DECOMPOSITION AND DECOUPLING ANALYSIS OF NIGERIA INDUSTRIAL EMISSION FROM LMDI AND TAPIO MODELS: CASE STUDY OF THE CEMENT INDUSTRY

Igwe J. E (1, *)
Ashimedua O.G (2)
Okoye O. A (1)

Received: 17/06/2025
Revised: 08/07/2025
Accepted: 09/07/2025

© 2025 University of Science and Technology, Aden, Yemen. This article can be distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

© 2025 جامعة العلوم والتكنولوجيا، المركز الرئيس عدن، اليمن. يمكن إعادة استخدام المادة المنشورة حسب رخصة مؤسسة المشاع الإبداعي شريطة الاستشهاد بالمؤلف والمجلة.

---

(1) Mechanical Engineering department, Michael Okpara University of Agriculture Umudike, Nigeria
(2) Delta State Polytechnic, Ogwashi-Uku, Nigeria.
*Corresponding Author's Email: igwe.johnson@mouau.edu.ng

DECOMPOSITION AND DECOUPLING ANALYSIS OF NIGERIA INDUSTRIAL EMISSION FROM LMDI AND TAPIO MODELS: CASE STUDY OF THE CEMENT INDUSTRY

Igwe J. E
Mechanical Engineering department
Michael Okpara University of
Agriculture Umudike, Nigeria
igwe.johnson@mouau.edu.ng

Ashimedua O.G
Delta State Polytechnic
Ogwashi-Uku, Nigeria

Okoye O. A
Mechanical Engineering department
Michael Okpara University of
Agriculture Umudike, Nigeria

Abstract— *This study investigates the relationship between carbon dioxide emissions and economic growth in Nigeria's cement industry from 2000 to 2019, using the Logarithmic Mean Divisia Index (LMDI) and Tapio decoupling models. The results reveal that carbon dioxide emissions increased by 145% over the study period, while economic growth, measured by gross output, increased by 235%. The LMDI analysis identifies energy intensity as the primary driver of carbon dioxide emissions, contributing 67.2% to the total increase, followed by industrial structure (21.5%). The Tapio decoupling model indicates that the industry experienced strong decoupling of carbon dioxide emissions from economic growth in 45% of the studied years but weak decoupling in 55%. The study's findings have important implications for policymakers and industry stakeholders seeking to reduce carbon dioxide emissions from Nigeria's cement industry while promoting sustainable economic growth.*

Keywords— Decoupling, *carbon dioxide* emissions, cement industry

I. INTRODUCTION

Nigeria's cement industry is crucial to the country's economy, but it faces significant environmental challenges. Industrial emissions from the sector contribute substantially to Nigeria's carbon footprint, raising concerns about sustainability (Adekomaya and Adeniyi, 2022). The industry's environmental footprint, primarily in the form of industrial emissions, poses significant local and global environmental concerns, including air pollution and climate change (Amadi et al., 2022). Despite growing awareness of sustainable industrial practices, Nigeria's cement industry faces challenges in managing its environmental impact (Ogundari and Abdul-Rahim, 2022). A comprehensive analysis using advanced models, such as the Logarithmic Mean Divisia (LMDI) and Tapio, is necessary to understand emission trends and decouple economic growth from environmental degradation (Wang et al., 2022). The LMDI and Tapio models are necessary to understand the drivers of emission trends and the relationship between economic growth and environmental impacts (Wang et al., 2022). A detailed case study applying these models can help identify key factors influencing emissions and inform strategies for sustainable industrial development in Nigeria (Ogundari and Abdul-Rahim, 2022).

LMDI decomposition analysis is a widely used method for examining the drivers of temporal changes in aggregate indicators. Initially proposed by Ang et al. (2001), the LMDI method was later improved by Ang (2004) to address issues with zero and negative values. This refined method enables the decomposition of multiple factors (Ang, 2015). Due to its advantages, including full decomposition, no residuals, and ease of use and interpretation, LMDI has been extensively applied in various fields. The LMDI decomposition method has been employed to study the driving factors of CO_2 emissions at national, regional, provincial, and industrial levels. Moreover, its application has expanded to analyzing economic belts and provinces (Jiang et al., 2021).

