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Examining the Decoupling Phenomenon Between Economic Growth and Carbon Dioxide Emissions: Empirical Study on Four Countries During the Period (1990-2020)

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فحص ظاهرة الانفصال بين النمو الاقتصادي وانبعاثات ثاني أكسيد الكربون.. دراسة قياسية حول أربع دول خلال الفترة (1990–2020)

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Abstract

With the growing concern for climate change and minimizing environmental degradation, the relation between CO_2 emissions and economic growth has been grabbing attention as an important matter to look into and study. In this paper, the decoupling states between CO_2 emissions and economic growth is discussed and this phenomenon is examined in two developed countries (USA & Japan) and two developing countries (Egypt & India) stating the calculated values, based on the adopted methodology, and defining each decoupling state of each country in six time periods from 1990 to 2020. The causes of the decoupling state in each country are discussed with exploring the reasons for some spikes in CO_2 emissions, while maintaining economic growth, or in some cases declining economic growth. Finally, the trend of the decoupling forms in each country is depicted based on Environmental Kuznets Curve (EKC), Brundtland Curve and the Daly curve. The USA achieved a level of decline in CO_2 emissions while maintaining positive GDP growth rates, In Japan, the level of decoupling can be best described by the Daly curve in the first couple of periods. Observing Egypt, the Daly curve described the first couple of periods only, while in India, Brundtland's curve can describe India's situation. Based on these empirical results, important policy implications are suggested.

Keywords: Economic growth; CO_2 emissions; decoupling; decoupling elasticity; developing countries; Tapio elastic analysis method

Introduction

Environmental degradation is one of the biggest problems facing us today. The long-, short-term, local, regional, and global effects of the severe pollution that has been occurring for many years are dreadful. Among all greenhouse gases that impact the environment, CO_2 is responsible for more than 60% of environmental degradation while promoting economic growth. As environmental pollution contaminates drinking water and air, it hurts ecosystems. The effects of climate change ultimately hurt society in terms of health, poverty, living conditions, hunger, and population, among other things. Thus, economic growth is often pointed out as the cause of environmental issues based on the notion that increased production equals increased pollution. However, some researchers hypothesise that the relationship between economic growth and environmental degradation is more complex than that. Some even argue that economic growth could improve the environment.

Many models have been tested to examine the relationship between various environmental indicators and economic growth. However, the Environmental Kuznets Curve (EKC) hypothesis provides the systematic foundation for environmental degradation and economic growth. The Kuznets Curve hypothesises that at the initial phase of economic development, the country starts industrial processes on a large scale along with technological inclusion, which leads to an escalation in environmental degradation (Panayotou, 1993). However, as the initial stage ends, the country experiences a significant rise in per capita income, or GDP along with institutional quality, and awareness about environmental issues increases. As a result, environmental degradation decreases because the overall benefits of economic growth are shared with the entire society.

Several propositions have been put forward to explain the phenomenon. So far, nobody seems to have suggested that heavy industrial processes would have stopped altogether. Rather, it has been argued that its weight has increased and, thus, nullified the positive technical development. (Tapio, 2005)

In this study, we are addressing this problem by using a method of calculating the degree of decoupling between economic growth and environmental degradation to compare two developed countries: the United States, which is considered an established developed country, and a relatively new developed country represented in Japan, and two developing countries with huge populations, growing energy demand, and the urge to achieve higher economic growth (Egypt and India) over the course of 30 years between 1990 and 2020. Ultimately, answering the question of whether economic prosperity could be achieved while preventing environmental degradation and how the differences between developed and developing countries affect the equation. The research regarding the decoupling phenomenon is very limited. Not to mention, to signify our thesis, we used the USA and India, as they are two of the most significant CO_2 emissions producers, according to the World Bank data.

The research is structured as follows: The first part is a study of the relation between GDP growth and CO_2 emissions in the previous theoretical and empirical literature, followed by a study of methodology and data analysis. Following this, the empirical part of the study consists of two sections: Examining decoupling in the selected cases and stating the key findings of the study. Finally, the last part concludes with the main findings and provides some policy recommendations.

Literature review

The already existing research concerning the correlation between economic growth and environmental degradation has increased in number in the past few decades. The correlation between the two factors has been analyzed in numerous papers using a variety of methods, as discussed below, providing mixed evidence. Some of them find that the relationship between CO_2 emissions and economic growth is negative, or that it is initially positive but then turns negative; other papers report instead a positive relationship. The upcoming section presents a review of both theoretical and empirical studies.

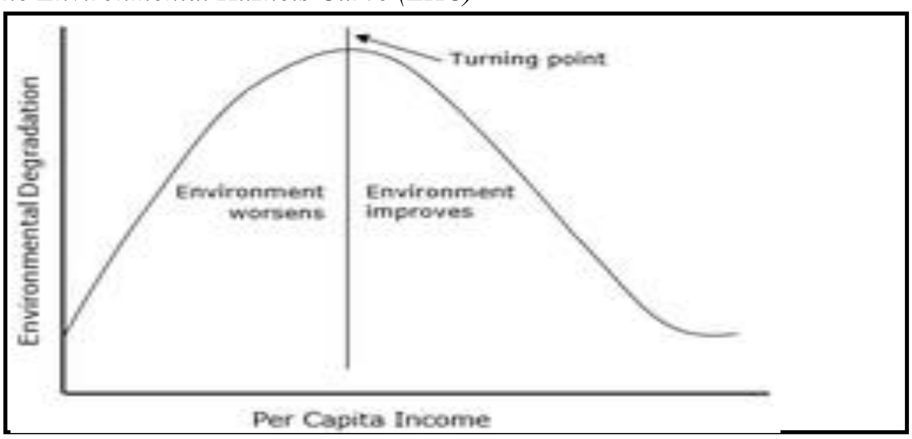
Theoretical framework

The relationship between economic growth and the environment is a relatively new subject in economics, and due to this, there are not many established theories in the area. However, the most extensive theory is the EKC theory, which has theoretical roots in classical economic topics such as income elasticity, trade, and competitive markets. Two major theories followed the EKC which are the Brundtland Curve and the Daly Curve. afterward, we delve into the Porter Hypothesis, which presents an alternative perspective. This section analyzes three theories and the Porter Hypothesis, describing the connection between economic growth and environmental damage, and then concludes with a theoretical summary.

