 Kirovohrad	2.04	0.86	1.31	1.46	0.75	1.00	1.95	0.57	1.63
R11 Luhansk	2.49	1.32	1.76	37.68	37.73	37.71	0.66	0.39	0.60
R12 Lviv	1.31	1.82	1.63	1.23	1.79	1.59	4.10	7.44	4.88
R13 Mykolayiv	0.80	0.70	0.73	0.64	0.55	0.58	3.24	4.35	3.50
R14 Odesa	1.29	3.09	2.41	1.15	2.82	2.24	2.69	8.25	3.98
R15 Poltava	7.01	2.81	4.40	6.12	2.49	3.76	5.96	1.87	5.01
R16 Rivne	0.79	0.78	0.78	0.68	0.58	0.61	1.26	0.98	1.19
R17 Sumy	1.74	0.88	1.20	1.54	0.83	1.07	1.98	0.58	1.66
R18 Ternopyl	0.69	0.53	0.59	0.53	0.48	0.50	1.08	0.98	1.06
R19 Kharkiv	7.51	6.49	6.88	6.98	6.64	6.76	4.72	5.54	4.91
R20 Kherson	1.85	0.91	1.27	1.25	0.53	0.78	1.14	0.55	1.00
R21 Khmelnytskiy	1.34	0.76	0.98	1.03	0.55	0.72	1.81	0.64	1.54
R22 Cherkasy	2.58	1.07	1.64	2.05	0.99	1.36	2.69	1.14	2.33
R23 Chernivtsi	0.39	0.56	0.49	0.31	0.41	0.37	0.57	0.52	0.56
R24 Chernihiv	1.16	0.73	0.89	0.97	0.64	0.76	1.89	0.71	1.62
R25 Kyiv city	4.23	19.10	13.49	4.79	25.55	18.32	16.51	45.59	23.23
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

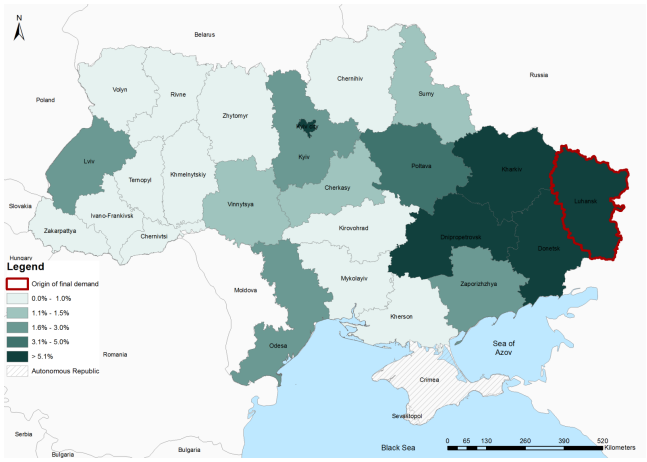
Source: Interregional Input-Output System for Ukraine, 2019.

Figure 7. Identification of Regions Relatively More Affected by a Specific Regional Demand, by Origin of Final Demand

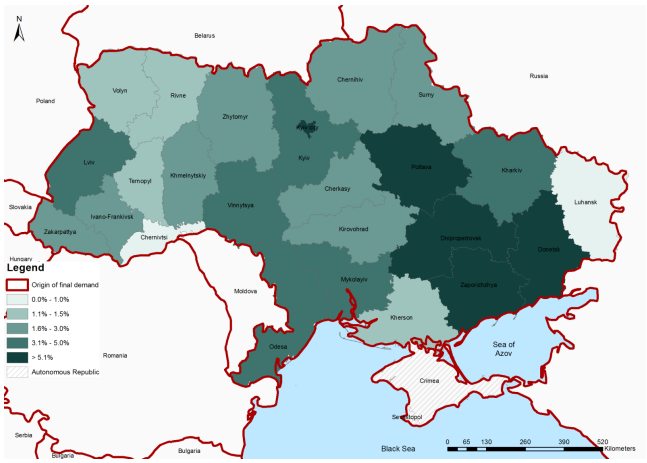
R04 - Donetsk



R11 – Luhansk



Foreign Exports



4.3. Hypothetical Extraction

Given an inter-regional input-output structure, it is possible to evaluate the economic importance of a region by hypothetically extracting it from the system. The hypothetical extraction (HE) method consists of removing trade flows from a given region in the input-output structure (Dietzenbacher et al., 1993). The economic impacts of extracting part of the intermediate and final demand are measured from this HE. Thus, this technique allows analyzing the importance of a region in an economic structure given its extraction and consequent reduction in the activity level in the economy.

The HE is modeled in an interregional input-output table, represented in Equation (64), replacing by zero the row and column of the block matrix $\mathbf{A}$ of a given region (r) that will be extracted from the model, giving rise to matrix $\overline{\mathbf{A}}_{(r)}$. The same procedure is performed for the final demand vector, generating a new vector $\bar{\mathbf{f}}_{(r)}$ for the reduced final demand. Output in the reduced economy will be given by $\bar{\mathbf{x}}_{(r)} = \left(\mathbf{I} - \overline{\mathbf{A}}_{(r)}\right)^{-1}\bar{\mathbf{f}}_{(r)}$. Let $\mathbf{x}$ be the original production vector; it is possible to estimate the effect of extraction on the output as $\Delta\mathbf{x} = \mathbf{x} - \bar{\mathbf{x}}_{(r)}$. For other variables, such as value added and employment, it is sufficient to adopt a conversion coefficient.

We proceeded with the following analyses from the hypothetical extraction approach. First, we assess the losses resulting from the total economic shutdown in Donetsk. In this case, a total extraction was performed in which sectoral exchanges in the region (intermediate consumption vectors) and their final demand components are removed. Next, we investigated the effects of hypothetical removal from the Luhansk region. This experiment is justified as the Russia-Ukraine conflict severely impacted these border regions.

