Scientific African 20 (2023) e01690

Contents lists available at ScienceDirect

Scientific African

journal homepage: www.elsevier.com/locate/sciaf

Analysis of economic and environmental impacts of shutting down the Moroccan Refinery Samir: An interregional input-output approach

Eduardo A. Haddad[a,b,c,*], Inácio F. Araújo[b], Chaimaa Chawki[a], Rachida El-Mansoum[a], Marouane Masnaoui[a]

[a] Université Mohammed VI Polytechnique, Rabat, Morocco
[b] Department of Economics at USP and NEREUS, São Paulo, Brazil
[c] Policy Center for the New South, Rabat, Morocco

ARTICLE INFO

Article history:
Received 12 July 2022
Revised 21 October 2022
Accepted 1 May 2023

Editor: DR B Gyampoh

Keywords:
Interregional input-output analysis
Hypothetical extraction
CO_2 emissions
Intersectoral impacts
Oil supply chain

ABSTRACT

The closing of Samir's Mohammedia refinery in August 2015 due to financial constraints has dramatically affected the fuel oil market in Morocco. In this paper, we assess the economic and environmental impacts of the disruption of Morocco's only refinery activities. We can isolate the oil refinery sector associated with Samir in a fully specified interregional input-output database, considering 20 industries in 12 Moroccan regions. We base our empirical strategy on the "hypothetical extraction" method, which serves as the methodological anchor to isolate the systemic measures of value-added and CO_2 emissions related to the refinery activities in a typical year of operation. The overall impact of the shutdown is 4.4% of the country's output, with more substantial regional effects faced by Grand Casablanca-Settat, followed by its neighboring regions.

Introduction

Created in 1959, the Moroccan Refinery Samir[1] facilitated the production of diesel and encouraged domestic production. The refinery is located near the oil port of Mohammedia, in the most significant industrial fuel zone in Morocco. The establishment in this location was the result of social, economic, technical factors and restrictions.

The location of Refinery Samir also affects territorial developmental processes. The establishment of Samir in Mohammedia is desirable from an economic and local development point of view, as it created output and jobs in the region. The Refinery can also exert a positive influence on the regional economic structure due to spatial spillovers along production chains. However, its positive economic impacts on income generation may be offset by negative externalities, such as increased environmental pollution.

* Corresponding author at. Av. Prof. Luciano Gualberto, 908, FEA2, sala C122, Cidade Universitária, São Paulo-SP, Brazil. 05508-010.
E-mail addresses: ehaddad@usp.br (E.A. Haddad), inacio.araujo@usp.br (I.F. Araújo), chaimaa.chawki@um6p.ma (C. Chawki), rachida.elmansoum@um6p.ma (R. El-Mansoum), marouane.masnaoui@um6p.ma (M. Masnaoui).

[1] SAMIR: Société Anonyme Marocaine de l'Industrie du Raffinage.

https://doi.org/10.1016/j.sciaf.2023.e01690

Samir, Morocco's single oil refinery, has already been considered a strategic asset for national development. Morocco imports all its energy inputs, from which a significant share are the refined oil and gas products. Besides boosting economic growth because of its interindustry relations, the refining industry would be an alternative for the supply of energy inputs, improving energy security in the country. With a production that reached 150,000 barrels per day [1], Samir shut down production from 2015.[2] It decreed the permanent closure in 2019 caused by the accumulation of debts — against a backdrop of instability of international oil prices and discussions about the budget deficit in the Moroccan economy because of subsidies on imported oil products [2]. Its closure and those of other small refineries in oil-importing developing countries is part of a debate underway since the 1980s [3].

The economic and environmental impacts of the closure of Refinery Samir are of particular interest in our analysis. The closure of the activities of one sector of activity can generate structural changes with effects on the pattern of location of the other sectors, which can extend to other regional economies and consequently affecting output and employment trends. This reorganization of the industry can benefit some regions and arrears for others [4]. In addition to implying a possible change in the use of urban space, as in the United States cities located in the 'Rust Belt', where the downturn in the automotive industry led to high unemployment and population declines [5].

In this paper, we assess the economic and environmental impacts of the disruption of Samir's Mohammedia Refinery activities, Morocco's only refinery. We can isolate the oil refinery sector associated with Samir in a fully specified interregional input-output database, considering 20 industries in 12 Moroccan regions. We base our empirical strategy on the "hypothetical extraction" method, which serves as the methodological anchor to isolate the systemic measures of gross output, value-added and CO_2 emissions related to the refinery activities in a typical year of operation.

To the best of our knowledge, our study is the first to analyze the structural effects of the closure of Samir's Mohammedia refinery on Morocco's economy. The impact analysis designed in our study can be useful in the current discussions about bringing back online the refinery's activities [6–8]. Our main results show that the closure of the refinery generates a loss of gross output and value added, as well as a reduction in CO2 emissions. On the one hand, our evidence reveals which industries are most impacted by the disruption of the local oil supply chain. Knowing the most impacted regions and sectors can help decision-makers to define strategies to mitigate the short and medium-term impacts on the economy. On the other hand, the closure of an oil refinery park can affect the air pollutant concentrations [9]. Our evidence on the environmental impacts can support discussions on the production of energetic alternative sources in Morocco [10] and structural change for improving the supply chains of other economic activities toward green growth [11].

In this study, we propose an extension of the hypothetical extraction method to address value chain effects. We identify the main direct and indirect linkages of the supply chain of the oil refinery sector in Morocco through the decomposition of the hypothetical extraction results. This allows us to evaluate the systemic effects of the shutting down of the Refinery Samir's along with the sectors of activity at different stages of production. Our approach provides a novel way to assess the economic impacts of a structural change from a supply chain perspective.

This paper is organized into five sections in addition to this introduction. Section 2 describes the method we use; section 3 describes the database; section 4 summarizes the Moroccan economy's primary regional and sectoral characteristics, highlighting the intersectoral linkages associated with the Refinery Samir's production chain; section 5 presents and discusses the results, and section 6 concludes.

The structure of the Moroccan economy

The Moroccan economy had at an average annual GDP growth rate of 4.2% between 2000 and 2019 [12]. However, the regional disparities in terms of GDP are persisting [13]. According to the regional accounts for the year 2018, published by the High Commission for Planning, the three regions Casablanca-Settat, Rabat-Salé-Kénitra, and Marrakech-Safi, generated 56% of GDP, reflecting the economic concentration in a small number of regions. Regional disparities are also present in income distribution. At the national level, the GDP per capita is 31,473 dirhams (DHS), reaching DHS 49,654 in Casablanca-Settat and DHS 16,747 in Drâa-Tafilalet. The southern regions are an exception, with DHS 85,669 in Dakhla-Oued Eddahab and DHS 49,275 in Laâyoune-Sakia El Hamra, due to a small population and the growing investment in the fish export industry and the service sector of these regions.

The Moroccan GDP was around DHS 822,071 million in 2013. Grand Casablanca-Settat is the most contributing region with around 30% of the total value-added. Economic activity is concentrated, mainly, in only six regions in the North and the North-West of the country, Grand Casablanca-Settat, Rabat-Salé-Kénitra, Marrakech-Safi, Fès-Meknès, Tangier-Tetouan-Al Hoceima and Béni Mellal-Khénifra contributing together to 81% of the national GDP (Figs. 1 and 2).

Agricultural activities show a significant contribution to the Moroccan economy, representing 13.8% of GDP (Fig. 3). Real estate (11.6%), public administration (10.3%), education (9.7%), and trade (9.4%) are the most significant contributors to GDP. Gross output is concentered, mainly in agriculture (11.2%), food industry (10.7%), and constructions (8.2%).

[2] The plant's nameplate crude processing capacity were 200,000 barrels per day since an upgrade was completed in 2012, but the SAMIR refinery has never achieved that rate [33].

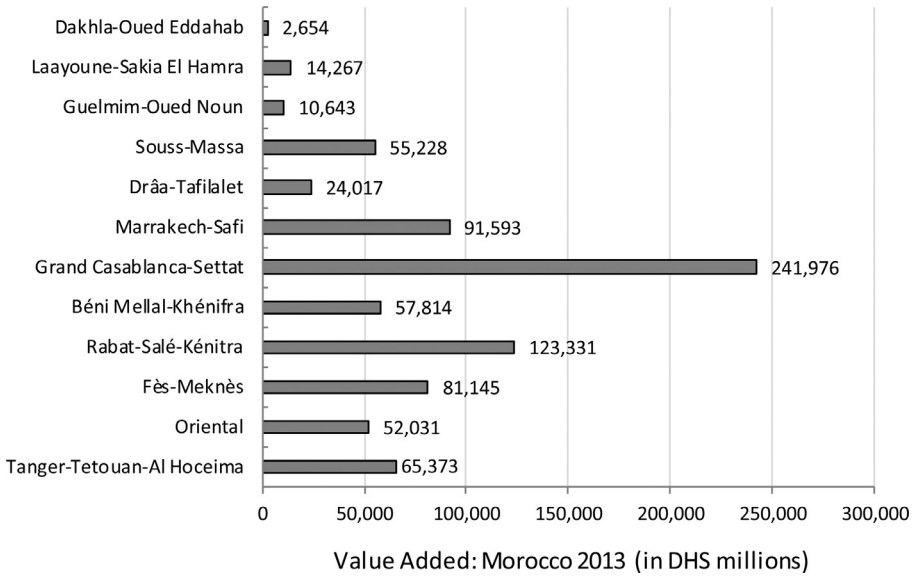

Fig. 1. Value-added in Morocco by region, 2013
Source: Interregional Input-Output Table for Morocco, 2013.