The environmental Kuznets curve (EKC)

The relation between ambient CO_2 concentrations and GDP per capita was initially identified as the Environmental Kuznets Curve (EKC) in the World Development Report of the World Bank (1992). Per capita income and Carbon dioxide concentration is directly correlated up to a certain point (called a turning point) in the EKC's inverted U shape, after which the trend reverses and the opposite relationship is seen. The EKC is represented as follows in Figure (1); per capita GDP is represented on the x-axis and environmental damage on the y-axis.

Figure 1.
The Environmental Kuznets Curve (EKC)



Source: (World Bank, 1992).

One must identify the many components of the EKC hypothesis to get a more comprehensive understanding of the mechanisms underlying the shape of the EKC. The scale effect refers to the initial acceleration of environmental damage as economies grow. Increased input is necessary for increased output, which results in greater use of natural resources and increased pollution. The EKC's form suggests the possibility of additional mechanisms that counteract the scale effect. Together, these factors have the effect of reducing environmental deterioration as economies develop and could be listed as follows:

The technology effects. As fundamental economic theory explains, businesses attempt to reduce the cost of manufacturing by making investments both in already successful technology and in the internal development of new technology, all to increase profits. Less input is needed for more efficient production, which is expected to lower pollution levels (Bozkurt & Akan, 2014).

The composition effects. The composition impact refers to the relative change in the composition of commodities and services produced when an industry-heavy economy transitions to a more service-intensive economy happens, which can be attributed to an increased need for R&D. In other words, if the output mix changes, pollution levels might not rise in line with economic growth (Cederborg & Snöbohm, 2016).

Consequences of global trade

Large variations in the preconditions of trade between developed and developing countries result from richer countries using more high-tech equipment, investing more in R&D, and operating in a more service-centralised economy. The results of international trade divide global production into "dirty" production with high levels of pollution in developing countries and "green" production with lower levels of pollution in developed countries (Cederborg & Snöbohm, 2016).

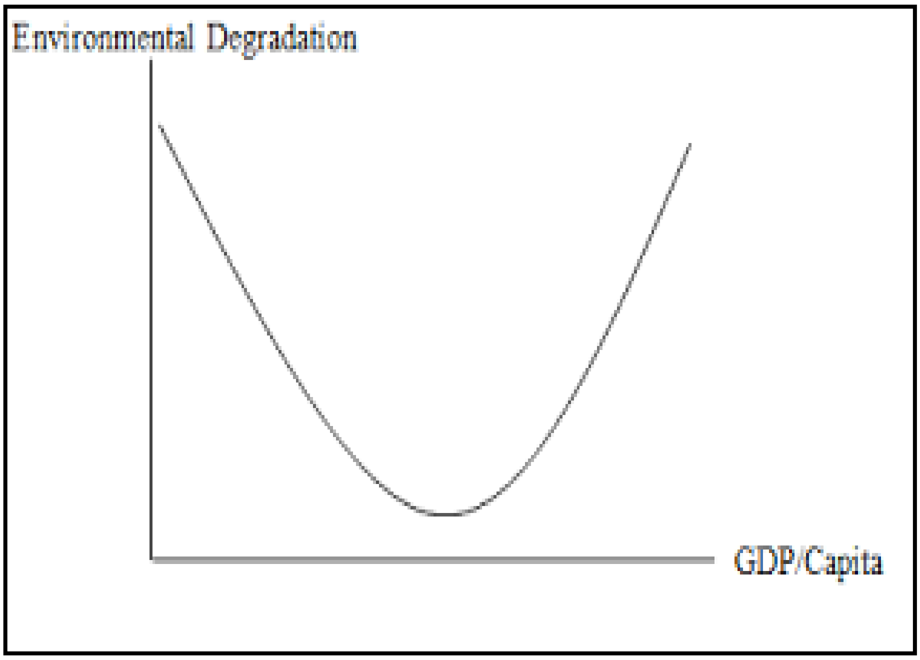
Increased demand for a clean environment. The desire to pay for a clean environment increases along with income. At some point, the willingness to pay for a clean planet increases relatively more than the increase in income. Customers demonstrate this by selecting products that have less of an impact on the environment, making donations to environmental charities, and voting for political candidates who share their values.

Strengthened regulations. Emission taxes and subsidies, emission standards, and property rights are a few of the several sorts of regulations that are utilised to lower pollution levels. The median voter theorem might provide some insight into our situation because people have a greater need for a clean environment as income grows. According to the median voter theorem, officials should try to get as many votes as possible by adapting their policies to the median voter (Bozkurt & Akan, 2014).

The Brundtland curve

Another perspective on the connection between GDP and environmental damage is provided in the 1978 "Our Future" WCED study, also referred to as the Brundtland report. The report's authors contend that poor countries initially contribute significantly to environmental deterioration, which then declines as economies develop until a tipping point is reached, after which environmental degradation grows. The Brundtland curve is a U-shaped curve in contrast to the EKC. The following Figure (2) represents the Brundtland curve. Per capita GDP is represented on the x-axis and environmental damage on the y-axis. The level of environmental damage follows a U-shaped curve (A), where the lowest environmental damage is caused by middle-income economies.

Figure 2.
The Brundtland curve



Source: (Onyango et al., 2021).

