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A Comparative Analysis Of CO_2 Emissions In India And Brazil Using The Logarithmic Mean Divisia Index

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Abstract:
Background: *Carbon dioxide (CO_2) emissions related to energy grew by 1.1 percent globally and reached a new height of 37.4 Gt in 2023. In contrast, the Paris Agreement calls for a significant reduction in CO_2 emissions. However, the percentage increase in emissions was significantly lower than the growth rate of the world GDP, which was 3 percent in 2023. In 2023, India stood at the third rank in terms of CO_2 emissions. The Indian economy grew at a 6.7 percent annual rate, while CO_2 emissions rose by 7 percent per annum in 2023*
Materials and Methods: *The purpose of the study is to use decomposition analysis to quantify the factors drive emissions of carbon dioxide (CO_2). The Logarithmic Mean Divisia Index (LMDI) is used to examine the factors that influence sector-wise CO_2 emissions from 2011 to 2021. The drivers of sectoral emissions of CO_2 are divided into the population, economic activity, energy intensity, and carbon intensity. Identifying the drivers responsible for CO_2 emissions in India and Brazil would help policymakers in determining the areas that require attention.*
Results: *The study finds that in the case of India, population and economic activity effects have been always positive contributors to the sectoral CO_2 emissions in India. However, economic growth has the dominant share in the sectoral CO_2 emissions. Hence, the study also examined Topio Decoupling Index (2005). The negative energy intensity and carbon intensity effect have shown an improvement in terms of energy use.*
Key Word: *Decomposition Analysis, LMDI, CO_2 emission, Economic growth, India, Brazil*

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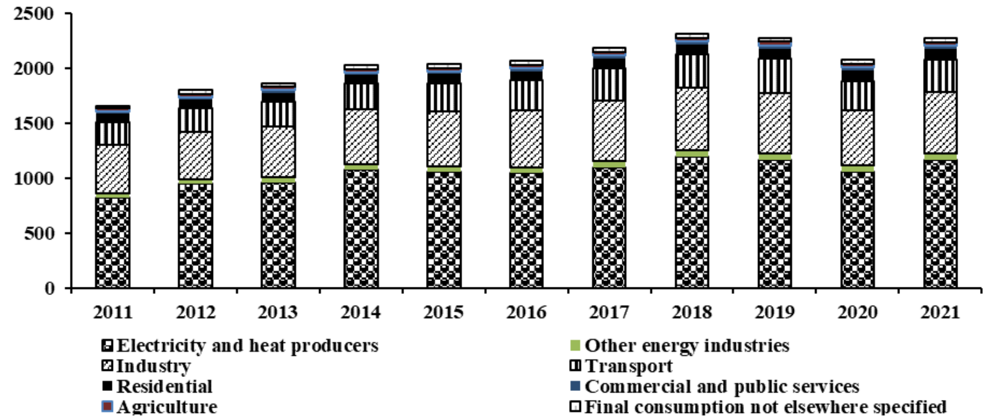
I. Introduction

Carbon dioxide (CO_2) emissions related to energy use grew by 1.1 percent globally and reached a new height of 37.4 Gt in 2023. In contrast, the Paris Agreement calls for a significant reduction in CO_2 emissions. However, the percentage increase in emissions was significantly lower than the growth rate of the world GDP, which was 3 percent in 2023. In 2023, India stood at the third rank in terms of CO_2 emissions. The Indian economy grew at a 6.7 percent annual rate, while CO_2 emissions rose by 7 percent per annum in 2023. The CO_2 emissions in India rose to 190 Mt in 2023. Nevertheless, India's CO_2 emissions per person stayed low at 2 tonnes, much lower than the global average of 4.6 tonnes[1].The current increase in CO_2 emissions was caused by India's fast economic growth following the pandemic, an increase in the country's steel and cement industries' output and a weak monsoon that affected country's ability to generate hydropower and increased energy consumption[2]. Brazil, On the other hand, stood first in the Central and South American regional ranking and ranked 12th globally in 2021 based on CO_2 emissions. Brazil jumped up to seventh place in 2023 with CO_2 emissions of 0.44 Gt. In 2022, Brazil's per capita CO_2 emissions remained above 2 tonnes[3].