4.3.1 Main results

Figure 8a shows the economic impacts of extracting Donetsk on value added. The regions with the highest value-added losses are Zaporizhzhya (8,125 mln.UAH), Poltava (9,608 mln.UAH), Kharkiv (14,787 mln.UAH), Dnipropetrovsk (18,214 mln.UAH), and Kyiv City (34,353 mln.UAH). Donetsk contributes 176,350 mln.UAH to Ukraine's value added. If all economic relations from Donetsk with the rest of Ukraine were excluded, the total loss of value added in Ukraine would be 315,598 mln.UAH (9.2% from baseline). A similar regional dynamic is seen in the labor market (Figure 8b). The regions with the highest employment losses are Poltava (34,100), Zaporizhzhya (42,548) and

Kyiv City (51,440), Dnipropetrovsk (75,777), and Kharkiv (89,262 jobs). Donetsk concentrated 747,200 jobs, and the total loss of jobs in Ukraine after removing all economic relations with this region would be 1,399,303 jobs (8.4% from baseline).

The economic impacts on supply chains following the exclusion of trade relations with Donetsk are varied at the sectoral level. The simulations indicate that the Donetsk HE mainly affects Kharkiv (manufacturing sector), Poltava (manufacturing sector), Dnipropetrovsk (manufacturing sector), and Kyiv city (real estate and transportation activities). All data are presented in more detail in Tables A4-A6 in the Appendix.

Figure 8. Regional Impacts of Donetsk Hypothetical Extraction

(a) Value Added

(b) Employment

Figure 9a shows the economic impacts of extracting Luhansk on value added. The regions with the highest value added losses are Dnipropetrovsk (2,711 mln.UAH), Donetsk (3,299 mln.UAH), Kharkiv (3,414 mln.UAH), and Kyiv City (11,379 mln.UAH). Luhansk contributes 34,660 mln.UAH to Ukraine's added value. If all economic relations from Luhansk with the rest of Ukraine were excluded, the total loss of value added in Ukraine would be 67,548 mln.UAH (2.0% from baseline). Luhansk concentrated 303,700 jobs (Figure 9b). Luhansk HE would lead to a reduction of 442,970 jobs in Ukraine (2.7% from baseline). The regions with the highest employment losses are Dnipropetrovsk (11,727), Kyiv City (15,717), Donetsk (16,042), and Kharkiv (19,856).

The economic impacts on supply chains following the exclusion of trade relations with Luhansk are varied at the sectoral level. The simulations indicate that the Luhansk HE mainly affects Donetsk (manufacturing) and Kyiv city (real estate and scientific and technical activities). All data are presented in more detail in Tables A7-A8 in the Appendix.

Figure 9. Regional Impacts of Luhansk Hypothetical Extraction

(a) Value Added

(b) Employment

5. Concluding Remarks

Dealing with sustainable development of territories, in the spirit of the UN SDGs, requires support, among others, from advanced spatial modeling. Multiregional input-output analysis is part of a multidisciplinary scientific toolbox that has proven its validity and applicability worldwide, involving researchers and practitioners from different areas, such as regional scientists, planners, economists, geographers, social scientists, transportation experts, and environmental scientists.

In this paper, we developed an interregional input-output system for Ukraine, providing the numerical basis for developing analytical frameworks to support knowledge building in the recovery process of distressed territories during the post-war period. We offer this database to the international scientific community to support modeling projects focusing on structural features of the Ukrainian economy. As shown in our illustrative exercises, understanding the structure of intersectoral and interregional linkages is critical to understanding better the propagation of exogenous shocks in the economy.

Availability of Data and Material

The datasets generated and analyzed during the current study are available in the ResearchGate repository, downloadable at:

http://dx.doi.org/10.13140/RG.2.2.13114.26567

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Appendix

Table A1. List of Sectors: Aggregation

Input-Output Table of Ukraine[1]			Interregional Input-Output System	
NACE code	Code	Sector	Code	Description
A01-A03	S1	Agriculture, forestry and fishing	1	Agriculture, forestry and fishing
B05	S2	Mining of coal and lignite	2	Industry
B06	S3	Extraction of crude petroleum and natural gas	2	Industry
B07-B09	S4	Mining of metal ores; other mining and quarrying; mining support service activities	2	Industry
C10-C12	S5	Manufacture of food products; beverages and tobacco products	2	Industry
C13-C15	S6	Manufacture of textiles, wearing apparel, leather and related products	2	Industry
C16-C18	S7	Manufacture of wood, paper, printing and reproduction	2	Industry
C19.1	S8	Manufacture of coke	2	Industry
C19.2	S9	Manufacture of refined petroleum products	2	Industry
C20	S10	Manufacture of chemicals and chemical products	2	Industry
C21	S11	Manufacture of basic pharmaceutical products and pharmaceutical preparations	2	Industry
C22	S12	Manufacture of rubber and plastic products	2	Industry
C23	S13	Manufacture of other non-metallic mineral products	2	Industry
C24	S14	Manufacture of basic metals	2	Industry
C25	S15	Manufacture of fabricated metal products, except machinery and equipment	2	Industry
C26	S16	Manufacture of computer, electronic and optical products	2	Industry
C27	S17	Manufacture of electrical equipment	2	Industry
C28	S18	Manufacture of machinery and equipment n.e.c.	2	Industry
C29	S19	Manufacture of motor vehicles, trailers and semi-trailers	2	Industry
C30	S20	Manufacture of other transport equipment	2	Industry
C31-C33	S21	Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	2	Industry
D35	S22	Electricity, gas, steam and air conditioning supply	2	Industry
E36-E39	S23	Water supply; sewerage, waste management and remediation activities	2	Industry

Table A1. List of Sectors: Aggregation (cont.)