Tapio decoupling models have been used to investigate the relationship between economic growth and environmental indicators, such as carbon emissions and water usage. For instance, Zhang et al. (2019) used the Tapio model to analyze the decoupling effect between industrial growth and carbon emissions at the provincial level in China, finding that energy intensity and energy mix were key factors influencing the decoupling process. Similarly, Wang et al. (2018) applied the Tapio decoupling indicator to study the decoupling status between economic growth and water usage in major Chinese cities. Additionally, Wu et al. (2018) reviewed various decoupling index calculation methods, concluding that the Tapio decoupling elasticity exhibited greater accuracy. Further research by Wu et al. (2019) utilized the Tapio model, Johansen co-integration theory, and Granger causality test to examine the impact of urbanization and industrialization on China's decoupling of economic development from carbon emissions. The study found that urbanization promoted decoupling, while industrialization had an inhibitory effect in the early stages. Wang et al. (2018) investigated the decoupling status and driving forces of CO_2 emissions in China and the US using the Tapio and LMDI analysis approaches. The results showed that China experienced weak decoupling and expansive coupling, whereas the US exhibited weak and strong decoupling. Further studies have also employed various decomposition techniques, including the LMDI and Tapio decoupling model, to investigate the drivers of carbon emissions and their relationship with economic growth in different countries and regions, including Pakistan (Lin et al., 2019), China (Xie et al., 2019; Zhu et al., 2021), and Africa (Simbi et al., 2021).

The findings suggest that economic growth, population, and energy structure are significant drivers of CO_2 emissions, while energy and emission intensities have fluctuating impacts (Köne et al., 2019). Additionally, trade openness has been found to have varying effects on decoupling carbon

https://doi.org/10.20428/jst.v30i7.3084

emissions from economic growth, depending on the country's income level (Wang and Zhang, 2021).

The decomposition and decoupling analysis of industrial emissions, particularly within the context of the cement industry in Nigeria, has garnered significant attention in recent years. Several studies have delved into similar analyses, utilizing methodologies such as the Logarithmic Mean Divisa Index (LMDI) and the Tapio model to understand the dynamics of industrial emissions and their relationship to economic activity. In a study by Kong et al. (2022), the LMDI method was applied to decompose changes in industrial emissions in Nigeria, focusing on factors such as production volume, energy intensity, and emission factors. The study highlights the importance of understanding the specific drivers of emissions changes and how they relate to industrial processes and energy consumption within the cement industry. The strategic application of cutting-edge methodologies, such as LMDI and the Tapio model, has significantly enhanced our understanding of the complex relationships between economic growth, energy consumption, and environmental degradation. By harnessing the insights generated from these advanced analytical tools, the study will assist in informed, evidence-based policy decisions, guide sustainable industry practices, and support global efforts to mitigate climate change.

II. MEASURING CARBON EMISSIONS

Carbon emissions can be measured using two primary methods: actual measurement and coefficient measurement. The actual measurement method involves direct measurement using specialized instruments, offering high accuracy but being costly and challenging to implement (IPCC, 1990). In contrast, the Coefficient Measurement method, proposed by the Intergovernmental Panel on Climate Change (IPCC), utilizes carbon emissions coefficients to estimate emissions based on energy consumption (IPCC, 1990) as follows:

$$C = \sum C_i = \sum K_i \, O_i \, E_i \qquad 1$$

Where C is the carbon emissions, i represents the energy type, Ci represents the carbon emissions of energy type i, Ki is the coefficient of the energy type i, Oi the conversion factors of energy type.

A. Energy-related CO2 emissions

Emissions of CO₂ from energy-related sources are those produced when fossil fuels are burned. The calculation of the CO₂ emissions approach from Shan et al. (2018) was utilized in this study to estimate the energy-related emissions of Nigeria's cement-making industry.

The method for calculating CO2 emissions related to fossil fuels is shown in Eq. 2.

$$CE_{ik} = AD_{ik} \, .NCV_i \, .CC_i \, .O_{ik} \qquad 2$$

Where, subscripts i and k stand for the different types of fossil fuels used in the cement industry, respectively. CEik represents the CO2 emissions from the combustion of fossil fuel i in sector k. The use of fossil fuel i in sector k is represented by ADik . NCVi represents the net calorific value, which indicate the calorific value produced by burning one physical unit of fossil fuel i. CCi represents carbon content, which shows the CO2 emissions generated by burning fossil fuel i per unit calorific value, and Oik is the oxidation efficiency, which stands for the oxidation rate of fossil fuel when burning.

B. Process-related CO2 emission

The CO₂ generated by physical and chemical processes throughout the technological process is known as process-related emissions. Most process-related CO₂ emission in Nigeria is caused by the cement industry. So, we counted the cement-related CO₂ emission. The equation as in Eq. (3.2)

$$CE_r = AD_r \, .EF_r$$

where, CEr stands for the CO₂ emissions associated with the process of cement industry,

ADr represents the activity data of the cement industry. EFr refers to the emission factor of cement manufacture, which was obtained by Liu et al. (2015).