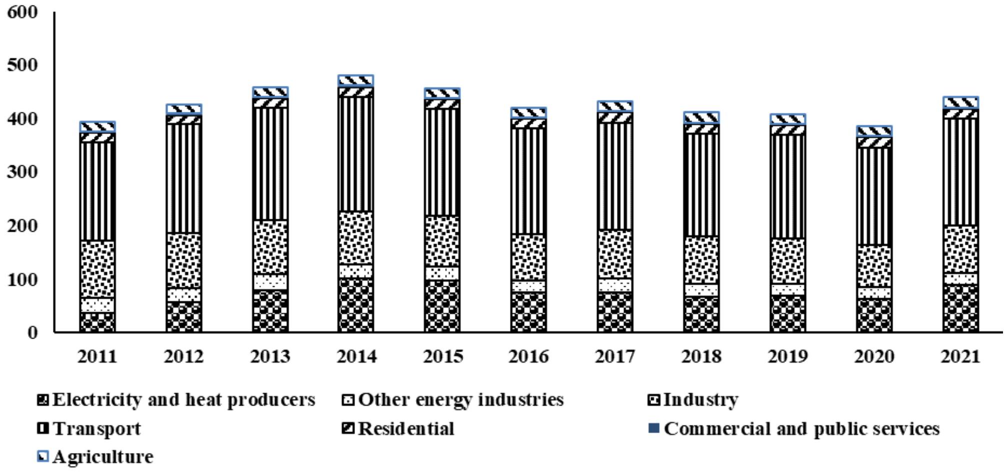
The primary source of CO_2 emissions is the energy sector for Brazil and India owing to the combustion of fossil fuels like coal, oil, and natural gas for power generation or as fuel for machinery and automobiles. The energy system's and the economy's structural makeup determine how energy-related CO_2 emissions are broken down in different sectors. Burning fuels to produce heat and electricity, power plants release emissions into the atmosphere. In most nations, automobiles account for most emissions related to transportation. Even with the swift expansion of electric vehicles, consumer cars etc. countries are still heavily dependent on fuels derived from oil. Home emissions are primarily caused by the burning of fossil fuels for heating. Figure 1 shows that energy and heat producing sector has made the largest contribution to India's CO_2 emissions which is followed by industry. In the case of Brazil, transport emerged as a major CO_2 emitter sector over the period replacing electricity and heat producing and other industries (Figure 2).

Figure 1: Sectoral contribution of CO_2 emissions in India



Source: International Energy Agency, 2023.

Figure 2: Sectoral contribution of CO_2 emissions in Brazil



Source: International Energy Agency, 2023.

The objective of this paper is to understand various drivers behind the growth in emissions and provide insights into the progress and prospects for the energy transition policies. The reminder of this paper is as follows: Section Two provides an overview of the data sources and methodology used to quantify growth drivers in the sectoral contribution of CO_2 emissions. Section Three discusses results and Section Four covers discussion and policy implications, and Section Five concludes the paper.

II. Material And Methods

The total CO_2 emissions are divided into different categories based on sectors, namely, industry, transport, residential, commercial and public services and final consumption including agriculture. Industry sector with electricity, heat and energy producers. The annual data for total CO_2 emissions for each of the categories from 2011 to 2021 for India and Brazil is retrieved from the International Energy Agency[4]. The data for population and GDP in constant 2015 USD is sourced from World Developmental Indicators database of the World Bank[5].

Log Mean Divisia Index (LMDI):

The study employed the Log Mean Divisia Index (LMDI) developed by Ang in 1998[6]. The various studies domain, such as the industrial, textile, and power industries, as well as environmental studies, have embraced the LMDI methodology using the method discussed by Ang and Zhang (2000)[7]. Several studies have employed LMDI on the empirical data to investigate the variables influencing energy usage and carbon emissions. It is possible to formulate a decomposition analysis multiplicatively or additively. The arithmetic (or difference) change of an aggregate indicator and the results are provided in a physical unit in the additive decomposition analysis. In multiplicative decomposition analysis the ratio change of an aggregate indicator is decomposed. In this case, the aggregate change and decomposition results are expressed in terms of an index[8].

Due to its theoretical foundation and sophisticated non-parametric methodology with weighted arithmetic mean, LMDI was employed in numerous investigations. Furthermore, in both additive and multiplicative forms of decomposition analysis, it permits perfect decomposition without residuals and offers precise and direct connection[9]. The properties of factor and time reversal are likewise satisfied by LMDI. Another advantage is, even if datasets contain zero or negative values, the decomposition approach is still successful. LMDI-I and LMDI-II are the two techniques used in LMDI decomposition analysis. Their weight formulas differ from one another[8]. Despite the similarity in outcomes between the two methods, LMDI-I is more widely employed because of its simple application[10].

