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Leading Sectors and Low Carbon Development: An Approach of Environmentally-Extended Input-Output Table

Sektor Unggulan dan Pembangunan Rendah Karbon: Sebuah Pendekatan Tabel Input-Output Lingkungan

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ABSTRAK

Isu perubahan iklim telah menjadi pertimbangan penting di Indonesia karena adanya kompromi antara pembangunan ekonomi dan perlindungan lingkungan. Akan tetapi, penelitian yang menggabungkan aspek lingkungan ke dalam model ekonomi masih terbatas. Penelitian ini bertujuan untuk mengembangkan Tabel Input-Output Lingkungan (*EE-IOT*) dan menentukan sektor-sektor unggulan dalam ekonomi Indonesia dengan mempertimbangkan emisi gas rumah kaca sebagai tekanan lingkungan. *EE-IOT* dibangun dalam bentuk model I-O Wilayah Tunggal. Hasil penelitian menunjukkan bahwa sebagian besar emisi CO_2 langsung dihasilkan oleh sektor-sektor produktif dan sisanya berasal dari konsumsi rumah tangga. Berdasarkan analisis sektor unggulan, sektor Industri Produk Makanan dan Minuman menjadi sektor unggulan dengan emisi CO_2 rendah. Selain itu, sektor dengan pengganda output tertinggi dan pengganda CO_2 relatif rendah adalah Jasa Penyediaan Makanan dan Minuman. Sementara itu, sektor Peternakan memiliki pengganda CO_2 terendah dan pengganda output yang tinggi. Namun, perkembangan sektor unggulan ini tidak dapat berdiri sendiri, melainkan memiliki keterkaitan dengan sektor-sektor lain dalam hal input dan output karena sektor-sektor pendukung ini juga akan menghasilkan emisi CO_2. Oleh karena itu, dengan pendekatan rendah emisi, pemerintah perlu melakukan upaya tambahan untuk mendorong sektor-sektor pendukung ini, seperti sektor energi, transportasi, pertanian, dan kehutanan.

Kata kunci: emisi, input-output, perubahan iklim, rendah karbon, sektor unggulan

ABSTRACT

Climate change issues have become a consideration in Indonesia due to the trade-off between economic development and environmental conservation. However, studies that incorporate environmental aspects into economic models are still limited. This study aims to develop the Environmentally-Extended Input-Output Table (EE-IOT) and determine the leading sectors in the Indonesian economy by considering greenhouse gas emissions as environmental pressures. EE-IOT is built in the form of Single-Region I-O. The result shows that the most direct CO_2 emissions are produced by productive sectors and the rest from household consumption. Based on the leading sector analysis, the manufacturing of Food and Beverages Products is the leading sector with low CO_2 emissions. Moreover, the sector with the highest output multiplier and relatively low CO_2 multiplier is Food and Beverage Services. Meanwhile, Animal Productions has the lowest CO_2 multiplier and high output multiplier. However, the development of these leading sectors cannot stand alone because it will have linkages with other sectors regarding inputs and outputs. After all, these supporting sectors will produce CO_2 emissions as well. Therefore, with a low-emission approach, the government needs additional efforts to encourage these supporting sectors, such as energy, transportation, agriculture, and forestry.

Keywords: *climate change, emissions, input-output, leading sector, low carbon*
JEL classification*:* Q56, Q54, H23, E01

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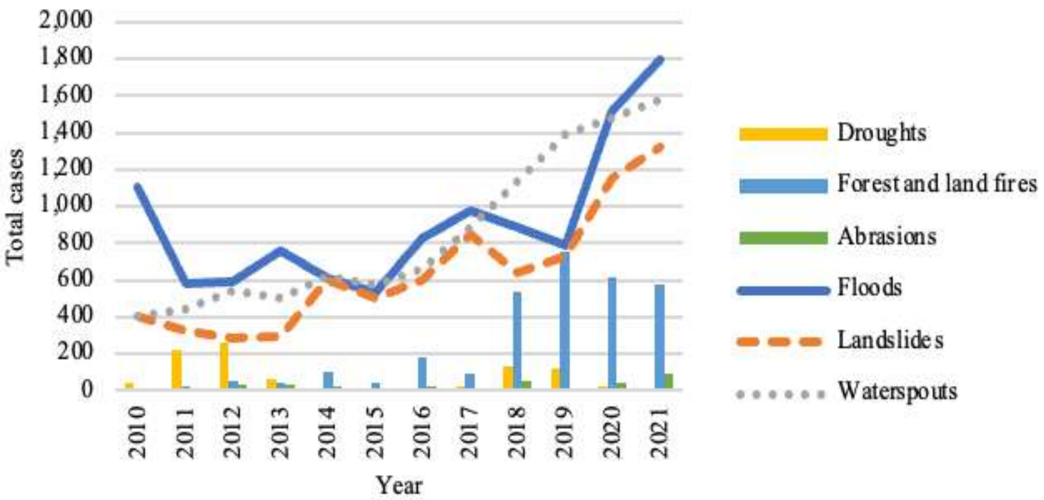
INTRODUCTION

Addressing global climate change is a crucial concern that has garnered the interest of various stakeholders (Bappenas 2021; Kemenkeu 2021a). Climate change can adversely affect natural calamities like wildfires, insufficient water supply, reduced agricultural output, or widespread migration (UN 2020). Bappenas (2021) also stated that climate change could cause an increase in extreme weather, which increases the frequency and intensity of disasters, especially hydrometeorological disasters. As illustrated in Figure 1, the hydrometeorological disasters in Indonesia exhibited a rising trend from 2010 to 2021 and are poised to escalate in frequency due to the climate crisis.