C. LMDI Decomposition Analysis method

In this study, we use the LMDI decomposition method proposed by Ang et al. (2015) to analyze driving factors of CO₂ emissions in the Nigerian cement industry, which can be decomposed into six factors: CO₂ emission coefficient (F), energy structure (U), energy intensity (S), industrial structure (Is), economic output (A), and population (P). The fundamental equation is as follows:

$$C = \sum_{ik} C_{ik} = \sum_{ik} \frac{C_{ik}}{E_{ik}} . \frac{E_{ik}}{E_i} . \frac{E_i}{Q_i} . \frac{Q_i}{Q} . \frac{Q}{P} . P = \sum_{ik} F_{ik} U_{ik} S_i Is_i AP \ldots (4)$$

Where:

F_{ik} = Cik/Eik (CO2 emission coefficient of fossil fuel k in industry/sector i)

U_{ik} = Eik/Ei (Energy consumption structure of industry/sector i)

S_i = Ei/Qi (Energy intensity of sector, i)

Is_i = Qi/Q (Industrial structure of industry/sector i)

A = Q/P (Economic output per capita GDP)

C = Total CO2 emissions

C_{ik} = CO2 emissions from fuel type k in industry/sector i

E_i= Total energy consumption of industry/sector i

E_{ik} = Energy consumption of industry/sector i by fuel type k

Q = Gross Domestic Product (GDP)

Q_i = GDP of industry/sector i

P = Population.

According to LMDI model the total changes in carbon emissions over period (0 to T) (ΔC_T)

Is the sum of changes those six factors as show in the listed equations:

$$\Delta C_{tot} = C_T - C_0 = \Delta C_F + \Delta C_U + \Delta C_S + \Delta C_I + \Delta C_Q + \Delta C_P$$

$$\Delta C_F = \sum_i \frac{C_i^T - C_i^o}{LnC_i^T - LnC_i^o} Ln(\frac{F_{ik}^T}{F_{ik}^o})$$

$$\Delta C_U = \sum_i \frac{C_i^T - C_i^o}{LnC_i^T - LnC_i^o} Ln\left(\frac{U_{ik}^T}{U_{ik}^o}\right) \qquad 7$$

$$\Delta C_S = \sum_i \frac{C_i^T - C_i^o}{LnC_i^T - LnC_i^o} Ln\left(\frac{S_i^T}{S_i^o}\right) \qquad 8$$

$$\Delta C_I = \sum_i \frac{C_i^T - C_i^o}{LnC_i^T - LnC_i^o} Ln\left(\frac{Is_i^T}{Is_i^o}\right) \qquad 9$$

$$\Delta C_Q = \sum_i \frac{C_i^T - C_i^o}{LnC_i^T - LnC_i^o} Ln\left(\frac{A^T}{A^o}\right) \qquad 10$$

$$\Delta C_P = \sum_i \frac{C_i^T - C_i^o}{LnC_i^T - LnC_i^o} Ln\left(\frac{P^T}{P^o}\right) \qquad 11$$

Where shows the change in the CO_2 emissions from the base year to the target year, CT is the CO_2 emission in the target year, and C0 is the CO_2 emission in the base year.

ΔCF, ΔCU, ΔCS, ΔCI, ΔCQ, and ΔCP are the six driving factors effects on emissions.

D. Tapio decoupling model

From Tapio's decoupling method, the decoupling formula between CO_2 emissions and the economy in Nigeria Cement's industry is shown in Eq. 12.

$$d = \frac{\frac{\Delta C}{C_o}}{\frac{\Delta G}{G_o}} \qquad 12$$

Where d is the decoupling index, ΔC is the change in CO2 emissions, Co is the base year emissions, ΔG is the change in GDP, and Go is the base year GDP.