For the application of LMDI, the aggregate is determined, which is total CO_2 emissions denoted as C in the study. The IDA identity function is given in equation 1. The function must be equal to the aggregate to be studied, namely C.

$$\sum_i C_i = \sum_i P * \frac{G}{P} * \frac{E}{G} * \frac{CO_{2_i}}{E_i} \qquad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_(1)}$$

where,
P = Population,
G = Gross Domestic Product (GDP), and
E = The amount of fuel consumed where i is the sector.

$$\sum_i C_i = \sum_i P * M * \mathrm{I} * S_i \qquad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (2)}$$

where, M is the GDP per capita. I is the energy intensity in ktoe per GDP, and S_i is the carbon intensity. The four effects are studied in the present study population effect, economic activity, energy intensity and carbon intensity effect. The energy intensity effect is measured in ktoe per million USD, or I. A decrease in the energy intensity means the production process has become more efficient. The carbon intensity (S) suggests amount of CO_2 emissions produced per unit of energy consumed in the sector. It is used to measure the environmental impact of various processes or sectors. Essentially, it quantifies how much greenhouse gas emissions are generated relative to the output or activity. Lower carbon intensity indicates a more efficient and environmentally friendly process, while higher carbon intensity implies greater emissions and a larger environmental footprint[11].

Following are the equations for four effects;

Population effect:

$$\Delta C_{Pop}^{T} = \sum_i L(C_i^T - C_i^0)\, ln\left(\frac{P^T}{P^0}\right) \qquad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (3)}$$

Economic activity effect:

$$\Delta C_{act}^{T} = \sum_i L(C_i^T - C_i^0)\, ln\left(\frac{M^T}{M^0}\right) \qquad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (4)}$$

Energy intensity effect:

$$\Delta C_{int}^{T} = \sum_i L(C_i^T - C_i^0)\, ln\left(\frac{I^T}{I^0}\right) \qquad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (5)}$$

Carbon intensity effect

$$\Delta C_{str}^{T} = \sum_i L(C_i^T - C_i^0)\, ln\left(\frac{S^T}{S^0}\right) \qquad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (6)}$$

The population, economic activity, energy intensity, and carbon intensity can all be added up to determine the changes in CO_2 emissions relative to the base year of 2011[12].

Topio Decoupling Index:

According to OECD, decoupling refers to breaking the link between environmental bads and economic goods[13]. Decoupling environmental pressures from economic growth. Decoupling occurs when the rate of environmental pressure is less than that of economic driver such as GDP for a given period. Decoupling can be either absolute or relative. Absolute decoupling is when the rate of environmental related variable is stable or decreasing while GDP is growing. When the rate of environmental related variable is increasing but at a slower rate than GDP it is called relative decoupling. Tapio developed the decoupling elasticity theory for processing causal links between variables. Topio studied the correlation between CO_2 emissions in the transport sector and the GDP of 15 EU countries, taking elastic value of environmental pressure on driving factors as division basis[14]. The following ratio suggests GDP elasticity of CO_2 emissions.

$$Dt = \frac{\%\Delta CO2}{\%\Delta GDP} = \frac{\frac{\Delta CO_2}{CO_2}}{\frac{\Delta GDP}{GDP}}$$

______________________ (7)

where,
D_t = GDP elasticity of CO_2 emissions.
ΔCO_2 = Growth in the CO_2 emissions.
ΔGDP = Growth in the GDP (Growth in the Economy).

The Tapio decoupling provides further information regarding the decoupling states (Table 1). This method's outcomes fall into eight categories. The judgement rules of Topio decoupling are as follows for two economic phrases namely, economic expansion and economic recession. The study calculated Topio Decoupling index on year-on-year basis.

Table 1: Judgement categories of the Topio Decoupling Index

Economic Growth	Decoupling State	$\Delta CO2$	ΔGDP	Decoupling Index
Economic Expansion	Expansive Negative Decoupling (END)	>0	>0	$D_t > 1.2$
	Expansive Coupling (EC)	>0	>0	$0.8 \leq D_t \leq 1.2$
	Weak Decoupling (WD)	>0	>0	$0 \leq D_t \leq 0.8$
	Strong Decoupling (SD)	<0	>0	$D_t < 0$
Economic Recessive	Recessive Decoupling (RD)	<0	<0	$D_t > 1.2$
	Recessive Coupling (RC)	<0	<0	$0.8 \leq D_t \leq 1.2$
	Weak Negative Decoupling (WND)	<0	<0	$0 \leq D_t \leq 0.8$
	Strong Negative Decoupling (SND)	>0	<0	$D_t < 0$

Source: Wu *et al*, 2020 [15]

III. Result

This section covers two sub-sections. To describing the driving forces of sectoral CO_2 emissions in India and Brazil, this sub-section analyses the contribution of population, activity, energy intensity and carbon intensity. Second sub-section explains Topio Decoupling Index for India and Brazil.

