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Evaluating the Environmental and Socioeconomic Costs of International Trade: Insights from Iran's Carbon Emissions

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Abstract

In the modern era, heightened awareness of environmental conservation has spurred countries and corporations to adopt ecological initiatives aimed at improving environmental performance. This study examines the environmental and socioeconomic costs tied to carbon emissions from activities related to Iran's exports. By focusing on the financial damages caused by air pollution, the research employs monetary values to comparisons these damages with The economic effects of trade, pinpoint industries that contribute to pollution, and calculate trade balance indicators from a more comprehensive viewpoint. Using the input-output tables, pollution levels in different industries were calculated. The findings reveal that the losses caused by international trade are significant and cannot be ignored. Iran's 2015 economic data indicate that importing goods avoided 2,432million USA $ in damages, while export caused 3,448 million USA $ in damages. Had imports been produced domestically, 2,439 million USA $ damages and 2,049 million USA $ value added would have been created. Net damages generated by the trade amounted to $1008 million, which accounts for 0.84 % of the net value added created by the trade of Agriculture. This implied that the net effect of trade was a $1016-million increase in damages caused by CO2 in 2015. Furthermore, the results show that every $1 million of net value added generated by trade caused emission-related net damages of $0.321 million overall.

Highlights

- The research reveals substantial environmental costs associated with international trade.
- For 2015,the net damage from trade (exports minus avoided import damages) related to CO2 emissions was estimated at $1,016 million USD.
- Every $1million USD of net value added from trade resulted in $0.321 million USD in emission-related damages.

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1. Introduction

In recent years, the growing emphasis on environmental protection has led to the adoption of ecological measures aimed at enhancing environmental performance. This has led to an increased focus on initiatives such as limiting the emission of environmental pollutants, reducing the use of raw materials and energy, promoting recycling and the use of renewable energies (Sorroche del Rey, Piedra Muñoz, & Galdeano Gómez, 2022). A longstanding challenge in environmental economics has been the development of reliable accounting systems and accurate computations of environmental damages (Muller, Mendelsohn, & Nordhaus, 2011). Empirical research worldwide indicates that the persistence of pollutants in developed countries is partly due to increased imports from developing countries (Xu, Dietzenbacher, & Los, 2020). The globalization of the world economy has sparked debates about whether globalization leads to environmental damage or contributes to its protection. The impacts of environmental regulations on global trade have often been analyzed using conventional assumptions of comparative advantage, such as differences in efficiency and factor endowments (Sorroche del Rey, Piedra Muñoz, & Galdeano Gómez, 2022).

Since the mid-20th century, the growth of national air transport industries has significantly contributed to the development of global trade. However, the global air transport industry has also caused environmental pollution, particularly in tourism-based economies during the early stages of economic development, as the air transport industry is often underdeveloped (Balsalobre-Lorente, Driha, Leitão, & Murshed, 2021). This has led to extensive debates over the relationship between trade and the environment in recent decades.

The global growth rate of CO2 Emissions from Flaring is 2.9% annually, while for Iran, it is 1.2% for the same period (BP, 2022). As the effects of carbon emissions become more pronounced, it is increasingly important to recognize the role of trade in this issue. Buterbaugh (2022) suggests that changes in trade policies may be necessary if trade directly or indirectly affects greenhouse gas emissions. This has led to debates among international organizations responsible for regulating trade and environmental protection. While the WTO has been criticized for hindering environmental protection, it has also demonstrated that open trade does not have to come at the expense of the environment.

As developed nations adopted Emissions Trading Systems (ETS), many of their high-emission industries shifted operations to developing regions. Sectors that continued domestic production, such as steel and cement, now represent only a minor share of these countries' economies. Consequently, even in cases of carbon leakage, the consequences for both national economic stability and global climate objectives would be limited. With developed countries having peaked their carbon emissions, developing economies have emerged as central to worldwide decarbonization initiatives. Nevertheless, substantial carbon leakage could jeopardize these initiatives and create major challenges for international climate management by distorting emission reduction progress and amplifying risks to coordinated global climate governance.

Most studies on emissions transfer through global trade have primarily focused on measuring the volume of pollutants released. In contrast, this research highlights the monetary impact of emissions. For example, the United States mitigates domestic environmental damages by importing goods rather than producing them locally, yet it incurs internal damages when manufacturing for export (Xu, Dietzenbacher, & Los, 2020). Evaluating environmental effects in financial terms provides multiple benefits. This approach allows for straightforward comparisons of harm caused by various air pollutants and simplifies the process of aggregating the cumulative impacts of multiple contaminants. Financial metrics also bridge economic and environmental outcomes, offering policymakers a framework to assess trade-offs in regulations by incorporating the hidden costs of production externalities. However, this method has drawbacks, particularly the inherent subjectivity in assigning monetary values to environmental impacts.

The research investigates shifts in net environmental costs arising from Iran's international trade in 2016. It specifically measures the ecological costs tied to Iran's exports and contrasts these with the hypothetical damages that would have occurred if imported goods were manufactured domestically. The analysis leverages Iran's Input-Output (IO) and Social Accounting Matrix (SAM) frameworks, supported by an extensive dataset quantifying air pollution's environmental harm. This methodology aims to provide a holistic view of how trade influences both economic and environmental outcomes in the country.The global growth rate of CO_2 Emissions from Flaring per annum is 2.9%, while for Iran it is 1.2% for the same period (Bp 2022).