Input-Output Table of Ukraine[1]			Interregional Input-Output System	
NACE code	Code	Sector	Code	Description
F41-F43	S24	Construction	3	Construction
G45-G47	S25	Wholesale and retail trade; repair of motor vehicles and motorcycles	4	Wholesale and retail trade; repair of motor vehicles and motorcycles
H49-H52	S26	Transport, warehousing	5	Transportation and storage
H53	S27	Postal and courier activities	5	Transportation and storage
I55-I56	S28	Accommodation and food service activities	6	Accommodation and food service activities
J58-J60	S29	Publishing, motion picture, video, television programme production; sound recording, programming and broadcasting activities	7	Information and communication
J61	S30	Telecommunications	7	Information and communication
J62-J63	S31	Computer programming, consultancy, and information service activities	7	Information and communication
K64-K66	S32	Financial and insurance activities	8	Financial and insurance activities
L68	S33	Real estate activities	9	Real estate activities
M69-M71	S34	Legal and accounting activities; activities of head offices; management consultancy activities; architectural and engineering activities; technical...	10	Professional, scientific and technical activities
M72	S35	Scientific research and development	10	Professional, scientific and technical activities
M73-M75	S36	Advertising and market research; other professional, scientific and technical activities; veterinary activities service activities	10	Professional, scientific and technical activities
N77-N82	S37	Administrative and support	11	Administrative and support service activities
O84	S38	Public administration and defence; compulsory social security	12	Public administration and defence, compulsory social security2
P85	S39	Education	13	Education
Q86-Q88	S40	Human health activities, residential care activities and social work activities without accommodation	14	Human health and social work activities
R90-R93	S41	Arts, entertainment and recreation	15	Arts, entertainment and recreation
S94-S96, T97	S42	Other service activities	16	Other types of economic activity

Note: [1] State Statistics Service of Ukraine. Economic statistics. National accounts. Input-Output Table of Ukraine (at basic prices). Link: https://ukrstat.gov.ua/

Table A2. Interregional Trade: Purchases Shares, 2019

Origin \ Destination	R01	R02	R03	R04	R05	R06	R07	R08	R09	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22	R23	R24	R25	**Total**
R01 - Vinnytsya	0.558	0.015	0.011	0.011	0.036	0.019	0.011	0.016	0.025	0.018	0.009	0.016	0.017	0.019	0.009	0.017	0.010	0.023	0.006	0.013	0.037	0.016	0.019	0.015	0.024	**0.036**
R02 - Volyn	0.008	0.611	0.004	0.005	0.010	0.014	0.004	0.012	0.006	0.005	0.004	0.019	0.005	0.006	0.005	0.031	0.004	0.016	0.003	0.004	0.010	0.005	0.010	0.006	0.010	**0.019**
R03 - Dnipropetrovsk	0.026	0.018	0.576	0.071	0.021	0.029	0.137	0.020	0.027	0.046	0.042	0.019	0.042	0.033	0.063	0.020	0.037	0.021	0.057	0.048	0.021	0.036	0.023	0.026	0.037	**0.100**
R04 - Donetsk	0.019	0.015	0.047	0.542	0.017	0.026	0.050	0.017	0.021	0.023	0.071	0.017	0.032	0.031	0.031	0.016	0.025	0.016	0.036	0.030	0.016	0.022	0.019	0.019	0.027	**0.061**
R05 - Zhytomyr	0.021	0.010	0.005	0.006	0.500	0.009	0.005	0.007	0.014	0.007	0.004	0.009	0.007	0.008	0.006	0.015	0.006	0.009	0.004	0.005	0.012	0.008	0.008	0.010	0.024	**0.023**
R06 - Zakarpattya	0.004	0.004	0.003	0.003	0.003	0.494	0.003	0.006	0.002	0.002	0.002	0.006	0.003	0.003	0.002	0.004	0.002	0.005	0.001	0.002	0.004	0.002	0.005	0.002	0.004	**0.011**