Sectoral linkages

In the framework of an input-output model, the sectors can impulse economic activity by demand-side (backward linkages) or supply-side (forward linkages). The backward and forward linkages identify "key" or "leading" sectors [14,15]. The backward (U_j) and forward (U_i) linkages indices are calculated from the input-output table. The sectors with U_j and U_i above the unit are classified as key sectors.

Fig. 4 shows the classification of backward and forward linkages for Morocco's economy. Following Miller and Blair [16], the sectors are distributed over a four-way classification as (1) generally dependent on (connected to) other sectors (both linkages measures greater than 1); (2) dependent on interindustry supply (only backward linkages index greater than 1); (3) dependent on interindustry demand (only forward linkages index greater than 1); and (4) generally independent of (not strongly connected to) other sectors (both linkages measures less than 1).

Oil refining, food industry, mechanical industry, other manufacturing, and agriculture are classified as key sectors in the Moroccan economy (Fig. 4). Those sectors can generate impacts higher than average on the whole economy. In addition to its significant role as input supplier to almost every industry in the economy, the oil refining industry also depends on other sectors' supply. Its strong backward and forward linkages lead us to anticipate a significant effect of its shutdown on the economy.

Fig. 5 shows the most relevant intersectoral linkages in the Moroccan economy. We prepared this graph using the Leontief inverse for Morocco's national input-output matrix. This figure allows us to visualize the backward and forward linkages; showing the most connected sectors in the Morocco economy. The size of the nodes represents the sector output multiplier. We obtained the links between the nodes by the largest linkages (20% of edges) in the Leontief inverse matrix. The clustering coefficient, calculated by the modularity algorithm [17], determines the node colors. Fig. 5 represents the production chain and summarizes the insertion of Samir's Mohammedia Refinery in the Moroccan economy.

In the input-output analysis, the backward linkage shows the upstream interactions in the supply chain. In Morocco, the domestic economy demand from the oil refining industry (as a purchaser) is primarily linked to the mining and trade sectors. On the other hand, the forward linkage presents downstream interactions in the production chain. The supply from the oil refining industry (as a seller) is mainly for transport, fishing, electricity, mining, construction, and other manufacturing (Figs. 5 and 6).

The oil refining sector

Morocco is not an oil producer and imports most of its energy inputs. The oil refining sector allocates 65% of its expenses for importing inputs from the rest of the world, especially crude oil. The industry also directs 34% of expenses to acquire intermediate inputs from other domestic sectors, 0.6% for taxes, and 0.07% for capital and labor payment (Table 1).

The oil refining sector is based on the treatment of crude oil through processes to obtain finished products, such as gasoline, 50 ppm diesel, fuels, lubricants, bitumens, and intermediate products (naphtha, distillate) meeting Moroccan standards. This sector contributed to less than 4% of the gross national output in 2013 (DHS 47,860 million). Also, almost half of the

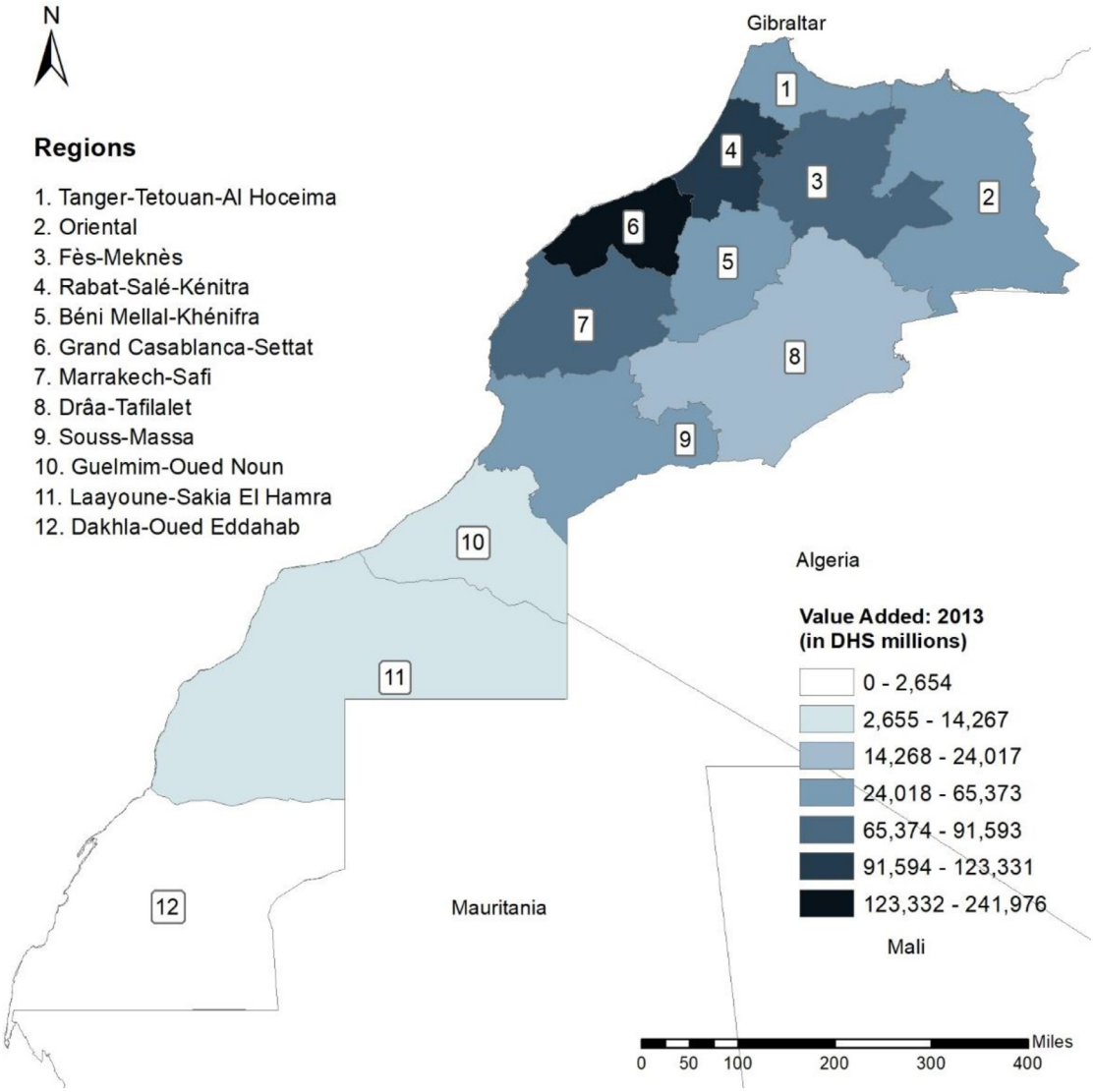

Fig. 2. Spatial distribution of the value-added in Morocco, 2013
Source: Interregional Input-Output Table for Morocco, 2013.

Table 1
Oil refining and other energy products in Morocco, 2013

	Value (in DHS millions)	Share (in %)
Intermediate consumption	22,700	47.43
Investment demand	8	0.02
Household demand	13,456	28.12
Government demand	0	0.00
Foreign exports	10,354	21.63
Statistical discrepancies	1,342	2.80
Total Demand	**47,860**	**100.00**
Intermediate consumption	16,391	34.25
Imports	31,150	65.09
Taxes and subsidies	287	0.60
Value Added	32	0.07
Gross Output	**47,860**	**100.00**

Source: Interregional Input-Output Table for Morocco, 2013.

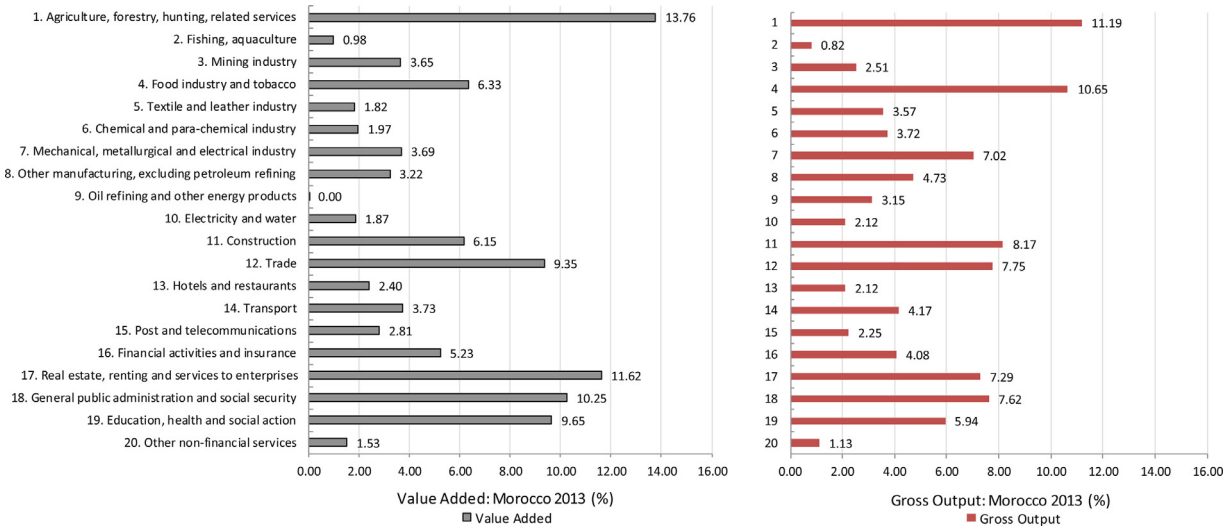

Fig. 3. Value-added and gross output in Morocco: sectoral structure, 2013 (in %)
Source: Interregional Input-Output Table for Morocco, 2013.