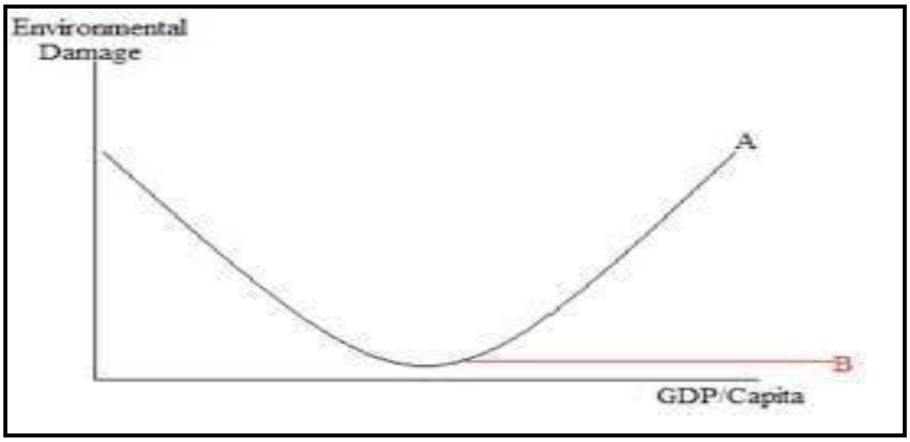
The Brundtland Curve hypothesis states poorer nations have a greater impact on the environment because they are less able to put environmental protection first. Environmental degradation declines as the economy expands because the factors causing the high amount of environmental damage are reduced, and poverty declines. It is assumed that once the turning point is achieved, economic expansion will cause pollution to rise along with it until it reaches its initial level. Based on the Brundtland Curve hypothesis, greater production due to increased consumption is what is driving the upward trend in environmental degradation (Onyango et al., 2021).

According to the Brundtland curve, the future may look grim, but it also offers an alternative scenario. Marked by the letter (B) in Figure (3), suggests that the level of environmental damage could reach the turning point on the Brundtland curve and stabilize instead of the normal assumption of increasing. This scenario, which has very low environmental damage, is only possible if green technology and development are the main priorities (Bratt, 2012). Wealth could have a positive effect on the environment, depending on how willing high-income countries are to adopt eco-friendly technology.

The alternative path (B) implies a stagnation in the level of environmental damage instead of an increase in environmental degradation as the U-shaped Brundtland curve.

Figure 3.

The alternative Brundtland curve



Source: (Onyango et al., 2021).

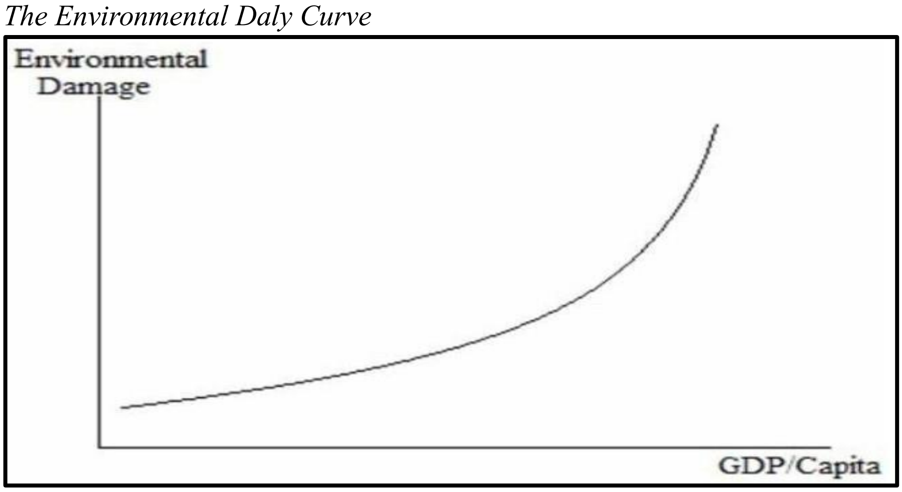
The Daly curve

Unlike the EKC and the Brundtland Curve, which shows a change in the amount of environmental damage after reaching a certain level of GDP, the Daly curve does not indicate any such turning point. The Daly curve assumes environmental damage increases monotonically with economic growth. Ecological economist Daly argues that economic growth, driven by increasing production, is unsustainable and that a steady-state economy may be the only viable option. He questions the value of human ingenuity and the effectiveness of green technologies in reducing pollution. Daly suggests that even with incentives for sustainable production, environmental harm will already be done. The environmental Daly curve hypothesis suggests that rising per capita GDP will lead to greater environmental degradation, regardless of population and political willingness (Daly & Farley, 2004).

The following Figure (4) represents the environmental Daly curve. The environmental damage increases with economic growth. Per capita GDP is represented on the x-axis and environmental damage on the y-axis.

Figure 4.

The Environmental Daly Curve



Source: (Daly, 1973).

The Porter hypothesis

The Porter Hypothesis, proposed by economist Michael Porter in the 1990s, suggests that stringent environmental regulations and policies can actually drive innovation and lead to a "win-win" scenario, where economic growth and environmental protection are not mutually exclusive. Specifically, it focuses on the idea that well-designed environmental regulations can encourage businesses to adopt cleaner technologies and practices, thereby improving their competitiveness, reducing resource waste, and ultimately decoupling economic growth from CO_2 emissions (Porter et al., 1995).

The key points of the Porter hypothesis in decoupling growth and CO_2 emissions can be summarized as follows:

1. **Innovation as a driver.** Porter's hypothesis posits that when businesses face environmental regulations, they are incentivised to innovate and develop cleaner technologies and processes. This innovation can enhance their efficiency and reduce resource consumption, which can lead to cost savings.
2. **Competitive advantage.** Firms that embrace these cleaner technologies and practices can gain a competitive advantage in the marketplace. They may reduce operational costs, enhance product quality, and appeal to environmentally conscious consumers.
3. **Decoupling economic growth.** The ultimate goal of the Porter hypothesis is to demonstrate that economic growth can occur independently of increasing CO_2 emissions. In other words, it challenges the conventional notion that economic prosperity must come at the expense of environmental degradation.
4. **Positive feedback loop**. As more companies adopt cleaner technologies due to regulatory pressure, it can create a positive feedback loop of innovation and environmental improvement, further supporting the decoupling of growth and emissions.
5. **Policy implications**. The Porter hypothesis suggests that governments should pursue well-crafted environmental policies that provide clear incentives for businesses to innovate and reduce their environmental footprint. It implies that smart regulations can stimulate economic growth while protecting the environment.