R07 - Zaporizhzhya	0.011	0.008	0.064	0.034	0.009	0.014	0.502	0.009	0.013	0.020	0.018	0.009	0.022	0.018	0.021	0.009	0.014	0.009	0.018	0.024	0.010	0.016	0.010	0.011	0.015	**0.042**
R08 - Ivano-Frankivsk	0.012	0.016	0.005	0.006	0.009	0.031	0.005	0.609	0.008	0.007	0.005	0.033	0.008	0.009	0.005	0.015	0.005	0.030	0.003	0.006	0.018	0.006	0.034	0.007	0.010	**0.025**
R09 - Kyiv	0.035	0.017	0.014	0.016	0.036	0.023	0.016	0.018	0.580	0.025	0.016	0.016	0.023	0.029	0.018	0.023	0.018	0.021	0.014	0.017	0.024	0.030	0.021	0.029	0.072	**0.061**
R10 - Kirovohrad	0.011	0.005	0.014	0.011	0.007	0.009	0.014	0.006	0.010	0.561	0.008	0.006	0.011	0.011	0.012	0.006	0.007	0.007	0.008	0.012	0.008	0.020	0.007	0.008	0.009	**0.020**
R11 - Luhansk	0.002	0.002	0.006	0.019	0.002	0.003	0.006	0.002	0.003	0.003	0.508	0.002	0.004	0.003	0.005	0.002	0.004	0.002	0.005	0.004	0.002	0.003	0.002	0.003	0.004	**0.011**
R12 - Lviv	0.019	0.045	0.008	0.011	0.018	0.052	0.009	0.053	0.012	0.010	0.011	0.653	0.013	0.013	0.009	0.035	0.010	0.054	0.007	0.011	0.029	0.010	0.031	0.011	0.019	**0.052**
R13 - Mykolayiv	0.005	0.003	0.005	0.006	0.004	0.005	0.006	0.004	0.005	0.005	0.004	0.003	0.499	0.023	0.003	0.003	0.003	0.004	0.003	0.023	0.004	0.004	0.004	0.004	0.006	**0.018**
R14 - Odesa	0.018	0.011	0.010	0.018	0.013	0.017	0.016	0.013	0.014	0.016	0.018	0.010	0.063	0.599	0.010	0.011	0.011	0.014	0.009	0.044	0.016	0.014	0.015	0.013	0.018	**0.045**
R15 - Poltava	0.020	0.018	0.050	0.036	0.023	0.026	0.036	0.017	0.030	0.033	0.027	0.018	0.024	0.026	0.568	0.019	0.047	0.017	0.062	0.023	0.017	0.037	0.018	0.029	0.043	**0.061**
R16 - Rivne	0.010	0.030	0.005	0.006	0.014	0.012	0.005	0.011	0.008	0.005	0.004	0.015	0.005	0.006	0.005	0.551	0.004	0.017	0.003	0.004	0.012	0.006	0.009	0.006	0.014	**0.019**
R17 - Sumy	0.005	0.004	0.010	0.010	0.006	0.007	0.008	0.004	0.007	0.006	0.009	0.005	0.006	0.006	0.014	0.005	0.561	0.004	0.013	0.006	0.005	0.008	0.005	0.010	0.010	**0.020**
R18 - Ternopyl	0.009	0.012	0.004	0.004	0.007	0.012	0.004	0.015	0.005	0.005	0.004	0.017	0.006	0.005	0.003	0.013	0.003	0.537	0.002	0.004	0.021	0.004	0.012	0.005	0.005	**0.014**
R19 - Kharkiv	0.016	0.016	0.057	0.055	0.019	0.023	0.039	0.014	0.023	0.027	0.054	0.016	0.027	0.021	0.073	0.016	0.057	0.014	0.632	0.031	0.016	0.027	0.015	0.026	0.033	**0.071**
R20 - Kherson	0.005	0.003	0.011	0.012	0.004	0.006	0.013	0.004	0.005	0.009	0.006	0.004	0.035	0.015	0.006	0.003	0.005	0.004	0.005	0.546	0.004	0.006	0.004	0.004	0.005	**0.017**
R21 - Khmelnytskiy	0.027	0.013	0.007	0.007	0.015	0.016	0.007	0.016	0.011	0.009	0.005	0.016	0.009	0.010	0.006	0.014	0.006	0.031	0.004	0.007	0.553	0.008	0.020	0.008	0.012	**0.023**
R22 - Cherkasy	0.015	0.009	0.015	0.013	0.013	0.013	0.014	0.009	0.023	0.030	0.009	0.009	0.014	0.017	0.017	0.010	0.013	0.010	0.010	0.012	0.011	0.580	0.010	0.017	0.024	**0.030**
R23 - Chernivtsi	0.006	0.005	0.003	0.004	0.004	0.007	0.003	0.011	0.003	0.004	0.003	0.006	0.004	0.003	0.003	0.004	0.002	0.008	0.002	0.003	0.009	0.003	0.567	0.003	0.005	**0.011**
R24 - Chernihiv	0.007	0.005	0.006	0.007	0.008	0.007	0.006	0.005	0.010	0.007	0.005	0.005	0.007	0.007	0.008	0.006	0.009	0.005	0.005	0.005	0.006	0.009	0.005	0.546	0.018	**0.020**
R25 - Kyiv city	0.129	0.105	0.061	0.088	0.203	0.123	0.082	0.100	0.133	0.119	0.153	0.070	0.114	0.079	0.097	0.151	0.137	0.123	0.086	0.117	0.137	0.118	0.127	0.183	0.551	**0.188**
Total	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**

