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Determinants of the changes in the elasticity of CO_2 emissions in Iran

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ABSTRACT

In this study, while calculating the CO_2 emission demand elasticity and CO_2 emission output elasticity of production sectors for 2001 and 2011 using Input-Output analysis, CO_2 emission elasticities are decomposed using structural decomposition analysis to identify stimuli. Findings show that the "Electricity generation, transmission, and distribution" sector has the most elasticity in these years. The "Ghosh inverse matrix" effect is a strong stimulus to the CO_2 emission elasticity of the sectors. This result indicates that the change in the share of output i, which is sold to sector j as an intermediate input, is a strong stimulus to increase the elasticity of CO_2 emissions. These changes can be due to increased economic activities and the inefficiency of production structure. Increasing the share of renewable energy in the energy consumption basket of production sectors, increasing energy efficiency (reducing energy intensity) by replacing new and advanced equipment with old and worn equipment and improving production structure can help reduce the elasticity and CO_2 emission in Iran's production sectors. The results of this study are significant for energy and environmental policymakers.

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1- Introduction

Today, the environment is one of the most challenging economic and political issues in international politics. In recent years, numerous meetings and conferences have focused on climate change and environmental challenges, reflecting the concerns of economists, politicians, and ecologists about environmental issues.

In 2019, Iran is ranked sixth among world countries and fifth among Asian countries (including Russia) in terms of CO_2 emissions.[1] Therefore, studying the CO_2 emission elasticity of the production sectors of this country is significant and important for energy and environmental policymakers. What factors influence changes in CO_2 emission elasticities? Which are the stimulants and which are the inhibitors? The answers to these questions are useful in reducing and controlling CO_2 emissions. In the present study, CO_2 emission elasticities of production sectors are calculated, and then, with the aim of identifying CO_2 emission elasticity stimuli, the changes in CO_2 emission elasticities are broken down into different components.

The methodology of this research is based on Input-Output analysis and decomposition analysis. The economy of all countries of the world is composed of different sectors that in a general classification can be divided into two groups of manufacturing industries and non-manufacturing industries. Input-Output tables are widely used today in predicting and describing the environmental conditions of countries due to their inclusion of manufacturing and non- manufacturing groups. It can be said that Input-Output analysis and decomposition analysis are used in conjunction with econometric techniques, and perhaps even more econometric techniques are used to explain and describe environmental and energy issues. In recent years, Structural Decomposition Analysis (SDA) has been an important tool for breaking down and analyzing changes in physical

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[1] http://www.statista.com

variables, such as energy consumption or CO_2 emissions, to changes in their economic and physical determinants. Structural decomposition analysis is a static comparative technique in which the structural term refers to the inclusion of output and demand structure by Input-Output tables (Rormose, 2011). In the analysis of the complex interaction between the economy and the environment, it is very important to obtain all the details of the consumption and production structure obtained by Input-Output tables.

The novelty of this paper is to determine and calculate the components of changes in CO_2 emission elasticities using SAD. Guo et al. (2018) have presented a method for calculating CO_2 emission elasticities based on the Input-Output analysis. CO_2 emission demand elasticity is the percentage change in CO_2 emissions of the economy as a result of a 1% change in the final demand of sector and CO_2 emission output elasticity is the percentage change in sectoral CO_2 emissions as a result of a 1% change in the final demand of all sectors. In this study, first CO_2 emission elasticities calculated based on Input-Output analysis and then decomposed based on the structural decomposition analysis with the aim of identifying the stimuli of CO_2 emission elasticities. In this study, unlike Guo et al. (2018), it takes two years (not one year) for the purpose of the study, and by having two times, the components of the changes in CO_2 emission elasticities are calculated (Guo, Zhang, & Zhang, 2018).

Based on the decomposition analysis, we have identified the effect of "changing the Ghosh inverse matrix", the effect of "changing the share of final demand in the total output of sector" and the effect of "changing the share of CO_2 emission of sectors" for changes in CO_2 emission demand elasticity and the effect of "changing the Ghosh inverse matrix" and the effect of the "changing the share of final demand in the total output of sectors" and the effect of the "changing the share of CO_2 emission of sector" for changes in the production elasticity of CO_2 emissions.

The organization of the article is as follows: the literature review is presented in the second section. Methodology and data analysis are explained in the third section. Experimental findings and discussion are dedicated to the fourth and fifth sections, respectively. Finally, conclusions and recommendations are the subjects of section six.

2- Literature Review

In the 1970s, oil shocks coupled with the recession led economists to focus on energy input. At the same time, due to the importance and role of energy consumption in economic growth, environmental concerns were raised and the quality of the environment was considered by economists and politicians. Since then, extensive research has been conducted on environmental quality and emissions of pollutants. The answer to the question of what factors affect CO_2 emissions has always been of interest to energy and environmental researchers and policymakers.

Some research studied Environmental Kuznets Curve hypothesis (Ahmadian, Abdoli, Jabalameli, Shabankhah, & Khorasani, 2019; Apergis & Ozturk, 2015; Azomahou, Laisney, & Van, 2006; Chen & Chen, 2015; Grossman & Krueger, 1991, 1995; Selden & Song, 1994; Shafik & Bandyopadhyay, 1992; Stern, 2015; Tao, Zheng, & Lianjun, 2008) and examined the impact of economic growth on emissions and some research studied Pollution Haven hypothesis (Cole, 2004; Guzel & Okumus, 2020). The pollution haven hypothesis posits that, when large industrialized nations seek to set up factories or offices abroad, they will often look for the cheapest option in terms of resources and labor that offers the land and material access they require. However, this often comes at the cost of environmentally unsound practices. Some studies focused on econometric methods and examined the impact of effective factors (economic growth, technological factors, financial factors, international trade factors and political factors) on CO_2 emissions (Adams & Klobodu, 2018; Al-Mulali & Ozturk, 2015; Gorus &

Aslan, 2019; Nasreen, Anwar, & Ozturk, 2017; Ozcan, Tzeremes, & Tzeremes, 2020; Pandey & Rastogi, 2019; Salahuddin, Alam, Ozturk, & Sohag, 2018; Y. Zhang & Zhang, 2018). Numerous studies have been conducted since the early 1990s on the relationship between economics and the environment using Input-Output analysis and decomposition analysis (structural decomposition analysis and index decomposition analysis). In this group of studies, the factors affecting CO_2 emissions are examined (Chang, Lewis, & Lin, 2008; Kim, Yoo, & Oh, 2015; Lim, Yoo, & Kwak, 2009; Paul & Bhattacharya, 2004; Su, Ang, & Li, 2017; Tunc, Türüt-Aşık, & Akbostancı, 2007; Wang, Chen, Zhang, & Niu, 2015; Yabe, 2004; Yu, Zheng, Ba, & Wei, 2016; Y.-J. Zhang, Bian, Tan, & Song, 2017; Y.-J. Zhang & Da, 2015). Some researchers in the coming years have tried to use the concept of *elasticity* to link CO_2 emissions and economic activity. Heutel (2012), Klarl (2015 and 2020), Azami and Angazbani (2020) estimated elasticity of CO_2 emissions with respect to GDP by use of DSGE, MSDR and MSAR, respectively (Azami & Angazbani, 2020; Heutel, 2012; T Klarl, 2015; Torben Klarl, 2020). They showed there is a difference between elasticity of CO_2 emissions during expansions and elasticity of CO_2 emissions during recessions. A group of studies such as Rafaty et al. (2020) investigated the impact of carbon pricing on elasticity of CO_2 emissions (Rafaty, Dolphin, & Pretis, 2020). Another group of studies has tried to link CO_2 emissions and economic activity using Input-Output analysis and elasticity (Guo et al., 2018; Hondo, Sakai, & Tanno, 2002; Morán & del Río González, 2007; Tarancón & Del Rio, 2007). Guo et al. (2018) examine the key sectors that save energy and reduce CO_2 emissions in China by using the Input-Output analysis and calculating emission elasticities. We also look for determinants of elasticity changes by decomposing elasticities. This study seeks to determine the changes in CO_2 emission elasticities of the production sectors by calculating and decomposing elasticities (Guo et al., 2018).

3- Methodology and Data

3-1- Methodology

Following Guo et al. (2018), we calculate the elasticity of CO_2 emissions (Equations 1-7) (Guo et al., 2018). The output equation of production sectors is considered as Equation (1).

(1) $$X = (I - A)^{-1} Y$$

Where X is total output, Y is the final demand and $(I - A)^{-1}$ is the Leontief inverse matrix. I is unit matrix and A is technical coefficient matrix. CO_2 emissions of production sectors are calculated according to the CO_2 emissions intensity and the total output as Equation (2).

