REVISTA MEXICANA DE ECONOMÍA Y FINANZAS
Nueva Época
REMEF
(THE MEXICAN JOURNAL OF ECONOMICS AND FINANCE)

Revista Mexicana de Economía y Finanzas, Nueva Época

Volumen 20 Número 3, Julio - Septiembre 2025, pp. 1-21, e1030

DOI: https://doi.org/10.21919/remef.v20i3.1030

(Received: May 3, 2024, Accepted: June 4, 2025, Published: June 23, 2025)

imef fundación de investigación

Balancing Economic Growth and Carbon Intensity in Indonesia

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Abstract

It is essential in balancing the economic growth and the environmental factor. Indonesia, positioned as a good place in the world economy, can be seen from rapid economic development. It is a milestone regarding the price of sustainability and the environment. This research investigates the economic growth and carbon intensity in Indonesia. It aims to assess the trade-offs associated with economic development's contribution to CO_2 emissions. This study uses econometric data processing in EViews and discusses balancing economic and environmental factors. The study examines the effects of industrialization and economic development in Indonesia as a developing country on carbon emissions. It emphasizes emissions reduction and sustainable economic growth. The recommendations from the survey include clean technologies, renewable energy, international cooperation, and public awareness. Data availability is scarce, and proposed remedies depend on the government's will. The study results are essential for policymakers in Indonesia and other emerging economies. The study offers a unique viewpoint on the industrial structure, economic development, and dynamics of carbon emissions in Indonesia. With cleaner technologies and evidence-based policies, it is possible to have both economic growth and sustainability.

JEL Classification: O4, O13, L60, F64, Q01

Keywords: Economic Growth; Energy Consumption; Industrialization; Carbon; Sustainability

Equilibrando el crecimiento económico y la intensidad de carbono en Indonesia

Resumen

Es esencial para equilibrar el crecimiento económico y el factor medioambiental. Indonesia ocupa un buen lugar en la economía mundial, como demuestra su rápido desarrollo económico. Es un hito en lo que respecta al precio de la sostenibilidad y el medio ambiente. Esta investigación estudia el crecimiento económico y la intensidad de carbono en Indonesia. Su objetivo es evaluar las compensaciones asociadas a la contribución del desarrollo económico a las emisiones de CO_2. Este estudio utiliza el procesamiento econométrico de datos en EViews y analiza el equilibrio entre los factores económicos y medioambientales. El estudio examina los efectos de la industrialización y el desarrollo económico en Indonesia como país en desarrollo sobre las emisiones de carbono. Hace hincapié en la reducción de emisiones y el crecimiento económico sostenible. Entre las recomendaciones del estudio figuran las tecnologías limpias, las energías renovables, la cooperación internacional y la concienciación pública. La disponibilidad de datos es escasa, y las soluciones propuestas dependen de la voluntad del gobierno. Los resultados del estudio son esenciales para los responsables políticos de Indonesia y otras economías emergentes. El estudio ofrece un punto de vista único sobre la estructura industrial, el desarrollo económico y la dinámica de las emisiones de carbono en Indonesia. Con tecnologías más limpias y políticas basadas en pruebas, es posible tener tanto crecimiento económico como sostenibilidad.

Clasificación JEL: O4, O13, L60, F64, Q01

Palabras clave: Crecimiento Económico, Consumo de energía, Industrialización, Carbón, Sostenibilidad

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* No source of funding for research development

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1. Introduction

Recently, there has been an urgency to have balanced economic development and the environment. There is an interesting case study for the rest of the world, especially Indonesia, a country similar to the Southeast Asian region, one of the biggest countries in the world by population and a rapidly growing economy. Southeast Asian countries are now at the stage of industrialization, which has trade-offs between higher carbon emissions and more significant economic growth. The challenge of the century is supplying food to a growing population. Present tendencies are declining of natural resources and non-renewable sustains (Herrmann,2014).

According to Elfaki et al. (2021), rising economic growth and industrialization enhance economic growth prospects for Indonesia. In the long run, economic growth is driven by industrialization, energy usage, and financial development. Also driven by a growing population, urbanization, and natural resource-rich sectors, the development propelled Indonesia to be one of the strongest economies. Still, this industrialization phase has raised many alarm bells regarding its environmental impact, particularly concerning carbon intensity.

It is crucial to comprehend the role of economic growth and industrialization on the carbon intensity in Indonesia. This developmental path has consequences for the Indonesian people and the world, which is moving towards fighting climate change and protecting the environment. Glaeser & Glaser (2010) examine the influence of globalization and climate change on livelihoods along the coast of Indonesia and emphasize the need for multi-level and interdisciplinary research in an era of environmental change characterized by both local and global drivers.

The study aims: (1) There is evidence of potential trade-offs between industrialization gains and environmental losses by delineating the associations between industrialization, carbon intensity, and economic growth. It is essential to see whether development will ever produce more carbon or whether we can develop into more carbon-free paths. (2) Better policy implication from the study findings Policymakers in Indonesia and other similar economies will benefit from insights into reconciling efforts to grow their economies with the need to reduce carbon and create an environmentally sustainable future.

National income measures a country's economic output and gains over a year. Gross Domestic Product (GDP) is the aggregate value of all goods and services produced within a nation, in this case, by citizens, even if a portion of the income is not spent there (Todaro & Smith, 2014). The Importance of Industrial Output and Energy Consumption to National Income correlates with renewable energy usage and GDP development for South Asian countries, contributing directly to GDP, jobs, tax revenue, and foreign exchange (human capital and R&D). At the same time, Bangladesh and Pakistan show a negative long-term relationship, and Sri Lanka positively correlated with India in the short term (Rahman et al., 2023). Furthermore, industrialism can encourage the development of new technologies and production methods. Industrialism, technical progress, city life, and environmental problems have disturbed the balance of ecological of the earth, as a result of which climate change and many other related issues have been caused (Ali et al., 2022). Long-term sustainability is key to managing the environmental impact and ensuring stable incomes over the long run. Indonesia's income levels increased through industrialization, and there may be more carbon intensity. As per Kusumawardhani et al. (2022), economic growth and industrial value added

DOI: https://doi.org/10.21919/remef.v20i3.1030

in Indonesia positively influence CO2 emissions in the short or long run. Energy consumption, to some extent, leads to emissions, but only in the long term, so cleaner technologies and a sustainable way of handling energy are essential to avoid disasters in the long term.

Common theoretical perspectives of sustainable development are based on achieving economic growth and managing environmental quality. Nevertheless, economists have different views on the balance and the relationship between economic growth and sustainable development (Weber et al. (2024). Once the basic concepts and principles of sustainable development are understood, the analytical tools provided by conventional economic theory can be applied (Todaro & Smith 2015). This includes discounting future social benefits correctly, addressing market imperfections (focusing on externalities and public goods), and treating natural capital as a capital stock instead of a flow of consumption. It highlights sustainable natural resource management, pollution control, and renewable energy sources. Development policies must balance sustainability and economy and environmental protection and development. According to Correa et al. (2022), implications for public and planetary health: ecological economics. It challenges GDP and argues for sustainability and well-being-oriented development.