Source: Interregional Input-Output System for Ukraine, 2019.

Table A3. Interregional Trade: Sales Shares, 2019

Origin \ Destination	R01	R02	R03	R04	R05	R06	R07	R08	R09	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22	R23	R24	R25	**Total**
R01 - Vinnytsya	0.541	0.008	0.032	0.019	0.024	0.009	0.013	0.011	0.038	0.009	0.003	0.025	0.012	0.027	0.012	0.009	0.006	0.010	0.011	0.007	0.024	0.012	0.006	0.009	0.126	**1.000**
R02 - Volyn	0.015	0.596	0.023	0.017	0.013	0.012	0.010	0.015	0.018	0.004	0.003	0.053	0.007	0.014	0.012	0.030	0.005	0.013	0.011	0.004	0.012	0.006	0.006	0.006	0.097	**1.000**
R03 - Dnipropetrovsk	0.009	0.003	0.621	0.044	0.005	0.005	0.059	0.005	0.015	0.008	0.006	0.010	0.011	0.017	0.030	0.004	0.008	0.003	0.036	0.009	0.005	0.009	0.003	0.005	0.070	**1.000**
R04 - Donetsk	0.011	0.005	0.083	0.554	0.007	0.007	0.035	0.007	0.019	0.007	0.015	0.015	0.013	0.025	0.024	0.005	0.009	0.004	0.036	0.009	0.006	0.009	0.003	0.006	0.084	**1.000**
R05 - Zhytomyr	0.032	0.009	0.025	0.016	0.525	0.007	0.010	0.007	0.035	0.005	0.003	0.021	0.008	0.018	0.014	0.012	0.005	0.006	0.011	0.004	0.012	0.009	0.004	0.009	0.194	**1.000**
R06 - Zakarpattya	0.011	0.006	0.024	0.018	0.005	0.720	0.010	0.013	0.011	0.004	0.003	0.029	0.006	0.011	0.009	0.006	0.004	0.006	0.008	0.004	0.008	0.004	0.005	0.004	0.071	**1.000**
R07 - Zaporizhzhya	0.009	0.004	0.164	0.050	0.005	0.005	0.514	0.005	0.017	0.009	0.005	0.012	0.013	0.021	0.024	0.004	0.007	0.003	0.026	0.010	0.005	0.010	0.003	0.005	0.068	**1.000**
R08 - Ivano-Frankivsk	0.017	0.012	0.023	0.016	0.009	0.021	0.009	0.586	0.019	0.005	0.003	0.074	0.008	0.018	0.010	0.011	0.004	0.018	0.009	0.005	0.017	0.006	0.016	0.006	0.078	**1.000**
R09 - Kyiv	0.020	0.005	0.024	0.017	0.014	0.006	0.012	0.007	0.528	0.007	0.003	0.014	0.010	0.024	0.014	0.007	0.006	0.005	0.014	0.005	0.009	0.013	0.004	0.010	0.222	**1.000**
R10 - Kirovohrad	0.018	0.005	0.073	0.035	0.008	0.008	0.031	0.008	0.028	0.514	0.005	0.016	0.014	0.028	0.029	0.005	0.008	0.005	0.024	0.010	0.009	0.026	0.004	0.008	0.082	**1.000**
R11 - Luhansk	0.007	0.003	0.057	0.103	0.004	0.005	0.024	0.004	0.013	0.005	0.592	0.010	0.009	0.014	0.021	0.003	0.008	0.002	0.030	0.006	0.004	0.007	0.002	0.005	0.061	**1.000**
R12 - Lviv	0.013	0.016	0.017	0.013	0.008	0.017	0.007	0.024	0.013	0.004	0.003	0.694	0.006	0.013	0.008	0.013	0.004	0.016	0.008	0.004	0.013	0.005	0.007	0.005	0.070	**1.000**
R13 - Mykolayiv	0.009	0.003	0.030	0.020	0.005	0.005	0.014	0.005	0.015	0.005	0.003	0.010	0.689	0.063	0.009	0.003	0.003	0.003	0.010	0.022	0.005	0.006	0.002	0.004	0.057	**1.000**
R14 - Odesa	0.013	0.004	0.024	0.025	0.007	0.006	0.015	0.007	0.018	0.006	0.005	0.012	0.035	0.667	0.011	0.005	0.005	0.005	0.013	0.017	0.008	0.008	0.004	0.006	0.074	**1.000**
R15 - Poltava	0.012	0.006	0.089	0.037	0.009	0.007	0.026	0.007	0.027	0.010	0.006	0.017	0.010	0.022	0.452	0.006	0.016	0.004	0.063	0.007	0.007	0.016	0.003	0.010	0.133	**1.000**
R16 - Rivne	0.019	0.030	0.026	0.018	0.018	0.011	0.010	0.014	0.023	0.005	0.003	0.044	0.007	0.016	0.013	0.541	0.005	0.013	0.011	0.004	0.014	0.008	0.006	0.007	0.136	**1.000**
R17 - Sumy	0.009	0.004	0.051	0.032	0.007	0.006	0.018	0.005	0.019	0.006	0.006	0.013	0.008	0.016	0.035	0.005	0.593	0.003	0.041	0.005	0.005	0.010	0.003	0.010	0.091	**1.000**
R18 - Ternopyl	0.023	0.016	0.027	0.019	0.012	0.014	0.011	0.025	0.020	0.007	0.003	0.066	0.010	0.017	0.011	0.016	0.005	0.556	0.009	0.005	0.033	0.007	0.010	0.007	0.070	**1.000**
R19 - Kharkiv	0.008	0.004	0.086	0.048	0.007	0.005	0.024	0.005	0.018	0.007	0.010	0.012	0.010	0.015	0.050	0.004	0.017	0.003	0.549	0.008	0.005	0.010	0.002	0.007	0.087	**1.000**
R20 - Kherson	0.010	0.003	0.068	0.042	0.005	0.006	0.032	0.005	0.016	0.009	0.005	0.011	0.052	0.043	0.018	0.003	0.006	0.003	0.018	0.569	0.005	0.009	0.002	0.005	0.055	**1.000**
R21 - Khmelnytskiy	0.041	0.010	0.031	0.020	0.015	0.012	0.013	0.017	0.026	0.007	0.003	0.038	0.010	0.022	0.013	0.012	0.005	0.020	0.011	0.005	0.545	0.009	0.010	0.007	0.100	**1.000**
R22 - Cherkasy	0.017	0.005	0.052	0.026	0.010	0.007	0.021	0.007	0.042	0.018	0.004	0.016	0.012	0.029	0.027	0.006	0.009	0.005	0.021	0.007	0.008	0.488	0.004	0.012	0.148	**1.000**
R23 - Chernivtsi	0.020	0.008	0.031	0.022	0.009	0.011	0.012	0.025	0.018	0.006	0.003	0.030	0.009	0.016	0.012	0.008	0.005	0.012	0.009	0.005	0.019	0.007	0.608	0.006	0.090	**1.000**
R24 - Chernihiv	0.013	0.005	0.033	0.021	0.010	0.006	0.014	0.006	0.029	0.006	0.004	0.014	0.009	0.018	0.019	0.006	0.010	0.004	0.016	0.004	0.007	0.012	0.003	0.559	0.173	**1.000**
R25 - Kyiv city	0.024	0.011	0.035	0.029	0.026	0.011	0.019	0.013	0.039	0.012	0.011	0.020	0.015	0.021	0.025	0.015	0.015	0.010	0.028	0.011	0.017	0.016	0.008	0.020	0.550	**1.000**
Total	**0.035**	**0.019**	**0.108**	**0.062**	**0.024**	**0.017**	**0.043**	**0.024**	**0.056**	**0.018**	**0.013**	**0.055**	**0.026**	**0.050**	**0.048**	**0.019**	**0.021**	**0.015**	**0.062**	**0.018**	**0.023**	**0.026**	**0.011**	**0.020**	**0.188**	**1.000**

Source: Interregional Input-Output System for Ukraine, 2019.