(2) $$X = f'(I - A)^{-1} Y$$

Where E is a row vector whose elements represent the total CO_2 emissions of each sector in the production activity system and f' is a row vector whose elements represent the CO_2 emissions caused by per unit of output in each sector. According to the purpose of CO_2 emission elasticity calculation, the following changes in CO_2 emission are calculated:

(3) $$\Delta E = f'(I - A)^{-1} Y\theta$$

Where θ is the proportion of changes in the final demand. According to $S = \widehat{X}^{-1} Y$:

(4) $$\Delta E = f'(I - A)^{-1} \widehat{X} S\theta$$

Where the symbol ^ represents the corresponding vector diagonalisation. S is a column vector whose elements represent the shares of the final demand of each sector in the total output. According to the purpose of CO_2 emission elasticity calculation, both sides of equation (4) are divided by E :

(5) $$E^{-1}\Delta E = E^{-1} f'(I-A)^{-1}\widehat{X}S\theta$$

According to: $f' = E\beta'\widehat{X}^{-1}$

(6) $$E^{-1}\Delta E = \beta'\widehat{X}^{-1}(I-A)^{-1}\widehat{X}S\theta$$

β' is a row vector whose elements represent the shares of CO_2 emissions in each sector in the total CO_2 emissions caused by the final use of all sectors. According to $\widehat{X}^{-1}(I-A)^{-1}\widehat{X} = (I-\vec{A})^{-1}$, the equation for calculating CO_2 emission elasticity is summarized as Equation (7):

(7) $$E^{y} = \widehat{\beta}'(I-\vec{A})^{-1}\widehat{S} = \widehat{\beta}'(I-B)^{-1}\widehat{S}$$

According to Equation (7), the matrix E^{y} is written as Equation (8):

(8) $$E^{y} = \begin{bmatrix} \beta_1 g_{11}\frac{y_1}{x_1} & \beta_1 g_{12}\frac{y_2}{x_2} & \cdots & \beta_1 g_{1n}\frac{y_n}{x_n} \\ \vdots & \vdots & & \vdots \\ \vdots & \vdots & & \vdots \\ \beta_n g_{n1}\frac{y_1}{x_1} & \beta_2 g_{n2}\frac{y_2}{x_2} & \cdots & \beta_n g_{nn}\frac{y_n}{x_n} \end{bmatrix}$$

g_{ij} is matrix elements of $(I-B)^{-1}$. $B = \frac{x_{ij}}{x_i}$ is the direct output coefficients matrix and shows the proportions that each sector i sells to every other sector j out of its total output and $(I-B)^{-1}$ is the Ghosh inverse matrix and show the direct and indirect sales that sector j must encourage to every other sector i. $A = \frac{x_{ij}}{x_j}$ is the technical coefficients matrix, the proportion of each good i that each sector j uses in as input to produce a product and $(I-A)^{-1}$ is the Leontief inverse matrix and shows the direct and indirect requirements of inputs produced by sector i per unit of output produced sector j.

In the following TI_j and DI_i are rewritten according to Equation (8):

(9) $$TL_j = \sum_i E_{ij}^y = \sum_i \beta_i g_{ij} \frac{y_j}{x_j} = \frac{y_j}{x_j} \sum_{i=1}^{n} \beta_i g_{ij}$$

(10) $$DI_i = \sum_j E_{ij}^y = \sum_j \beta_i g_{ij} \frac{y_j}{x_j} = \beta_i \sum_{j=1}^{n} \frac{y_j}{x_j} g_{ij}$$

TI_j indicates the percentage change in CO_2 emissions of the economy as a result of a 1% change in the final demand of sector. This elasticity shows the effect of demand structure on CO_2 emissions of the whole economic system. DI_i indicates the effect of one percent change in the final demand of all economic sectors on the CO_2 emissions of sector i. DI_i indicates the percentage change in sectoral CO_2 emissions as a result of a 1% change in the final demand of all sectors. This elasticity shows the effect of production structure on CO_2 emissions of the whole economic system.

Based on the structural decomposition approach, the increase in TI_j over a specific period can be decomposed as follows:

(11) $$\Delta TI_j = \Delta(\frac{y_j}{x_j}) \sum_i \beta_i g_{ij} + \Delta(\sum_i \beta_i g_{ij}) \frac{y_j}{x_j}$$
$$= \Delta(\frac{y_j}{x_j}) \sum_i \beta_i g_{ij} + \frac{y_j}{x_j} (\sum_i \beta_i \Delta g_{ij}) + \frac{y_j}{x_j} (\sum_i g_{ij} \Delta \beta_i)$$

According to the decomposition ΔTI_j and based on Equation (11), ΔTI_j is decomposed into three factors; "changing the share of final demand in the total output of sector", "changing the Ghosh inverse matrix" and "changing the share of CO_2 emission of sector". The interpretation of "change in the Ghosh inverse matrix" is derived from the matrix of production coefficients (or allocation coefficients); A change in the share of industry i production that is sold to industry j as an intermediate input.

Based on the structural decomposition approach, the increase in DI_i over a specific period can be decomposed as follows:

$$\Delta DI_i = \Delta(\beta_i)\sum_j\left(\frac{y_j}{x_j}\right)g_{ij} + \Delta\left(\sum_j \frac{y_j}{x_j} g_{ij}\right)\beta_i \tag{12}$$
$$= \beta_i\left(\sum_j g_{ij}\Delta\left(\frac{y_j}{x_j}\right)\right) + \beta_i\left(\sum_j \frac{y_j}{x_j}\Delta g_{ij}\right) + \Delta\beta_i\sum_j \frac{y_j}{x_j} g_{ij}$$

According to the decomposition of ΔDI_i and based on Equation (12), ΔDI_i is decomposed into three effects; "changing the share of final demand in the total output of sectors", "changing the Ghosh inverse matrix" and "changing the share of CO_2 emission of sector". It should be noted that the effect of "changing the Ghosh inverse matrix" on elasticity decomposition of TI_j $\left(\beta_i\left(\sum_j \frac{y_j}{x_j}\Delta g_{ij}\right)\right)$ is different from this effect on elasticity decomposition of DI_i ($\frac{y_j}{x_j}\left(\sum_i \beta_i \Delta g_{ij}\right)$).

3-2- Data

The Statistics Center of Iran and the Central Bank of Iran publish input-output tables for Iran. In this study, we have used input-output tables published in 2001 and 2011 by the Statistics Center of Iran[2].

To accurately calculate the share of CO_2 emissions of production sectors, we need to eliminate the influence of inflation. Therefore, the input -output tables of 2001 and 2011 with the price of 2011 are converted into input-output tables with a constant price. Due to the differences in the sector classification of the input-output tables of 2001 and 2011, we match some production sectors and finally take into account the 65 unified sectors. Also, for price indices, the 82-sectors table of the statistics center has been used, which has been aggregated into 65 sectors.

In order to calculate the CO_2 emission of each production sector, we first obtain the total consumption of each energy for each year from the Iranian energy balance sheet, and then we allocate each energy consumption to production sectors and single household sector, according to input-output tables and the share of production sectors and the share of the household sector (Kim et al., 2015). Then, using the 1996 IPCC guidelines and according to the emission factors of each energy source, we calculate the CO_2 emissions of each sector (Eggleston, Buendia, Miwa, Ngara, & Tanabe, 2006). The types of energy source used in Iran's production sectors and the details of CO_2 emissions related to each source are reported in **Tabel 1**.

Tabel 1. CO_2 emission factors of different energy sources
Source: Research calculations

Code	Energy source	kton CO_2 /Pj
1	furnace oil	76.593
2	gas oil	73.326
3	kerosene	71.148

[2] This article is taken from the master's thesis that was defended in 2021 and data was collected in 2020, which at that time the last published input -output table was table of 2001. Recently, the input -output table of 2016 has been published.

4	gasoline	68.607
5	natural gas	55.820
6	liquefied gas	62.436
7	light jet fuel	68.244
8	heavy fuel jet	75.785
9	coal	92.500
10	electricity	148.333
11	coke	100.842
12	solid fuel	92.5

Fuels used to generate electricity include natural gas, kerosene, gas oil, gasoline, and fuel oil. Blast furnace gas, coke, coke gas, and tar are also products obtained from coal and due to lack of access to their emission factor, the amount of carbon dioxide emissions is calculated for coal in general. Firewood, charcoal, and animal waste have been used as energy in Iranian industries and their CO_2 emissions have been calculated based on solid fuels in the 1996 IPCC guidelines due to their lack of emission factors.

4- Experimental findings

Aim of this paper is to investigate the factors affecting CO_2 emission elasticities, CO_2 emission demand elasticity and CO_2 emission production elasticity. In the first step, the elasticities are calculated; TI_j is the percentage change in CO_2 emissions of the whole economic system compared to one percent change in final demand of sector j (CO_2 emission demand elasticity) and DI_i is the percentage change in CO_2 change in sector i to one percent change in final demand of all production sectors (CO_2 emission output elasticity). In the second step, changes of elasticities are decomposed.