Driving forces of sectoral CO_2 emissions using LMDI:

Table 2 represents the trend of CO_2 emissions of the India over the period 2011–2021. The aggregate CO_2 emission has increased from 1661.67 Mt in 2011 to 2279.00 Mt in 2021, with a CAGR of 2.84 percent. From 2011 to 2021, CO_2 emissions from industry including energy, heat producers increased from 1302.69 Mt to 1782.76 Mt, with a CAGR of 2.71 percent per annum. Transportation's CO_2 emissions increased from 209.29 Mt in 2011 to 295.09 Mt in 2021 with a CAGR of 3.76 percent per annum. The CO_2 emissions from residential use has increased from 77.623 Mt in 2011 to 95.54 Mt in 2021 at a CAGR of 2.30 percent per annum. The CO_2 emissions from commercial and public services increased from 19.10 Mt in 2011 to 33.67 Mt in 2021 at a CAGR of 6 percent. Likewise, Table 3 depicts CO_2 emissions in Brazil over the period from 2011 to 2021. The aggregate CO_2 emission has increased from 392.76 Mt in 2011 to 439.21 Mt in 2021, with a negative CAGR of 0.49 percent. Brazil demonstrated generation producers, transportation, and commercial and public services respectively. Brazil experienced a negative CAGR of 0.80, 0.45, 2.10 percent per annum for industry including energy and heat demoed a rise in CO_2 emissions in the final consumption including agriculture from 17.47 Mt in 2011 to 18.35 Mt in 2021 with a CAGR of 0.53 percent per annum. Brazil's CO_2 emissions in the case of final consumption including agriculture has depicted growth at 1.44 percent per annum due to deforestation. Agriculture is the second largest source of emissions in Brazil and has been a key driver of deforestation. Both legal and criminal deforestation have expanded throughout the Amazon. Legal deforestation is fuelled by land-use change licenses for road construction, big infrastructure, cattle ranching, and mining. illicit deforestation is caused by the hunting of endangered native species and uncontrolled fishing, illicit traditional mining and logging, and permitted by deteriorating monitoring and enforcement mechanisms in isolated sections of the Amazon[16].

Table 2: Sector-Wise Contribution Of CO_2 Emissions In India During 2011-2021

Year	Industry	Transport	Residential	Commercial and public services	Final consumption not elsewhere specified	Total CO_2 emissions
2011	1302.69	209.29	77.62	19.10	52.97	1661.67
2012	1420.18	221.52	76.48	20.97	65.43	1804.58
2013	1474.45	226.26	78.16	21.43	59.88	1860.18
4	1623.32	235.75	81.96	21.79	64.09	2026.90
2015	1605.83	257.75	84.04	23.78	64.34	2035.74
2016	1619.95	269.39	85.59	26.27	66.22	2067.42
2017	1709.99	291.23	85.84	28.35	69.02	2184.43
2018	1820.50	305.69	88.61	30.33	71.11	2316.24
2019	1776.98	308.46	90.68	32.58	69.09	2277.77
2020	1617.29	268.66	94.29	30.27	64.13	2074.64
2021	1782.76	295.09	95.55	33.67	71.93	2279.00
CAGR	**2.71**	**3.76**	**2.30**	**6.00**	**1.98**	**2.84**

Table 3: Sector-Wise Contribution CO_2 Emissions In Brazil During 2011-2021

Year	Industry	Transport	Residential	Commercial and public services	Final consumption not elsewhere specified	Total CO_2 emissions
2011	170.66	185.15	17.47	2.70	16.78	392.76
2012	185.93	202.54	17.58	2.53	17.46	426.04
2013	209.82	209.78	18.00	2.43	17.48	457.51
2014	225.78	214.78	18.00	2.50	18.18	479.23
2015	216.82	200.79	18.02	2.23	18.30	456.16
2016	182.79	199.05	18.21	2.24	17.92	420.20
2017	192.09	200.18	18.35	2.17	19.17	431.96
2018	179.57	191.87	18.21	2.21	18.78	410.63
2019	175.14	193.17	18.13	2.23	19.12	407.78
2020	163.12	182.61	18.85	2.00	19.42	386.00
2021	198.86	200.17	18.31	2.27	19.53	439.13
CAGR	**-0.80**	**-0.45**	**0.53**	**-2.20**	**1.44**	**-0.49**