Due to its geographic location, regional attributes, sizable population, and reliance on crucial livelihood sectors such as agriculture, marine activities, water resources, and health on climatic conditions, Indonesia is susceptible to the impacts of climate change (Bappenas 2018). For example, climate change in the agricultural sector will significantly reduce the average production of agricultural products due to temperature change, shifting rainfall patterns, and rising sea levels. Moreover, in the marine and coastal sectors, there will be an increase in the frequency of tropical cyclones, storms, or extreme waves, which are very dangerous for fishing vessels, and the disappearance or displacement of fish catch areas (Bappenas 2021). Furthermore, climate change will also affect the water accounts in projecting the danger of flooding, water availability, and drought. In addition, in the health sector, when it is associated with changes in temperature and flooding, including flooding in coastal areas, it triggers an increase in disease cases. The diseases affected by climate change include vector-borne diseases such as dengue haemorrhagic fever and malaria, water-borne diseases such as diarrhea and leptospirosis, and those caused by increased heat stress such as heat stroke and hypertension (Bappenas 2021).

The Government of Indonesia (GoI) supports the point on climate in the Sustainable Development Goals (SDGs), Goal 13, on combating climate change: take urgent action to combat climate change and its impacts (BPS 2021a). The Indonesian government is also trying to control greenhouse gas emissions (GHG) as the main cause of climate change by taking breakthrough steps through low-carbon and climate-resilient development, which is expected to lead to stable economic growth with low GHG. The GoI's commitment to reducing emissions targets is reflected in official documents such as Nationally Determined Contribution (NDC), especially in the Third Biennial Update Report and Long-Term Strategy for Low Carbon and Climate Resilience (LTS-LCCR) 2050 (KLHK 2021b, 2021a).



Source: (BNPB, 2022)

Figure 1. Indonesia's hydrometeorological disasters 2010-2021

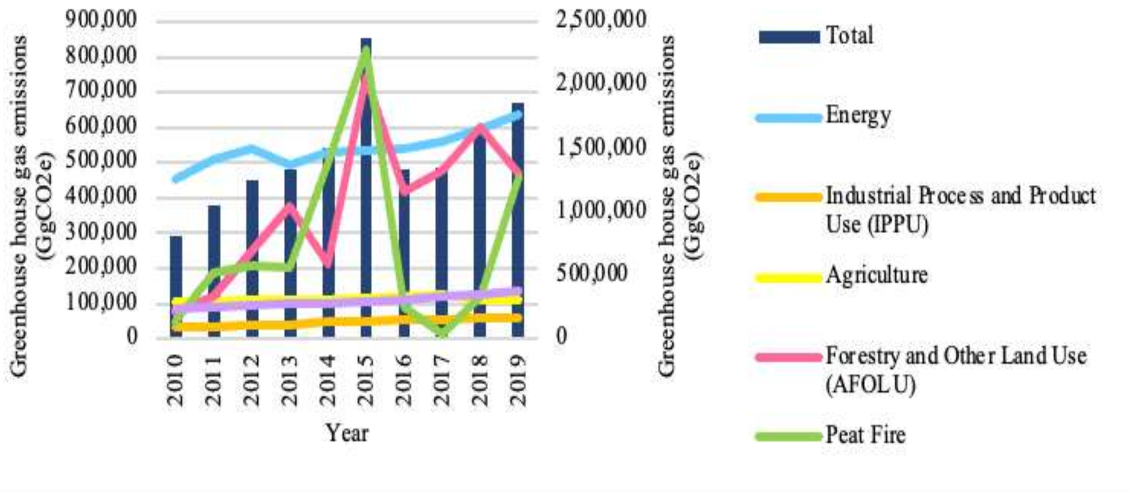
The development mentioned before is a form and effort to overcome the impact of climate change, improve environmental quality, and reduce the value of potential losses due to the effects of climate change. Promoting development that is low in carbon emissions and resilient to climate change has the potential to reduce the conflict between economic progress and environmental preservation (LCDI 2021).

Addressing climate change remains a global challenge, encompassing countries worldwide, Indonesia included. The achievement of development in Indonesia in terms of economic growth and poverty reduction will be in vain if it does not guarantee that development can sustainably take place. There are increasing GHG that threaten climate conditions and can impact various losses in the future. Hence, low-carbon development needs to be a priority. Suppose low-carbon development policies to support climate resilience are not followed up on, and interventions are not taken seriously. Under those circumstances, an additional one million individuals are projected to experience poverty (Bappenas 2019). In addition, there will be an increased mortality rate, and the level of human development will be diminished. Moreover, progress in education and health will slow down, and the cumulative loss of income could reach US$130 billion over the period 2019-2024 (Bappenas 2019), and the risk of losing Gross Domestic Product (GDP) of up to 50.4 percent by 2024 (LCDI 2021).

Global attention on climate change is manifested in a commitment to attend the Conference of the Parties (COP) 26 meetings in Glasgow, Scotland, on 1-2 November 2021. The main priority at COP 26 is to ensure all countries are committed to achieving net zero emissions by 2050, with more ambitious and rapid carbon reductions by 2030. The participation of all countries is urgently needed to achieve this target. However, each country's perspective may differ, and not all countries have the same starting point. The developed countries are required to determine more ambitious action steps to realise these targets before 2050. Meanwhile, developing countries must do their best to reduce emissions (Kemenkeu 2021b). The unconditional target of emissions reduction in Indonesia is 29 percent, and the conditional target of up to 41 percent from the business as usual (BAU) emission by 2030, with the main focus on land use change and forestry (LUCF) and the energy sector (KLHK 2021b, 2021a).