4-1- Calculating the TIj and DIi elasticities of Iran's production sectors

Using Equations (9) and (10), the TI_j and DI_i elasticities are calculated for 65 production sectors in Iran in 2001 and 2011. S_i is the share of final demand in output and β_i is the share of emissions in sector i.

Tabel 2. Calculation of TI_j and DI_i elasticities of Iran's production sectors in 2001 and 2011
Source: Research calculations

Sectors		2001				2011			
Sector code	Sector name	TI_j	DI_i	S_i	β_i	TI_j	DI_i	S_i	β_i
1	agriculture and horticulture	0.024169	0.022358	0.668817273	0.031632245	0.032376	0.025564	0.665432594	0.023790262
2	agriculture, forestry and animal husbandry	0.008118	0.009153	0.312431256	0.023027219	0.012143	0.017091	0.231718609	0.016385703
3	fishing	0.001621	0.001409	0.815738129	0.001699211	0.003082	0.001603	0.839754298	0.001589667
4	crude oil extraction, natural gas and mining support services	0.05513	0.054327	0.881619465	0.061568594	0.061104	0.10117	0.570152987	0.099241779
5	extraction of other mines	4.65E-05	0.000353	0.008931604	0.004814287	0.002222	0.006609	0.17329943	0.005300576
6	production of food and beverage products	0.038296	0.035055	0.7180013	0.047478129	0.085693	0.036965	0.771356538	0.03558251
7	productio	0.000	0.000	0.96308	0.00057	0.000	0.000	0.98729	0.00051

	n of tobacco products and Tobacco	686	556	9382	6881	939	526	1699	4147
8	textiles	0.006692	0.002952	0.64329686	0.004274092	0.010219	0.005019	0.600210012	0.004528578
9	apparel	0.00318	0.002804	0.815926481	0.003353599	0.009842	0.005891	0.938531423	0.005303402
10	Production of leather and related products	0.001238	0.000915	0.758368905	0.001152444	0.004603	0.002804	0.876703238	0.002433833
11	wood and wood products	-7.2E-05*	6.71E-05	-0.042837402	0.001449739	0.00044	0.003491	0.047390807	0.002542956
12	paper and paper products, printed paper	0.000404	0.000488	0.117696168	0.002365285	0.00151	0.004872	0.167109134	0.002854148
13	coke, oil refining products	0.055123	0.06031	0.737428595	0.074569839	0.090275	0.054433	0.788624651	0.052079401
14	chemicals and chemical products	0.019567	0.026007	0.384793177	0.049754163	0.033408	0.029175	0.478957502	0.023654668
15	rubber and plastic products	0.0012	0.001349	0.18465774	0.005103125	0.00205	0.007913	0.095465441	0.005988283
16	other non-	0.002	0.002	0.17579	0.00897	0.010	0.011	0.24174	0.01045

	metallic mineral products	304	312	0716	8067	656	116	3218	1951
17	production of base metals	0.001 905	0.003 317	0.09580 9532	0.01632 7833	0.006 299	0.035 061	0.07439 4868	0.01954 4194
18	production of metal products except machinery and equipment	0.007 939	0.007 494	0.40580 3637	0.01575 5988	0.038 423	0.019 583	0.47239 104	0.01699 733
19	production of computer, electronic and optical products, electrical equipment	0.009 377	0.008 509	0.83884 2725	0.00938 5834	0.015 822	0.013 1	0.56120 2543	0.00909 8969
20	production of machinery and equipment not elsewhere classified	0.013 184	0.012 719	0.77138 0008	0.01468 1745	0.017 612	0.021 913	0.65975 1447	0.01310 0428
21	production of motor vehicles and other	0.024 495	0.022 968	0.86534 2345	0.02546 6902	0.063 667	0.031 307	0.59489 7828	0.02521 4345

	transport equipment								
22	production of furniture	0.002587	0.002416	0.955580291	0.002523266	0.007966	0.003377	0.844223587	0.003271084
23	Production of other products	0.001786	0.001815	0.604162515	0.002807355	0.003158	0.003131	0.569450965	0.002568658
24	Production, transmission and distribution of electricity	0.063811	0.080058	0.224109681	0.272470858	0.088833	0.336381	0.241325604	0.301880684
25	Production and distribution of natural gas	0.001361	0.001496	0.075676308	0.017871298	0.018418	0.028059	0.605214025	0.026066716
26	Water supply, Waste management, Wastewater and treatment activities	0.000896	0.000766	0.349278115	0.001888975	0.002751	0.001962	0.263170897	0.001873434
27	Residential buildings	0.019642	0.018848	0.913246671	0.020051175	0.059116	0.018416	0.873998891	0.018369022
28	Other buildings	0.029724	0.027015	0.867101611	0.030734564	0.096652	0.031323	0.90714507	0.031161826

29	Wholesale and retail, Repair of motor vehicles	0.052939	0.049043	0.786376588	0.059584274	0.087055	0.058989	0.644530666	0.05635773
30	Repair services	0.004984	0.003888	0.989345732	0.003596716	0.005184	0.004346	0.486199333	0.004118131
31	Transportation Quoted from Intercity rail	0.001349	0.001346	1.040003977	0.001229232	0.00078	0.001076	0.298100285	0.000973077
32	other land transportation	0.01339	0.012865	0.431596614	0.027235504	0.021625	0.026186	0.481377662	0.024341375
33	pipeline transportation	0.00027	0.000223	0.568584842	0.000384295	0	0.00101	0	0.000945491
34	water transportation	0.002727	0.00183	0.60028923	0.002767792	0.004384	0.002377	0.599259983	0.00192112
35	air transportation	0.00241	0.001153	0.795600972	0.001393523	0.002623	0.006868	0.441028935	0.003204695
36	warehousing and transportation support activities	0.000877	0.001179	0.27792154	0.002769185	0.001324	0.003242	0.208009695	0.002614209
37	post and courier activities	0.013897	0.014085	1.267393397	0.010747794	0.015515	0.009264	0.542434139	0.009011625

38	accommodation	0.000643	0.000477	0.449960364	0.001018178	0.003429	0.005455	0.767467178	0.003089822
39	service activities related to Food & Beverage (Restaurants, etc.)	0.006131	0.005202	0.75738724	0.006771503	0.015289	0.007767	0.895467135	0.007518823
40	Information and Communication	0.001207	0.001302	0.93009283	0.001284961	0.000951	0.000889	0.556753349	0.000708219
41	Banks and Financial Institutions	0.004046	0.004722	0.403143973	0.00970259	0.00626	0.00983	0.340141749	0.009465134
42	Other Financial and Insurance Services	0.000202	0.000216	0.078277766	0.002447236	0.000167	0.002948	0.059098486	0.002227565
43	Insurance	0.001101	0.001523	0.499661185	0.002154759	0.000825	0.002171	0.270661127	0.002058544
44	Private Housing Services	0.009081	0.008063	0.308359064	0.026147926	0.028682	0.025205	1	0.02520463
45	Rental Housing Services	0.003207	0.003104	0.265267678	0.011699654	0.012602	0.011311	0.997413504	0.011307296
46	Non-Housing Services	8.22E-06	0.000243	0.001682709	0.004626629	0	0.007287	0	0.006902426
47	Brokers	0.001	0.001	0.71555	0.00230	0.001	0.001	0.61779	0.00141

	Services	708	696	7892	5136	551	532	7838	205
48	Research and Development	0.0018	0.00177	1.132275398	0.001527756	0.001853	0.001352	0.693641498	0.001319611
49	Other professional, scientific and technical activities	0.002167	0.002642	0.402490058	0.005202588	0.003631	0.004302	0.35043571	0.003808887
50	veterinary activities	0.000248	0.000245	1.264216432	0.000188283	0.000217	0.000184	0.615732103	0.000181086
51	public administration, social services	0.013042	0.012213	1.155382433	0.010567067	0.024259	0.012573	0.874879153	0.012398222
52	defense	0.013147	0.012353	1.294653816	0.009540971	0.02173	0.009467	0.996963278	0.009453737
53	law enforcement	0.00221	0.001889	0.599367724	0.003150259	0.004743	0.003039	0.938534293	0.003036529
54	compulsory social security	0.001353	0.001273	1.864569088	0.000682556	0.002488	0.000751	1	0.000750761
55	public primary education	0.004562	0.004351	1.149251955	0.003785761	0.004912	0.003633	1	0.003633281
56	private primary education	0.000287	0.000264	1.591047	0.000165868	0.000362	0.000135	1	0.000135404
57	general	0.005	0.005	1.04368	0.00499	0.009	0.004	1	0.00479

	and technical secondary education	491	216	1595	7979	623	799		8736
58	public vocational education and Technical Vocational High Schools	0.000619	0.000558	1.377863112	0.000404721	0.000871	0.00037	1	0.000370292
59	Public Higher Education	0.003079	0.002738	0.935289839	0.002927643	0.005863	0.002956	0.999999976	0.002956368
60	Private Higher Education	0.004315	0.004264	1.209721972	0.003522258	0.00393	0.002422	0.999999964	0.002422069
61	Adult Education	0.001161	0.000815	0.755309195	0.001057805	0.001383	0.001203	0.782964508	0.001170764
62	Human Health and Social Welfare Activities	0.013626	0.012108	0.845591547	0.014295481	0.024647	0.013604	0.9747672	0.01357965
63	Arts, Entertainment	0.006469	0.006344	1.255834845	0.005012846	0.007643	0.002913	0.938512261	0.002888534
64	Religious Organizations and Member Organizations	0.001446	0.000653	0.660780284	0.00096748	0.001432	0.000678	0.61934616	0.000659839

65	Other Personal Service Activities	0.002871	0.002788	1.125312149	0.002373077	0.004569	0.001684	0.975946756	0.001665714

* Negative numbers are due to negative inventory in these sectors.