E. Decoupling effort model

This research integrates the Logarithmic Mean Divisia Index (LMDI) decomposition model with the Tapio model to evaluate the impact of various factors on CO_2 emissions and the economy (Wang & Wang, 2019). The integrated decoupling effort model analyzes the specific contribution of each factor (population scale, energy structure, energy intensity, and industrial structure) to achieving decoupling while excluding the influence of economic growth. The equation is shown in Eq. 13.

$$\Delta E = \Delta C - C_Q = \Delta C_u + \Delta C_S + \Delta C_I + \Delta C_P \qquad 13$$

where ΔE is the sum of the effects after excluding the effect of economic development. When the effect of economic growth is positive, the decoupling effort index formula could be expressed as

$$D = -\frac{\frac{\Delta E}{C_o}}{\frac{\Delta G}{G_o}} = \frac{\Delta E}{\Delta G} X \frac{G_o}{C_o} =$$
$$-\left(\frac{\Delta C_u}{\Delta G} \times \frac{G_o}{C_o} + \frac{\Delta C_S}{\Delta G} \times \frac{G_o}{C_o} + \frac{\Delta C_I}{\Delta G} \times \frac{G_o}{C_o} + \frac{\Delta C_P}{\Delta G} \times \frac{G_o}{C_o}\right)$$
$$= D_U + D_S + D_I + D_P \qquad 14$$

Where:

D is the total decoupling effort index, DU is the decoupling effort of the energy structure effect, DS is the decoupling effort of the energy intensity effect, DI is the decoupling effort of the industrial structure, and DP is the decoupling effort of the population scale effect. D ≥ 1 indicates a strong decoupling effort; D ≤ 0 shows no decoupling effort; and 0 < D < 1 shows a weak decoupling effort.

III. RESULTS AND DISCUSSION

Cement industry annual CO2 Emissions:

Fig. 1 shows the emissions from Nigeria's cement industry with a steady increase from 2000 to 2019, rising by 164% from 3,142 tons to 8,284 tons. The emissions growth was consistent, with some fluctuations, and was likely driven by factors such as increasing cement production, energy consumption patterns, and economic growth. The emissions remained stable in 2007-2008, while a rapid growth phase occurred between 2010 and 2015, potentially attributed to Nigeria's growing economy and infrastructure development. The emissions trend shows the need for sustainable practices and emissions reduction strategies in Nigeria's cement industry to mitigate its environmental impact.

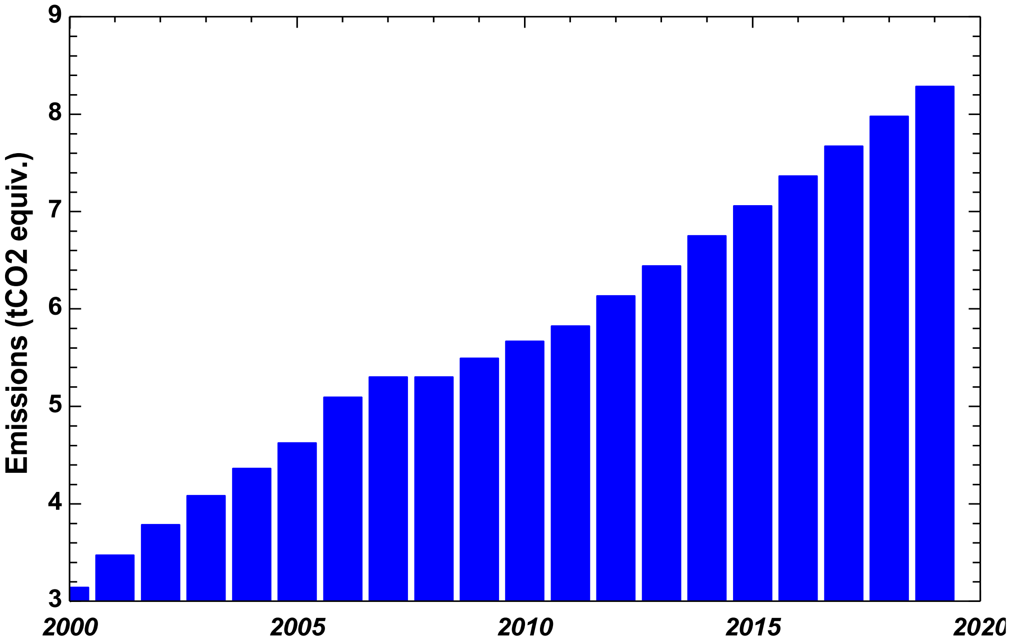

Fig. 1. Total CO2 emissions from cement industry (2000-2019)

A. Contribution of decoupling Factors

Table 1 and Fig. 2 show the LMDI decoupling emissions results, which decompose the changes in CO_2 emissions from Nigeria's cement industry into several factors, including energy structure, energy intensity, industrial structure, economic output, and population growth.

Energy structure

The energy structure factor consistently shows a negative contribution to CO_2 emissions growth throughout the period. This indicates that the cement industry in Nigeria has been shifting towards cleaner energy sources, such as renewable energy or more efficient fossil fuel technologies. This trend is expected to continue as the industry adopts more sustainable practices.