Table 4: Decomposition Of The Change In The Levels Of CO_2 Emissions ($Mtco_2$) In India With Respect To The Level Of Emissions In 2011

Year	Population effect	Economic activity	Energy Intensity	Cabon Intensity	CO_2 emissions
2012	23.07	68.94	-69.00	119.90	142.92
2013	46.26	156.08	-78.18	74.36	198.51
2014	71.13	271.67	-89.27	111.70	365.23
2015	93.18	392.15	-162.29	51.02	374.07
2016	115.93	520.61	-233.76	2.98	405.76
2017	141.38	639.24	-242.77	-15.08	522.77
2018	167.22	761.01	-281.81	8.15	654.57
2019	185.77	808.47	-357.12	-21.01	616.11
2020	194.72	640.53	-320.35	-101.92	412.98
2021	220.08	826.42	-342.43	-86.74	617.34

Table 5: Percent Share Of The Effect In CO_2 Emissions ($Mtco_2$) In India With Respect To The Level Of Emissions In 2011

Year	Population effect	Economic activity	Energy Intensity	Cabon Intensity	CO_2 emissions
2012	16.14	48.24	-48.28	83.90	100.00
2013	23.30	78.63	-39.38	37.45	100.00
2014	19.48	74.38	-24.44	30.58	100.00
2015	24.91	104.83	-43.38	13.64	100.00
2016	28.57	128.30	-57.61	0.73	100.00
2017	27.04	122.28	-46.44	-2.88	100.00
2018	25.55	116.26	-43.05	1.25	100.00
2019	30.15	131.22	-57.96	-3.41	100.00
2020	47.15	155.10	-77.57	-24.68	100.00
2021	35.65	133.87	-55.47	-14.05	100.00

Figure 3: Decomposition Of The Difference In The Level Of Emissions In Mtco₂ With Respect To The Level Of Emissions In 2011 For India

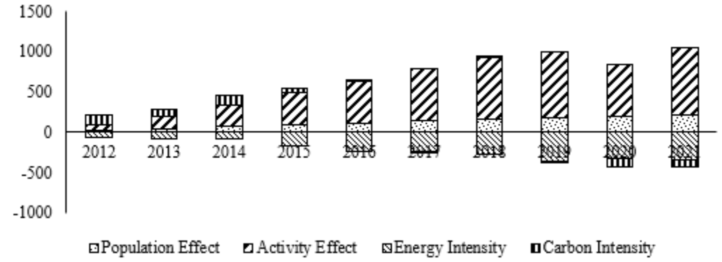


Table 6: Decomposition Of The Change In The Levels Of CO_2 Emissions ($Mtco_2$) In Brazil With Respect To The Level Of Emissions In 2011

Year	Population effect	Economic activity	Energy Intensity	Cabon Intensity	CO_2 emissions
2012	3.68	4.10	6.11	19.39	33.28
2013	7.50	13.13	2.91	41.21	64.75
2014	11.41	11.90	5.18	57.98	86.47
2015	14.70	-7.27	9.61	46.36	63.40
2016	17.41	-23.80	17.97	15.87	27.44
2017	20.91	-21.99	18.46	21.82	39.20
2018	23.57	-17.52	2.43	9.39	17.88
2019	26.56	-15.67	0.11	4.03	15.02
2020	28.42	-30.80	7.77	-12.15	-6.76
2021	32.53	-14.84	5.46	23.22	46.37

Table 7: Percent Share Of The Effect In CO_2 Emissions ($Mtco_2$) In Brazil With Respect To The Level Of Emissions In 2011

Year	Population effect	Economic activity	Energy Intensity	Cabon Intensity	CO_2 emissions
2012	11.06	12.32	18.36	58.26	100.00
2013	11.58	20.28	4.49	63.64	100.00
2014	13.20	13.76	5.99	67.05	100.00
2015	23.19	-11.47	15.16	73.12	100.00
2016	63.45	-86.73	65.49	57.84	100.00
2017	53.34	-56.10	47.09	55.66	100.00
2018	131.82	-97.99	13.59	52.52	100.00
2019	176.83	-104.33	0.73	26.83	100.00
2020	420.41	-455.62	114.94	-179.73	100.00
2021	70.15	-32.00	11.77	50.08	100.00