As can be seen from **Tabel 2**, the sector "Electricity generation, transmission and distribution" has the highest amount of DI_i elasticity and the highest amount of emission share in 2001 and 2011 and the highest amount of TI_j elasticity in 2001. This is due to the high share of CO_2 emissions and the share of final demand in the total output of this sector. The highest amount of TI_j elasticity in 2011 is allocated to the sector "Coke production, products of oil refining" and "Other buildings". This is due to the high share of final demand in the total output of these sectors and the inefficiency of production structure.

4-2- Decomposition of TI_j and DI_i elasticities of Iran's production sectors in 2001-2011

In this section, TI_j changes are decomposed using Equation (11) and DI_i elasticity changes are decomposed using Equation (12).

Tabel 3. Decomposition of TI_j and DI_i elasticities of Iran's production sectors
Source: Research calculations

Sector code	dTI			dDI		
	$\frac{y_j}{x_j}(\sum_i \beta_i \Delta g_{ij})$	$\Delta(\frac{y_j}{x_j})\sum_i \beta_i g_{ij}$	$\frac{y_j}{x_j}(\sum_i g_{ij}\Delta\beta_i)$	$\beta_i(\sum_j \frac{y_j}{x_j}\Delta g_{ij})$	$\beta_i(\sum_j g_{ij}\Delta(\frac{y_j}{x_j}))$	$\Delta\beta_i \sum_j \frac{y_j}{x_j} g_{ij}$
1	0.015383883	-0.000164676	-0.00701235	0.011591229	4.16082E-05	-0.00842659
2	0.011607778	-0.004229631	-0.00335288	0.016118988	-0.001254246	-0.00692731
3	0.001538102	8.81448E-05	-0.00016555	0.000249123	5.49495E-05	-0.00011044
4	0.005727596	-0.03338007	0.033625919	0.026405223	-0.017966919	0.038405323
5	6.09641E-05	0.00210718	7.04705E-06	0.005203221	0.00044593	0.000606322
6	0.057106705	0.005927472	-0.01563714	0.011415015	0.002853563	-0.01235787
7	0.000318905	2.30284E-05	-8.8732E-05	1.797E-05	1.6474E-05	-6.4221E-05
8	0.004980494	-0.00073355	-0.00072021	0.001962908	-0.000178467	0.000282026
9	0.003781825	0.001285754	0.001595054	0.000581417	0.000339866	0.002166008
10	0.001646922	0.000621232	0.001096198	0.000260589	0.000152186	0.001476252
11	-0.000245834	0.000836906	-7.9532E-05	0.001819257	0.000103816	0.001500749

12	0.000566982	0.000446527	9.2526E-05	0.003685177	-0.000135409	0.000834551
13	0.034241159	0.005860513	-0.00494934	0.014244989	0.003384758	-0.02350674
14	0.01842944	0.006568078	-0.01115635	0.031408149	0.003950146	-0.03219033
15	0.003056091	-0.001914849	-0.00029214	0.00629099	-0.000897345	0.001169596
16	0.004800556	0.002907077	0.000643642	0.006417979	0.000818459	0.001567585
17	0.005364646	-0.001813238	0.000843083	0.028561157	-0.002587183	0.005769977
18	0.022550714	0.005416081	0.002517987	0.011203998	-0.000544726	0.001430213
19	0.014080297	-0.007827754	0.000193235	0.008381448	-0.003377421	-0.00041302
20	0.008059784	-0.002979922	-0.00065206	0.016720827	-0.004882339	-0.00264504
21	0.066196235	-0.028943229	0.001918374	0.022542625	-0.013890518	-0.00031358
22	0.005094059	-0.001050771	0.001335619	0.000574822	-0.000385699	0.000772115
23	0.001752794	-0.000192495	-0.00018842	0.001835261	-0.000228389	-0.00029099
24	0.010834215	0.006337262	0.007850753	0.245067126	-0.02151473	0.032770944
25	0.000268031	0.016114624	0.0006744	0.008106734	0.00963448	0.008821765
26	0.002511585	-0.000900043	0.000243404	0.00157467	-0.000362529	-1.6271E-05
27	0.041406405	-0.002654655	0.0007223	0.00177474	-0.000519785	-0.00168648
28	0.058502186	0.004266423	0.004159377	0.002760769	0.001118061	0.000429475
29	0.050786308	-0.019158761	0.002488479	0.022999921	-0.009676295	-0.0033772
30	0.004943753	-0.005364398	0.000620073	0.00180311	-0.001894977	0.000550316
31	0.001624431	-0.001941413	-0.00025145	0.001071111	-0.001057447	-0.00028328
32	0.007329967	0.002236361	-0.00133063	0.015913002	0.000520782	-0.00311343
33	0.000719872	-0.00140755	0.000417587	0.000269792	-8.25408E-05	0.000599505
34	0.002049795	-7.52987E-06	-0.00038467	0.001717198	-0.00012296	-0.00104752
35	0.000770286	-0.002108559	0.001551413	0.002454895	-0.000621638	0.003881366
36	0.000865608	-0.000444997	2.59129E-05	0.002958093	-0.000702573	-0.00019219
37	0.023748802	-0.020735508	-0.00139575	0.008482754	-0.011518433	-0.0017848
38	0.000398934	0.001418415	0.000967867	0.001085957	0.000234911	0.00365771
39	0.006595622	0.002357582	0.000205446	0.000949742	0.000843304	0.000771982
40	0.000868271	-0.000637383	-0.00048786	0.000977099	-0.000666356	-0.00072381
41	0.003317586	-0.001159442	5.57378E-05	0.006507368	-0.00115295	-0.0002466
42	3.47073E-05	-5.41809E-05	-1.5414E-05	0.003275222	-0.000252066	-0.00029073
43	0.000475179	-0.000697716	-5.3411E-05	0.001402647	-0.000652984	-0.00010149
44	1.14593E-05	0.019837466	-0.00024868	0	0.018084976	-0.0009433
45	0.000241736	0.009250268	-9.708E-05	3.45819E-05	0.008564196	-0.00039247
46	7.90369E-06	-2.01429E-05	4.0241E-06	0.005398163	-0.000756322	0.002402623
47	0.000685129	-0.000245507	-0.00059658	0.00105464	-0.000248501	-0.00096926
48	0.00145965	-0.001171722	-0.00023453	0.000527441	-0.000732679	-0.00021325
49	0.002408534	-0.00053939	-0.00040511	0.003897353	-0.00066317	-0.00157409
50	0.000242179	-0.000229044	-4.3581E-05	7.22308E-05	-0.000125683	-7.33E-06
51	0.015576766	-0.007777818	0.003417677	0.001600404	-0.003096903	0.001856967
52	0.015500231	-0.006488506	-0.00042845	4.09859E-05	-0.002839923	-8.7353E-05
53	0.000895092	0.001714047	-7.5876E-05	0.000252582	0.001011705	-0.00011383
54	0.002916431	-0.002150989	0.000369629	0	-0.000590117	6.82057E-05
55	0.001217944	-0.000733118	-0.00013518	0	-0.000565032	-0.00015248
56	0.00033704	-0.000214022	-4.8293E-05	0	-9.80357E-05	-3.0464E-05
57	0.004351307	-0.000420334	0.000200529	0	-0.00021832	-0.00019924
58	0.000625138	-0.000329195	-4.3473E-05	0	-0.000152929	-3.4428E-05
59	0.002350312	0.000379369	5.39759E-05	9.13744E-11	0.000189448	2.87252E-05
60	0.001777497	-0.000824277	-0.00133806	-2.75225E-06	-0.000738695	-0.00110019
61	9.91609E-05	4.88399E-05	7.35799E-05	0.000271499	4.63064E-07	0.000116049
62	0.008533433	0.003266233	-0.00077841	0.000353336	0.001860605	-0.00071713
63	0.006241388	-0.00258431	-0.00248241	0.000356245	-0.001644729	-0.00214236

64	0.000247439	-9.57975E-05	-0.00016586	0.000433929	-9.2504E-05	-0.00031627
65	0.003039617	-0.000699217	-0.00064269	-1.79222E-05	-0.000370015	-0.00071531

As can be seen from **Tabel 3**, the highest amount of incremental changes in TIj and DIi elasticity in the period 2001-2011 are related to the "Electricity generation, transmission and distribution" and "Other Buildings" sectors, respectively. In the period 2001-2011, out of 65 production sectors, 42 sectors have experienced an increase in TI_j elasticity and DI_i elasticity, 13 sectors an increase in TI_j elasticity and a decrease in DI_i elasticity, 5 sections a decrease in TI_j elasticity and an increase in DI_i elasticity, and 5 sectors a decrease in TI_j elasticity and a decrease in DI_i elasticity.