One of the economic theories that suggests an inverted U-shape between per capita income and environmental degradation is the Environmental Kuznets Curve (EKC). Kuznets proposed the U-shaped hypothesis (Younsi & Bechtini, 2018), which suggests that income inequality rises with economic growth and financial development in the early stages but falls later as the economy matures in the early stages of development, environmental degradation and pollution increase along with income levels. However, the environmental impact begins to diminish again at higher income levels as technological advances and higher demand for environmental quality take over. In other words, with a nation's income rising, its environmental impact and pollution will also increase. The EKC theory poses the question of the relationship between economic growth and the environment, which is the primary objective of the current study. The Environmental Kuznets Curve implies that environmental degradation is positively associated with income growth for only the early stages of development. Irrespective of industrialization and income development, we can benefit from it for carbon intensity dynamisms used in Indonesia. The Environmental Kuznets Curve illustrates that pollution rises with income per capita and then falls for some pollutants—including crucial ones such as greenhouse gases (Todaro & Smith, 2015).

Decoupling theory refers to the decoupling of economic growth from resource use and environmental impact. It refers to the process of economic development that meets economic growth while minimizing the decommissioning of natural resources to provide sustainable development (Scheel et al., 2020). This means a country can experience economic growth while the consumption of resources or environmental harm does not correspond. Decoupling can occur in multiple ways, such as circularity, resource efficiency, innovation technology, or design. The decoupling theory is highly relevant because it assesses how Indonesia can separate economic growth from environmental harm. This concept helps evaluate whether the country is on a path to reduce carbon intensity while continuing to grow economically.

The hypothesis for this study in the case of Indonesia is as follows: (1) As Indonesia advances in its industrialization path and income levels rise, carbon intensity is predicted to increase. It is associated with the early stages of the Environmental Kuznets Curve (EKC), which are characterized by resource-intensive industrial activity and more significant emissions. (2) In the longer term, as the income levels of Indonesians grow further, cleaner technologies must be adopted, and a declining trend in carbon intensity is expected. They aspire to achieve sustainable development and join the worldwide call to cut carbon emissions.

This paper examines Indonesia's economic growth, industrialization, energy consumption, and carbon emissions data and empirically tests these theories. The study uses rigorous statistical approaches and econometric modeling to investigate the relationship between economic advancement and environmental impact and a more profound knowledge of the difficulties and potential of national welfare and sustainability in Indonesia.

2. Methodology

The methodology collects crucial data from credible sources to demonstrate links between Indonesia's economic growth, industrialization, and carbon intensity. Key economic metrics such as GDP, industrial output, and energy consumption are collected. The World Bank provides data on CO2 emissions and GDP. Data on pure minerals processed into glass, ceramics, and cement are derived from the Indonesian Central Statistics Agency (Badan Pusat Statistik/BPS). Data on energy consumption is used from Our World Data.

The study implemented a unit root test and cointegration analysis to test whether the time-series data are stationary; hence, we conduct unit root tests, i.e., (Augmented Dickey-Fuller (ADF) and Phillips-Perron–Perron (PP) tests. Stationarity is a requirement, but not a strong one, because an additional regression analysis conducted for (non-stationary) data results in false estimates. Using the Johansen cointegration test, the authors examined long-run relationships (GDP, industrial output, energy consumption, and CO2 emission). A relationship allows us to interpret these variables meaningfully using the most recent advanced econometric techniques.

The data analysis involves searching for patterns and external information from the collected source. By analyzing the underlying relationship between carbon emissions, economic indicators, and industrial activities, the study demonstrates how a development trajectory of carbon intensity change unfolds during economic development. Such analyses help evaluate whether the Indonesian industrialization path is an EKC path. The econometric model contains major economic indicators, GDP, industrial output, and energy consumption in the following equation:

$$\mathrm{LnPCO_2} = a + b\ \mathrm{lnPGDP} + c\ \mathrm{lnPIO} + d\ \mathrm{lnPEC} + \varepsilon \tag{1}$$

Where:

- PCO_2 shows carbon emissions per capita (a proxy for environmental damage).
- $PGDP$ signifies per capita economic output or Gross Domestic Product.
- PIO denotes per capita industrial output.
- PEC represents per capita energy consumption.
- α, b, c, and d are parameters which determined by empirical analysis.
- ε is the error term capturing unobserved factors.

This approach gathers qualitative data from credible sources to establish connections between Indonesia's economic growth, industrialization, and carbon intensity. Key economic metrics such as GDP, industrial output, and energy consumption are collected. The World Bank provides data on CO2 emissions and GDP. Data on pure minerals processed into glass, ceramics, and cement are derived from the Indonesian Central Statistics Agency (Badan Pusat Statistik/BPS). Data on energy consumption is used from Our World Data.

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The analysis seeks to ascertain whether the model holds in the Indonesian context, specifically whether a turning point exists beyond which economic development leads to reduced carbon intensity. The model includes GDP, industrial output, and energy consumption as determinants to explain the multi-dimensional nexus between economic growth, industrialization, and environmental impact. The stationarity of the time series data was tested using the ADF, and PP tests and a Johansen Cointegration test was used to test long-run relationships. The Breusch-Godfrey Serial Correlation LM Test shows that the time-series data has no autocorrelation, and the Breusch-Pagan-Godfrey test confirms no heteroskedasticity in time-series data. These data were validated using the OLS method. All econometric tests and estimation of long-run equations were realized in EViews Software.

3. Results and Discussion

3.1 Results

Figure 1 shows Indonesia's per capita CO_2, GDP, industrial output, and energy consumption data from 1995–2021 (World Bank, 2023; Badan Pusat Statistik, 2023; Ritchie, Roser & Rosado (2022). Per capita, CO2 shows a rising behavior from 1995 until 2013 and then exhibited fluctuating characteristics until 2021. Generally, the per capita carbon dioxide emissions are on an upward slope. Total per capita CO2 emissions began at 1.129 tons in 1995, gradually increasing to 2.449 tons in 2021. The average PCO2 emissions during this period was 1.678 tons.

The gross domestic product per capita (PGDP) shows an upward trend with ups and downs. Values are generally higher, indicating the economy's growth in GDP per capita year by year. The increase in Per capita GDP over the years indicates economic development. In 1995, it was 1.922 US dollars, and in 2021, it was 3.893 US dollars. The PGDP has an average of 2.657 US dollars over the period. Industrial Output per Capita (PIO) shows irregularity with ups and downs. It has increased drastically, from IDR 32.815 in 1995 to IDR 853.462 in 2021. During that period, the average PIO was IDR 391.071.