2. A Review of the Related Literature

Sorroche del Rey et al. (2022) systematically reviewed theoretical frameworks exploring how international trade interacts with environmental performance (EP), particularly through sustainable development metrics. Their analysis organized EP indicators into five categories—energy consumption, resource utilization, emissions, risk exposure, and toxicity—and underscored the multifaceted theoretical linkages between trade dynamics and environmental outcomes.

Ortiz et al. (2021) developed a conceptual model to dissect the environment-agriculture-trade nexus, emphasizing biodiversity's critical role. Their work identified unresolved questions about synergies and trade-offs among biodiversity conservation, agricultural practices, climate change mitigation, and global trade systems.

Balsalobre-Lorente et al. (2021) provide empirical support for the Environmental Kuznets Curve (EKC), which shows that there is an inverted U-shaped relationship between economic development and CO_2 emissions. Their study also validated the Pollution Haven Hypothesis, linking foreign direct investment (FDI) to higher emissions, while highlighting renewable energy innovation and adoption as effective countermeasures against emissions from sectors like aviation.

Buterbaugh (2022) scrutinized historical and contemporary debates on trade-environment interactions, focusing on the roles of GATT/WTO governance, climate policy disputes between developed and developing nations, and the interplay between multilateral trade rules and environmental agreements.

Yu et al. (2021) employed a propensity score matching difference-in-differences (PSM-DID) approach to assess China's emissions trading system (ETS) on outward direct investment (ODI). They observed that the ETS spurred ODI growth, particularly in non-ETS host countries participating in the Belt and Road Initiative, thereby exacerbating carbon leakage.

Ma & Wang (2021) analyzed how international trade influences emission intensities, finding that trade reduces CO_2 intensity but has negligible effects on SO_2. Their study noted that goods trade outperforms services trade in emission reduction, with developing nations achieving greater success in leveraging trade for environmental gains.

Naeimifar & Abedi (2020) applied input-output analysis to Iran's 2019 trade data, revealing the country as a net importer of air pollution, with environmental costs equivalent to 4.8% of net value added and 1.7% of its trade deficit. Similarly, Taghavee et al. (2016) quantified air pollution damages from Iran's trade, showing exports incurred disproportionately higher environmental costs than imports, exacerbating trade deficits.

Harati et al. (2015) evaluated how trade and political factors influenced the Environmental Performance Index (EPI) across 110 countries (2000–2012). They found goods exports negatively impacted EPI, whereas services exports and FDI improved it, reaffirming the EKC hypothesis.

Lastly, Naeimifar & Abedi (2020) mapped Iran's integration into global trade networks, assessing its export-import linkages and commercial interdependencies.

3. Methodelogy

3.1 Model Specification

The economy can be divided into n distinct sectors. For each sector ii, its total production output $x_i$is distributed in two primary ways: (1) as sales to other sectors within the economy and (2) to fulfill final demandf_i, which represents goods consumed by end users (e.g., households, governments, or exports). This relationship can be summarized by a simple equation that balances a sector's total output with its inter-sector transactions and final demand.

$$x_i = z_{i1} + \cdots + z_{ij} + \cdots + z_{in} + f_i = \sum_{i=1}^{n} z_{ij} + f_i \tag{1}$$

The z_{ij}equation show inter-industry sales by sector i (also referred to as intermediate sales) to all sectors j (involving itself, where j = i). Equation (1) shows the distribution of sector i output. An equation like this exists that unveils the sales of the output of every n sector:

$$\begin{gathered} x_1 = z_{11} + \cdots + z_{1j} + \cdots + z_{1n} + f_1 \\ \vdots \\ x_i = z_{i1} + \cdots + z_{ij} + \cdots + z_{in} + f_i \\ \vdots \\ x_n = z_{n1} + \cdots + z_{nj} + \cdots + z_{nn} + f_n \end{gathered} \quad (2)$$

$$x = \begin{bmatrix} x_1 \\ \vdots \\ x_n \end{bmatrix}, \quad Z = \begin{bmatrix} z_{11} & \cdots & z_{1n} \\ \vdots & \ddots & \vdots \\ z_{n1} & \cdots & z_{nn} \end{bmatrix} \; and \quad f = \begin{bmatrix} f_1 \\ \vdots \\ f_n \end{bmatrix} \quad (3)$$

All thought this article, lower-case bold letters are used for (column) vectors, as in f and x (so x' is the relevant row vector) and upper case bold letters are employed for matrices, as in Z. Having this in mind, the data in (2) on the distribution of each sector's sales could be briefed in matrix notation as:

$$x = Zi + f \quad (4)$$

i refers to a column vector of 1's (of proper dimension – in this case, *n*). It is referred to as a "summation" vector.