The concern for developing countries on environmental issues related to climate change is due to the trade-off between economic development and environmental conservation. On the one hand, the government seeks to increase economic growth. However, without proper action, economic growth resulting from industries can harm climate change (BPS 2021a). It is related to the Environmental Kuznets Curve (EKC), which explains how economic growth will initially affect the increase in environmental damage in an area (Panayotou 1993). The likelihood of producing GHG, potentially rough for the environment, can increase with an upsurge in economic activity and community mobility (IPCC 2014). According to data from the Ministry of Environment and Forestry, the overall volume of GHG continues to exhibit an increasing pattern, reaching 1,866,552 $GgCO_2e$ (gigagram of CO_2-equivalent) in 2019 (KLHK 2021c). As shown in Figure 2, the energy sector contributes significantly to GHG emissions in Indonesia. This explains why the energy sector has become one of the government’s priorities.

In addition, the low attention of developing countries such as Indonesia to issues related to the environment is also due to the insufficiency of available research that incorporates environmental aspects into economic models. This issue is essential because analytical and modelling techniques that include economic-environmental elements are needed to take an evidence-based policy. Several countries have conducted studies related to economic-environmental problems, such as using Input-Output tables and using models such as the Computable General Equilibrium (CGE) by including environmental factors in the analysis (Li 2021; Ojha, Pohit, and Ghosh 2020; Othman and Jafari 2016; Reyes 2009; Tukker et al. 2006; Yusuf and Resosudarmo 2015).



Source: (KLHK, 2021c)

Figure 2. Indonesia's GHG 2010-2019

This research is expected to contribute to the availability of studies integrating economic-environmental aspects in Indonesia to realise sustainable development. The sustainable development goals will certainly not be realised if the government is incorrectly focusing on which economic sector in development needs more attention to reducing GHG. It is necessary to have information on what economic sectors need more attention to support the success of low-carbon and climate-resilient development that maintains economic growth. These economic sectors must be sectors that produce low GHG in the production process but can still be a booster in the economy. Therefore, conducting an analysis using the Environmentally-Extended Input-Output Table (EE-IOT) more likely supports the success of low-carbon and climate-resilient development by providing recommendations for economic sectors that need scrutiny by considering the pressure given to the environment. In addition, these findings can strengthen the information needed regarding emissions reduction based on sectors stated in the NDC document. For example, the impact of the policy in the energy sector, such as the carbon tax on coal-fired power plants, can be estimated using this analytical tool. Other researchers are more likely to use the conventional input-output model (Sutisna 2023; Kamil et al. 2023); however, they did not construct EE-IOT as the United Nations Statistics Division (UNSD) recommended. This EE-IOT is a consistent analytical tool as it follows national accounts principles (UN et al. 2014, 2017).

Based on the description above, the objectives of this study include developing EE-IOT, which contains elements of GHG as a form of pressure on the environment and determining the leading sectors in Indonesia's economy. The scope of this research is at the national level using the Indonesian IOT of domestic transactions based on producer prices for 52 industries in 2016, along with GHG data, specifically carbon dioxide (CO_2), produced based on Air Emissions Accounts (AEA) in 2016 by BPS-Statistics Indonesia. The other GHG emissions, such as CH4 and N2O, are unavailable for 52 sectors; hence, this EE-IOT is constructed using CO_2 emissions. On the other hand, CO_2 is the primary GHG emitted through human activities (EPA 2019).

METHOD

Air emissions account

UN et al. (2014) stated that the air emission account is a record that documents the gases and particulate matter discharged into the atmosphere by both industries and households due to various production, consumption, and accumulation activities. This account specifically categorises and records the air emissions generated by residential economic units based on the type of substances involved. The air emission account employs an energy-centric methodology, as Indonesia has established an energy flow account derived from an energy balance utilising the 2012 System of Environmental-Economic Accounting Central Framework (SEEA-CF). The data on industrial energy consumption is the foundation for computing carbon dioxide emissions from fuel combustion. The calculation of carbon dioxide emissions relies on emission factors outlined in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Data obtained from air emission accounts can be integrated with information from national accounts to generate indicators of air emission intensity. These indicators assess whether there is a disconnection or decoupling of emissions from economic activities (Eurostat 2015). In addition, the air emission account can also offer indicators of the 9th SDG focused on industry, innovation, and infrastructure.

The air emissions account has the flexibility to encompass various types of substances. Each country has the autonomy to decide the priority of substances to be documented in its specific air emissions account based on the nation's needs and urgency. Eurostat (2015) states that the main focus in preparing the air emission account is usually the type of substance, usually GHG. The most common types of GHG recorded include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The industry classification should align with the industries used in the national and energy flow accounts.

The air emission account is presented as the Physical Supply and Use Table (PSUT). The supply table within this PSUT illustrates the overall emissions generated by both industries and households. In contrast, the use table features a single column dedicated to the environment, serving as a direct pathway for all emissions produced by various economic units (UN et al. 2014). The structure of the air emission account is shown in Table 1.