However, it is essential to note that the Porter hypothesis is not universally accepted, and its applicability can vary across industries and regions. Critics argue that its success depends on various factors, including the stringency of regulations, market conditions, and the willingness of businesses to invest in cleaner technologies. Nonetheless, it remains a significant concept in the discourse surrounding sustainable economic growth and environmental protection (Ambec et al., 2013).

Theoretical summary. The EKC theory is the most widely accepted. According to the EKC, which follows an inverted U-shape, environmental degradation initially rises along with a developing economy before falling off after reaching a certain point of income, According to the Brundtland curve hypothesis, environmental harm initially declines before increasing or, in some cases, stagnating at a certain point of economic expansion.

Both the existence of a turning point and the theoretical justification for the rise in environmental damage are similar in these two curves. The mechanism is the same, even though the Brundtland curve theory may not refer to it as the scale effect. However, the two ideas offer different explanations for why environmental damage has decreased.

A third theory, the Daly theory, which excludes any sort of turning point, joins the two opposing ones. The Daly theory states that unless the fundamental tenets of the current world economy are altered, environmental degradation will worsen as economic growth continues. Again, the scale effect is the main driver behind the increase in environmental damage and is the common denominator for the three theories stated above.

The Porter hypothesis, on the other hand, creates a "win-win" scenario where economic growth and environmental protection are compatible. It emphasises that well-designed regulations can motivate businesses to adopt cleaner technologies, enhancing efficiency, reducing resource waste, and disconnecting economic growth from CO_2 emissions. Critics argue that its success depends on various factors, but the hypothesis remains a significant concept in discussions of sustainable growth and environmental preservation.

Empirical framework

The study of the decoupling between CO_2 emissions and economic growth has gained significant attention in recent years. A survey conducted by Vaden et al. (2020) showed that most of the articles focused on China and its regions, but the empirical findings were varied and abundant. This review summarises empirical findings from various studies, based on diverse methodologies and perspectives, areas of focus, and key findings.

Methods employed in previous studies

Many studies relied heavily on the Tapio decoupling method and the Logarithmic Mean Divis Index (LMDI) decomposition analysis. Some researchers combine both methods to enhance the depth and scope of their analyses. In addition, Kaya's identity has frequently been used to break down total carbon emissions.

Studies using the LMDI method

Zhao et al. (2017) studied the decoupling effect of economic growth from CO_2 emissions during the 1992–2012 period in China using LMDI methods, decomposing driving indicators of economic growth from CO_2 emissions in the major five economic sectors into several factors and measuring the contribution of each factor to the decoupling of China’s overall economy from CO_2 emissions. The study findings showed weak decoupling in the five different periods. Also, energy intensity and economic activity were the most important factors affecting decoupling in China.

Gao et al. (2021) provided an analysis of the decoupling relationship between CO_2 emission in the power industry and GDP in China based on the LMDI method with the Cobb-Douglas production function to study the emission driving force. Also using the 2006 Intergovernmental Panel on Climate Change (IPCC) guidelines to calculate the energy-related CO_2 emissions, the key finding was the separation of economic activities from energy consumption. Also, most provinces had been weakly decoupled during the whole period; expansive coupling appeared during the first stage and the second stage, while approaching the third stage, energy consumption was reduced in some provinces, leading to recessive decoupling and recessive coupling. Several provinces moved from the expansive coupling to weak decoupling and strong decoupling.

A great comprehensive effort was done by Wang and Wang (2019) to study the state of decoupling in the USA (1997–2015) using the extended Kaya identity and LMDI method**.** Constituting the decoupling effort model, which refers to all direct and indirect efforts to reduce carbon emissions. Their data was obtained from the Bureau of Economic Analysis, the Energy Information Administration, and the World Bank. Their finding showed that the USA exhibited decoupling in 2007, but carbon emissions showed an increase in the transport and commerce sectors, and the main inhibitor to decoupling was economies of scale, while the main contributor was energy intensity.

Studies using the Tapio method

Starting with the original work of Tapio **(**2005), he focused on tackling the possibility of decoupling in the EU15 countries and specifically regarding the dynamic relationship between GDP growth, road traffic, and CO_2 emissions in Finland in the spectrum between 1970 and 2001. Findings showed three types of decoupling: expansive negative decoupling, expansive coupling, and weak decoupling

A unique study by Wang and Zhang (2020) tackled decoupling in BRICS countries utilizing the Tapio model (Tapio, 2005) to measure the decoupling degrees to find the linkage between increased research and development and the promotion of economic growth decoupling from carbon emissions by using the fully modified least squares for empirical estimation from 1996 to 2014. The finding showed that every 1% increase in R&D expenditure reduced carbon emissions by 0.8122% for the BRICS as a whole. The study highlighted that China had the most impact, while Russia and India had the least.

Studies using both LMDI and Tapio methods

Xie et al. (2019) provided an in-depth article by studying the decoupling relationship between CO_2 emissions in the power industry and GDP in China based on the LMDI method (1985–2016), and also combining it with Kaya identity and Tapio decoupling for more sophisticated analysis. Data were obtained from the Bureau of Statistics of China. The main findings were expansive negative decoupling and weak decoupling. Also, from their decomposition results, it is clear that the biggest inhibitor to strong decoupling was economies of scale, followed by electrification, while energy intensity was the most favorable.

Engo (2019) highlighted decoupling in Africa, specifically in Cameroon, taking into consideration the transport sector as the main source of CO_2 emissions. The author configured the Tapio and LMDI models and based them on Kaya's identity**,** sub-branching the decoupling indicators into five factors: energy structure, energy intensity, economic structure, population, and economic activity. The empirical findings stated that during the period 1990–2016, weakness was a general phenomenon. On the yearly decoupling analysis, various stages of decoupling were observed.