In I-O area, a basic hypothesis is that the inter-industry flows from i to j have in mind that these are for a certain duration, e.g. one year-rely completely on the overall output of sector j for that similar duration. It is obvious that there is no argument against the concept that the higher the number of annual car manufacturing, the more requirement for steel over that year by automobile manufacturers. The argument is over the exact nature of this relationship. In I-O analysis, the relationships are as follows: where z_{ij} and x_j for example, input of aluminum (i) purchased by aircraft manufacturers (j) previous year and aggregate aircraft manufacturing former year from the ratio of aluminum input to aircraft output, z_{ij}/x_j [the units are ($/$)], and referred to by a_{ij}:

$$a_{ij} = \frac{z_{ij}}{x_i} \quad (5)$$

For those with some knowledge of basic microeconomics, it is possible to recognize the type of production function present in the I-O system and compare it to the production function used in general neoclassical microeconomic method. Production functions link the sum of inputs used by a sector to the maximum output produced with those inputs. . An example is:

$$x_j = f(z_{1j}, z_{2j}, \ldots, z_{nj}, v_j, m_j) \quad (6)$$

Via the definition of the specialized coefficients in (5), it can be observed that in the Leontief model this becomes

$$x_j = \frac{z_{1j}}{a_{1j}} = \frac{z_{2j}}{a_{2j}} = \ldots = \frac{z_{nj}}{a_{nj}} \quad (7)$$

(This ignores, for an instant, the contributions of v_j and m_j.)

These equations can be displayed briefly in shape of a matrix. In matrix algebra notation, a "hat" over a vector shows a diagonal matrix with the components of the vector along the original diagonal, so, for instance, $\hat{x} =$

$\begin{bmatrix} x_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & x_n \end{bmatrix}$. From the primary definition of an inverse, $(\hat{x})(\hat{x})^{-1} = I$, one can conclude that $\hat{x}^{-1} = \begin{bmatrix} 1/x_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 1/x_n \end{bmatrix}$. Furthermore, post multiplication of a matrix, M, by a diagonal matrix, $\hat{d}$, makes a matrix where every component in column j of $\boldsymbol{M}$ is multiplied by d_j in $\hat{d}$. Thus, the $n \times n$ matrix of technical coefficients could be shown as:

$$A = Z\hat{x}^{-1} \tag{8}$$

Employing the definitions in the upper section, the expression matrix for (6) is :

$$x = Ax + f \tag{9}$$

Assume that I is the n × n identity matrix ones on the major diagonal and zeros some where else:

$$(I - A)x = f \tag{10}$$

For a certain set of f 's, set of n linear equations in the n unknowns, $x_1, x_2, . . . , x_n$ is this and thus it may or may not be feasible to discover a matchless solution. As a matter of fact, the existence or non-existence of a matchless solution relies on if (I−A) is singular or not; that is, if $(I−A)^{-1}$ exists or not. The matrix **A** is referred to as the technical (or input–output, or direct input) coefficients matrix. From the primary definition of an inverse for a square matrix, $(I−A)^{-1} = (1/|I−A|)[adj(I−\mathbf{A})]$. If $|I−A|\neq0$, then $(I−A)^{-1}$ could be discovered, and employing standard matrix algebra findings for linear relations, the matchless solution to (10) is shown by:

$$x = (I - A)^{-1}f = Lf \tag{11}$$

Where $(I−A)^{-1}=L =[l_{ij}]$ is referred to as the Leontief inverse or the aggregate requirements matrix (Miller, 2009).

Using an (I-O) table for Iran, a vector of output changes across various industries can be derived based on a one-dollar increase in final demand for the output of industry i. It is shown as $(I - A_{US})^{-1}\delta^i$ in which I is the identity matrix; A_{US} input-output table represents the direct domestic input coefficient matrix for various industries in Iran (or for other countries), δ_i refers to a column vector with the i^{th} component amounting to one and zeros some place else. The matrix $(I−A_{US})^{-1}$ is often referred to as the Leontief inverse.

Regarding pollutant s, "unit damage" is defined as the damage caused by the marginal demand of one dollar for the output of industry i, denoted as UDs,i. Similarly, "unit value added" can be defined as the value added resulting from one dollar of final demand for the goods of industry i. Which is shown as u_i.

$$UD_{s,i} = d_s^{'}(I - A_{US})^{-1}\delta^i \tag{12}$$

$$u_i = v'(I - A_{US})^{-1}\delta^i \tag{13}$$

Where d_s is the vector of damage coefficients that provides for every industry the damages in dollars pertinent to pollutant s per dollar of gross output, and v is value added coefficient vector which provide the value added per dollar of gross output. The damage coefficients vector ds has been estimated via several stages:

$$d_{s,i} = GED_{s,i} / x_i \tag{14}$$

Where x_i is the gross output in dollars of industry i and $GED_{s,i}$ shows the USD value of damages attributed to pollutant s caused by industry i. To arrive at $GED_{s,i}$, the sum of $GED_{s,i,j}$ in different locations *j* were calculated:

$$GED_{s,i} = \sum_j GED_{s,i,j} \tag{15}$$

Muller et al. (2011) estimated the $GED_{s,i,j}$ by multiplying the emissions in every place to the pollutant-specific marginal harm in the same place. Thus, Eq. (15) can be rewritten as:

$$GED_{s,i,j} = E_{s,i,j} MD_{s,j} \tag{16}$$

In which $E_{s,i,j}$ is the emissions of pollutant s in location j in industry i, and $MD_{s,j}$ is the marginal damage of pollutant *s* in location j.

Eqs. (12) and (16) yield $d_{s,i} = \sum_j (MD_{s,j} E_{s,i,j}) / x_i$ and show a vital hypothesis in this research. To calculate "unit damages", it is supposed that locations shares in the emissions of all industries explicitly and implicitly engaged in the manufacturing of one dollar of final output of industry *i* amount to the industrial means.