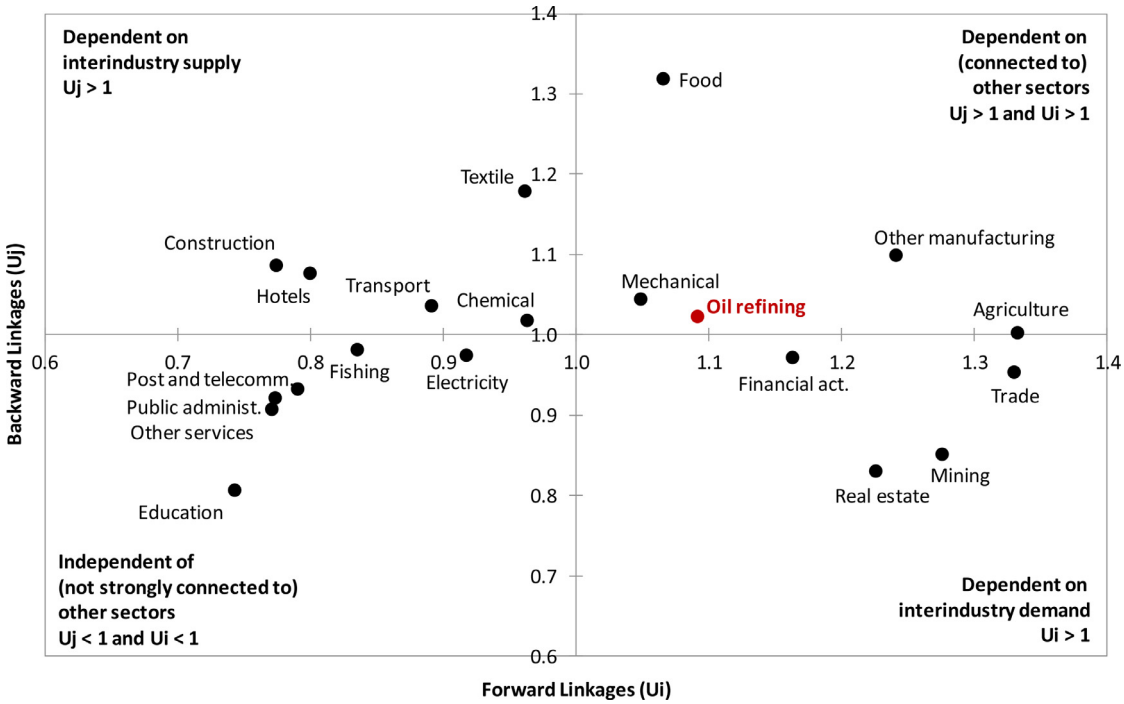

Fig. 4. Classification of backward and forward linkages for Morocco's Economy
Source: Interregional Input-Output Table for Morocco, 2013.

Oil refining sector's output is consumed, as input, by other industries (47%). The rest is shared between household's demand (28%) and foreign exports (22%).

Refinery Samir is located in Mohammedia, part of the region of Grand Casablanca-Settat (Fig. 7). Before its shutdown, the refinery imported around 1.7 million mt a year of fuel oil and other products from different ports in Tangier, Mohammedia, Jorf Lafar, Agadir, Laayoune, and Dakhla. After its closure, the port of Tanger Med (located in the city of Tangier) has become the main entry to satisfy the domestic market oil requirements.

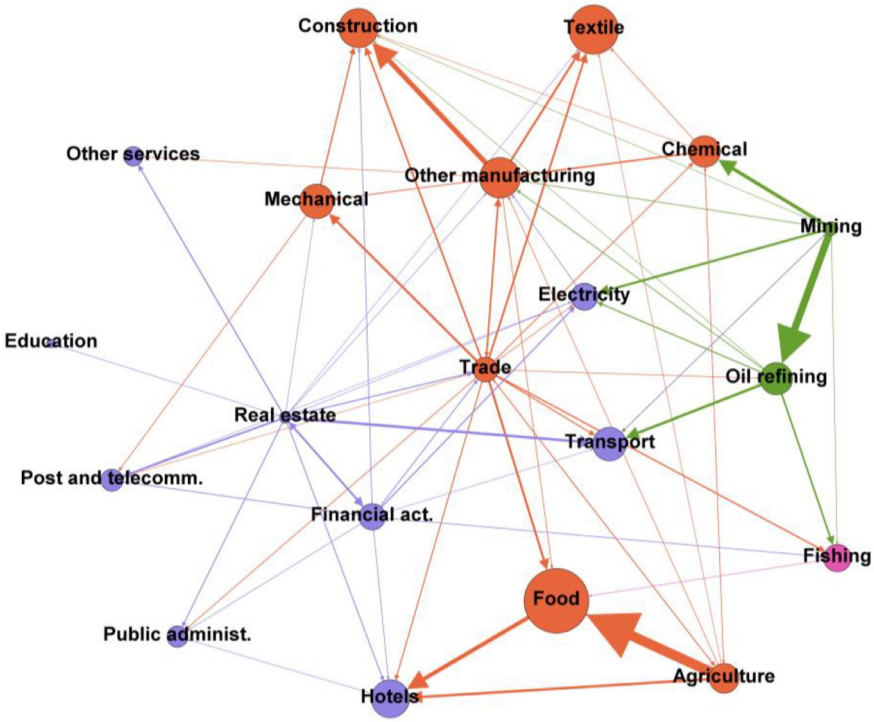

Fig. 5. Production structure of Morocco: output multipliers
Source: Interregional Input-Output Table for Morocco, 2013.

Methodology

The interindustry and interregional linkages in the input-output analysis reveal the economic and environmental importance of the relations between suppliers and consumers of the Samir's Mohammedia refinery in Casablanca and in different Moroccan regions. Given the interindustry relations in the oil supply chain, the input-output model is a suitable tool, from this perspective, to assess the structural changes caused by the closing of the refinery.

We use the hypothetical extraction approach to evaluate the impact of shutting down the Moroccan Refinery Samir. Specifically, the method assesses the output change of an economy if a sector or region were removed from that economic system. Described in Miller and Lahr [18], this method was initially conceived by Paelinck et al. [19], based on national input-output models, then extended to a regional approach, applied in Dietzenbacher et al. [20] and originated by Miller (1966; 1969).

There are broad aspects that are studied using the hypothetical extraction method. They include sectoral analysis (Song and Langston, 2006; [21]), energy [22,23], and emissions [24,25]. In recent applications, the hypothetical extraction was adapted to assess the economic impacts of control strategies for mitigating the effects of the COVID-19 pandemic [13] and applied for evaluating the regional economic effects of lockdown measures in Colombia [26].

Considering an interregional input-output model describing an economy with r regions and s sectors, the classic input-output relationship holds, such that:

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

where $\mathbf{x}$ is an $(n\ x\ 1)$ vector of gross output, containing the output of each of the s sectors located within each region r. $\mathbf{I}$ is an $(n\ x\ n)$ identity matrix and $\mathbf{A}$ is an $(n\ x\ n)$ matrix of input coefficients, defined as the amount of intermediate input from an industry i to an industry j ($\mathbf{Z}$) per unit of industry j gross output, that is, $\mathbf{Z}\hat{\mathbf{x}}^{-1}$. $\mathbf{f}$ is an $(n\ x\ 1)$ vector of final demand (investment demand, household demand, government demand, and foreign exports) Finally, $(\mathbf{I} - \mathbf{A})^{-1}$ is referred to as the Leontief inverse matrix (or **B** matrix), its elements b_{ij} represent output in sector i directly and indirectly required to satisfy one unit of final demand in industry j.

Starting from the interregional input-output framework described in Equation (1), we performed the hypothetical extraction method by removing (i.e., replacing by zeros) the values in row and column of the sector of interest, say the jth, from the input coefficients matrix and in the row of final demand vector. We can write the new model as follow:

$$\mathbf{x}^* = (\mathbf{I} - \mathbf{A}^*)^{-1}\mathbf{f}^* \tag{2}$$

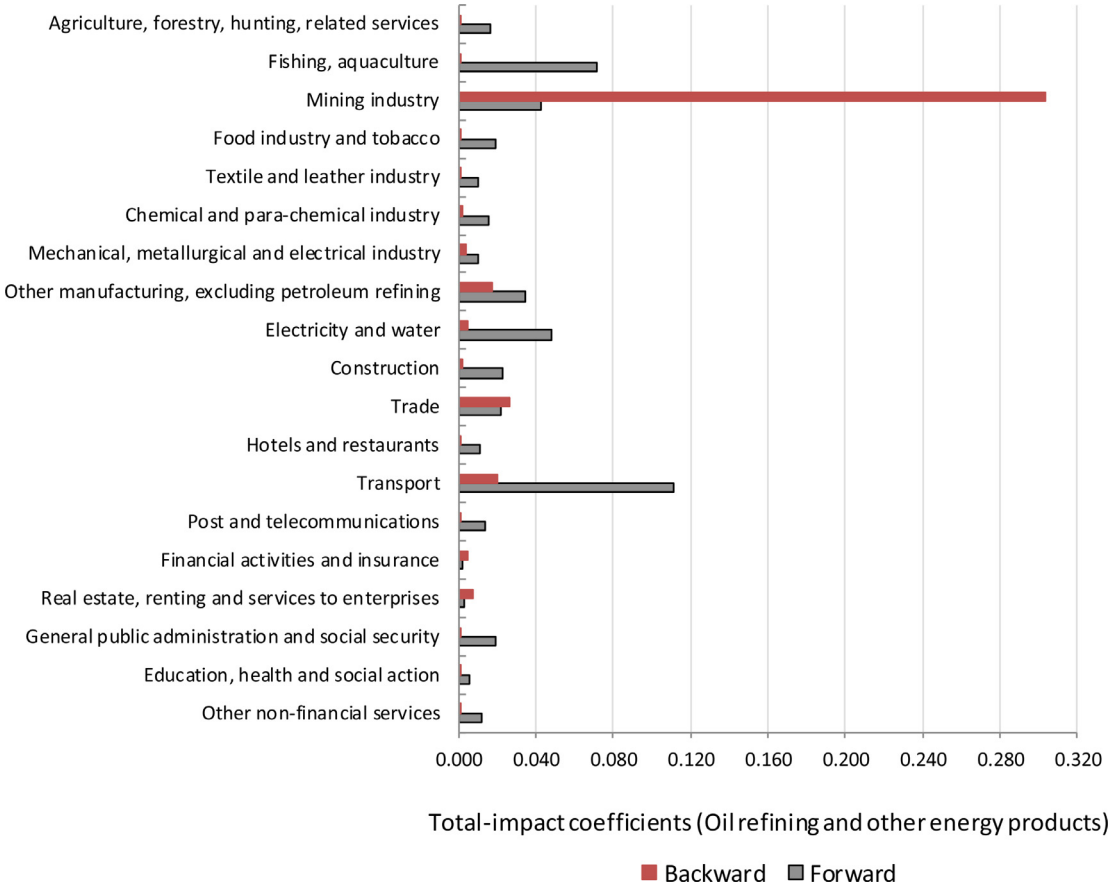

Fig. 6. Backward and forward linkages for oil refining and other energy products in Morocco
Note: The total-impact coefficients are obtained from the Leontief inverse matrix.
Source: Interregional Input-Output Table for Morocco, 2013.