Table A3. Average Travel Time (in minutes)

	Oblast	Centre city	R01	R02	R03	R04	R05	R06	R07	R08	R09	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22	R23	R24	R25
R01	Vinnytsya	Vinnytsia	0	320	464	706	110	538	505	331	174	258	873	323	419	313	487	246	506	207	593	531	120	280	271	341	211
R02	Volyn	Lutsk	321	0	709	914	206	372	763	248	345	548	969	142	708	602	558	73	598	158	665	820	236	474	311	433	303
R03	Dnipropetrovsk	Dnipro	483	691	0	247	498	1007	86	800	418	221	414	792	403	526	172	617	309	676	172	303	589	299	742	451	385
R04	Donetsk	Donetsk	726	912	250	0	719	1250	230	1043	661	464	196	1035	567	690	377	838	458	919	285	457	832	547	985	673	606
R05	Zhytomyr	Zhytomyr	115	210	519	724	0	531	572	402	145	345	779	303	505	399	367	136	408	277	474	617	186	284	341	242	113
R06	Zakarpattya	Uzhhorod	509	360	960	1201	512	0	1000	254	649	754	1275	242	914	808	864	391	904	322	971	1026	409	775	373	739	609
R07	Zaporizhzhya	Zaporizhzhia	524	762	83	233	570	1048	0	841	459	262	418	833	385	509	244	689	388	717	250	286	630	340	784	523	457
R08	Ivano-Frankivsk	Ivano-Frankivsk	315	246	766	1007	380	265	806	0	455	560	1174	136	720	614	736	250	776	132	843	832	215	581	135	611	481
R09	Kyiv	Bila Tserkva	184	355	411	652	149	694	452	487	0	217	735	447	377	271	323	281	366	363	430	489	276	171	427	201	81
R10	Kirovohrad	Kropyvnytskyi	273	557	216	457	351	797	256	590	221	0	624	582	382	317	239	483	420	466	344	321	379	127	533	366	269
R11	Luhansk	Luhansk	894	978	418	199	786	1299	417	1149	736	633	0	1071	755	878	426	905	479	1087	306	645	1000	656	1154	739	673
R12	Lviv	Lviv	316	141	767	1008	294	252	808	139	434	561	1058	0	721	615	646	173	686	129	753	833	216	582	265	521	391
R13	Mykolayiv	Mykolaiv	431	714	400	555	508	955	385	748	379	381	740	740	0	125	556	640	704	624	567	116	537	440	690	566	446
R14	Odesa	Odessa	322	605	519	674	399	846	504	639	270	310	859	631	123	0	539	531	622	515	645	235	428	331	582	457	337
R15	Poltava	Poltava	478	566	178	372	374	887	256	737	324	253	427	659	572	558	0	492	189	640	122	472	553	244	704	327	261
R16	Rivne	Rivne	251	74	639	844	136	406	692	255	275	478	899	178	638	532	487	0	528	142	594	750	191	404	295	362	233
R17	Sumy	Sumy	522	610	310	461	418	931	393	781	369	432	481	703	708	628	187	537	0	684	177	608	598	320	748	295	303
R18	Ternopyl	Ternopil	198	160	649	891	264	342	690	138	339	443	1057	128	604	498	620	142	660	0	727	716	98	464	162	495	365
R19	Kharkiv	Kharkiv	588	676	174	288	483	997	257	846	433	360	308	768	572	665	123	602	177	750	0	472	663	354	813	437	370
R20	Kherson	Kherson	549	832	299	446	626	1073	285	866	497	318	631	858	120	243	455	758	604	742	466	0	655	432	808	672	574
R21	Khmelnytskiy	Khmelnytskyi	118	242	569	810	182	434	609	228	258	363	977	220	523	417	539	192	579	104	646	635	0	384	174	414	284
R22	Cherkasy	Cherkasy	293	479	290	532	286	817	331	610	166	132	647	571	442	336	236	405	312	486	343	439	399	0	552	248	174
R23	Chernivtsi	Chernivtsi	264	309	716	958	331	388	757	137	406	510	1124	266	671	565	687	291	728	164	794	783	172	531	0	562	432
R24	Chernihiv	Chernihiv	352	440	477	682	247	761	519	610	201	374	737	532	566	460	326	366	296	514	433	680	427	251	578	0	136
R25	Kyiv City	Kyiv City	221	309	407	612	116	630	471	479	80	271	667	401	445	339	255	235	296	383	362	557	296	172	446	130	0

Source: Google Maps.

Table A4. - Regional impacts of Donetsk Hypothetical Extraction

Region	Oblasts	Gross Output		Value Addded		Employment	
		(mln.UAH)	(%)	(mln.UAH)	(%)	(*k*)	(%)
R01	Vinnytsya	9,055.1	3.2	3,382.3	3.0	21.2	3.2
R02	Volyn	4,293.6	2.8	1,858.4	2.9	10.5	2.8
R03	Dnipropetrovsk	49,200.7	5.3	18,214.5	5.4	75.8	5.4
R04	Donetsk	528,496.1	100.0	176,350.1	100.0	747.2	100.0
R05	Zhytomyr	4,976.6	2.8	2,013.2	2.7	14.1	2.7
R06	Zakarpattya	2,157.8	1.8	1,017.8	1.9	7.8	1.5
R07	Zaporizhzhya	23,244.0	6.3	8,125.3	6.1	42.5	5.7
R08	Ivano-Frankivsk	5,278.7	2.8	2,035.6	2.7	15.6	2.7
R09	Kyiv	14,184.3	3.0	5,790.1	3.1	21.8	2.8
R10	Kirovohrad	8,448.0	5.5	3,378.3	5.4	19.5	5.1
R11	Luhansk	11,216.6	13.9	4,576.5	13.2	37.8	12.4
R12	Lviv	8,690.6	2.0	3,558.2	1.9	21.3	2.0
R13	Mykolayiv	4,292.7	2.1	1,619.0	2.0	10.1	2.0
R14	Odesa	12,487.1	3.3	5,361.6	3.2	29.5	2.9
R15	Poltava	28,084.0	6.1	9,609.0	6.0	34.1	5.8
R16	Rivne	4,512.9	3.2	1,848.1	3.2	15.2	3.1
R17	Sumy	7,494.0	4.8	2,959.4	4.5	22.5	4.6
R18	Ternopyl	3,375.2	3.0	1,467.6	3.0	12.9	3.1
R19	Kharkiv	38,482.7	7.2	14,787.1	6.9	89.3	7.1
R20	Kherson	8,042.6	6.5	3,319.5	6.2	29.3	6.4
R21	Khmelnytskiy	6,022.3	3.5	2,413.8	3.4	18.2	3.4
R22	Cherkasy	10,530.1	4.6	4,032.8	4.5	23.5	4.4
R23	Chernivtsi	2,698.3	3.4	1,213.2	3.4	13.2	3.3
R24	Chernihiv	5,466.9	3.5	2,313.6	3.4	15.0	3.4
R25	Kyiv City	63,881.3	3.7	34,353.2	4.2	51.4	3.7
	Ukraine	864,612.2	10.3	315,598.1	9.2	1,399.3	8.4

Source: Interregional Input-Output System for Ukraine, 2019.