The components v_i of the value added coefficients vector *v* are estimated as:

$$v_i = va_i / x_i \tag{17}$$

Where the value-added of industry i is referred to as va_i , and x_i is the gross output in industry i. The necessary date are accessible in the input-output table itself. When "unit-damage" and "unit value added" are defined, damages associated with producing exports and damages evaded by imports could be estimated. Damages caused by manufacturing exports of the output of industry i are shown by:

$$DEX_{s,i} = UD_{s,i} e_i \tag{18}$$

Where ei refers to the US industry i's exports values. The cumulative amount, $\sum_s \sum_i DEX_{s,i}$, could be understood as the damages in the US related to manufacturing to fulfill the demand from other nations.

The evaded damages because of pollutant *s* in the US via importing goods and services manufactured by industry *i* in nations abroad are:

$$DIM_{s,i} = UD_{s,i} m_i \tag{19}$$

Where mi is imported products value from foreign rivals of industry i.

The effects of exports and imports on value added variations in industry i are respectively shown as VEX_i and VIM_i:

$$VEX_i = u_i e_i$$
$$VIM_i = u_i m_i \tag{20}$$

The total price of businesses in the output of industry i is defined, in relation to pollutant s, as the difference between, $DEX_{s,i}$ and $DIM_{s,i}$ and it is shown as $\Delta D_{s,i}$ {Xu, 2020 #11}:

$$\Delta D_{s,i} = DEX_{s,i} - DIM_{s,i} = UD_{s,i}(e_i - m_i) \tag{21}$$

Similarly, the net value added gain of business in the output of industry $i(\Delta VA_i)$ is defined as the variation between VEX_i and VIM_i:

$$\Delta VA_i = VEX_i - VIM_i = u_i(e_i - m_i) \tag{22}$$

4. Empirical Results

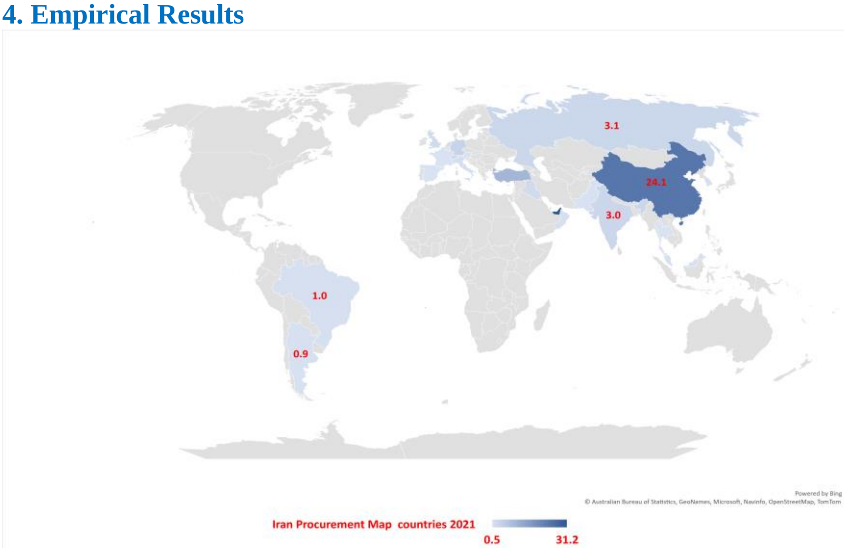

Figure 1. Iran Procurement Map countries 2021
Source: Trademap, 2022

Figure 1 shows that the majority of suppliers for required goods and services are located in Asian. In other words, 24.1% of Iran's suppliers of goods and services are from East Asian countries, with Russia alone accounting for approximately 3.1%. South American countries also hold a share of 1.9%.

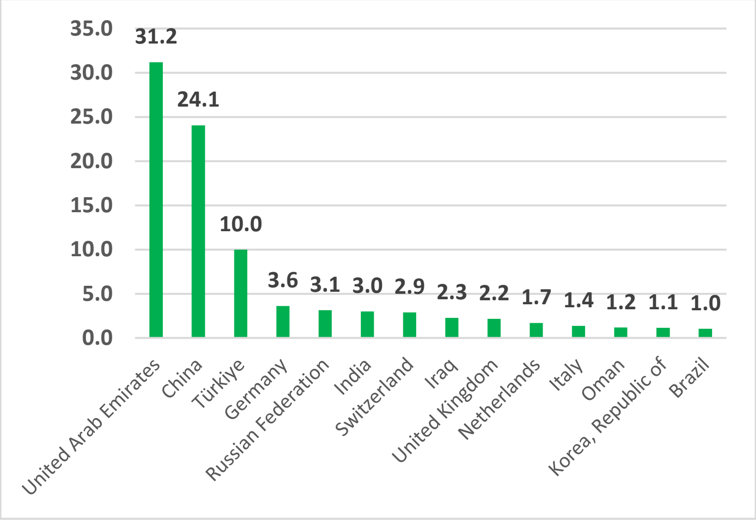

Figure2. Iran share percentage Procurement countries 2021
Source: Trademap, 2022

According to Figure 2, Iran's primary sources for imported goods include the United Arab Emirates (31.2%), China (24.1%), Turkey (10%), Germany (3.6%), along with Russia, India, and Switzerland. Together, these countries account for nearly 89% of Iran's total trade in procuring essential goods, though the text notes collaboration with 14 nations overall (the listed countries likely represent the largest contributors among them).