where $\mathbf{A}^*$ is now the shutdown-related matrix, $\mathbf{f}^*$ is the correspondingly reduced final-demand vector and $\mathbf{x}^*$ is the output in the "reduced" economy after extraction.

After extraction, the impact on total output in each region and sector is:

$$\Delta\mathbf{x} = \mathbf{x} - \mathbf{x}^* \tag{3}$$

where $\Delta\mathbf{x}$ is the difference between the initial gross output vector ($\mathbf{x}$) and the gross output after the extraction ($\mathbf{x}^*$), i.e., an aggregate measure of the economy's loss (decrease in gross output value) if sector j disappears — in our case, the oil refining industry.

In the full n-sector model, the sum of the above difference is measured by $T_j = \mathbf{i}'\Delta\mathbf{x}_{(j)}$, where $\mathbf{i}$ is an (n x 1) unit vector. T_j is one aggregate measure of the economy's loss (decrease in value of gross output) if sector j disappears – as such, it is a measure of the "importance" or total linkage of sector j [16].

Additionally, we propose a decomposition of the total effects, $\Delta\mathbf{x}$, considering round-by-round effects. Our approach provides a way to assess the economic impacts of a structural change, which allows us to decomposing the overall effects that propagate in the economy from a supply chain perspective. Thereby, the initial, direct, and indirect effects are decomposed by solving Equation (2) in separated rounds, that is, $\mathbf{x}^* = (\mathbf{I} - \mathbf{A}^*)^{-1}\mathbf{f}^* = (\mathbf{I} + \mathbf{A}^* + \mathbf{A}^{*2} + \mathbf{A}^{*3} + \ldots)\mathbf{f}^*$.

That is, the initial effect is as the gross output of the oil refining industry.

We defined the initial effect (first-round impacts), in the hypothetical extraction context, equivalent to the closure of the refinery itself. That is, the initial effect is equal to the gross output vector with the value only in the oil refinery industry and zero to other industries, $\mathbf{x}^{**}$:

$$\text{Initial effect} = \mathbf{x}^{**} \tag{4.1}$$

Direct effects (second-round impacts) are those caused by the loss of production from the refinery's suppliers. The direct effect is computed by:

$$\text{Direct effect} = \mathbf{Af} - \mathbf{A}^*\mathbf{f}^* \tag{4.2}$$

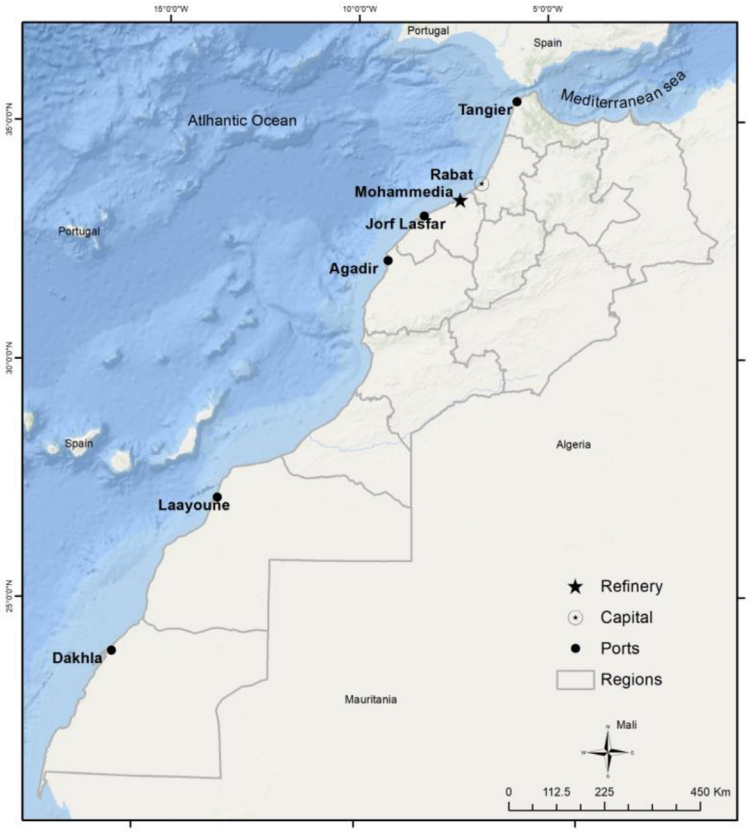

Fig. 7. Location of refinery and ports in Morocco
Source: Own elaboration.

Finally, indirect effects (subsequent rounds) focus on the suppliers of the refinery's suppliers, and so on. The indirect effect (IE) is equal to the total effect minus the initial and direct effects:

$$\text{Indirect effect} = \Delta\mathbf{x} - \text{Initial effect} - \text{Direct effect} \tag{4.3}$$

We convert the gross output results into the value-added and CO_2 emissions outcomes. To do so, we multiply the vector of the economy's loss, T_j, by a diagonal matrix, $\hat{\mathbf{V}}$, whose main diagonal contains the variable's coefficients (value-added and CO_2 emissions).

Database

The Interregional Input-Output Matrix for Morocco (IIOM-MOR) is calibrated for 2013 and contains data, in monetary terms, on payments, investment demand, household consumption, government spending, exports and imports, and intermediate consumption flows between and among the Moroccan regions [27]. The data describes the structure of the national economy in its 12 regions and 20 sectors. Thus, we look at the country's economy just before the shutdown of the Refinery Samir in 2015 and estimate its impacts on the Moroccan economy.

We use CO_2 emissions coefficients from the Eora database [28,29]. Due to data availability, the CO_2 emissions sectoral coefficients do not regionally differentiate in this study. In Eora, the accounts for emissions expressed in Megatonne (Mt) of CO_2 is available for 26 Moroccan sectors.[3] The consolidated information is presented in Table 2, in which the adjusted coefficients are shown in tons per million DHS[4]. The top sectors in terms of CO_2 emissions are electricity and water (E00), transport (I00), and chemical and para-chemical industry (D04).

[3] We consolidate Moroccan data from the 26 sectors in Eora26 MRIO to the 20 sectors in IIOM-MOR.
[4] Moroccan Dirham (DHS).

Table 2
Coefficients of CO_2 emissions by sector: Morocco, 2013

Sector		CO_2 Intensity Coefficients (tons/DHS millions)
A00	Agriculture, forestry, hunting, related services	7.95
B05	Fishing, aquaculture	3.97
C00	Mining industry	3.87
D01	Food industry and tobacco	6.83
D02	Textile and leather industry	13.74
D03	Chemical and para-chemical industry	135.51
D04	Mechanical, metallurgical, and electrical industry	15.16
D05	Other manufacturing, excluding petroleum refining	19.01
D06	Oil refining and other energy products	15.16
E00	Electricity and water	582.95
F45	Construction	9.53
G00	Trade	11.60
H55	Hotels and restaurants	16.67
I01	Transport	218.49
I02	Post and telecommunications	12.71
J00	Financial activities and insurance	8.00
K00	Real estate, renting, and services to enterprises	8.00
L75	General public administration and social security	12.39
MNO	Education, health and social action	8.53
OP0	Other non-financial services	7.35

Source: Adapted from Eora, Multi-Regional Input-Output Table.