While the overall energy consumption per capita (PEC) curve is increasing, it fluctuates around 2000 - 2010. Energy consumption rose continuously, from 4,392 kWh in 1995 to 8,432 kWh in 2021. The average PEC during the evaluation period was 6,669 kWh.

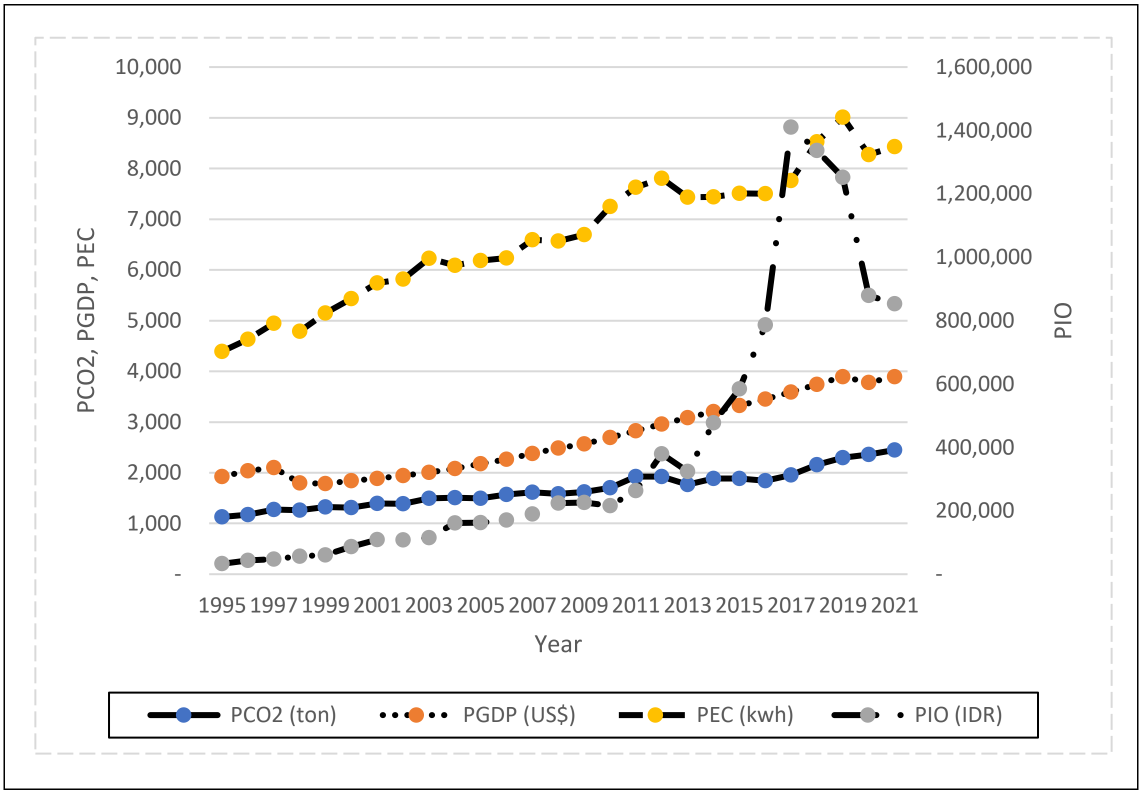

Figure 1. Trends in per capita CO2 Emissions, GDP, Industrial Output, and Energy Consumption of Indonesia (Source: World Bank, 2023; Ritchie, Roser, & Rosado, 2022; Badan Pusat Statistik, 2023, Data Processing)

Unit roots in time-series data were ascertained using the AugueDickey-Fuller (ADF) tests of EViews Statistical Data Processing. Unit root Test is an approach used to test for the non–stationary of time series data (Barry & Bernarto, 2020). A null hypothesis implies the presence of a unit root - non-stationarity, whereas the alternative hypothesis suggests stationarity. The results of ADF and PP unit root testing are shown in Table 1. LNPCO2 and LNPEC are stationary at the level, indicating no unit root, while LNPGDP and LNPIO are stationary at the first difference, according to the analysis. This finding implies that LNPCO2, LNPEC, LNPGDP, and LNPIO are suitable for further study, including cointegration tests, to explore their long-run relationships.

Table 1. Unit Root Tests

Statistic/ Diagnostic	**LNPCO₂**	**LNPGDP**	**LNPEC**	**LNPIO**
	Level with Trend and Intercept	1st difference with Intercept	Level with Intercept	1st difference with intercept
Test statistic ADF (t-Statistic)	-3.850716	-4.021274	-3.048883	-4.474597
Prob	0.0304**	0.0050**	0.0473**	0.0017**
Critical value 1% Level 5% Level	 -4.374307 -3.603202	 -3.724070 -2.986225	 -3.808546 -3.020686	 -3.724070 -2.986225

Statistic/ Diagnostic	$LNPCO_2$	LNPGDP	LNPEC	LNPIO
	Level with Trend and Intercept	1st difference with Intercept	Level with Intercept	1st difference with intercept
10% Level	-3.238054	-2.632604	-2.650413	-2.632604

Source: Data processing, 2023

According to Table 1, two variables (LNPCO2 and LNPEC) are at the level, while the other two (LNPGDP and LNPIO) are at the first difference. This observation suggests that the cointegration test should be performed. The proper lag time is selected to study variable behavior and relationships thoroughly. Cointegration testing helps understand economic relationships and ideas by comparing long-run and short-run models to actual economic data (Yussuf, 2021). Table 2 presents the results of three criteria, with lag 1 showing the optimal choice, as indicated by asterisks (*) denoting the best lag result for each measure. Therefore a lag length of 1 is chosen for the subsequent analysis, since it maximizes the results on all criteria.

Table 2. Optimum Lag Test

Lag	LogL	LR	FPE	AIC	SC	HQ
0	85.69292	NA	1.71e-08	-6.53543	-6.34041	-6.48134
1	166.6740	129.56*	9.6e-11*	-11.733*	-10.758*	-11.463*
2	176.9595	13.16542	1.70e-10	-11.2767	-9.52158	-10.7899

Source: Data processing, 2023

After determining the Lag Optimal, its stability is examined, which is crucial for subsequent tests. The stability requirement dictates that the modulus values must be less than 1. Table 3 reveals that all the modulus values meet this criterion, indicating that the lag fulfills the stability requirement.

Table 3. Stability Lag Optimus Test

Root	Modulus
0.969835	0.969835
0.047742 - 0.735636i	0.737183
0.047742 + 0.735636i	0.737183
0.631169 – 0.187442i	0.658414
0.631169 + 0.187442i	0.658414
-0.307397	0.307397
0.213394	0.213394
0.073097	0.073097

Source: Data processing, 2023

Trace and Max-Eigenvalue Test for Cointegration given in Table 4. The trace statistic on the None hypothesis exceeds the 0.05 significance level critical value (p-value = 0.0250), suggesting one or more cointegrating equation. Similarly, on the null of no cointegration, the Max-Eigen statistic is greater than the critical value at the 0.05 significance level (p-value of 0.0320), suggesting the existence of at least one cointegrating equation. At least one long-run relationship between the variables exist (at the 0.05 significance level), one cointegrating equation found.