5- Discussion

In the previous section, the elasticities and their changes for each sector were calculated. Based on the elasticity decomposition, the demand elasticity is affected by the three effects of "changing the Ghosh inverse matrix", "changing sectoral final demand share" and "changing the share of CO_2 emission of sectors", and the output elasticity is influenced by the three effects of "changing the Ghosh inverse matrix", "changing final demand share of sectors" and "changing sectoral share of CO_2 emissions". In the following, the sectors should be divided to 4 groups according to the changes of DI_i and TI_j. The aim is to investigate what factor in the production sectors of Iran is the determining factor in explaining the changes in CO_2 emission elasticity. In this regard, according to **Tabel 4** industries are divided into two groups once based on changes in TI_j (dTI_j): $dTI_j > 0$ and $dTI_j < 0$, and also once based on changes in DI_i (dDI_i) into two groups: $dDI_i > 0$ and $dDI_i < 0$.

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Tabel 4. A summary of the situation of production sectors in terms of the components of elasticity decomposition
Source: Research calculations

	Group	Number of industries in each group	The components of TI_j elasticity decomposition		
			changing the Ghosh inverse matrix	changing sectoral final demand share	changing the share of CO_2 emission of sectors
dTI_j	$dTI_j>0$	55	In 54 industries, it has increased TIj.	In 24 industries, it has increased TIj.	In 28 industries, it has increased TIj.
			In 46 industries, it has the greatest impact on growth.	In 7 industries, it has the greatest impact on growth.	In 2 industries, it has the greatest impact on growth
			108%	-11.4%	2.6%
	$dTI_j<0$	10	It has not reduced TIj in any industry.	In 10 industries, it has reduced TIj.	In 8 industries, it has reduced TIj.
			In no industry, has the greatest effect on reducing TIj.	In 7 industries, it has the greatest impact on reduction.	In 3 industries, it has the greatest impact on reduction.
			-333%	307%	126%
	Group	Number of industries in each group	The components of DI_i elasticity decomposition		
			changing the Ghosh inverse matrix	changing final demand share of sectors	changing sectoral share of CO_2 emissions
dDI_i	$dDI_i>0$	47	In 46 industries, it has increased DIi.	In 20 industries, it has increased DIi.	In 24 industries, it has increased DIi.
			In 33 industries, it has the greatest	In 6 industries, it has the greatest impact on	In 8 industries, it has the greatest impact on

			impact on growth.	growth	growth
			100%	-6.8%	6.8%
	$dDI_i<0$	18	In 2 industries, it has reduced DIi.	In 16 industries, it has reduced DIi.	In 17 industries, it has reduced DIi
			In no industry, it has the greatest effect on reducing DIi.	In 10 industries, it has the greatest effect on reducing DIi.	In 8 industries, it has the greatest effect on reducing DIi.
			-120%	79%	141%

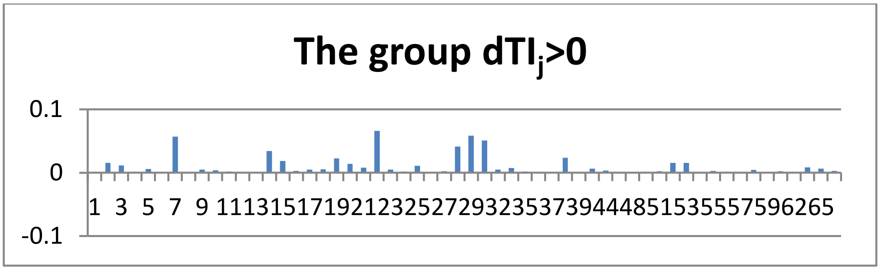
55 industries from 65 industries, 85% of industries, are placed in the group $dTI_j>0$. In general, in this group, the effect of "changing the Ghosh inverse matrix", "changing sectoral final demand share" and "changing the share of CO_2 emission of sectors" with a share of 108%, -11.4% and 2.6%, respectively have played a role in increasing TI_j elasticity. 10 of the 65 industries, 15% of the industries, are placed in the group $dTI_j<0$. In general, in this group, the effect of "changing the Ghosh inverse matrix", "changing sectoral final demand share" and "changing the share of CO_2 emission of sectors" with a share of -333%, 307% and 126%, respectively, have played a role in reducing TI_j.

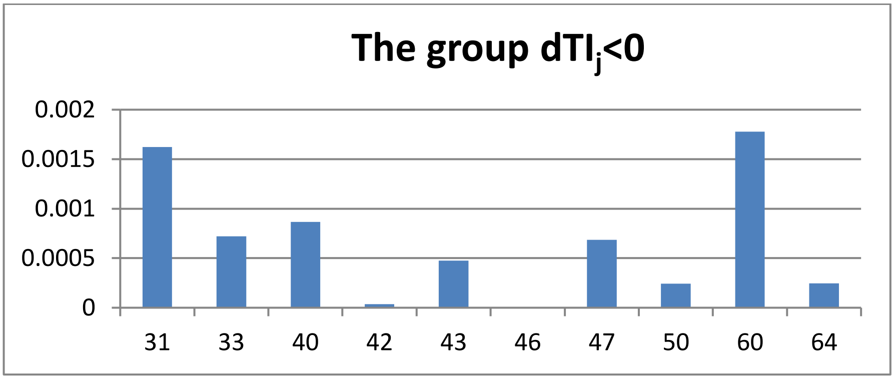
47 out of 65 industries, 72% of the industries are placed in the group $dDI_i>0$. In general, in this group, the effect of "changing the Ghosh inverse matrix", "changing final demand share of sectors" and "changing sectoral share of CO_2 emissions" with a share of 100%, -6.8% and 6.8%, respectively have played a role in increasing DI_i elasticity. 18 out of 65 industries, 28% of the industries are in the group $dDI_i<0$. In general, in this group, the effect of "changing the Ghosh inverse matrix", "changing final demand share of sectors" and "changing sectoral share of CO_2 emissions" with a share of -120%, 78% and 140%, respectively played a role in reducing DI_i elasticity.

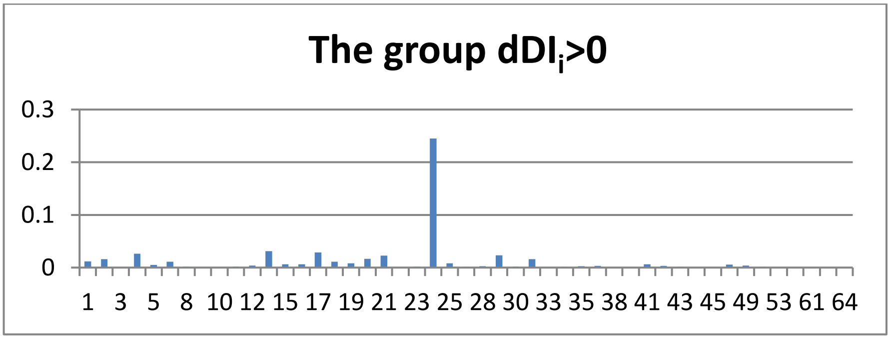
5-1- Analyzing the role of "the Ghosh inverse matrix" in elasticity changes: an inhibitory factor or a stimulus factor

"The Ghosh inverse matrix" is one of the factors of decomposition of the elasticity of CO_2 emissions. TI_j elasticity is the effect of a 1% change in the final demand of sector j on the CO_2 emissions of the whole economy. As a result of a 1% change in the final demand of sector j, sector j changes its purchases from other sections to meet the final demand, so the effect of "the Ghosh inverse matrix" on the TI_j elasticity decomposition indicates a change in the share of sales of sectors (as intermediate input) to sector j (change in the purchase share of sector j from the production of other sectors). DI_i elasticity is the effect of a one percent change in the final demand of all sectors on the CO_2 emissions of sector i. As a result of a 1% change in the final demand of all sectors, all sectors change their purchases from sector i, so the effect of "the Ghosh inverse matrix" on DI_i elasticity indicates a change in the output share of sector i as an intermediate input to other sectors (change the share of purchasing parts from sector i). As can be seen from **Tabel 4**, "the Ghosh inverse matrix" effect increased TI_j elasticity in all sectors of the group $dTI_j > 0$ except for sector 10 and decreased TIj elasticity in all sectors of the group $dTI_j<0$. This effect in the group $dDI_i > 0$ in 46 of the 47 sectors helped to increase the DI_i elasticity and in the group $dDI_i<0$ in 16 of the 18 sectors helped to increase the DI_i elasticity. Thus, as shown in **Tabel 4** and **Figure 1**, "the Ghosh inverse matrix" in sectors that have experienced an increase in TI_j and DI_i as well as in sectors that have experienced decrease in in TI_j and DI_i is a strong stimulus to increase in TI_j and DI_i.