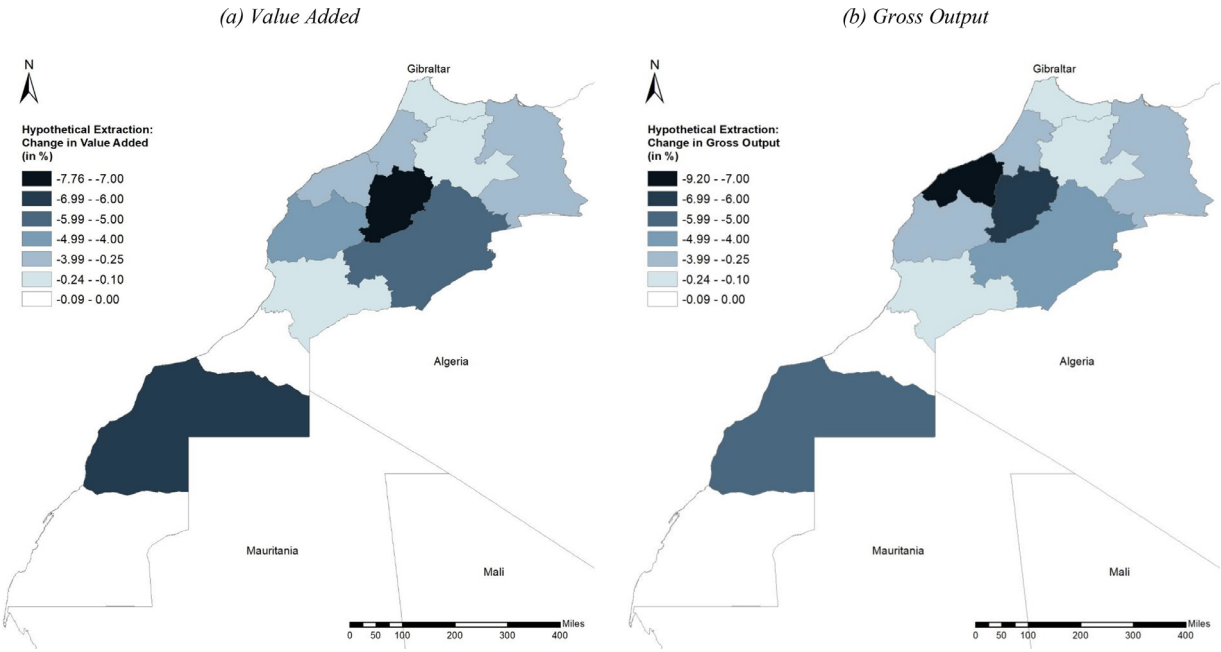

Fig. 8. Hypothetical extraction: change in value-added and gross output for Morocco, 2013 (in %)

Results

Economic impacts

The oil refining sector is an important sector to the Moroccan economy due to its strong backward and forward linkages to other sectors. It is an input to almost every industry in the economy and depends on other sectors' supply. The shutting down of the only operating firm in that sector in Morocco is, as expected, generated considerable impacts on the economy. The overall economic losses are evaluated in DHS 66,572 million, which represents a reduction by 4.4% of the country's total output and 1.7% of its value-added (Tables 3-5 and Fig. 8).

The economic impacts of the closure of the Refinery Samir's activities besides affecting Grand Casablanca-Settat may spread, affecting other regional economies. The input-output analysis provides insights into this spatial interaction related to the feedback effects and the hierarchical structure of the interregional system under consideration [30]. The "hypothetical

Table 3
Hypothetical extraction: change in value-added for Morocco, 2013 (in DHS millions)

		R1 Tanger-Tetouan-Al Hoceima	R2 Oriental	R3 Fès-Meknès	R4 Rabat-Salé-Kénitra	R5 Béni Mellal-Khénifra	R6 Grand Casablanca-Settat	R7 Marrakech-Safi	R8 Drâa-Tafilalet	R9 Souss-Massa	R10 Guelmim-Oued Noun	R11 Laayoune-Sakia El Hamra	R12 Dakhla-Oued Eddahab	Marocco
A00	Agriculture, forestry, hunting, related services	-2.6	-2.6	-5.4	-5.9	-5.6	-6.2	-6.1	-2.1	-2.3	-0.3	0.0	0.0	-38.9
B05	Fishing, aquaculture	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	-0.1	-0.1	0.0	-0.8
C00	Mining industry	0.0	-376.1	-58.1	-310.2	-4,265.7	-22.8	-4,114.1	-1,186.8	-7.7	0.0	-891.5	0.0	-11,233.0
D01	Food industry and tobacco	-0.3	-0.1	-0.8	-0.5	-0.5	-5.4	-0.6	0.0	-1.0	0.0	-0.1	0.0	-9.5
D02	Textile and leather industry	-1.0	0.0	-0.6	-0.6	0.0	-5.2	-0.3	0.0	0.0	0.0	0.0	0.0	-7.7
D03	Chemical and para-chemical industry	-0.9	-0.4	-1.5	-3.0	-0.3	-20.0	-1.5	0.0	-0.8	0.0	-1.4	0.0	-29.9
D04	Mechanical, metallurgical and electrical industry	-3.2	-2.9	-3.2	-3.4	-1.0	-37.7	-0.8	-0.1	-0.8	0.0	-0.1	0.0	-53.1
D05	Other manufacturing, excluding petroleum refining	-22.3	-4.1	-14.6	-26.4	-5.7	-193.1	-19.7	-0.4	-10.1	-0.3	-3.6	-0.2	-300.5
D06	Oil refining and other energy products	0.0	0.0	0.0	0.0	0.0	-32.0	0.0	0.0	0.0	0.0	0.0	0.0	-32.0
E00	Electricity and water	-6.4	-4.3	-6.7	-19.4	-12.6	-24.3	-17.7	-3.6	-4.6	-0.5	-3.3	-0.1	-103.4
F45	Construction	-0.6	-0.6	-0.6	-1.7	-2.3	-19.2	-2.8	-0.7	-0.4	0.0	-0.5	0.0	-29.3
G00	Trade	-19.6	-34.5	-36.2	-66.8	-71.0	-443.0	-86.1	-12.4	-14.7	-3.3	-8.8	-0.2	-796.5
H55	Hotels and restaurants	-0.3	-0.2	-0.4	-0.4	-0.3	-1.4	-6.5	-0.5	-2.7	0.0	-0.1	0.0	-12.8
I01	Transport	-16.7	-7.1	-36.1	-70.0	-63.9	-119.5	-90.2	-20.7	-25.2	-2.9	-6.2	-0.2	-458.8
I02	Post and telecommunications	-0.5	-0.5	-0.9	-2.1	-2.3	-6.7	-3.1	-0.6	-0.6	-0.1	-0.4	0.0	-17.7
J00	Financial activities and insurance	-2.2	-3.3	-3.7	-20.1	-10.6	-77.9	-20.0	-2.6	-2.7	-0.2	-1.7	0.0	-145.1
K00	Real estate, renting and services to enterprises	-6.1	-8.1	-11.1	-49.3	-30.6	-123.5	-56.2	-7.1	-8.3	-0.8	-4.2	-0.1	-305.4
L75	General public administration and social security	-0.5	-0.8	-0.9	-3.2	-5.6	-5.5	-6.0	-1.6	-0.5	-0.2	-1.3	0.0	-26.0
MNO	Education, health and social action	0.0	-0.1	-0.1	-0.1	-0.3	-0.6	-0.4	-0.1	-0.1	0.0	0.0	0.0	-1.8
OP0	Other non-financial services	-0.7	-1.1	-1.0	-4.4	-7.3	-6.7	-11.8	-1.4	-0.6	-0.1	-1.2	0.0	-36.3
	Total	-84.0	-446.8	-181.7	-587.5	-4,485.6	-1,150.8	-4,443.8	-1,240.7	-83.4	-8.8	-924.3	-0.8	-13,638.4

Note: Cells in darker colors highlight the biggest effects.

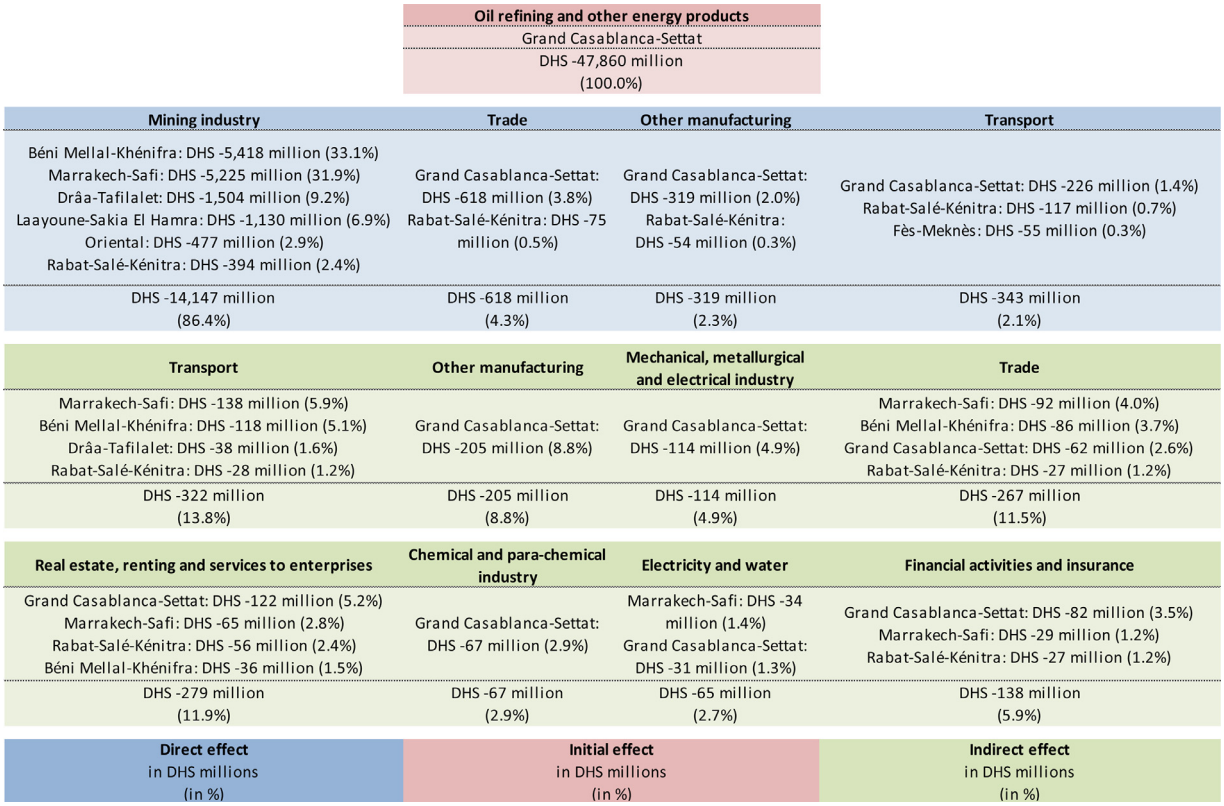

Fig. 9. Impacts of Oil Industry Extraction
Note: The figure shows the ten industries most affected by the direct effect (95.1%) and the twenty industries most affected by the indirect effect (62.4%).

extraction" method allows us to analyze the spatial geographic structure of these propagation effects. Thereby, this approach provides insights into the inter-industry and interregional interdependences of the oil refining industry in the Moroccan economy.