Table 4. Johansen Cointegration Test Result

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized		Trace	0.05	
No. of CE(s)	**Eigenvalue**	**Statistic**	**Critical Value**	**Prob.****
None *	0.687414	50.92998	47.85613	0.0250
At most 1	0.447175	21.85807	29.79707	0.3064
At most 2	0.226331	7.040228	15.49471	0.5730
At most 3	0.024688	0.624950	3.841465	0.4292
Trace test indicates one cointegrating eqn(s) at the level 0.05 level				
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized		**Max-Eigen**	**0.05**	
No. of CE(s)	**Eigenvalue**	**Statistic**	**Critical Value**	**Prob.****
None *	0.687414	29.07190	27.58434	0.0320
At most 1	0.447175	14.81785	21.13162	0.3019
At most 2	0.226331	6.415278	14.26460	0.5605
At most 3	0.024688	0.624950	3.841465	0.4292
The Max-eigenvalue test indicates one cointegrating eqn(s) at 0.05.				
Source: Data processing, 2023				

According to the Table 5, each one unit increase in GDP causes 0.217316 unit decline in the long-term CO2 emissions. CO2 emissions usually decline as GDP rises, potentially indicating a link between the growth of the economy and a healthy environment. For each unit increase in energy use, long-term CO_2 emissions decrease by about 0.538730 units. Potential connection over time, when the energy consumption is increasing, the CO_2 emissions decrease.

Table 5. Long-Term Performance of the Vector Error Correction Model

	Variable	Coefficient	t-Statistic
LNPCO2(-1)	LNGDP(-1)	-0.217316	[-5.17613]
	LNPEC(-1)	-0.538730	[-7.83386]
	LNPIO(-1)	-0.017063	[-1.17794]

Source: Data processing, 2023

For every unit of growth in industrial output, long-term CO_2 emissions decline by around 0.017063 units. Despite this unwanted correlation, industrial production has a smaller and statistically less important impact on emissions compared to these two drivers (GDP and energy consumption).

Table 6. Short-Term Vector Error Correction Model

	Variable	**Coefficient**	**t-Statistic**
D(LNPCO2)	CointEq1	-1.575501	[-3.78286]
	D(LNPCO2(-1))	0.412178	[1.14010]
	D(LNPGDP(-1))	-0.204542	[-0.86367]
	D(LNPEC(-1))	-0.037550	[-0.09855]
	D(LNPIO(-1))	0.008322	[0.17810]
	C	0.014660	[1.22346]
D(LNPGDP)	CointEq1	0.583787	[1.47423]
	D(LNPCO2(-1))	-0.436105	[-1.268710]

	D(LNPGDP(-1))	0.333647	[1.48170]
	D(LNPEC(-1))	0.068164	[0.18815]
	D(LNPIO(-1))	0.038236	[0.86057]
	C	0.020671	[1.81435]
D(LNPEC)	CointEq1	-0.855037	[-2.20901]
	D(LNPCO2(-1))	0.353687	[1.05266]
	D(LNPGDP(-1))	-0.380016	[-1.72654]
	D(LNPEC(-1))	-0.211433	[-0.59706]
	D(LNPIO(-1))	0.025514	[0.58748]
	C	0.027635	[2.48155]
D(LNPIO)	CointEq1	- 1.099857	[-0.51349]
	D(LNPCO2(-1))	0.004719	[0.00254]
	D(LNPGDP(-1))	0.089025	[0.07309]
	D(LNPEC(-1))	-0.031737	[-0.01620]
	D(LNPIO(-1))	0.062208	[0.25885]
	C	0.108932	[1.76767]

Source: Data processing, 2023

The short-term connections between the variables are interpreted in Table 6. According to the D(LNPCO2) equations, an increase in CO2 emissions of 0.412178 units is connected to the previous emissions increase of one unit at a lag of one period (-1). An increase in short-term GDP of 0.436105 units is associated with a one-unit rise in historical CO2 emissions at a lag of one period (-1). Continuing increased CO_2 emissions of one unit at a lag of one period (-1) linked to the rise in short-term energy consumption of roughly 0.353687 units. Increased previous CO2 emissions with a lag of one period (-1) and an increase of approximately 0.004719 units of the industry's production in the short term are weakly positively correlated. The Granger Causality Test is used to see causality in econometric analysis (Hejduková & Kureková, 2016) to evaluate the causal relationship between each variable and demonstrate the cointegration causes of the variables. The Granger causality test uses a confidence level of 0.10 with a lag length of 1, the ideal lag length. The result of Granger causality test is shown in Table 7.

Table 7. Pairwise Granger Causality Tests

Null Hypothesis:	**Obs**	**F-Statistic**	**Prob.**
LNPGDP is not Granger Cause LNPCO2	26	1.46475	0.2385
LNPCO2 is not Granger Cause LNPGDP		1.48743	0.2350
LNPEC does not affect on Granger Cause LNPCO2	26	3.66572	0.0681
LNPCO2 has no effect on Granger Cause LNPEC		2.20934	0.1508
LNPIO is recognized Granger Cause LNPCO2	26	4.66290	0.0415
LNPCO2 is not Granger Cause LNPIO		0.04946	0.8260
LNPEC is not Granger Cause LNPGDP	26	2.63092	0.1184
LNPGDP is not Granger Cause LNPEC		0.39685	0.5349
LNPIO does not Granger Cause LNPGDP	26	3.02407	0.0954
LNPGDP does not Granger Cause LNPIO		0.88465	0.3567
LNPIO does not affect on Granger Cause LNPEC	26	4.66491	0.0414
LNPEC does not effect on Granger Cause LNPIO		0.08283	0.7761

Pairwise Granger causality tests evaluate whether one variable's historical values may predict another's future. According to the table, historical GDP values and vice versa cannot reliably forecast future CO2 emissions. The link between these two variables is complicated and influenced by several variables, some of which may need to be adequately captured by historical GDP. The CO_2 released in the past has consequences for today's economic growth. Industrial production might relate to CO_2 emission through a persistent mechanism in which past industrial production affects future emissions.

In addition, this study applied novel accounting approaches to evaluate the role of individual drivers and their interaction with each other, such as Impulse Response Function (IRF) and Variance Decomposition (VD). All of these investigations are represented in Figure 2.

Statistically, statisticians utilize the impulse response function analysis to comprehend how a particular variable responds to shocks or changes in other related variables over time. The impact or shock caused by changes in the GDP, energy consumption, and industrial output is examined using the IRF analysis.