Environmentally-Extended Input-Output Tables (EE-IOT)

Leontief (1970) stated that pollution is a by-product of regular economic activities. These by-products are often overlooked (including something as valuable as unpaid natural inputs) that are directly connected to the network of tangible connections that dictate the daily functioning of our economic systems. According to Leontief (1970), conventional I-O calculations can provide specific responses to certain factual inquiries concerning the adverse environmental impacts of contemporary technology and unrestrained economic expansion. Interest in the issue of research that extends by adding environmental factors in conventional I-O analysis is also increasing and attracting attention, one of which is the formation of EE-IOT (Brown et al. 2021).

Table 1. Air emission account framework

	Supply table				Use table	
	Industries	Households	Accumulation	Total supply	Environment	Total Use
Type of substance						
Carbon dioxide						
Methane						
Dinitrogen oxides						
Hydrofluorocarbons						
Sulphur hexafluoride						
Carbon monoxide						
Particulates (including PM10 and dust)						

Extended I-O tables typically encompass valuable data derived from satellite systems integrated into national accounts. This data encompasses aspects such as investment, capital, and labour. However, it is also possible to supplement the table with additional information related to energy, emissions, natural resources, waste, and water (UN 2018).

EE-IOT is a standardised economic IOT expanded to include environmental flows. This dataset integrates details about economic transactions quantified in monetary units with information about environmental flows, including natural inputs or residual flows, measured in physical units (UN et al. 2017).

The EE-IOT portrays industries and product specifics using both physical and monetary measurements, encompassing essential economic and environmental data. This comprehensive tool serves as a potent instrument for research and analysis. Models grounded in EE-IOT have been employed to investigate the repercussions of alterations in carbon emissions on economic endeavours, the correlation between water utilisation and industrial efficiency, and the connection between economic activities and the geographical occurrence of environmental pressures (UN et al. 2017).

Based on Miller and Blair (2009), one type of EE-IOT is the Generalised Input-Output Model. It is created by expanding the technical coefficient matrix with supplementary rows or columns to account for production and pollution reduction activities. Two model variations are intended for impact analysis and the other for planning applications.

Furthermore, UN et al. (2017) explained the Single-Region Input-Output (SRIO) Table. Table 2 presents a simplified version of SRIO. This table delineates the internal production processes and transactions occurring within a country (or region), typically organised in a format that details either products or industries.

The total output of industries is equal to the sum of intermediate consumption (Z), final consumption (c), gross capital formation (f) – which includes inventory changes – and exports (e). In each of these categories, the value in each cell represents the cumulative total of both domestically produced goods and services and imported products., i.e.: (1) $Z = Z_d + Zm$; (2) $c = c_d + cm$; (3) $f = f_d + f_m$; (4) $e = e_d + e_m$.

The subscript "d" signifies the utilisation of domestic products, while "m" denotes the utilisation of imported products. Inputs for each domestic industry encompass input categories ranging from (Z) to value-added (v), incorporating elements such as workers' compensation (wages) and gross operating surplus (profit). Since inputs into the industries must equal output, the number of columns is thus equivalent to the output (q). In contrast, the number of rows equals domestic output plus imported products (q+m). All variables with the subscript "tot" are scalars indicating the total for each row or column.

Table 2. Framework table incorporating environmental data in the SRIO

		Data in monetary terms				
		Industries	**Final use**			**Total Output**
		1 … j	Final consumption	Gross capital formation	Exports	
Industries	1 … j	Z	c	f	e	q+m
Value added		v				
Total inputs		q	c_{tot}	f_{tot}	e_{tot}	
		Data in physical (non-monetary)				
Natural inputs/ residuals		r				r_{tot}

The intermediate input matrix (Z) of the I-O table is both a square matrix (with an equal number of rows and columns) and a symmetric matrix (with items in the rows and columns representing either all products or all industries). The I-O table is then added using the environmental flow data by industry (denoted by the vector r) to create the EE-IOT, which can be extracted from the relevant SEEA accounts.

Tukker et al. (2006) stated that owing to its thorough and organised depiction of interconnections within economic systems, the EE-IOT is a valuable instrument for evaluating the extensive economic consequences of policy measures and exploring the environmental repercussions of hypothetical scenarios.

Data Sources

The statistical data used in this study were sourced from the official publications of Statistics Indonesia (BPS), including: (1) Indonesian Input-Output table in domestic transactions based on producer prices for 52 industries in 2016; (2) Air emissions account 2014-2018 from Indonesia energy flow account report.

The I-O table for Indonesia 2016 was compiled using the 2008 System of National Accounts method. The first step was preparing the Supply and Use Table (SUT) before transforming it into the IOT. Based on the recommendations of (UN et al. 2009) in preparing SUT is the valuation of output and value added to the basic price. The basic price is the economic price of goods and services at the producer level prior to government intervention related to taxes and subsidies. Goods and services produced for sale at economically significant prices can be valued at the basic price, producer price, or purchaser price. The recommended valuation method is the basic price, especially if the tax system runs well. Producer prices are only used when assessing the basic price is impossible (BPS 2021b). Therefore, this study used I-O tables with domestic transactions based on producer prices to analyse 52 economic sectors.

The purpose of this study is to compile an EE-IOT that includes elements of GHG as a form of pressure on the environment. The EE-IOT that will be built in this research is Single-Region Input-Output (SRIO) tables based on UN et al. (2017) or based on Miller and Blair (2009) called Generalized Input-Output Models. The dimensions of this I-O table are 52×52 industries with a monetary unit of billions of Rupiah. The air emission account published by BPS is added in the bottom row of the IOT in the form of a 1×52 vector, with physical units of Gigagram (Gg). The dummy table of EE-IOT can be seen in Table 3.