Focusing on the regional distribution of those effects, Grand Casablanca-Settat faced the highest reduction of gross output (9.2%), followed by its neighbor Beni Mellal-Khenifra (6.6%), Laayoun-Sakia El Hamra (5.1%), Drâa-Tafilalet (4.2%), and Marrakech-Safi (3.9%). Losses in Laayoun-Sakia El Hamra concentrate in the mining industry. While the Rabat-Salé-Kénitra, Beni Mellal-Khenifra, and Marrakech-Safi regions, neighboring Grand Casablanca-Settat, are also heavily impacted on trade, transport, financial activities, real estate, and other manufacturing. This result helps to understand the location pattern of investments in sectors that support the refinery's activities.

The mining industry faced the most noticeable losses in terms of its value-added (37.5%). This industry lost DHS 11,233 million in value-added and DHS 14,329 million in gross output. The strong backward linkages mainly explain the size of the effect with the extracted sector (Tables 3 and 4). Transport (1.5%), trade (1.1%), and other manufacturing (1.1%) are also significantly affected by the shutting down of the Moroccan Refinery Samir, with total loss of production reaching 3.7%, with impacts mainly in the R4-R8 regions (Table 5).

The economic impacts of the shutting down of the Refinery Samir's activities on the Morrocan's supply chains are decomposed using Equations (4.1) and (4.2). The initial effect (first-round impacts) is equivalent to the closure of the refinery itself. Direct effects (second-round impacts) are those caused by the loss of production from the refinery's suppliers, and indirect effects (subsequent rounds) focus on the suppliers of the refinery's suppliers, and so on. Table 6 shows the decomposition of the total effects considering round-by-round effects and helps visualize how the overall effect propagates in the economy. In the second round, direct effects, the sectors most affected are the mining industry, trade, and transport. Afterward, in the subsequent rounds (indirect effects), manufacturing, transport, financial activities, and real estate services are the most affected sectors.

Fig. 9 shows graphically the economic impacts for the sectors most heavily affected by the closure of Refinery Samir in each round of effects. Most of the impacted sectors, in the direct effects, are the same; nevertheless, with differences in the magnitude of the impact in which region. There are some regional differences, especially in industries impacted by indirect effects.

Table 4
Hypothetical extraction: change in gross output for Morocco, 2013 (in DHS millions)

		R1 Tanger-Tetouan-Al Hoceima	R2 Oriental	R3 Fès-Meknès	R4 Rabat-Salé-Kénitra	R5 Béni Mellal-Khénifra	R6 Grand Casablanca-Settat	R7 Marrakech-Safi	R8 Drâa-Tafilalet	R9 Souss-Massa	R10 Guelmim-Oued Noun	R11 Laayoune-Sakia El Hamra	R12 Dakhla-Oued Eddahab	Marocco
A00	Agriculture, forestry, hunting, related services	-3.8	-3.9	-8.1	-8.8	-8.4	-9.4	-9.2	-3.1	-3.4	-0.5	0.0	0.0	-58.6
B05	Fishing, aquaculture	-0.1	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	-0.5	-0.2	-0.2	-0.1	-1.3
C00	Mining industry	0.0	-479.7	-74.1	-395.7	-5,441.4	-29.1	-5,248.0	-1,513.9	-9.9	0.0	-1,137.2	0.0	-14,329.0
D01	Food industry and tobacco	-1.0	-0.4	-2.4	-1.7	-1.7	-16.8	-1.8	-0.1	-3.0	-0.1	-0.5	0.0	-29.5
D02	Textile and leather industry	-3.5	-0.2	-2.2	-2.1	0.0	-18.9	-1.0	0.0	0.0	0.0	0.0	0.0	-28.0
D03	Chemical and para-chemical industry	-3.3	-1.5	-5.2	-10.4	-1.1	-70.2	-5.3	-0.1	-2.7	0.0	-5.0	0.0	-104.8
D04	Mechanical, metallurgical and electrical industry	-11.2	-10.3	-11.1	-12.0	-3.5	-132.8	-2.8	-0.2	-3.0	0.0	-0.3	0.0	-187.1
D05	Other manufacturing, excluding petroleum refining	-60.5	-11.1	-39.7	-71.6	-15.4	-524.5	-53.5	-1.1	-27.5	-0.9	-9.9	-0.4	-816.0
D06	Oil refining and other energy products	0.0	0.0	0.0	0.0	0.0	-47,860.0	0.0	0.0	0.0	0.0	0.0	0.0	-47,860.0
E00	Electricity and water	-13.5	-9.0	-14.0	-40.6	-26.3	-50.9	-37.2	-7.5	-9.6	-1.0	-6.8	-0.2	-216.6
F45	Construction	-1.5	-1.4	-1.5	-4.2	-5.5	-47.2	-6.9	-1.7	-0.9	-0.1	-1.1	0.0	-72.0
G00	Trade	-30.1	-52.9	-55.6	-102.6	-109.0	-680.1	-132.2	-19.0	-22.6	-5.1	-13.4	-0.3	-1,222.8
H55	Hotels and restaurants	-0.5	-0.3	-0.6	-0.6	-0.5	-2.4	-10.7	-0.9	-4.4	0.0	-0.1	0.0	-20.9
I01	Transport	-34.6	-14.6	-74.5	-144.5	-132.1	-246.8	-186.2	-42.8	-52.1	-6.0	-12.9	-0.4	-947.5
I02	Post and telecommunications	-0.7	-0.8	-1.4	-3.1	-3.5	-10.0	-4.5	-0.9	-0.8	-0.2	-0.5	0.0	-26.3
J00	Financial activities and insurance	-3.2	-4.8	-5.3	-29.1	-15.3	-112.3	-28.8	-3.8	-3.9	-0.4	-2.4	0.0	-209.3
K00	Real estate, renting and services to enterprises	-7.0	-9.5	-12.9	-57.3	-35.6	-143.5	-65.3	-8.3	-9.7	-0.9	-4.8	-0.1	-354.8
L75	General public administration and social security	-0.6	-1.1	-1.3	-4.3	-7.7	-7.6	-8.2	-2.2	-0.7	-0.3	-1.7	0.0	-35.7
MNO	Education, health and social action	0.0	-0.1	-0.1	-0.2	-0.3	-0.7	-0.5	-0.1	-0.1	0.0	0.0	0.0	-2.1
OP0	Other non-financial services	-1.0	-1.5	-1.3	-6.0	-10.0	-9.2	-16.1	-1.9	-0.8	-0.1	-1.6	0.0	-49.7
	Total	-176.2	-603.0	-311.3	-894.9	-5,817.4	-49,972.2	-5,818.3	-1,607.5	-155.6	-15.5	-1,198.4	-1.6	-66,572.0

Note: Cells in darker colors highlight the biggest effects.

Table 5
Hypothetical extraction: change in value-added and gross output for Morocco, 2013 (in %)

		R1 Tanger-Tetouan-Al Hoceima	R2 Oriental	R3 Fès-Meknès	R4 Rabat-Salé-Kénitra	R5 Béni Mellal-Khénifra	R6 Grand Casablanca-Settat	R7 Marrakech-Safi	R8 Drâa-Tafilalet	R9 Souss-Massa	R10 Guelmim-Oued Noun	R11 Laayoune-Sakia El Hamra	R12 Dakhla-Oued Eddahab	Marocco
A00	Agriculture, forestry, hunting, related services	-0.03	-0.03	-0.03	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.02	0.00	0.00	-0.03
B05	Fishing, aquaculture	-0.01	-0.01	0.00	-0.01	0.00	-0.01	-0.02	0.00	-0.01	-0.01	-0.01	0.00	-0.01
C00	Mining industry	0.00	-42.12	-37.35	-53.73	-27.98	-42.70	-50.57	-44.49	-33.74	0.00	-39.90	0.00	-37.46
D01	Food industry and tobacco	-0.01	-0.01	-0.02	-0.02	-0.03	-0.02	-0.02	-0.02	-0.01	-0.01	-0.02	0.00	-0.02
D02	Textile and leather industry	-0.03	-0.03	-0.04	-0.04	-0.16	-0.06	-0.08	0.00	-0.09	0.00	0.00	0.00	-0.05
D03	Chemical and para-chemical industry	-0.21	-0.28	-0.30	-0.36	-0.65	-0.16	-0.10	-0.36	-0.31	-0.23	-0.56	-0.13	-0.19
D04	Mechanical, metallurgical and electrical industry	-0.04	-0.23	-0.24	-0.13	-0.60	-0.23	-0.41	-0.37	-0.25	0.00	-0.59	-0.12	-0.18
D05	Other manufacturing, excluding petroleum refining	-0.81	-0.80	-0.94	-1.56	-1.73	-1.17	-1.29	-1.01	-0.88	-0.60	-1.25	-0.37	-1.13
D06	Oil refining and other energy products	0.00	0.00	0.00	0.00	0.00	-100.00	0.00	0.00	0.00	0.00	0.00	0.00	-100.00
E00	Electricity and water	-0.37	-0.41	-0.40	-0.61	-1.55	-0.72	-1.05	-0.99	-0.43	-0.32	-1.60	-0.18	-0.67
F45	Construction	-0.01	-0.01	-0.01	-0.03	-0.07	-0.19	-0.04	-0.02	-0.01	-0.01	-0.04	0.00	-0.06
G00	Trade	-0.27	-0.42	-0.40	-0.66	-1.48	-2.30	-0.97	-0.73	-0.27	-0.34	-1.07	-0.08	-1.04
H55	Hotels and restaurants	-0.02	-0.03	-0.03	-0.05	-0.17	-0.06	-0.09	-0.10	-0.05	-0.03	-0.17	-0.01	-0.06
I01	Transport	-0.65	-0.27	-1.08	-1.51	-4.31	-1.34	-2.91	-2.52	-1.17	-0.59	-1.60	-0.19	-1.49
I02	Post and telecommunications	-0.02	-0.03	-0.04	-0.06	-0.21	-0.10	-0.13	-0.09	-0.03	-0.03	-0.12	-0.01	-0.08
J00	Financial activities and insurance	-0.10	-0.15	-0.14	-0.22	-0.91	-0.42	-0.54	-0.46	-0.13	-0.10	-0.76	-0.04	-0.34
K00	Real estate, renting and services to enterprises	-0.13	-0.17	-0.18	-0.24	-1.18	-0.30	-0.69	-0.56	-0.18	-0.14	-0.85	-0.05	-0.32
L75	General public administration and social security	-0.01	-0.01	-0.01	-0.01	-0.13	-0.04	-0.08	-0.06	-0.01	-0.01	-0.03	0.00	-0.03
MNO	Education, health and social action	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OP0	Other non-financial services	-0.07	-0.14	-0.09	-0.16	-1.25	-0.20	-0.66	-0.61	-0.08	-0.06	-1.38	-0.03	-0.29
	Value Added	-0.13	-0.86	-0.22	-0.48	-7.76	-0.48	-4.85	-5.17	-0.15	-0.08	-6.48	-0.03	-1.66
	Gross Output	-0.13	-0.70	-0.22	-0.45	-6.55	-9.20	-3.88	-4.24	-0.16	-0.09	-5.13	-0.02	-4.38