This response is shown graphically in Figure 2 of ten years. It allows for comparing what happens to CO2 levels to GDP, energy use, and industrial output change. This also helps to understand the dynamics and interactions between one another and their impact on carbon dioxide. It can illustrate the role of energy and economy-related factors in determining environmental quality and carbon emissions.

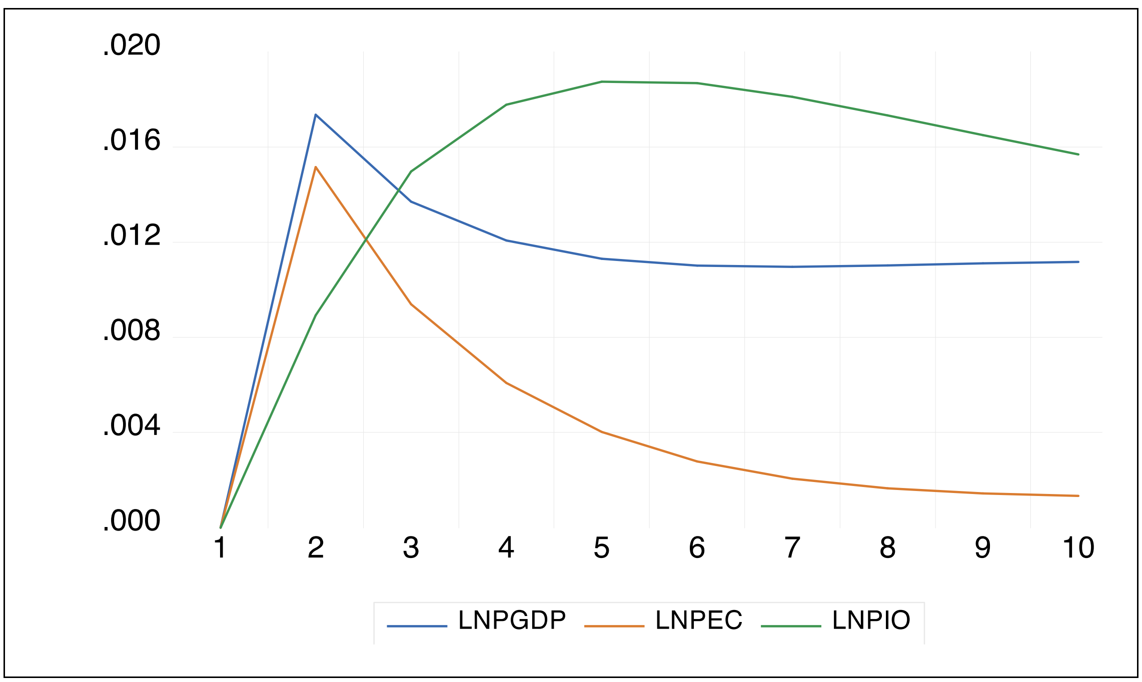

Figure 2. Reaction of PCO2 to the shock from PGDP, PEC, and PIO (Data Processing, 2023)

CO2 response to the GDP shock during ten years regarding the GDP (Gross Domestic Product), energy consumption, and industrial output shocks are shown in Figure 2. Initially, CO_2 emissions rise in response to a shock or shift in GDP. In the first two years, this growth continues. The CO2 emissions started to decline after the second year. It suggests that a shock to GDP causes an increase in CO2 emissions at first but then drops during the following years. A shock in energy consumption causes CO2 emissions to rise initially, much like the GDP shock did. The first two years of this growth were noted, then CO2 emissions started to drop. The impact of the energy consumption shock causes more significant CO2 emissions at first, followed by a drop, the same as the PGDP shock. CO_2 emissions rise in response to a shock in industrial output. In the first five to six years, there is a rise. There is a downward tendency in CO2 emissions after year six. CO_2 emissions initially increase in response to the shock of industrial output before gradually declining.

Throughout the ten years, the reaction to a shock generated by a change is continuously higher than the reaction to a shock caused by a shift in energy consumption. This implies that the variation in GDP is a key factor on which CO2 emissions are highly dependent, as opposed to changes in energy consumption. The third-year response of CO2 emissions to a GDP shock exceeds the response of industrial output to a shock from the first to third year. This proves that GDP differences are more significant in affecting CO2 in this period than in industrial production benchmarked differences. The reaction of CO2 emissions to a shock in energy consumption remains above that of a shock to industrial output long after the first year until approximately year two and a half. It implies that the change in energy use in terms of CO2 is more effective than that of industrial production over this period. Notably, for a period lasting approximately from year three to year ten, the impact of a shock in industrial output on CO2 emissions exceeds the effect of a shock in GDP. Industrial production has more impact on CO2 emissions compared to economic growth.

The Variance Decomposition (VD) study, performed over a period of ten years, examined the impact of variables PGDP, PEC, and PIO on PCO2. The data for this study are annual data from 1995 to 2021, given in Table 8.

Table 8. PCO2 Variance Decomposition

Period	S.E.	LNPCO2	LNPGDP	LNPEC	LNPIO
1	0.044301	100.0000	0.000000	0.000000	0.000000
2	0.052264	77.64626	11.02429	8.411175	2.918274
3	0.057919	66.88690	14.57438	9.478742	9.059984
4	0.062788	59.17353	16.09558	9.002480	15.72841
5	0.067115	53.27752	16.92218	8.238130	21.56217
6	0.070956	48.70418	17.54892	7.523731	26.22317
7	0.074363	45.11096	18.15377	6.926399	29.80887
8	0.077396	42.23871	18.78878	6.041665	32.53202
9	0.080116	39.90134	19.45719	6.041665	34.59980
10	0.082577	37.96062	20.14563	5.712833	36.18092

Source: Data processing, 2024

Table 8 shows a variance decomposition of CO2 for an impulse/shock from different sources over the short run. In the initial phase, the shock to CO_2 is exclusively attributed to CO_2 itself. It shows that the historical values are the primary driver of the peak of CO2 emissions in this first period. The value history of CO_2 emissions is the most critical factor to affect current CO_2 emissions. Historical CO_2 emission sources, such as industrial activities, energy consumption, and economic activities, influence present-day CO_2 emissions. On CO2 emissions, 77.6 percent is still attributed to past levels in subsequent periods. This underscores how life-cycle persistent CO_2 emissions are over the long term; historical emissions are the primary driver for current CO_2 emissions. Alternatively, other variables account for part of the variance in CO_2 emissions. It represents about 11.02 percent of GDP. Indicates that CO2 emissions are starting to respond to economic growth. This could also mean that emissions are increasing due to heightened economic activity. Energy consumption is such a significant contributor to emissions, accounting for 8.41 percent, that its importance cannot be overemphasized. More emissions could inherit more energy use. Industrial output is estimated to be responsible for about 2.92 percent of CO2 emissions, a small but significant role. At this stage, industrial processes might result in emissions.