To assess indirect economic impacts, I-O Accounts (make and use tables) from the Central Bank of Iran (CBI) were utilized. However, due to data limitations—IO tables are only available for 2015—the analysis for this specific methodology was restricted to that year. The accompanying table summarizes the structure of Iran's economy in 2015 based on the input-output framework, highlighting sectorial interdependencies and resource flows.

Table1. Input-Output data, Iran 2015 (in million USA $s of $).

Industries	Final Demand	Import	Export	Gross Value Added	Total Output
Agriculture	3297.97	664.16	308.77	4036.87	7334.85
Oil and Mining	549.65	18.39	3505.28	6281.24	6830.90
Manufacturing	16648.59	5567.60	2490.12	7061.40	23709.98
Public Utilities for Power, Water, and Gas	800.33	60.50	1153.00	3394.17	4194.51
Residential and Wholesale Building	5056.46	-	439.43	8348.05	13404.52
Transportation	1624.07	279.00	705.12	3081.43	4705.51
Services	3948.21	627.329	283.33	16025.22	19973.44

** 1$ = 310000 Rial (2015)*

*** Aggregated industries*
Source: Iranian's input output table for year 2015

Industrial manufacturing has been the most in-demand final product, and it has also had the largest amount of imports with a 77% share of total imports. In the export sector, the oil and mining industry accounted for the largest export of the economy with 39.5% while the net exports of agriculture, manufacturing, and services have negative numbers, which shows that these industries used imports. The service industry had the largest share of gross added value. In the whole economy, industrial manufacturing had the largest share with 29.6% of total output.

Table2. Import from different countries (SAM matrix 2015)

Industries	JPN	CHN	IND	DEU	TUR	NLD	IRQ	RUS	ARE	Other
Agriculture	0.300	12.54	34.91	114.3	6.412	4.638	0.219	80.60	0.248	409.9
Oil and mining	0.000	0.851	0.951	0.029	0.248	0.067	0.000	0.093	0.029	16.12
Manufacturing	31.44	2652	468.0	243.6	316.6	21.35	0.706	96.86	243.3	1492
Public Utilities for Power, Water, and Gas	0.790	25.41	1.103	2.296	12.74	0.806	0.064	0.680	1.000	15.59
Residential and wholesale building	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Transportation	17.03	39.61	10.44	13.07	4.058	3.235	1.783	9.670	8.358	171.7
Services	37.08	78.70	17.70	31.15	5.777	6.967	2.541	14.55	17.73	418.0

** 1$ = 310000 Rial (2015)*
*** Aggregated industries*
Source: Iranian's input output table for year 2015

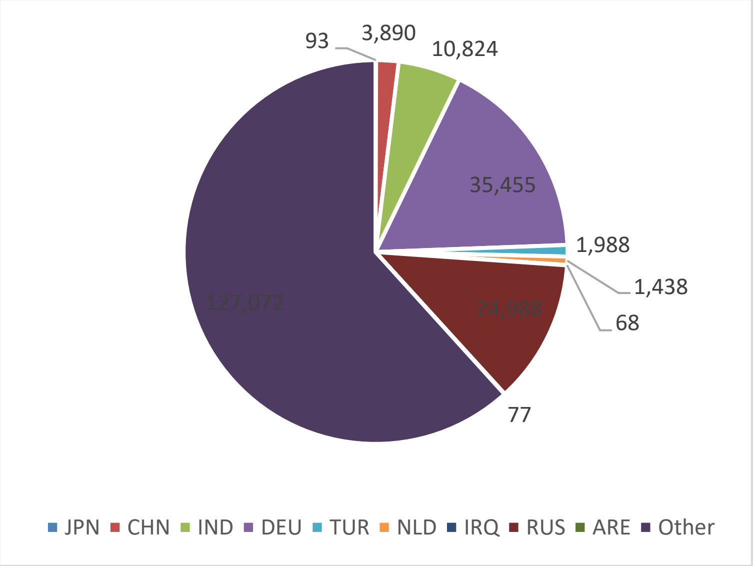

Figure 3. Country's share of imports
Source: *Trademap, 2022*

Table 2 and figure 3 show that in the agriculture sector, the largest import is related to other countries with 61.7 percent, followed by Germany with 17.2 percent. In general, for the imports, the largest share is related to industrial Manufacturing, and apart from that, this share is different in each country. For example, agriculture is the most important industry in India, Germany and Russia is, yet the most important industry is service provision in Japan, Netherlands, Iraq and the United Arab Emirates.

Table3. Fuel consumption according to fuel type (Input-output 2015)

Fuel /Industries	Agriculture	Oil and Mining	Manufacturing	Public Utilities for Power, Water, and Gas	Residential and Wholesale Building	Transportation	Services
Coal	0.00	0.00	0.00	0.00	37.57	0.725	0.00
Natural Gas	0.00	0.00	0.00	27.62	58.83	0.00	0.00
Electricity	88.72	15.99	106.7	243.7	280.9	20.95	46.69
Natural gas distribution	37.14	63.73	22.09	128.2	204.9	5.722	8.916
gasoline	10.01	110.0	9.319	1.035	37.89	3.787	27.86
white oil	7.193	0.170	1.593	0.022	10.10	0.112	3.148
Gasoline	4.090	173.6	14.35	8.967	14.12	16.55	86.47

Fuel oil	0.293	11.41	3.061	7.774	19.74	0.006	5.374
Liquid gas	3.380	0.035	3.232	0.064	803.1	0.083	2.574
Unclassified petroleum	0.664	0.867	1.951	0.100	46.47	0.077	5.200
Other non-petroleum	2.890	115.7	62.74	9.329	222.3	1.193	16.34
Total	154.4	491.6	225.1	426.9	1736	49.20	202.5

** 1$ = 310000 Rial (2015)*
*** Aggregated industries*
source: Iranian's input output table for year 2015

In Table 3, the fuel consumption in each industry is presented. Fuel consumption is classified by fuel type. The largest fuel consumption is related to the Residential and wholesale Construction industry with $1736 million USA $. Meanwhile, the most consumed type of fuel in this industry is Liquid Gas with $803.1 million USA $, and the lowest fuel consumption is for Coal with a sum of $37.57 million USA $.