Note: Cells in darker colors highlight the biggest effects.

Table 6
Hypothetical extraction: initial, direct, and indirect impacts on gross output by industry (in DHS millions)

Industry	*Initial*	*Direct*	*Indirect*	*Total*
Agriculture, forestry, hunting, related services	0.0	-1.4	-57.2	-58.6
Fishing, aquaculture	0.0	0.0	-1.3	-1.3
Mining industry	0.0	-14,259.6	-69.4	-14,329.0
Food industry and tobacco	0.0	-0.7	-28.8	-29.5
Textile and leather industry	0.0	-6.6	-21.4	-28.0
Chemical and para-chemical industry	0.0	-4.3	-100.4	-104.8
Mechanical, metallurgical and electrical industry	0.0	-28.6	-158.5	-187.1
Other manufacturing	0.0	-504.3	-311.8	-816.0
Oil refining and other energy products	-47,860.0	0.0	0.0	-47,860.0
Electricity and water	0.0	-49.8	-166.9	-216.6
Construction	0.0	-46.7	-25.2	-72.0
Trade	0.0	-870.4	-352.4	-1,222.8
Hotels and restaurants	0.0	-0.9	-20.1	-20.9
Transport	0.0	-536.8	-410.7	-947.5
Post and telecommunications	0.0	-1.7	-24.6	-26.3
Financial activities and insurance	0.0	-33.3	-176.0	-209.3
Real estate, renting and services to enterprises	0.0	-23.3	-331.5	-354.8
General public administration and social security	0.0	-2.1	-33.6	-35.7
Education, health and social action	0.0	-0.1	-2.0	-2.1
Other non-financial services	0.0	-1.5	-48.1	-49.7
Morocco	**-47,860.0**	**-16,372.1**	**-2,339.8**	**-66,572.0**

Environmental impacts

The oil refining industry is a significant source of greenhouse gas (GHG) emissions such as CO_2 and methane [31]. Its emissions cover their activity in the broad sense, from the extraction of hydrocarbons to their consumption by the final customer, in the form of fuel, gas for heating, electricity generated from gas, or even plastic.

The closing of the Refinery Samir led to an overall reduction of 2.1% of the national CO_2 emissions which represents a reduction of around 1,170,000 million tons (Mt). The geographical location of the refinery in the region of Grand Casablanca-Settat has led to a substantial regional contribution to the emissions decline (62.1% of the total). Its neighboring regions also contributed significantly to the emissions reduction (Fig. 10): Marrakech-Safi (7.5% of total reduction), Beni Mellal-Khénifra (5.8%), and Rabat-Salé-Kénitra (5.3%).

As their local activities depend widely on fuel, electricity, and transport, CO_2 emissions faced the most significant reductions in Grand Casablanca-Settat, Rabat-Salé-Kénitra, Marrakech-Safi, Souss-Massa, Oriental and Fès-Meknès. These regions are home to important industries in different sectors, have the most critical transport lines in the country, and are the central regions with access to electricity and water. The major CO_2 emission reductions occur in the transport, electricity, and water sectors, which, together with the oil refining sector, contribute to over 90% of the total decline.

Implications and conclusions

This paper provided a detailed analysis of the interindustry linkages and economic contributions from the oil refinery industry within the Moroccan economy. For this, we explored the structural interdependence among Moroccan sectors and regions. Precisely, we measure the economic and environmental impacts of shutting down the Moroccan Refinery Samir. We based our study on an empirical strategy developed from the “hypothetical extraction” method using the Interregional Input-Output Matrix for Morocco.

The shutting down of the Refinery Samir decrease the country’s gross output by 4.4%, with different regional and sectoral effects. When exploring the connectivity of the Moroccan interregional system, the input-output analysis allowed us to identify the main production links related to the supply chain of the oil refining industry. Thus, we present a detailed mapping of the sectors and their respective regions most affected by the shutting down of the oil refinery activities.

The results also show that the shutting down of the Refinery Samir can cause a structural transformation in the Moroccan economy, especially in Grand Casablanca-Settat, which decreased 9.2% of its gross output. This structural transformation relates to the changing sectoral composition of output and employment. Tyler et al. (2016) reinforce that identifying the sectors most affected can be of particular interest to policymakers to deal with the structural changes in the economy and formulate policies that assist the changing process in enhancing local economic growth.

Moroccan CO_2 emissions have been reduced by 2,1%, suggesting a trade-off between economic prosperity and environmental protection. Nonetheless, the reduction in CO_2 emissions because of the closure of activities at the Refinery Samir does not mean an immediate change in the energy matrix in Morocco. Furthermore, from a global perspective, the country’s current dependence on imports of refined energy products, which weigh on the balance of payment, has resulted in carbon leakage, transferring emissions to other countries.

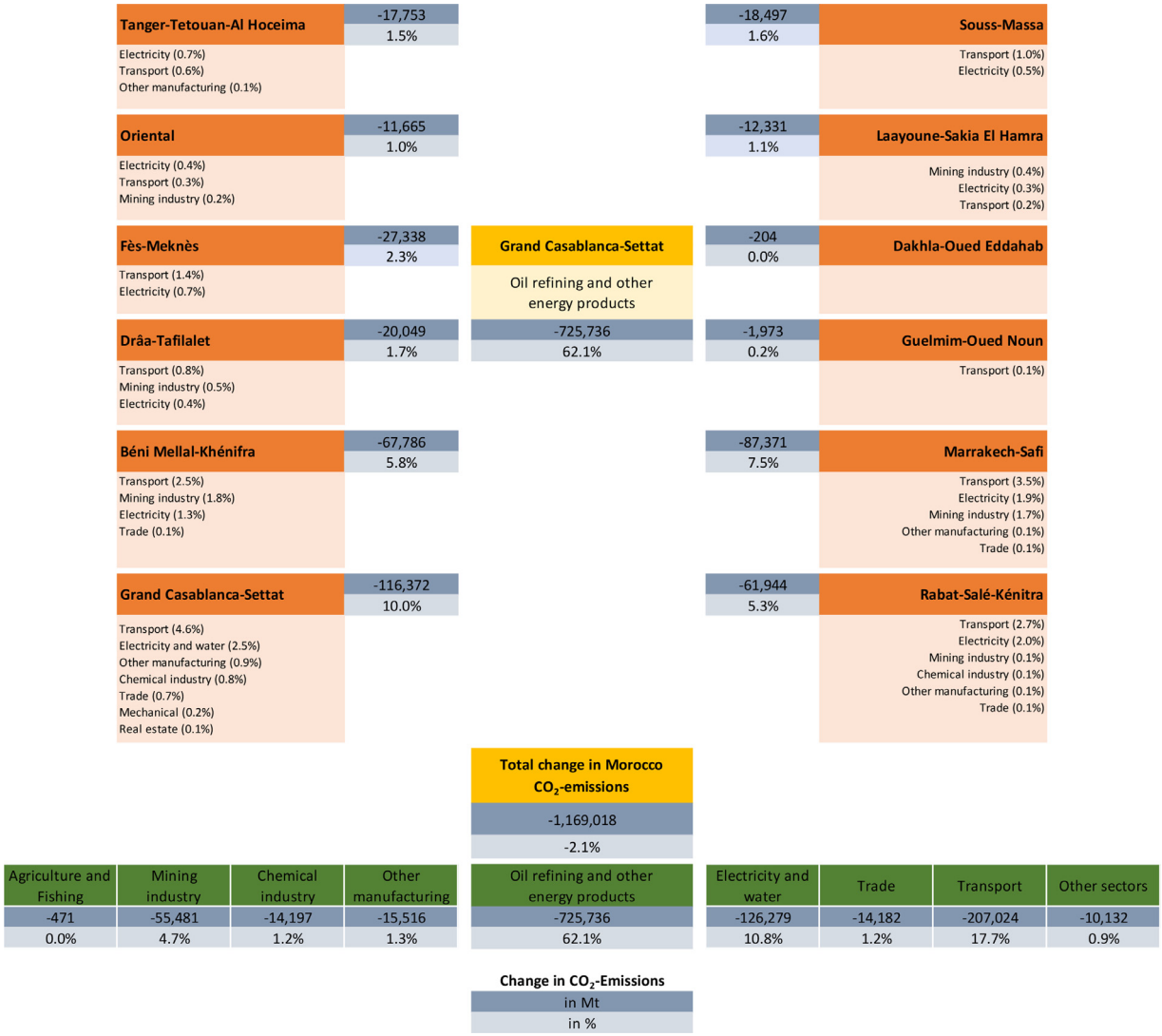

Fig. 10. Changes in Morocco CO_2-emissions due to the shutting down of the Moroccan Refinery Samir in Grand Casablanca