The variation decomposition pattern in the following periods is the same, and in the tenth period, the further decomposition of factors influencing CO2 emissions. They continue to hold the controlling interest, roughly 37.96 percent. This means that emissions from a long time ago remain a significant and lasting part of the amount of CO2 in the atmosphere today. Ten periods later, the critical effect of past emissions on present emissions underscores the lasting impact on the ecosystem. Historical levels of GDP were scaled at the beginning of the ninth period to show that CO2 emissions by the ninth period ranged by approximately 20.15 percent based on the historical levels of GDP. It suggests that differences in emissions are still tied to economic growth. More economic growth means more energy consumption and production, raising emissions.

The influence of previous energy consumption in moving CO2 emissions is approximately 5.71 percent. This indicates that emissions right now are still affected by energy use trends in the past. Changes in energy use behavior can influence emission trends. Industrial output has a historic share of 36.18 percent and it is used to explain this difference in CO2 emissions. Long-term changes in emissions are influenced by industrial output as one of the most climatically significant socioeconomic factors. Significant emissions can be produced by industrial processes and activities, and past industrial output patterns continue to influence contemporary emissions.

3.2 Discussion

Based on this study, Indonesia's per capita carbon dioxide emissions climbed steadily, reaching a peak around 2013. According to Sasana & Putri (2017), carbon dioxide emissions are already a global problem, primarily in developing countries, including Indonesia.

From 1995 to 2021, Indonesia's GDP per capita consistently increased, showing fluctuations, indicating long-term economic progress. Irwansyah et al. (2022) stated that Indonesia saw erratic annual economic development, with a low point in 1998 due to the financial crisis and a high point the following year. Industrial output per capita exhibits an uneven trend with substantial swings, demonstrating general growth in industrialization throughout time. The cement sector is one of the leading industrial manufacturing outputs, and it is critical to support this by meeting the demand for construction materials. Infrastructure development is essential for Indonesia's economic progress (Noviani et al., 2023).

Energy consumption per capita shows a generally upward trend, particularly from the 2000s to 2010, followed by volatility, demonstrating a general increase in energy consumption per capita. The values typically rise, implying an increase in energy consumption per capita. Rising population

DOI: https://doi.org/10.21919/remef.v20i3.1030

density in Indonesia is linked with higher energy consumption, particularly fuel and electricity (Muzayanah et al., 2022).

Like many developing economies, Indonesia uses hydrocarbons (coal, oil, and natural gas) to generate electricity. This reliance on fossil fuels is a major driver of the country's carbon intensity. The use of hydrocarbons for energy generation in less-developed economies is due to relatively low upfront costs, poor access to renewable energy technologies, and economic reasons. Unlike renewable energy, this trend is typical for emerging economies where industrialization and energy needs exceed the transition to cleaner alternatives (Barua, 2022). Driven by the ongoing industrialization of Indonesia, the energy consumption characteristics will still reflect heavy reliance on these fossil fuels in the short to medium term, leading to persistent carbon emission issues.

According to this study, long-term CO_2 emissions decrease as GDP grows. The United States economy increased from 1982 to 1996 but declined from 1996 to 2013. This trend confirms the presence of an inverted U-shaped Environmental Kuznets Curve (Aslan et al., 2017). Gyamerah and Gil-Alana's (2023) research supports the positive impact of long-term economic expansion on CO2 emissions. Environmental quality will increase when the per capita income hits a tipping point (Chng, 2019).

Increasing energy consumption is related to reduced long-term CO2 emissions, implying a relationship between energy efficiency and lower emissions. Rahmayani et al. (2023) highlight the positive influence of factors such as population growth and increased oil and coal use on CO2 emissions over time. Climate change and environmental problems are global priorities exacerbated by carbon emissions from energy sources (Gyimah et al., 2023). Short-term relationships demonstrate links between rising CO2 emissions and prior emissions. Global energy-related CO2 emissions has recently increased (International Energy Agency, 2023).

Short-term GDP growth in Indonesia is associated with more significant historical CO2 emissions, consistent with Kusumarwardhani et al. (2023) findings on the association between rapid economic growth and increased CO2 emissions. The rise in historical CO2 emissions is connected with increased short-term energy consumption, driven by a significant increase in Indonesia's energy supply (International Energy Agency, 2023). Despite a substantial increase in total emissions, Indonesia's energy-related CO2 emissions per person remain comparatively low at two tons, half the global average.

Short-term CO_2 emissions are caused by neither energy use nor economic expansion. It may imply that policies should be more comprehensive and long-term in nature. Policymakers may need to concentrate on long-term initiatives like carbon pricing, industry restructuring, and subsidies for renewable energy. Placing a price on carbon emissions and connecting it with climate policy objectives, carbon pricing in South Africa encourages emissions reductions and the uptake of clean energy (Qu, 2023).

This study shows that past CO_2 emissions affect present economic growth. Environmental damage brought on by high levels of historical CO2 emissions frequently entails financial consequences in resource depletion, medical expenses, and ecosystem restoration. These expenses may weigh down the economy and restrict expansion. Climate change impacts food and water supplies in developing markets, which causes shortages (Aggarwal & Singh, 2010). Disruptions from climate-related extremes can significantly impact global shipping, trade, and supply chains

(Verschuur et al., 2023). These situations may result in political unrest. They also impede regional economic expansion.

Prior energy consumption patterns may impact current emissions. Understanding how consumer decisions, influenced by money, lifestyle, and tastes, affect energy consumption and emissions will help better comprehend the indirect relationship between energy consumption and CO2 emissions. For producers and customers, there is a need for good communication in green marketing (Machová et al., 2022). When transitioning to a low-carbon economy and achieving the growth sustainably, it is crucial to understand the dynamics between industrial output and CO2 emissions, particularly how past industrial output impacts future emissions (Chen, 2023).

Over a decade, shocks in GDP, energy consumption, and industrial output induce an increase in CO2 emissions in the first two years, followed by a decrease. The study found that throughout a decade, CO2 emissions are initially more responsive to changes in GDP than to changes in energy consumption. However, beginning in year three, industrial activity became the dominant source of CO2 emissions. It is similar to the Wong & Feng (2017) study, China's industrial sector's largest source of CO2 emissions, which has been recognized as industrial activity.

CO2 emissions respond positively to economic growth, industrial output, and energy consumption shocks in the short run. According to Niyonzima et al. (2022), who analyzed CO2 emissions and economic development in 10 countries from 2010 to 2019, economic growth leads to higher energy use and CO2 emissions, with a positive long-run correlation between GDP and emissions. Rising CO2 emissions negatively affect GDP growth in the short term despite energy policies promoting growth. To reduce emissions without hindering economic growth, BRIC countries should invest in energy supply, improve energy efficiency, and strengthen energy conservation policies (Pao & Tsai, 2010).