This research aims to determine the leading sectors in the Indonesian economy by considering GHG emissions that can pressure the environment. Several scenarios will be carried out in analysing leading economic sectors by considering GHG emissions as CO_2 gas.

Table 3. Indonesia EE-IOT 2016

		Indonesia Input-Output Table (Billion Rp)				
		Industries	**Final use**			**Total Output**
		1 … 52	**Final consumption**	**Gross capital formation**	**Exports**	
Industries	1 … j	Z	c	f	e	q+m
Value added		v				
Total Inputs		q	c_{tot}	f_{tot}	e_{tot}	
			Air emissions account (Gg)			
CO_2 emissions		r				r_{tot}

a. Scenario 1: Analysing leading sectors with a dispersive power index or normalised backward linkage (NBL) and a degree of sensitivity index or normalised forward linkage (NFL) of more than 1, then identifying which leading sectors have the lowest multiplier CO_2 emissions.

b. Scenario 2: Analyse the sectors in the economy with the highest output multiplier (the top 10 highest), then identify sectors among the highest output multiplier, which also have the lowest multiplier of CO_2 emissions.

c. Scenario 3: Analyse the sectors in the economy with the lowest CO_2 multiplier emissions (the top 10 lowest), then identify sectors among the lowest CO_2 multiplier with the highest multiplier output.

EE-IOT Analysis

Equation (1) is associated with the I-O model based on the single-region EE-IOT. The formula for estimating the amount of environmental pressure is as follows:

$$r_{tot} = (r \cdot \hat{q}^{-1}) \cdot (I - A_d)^{-1} \cdot (c_d + f_d + e_d) \ldots\ldots (1)$$

Where:

r_{tot} = sum of environmental pressure (scalar)
r = environmental pressure per industry (1×j vector)
q = output per industry (1×j vector)
I = identity matrix (zero matrix with a value of 1 on the diagonal)
A_d = technical coefficient of domestic output (j×j matrix)
Z_d = demand between domestic outputs (j×j matrix)
c_d = final consumption expenditure (vector j×1)
f_d = gross capital formation (vector j×1)
e_d = export (j×1 vector)

A multiplier analysis was carried out on the EE-IOT for the low-carbon development plan to describe the effect of increasing final demand units on economic output and carbon dioxide emissions. This analysis uses the environmental multiplier (β).

$$\beta = (r \cdot \hat{q}^{-1}) \cdot L \ldots\ldots (2)$$

Where:

β = environment multiplier (1×j vector)
L = Leontief inverse matrix

Multiplier analysis demonstrates that elevating environmental pressures in one industry will result in heightened environmental pressures in another industry due to direct and indirect demand. Simultaneously, the assessment of the multiplier must account for the soundness of the assumptions intrinsic to the input-output model, including the assumption of perfect elasticity, implying the absence of resource constraints.

The practical steps for calculating the above equation are summarised in the EE-IOT analysis emission model based on UN (2018), shown in Table 4. The stages in compiling the EE-IOT emission model are as follows.

a. In rows (1)-(3), enter data on direct emissions from the 2016 air emission account in 1000 tons or Gigagram units.
b. Row (4) is the total output data from the 2016 I-O table for Indonesia, column 3100, with units of billion Rupiah.
c. In rows (5)-(7), the emission coefficient is the division between each direct emission and the total output in Gg/billion Rupiah units.
d. Rows (8)-(59) are filled by the Leontief inverse matrix $(I-A)^{-1}$.
e. Rows (60)-(62) contained direct and indirect emissions per unit of output obtained by the formula $B(I-A)^{-1}$, which is the product of the emission coefficient and the Leontief inverse matrix. This section is known as the emission multiplier so that the emission multiplier for CO_2 is obtained. It is worth noting that AEA compilation uses emission factor data from the IPCC Guidelines for National Greenhouse Gas Inventories; hence, it should be consistent with the IPCC emissions factor database. However, AEA Indonesia as a database is limited because it only contains air emissions from fuel combustion activities and has not accommodated non-combustion activities.
f. Rows (63)-(114) contained the final demand data from the diagonalised IOT.
g. In rows (115)-(117) is the emission content of the final demand obtained by the formula $Z = B(I-A)^{-1}Y$. This part can also be interpreted as the impact of emissions produced to accommodate final consumption. Moreover, $Z = B(I-A)^{-1}Y + E_h$ where E_h is the emission generated by household consumption so that the total output in column (58) and row (1)-(3) will be equal to the total output in column (58) and rows (115)-(117).
h. It should be noted that further analysis in this study is CO_2 emissions according to the scope of the study. CO_2 is the main GHG that plays a significant role in causing climate change.