Figure 4: Individual Effects On CO_2 Emissions For India And Brazil

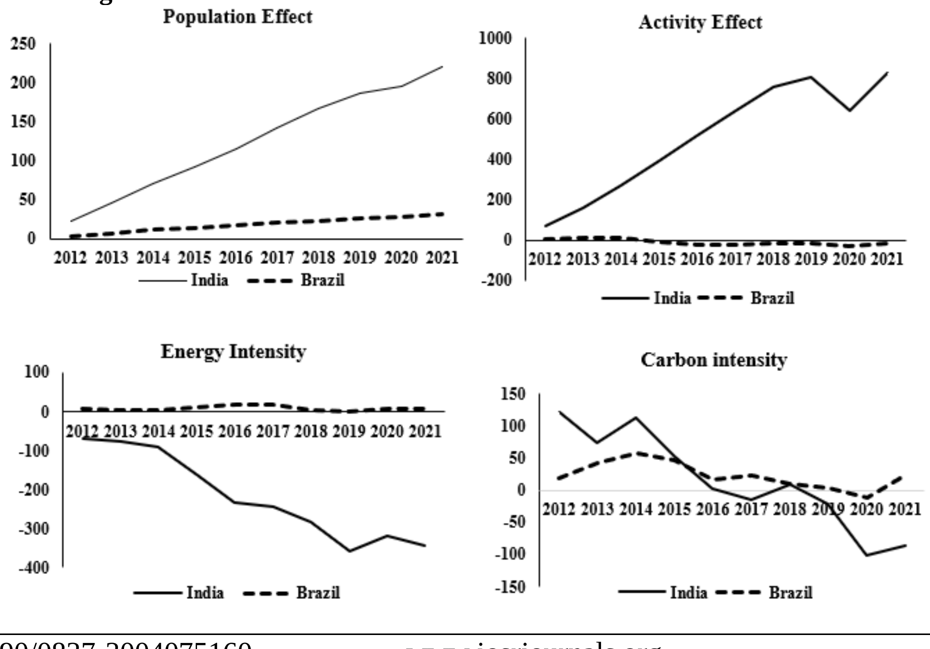
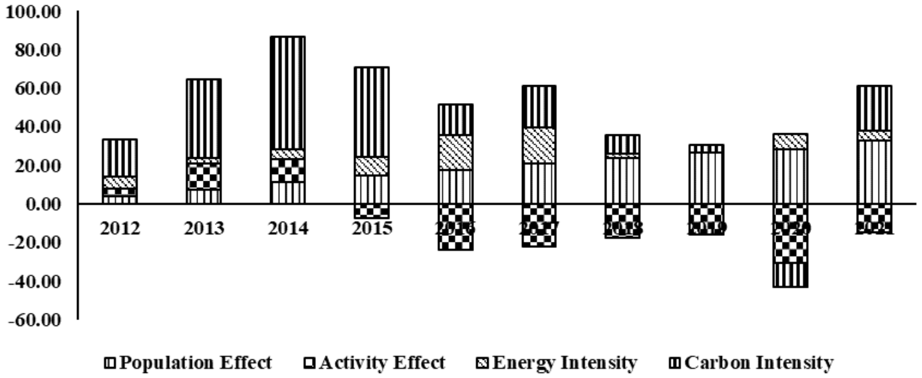


Figure 5: Decomposition Of The Difference In The Level Of Emissions In Mtco₂ With Respect To The Level Of Emissions In 2011 For Brazil



Topio Decoupling Index: The decoupling index for India suggests that from 2001 to 2021, CO_2 emissions increased with the economic growth, although at a slower rate than GDP, indicating an improvement in the energy consumption of this sector. Over the period, India depicted six decoupling states of CO_2 emissions from economic growth as listed in Table 8. Brazil's economic performance after 2015 was influenced by a combination of internal and external factors, leading to prolonged periods of low growth due to political instability and cumbersome business environment[17].