Diverse strategies are needed to address industrial expansion and environmental sustainability trade-offs. Recognizing that economic growth and sustainability are not mutually exclusive, policymakers should work to integrate them. Particularly in every country's economic and long-term development framework, carbon dioxide (CO2) emissions have become a significant cause for concern (Daniyal et al., 2023).

Promoting green economic practices is critical to addressing the environmental consequences of economic growth (Gyamerah & Gil-Alana, 2023). Promoting green economic practices is both a social and economic opportunity and a moral obligation to safeguard the environment and deal with the consequences of economic expansion. These approaches provide a way to achieve sustainable development, a higher standard of living, and resilience in the face of international difficulties. Therefore, governments, corporations, and people should energetically pursue and support the transition to a green economy. Create thorough strategies for green growth that give sustainable industrialization top priority. This involves a transition of technologies, renewable energy sources, and sustainable practices at an industrial level.

Establish and enforce emissions reduction targets for specific sectors of industry. These targets should promote a reduction in carbon intensity and be both ambitious and achievable. According to Dragomir et al. (2023), policymakers should encourage defined, time-bound goals for short- and medium-term goals, focusing on absolute emissions reduction, to create realistic industry-specific carbon reduction targets.

Establish carbon pricing, which includes carbon tax or carbon cap-and-trade behavioural, that will internalize environmental damage from industrial activities. This motivates businesses to implement cleaner processes. Duggal (2023) states that the burgeoning interest in carbon pricing (including taxes and emissions trading) observed in many Asian countries can help reduce emissions as economically efficiently as possible and deliver on climate targets. The region must find specific policy solutions to problems, including regulated electricity markets, distributional effects, and capacity challenges.

The government should consider regionally distinct environmental policies and encourage interregional coordination and communication to cut carbon emissions successfully (Xu, 2023). Comprehensive Environmental Impact Assessments (EIAs) are required for all significant industrial projects to evaluate potential environmental effects and suggest mitigation measures. In many countries worldwide, EIAs are used to create sustainable management requirements. Since the beginning of the industrial era, anthropogenic carbon dioxide (CO2) emissions have substantially contributed to global warming (Jones et al., 2023). Invest in research and innovation or anything that helps industries move towards greener more sustainable industries as well as conduct ease of doing business in growing industry segments. Green innovation is only achieved if environmental regulations allow investment-based regulation (Chang et al., 2023).

Instead, the focus of the decision-maker should be on improving the process of decision-making and helping to make informed choices. By considering several factors and relationships, complex thinking helps people understand unclear circumstances and make wise decisions (Velázquez et al., 2023). Continuously collect and analyze data to assess whether industrial development correlates with environmental sustainability. Data should be transparent and accessible. This approach incorporates policy deliberations and decisions among stakeholders, such as environmental experts, business stakeholders, and the local community in the area. Non-governmental organizations adopting a grassroots strategy are advised to promote acceptability, trust, and long-term viability (Zikargae et al., 2022).

Create flexible regulations that can change as new information becomes available. Flexibility is crucial to adapt to shifting industrial and environmental dynamics flexibility. Indonesia has set renewable energy targets, but the transition has not been prioritized. The Institute for Essential Services Reform's (ISSR) involvement is crucial in developing a roadmap for renewable energy transition (Anggraini & Indah, 2021). Learn from each other and harmonise action against challenges in the global environment by collaborating with international partners. A study by Avoyan (2022) underlines prioritizing cooperative environments for innovation in sustainable environmental management.

Invest in government agency capacity-building to give them the know-how to create and carry out efficient environmental policies. It is difficult and expensive for the government to focus on enhancing and expanding environmental capability (Nihayah, 2022). Educate people on the value of sustainable development and their part in lowering their carbon footprint. Achieving environmental sustainability while reducing costs is a problem for businesses. The carbon footprint left by regular company operations has to be more widely recognized by organizations (Jackson & Hodgkinson, 2022).

4. Conclusion

This research studies the intertwining of the complexity of economic development and environmental sustainability in Indonesia. It shows the audience the struggle between development and prosperity on one hand and carbon on the other hand. Although these processes tend to lead towards higher emissions, this realisation also leads towards greener, sustainable development approaches. This evidence highlights the importance of tailored approaches to each particular sector. Customized mitigation strategies are essential as carbon intensity varies significantly by industry. In particular, the sector of energy and manufacturing are the most contributors to carbon emissions in Indonesia because both of these sectors are very dependent on fossil-based energy and industrial processes. This, along with other measures discussed, can help policymakers reduce emissions and grow the economy at the same time.

The results also emphasize the vast policy relevance of the study. The results presented in this way can serve as a significant influence for policymakers in Indonesia and other similar-sized economies. They have to blend economic growth with the desperate need to cut carbon emissions and open the door to a more sustainable and eco-friendly future. To effectively confront the aforementioned trade-offs, the promotion of sustainable industrialization through the transition to clean technologies and increased adoption of renewable energy is necessary. This will require creating achievable, sector-specific emissions reduction targets, establishing carbon price mechanisms and performing critical environmental assessments. To achieve these objectives, it is important to encourage innovation in clean technology.

Policymakers' decisions should be based on open and current facts. Participating the appropriate parties in the decision-making process guarantees the policies are well-researched and broadly supported. Policy design should prioritize adaptation and flexibility. Cross-border collaboration can lead to valuable insights and actionable solutions. Moreover, raising public awareness about sustainability issues and public sector capability is also essential. This calls for the formulation of integrated policies that maximise sustainability with economic growth. The regulations should also be flexible. Policies if targeted around the carbon intensity of sectors will perform the best. Promoting clean technology investments would promote sustainable industrialization. Raising public understanding of environmental issues will create a culture of sustainability. Working with international partners can make it easier to share information and resources and successfully address environmental problems.

There is a limitation data availability across different sectors and the complexity of predicting long-term outcomes for policy effectiveness. The effectiveness of proposed strategies may also vary based on political will of the government and resource availability.

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Appendix

Table 4. Dow Jones Industrial Average components in history with more 4,789 rolling returns: 2000-2020.

1	Alcoa Inc.	AA-US	21	International Paper Company	IP-US
2	3M Company	MMM-US	22	JPMorgan Chase & Co.	JPM-US
3	Honeywell International	HON-US	23	Johnson & Johnson	JNJ-US
4	Altria Group Incorporated	MO-US	24	McDonald's Corporation	MCD-US
5	American Express Company	AXP-US	25	Merck & Co., Inc.	MRK-US
6	American International Group, Inc.	AIG-US	26	Nike, Inc.	NKE-US
7	Amgen Inc.	AMGN-US	27	Pfizer Inc.	PFE-US
8	Apple Inc.	AAPL-US	28	Raytheon Technologies Corporation	RTX-US
9	AT&T Inc.	T-US	29	The Boeing Company	BA-US
10	Bank of America Corporation	BAC-US	30	The Coca-Cola Company	KO-US
11	Caterpillar Inc.	CAT-US	31	The Goldman Sachs Group, Inc.	GS-US
12	Chevron Corporation	CVX-US	32	The Home Depot, Inc.	HD-US
13	Cisco Systems, Inc.	CSCO-US	33	The Procter & Gamble Company	PG-US
14	Citigroup Inc.	C-US	34	The Travelers Companies, Inc.	TRV-US
15	DowDuPont Inc.	DD-US	35	The Walt Disney Company	DIS-US
16	Exxon Mobil Corporation	XOM-US	36	UnitedHealth Group Inc.	UNH-US
17	General Electric Company	GE-US	37	Verizon Communications Inc.	VZ-US
18	Hewlett-Packard Company	HPQ-US	38	Walgreens Boots Alliance, Inc.	WBA-US
19	Intel Corporation	INTC-US	39	Walmart Inc.	WMT-US
20	International Business Machines Corporation	IBM-US	40	Dow Jones industrial Average	DJ

Source: own elaboration and data from FactSet.