Energy Intensity

The energy intensity factor exhibits a volatile trend, with both positive and negative contributions to CO_2 emissions growth. This suggests that the industry's energy efficiency has been improving in some years but worsening in others. Factors such as changes in production processes, technology upgrades, or fluctuations in energy prices might have influenced this trend.

Industrial Structure

The industrial structure factor shows a mix of positive and negative contributions to CO_2 emissions growth. This indicates that changes in the industry's structure, such as shifts in production capacity or changes in the types of cement produced, have had varying impacts on emissions. Factors such as changes in market demand, government policies, or competition might have influenced this trend.

Economic Output

The economic output factor generally shows a positive contribution to CO_2 emissions growth, indicating that the industry's economic growth has been driving up emissions. This is expected, as increased economic activity typically leads to higher energy consumption and emissions. However, the factor's contribution has been decreasing in recent years, suggesting that the industry might be adopting more sustainable practices.

Population Growth

The population growth factor consistently shows a positive contribution to CO_2 emissions growth, indicating that Nigeria's growing population has been driving up demand for cement and, consequently, emissions. This trend is expected to continue, as Nigeria's population is projected to continue growing.

These variations can generally be attributed to changes in energy prices, technological advancements, and government policies and regulations. Others are changes in government policies or regulations that might have influenced the industry's structure, energy consumption, or emissions. Market demand and competition and economic growth and development are suspected to have driven up energy consumption and emissions.

Table 1: Decoupling index calculation (2001-2019)

Year	ΔCu (MtCO2)	ΔCS (MtCO2)	ΔCi (MtCO2)	ΔCi (MtCO2)	ΔCp (MtCO2)	ΔCp (MtCO2)
2001	**-0.01195**	**-0.02753**	**0.167343**	**0.115559**	**0.087608**	**3.4727099**
2002	**-0.01365**	**-0.1879**	**-0.41476**	**0.832612**	**0.097315**	**3.78632881**
2003	**-0.01542**	**1.019346**	**-1.08929**	**0.275662**	**0.105894**	**4.08252711**
2004	**-0.01725**	**0.902026**	**-1.70098**	**0.981219**	**0.11376**	**4.36130481**
2005	**-0.01915**	**0.487739**	**-1.36442**	**1.036224**	**0.120965**	**4.6226619**
2006	**-0.02113**	**0.057117**	**-1.24153**	**1.321603**	**0.127882**	**4.8665984**
2007	**-0.02319**	**0.193972**	**-0.7129**	**0.633732**	**0.134911**	**5.09311428**
2008	**-0.02534**	**0.536199**	**-1.33515**	**0.892041**	**0.14134**	**5.30220957**
2009	**-0.02757**	**-0.37661**	**1.353654**	**-0.905**	**0.147209**	**5.49388425**
2010	**-0.02991**	**1.347991**	**-2.36222**	**1.065243**	**0.15315**	**5.66813833**
2011	**-0.03234**	**1.530859**	**-2.04074**	**0.54023**	**0.158827**	**5.8249718**
2012	**-0.05236**	**0.78131**	**-1.09507**	**0.510116**	**0.164344**	**6.13331317**
2013	**-0.05463**	**0.671922**	**-1.02729**	**0.548496**	**0.169562**	**6.44136722**
2014	**-0.05687**	**0.665722**	**-0.95319**	**0.478813**	**0.173297**	**6.74913396**
2015	**-0.05907**	**-0.46718**	**1.885437**	**-1.22709**	**0.175383**	**7.05661339**
2016	**-0.06123**	**0.236741**	**1.555773**	**-1.60482**	**0.180732**	**7.3638055**
2017	**-0.06336**	**2.505441**	**-1.57817**	**-0.74696**	**0.189956**	**7.6707103**
2018	**-0.06546**	**2.060807**	**-2.59208**	**0.708036**	**0.19531**	**7.97732779**
2019	**-0.06752**	**-2.59583**	**2.011137**	**0.759526**	**0.199025**	**8.28365796**