Table 4. EE-IOT emission model

		Products			Final use					
		Agriculture	…	**Other services**	**Final consumption: House holds**	**Final consumption: Govern ment**	**Gross fixed capital**	**Changes in inventories**	**Exports**	**Total Output**
		(1)	…	**(52)**	**(53)**	**(54)**	**(55)**	**(56)**	**(57)**	**(58)**
					Direct Emission (Gigagram)					
Carbon dioxide (CO_2)	(1)									
Methane (CH_4)	(2)									
Nitro oxide (N_2O)	(3)									
					Output (billion Rp)					
Output	(4)									
					Emission coefficients (Gigagram per billion Rp)					
Carbon dioxide (CO_2)	(5)									
Methane (CH_4)	(6)									
Nitro oxide (N_2O)	(7)									
					Inverse $(I-A)^{-1}$					
Agriculture	(8)									
…	…									
Other services	(59)									
					Direct and indirect emissions per unit of output $B(I-A)^{-1}$					
Carbon dioxide (CO_2)	(60)									
Methane (CH_4)	(61)									
Nitro oxide (N_2O)	(62)									
					Diagonal matrix of final demand Y					
Agriculture	(63)									
…	…									
Other services	(114)									
					Emission content of final demand $Z = B(I-A)^{-1}Y + E_h$					
Carbon dioxide (CO_2)	(115)									
Methane (CH_4)	(116)									
Nitro oxide (N_2O)	(117)									

RESULT AND DISCUSSION

EE-IOT Analysis

Based on data on direct emission of CO_2 gas produced during 2016, of the total CO_2 emissions of 560,522.96 Gg, 85.52 percent came from production activities, and 14.48 percent came from household consumption.

The most significant direct emission of CO_2 resulted from the productive sector, where the Electricity sector (43.24 percent) is responsible for producing CO_2 emissions of 242,382.14 Gg, Land Transport (7.35 percent) is responsible for producing CO_2 emissions of 41,194.29 Gg, Air Transport (6.56 percent) is responsible for producing 36,770.45 Gg of CO_2 emissions. Additionally, the other sectors (28.37 percent) contribute 159,006.91 Gg.

The sectors that contribute the largest direct emissions are sectors related to electricity generation and distribution, as well as transportation for transportation. If it was considered from the input structure per sector, Electricity required enormous input from Coal and Lignite Mining; Crude Petroleum, Natural Gas, and Geothermal; and Manufacture of Coal and Refined Petroleum Products. Furthermore, the Land Transport sector needs input from the Manufacture of Coal and Refined Petroleum Products; Wholesale and Retail Trade Repair of Motor Vehicles and Motorcycles; and Manufacture of Transport Equipment. Meanwhile, the largest inputs for the Air Transport sector come from the Manufacture of Coal and Refined Petroleum Products; Warehousing and Support Services for Transportation, Postal, and Courier; and Private Information and Communication Services. It can be said that the sector, whose inputs mostly use products from coal mining and oil and gas refining, releases significant direct emissions of CO_2 into the environment.

Additionally, the sectors that have the lowest direct CO_2 emissions consist of Other Financial Services (0.00009 percent), Real Estate (0.00007 percent), and Financial Supporting Services (0.000005 percent), each of which generates only 0.61, 0.51, and 0.38 Gg of CO_2 emissions.

The emission model can also generate the impact of CO_2 emissions generated by the final demand. The emission models are listed in the top 10 in Table 5. Based on a load of CO_2 emissions produced to meet the final demand, it can be seen that the largest CO_2 emissions are generated by the Construction sector (88,640.20 Gg), Electricity (70.188.06 Gg), and Air Transport (35,514.58 Gg). In their entire production process, these sectors produce CO_2 emissions so significant to meet the final demand of IDR 2,743,998 billion, IDR 83,396 billion, and IDR 339,941 billion, respectively.

Table 5. Top ten sectors with the impact of CO_2 emissions generated by final demand

Sector	**Code**	**CO_2 Emissions Impact Produced by Final Demand**	
		Gg	**Ranking**
(1)	**(2)**	**(3)**	**(4)**
Construction	I-31	88.640,20	1
Electricity	I-28	70.188,06	2
Air Transport	I-38	35.514,58	3
Manufacture of Food Products and Beverages	I-13	32.543,48	4
Land Transport	I-35	25.243,19	5
Public Administration and Defence; Compulsory Social Security	I-49	22.298,45	6
Wholesale Trade and Retail Trade, Except for Motor Vehicles and Motorcycles	I-33	17.639,21	7
Information and Communication	I-42	14.546,64	8
Manufacture of Fabricated Metal Products, Computers, and Optical Products, and Electrical Equipment	I-23	12.708,74	9
Private Education	I-50	12.248,99	10

Table 6. Sectors with the largest multiplier CO_2 emissions

Sector	**Code**	**CO_2 Emissions Multiplier**
(1)	(2)	(3)
Electricity	I-28	0,84162
Railways Transport	I-34	0,14062
Sea Transport	I-36	0,11243
Warehousing and Support Services for Transportation, Postal, and Courier	I-39	0,11202
Air Transport	I-38	0,10447
River, Lake, and Ferry Transport	I-37	0,09939
Land Transport	I-35	0,08417
Manufacture of Other Non-Metallic Mineral Products	I-21	0,05578
Manufacture of Basic Metals	I-22	0,04597
Manufacture of Rubber, Rubber Products, and Plastics Products	I-20	0,04234

Table 6 provides information on the sectors with the largest multiplier of CO_2 emissions. The majority of sectors in the economy that have the largest CO_2 multiplier are sectors related to Electricity, transportation, and warehousing, as well as several manufacturing industries, such as the Manufacture of Other Non-Metallic Mineral Products; Manufacture of Basic Metals; and the Manufacture of Rubber, Rubber Products, and Plastics Products. It seems that those sectors are related sector classification in IPCC where energy, IPPU, and AFOLU emitted relatively large amount of CO_2 (KLHK 2021b). If there is an increase in final demand in these economic sectors, it can increase CO_2 emissions, putting considerable pressure on the environment. Electricity, in this case, is the sector that has the largest CO_2 multiplier. If the final demand for the Electricity sector increases by IDR 1, then CO_2 emissions will increase by 0.84162 Gg. Therefore, using more environmentally friendly inputs in this sector's production process is crucial to achieving low-carbon and climate-resilient development.