Table A5. Sectorial impacts of Donetsk Hypothetical Extraction

Sector	Description	Gross Output (mln.UAH)	Value Addded (mln.UAH)	Employment (*k*)
S01	Agriculture, forestry and fishing	70,790.2	29,142.2	207.4
S02	Manufacturing	467,336.4	121,809.4	290.9
S03	Construction	40,134.2	7,551.3	52.6
S04	Wholesale and retail trade	98,877.0	49,177.1	353.0
S05	Transportation and storage	36,713.3	16,682.6	98.4
S06	Accommodation and food service activities	4,118.5	2,058.9	21.3
S07	Information and communication	19,102.6	9,317.3	15.6
S08	Financial and insurance activities	16,586.2	10,407.8	19.1
S09	Real estate activities	26,391.0	18,747.3	22.7
S10	Professional, scientific and technical activities	27,600.9	13,571.0	31.0
S11	Administrative and support service activities	9,224.1	4,636.2	30.8
S12	Public administration and defence	20,190.0	15,236.1	49.0
S13	Education	12,323.1	8,774.0	93.1
S14	Human health and social work activities	9,749.0	5,038.3	71.1
S15	Arts, entertainment and recreation	2,049.3	1,245.7	15.8
S16	Other types of economic activity	3,426.5	2,203.0	27.5
	Total	864,612.2	315,598.1	1,399.3

Source: Interregional Input-Output System for Ukraine, 2019.

Table A6. Regional/Sectorial Impacts of Donetsk Hypothetical Extraction: Value Added (mln.UAH)

Region	Oblasts	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10	S11	S12	S13	S14	S15	S16
R01	Vinnytsya	1245	749	182	473	94	11	60	133	46	41	19	66	193	54	3	13
R02	Volyn	345	305	26	590	86	6	14	112	198	21	10	76	41	19	2	8
R03	Dnipropetrovsk	721	6,785	452	2,904	2,105	153	247	1,064	1,419	436	395	361	488	341	54	288
R04	Donetsk	10,701	92,085	4,255	26,399	4,794	444	5,268	2,236	4,613	7,902	1,098	12,452	2,300	1,087	132	584
R05	Zhytomyr	591	394	27	612	51	9	17	112	8	18	14	75	42	30	2	12
R06	Zakarpattya	21	88	19	576	14	5	1	66	38	6	6	56	43	68	5	5
R07	Zaporizhzhya	605	3,896	97	1,296	225	39	64	357	418	217	72	166	444	150	15	65
R08	Ivano-Frankivsk	209	618	58	572	66	17	15	97	70	23	27	47	189	19	2	7
R09	Kyiv	939	1,281	111	761	930	80	53	482	594	93	118	170	58	80	11	29
R10	Kirovohrad	1,481	538	37	400	520	3	19	94	56	16	33	88	38	30	12	12
R11	Luhansk	1,478	825	28	1,753	32	8	10	101	47	32	18	130	66	32	8	7
R12	Lviv	235	767	149	839	191	98	118	229	335	88	68	131	130	136	19	24
R13	Mykolayiv	131	501	56	363	187	12	10	81	52	39	19	64	60	26	7	11
R14	Odesa	280	472	371	858	1,529	41	59	262	644	115	87	108	297	181	18	42
R15	Poltava	2,070	4,169	230	1,282	365	30	74	270	321	130	135	207	104	170	11	41
R16	Rivne	326	359	44	718	67	4	7	102	40	7	7	35	38	8	2	84
R17	Sumy	928	698	25	630	146	9	20	118	77	28	24	76	114	47	2	19
R18	Ternopyl	529	168	21	362	39	3	9	62	30	7	6	28	188	10	1	5
R19	Kharkiv	1,684	4,414	607	3,002	381	88	378	535	767	237	164	277	1,906	201	54	92
R20	Kherson	1,296	491	28	920	151	9	16	134	77	14	15	68	61	25	4	8
R21	Khmelnytskiy	916	411	52	627	65	4	12	95	63	17	21	56	49	16	2	6
R22	Cherkasy	1,409	1,062	31	559	310	11	50	199	149	34	35	65	68	28	5	17
R23	Chernivtsi	208	113	36	503	18	4	12	113	37	7	4	25	111	16	1	5
R24	Chernihiv	794	340	21	531	100	18	24	208	96	14	25	83	26	15	4	15
R25	Kyiv City	0	280	587	1,645	4,216	952	2,759	3,145	8,552	4,028	2,218	327	1,720	2,248	870	806

Source: Interregional Input-Output System for Ukraine, 2019.