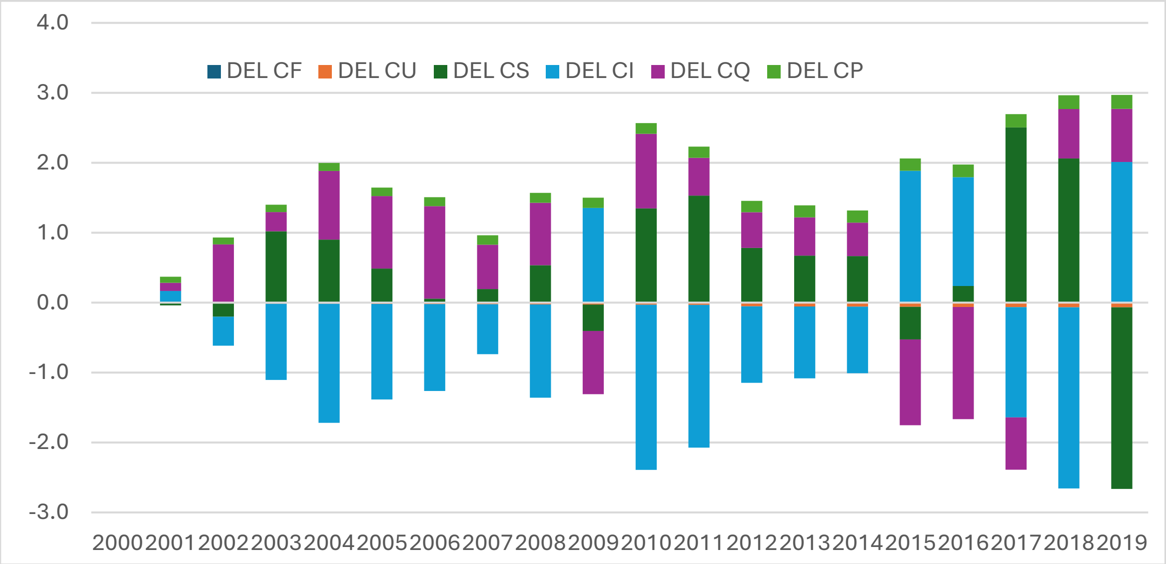

Figure 2: LMDI decomposition result

B. Decoupling Index results

The results of the decoupling analysis in the Nigerian cement industry are presented in the context of Tapio's decoupling model. Tapio's model identifies three types of decoupling in Table 2. The results of the analysis show that the Nigerian cement industry has experienced various types of decoupling over the years: Weak decoupling occurred in 2001-2002, 2009, 2015, and 2019, indicating that emissions grew, but at a slower rate than economic growth. Strong decoupling occurred in 2003-2005, 2008, 2010-2014, and 2017-2018, indicating that emissions declined or grew at a slower rate than economic growth. Expansive negative decoupling occurred in 2006-2007 and 2016, indicating that emissions declined while economic growth occurred.

These results suggest that the Nigerian cement industry has made efforts to reduce emissions, but these efforts have been inconsistent. The industry has experienced periods of strong decoupling, indicating that emissions reduction efforts have been successful. However, the industry has also experienced periods of weak decoupling, indicating that emissions reduction efforts have been insufficient.

Table 2: Summary of change in emissions and decoupling index

Years	ΔC (MtCO2)	d (decoupling index)	Decoupling state
2001	0.331040	0.88804782	Weak decoupling
2002	0.313619	0.59176842	Weak decoupling
2003	0.296198	-0.4749654	Strong decoupling
2004	0.278778	-0.5104818	Strong decoupling
2005	0.261357	-1.3289317	Strong decoupling
2006	0.243936	1.1775173	Expansive negative decoupling
2007	0.226516	4.13450249	Expansive negative decoupling
2008	0.209095	-0.7277555	Strong decoupling
2009	0.191675	0.30971062	Weak decoupling
2010	0.174254	-0.1711445	Strong decoupling
2011	0.156833	-0.1328738	Strong decoupling
2012	0.308341	-0.7790841	Strong decoupling
2013	0.308054	-1.0462981	Strong decoupling
2014	0.307767	-1.0704762	Strong decoupling
2015	0.307479	0.35481314	Weak decoupling
2016	0.307192	2.36145941	Expansive negative decoupling
2017	0.306905	-0.1699239	Strong decoupling
2018	0.306617	-0.204108	Strong decoupling
2019	0.306330	0.08708532	Weak decoupling

https://doi.org/10.20428/jst.v30i7.3084

C. Analysis of decoupling effort model

The results of the decoupling effects of different factors on CO2 emissions from Nigeria's cement industry are shown in Table

Energy Structure Decoupling Effect (Du)

The energy structure decoupling effect (Du) measures the impact of changes in energy sources on CO_2 emissions. A positive value indicates a reduction in emissions due to a shift towards cleaner energy sources. In most years, the energy structure decoupling effect was negligible (close to 0). However, in 2007, 2016, and 2019, the energy structure decoupling effect was significant, with values of 0.18, 0.03, and -0.09, respectively.