Table 7. Sectors with the lowest multiplier CO_2 emissions

Sector	**Code**	**CO_2 Emissions Multiplier**
(1)	**(2)**	**(3)**
Food Crops	I-01	0,00324
Forestry and Logging	I-06	0,00374
Fishery	I-07	0,00378
Horticultural Crops	I-02	0,00395
Plantation Crops	I-03	0,00460
Agriculture Services and Hunting	I-05	0,00608
Animal Production	I-04	0,00826
Financial Intermediary Services	I-43	0,00876
Insurance and Pension Fund	I-44	0,01013
Real Estate Activities	I-47	0,01085

Table 7 shows that most economic sectors with the lowest CO_2 multiplier come from agriculture, forestry, fisheries, real estate, some financial services, and insurance sectors. The Food Crops is the sector with the lowest CO_2 multiplier. If the final demand for the Food Crops sector increases by IDR 1, the resulting CO_2 emissions will only increase by 0.00324 Gg. It can be said that the primary sectors, such as the Agriculture, Forestry, and Fisheries sectors, are sectors that, in accommodating their final demand, the impact of increasing output and increasing CO_2 gas emissions is relatively not as large as other economic sectors. Likewise, the service sector, such as Financial Intermediary Services; and Insurance and Pension Funds, have the lowest impact of CO_2 emissions generated by final demand compared to other sectors. This finding focuses on CO_2 emissions that are emitted from the production process, specifically combustion activities. Therefore, it explains why AFOLU sectors have a relatively low CO_2 emission multiplier.

Analysis of Leading Sector in the Economy with Consideration of GHG

Table 8 (Scenario 1) shows that sectors with high multiplier output also have relatively high multiplier CO_2 emissions, such as in the Electricity Sector. This high multiplier in emissions will cause economic growth followed by high environmental degradation; in other words, there will be high carbon development. High-carbon development is hazardous and has a damaging impact on climatic conditions. In the electricity sector, if there is an increase in final demand of IDR 1, then 0.84162 Gg of CO_2 emissions will be released into the atmosphere.

If a sector can be a booster in the economy but still considers the resulting CO_2 emissions, then the Manufacture of Food Products and Beverages can be a concern. The food and beverage industry includes processing agricultural, forestry, and fishery products into food or beverages. Also, it includes semi-finished products that do not directly make particular food or beverage products but have added value compared to before processing.

The Manufacture of Food Products and Beverages is a leading sector with an NBL and NFL value of more than 1. This state means that this sector can attract sectors that provide inputs for it (upstream sector) and encourage sectors that use its output (downstream sector). In addition, the output multiplier from the Manufacture of Food Products and Beverages is also quite large, around 1.89739, meaning that if there is an increase in final demand by IDR 1, the output will be increased by about IDR 2 and release the emissions around 0,02473 Gg.

Table 8. Leading sectors taking into account the CO_2 emission multiplier (Scenario 1)

Sector	NBL	NFL	CO_2 Emissions Multiplier	Output Multiplier	Key Sector Status
(1)	(2)	(3)	(4)	(5)	(6)
Electricity	1,88593	2,20803	0,84162	3,05758	Y
Manufacture of Food Products and Beverages	1,17032	1,73304	0,02473	1,89739	Y
Manufacture of Paper and Paper Products, Printing and Reproduction of Recorded Media	1,15593	1,10784	0,04117	1,87406	Y
Construction	1,12516	1,02427	0,03230	1,82417	Y
Manufacture of Chemicals, Pharmaceuticals, and Botanical Products	1,05827	1,65634	0,03439	1,71573	Y
Land Transport	1,04245	1,20235	0,08417	1,69008	Y
Manufacture of Fabricated Metal Products, Computer and Optical Products, and Electrical Equipment	1,01068	1,05466	0,03607	1,63858	Y

Note: Y = leading sector; N = not a leading sector

Table 9. Sectors with the highest output multiplier taking into account the CO_2 emission multiplier (Scenario 2)

Sector	NBL	NFL	CO_2 Emissions Multiplier	Output Multiplier	Key Sector Status
(1)	(2)	(3)	(4)	(5)	(6)
Electricity	1,88593	2,20803	0,84162	3,05758	Y
Railways Transport	1,21473	0,63026	0,14062	1,96938	N
Manufacture of Rubber, Rubber Products, and Plastics Products	1,19586	0,98474	0,04234	1,93879	N
Sea Transport	1,18413	0,76748	0,11243	1,91978	N
Manufacture of Food Products and Beverages	1,17032	1,73304	0,02473	1,89739	Y
Manufacture of Other Non-Metallic Mineral Products	1,16631	0,79544	0,05578	1,89089	N
Manufacture of Paper and Paper Products, Printing and Reproduction of Recorded Media	1,15593	1,10784	0,04117	1,87406	Y
Manufacture of Basic Metals	1,13542	0,82074	0,04597	1,84081	N
Food and Beverage Service Activities	1,13349	0,80929	0,01246	1,83768	N
Construction	1,12516	1,02427	0,03230	1,82417	Y

Note: Y = leading sector; N = not a leading sector

Based on Table 9 (Scenario 2), it is known that ten major sectors have the highest output multiplier. Among the ten sectors, the sector that has the lowest CO_2 emissions multiplier is Food and Beverage Service Activities. Food and Beverage Service Activities include eating and drinking services that provide food or drinks for immediate consumption in traditional restaurants, self-service restaurants, or takeaway restaurants in permanent or temporary places with or without seating.