Wu et al. (2019) also examined China's decoupling economic growth from CO_2 emissions based on 30 Chinese provinces during the period (2001–2015), focusing on carbon intensity perspectives, per capita carbon emissions, and total carbon emissions using the LMDI method. The authors neglected the method used by the OECD because of its sensitivity to the benchmark years, creating poor stability of the results. So, the researchers chose to use the Tapio decoupling indicator to compensate for the weaknesses of the other model. Carbon emissions were based on the consumption of fossil fuels, as calculated by the IPCC (2006). Findings showed that during the whole period, strong decoupling and weak decoupling were dominant among most of the 30 provinces, and a strong decoupling relationship between GDP and carbon intensity existed in most of the Chinese provinces.

Comparative study

Most research lacks a systematic review and comparison of decoupling calculation methods and decoupling status between different regions and countries. Wu et al. (2018) filled this gap by comparing the decoupling between developed and developing countries in the period (1965–2015). Employing three methods to compare trends: OECD factor model, the TEA method known as the Tapio method, and the IGTX decoupling model. Data were obtained from British petroleum company, the World Bank, and the International Energy Agency. The findings regarding the comparison showed Tapio method and IGTX showed a high degree of correlation, while the OECD decoupling factor model showed a low correlation with the other. The decoupling status showed two trends: strong decoupling in developed countries moving toward stabilization, while developing countries showed weak decoupling with no clear trend.

Summary

The main research gap was that most of the studies focused on specific countries or regions, such as China, and often concentrated on specific sectors. There is a need for more comprehensive and comparative analyses that encompass a broader range of countries, regions, and cross-country comparisons to identify global trends and variations in decoupling.

Research Hypothesis

We expect that positive decoupling cases will only appear in the two developed countries according to The Environmental Kuznets Curve (EKC) hypothesis, as the technological effect would only be able to offset the scale effect in these cases.

Methodology

Decoupling suggests that significant emission reduction is feasible with little or no impact on economic growth (Deutch, 2017). In our study, we depend on the Tapio (2005) decoupling model presented in his research entitled "Towards a theory of decoupling: Degrees of decoupling in the EU and the case of road traffic in Finland between 1970 and 2001". This method was originally started by Vehmas et al. (2003 and 2007). The original study measured the decoupling of transport volume growth and economic growth.

In our study, instead of the transport volume, we use CO_2 emissions as they are the main component of greenhouse gases; the main human cause of global warming is the CO_2 emissions from economic activities, especially the use of fossil fuels. Wu et al. (2018) and Vavrek and

Chovancova (2016) used this method to study the decoupling of greenhouse gas emissions from economic growth in V4 countries. Also, Li et al. (2021) used the same method to study the decoupling of economic growth from CO_2 emissions in Yangtze River Economic Belt cities.

The Tapio method offers significant benefits, primarily through its state decentralization, which is characterized by its simplicity, clarity, and minimal data requirements. Furthermore, it remains unaffected by the number of years that is covered by the research. Conversely, a notable drawback is the potential for conceptual confusion stemming from the numerous divisional categories, which might hinder the identification of precise factors underlying the observed phenomenon. (Wu et al., 2018).

This method depends mainly on the elasticity values, dividing the decoupling and non-decoupling states into eight different types. To measure the decoupling of CO_2 emissions from economic growth it is simply dividing the percentage change of CO_2 emissions by the percentage change in GDP over a given period. The calculation outcome is the elasticity value.

$$\mathbf{e = \%\Delta CO_2 / \%\Delta GDP} \quad \text{(Decoupling Elasticity Equation)}$$

Decoupling interpretation

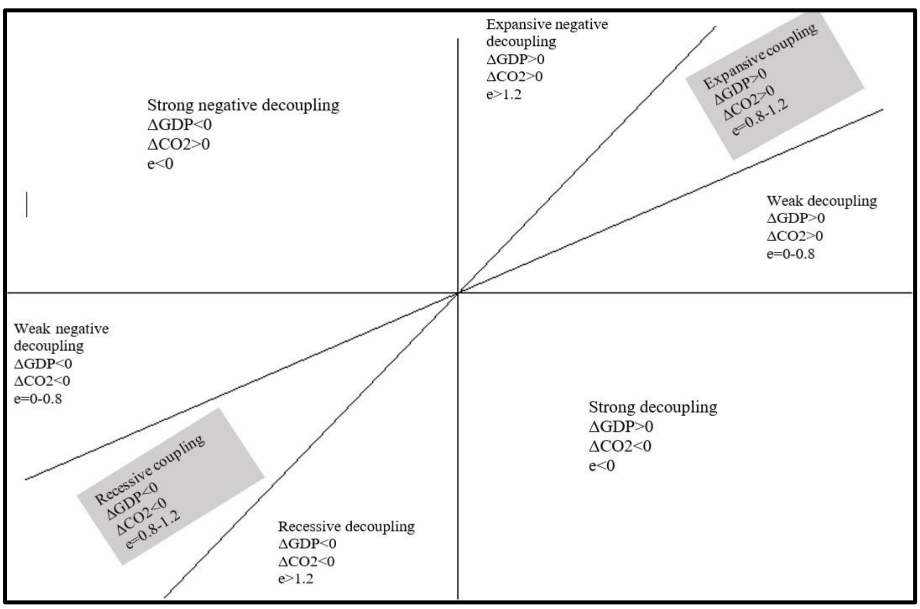
There are three types of decoupling:

1. **Weak decoupling**. GDP and emissions both increase, but GDP grows faster than emissions (elasticity between 0 and 0.8). Emissions continue to rise, albeit more slowly than GDP.
2. **Strong decoupling.** GDP grows while CO_2 emissions decrease (elasticity less than zero).
3. **Recessive decoupling.** Both GDP and CO_2 emissions fall, but emissions decline faster than GDP (elasticity over 1.2).