Table 8: Topio Decoupling Index for India and Brazil during 2011 to 2021

India					Brazil			
Year	$\%\Delta CO2$	$\%\Delta GDP$	D_t	State	$\%\Delta CO2$	$\%\Delta GDP$	D_t	State
2012	8.60	5.46	1.58	END	8.47	1.92	4.41	END
2013	3.08	6.39	0.48	WD	7.39	3.00	2.46	END
2014	8.96	7.41	1.21	END	4.75	0.50	9.42	END
2015	0.44	8.00	0.05	WD	-4.81	-3.55	1.36	RD
2016	1.56	8.26	0.19	WD	-7.88	-3.28	2.41	RD
2017	5.66	6.80	0.83	EC	2.80	1.32	2.12	END
2018	6.03	6.45	0.93	EC	-4.94	1.78	-2.77	SD
2019	-1.66	3.87	-0.43	SD	-0.69	1.22	-0.57	SD
2020	-8.92	-5.83	1.53	RD	-5.34	-3.28	1.63	RD
2021	9.85	9.05	1.09	EC	13.76	4.99	2.76	END

IV. Discussion

The LMDI suggest population effect for Brazil has always been dominant contributor of CO_2 emissions. Carbon intensity showed a negative share in 2019 due to the lockdown of covid-19. Economic activity effect on the other hand is negative from 2015 onwards. Brazil has witnessed a recession since 2015 due lack of investors' confidence, corruptive government, unsteady political environment, burden tax system and inefficient regulations, high cost of starting business, limited competition, sizable informal sector etc. Inefficient regulations in Brazil led to difficulties in long term financing as a result fixed investment dropped by 5 percent in 2017[18]. Due to high tax rates, firms are worried about application and paying taxes rather than producing a product efficiently. Hence, energy and carbon intensity effect also displayed positive contribution throughout the period[19]. Carbon intensity showed negative share due to pandemic-induced disruptions.

For India, contribution of population growth to CO_2 emission levels remained positive throughout the period. The population in India has grown 1.14 percent per annum during 2011 to 2021. The growth in the population influence consumption patterns, accelerates demand for various goods and services that require consumption of energy reflecting increase in CO_2 emissions by all the sectors in India. Demand for energy driven appliances in India are leading to higher emissions in supply chain. At the same time rapid urbanization resulting in more demand for public utility services and thereby CO_2 emissions in the sectors such as industry including heat producing, transportation and public utility services. Urbanization, increase in infrastructure and transportation resulting into increase in CO_2 emissions. For Brazil, population effect has always been dominant contributor of CO_2 emissions. Population in Brazil is growing at a CAGR of 0.80 percent per annum. The rate of increase in population is more than last few decades which resulted in change in the processes of occupation and territorial formation, the natural environment is replaced by humanized environment. The population has increased and migrated to the cities and cultivation of the major crops also moved northwards and westwards, Amazon Basin[20].

The economic activity effect found dominating; the CO_2 emissions in India are increasing with economic growth (Figure 4). Economic growth drives energy consumption During the period between 2011 and 2021, both CO_2 and the Indian economy grew consistently. CO_2 emissions increased at a CAGR of 2.89 percent whereas economy registered growth rate of 5.76 percent during the period. Hence, the study inferred that GDP growth (scale effect) is the major determinant of increase in CO_2 emissions in India. It is evident from Figure 3 that in 2020, India experienced a dip in CO_2 emissions due to COVID19 lockdown. For Brazil, contribution of CO_2 emissions was negative because of the uncertain political climate and investors had better choices for protecting their money in financial instruments rather than risking it in physical plants[19].

Energy intensity effect shows that when energy intensity goes down then level of CO_2 emissions goes down too. Energy intensity can be improved by using energy-saving technologies. Due to government led initiatives India is showing improvement in terms of efficiency which is depicted by negative energy intensity. The National Mission for Enhanced Energy Efficiency (NMEEE) has four initiatives namely, Perform Achieve and Trade Scheme (PAT), Market Transformation for Energy Efficiency (MTEE), Energy Efficiency Financing Platform (EEFP), Framework for Energy Efficient Economic Development (FEEED). PTA cycle 1 (2012-13 to 2014-15) confined to reduced energy specific consumption in 8 sectors which resulted in energy saving of 8.67 Mtcoe translating into about 31 Mtcoe. PAT cycle 2 (2016-19) added 3 more sectors in energy saving and avoided about 14.08 Mtcoe translating into avoiding of about 68 million tonne of CO_2 emission[21].

The contribution of energy intensity in Brazil is positive but exhibited fluctuations in the intermediate period. Brazil's energy mix includes a significant percentage of renewables, with major hydropower plants providing 80 percent of the country's electricity. With recent large increase in wind and solar power generation investments, Brazil now has one of the lowest carbon-intensive electricity sectors globally. Climate change is a problem, too, since the nation now must rely on more costly thermal power facilities and imports to meet its electrical needs. This creates difficulties for the system's egalitarian, secure, and sustainable aspects[22]. Moreover, A record drought has reduced reservoir levels, putting Brazil's hydro-dominated electricity system in jeopardy. This is particularly hard because the country is only just starting to recover from the COVID-19 pandemic and underlines the vulnerability of Brazil's energy infrastructure to rising climate change impacts[23].