The activity of providing food and drink has an output multiplier of 1.83768. This finding means that if there is an increase in the final demand of IDR 1, the output of this sector will increase by around IDR 2, and the emission produced is relatively low by 0.01246 Gg. In addition, the Food and Beverage Service Activities and Construction sectors can be considered a booster in the economy because the CO_2 multiplier is relatively lower than the other sectors with the highest multiplier output.

Table 10 provides information on the economic sectors with the lowest CO_2 emissions. None of the ten sectors is a key sector because NBL and NFL are less than 1. However, the output multiplier still has a value of more than 1. In other words, these sectors still have a relatively strong relationship with the industry, which provides input for it. Among the ten sectors that have the lowest multiplier CO_2 emissions, Livestock is the sector that has a reasonably high multiplier output. It means that if there is an increase in the final demand of IDR 1 in the Animal Production sector, the output will increase by around IDR 2, and the resulting CO_2 emission will be only 0.00758 Gg. In addition, sectors that can be considered a booster in the economy because the output multiplier is relatively high compared to other sectors with the lowest CO_2 multiplier are the Insurance, Pension Funds, and Real Estate sectors.

Table 10. Sectors with the lowest multiplier CO_2 emissions considering a relatively high multiplier output (Scenario 3)

Sector	NBL	NFL	CO_2 Emissions Multiplier	Output Multiplier	Key Sector Status
(1)	(2)	(3)	(4)	(5)	(6)
Food Crops	0,75557	0,91964	0,00338	1,22498	N
Forestry and Logging	0,73259	0,87935	0,00401	1,18772	N
Horticultural Crops	0,75024	0,72343	0,00414	1,21634	N
Plantation Crops	0,79299	1,13070	0,00468	1,28564	N
Fishery	0,74902	0,77935	0,00504	1,21435	N
Agriculture Services and Hunting	0,82272	0,67466	0,00608	1,33384	N
Animal Production	0,95969	0,79065	0,00758	1,55590	N
Financial Intermediary Services	0,84009	1,33327	0,00864	1,36201	N
Insurance and Pension Fund	0,87591	0,72132	0,00991	1,42008	N
Real Estate Activities	0,84107	0,96733	0,01072	1,36359	N

Note: Y = leading sector; N = not a leading sector

CONCLUSION

This research has succeeded in compiling the EE-IOT, which includes elements of GHG as a form of pressure on the environment consisting of 52 economic sectors. Further analysis focused on CO_2 gas as the main GHG, which has a very significant role in causing climate change. The productive sector produces the most direct CO_2, and the rest is contributed by household consumption. The productive sectors with the largest direct CO_2 emissions are Electricity, Land Transportation, and Air Transportation. Based on the input structure of the three sectors, the most useful products are from coal mining and oil and gas refining, so large amounts of CO_2 can be released into the environment through burning fossil fuels.

Based on the results of scenario 1, the Manufacture of Food Products and Beverages; Construction, Manufacture of Chemicals and Pharmaceuticals, and Botanical Products are the leading sectors, with NBL and NFL more than 1. Furthermore, an increase in final demand means this sector can attract sectors that provide inputs (upstream sector) and encourage sectors that use their output (downstream sector). In addition, the output multiplier from the three sectors is also quite large, and the potential for CO_2 emissions released into the atmosphere is relatively low if there is an increase in final demand. In scenario 2, the Food and Beverage Service Activities, Manufacture of Food Products and Beverages, and Construction are the sectors with the highest output (top 10 highest) in the Indonesian economy and a relatively low CO_2 emission multiplier if there is an increase in final demand. Whereas in scenario 3, Animal Production, Insurance, Pension Funds, and Real Estate are the sectors with the lowest CO_2 emission multiplier (10th lowest), this sector still has a reasonably high output multiplier in the economy if there is an increase in final demand.

Furthermore, to accelerate the achievement of low-carbon development, the government should focus on leading sectors with low CO_2 emission multipliers. However, the development of this leading sector also cannot stand alone because it will link with other sectors regarding inputs and outputs, where these supporting sectors will produce CO_2 emissions as well in their production process. Therefore, with a low-emission approach, the government needs additional efforts to encourage these supporting sectors, such as energy, transportation, agriculture, and forestry.

It is worth pointing out that this finding focuses on reducing CO_2 emissions only; hence, it has some limitations. For instance, although it has a low CO_2 multiplier, the Animal Production sector can contribute GHG from CH_4 and N_2O gases from the digestive system and livestock manure management. However, its contribution to national GHG is still below 2 percent of total GHG (Widiawati and Rofiq 2019). Therefore, to obtain a more comprehensive analysis, it is important to incorporate other GHG emissions gases in future research.

Updating the EE-IOT table to the latest year version is recommended for further research. Additionally, impact analysis simulation can be carried out by considering GHG factors, not only CO_2 gas but also other GHG such as CH_4 and N_2O. Analysis in econometric models can also be done by including environmental pressure factors obtained from the EE-IOT. Furthermore, if emission data is available up to the regional level, the EE-IOT can be developed in a regional scope.

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