But what do these results mean? The strong stimulus of the "the Ghosh inverse matrix" effect on TI_j elasticity indicates a change in the share of output of sectors that are sold to sector j as an intermediate input (increasing the purchase share of sector j from the output of other sectors). The strong stimulus of "the Ghosh inverse matrix" effect on DI_i elasticity indicates a change in the share of output of sector i, which sells as an intermediate input to all sectors (increasing the share of purchases of other sectors from sector i).







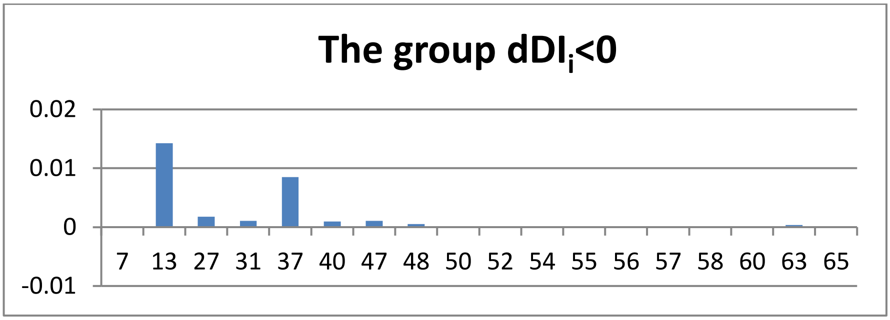


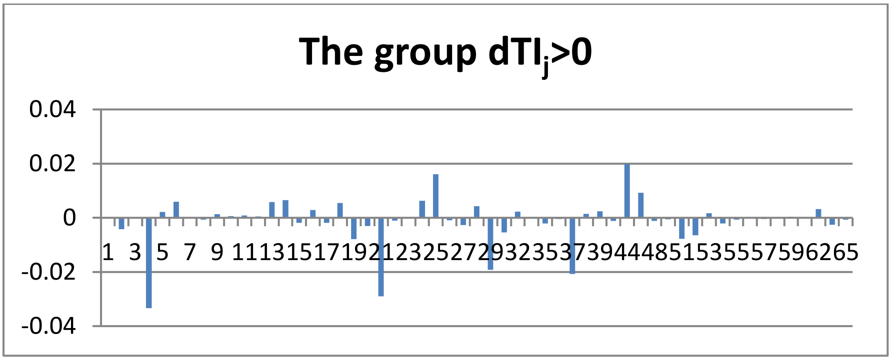
Figure 1. The contribution of "the Ghosh inverse matrix" in the decomposition of elasticity in the production sectors of Iran in the period 2001-2011

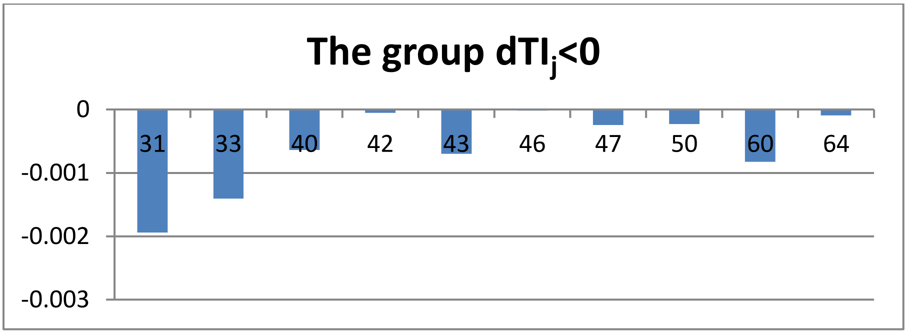
Source: Research calculations

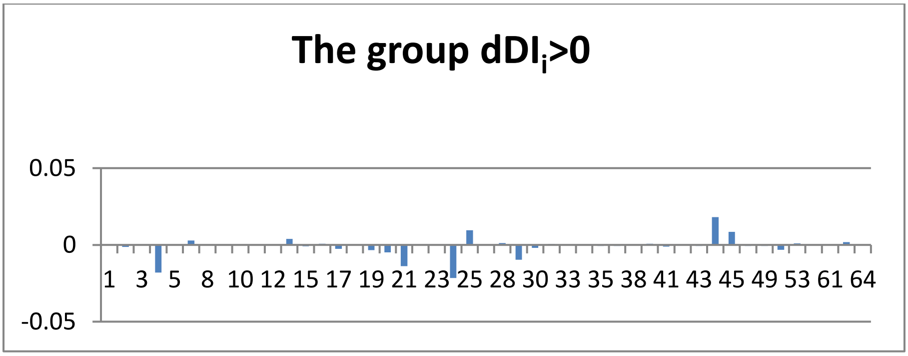
5-2- Analyzing the role of "final demand share" in elasticity changes: an inhibitory factor or a stimulus factor

The share of final demand in the output is one of the factors that break down the elasticity of CO_2 emissions. As can be seen from **Tabel 4**, "the sectoral final demand share" factor reduced TI_j in 31 of the 55 sectors of the group $dTI_j > 0$ and in all sectors of the group $dTI_j < 0$. The reason for this result is that the share of final demand in the output of these 31 sectors has decreased from 55 sectors of the group $dTI_j > 0$ and all sectors of the group $dTI_j < 0$ in the period 2001-2011. "The share of final demand of sectors" has helped to reduce the DI_i elasticity in 27 of the 47 sectors of the group $dDI_i > 0$ and in 16 of the 18 sectors of the group $dDI_i < 0$. Therefore, "Changing the share of final demand in output" effect has helped to reduce the TI_j in 41 of the 65 sectors (63% of the industries) and reduce the DI_i in 43 of the 65 sectors (66% of the industries).

Figure 2 shows the share of final demand in the output in the decomposition of elasticity of Iran's production sectors in the period 2001-2011.


The group $dTI_j>0$
0.04
0.02
0
-0.02
-0.04
1 3 5 7 9 111315171921232527293235373944485153555759626 5


The group $dTI_j<0$
0
-0.001
-0.002
-0.003
31
33
40
42
43
46
47
50
60
64


The group $dDI_i>0$
0.05
0
-0.05
1 3 5 8 10 12 15 17 19 21 23 25 28 30 33 35 38 41 43 45 49 53 61 64

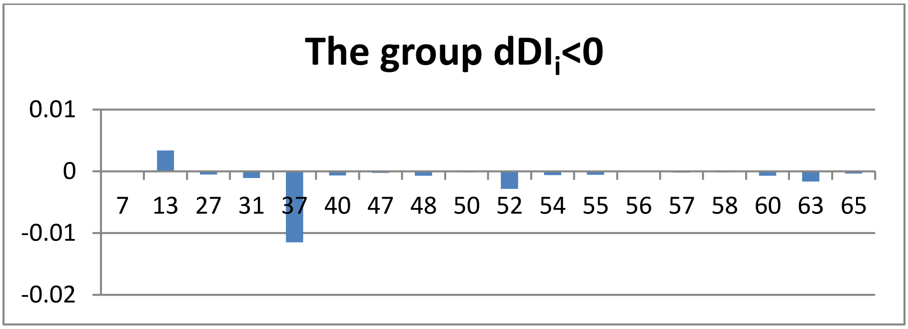


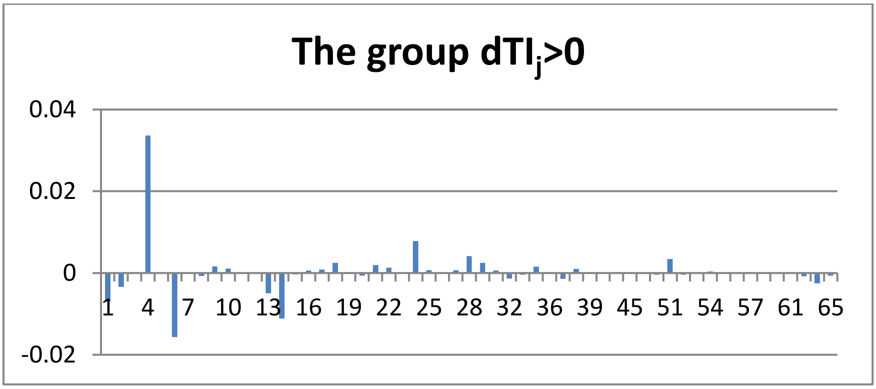
Figure 2. The share of final demand in the output in the decomposition of elasticity of Iran's production sectors in the period 2001-2011