However, the environmental impacts, driven by this reduction of CO_2 emissions, are an essential step toward it and the achievement of Morocco's ambitious goal of reducing greenhouse gas (GHG) emissions to 42% by 2030 (Moroccan Secretary of State for Sustainable Development). Accountability of the pressure on using the world's natural resources has reached the political debate, as attempts to characterize countries according to their historical, current and expected role played in this process have reopened political fissures [32]. In this sense, uncertainty about the permanent closure faced by Morocco's single oil refinery offers the country an opportunity to accelerate its energy transition path. While coping with fuel importers to secure the short-term strategic reserve of domestic needs, the country makes sound plans to take up the vast opportunity it faces in green energy, such as solar power. Given its undeniably large renewable energy potential, the diversification of energy supply sources can provide a strategy for the Moroccan energy policy. Its future developments may compensate in the long run the negative economic impacts associated with the shutting down of Refinery Samir, creating a new geography of the energy economy in Morocco, potentially contributing to a less spatially concentrated economic development.

An additional contribution of the paper is the extended of the hypothetical extraction method to include the initial, direct, and indirect effects on the value chain. We measure the contribution of the SAMIR refinery to the Moroccan economy, in terms of value added, gross output, and CO_2 emissions. However, our study did not aim to evaluate the substitution of domestic oil products for imported products. To make this type of evaluation, other types of modeling are necessary, such as general equilibrium models.

Declaration of Competing Interest

The authors report there are no competing interests to declare.

Funding

Eduardo A. Haddad acknowledges financial support from CNPq (Grant 302861/2018-1) and the Policy Center for the New South (PCNS). Inácio F. Araújo acknowledges financial support from FAPESP (Grant 2021/12397-9). This work was partially supported by the Brazilian Research Network on Global Climate Change FINEP/Rede CLIMA (Grant 01.13.0353-00), and the INCT-Climate Change Project Phase 2 (Grants FAPESP 2014/50848-9, CNPq 465501/2014-1, and CAPES/FAPS N° 16/2014).

References

[1] C. Gossart, Routines and firms' HSE behaviour: the cases of European and North African oil refineries, Thesis in Science and Technology Policy Studies, University of Sussex, 2005.
[2] E.M. Bentour, On the removal of energy products subsidies in an importing oil country: impacts on prices and policy implications in Morocco, J. Econ. Cooper. Develop. 37 (2) (2016) 127–158.
[3] P. Meier, Refinery deregulation in developing countries: the case of Morocco, in: Natural Resources Forum, 14, Blackwell Publishing Ltd, Oxford, UK, 1990, pp. 135–142.
[4] P. Tyler, E. Evenhuis, R. Martin, P. Sunley, B. Gardiner, Growing apart? Structural transformation and the uneven development of British Cities, Cambrid. J. Region. Econ. Soc. 10 (3) (2017) 425–454.
[5] N. Hoalst-Pullen, M.W. Patterson, J.D. Gatrell, Empty spaces: neighbourhood change and the greening of Detroit, 1975–2005, Geocarto Int. 26 (6) (2011) 417–434.
[6] Al-Monitor (2022, Octuber 19). Calls rise to reactivate Morocco's only refinery as oil prices soar. Available at "https://www.al-monitor.com/originals/2022/06/calls-rise-reactivate-moroccos-only-refinery-oil-prices-soar".
[7] IndustriALL (2022, October 19). Global Union. Morocco: workers take action for oil refinery. Available at "https://www.industriall-union.org/morocco-workers-take-action-for-oil-refinery".
[8] North Africa Post (2022, Octuber 19). Morocco needs to have its own refining capacity. Available at "https://northafricapost.com/58434-morocco-needs-to-have-its-own-refining-capacity.html".
[9] C.Y. Hsu, Y.T. Chang, C.R. Lin, How a winding-down oil refinery park impacts air quality nearby? Environ. Int. (2022) 107533.
[10] S. Touili, A.A. Merrouni, A. Azouzoute, Y. El Hassouani, A.I. Amrani, A technical and economical assessment of hydrogen production potential from solar energy in Morocco, Int. J. Hydrogen Energy 43 (51) (2018) 22777–22796.
[11] M. Bagheri, Z. Guevara, M. Alikarami, C.A. Kennedy, G. Doluweera, Green growth planning: a multi-factor energy input-output analysis of the Canadian economy, Energy Econ. 74 (2018) 708–720.
[12] World Bank (2022). World Development Indicators. Avaliable at "https://data.worldbank.org/country/morocco".
[13] E.A. Haddad, F.S. Perobelli, I.F. Araújo, K.S. Bugarin, Structural propagation of pandemic shocks: an input-output analysis of the economic costs of COVID-19, Spat. Econ. Analy. (2020) 1–19.
[14] A.O. Hirschman, The Strategy of Economic Development, Conn. Yale University, New Haven, 1958.
[15] P. Rasmussen, Studies in Inter-Sectoral Relations, Einar Harks, Copenhagen, 1956.
[16] R.E. Miller, P.D. Blair, Input-Output Analysis: Foundations and Extensions, Cambridge University Press, 2009.
[17] V.D. Blondel, J.L. Guillaume, R. Lambiotte, E. Lefebvre, Fast unfolding of communities in large networks, J. Stat. Mech. Theory Exp. 2008 (10) (2008) P10008.
[18] R.E. Miller, M.L. Lahr, A taxonomy of extractions, in regional science perspective in economic analysis, in: A Festschrift in Memory of Benjamin H. Stevens, 2001, pp. 407–441.
[19] J. Paelinck, J. Caevel, J. Degueldre, in: Analyse Quantitative de Certaines Phénomènes du Développement Régional Polarisé, Essai de Simulation Statique d'itérarires de Propogation, 1965, pp. 341–387.
[20] E. Dietzenbacher, J. van der Linden, A. Steenge, The regional extraction method: EC input-output comparisons, Econ. Syst. Res. 5 (2) (1993) 185–206.
[21] U. Temurshoev, Identifying optimal sector groupings with the hypothetical extraction method, J. Region. Sci. 50 (4) (2010) 872–890.
[22] G. Deng, Y. Ma, L. Zhang, G. Liu, China's embodied energy trade: based on hypothetical extraction method and structural decomposition analysis, Energy Source. Part B: Econ. Plann. Policy 13 (11-12) (2019) 448–462.
[23] B. Zhang, Z.M. Chen, X.H. Xia, X.Y. Xu, Y.B. Chen, The impact of domestic trade on China's regional energy uses: a multi-regional input-output modeling, Energy Policy 63 (2013) 1169–1181.
[24] L. Zhang, B. Liu, J. Du, C. Liu, H. Li, S. Wang, Internationalization trends of carbon emission linkages: a case study on the construction sector, J. Clean. Prod. 270 (2020) 1–18.
[25] Y. Zhao, Y. Liu, S. Wang, Z. Zhang, J. Li, Inter-regional linkage analysis of industrial CO2 emissions in China: an application of a hypothetical extraction method, Ecol. Indic. 61 (2016) 428–437.
[26] J. Bonet-Morón, D. Ricciulli-Marín, G.J. Pérez-Valbuena, L.A. Galvis-Aponte, E.A. Haddad, I.F. Araújo, F.S. Perobelli, Regional economic impact of COVID-19 in Colombia: an input–output approach, Reg. Sci. Policy Pract. 12 (6) (2020) 1123–1150.
[27] E.A. Haddad, F. El-Hattab, A. Ait-Ali, A practitioner's guide for building the interregional input-output system for Morocco, 2013, OCP Policy Center Research Paper, 2017 RP-17/02.
[28] M. Lenzen, K. Kanemoto, D. Moran, A. Geschke, Mapping the structure of the world economy, Environ. Sci. Technol. 46 (15) (2012) 8374–8381.
[29] M. Lenzen, D. Moran, K. Kanemoto, A. Geschke, Building eora: a global multi-regional input-output database at high country and sector resolution, Econ. Syst. Res. 25 (1) (2013) 20–49.
[30] M. Sonis, G.J. Hewings, Y. Okuyama, Vertical specialization and interregional trade: hierarchy of spatial production cycles and feedback loop analysis in the midwest economy, in: G.J. Hewings, M. Sonis, D. Boyce (Eds.), Trade, Networks and Hierarchies: Modeling Regional and Interregional Economies, Springer-Verlag, Berlin, Heidelberg, 2002, pp. 347–364.
[31] EPA, United States environmental protection agency. Available and emerging technologies for reducing greenhouse gas emissions from the petroleum refining industry, Environmental Protection agency. Office of Air and Radiation, 2010 October 2010.
[32] D.G. Victor, R. Gerlagh, G. Baiocchi, IPCC Lessons from Berlin: getting serious about categorizing countries, Science 345 (6192) (2014) 34–38.
[33] MEES (2022, October 19). Cash-Strapped Samir Shuts Morocco's Refinery Temporarily. Available at "https://www.mees.com/"