The coupling stages are shown in Figure (5).

Figure 5.

The different stages of decoupling



Source: (Tapio, 2005).

Decoupling with an elasticity of 1.0 means both GDP and emissions grow at the same rate. A 20% deviation from this value, between 0.8 and 1.2, is considered coupling. Variable change rates can be either positive (represented as expansive coupling) or negative (stated as recessive coupling), (Tapio,2005; Finel & Tapio, 2012).

Negative decoupling also has three forms:

1. **Weak negative decoupling.** Both GDP and emissions rise, with emissions growing faster (elasticity greater than 1.2).

2. **Substantial negative decoupling**. GDP falls while emissions rise, resulting in an elasticity of 0.

3. **Strong negative decoupling**. Both GDP and emissions decrease, but GDP decreases more slowly (elasticity between 0 and 0.8).

The research regarding the decoupling phenomenon is very limited. We used the USA and India as they are two of the most significant CO_2 emissions producers, according to the World Bank data.

We used a timeframe from 1990 to 2020 to study the decoupling of economic growth from CO_2 emissions, and divided the timeframe into six sub-periods. The reason for dividing it into six periods, instead of calculating the changes annually, is because “the Tapio decoupling model” has a better descriptive ability in the long term. The more general the trend analysed, the longer the time period should be from 5 to10 years (Tapio, 2005).

The data over the whole period was acquired from the World Bank. Real GDP is measured using PPP expressed in US Dollars, using 2017 as the base year, eliminating price changes. CO_2 emissions are measured in kilotons.

Examining decoupling in the selected cases

This section examines the results generated through TEA analysis to assess their consistency with the stated hypothesis. The results are described and compared to prior expectations for each of the four countries using the time series analysis that will be conducted in the following section.

Using the Tapio elastic analysis (TEA) method, the decoupling indices in both developed (the USA & Japan) and developing (India & Egypt) countries between 1990 and 2020 are calculated as seen in Table (1).

Table 1.

The decoupling state analysis of CO_2 emissions and economic growth (1990-2020)

Time	Indicator	Egypt	India	The USA	Japan
1990-1995	ΔC	6.8	30.92	5.63	7.38
	ΔGD,P	18.28	28.12	13.5	7.87
	%ΔC/%ΔGDP	0.37	1.10	0.42	0.94
	Decouple state	Weak	Expat. Coup.	Weak	Expansive
1996-2000	ΔC	22.29	27.11	12.87	0.99
	ΔGDP	31.91	34.30	23.51	5.31
	%ΔC/%ΔGDP	0.70	0.79	0.55	0.19
	Decouple state	Weak	Weak	Weak	Weak
2001-2005	ΔC	41.54	21.18	-0.39	2.55
	ΔGDP	18.96	36.7	13.42	6.08
	%ΔC/%ΔGDP	2.19	0.58	-0.03	0.42
	Decouple State	Expansive	Weak	Strong	Weak
2006-2010	ΔC	23.48	46.06	-6.28	-4.65
	ΔGDP	34.94	40.35	5.02	-0.24
	%ΔC/%ΔGDP	0.67	1.14	-1.25	19.27
	Decouple state	Weak	Expan. Coup.	Strong	Recessive
2011-2015	ΔC	12.96	30	-7.44	1.99
	ΔGDP	14.19	36.96	11.13	5.36
	%ΔC/%ΔGDP	0.91	0.81	-0.67	0.37
	Decouple state	Expan. Coup.	Expan. Coup	Strong	Weak
2016-2020	ΔC	10.2	13.82	-3.47	-8.3
	ΔGDP	25.16	19.25	6.43	-1.84
	%ΔC/%ΔGDP	0.41	0.72	-0.54	4.51
	Decouple state	Weak	Weak	Strong	Recessive

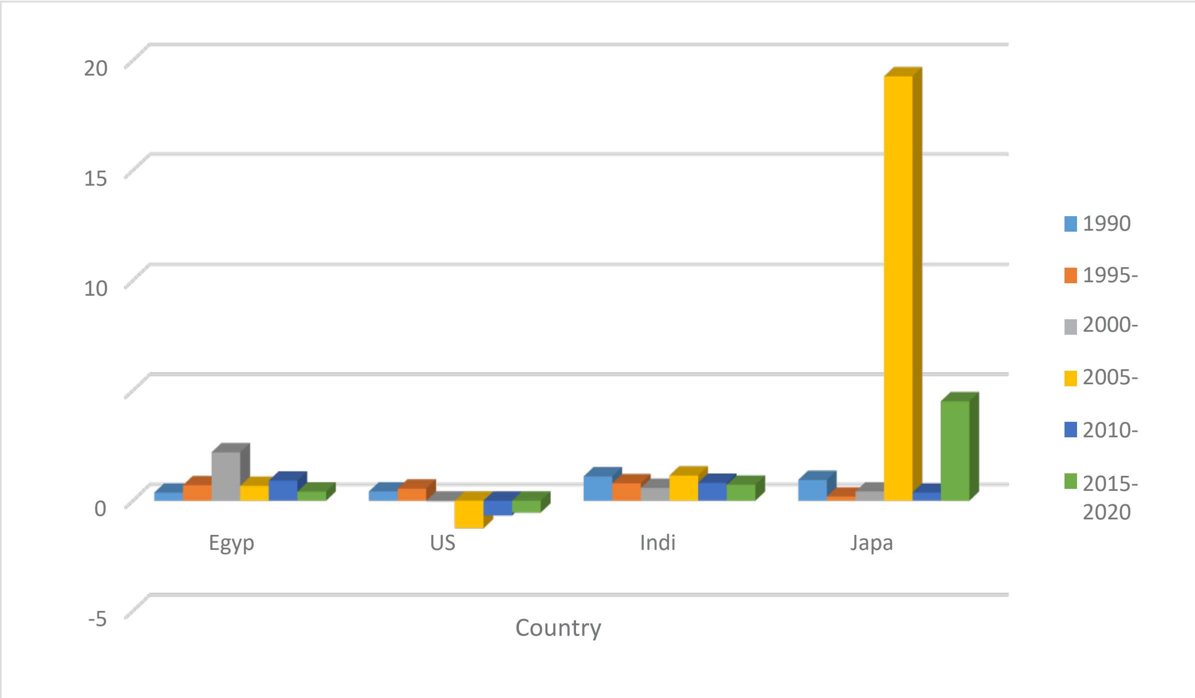
Source: Prepared by the authors

Observed as individual countries, Table (1) shows many contradicting trends in degrees of decoupling, especially in the third interval (2001–2005).