Table A7. Regional impacts of Luhansk Hypothetical Extraction

Region	Oblasts	Gross Output		Value Addded		Employment	
		(mln.UAH)	(%)	(mln.UAH)	(%)	(*k*)	(%)
R01	Vinnytsya	1,573.0	0.6	622.8	0.6	3.9	0.6
R02	Volyn	750.1	0.5	340.0	0.5	2.1	0.5
R03	Dnipropetrovsk	6,837.3	0.7	2,711.3	0.8	11.7	0.8
R04	Donetsk	9,739.4	1.8	3,299.3	1.9	16.0	2.1
R05	Zhytomyr	876.3	0.5	363.2	0.5	3.0	0.6
R06	Zakarpattya	358.1	0.3	178.6	0.3	1.6	0.3
R07	Zaporizhzhya	2,938.9	0.8	1,110.9	0.8	6.1	0.8
R08	Ivano-Frankivsk	932.0	0.5	389.1	0.5	3.1	0.5
R09	Kyiv	2,953.9	0.6	1,264.5	0.7	5.4	0.7
R10	Kirovohrad	1,312.9	0.9	541.2	0.9	3.5	0.9
R11	Luhansk	80,770.8	100.0	34,660.1	100.0	303.7	100.0
R12	Lviv	1,830.2	0.4	806.4	0.4	4.8	0.4
R13	Mykolayiv	702.6	0.4	281.7	0.4	2.0	0.4
R14	Odesa	2,605.0	0.7	1,197.1	0.7	6.2	0.6
R15	Poltava	4,731.5	1.0	1,687.7	1.0	6.7	1.1
R16	Rivne	746.6	0.5	312.8	0.5	2.9	0.6
R17	Sumy	1,354.3	0.9	565.2	0.9	4.8	1.0
R18	Ternopyl	596.7	0.5	284.4	0.6	2.5	0.6
R19	Kharkiv	7,806.1	1.5	3,414.3	1.6	19.9	1.6
R20	Kherson	1,031.7	0.8	432.3	0.8	4.2	0.9
R21	Khmelnytskiy	927.2	0.5	378.1	0.5	3.2	0.6
R22	Cherkasy	1,755.1	0.8	695.4	0.8	4.4	0.8
R23	Chernivtsi	433.5	0.6	208.6	0.6	2.3	0.6
R24	Chernihiv	969.3	0.6	424.1	0.6	3.2	0.7
R25	Kyiv City	20,787.5	1.2	11,379.4	1.4	15.7	1.1
	Ukraine	155,320.0	1.9	67,548.5	2.0	443.0	2.7

Source: Interregional Input-Output System for Ukraine, 2019.

Table A8. Sectorial Impacts of Luhansk Hypothetical Extraction

Sector	Description	Gross Output (mln.UAH)	Value Addded (mln.UAH)	Employment (*k*)
S01	Agriculture, forestry and fishing	23,268.0	9,578.7	60.2
S02	Manufacturing	48,020.3	12,516.3	75.7
S03	Construction	5,397.6	1,015.6	18.7
S04	Wholesale and retail trade	27,500.0	13,677.3	103.9
S05	Transportation and storage	7,549.5	3,430.5	29.5
S06	Accommodation and food service activities	1,247.4	623.6	9.1
S07	Information and communication	4,277.6	2,086.4	4.9
S08	Financial and insurance activities	3,797.0	2,382.6	4.4
S09	Real estate activities	6,478.8	4,602.3	7.2
S10	Professional, scientific and technical activities	4,998.4	2,457.7	13.7
S11	Administrative and support service activities	2,105.8	1,058.4	7.4
S12	Public administration and defence	8,834.6	6,666.9	23.1
S13	Education	5,739.9	4,086.8	40.3
S14	Human health and social work activities	4,198.3	2,169.7	29.2
S15	Arts, entertainment and recreation	861.5	523.7	5.2
S16	Other types of economic activity	1,045.3	672.1	10.3
	Total	155,320.0	67,548.5	443.0

Source: Interregional Input-Output System for Ukraine, 2019.

Table A9. Regional/Sectorial Impacts of Luhansk Hypothetical Extraction: Value Added (mln.UAH)

Region	Oblasts	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10	S11	S12	S13	S14	S15	S16
R01	Vinnytsya	179	123	32	56	21	3	21	25	12	11	4	18	90	23	1	4
R02	Volyn	55	53	5	58	19	2	4	22	54	5	2	24	22	9	1	3
R03	Dnipropetrovsk	82	828	60	234	366	34	69	161	276	104	68	72	168	105	14	71
R04	Donetsk	125	1,712	54	302	167	17	128	75	178	223	32	109	103	48	5	22
R05	Zhytomyr	93	72	5	72	12	3	6	22	2	5	3	24	23	14	1	4
R06	Zakarpattya	3	15	3	48	3	2	0	12	10	2	1	19	23	33	2	2
R07	Zaporizhzhya	65	448	12	103	37	8	17	51	78	45	12	31	143	43	4	15
R08	Ivano-Frankivsk	31	102	10	57	14	5	5	18	18	6	6	13	93	8	1	2
R09	Kyiv	146	239	23	114	233	26	20	106	169	28	29	52	30	37	4	10
R10	Kirovohrad	196	80	6	45	110	1	6	16	13	4	7	22	16	11	4	4
R11	Luhansk	7,002	6,519	370	11,148	504	91	283	615	386	357	174	5,813	833	372	99	94
R12	Lviv	38	136	29	94	46	34	44	49	95	26	17	43	71	67	8	9
R13	Mykolayiv	18	74	9	34	40	3	3	15	13	11	4	17	26	10	2	3
R14	Odesa	39	77	64	99	358	12	21	53	166	32	20	30	134	73	6	13
R15	Poltava	309	665	40	156	81	9	24	52	84	35	29	55	52	76	4	14
R16	Rivne	51	63	8	71	15	1	2	19	11	2	2	10	20	4	1	32
R17	Sumy	148	119	5	67	36	3	8	24	23	8	6	24	63	23	1	7
R18	Ternopyl	78	28	4	35	8	1	3	11	7	2	1	8	91	4	0	2
R19	Kharkiv	265	729	111	322	93	29	150	113	220	74	41	86	1,028	97	21	34
R20	Kherson	164	67	4	68	28	2	4	20	16	3	3	16	25	9	1	2
R21	Khmelnytskiy	133	67	9	62	14	1	4	17	15	4	4	15	24	7	1	2
R22	Cherkasy	203	172	6	68	67	3	16	38	38	9	8	17	32	12	2	6
R23	Chernivtsi	31	18	6	42	4	1	3	21	9	2	1	7	54	7	0	1
R24	Chernihiv	125	61	4	60	24	6	8	44	27	4	6	27	14	7	2	5
R25	Kyiv City	0	52	135	264	1,132	324	1,236	783	2,681	1,455	580	114	908	1,068	340	308

Source: Interregional Input-Output System for Ukraine, 2019

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