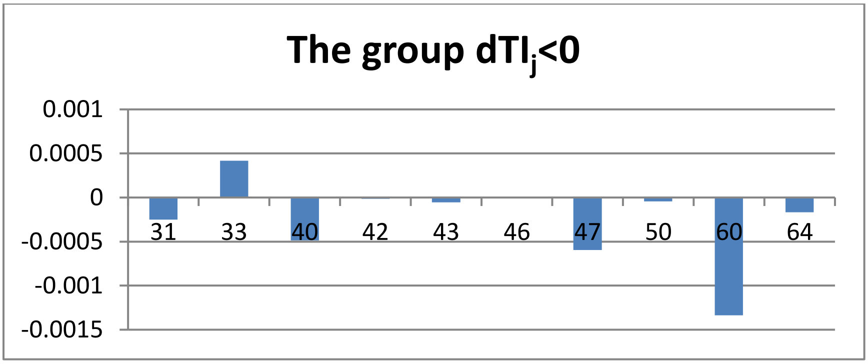
Source: Research calculations

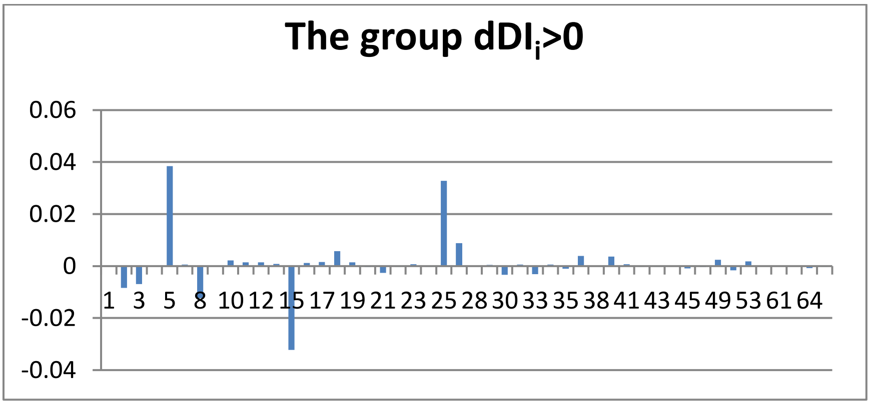
5-3- Analyzing the role of "CO_2 emission share" in elasticity changes: an inhibitory factor or a stimulus factor

CO_2 emission share is one of the factors in the decomposition of CO_2 emission elasticity. As can be seen from **Tabel 4**, "the share of CO_2 emission of sectors" factor increased TI_j in 28 of 55 sectors of the group $dTI_j > 0$ and decreased the TI_j in 8 of the 10 sectors of the group $dTI_j<0$. The effect of "sectoral share of CO_2 emissions" increased in 24 of the 47 sectors of the group $dDI_i > 0$ and decreased the DI_i in 17 of the 18 sectors of the group $dDI_i<0$. The reason for this result is that the share of CO_2 emission of these 24 out of 47 sectors in the group $dDI_i > 0$ and 17 out of 18 sectors in the group $dDI_i<0$ increased and decreased in the period 2001-2011, respectively. Therefore, as shown in **Tabel 4** and **Figure 3**, the CO_2 emission share has been able to increase TI_j and DI_i elasticity in the groups $dTI_j > 0$ and $dDI_i > 0$ and in the groups $dTI_j<0$ and $dDI_i<0$ act as an inhibitory factor to increase the TI_j and DI_i elasticity. Therefore, "Changing CO_2 emission share" effect has helped to reduce the TI_j in 35 of the 65 sectors (54% of the industries) and reduce the DI_i in 40 of the 65 sectors (61.5% of the industries). This result is mainly due to the declining share of CO_2 emission of sectors that have experienced a decline in DI_i.

Figure 3 shows the share of CO_2 emissions in the decomposition of elasticity of Iran's production sectors in the period 2001-2011.







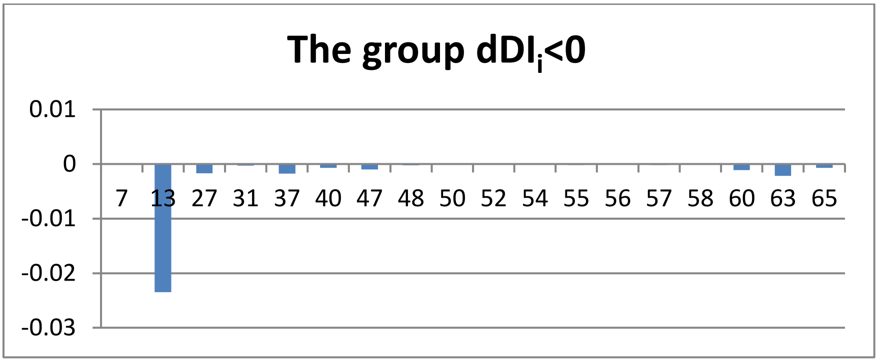


Figure 3. The share of CO_2 emissions in the decomposition of elasticity of Iran's production sectors in the period 2001-2011

Source: Research calculations

6- Conclusions and policy recommendations

In 2019, Iran ranks sixth in the world and fifth in Asia in terms of CO_2 emissions. The purpose of this article is to investigate the factors affecting the CO_2 emission demand elasticity and CO_2 emission output elasticity, and we seek to answer the question of what factors are able to explain the changes in these elasticities. What are the factors that stimulate and inhibit the elasticity of CO_2 emissions in Iran? We try to answer this question by decomposition of the CO2 emission elasticities.

We have calculated these two elasticities for all production sectors of Iran (65 sectors) in 2001 and 2011 and also based on the decomposition analysis and with the aim of identifying the drivers of CO_2 emission elasticities determined and calculated the components of changes in CO_2 emission elasticities. Based on the formula $E^y = \hat{\beta}'(I-B)^{-1}\hat{S}$ introduced by Guo et al. (2018), two types of CO_2 emission elasticities can be introduced for each sector; Final demand elasticity of CO_2 emissions (TI_j) and developmental elasticity of CO_2 emissions (DI_i). TI_j elasticity is the effect of one percent change in the final demand of sector j on CO_2 emissions of the whole economy and

DI_i elasticity is the effect of one percent change in the final demand of all sectors on CO_2 emissions of sector i. Based on the decomposition approach, CO_2 emission demand elasticity changes are decomposed to three effects: "changing the Ghosh inverse matrix", "changing the share of final demand in the total output of sector" and "changing the share of CO_2 emission of sectors", and CO_2 emission output elasticity changes are decomposed to three effects: "changing the Ghosh inverse matrix", "changing the share of final demand in the total output of sectors" and "changing the share of CO_2 emission of sector".

Due to the lack of access to CO_2 emission data of production sectors in Iranian information and data sources, we have calculated the CO_2 emissions of production sectors through the energy consumption of sectors. The results indicate that the sector "Electricity generation, transmission and distribution" in 2001 and 2011 had the highest amount of DI_i elasticity and the highest amount of CO_2 emission share and the highest amount of TI_j elasticity in 2001. The highest amount of TI_j elasticity in 2011 is allocated to "Coke production, products of oil refining" sector and "Other buildings" sector.

The highest amount of incremental changes in TI_j and DI_i elasticities in the period 2001-2011 are related to the "Electricity generation, transmission and distribution" and "Other Buildings" sectors, respectively. These two types of elasticities have increased in this time interval for 47 out of 65 industries. Now, the important question is why these elasticities have increased and what is the most important stimulus in this increase? "Changing the share of final demand in output" effect has helped to reduce the TI_j in 41 of the 65 sectors (63% of the industries) and reduce the DI_i in 43 of the 65 sectors (66% of the industries). "Changing CO_2 emission share" effect has helped to reduce the TI_j in 40 of the 65 sectors (61.5% of the industries) and reduce the DI_i in 35 of the 65 sectors (54% of the industries).