Energy Intensity Decoupling Effect (Ds)

The energy intensity decoupling effect (Ds) measures the impact of changes in energy efficiency on CO_2 emissions. A positive value indicates a reduction in emissions due to improved energy efficiency. The energy intensity decoupling effect was mostly negative, indicating that energy efficiency improvements were not sufficient to reduce emissions. Nevertheless, in 2007, 2014, and 2016, the energy intensity decoupling effect was significant, with values of -8.36, -3.82, and -16.85, respectively.

Industrial Structure Decoupling Effect (Di)

The industrial structure decoupling effect (Di) measures the impact of changes in industrial processes on CO_2 emissions. A positive value indicates a reduction in emissions due to changes in industrial processes. The results indicate that the industrial structure decoupling effect was mostly positive, indicating that changes in industrial processes contributed to reducing emissions. Between 2006, 2017, and 2019, the industrial structure decoupling effect was significant, with values of -2.59, -0.36, and -1.89, respectively.

Population Scale Decoupling Effect (Dp)

The population scale decoupling effect (Dp) measures the impact of changes in population on CO_2 emissions. A positive value indicates a reduction in emissions due to changes in population. The population scale decoupling effect was mostly negligible (close to 0). In 2019, the population scale decoupling effect was significant, with a value of 0.62. The changes in energy sources (Du) had a limited impact on reducing CO_2 emissions. Energy efficiency improvements (Ds) were not sufficient to reduce emissions in most years. Changes in industrial processes (Di) contributed to reducing emissions in most years. Changes in population (Dp) had a negligible impact on CO_2 emissions in most years.

Table 3. Result of decoupling effort model

Years	Energy structure decoupling effect Du	Energy intensity decoupling effect Ds	Industrial structure decoupling effect Di	Population scale decoupling effect Dp
2001	0.00	0.33	1.49	-0.02
2002	0.00	-2.24	1.20	-0.01
2003	0.04	-0.14	-0.92	0.01
2004	0.00	-0.73	0.62	0.01
2005	0.01	-2.14	0.62	0.04
2006	-0.05	0.06	-2.59	-0.03
2007	0.18	-8.36	10.89	-0.08
2008	-0.01	-3.10	9.35	0.02
2009	0.00	-2.84	6.03	-0.01
2010	0.00	0.21	0.30	0.01
2011	-0.09	-0.79	0.82	0.00
2012	0.00	-0.30	0.25	0.00
2013	0.00	-0.05	0.34	0.00
2014	0.00	-3.82	9.56	-0.01
2015	0.00	-0.80	0.42	0.00
2016	0.03	-16.85	23.51	-0.04
2017	0.00	-0.38	-0.36	-0.01
2018	0.00	-1.20	1.17	0.00
2019	-0.09	-0.60	-1.89	0.62

Conclusion

The study focused on evaluation and decoupling of emissions drivers in the cement industry using time series data from 2001 through 2019. Using the LMDI and Tapio models, CO_2 emissions from Nigeria's cement industry were decomposed into several factors, including energy structure, energy intensity, industrial structure, economic output, and population growth. From the results, the following major conclusions are made:

Decoupling of CO_2 Emissions and Economic Growth

- The Nigerian cement industry experienced both weak and strong decoupling of CO_2 emissions from economic growth over the study period.
- Strong decoupling occurred in several years, indicating that emissions reduction efforts were successful during those periods.

- Factors Influencing CO_2 Emissions
- Energy intensity and industrial structure were the primary factors influencing CO_2 emissions from the Nigerian cement industry.
- Changes in energy sources and population had a relatively minor impact on emissions.

Emissions Reduction Efforts

- The industry's efforts to reduce emissions were inconsistent, with periods of strong decoupling followed by periods of weak decoupling.
- To achieve sustained emissions reduction, the industry must adopt and maintain best practices, such as energy efficiency improvements and fuel switching.

Policy Implications

- Policy support and regulations can encourage the industry to adopt more sustainable practices and reduce emissions.
- Targeted policies addressing energy intensity and industrial structure can help achieve significant emissions reductions in the Nigerian cement industry.

REFERENCES:

[1] O. S. Adekomaya and O. Adeniyi, "Environmental impact assessment of iron and steel production in Nigeria," J. Environ. Manage., vol. 313, p. 114973, 2022.

[2] Adeyinka and P. U. Ikpor, "Industrialization and economic growth in Nigeria," J. Econ. Stud., vol. 49, no. 2, pp. 241–255, 2022.

[3] S. N. Amadi, A. E. Okorie, and N. Onyekwere, "Environmental impact assessment of industrial activities in Nigeria," J. Environ. Sci. Health, Part C, vol. 40, pp. 1–13, 2022.