To estimate the amount of CO2 emission, the results provided by Ministry of Petroleum Iran (MOPI) are used, as presented in Table 4.

Table 2. The emission factor of carbon production for type of fuel

Fuel	The Unit	Million USA $ Tons of Co2 production
Coal	Million USA $ tons	2.34000
Natural Gas	Million USA $ Square meter	0.00240
Electricity	Million USA $ MW	0.70900
Natural gas distribution	Million USA $ Liter	0.00240
gasoline	Million USA $ Liter	0.00243
white oil	Million USA $ Liter	0.00259
Gasoline	Million USA $ Liter	0.00272
Fuel oil	Million USA $ Liter	0.00298
Liquid gas	Million USA $ Liter	0.00166
Unclassified petroleum	Million USA $ Liter	0.00298
Other non-petroleum	Million USA $ Liter	0.00155

Source: Ministry of Petroleum Iran (MOPI)

We focus on carbon emissions for several reasons. First, CO2 emissions are the main driver of global climate change. It is widely believed that the world needs to urgently reduce greenhouse gas emissions to avoid the worst effects of climate change. Second, according to the available data, it is possible to estimate and calculate it.

The results related to carbon estimation are presented in Table 5. As can be seen, electricity production has the highest carbon emissions in all sectors. As can be seen, in industrial agriculture, the highest carbon production is due to the consumption of natural gas fuel and the lowest amount of carbon emission is related to coal. In industries such as oil, mining and manufacturing, the highest carbon production is due to the consumption of other non-petroleum. In industrial transportation, the highest carbon production is due to the consumption of Gasoline. The highest carbon emission is caused by the consumption of coal in industry Residential and wholesale buildings and the highest carbon emission is caused by the consumption of white oil in industrial agriculture.

Table 3. Carbon emissions in economic sectors (Million USA $ Tons of Co2)

Fuel /Industries	agriculture	Oil and mining	Manufacturing	Public Utilities for Power, Water, and Gas	Residential and wholesale building	Transportation	Services
Coal	0.000	0.000	0.000	0.000	6.814	0.131	0.000
Natural Gas	0.000	0.000	0.000	13.70	29.18	0.000	0.000
Electricity	7943	1432	9556	21821	25150	1875	4180
Natural gas distribution	12.01	20.61	7.148	41.49	66.29	1.852	2.885
gasoline	0.755	8.291	0.702	0.078	2.855	0.285	2.099
white oil	3.850	0.092	0.853	0.013	5.412	0.060	1.685
Gasoline	1.150	48.79	4.036	2.520	3.971	4.652	24.30
Fuel oil	0.091	3.516	0.943	2.394	6.081	0.002	1.655
Liquid gas	0.759	0.008	0.725	0.014	180.2	0.019	0.578
Unclassified petroleum	0.205	0.267	0.601	0.030	14.31	0.023	1.602
Other non-petroleum	1.393	55.74	30.229	4.494	107.1	0.574	7.874
Total	7963.8	1569.4	9601.9	21886	25573	1883	4223

Source: Iranian's input output table for year 2015

Table 4. Carbon not production due to imports (Million USA $ Tons of Co2)

Country / Industries	Agriculture	Oil and Mining	Manufacturing	Public Utilities for Power, Water, and Gas	Residential and Wholesale Building	Transportation	Services

JPN	0.316	0.001	67.94	7.537	0.000	9.571	73.68
CHN	13.19	0.487	5731	242.1	0.000	22.25	156.3
IND	36.72	0.544	1011	10.50	0.000	5.866	29.23
DEU	120.3	0.016	526.4	21.88	0.000	7.342	61.90
TUR	6.746	0.141	684.0	121.4	0.000	2.280	11.47
NLD	4.879	0.038	46.13	7.687	0.000	1.818	13.84
IRQ	0.231	0.000	1.528	0.628	0.000	1.002	5.049
RUS	84.78	0.054	209.2	6.492	0.000	5.432	28.92
ARE	0.262	0.016	525.7	9.538	0.000	4.694	35.24
Other	431.16	9.208	3225	148.6	0.000	94.46	830.7
Total	698.6	10.50	12028	576.5	0.000	156.7	1246

Source: Iranian's input output table for year 2015

Considering the volume of imports from various countries, it is also possible to estimate the corresponding carbon emissions, the results of which are presented in Table 5.

Considering the amount of import and export, and since exports are a major cause of carbon emission in Iran and import causes no carbon emission, the amount of net carbon emission can be estimated. The results are presented in Table 7.