Table 5. Annual returns statistics: 2000-2020.

						Quantile		
Ticket	**Mean**	**Median**	**Std**	**Kurtosis**	**Skewness**	**25 %**	**50%**	**75%**
AA-US	6.0%	0.2%	58.0%	21.55	3.14	-29.2%	0.2%	28.6%
MMM-US	8.4%	8.1%	19.0%	3.48	0.14	-4.1%	8.1%	21.3%
HON-US	10.4%	12.0%	23.6%	3.42	-0.42	0.1%	12.0%	24.2%
MO-US	12.9%	13.9%	26.9%	7.60	1.28	-2.9%	13.9%	24.1%
AXP-US	9.7%	11.2%	34.1%	12.62	1.74	-10.6%	11.2%	22.8%
AIG-US	-1.0%	0.4%	39.5%	11.15	0.97	-18.7%	0.4%	15.8%
AMGN-US	8.6%	6.3%	21.1%	3.64	0.47	-5.5%	6.3%	22.6%
AAPL-US	39.9%	38.7%	56.4%	4.36	0.77	0.3%	38.7%	66.9%
T.XX1-US	-13.5%	-13.9%	24.7%	2.40	0.15	-32.3%	-13.9%	2.7%
T-US	-0.3%	-0.7%	18.9%	3.28	0.14	-11.1%	-0.7%	11.5%

BAC-US	8.6%	7.3%	40.4%	15.92	1.89	-12.6%	7.3%	23.9%
CAT-US	16.6%	13.3%	34.5%	3.49	0.51	-8.1%	13.3%	38.3%
CVX-US	5.7%	6.4%	19.6%	2.82	- 0.11	-6.2%	6.4%	18.5%
CSCO-US	4.2%	3.9%	31.1%	3.62	-0.00	-15.2%	3.9%	24.2%
C-US	-1.0%	0.3%	35.1%	5.20	0.14	-19.7%	0.3%	16.7%
DOW-US	15.3%	2.4%	49.6%	3.57	1.18	-15.6%	2.4%	19.1%
DD-US	7.3%	3.5%	37.9%	22.64	2.98	-13.3%	3.5%	23.4%
DD.XX1-US	5.5%	3.2%	22.2%	3.97	0.18	-7.0%	3.2%	18.7%
EKDKQ-US	-22.7%	-22.7%	39.4%	4.29	0.52	-44.6%	-22.7%	-1.1%
XOM-US	2.4%	2.0%	19.0%	3.42	- 0.13	-10.3%	2.0%	14.8%
GE-US	-3.2%	-0.1%	28.7%	4.86	0.35	-22.0%	-0.1%	13.5%
MTLQQ-US	-26.5%	-25.2%	39.7%	2.30	0.02	-51.7%	-25.2%	0.4%
HPQ-US	6.3%	1.0%	35.9%	2.77	0.37	-21.3%	1.0%	34.3%
INTC-US	4.5%	4.4%	29.6%	3.62	0.33	-15.1%	4.4%	22.5%
IBM-US	2.3%	-0.2%	18.6%	3.10	0.52	-10.7%	-0.2%	14.6%
IP-US	7.0%	4.0%	40.8%	35.50	4.12	-13.3%	4.0%	18.2%
JPM-US	7.7%	4.8%	26.8%	4.50	0.76	-10.0%	4.8%	23.3%
JNJ-US	7.0%	6.7%	12.6%	2.79	0.23	-1.8%	6.7%	14.9%
MDLZ-US	5.9%	6.7%	14.4%	2.66	-0.23	-3.5%	6.7%	16.0%
MCD-US	11.6%	10.8%	21.3%	6.45	0.48	-0.5%	10.8%	23.9%
MRK-US	3.4%	3.1%	23.1%	2.64	-0.04	-11.8%	3.1%	19.9%
MSFT-US	11.7%	9.3%	23.5%	2.90	0.03	-4.2%	9.3%	29.0%
NKE-US	18.7%	20.4%	20.6%	3.08	0.02	3.8%	20.4%	33.3%
PFE-US	1.1%	2.0%	17.0%	2.44	-0.06	-11.5%	2.0%	13.3%
RTX-US	8.7%	10.1%	20.3%	3.21	0.07	-4.5%	10.1%	21.2%
CRM-US	35.0%	28.9%	41.7%	4.35	0.86	11.1%	28.9%	51.6%
BA-US	14.0%	14.3%	37.4%	2.90	0.18	-8.8%	14.3%	37.1%
KO-US	3.9%	4.4%	13.8%	2.81	-0.24	-3.9%	4.4%	13.1%
GS-US	9.4%	5.7%	32.4%	5.96	0.98	-12.5%	5.7%	28.3%
HD-US	11.7%	13.5%	25.1%	3.26	- 0.19	-2.2%	13.5%	27.0%
PG-US	7.8%	7.0%	14.2%	4.18	0.27	0.8%	7.0%	14.3%
TRV-US	8.0%	8.9%	19.5%	5.41	0.50	-3.4%	8.9%	18.8%
DIS-US	10.4%	11.3%	26.1%	3.40	0.24	-7.7%	11.3%	29.1%
UNH-US	22.4%	24.1%	27.4%	4.89	-0.26	8.9%	24.1%	38.6%
VZ-US	2.3%	1.4%	15.9%	3.12	-0.09	-7.2%	1.4%	13.2%
V-US	25.1%	24.6%	20.1%	2.98	-0.10	12.9%	24.6%	39.6%
WBA-US	4.3%	-0.5%	24.7%	2.93	0.69	-14.9%	-0.5%	20.8%
WMT-US	5.7%	5.0%	14.3%	3.36	0.31	-3.5%	5.0%	14.9%
DJIA	6.2%	7.3%	14.9%	4.54	- 0.48	-0.2%	7.3%	15.3%
TBILLS	1.9%	1.3%	1.8%	2.68	0.92	0.3%	1.3%	2.7%

Source: own elaboration and data from FactSet.