Figure (6) presents the GDP elasticity of CO_2 emissions in the period from 1990 to 2020 within the four countries, divided into six intervals of five years each. It may be concluded that weak decoupling was the most common trend during the whole period, especially in the second five-year interval. Weak decoupling occurred in the four countries, and Egypt appeared as a weak decoupling state during the whole period.

Figure 6.

GDP elasticity of CO_2 emissions from 1990 to 2020



Source: Compiled by the authors.

Illustration of the results

Following Table (1), this section is divided into six periods, each with its own findings beginning with Egypt.

Egypt

In the six-period decoupling analysis of GDP and CO_2 emissions, the first interval (1990–1995) showed weak decoupling; it was the best decoupling state, with GDP growth (ΔGDP) outpacing emission growth (ΔC) by a significant margin (ΔC = 6.8 < ΔGDP = 18.28) and an elasticity value of 0.37. In the second interval (1995–2000), decoupling weakened as ΔC accelerated to 22.29% and ΔGDP increased to 31.91%, with an elasticity value of 0.7. The third interval (2000–2005) was the worst decoupling period, with ΔC peaking at 41.54% and ΔGDP soaring to 18%, resulting in an expansive decoupling state with an elasticity value of 2.19. The fourth interval (2005–2010) saw a return to weak decoupling, as ΔC decreased to 23% and ΔGDP increased to 34.95%, with an elasticity value of 0.67. The fifth interval (2010–2015) showed expansive coupling with an elasticity of 0.91, indicating that ΔC (12.96) < ΔGDP (14.19), but both values decreased, partly due to political events. In the last interval (2015–2020), weak decoupling was observed again, with ΔGDP increasing by 11.42 and ΔC decreasing by 2.7, along with an elasticity value of 0.41. This period saw GDP growth outpacing emissions.

India

In the first interval (1990–1995), there was expansive coupling with (ΔC = 30.92 > ΔGDP = 28.12) and an elasticity of 1.1, indicating a natural correlation between CO_2 and GDP. The second interval (1995–2000) saw weak decoupling, with (ΔC = 27.11 < ΔGDP = 34.3) and an elasticity of 0.79, implying that CO_2 emissions increased with economic growth, but at a slower rate. In the third interval (2000–2005), weak decoupling continued with $\Delta GDP > \Delta C$, as ΔC decreased to 21.18 and ΔGDP increased to 36.7, resulting in an elasticity of 0.58. The fourth interval (2005-2010) witnessed a return to expansive coupling, with (ΔC = 46.06> ΔGDP 40.35), leading to an elasticity of 1.14. The fifth interval (2010–2015) also exhibited expansive coupling, with $\Delta C < \Delta GDP$ and elasticity of = 0.81, marking a prolonged period of this state. In the last interval (2015-2020), CO_2 emissions (ΔC) reached their lowest levels, possibly due to the 2020 pandemic, resulting in weak decoupling, with an elasticity of 0.72, although both ΔGDP and ΔC remained positive.

The USA

In the first two intervals (1990–1995 and 1995–2000), weak decoupling was observed, with an elasticity of 0.42 and 0.55, respectively. This indicated that ΔCO_2 emissions and ΔGDP both increased, but GDP grew at a faster rate. A turning point came in the third interval (2000–2005), marked by strong decoupling. ΔCO_2 emissions decreased slightly (-0.39%), while ΔGDP increased (13.42%) with an elasticity of -0.03. Strong decoupling persisted in the fourth interval (2005–2010), despite the financial crisis. ΔCO_2 emissions continued to decline (-6.28%), and ΔGDP increased by a modest 5.02%. The fifth interval (2010–2015) maintained strong decoupling with an elasticity of -0.67. ΔCO_2 emissions decreased significantly (-7.44%), and ΔGDP showed a positive increase, surpassing the previous period by 6.1%. Finally, in the last interval (2015–2020), the U.S. achieved strong decoupling. ΔCO_2 emissions decreased (-3.47%), while ΔGDP grew by 6.43%.