The results indicate that the most important stimulus to increase TI_j elasticity and DI_i elasticity is the effect of the "changing the Ghosh inverse matrix". In other words, the increase in the share of output of sector i, which is sold as an intermediate input to industry j, is a strong driver of CO_2 emission elasticity in Iran in the period 2001-2011. These changes can be due to increased economic activities and the inefficiency of production structure.

"Electricity generation, transmission and distribution" sector should be considered by energy and environmental policy makers due to having the highest amount and changes in CO_2 emission elasticity than other sectors. Increasing the share of renewable energy in the energy consumption basket of production sectors, increasing energy efficiency (reducing energy intensity) by replacing new and advanced equipment with old and worn equipment and improving production structure can help reduce the CO_2 elasticity and CO_2 emission in Iran's production sectors. The results of this study are significant for energy and environmental policymakers.

Finally, due to the high of CO_2 emission elasticities in the "Electricity generation, transmission and distribution" sector, future research can focus on this area and suggest solutions to increase production efficiency and energy efficiency. Also, future research can focus on the production structure of production sectors and provide solutions to improve the production structure of Iran's production sectors.

References

Adams, S., & Klobodu, E. K. M. (2018). Financial development and environmental degradation: does political regime matter? *Journal of cleaner production, 197*, 1472-1479.

Ahmadian, M., Abdoli, G., Jabalameli, F., Shabankhah, M., & Khorasani, S. A. (2019). Extracting The Dynamic Curve of the Kuznets Environment. *Quarterly Journal of Quantitative Economics, 16*(2), 1-36.

Al-Mulali, U., & Ozturk, I. (2015). The effect of energy consumption, urbanization, trade openness, industrial output, and the political stability on the environmental degradation in the MENA (Middle East and North African) region. *Energy, 84*, 382-389.

Apergis, N., & Ozturk, I. (2015). Testing environmental Kuznets curve hypothesis in Asian countries. *Ecological indicators, 52*, 16-22.

Azami, S., & Angazbani, F. (2020). CO2 response to business cycles: new evidence of the largest CO2-Emitting countries in Asia and the Middle East. *Journal of cleaner production, 252*, 119743.

Azomahou, T., Laisney, F., & Van, P. N. (2006). Economic development and CO2 emissions: A nonparametric panel approach. *Journal of Public Economics*, *90*(6-7), 1347-1363.

Chang, Y. F., Lewis, C., & Lin, S. J. (2008). Comprehensive evaluation of industrial CO2 emission (1989–2004) in Taiwan by input–output structural decomposition. *Energy Policy*, *36*(7), 2471-2480.

Chen, L., & Chen, S. (2015). The estimation of environmental Kuznets curve in China: nonparametric panel approach. *Computational Economics*, *46*(3), 405-420.

Cole, M. A. (2004). Trade, the pollution haven hypothesis and the environmental Kuznets curve: examining the linkages. *Ecological economics, 48*(1), 71-81.

Eggleston, S., Buendia, L., Miwa, K., Ngara, T., & Tanabe, K. (2006). IPCC guidelines for national greenhouse gas inventories.

Gorus, M. S., & Aslan, M. (2019). Impacts of economic indicators on environmental degradation: evidence from MENA countries. *Renewable and Sustainable Energy Reviews, 103*, 259-268.

Grossman, G. M., & Krueger, A. B. (1991). Environmental impacts of a North American free trade agreement. In: National Bureau of economic research Cambridge, Mass., USA.

Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *The Quarterly Journal of Economics, 110*(2), 353-377.

Guo, J., Zhang, Y.-J., & Zhang, K.-B. (2018). The key sectors for energy conservation and carbon emissions reduction in China: evidence from the input-output method. *Journal of cleaner production, 179*, 180-190.

Guzel, A. E., & Okumus, İ. (2020). Revisiting the pollution haven hypothesis in ASEAN-5 countries: new insights from panel data analysis. *Environmental Science and Pollution Research, 27*(15), 18157-18167.

Heutel, G. (2012). How should environmental policy respond to business cycles? Optimal policy under persistent productivity shocks. *Review of Economic Dynamics, 15*(2), 244-264.

Hondo, H., Sakai, S., & Tanno, S. (2002). Sensitivity analysis of total CO2 emission intensities estimated using an input–output table. *Applied Energy, 72*(3-4), 689-704.

Kim, Y.-G., Yoo, J., & Oh, W. (2015). Driving forces of rapid CO2 emissions growth: A case of Korea. *Energy Policy, 82*, 144-155.

Klarl, T. (2015). *The response of CO2 emissions to the business cycle: New evidence for the US based on a Markov-switching approach*. Retrieved from

Klarl, T. (2020). The response of CO2 emissions to the business cycle: New evidence for the US. *Energy Economics, 85*, 104560.

Lim, H.-J., Yoo, S.-H., & Kwak, S.-J. (2009). Industrial CO2 emissions from energy use in Korea: a structural decomposition analysis. *Energy Policy, 37*(2), 686-698.

Morán, M. A. T., & del Río González, P. (2007). A combined input–output and sensitivity analysis approach to analyse sector linkages and CO2 emissions. *Energy Economics, 29*(3), 578-597.

Nasreen, S., Anwar, S., & Ozturk, I. (2017). Financial stability, energy consumption and environmental quality: Evidence from South Asian economies. *Renewable and Sustainable Energy Reviews, 67*, 1105-1122.

Ozcan, B., Tzeremes, P. G., & Tzeremes, N. G. (2020). Energy consumption, economic growth and environmental degradation in OECD countries. *Economic Modelling, 84*, 203-213.

Pandey, K. K., & Rastogi, H. (2019). Effect of energy consumption & economic growth on environmental degradation in India: A time series modelling. *Energy Procedia, 158*, 4232-4237.

Paul, S., & Bhattacharya, R. N. (2004). CO2 emission from energy use in India: a decomposition analysis. *Energy Policy, 32*(5), 585-593.

Rafaty, R., Dolphin, G., & Pretis, F. (2020). Carbon pricing and the elasticity of CO2 emissions.

Rormose, P. (2011). *Structural decomposition analysis: Sense and sensitivity*. Paper presented at the 19th International Conference on Input-Output Techniques.

Salahuddin, M., Alam, K., Ozturk, I., & Sohag, K. (2018). The effects of electricity consumption, economic growth, financial development and foreign direct investment on CO2 emissions in Kuwait. *Renewable and Sustainable Energy Reviews, 81*, 2002-2010.

Selden, T. M., & Song, D. (1994). Environmental quality and development: is there a Kuznets curve for air pollution emissions? *Journal of Environmental Economics and management, 27*(2), 147-162.

Shafik, N., & Bandyopadhyay, S. (1992). *Economic growth and environmental quality: time-series and cross-country evidence* (Vol. 904): World Bank Publications.

Stern, D. (2015). The rise and fall of the environmental Kuznets curve. World Development, 32 (8): 1419–1439. https://doi.org/10.1016/j.worlddev. 2004.03. 004.

Su, B., Ang, B., & Li, Y. (2017). Input-output and structural decomposition analysis of Singapore's carbon emissions. *Energy Policy, 105*, 484-492.

Tao, S., Zheng, T., & Lianjun, T. (2008). An empirical test of the environmental Kuznets curve in China: a panel cointegration approach. *China Economic Review, 19*(3), 381-392.

Tarancón, M. Á., & Del Rio, P. (2007). CO2 emissions and intersectoral linkages. The case of Spain. *Energy Policy, 35*(2), 1100-1116.

Tunc, G. I., Türüt-Aşık, S., & Akbostancı, E. (2007). CO2 emissions vs. CO2 responsibility: an input–output approach for the Turkish economy. *Energy Policy, 35*(2), 855-868.

Wang, G., Chen, X., Zhang, Z., & Niu, C. (2015). Influencing factors of energy-related CO2 emissions in China: A decomposition analysis. *Sustainability, 7*(10), 14408-14426.

Yabe, N. (2004). An analysis of CO2 emissions of Japanese industries during the period between 1985 and 1995. *Energy Policy*, *32*(5), 595-610.

Yu, S., Zheng, S., Ba, G., & Wei, Y.-M. (2016). Can China realise its energy-savings goal by adjusting its industrial structure? *Economic Systems Research, 28*(2), 273-293.

Zhang, Y.-J., Bian, X.-J., Tan, W., & Song, J. (2017). The indirect energy consumption and CO2 emission caused by household consumption in China: an analysis based on the input–output method. *Journal of cleaner production*, *163*, 69-83.

Zhang, Y.-J., & Da, Y.-B. (2015). The decomposition of energy-related carbon emission and its decoupling with economic growth in China. *Renewable and Sustainable Energy Reviews, 41*, 1255-1266.

Zhang, Y., & Zhang, S. (2018). The impacts of GDP, trade structure, exchange rate and FDI inflows on China's carbon emissions. *Energy Policy*, *120*, 347-353.