A negative carbon intensity signifies change in the energy consumption, the structural effect has a small negative contribution in CO_2 emissions in India owing to the slight shift of change in the energy consumption from coal, pete, and oil shale to natural gas. In the case of Brazil, the trend of corban intensity is negative with a wavering trend in the intermediate period.

Topio Decoupling Index:

Topio decoupling analysis suggest India shows weak decoupling during sub-periods 2013, 2015-16,. For the period 2017, 2018 and 2021 it shows expansive coupling. In short, for most of the years, India shows a combination of expansive coupling and weak decoupling, indicating moderate progress in economic growth with some control over CO_2 emissions. This is result of weak decoupling linked to the subsequent reduction estimates: First, the slow growth of the CO 2 emission coefficient compared to the robust economic expansion. Despite an increase in the growth rate, emissions have slowed due to technological and renewable energy advancements, as well as the presence of numerous measures taken by the Indian government to improve energy efficiencies in India. In the year 2020, it exhibits recessive coupling. During 2020, both ΔCO_2 and ΔGDP scenarios were negative. As a result of early covid pandemic energy consumption, economic growth in GDP, and carbon coefficient decreased.

Brazil on the other hand, experienced expansive negative decoupling from 2012 to 2014, 2017 and 2021 suggesting significant increases in CO_2 emissions relative to economic growth. The country also experiences recessive decoupling during economic downturns, indicating reductions in both GDP and CO_2 emissions, but with CO_2 emissions decreasing more sharply. Brazil's economic performance after 2015 was influenced by a combination of internal and external factors, leading to prolonged periods of low growth due to political instability and cumbersome business environment[24].

V. Conclusion

The study finds that that in the case of India, population and economic activity effects have always been positive contributors to the sectoral CO_2 emissions in India. However, economic growth has dominant share in the sectoral CO_2 emissions. The negative energy intensity and carbon intensity effect has shown an improvement in terms of energy use. In the case of Brazil, population effect has always been predominant in sectoral CO_2 emissions because of rapid urbanization and increase in emission due to transportation sector. Interestingly, economic growth suggests a negative effect not because of energy efficiency achieved in the production process but due to negative growth of Brazilian economy.

Brazil has implemented sectoral plans to reduce emissions in other areas, such as the Mitigation and Adaptation to Climate Change for a Low-Carbon Emission Agriculture (ABC Plan), the Steel Industry Plan, the

Low Carbon Emission Economy in the Manufacturing Industry Plan, the Sectoral Transport and Urban Mobility Plan, and the Low-Carbon Emission Mining Plan. Most of these measures, however, are still not included in national development planning[16]. Brazil undergone expansive negative decoupling for most of the years suggesting significant increases in CO_2 emissions relative to economic growth. The result is supporting CAT findings. CAT rates Brazil policies and action as highly insignificant which indicates inconsistency in current policy trajectory.

Topio decoupling index suggest that the CO_2 emission coefficient has grown slowly in comparison to the substantial economic expansion. Despite an increase in the growth rate, emissions have not crossed 2gt due to technological and renewable energy breakthroughs, as well as the Indian government's numerous attempts to enhance energy efficiencies in India.

The study suggests that considering CO_2 emission drivers such as population and economic growth, urbanization and deforestation, Indian and Brazilian policy makers are facing challenge of promoting sustainable practices that balance economic development with environmental protection. The Environmental Sustainability Policy in India and Brazil should be designed to guide businesses, governments, and communities in the countries towards a more sustainable future. By developing target-oriented action plans with collaboration, innovation, and commitment to sustainability. The implementation of target orientating policies specifically to minimize the negative environmental impacts of industrialization by encouraging incentivized approach for adoption of cleaner production technologies, urbanization, and other economic activities. Adopting comprehensive framework based on four Rs (Reduce, Reuse, Recycle and Replant) should be incorporated in lifestyles through education and outreach programs. These efforts thereby can improve efficiency of resource use, reduce waste and promote recycling and renewable energy. Simultaneously, Government should take follow-ups with precisions for the development and enforcement of environmental regulations and standards to preserve natural habitats and biodiversity through conservation efforts and sustainable land-use practices. Land-use planning and management to prevent deforestation and habitat destruction. By fostering community engagement India and Brazil cam trigger their existing mechanism to achieve economic growth that is both environmentally sound and socially equitable.

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