Table7. Ratio of carbon production to net export (Million USA $ Tons of Co2)

Industries	agriculture	Oil and mining	Manufacturing	Public Utilities for Power, Water, and Gas	Residential and wholesale building	Transportation	Services
NCPI [1]	698.6	10.50	12028	576.5	0.000	156.7	1246
CPE [2]	324.7	2001	5379	10987	1147	396.0	562.9
CPNE [3]	-373.8	1991	-6648	10410	1147	239.3	-683.5

1.No carbon production from imports
2.Carbon production from exports
3.***Source:*** *Iranian's input output table for year 2015*

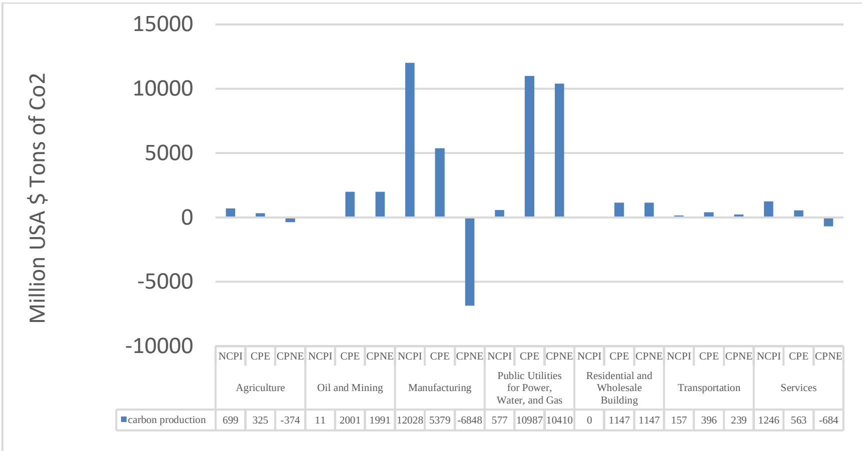

Figure4. Carbon production to net export (Million USA $ Tons of Co2)
Source: *Iranian's input output table for year 2015*

As the results of the table show, agriculture, manufacturing and services have respectively caused the non-emission of pollution by the amount of -373.8, -6648 and -683.5 million USA $ tons of Co2 due to the negativity of exports,. In other words, instead of domestic production in these industries, which causes carbon production and emission of pollution, carbon emission has been prevented by importing the desired products.

Our main findings on the environmental damages linked to Iran's international trade are presented in Table 8. The first row illustrates the damages generated by exports in each industry (DEX) and the corresponding value added (VEX). For instance, exports from the electricity, water, and gas sectors contributed approximately $1,821 million USA $ in damages while generating around $2,095 million USA $ in value added across all sectors in Iran. Conversely, if these products had been produced domestically, they would have resulted in $1,993 million USA $ in damages (DIM) and $819.6 million USA $ in value added (VIM).

The fifth row of Table 8 highlights that the net damages (ΔD) from the trade of electricity, water, and gas amounted to $1,725 million USA $, equating to 0.84% of the net value added from trade (ΔD/ΔVA) in the agriculture sector, which stands at $2,049 million USA $. Among all industries, manufacturing exports produced the highest value-added after adjusting for pollution-related damages, amounting to $941.5 million USA $ (ΔVA - ΔD).

Furthermore, Table 8 reveals significant variations in the net environmental impact of trade across different sectors. Total damages linked to exports reached approximately $3,448 million USA $, while importing goods helped avoid around $2,439 million USA $ in damages. Interestingly, the relationship between net damages and trade balances suggests that a trade deficit does not necessarily translate to environmental benefits and vice versa. For instance, the manufacturing sector experienced a trade deficit, with a net loss in value added (ΔVA = -$192.8 million USA $) but a reduction in pollution-related damages (ΔD = -$1,102 million USA $).

Table 5. Damage caused by trade in Iran's economy based on the data input-output table 2015

Industries	Export		Import		difference import and export		Comparisons	
	DEXO a	VEXO b	DIMO [c]	VIMO [d]	ΔDT [e]	ΔVAT [f]	ΔDT/ΔVAT	ΔVAT -ΔDT [g]
Agriculture	5.386	388.1	115.8	549.4	-61.96	-161.2	0.384	-99.31
Oil and Mining	331.8	5414	1.741	15.91	330.1	53.99	6.114	506.8
Manufacturing	891.8	626.7	1993	819.6	-1102	-192.8	5.715	941.5
Public Utilities for Power, Water, and Gas	1821	2095	95.57	45.74	1725	2049	0.841	324.0
Residential and Wholesale Building	190.2	1155	-	-	190.2	1155	0.164	96.50
Transportation	65.65	692.9	25.97	74.10	39.67	618.8	0.064	579.1
Services	0.002	34.31	206.6	544.4	-113.3	-201.2	0.563	-87.93
Total	3448	10716	2439	2049	1008	8667	0.116	7659

DEXo a*: Damages caused by product exports.*
VEXO b*: Value added from exports.*
DIMO c*: Damages avoided by importing goods and services.*
VIMO d*: Value added lost due to imports.*
ΔDT e*: Net damages from trade, calculated as the difference between DEXO and DIMO (ΔD = DEXO - DIMO).*
ΔVAT f*: Net value added from trade, calculated as the difference between VEXO and VIMO (ΔVAT = VEXO - VIMO).*
ΔVAT-ΔDT g*: Net value added gain from trade, adjusted for environmental damages.*
source: *Research findings*

The sectoral ratios of DEX to VEX do not necessarily match those of DIM to VIM. Table 9 presents a comparison of these sectoral ratios for DEX/VEX and DIM/VIM.