[4] B. W. Ang, "Decomposition analysis for policymaking in energy: Which is the preferred method?" Energy Policy, vol. 32, no. 9, pp. 1131–1139, 2004.

[5] B. W. Ang, "LMDI decomposition approach: A guide for implementation," Energy Policy, vol. 86, pp. 233–238, 2015.

[6] B. W. Ang, F. L. Liu, and E. P. Chew, "Perfect decomposition techniques in energy and environmental analysis," Energy Policy, vol. 29, no. 14, pp. 1131–1136, 2001.

[7] P. Gonzalez, "Decoupling of economic growth and carbon emissions: A study of the US cement industry," J. Cleaner Prod., vol. 32, pp. 75–84, 2012, doi: 10.1016/j.jclepro.2012.03.024.

[8] X. Jiang, Z. Deng, and H. Chen, "Decomposition analysis of carbon emissions in China's provincial regions," J. Cleaner Prod., vol. 278, p. 123914, 2021.

[9] Köne, A. C. Köne, and Ö. Yılmaz, "Past and future trends in CO2 emissions: A decomposition analysis," Energy Policy, vol. 129, pp. 1096–1106, 2019, doi: 10.1016/j.enpol.2019.02.056.

[10] Lin and X. Ouyang, "Decomposition analysis of electricity generation-induced CO2 emissions in Pakistan," J. Cleaner Prod., vol. 235, pp. 1229–1238, 2019, doi: 10.1016/j.jclepro.2019.06.275.

[11] K. Ogundari and A. S. Abdul-Rahim, "Decomposition analysis of CO2 emissions from the Nigerian iron and steel industry," Energy Policy, vol. 165, p. 112895, 2022.

[12] S. A. Raza, M. Shahbaz, and D. K. Nguyen, "Decoupling economic growth from CO2 emissions in the transportation sector: A Tapio model analysis," Energy Policy, vol. 138, p. 111192, 2020, doi: 10.1016/j.enpol.2020.111192.

[13] P. S. Simbi, T. S. Adebayo, and E. Muganyi, "Decoupling carbon emissions from economic growth in Africa: A Tapio-LMDI approach," Energy Policy, vol. 151, p. 112141, 2021, doi: 10.1016/j.enpol.2021.112141.

[14] Q. Wang, R. Li, and Y. Wang, "Decoupling analysis of CO2 emissions from economic growth in China and the US," J. Cleaner Prod., vol. 197, pp. 1042–1051, 2018, doi: 10.1016/j.jclepro.2018.06.124.

[15] Q. Wang, R. Li, and Y. Wang, "Analysis of CO2 emissions from the iron and steel industry in China using the LMDI method," J. Cleaner Prod., vol. 358, p. 131699, 2022.

[16] X. Wang and Y. Wang, "Decoupling economic growth from carbon emissions: A study of China's industrial sectors," J. Cleaner Prod., vol. 235, pp. 1370–1380, 2019, doi: 10.1016/j.jclepro.2019.06.299.

[17] Y. Wang and Y. Zhang, "Trade openness and decoupling carbon emissions from economic growth," Environ. Sci. Pollut. Res., vol. 28, no. 10, pp. 12441–12451, 2021, doi: 10.1007/s11356-020-12157-3.

[18] Y. Wu, J. Zhang, and X. Yang, "A review of decoupling index calculation methods," Ecol. Indic., vol. 89, pp. 806–816, 2018, doi: 10.1016/j.ecolind.2018.02.056.

[19] Y. Wu, J. Zhang, and X. Yang, "Urbanization and industrialization impacts on China's decoupling of economic development from carbon emissions," Energy Policy, vol. 132, pp. 1109–1118, 2019, doi: 10.1016/j.enpol.2019.06.037.

[20] X. Xie, C. Shuai, and W. Chen, "Decoupling analysis of carbon emissions from economic output in China's power industry," J. Cleaner Prod., vol. 235, pp. 1239–1247, 2019, doi: 10.1016/j.jclepro.2019.06.276.

[21] Y. Zhang, J. Zhang, and Z. Yang, "Decoupling analysis of industrial growth and carbon emissions in China's provinces," J. Cleaner Prod., vol. 235, pp. 1220–1228, 2019, doi: 10.1016/j.jclepro.2019.06.274.

[22] Q. Zhu, Y. Wang, and M. Li, "Carbon emissions and economic growth in China's logistics industry," Sustainability, vol. 13, no. 11, p. 6239, 2021, doi: 10.3390/su13116239.