Table 9. Ratio of damage to value added

Industries	DEX/VEX	DIM/VIM
Agriculture	0.013	0.210
Oil and mining	0.061	0.109
Manufacturing	1.422	2.432
Public Utilities for Power, Water, and Gas	0.869	2.089
Residential and wholesale building	0.164	-
Transportation	0.094	0.350
Services	0.000	0.379
Total	0.321	1.190

Source: *Research findings*

In other words, this table shows how much damage has happened per unit of value added in exports ($1 million USA $ damage per 1$ million USA $ value added of export), and on the other hand, it shows pollution per unit of import ($1 million USA $ Damages avoided per 1$ million USA $ value added of Import). In the export sector, the largest amount is for the manufacturing industry, which is 1.422. In other words, for every one million USA $ dollars of value added in the manufacturing industry, damage is 1.422 million USA $ dollars. However, in the import sector, with $1 million USA $ in imports from the manufacturing industry, $2.43 million USA $ of damages were avoided.

Table10. The share of each part of the damage

Industries	Export Damages	Import Damages avoided	Net Export Net Damages
Agriculture	1.56 %	4.75 %	-4.85 %
Oil and mining	9.62 %	0.07 %	14.44 %
Manufacturing	25.86 %	81.73 %	-86.28 %
Public Utilities for Power, Water, and Gas	52.82 %	3.92 %	75.50 %
Residential and wholesale building	5.52 %	0.00 %	8.32 %
Transportation	1.90 %	1.06 %	1.74 %
Services	2.71 %	8.47 %	-8.87 %

Source: *Research findings*

The electricity, water, and gas sector accounts for the majority of environmental damage linked to exports (52.82%), while the Manufacturing industry represents the largest proportion of environmental harm prevented through imports (81.73%). Countries benefit strategically by importing goods with higher environmental costs per unit and exporting those with lower unit damages. As shown in Table 10, these unit damages are quantified as the environmental impact caused per 1 million USA $ USA $ USA $ of exports or mitigated per1*million USA $ USA $ of exports or mitigated per*1 million USA $ USA $ of imports.

Table 6. Unit damages of trade by sector

Industries	Export		Import		Net Export
	weights	damage of intermediate	weights	Damages avoided of intermediate	damage of intermediate
Agriculture	0.034	0.019	0.092	0.051	0.322
Oil and Mining	0.394	0.120	0.002	0.0007	0.119
Manufacturing	0.280	0.323	0.771	0.891	0.567
Public Utilities for Power, Water, and Gas	0.129	0.661	0.008	0.042	0.618
Residential and Wholesale Building	0.049	0.069	0.000	---	0.069
Transportation	0.079	0.0.23	0.038	0.011	0.012
Services	0.031	0.033	0.086	0.092	0.058
Total	1	1.251	1	1.090	0.161

Source: *Research findings*

The results of the table show how much the cost of damage will be for everyone million USA $ USA $ dollars of export or import in each industry. Among the investigated industries for export, oil and gas industry has the largest export value (0.394), but the largest damage is related to the electricity, water and gas supply (0.661 million USA $ damage per million USA $ export) industry. Regarding imports, manufacturing industry has the largest import weight (0.771) and the largest damage of intermediate (0.891 million USA $ damage of intermediate per million USA $ import).

5. Concluding Remarks

This study examines the environmental and socioeconomic monetary costs associated with carbon emissions from activities supporting Iran's exports. The financial impact of air pollution has gained attention, and this research specifically focuses on quantifying pollution-related damages in monetary terms. By assigning monetary values to these damages, we can compare them against the economic benefits of trade, identify high-pollution industries, and calculate trade balance indicators with a broader perspective.

To achieve this, we utilized industry-specific data tables to assess pollution levels across various sectors. The findings indicate that the environmental costs of international trade are significant and cannot be overlooked. According to Iran's

2015 economic data, imports helped avoid $2,432 million USA $ in damages, while exports generated $3,448 million USA $ in pollution-related damages. Had the imported goods been produced domestically, they would have resulted in $2,439 million USA $ in damages (DIM) and $2,049 million USA $ in value added (VIM). The net damage (ΔD) from trade amounted to $1,008 million USA $, representing 0.84% of the net value added generated by trade in the agriculture sector. Overall, the net impact of trade in 2015 led to a $1,016-million USA $ increase in CO2-related damages. Moreover, the results reveal that every $1 million USA $ of net value added from trade resulted in $0.321 million USA $ in emission-related damages.

Power generation, particularly within the Utilities sector, is a highly polluting activity, with diesel-powered plants being a major contributor. As shown in Table 5, this sector has particularly high unit damages. A significant portion of the pollution embedded in exported goods stems from the production of their intermediate products. This underscores the importance of assessing trade-related damages using an input-output (IO) analysis, as many industries rely heavily on electricity for their operations.

Given these findings, policymakers are encouraged to integrate the Clean Development Mechanism and pollution reduction strategies into production and trade policies.

Author Contributions

Conceptualization, all authors; methodology all authors; formal analysis, all authors; resources, all authors; writing original draft preparation, all authors; writing review and editing, all authors; supervision, Zeinalzadeh, R. All authors have read and agreed to the published version of the manuscript.

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The authors declare no conflict of interest.

Data Availability Statement

The data used in the study were taken from.

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