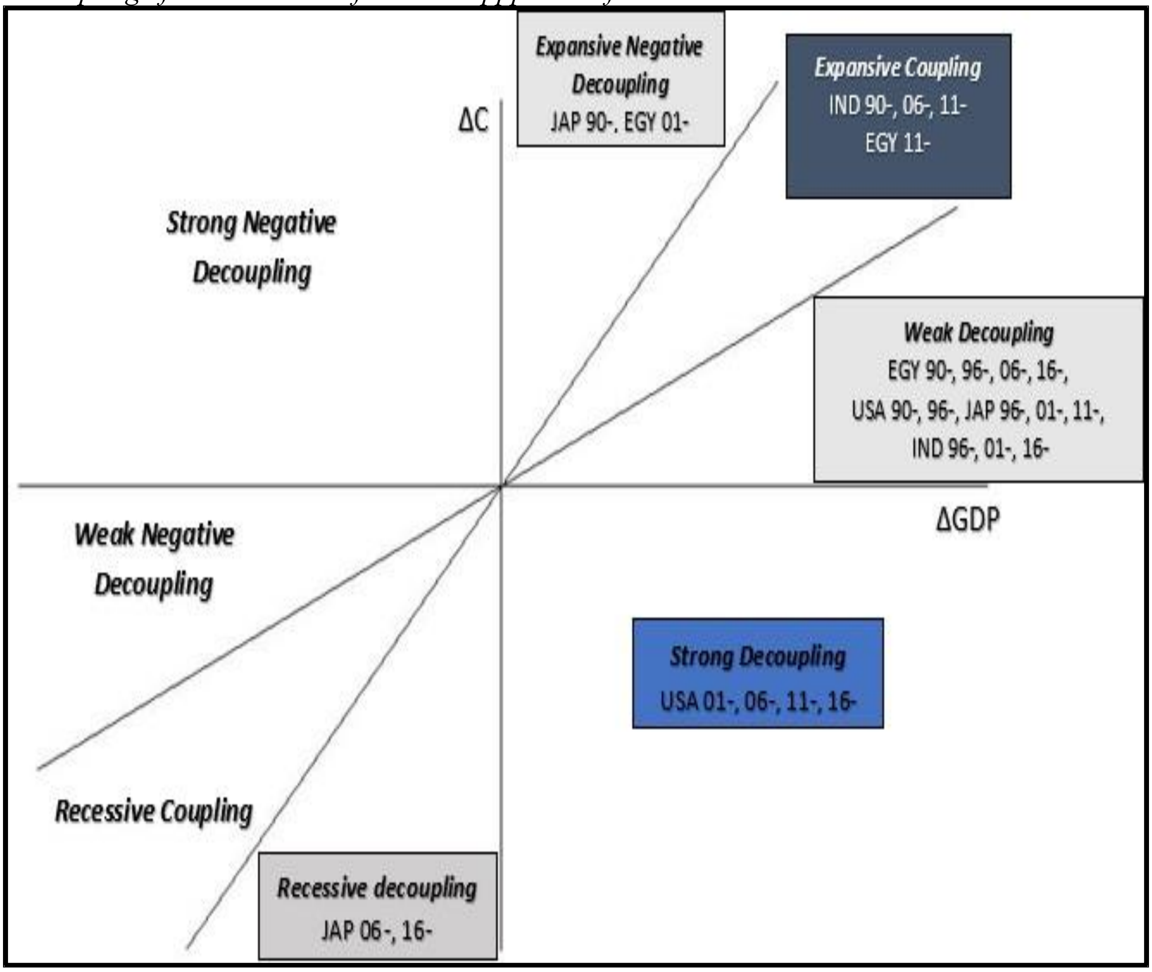
Japan

In the first period (1990–1995), a GDP elasticity of 0.94 indicated expansive coupling, where ΔCO_2 emissions grew in proportion to ΔGDP. Moving to the second interval (1995–2000), a GDP elasticity of 0.19 signified weak decoupling, with both ΔGDP and Δemissions increasing, but ΔGDP outpacing emissions. The third period (2000–2005) the trend of weak decoupling continued, with a GDP elasticity of 0.42. However, in the fourth interval (2005–2010), a remarkable shift occurred, with an elasticity of 19.27, indicating recessive decoupling. Both ΔGDP and ΔCO_2 emissions decreased, but emissions declined significantly faster than GDP. In the fifth interval (2010–2015), Japan returned to weak decoupling, with a GDP elasticity of 0.37. In the last interval (2015–2020), Japan's GDP elasticity was 4.51 as Δ CO_2 emissions were -8.3% Δ GDP growth rate was -1.84, The decoupling state in this period was recessive decoupling.

Overall, these intervals reflect varying degrees of decoupling between economic growth and CO_2 emissions in Japan, ranging from expansive to weak to recessive decoupling over the years.

Figure 7.

Decoupling of CO_2 emissions from GDP ppp in the four countries



Source: Compiled by the authors.

Key findings

We used the Tapio decoupling model to assess the relationship between carbon emissions and economic growth, because this model allows us to determine whether a country has decoupled its emissions from economic growth. However, it is important to note that this analysis may not identify the specific factors contributing to these observations (Madaleno et al., 2018)

The rates of changes in CO_2 emissions and GDP in the four selected countries, shown in the previous section, have developed in different ways and at different times. In the majority of cases, both emissions and GDP have been moving together; in some cases, they have grown at a similar rate (expansive coupling, i.e., India 2005-); in some countries the rate of GDP growth has been faster than the growth of emissions (weak decoupling, i.e., Egypt 90- and The USA 95-); and in some countries, both emissions and GDP have decreased, with a higher rate of decrease for emissions (recessive decoupling, i.e., Japan 2005-). However, there are also cases of strong decoupling, where GDP has grown and emissions have decreased (i.e., The USA, 2005-). A detailed description of the development in each country is presented in this section based on economic theories and previous studies.

Egypt

Egypt is one of the developing countries in the dilemma of achieving higher growth rates in GDP without increasing emissions. Although the industrial base in Egypt is characterised by heavily polluted industries such as cement, iron, steel, and aluminum. Few studies explore CO_2 emissions and the economic growth relationship in Egypt. The existing research relies on the EKC hypothesis (Ibrahiem, 2016).

Based on our findings, there is a positive correlation between CO_2 emissions and economic growth, with a 1% increase in GDP associated with an average 0.8% increase in emissions. This positive association aligns with economic theory and multiple studies (Raihan et al., 2023; Nkengfack & Fotio, 2019).

Furthermore, Raihan et al. (2023) conducted a study in Egypt that reveals a positive connection between fossil fuel energy consumption and CO_2 emissions, as well as between tourism and CO_2 emissions. Conversely, observing a negative relationship between renewable energy usage, agricultural production, and CO_2 emissions, not to mention that lower income stimulates the usage of cheaper fuel. Therefore, the increase in CO_2 emissions positively correlates with economic growth and depends on sectoral growth. Also, it is negative with income levels.

In this regard, it is noteworthy that Egypt has started a green transformation strategy since 2011, aiming for a green economy, also, developing the Sustainable Development Strategy: Egypt's Vision for 2030 with the goal of addressing environmental concerns, and tending to reduce the use of fossil fuels by 10%.

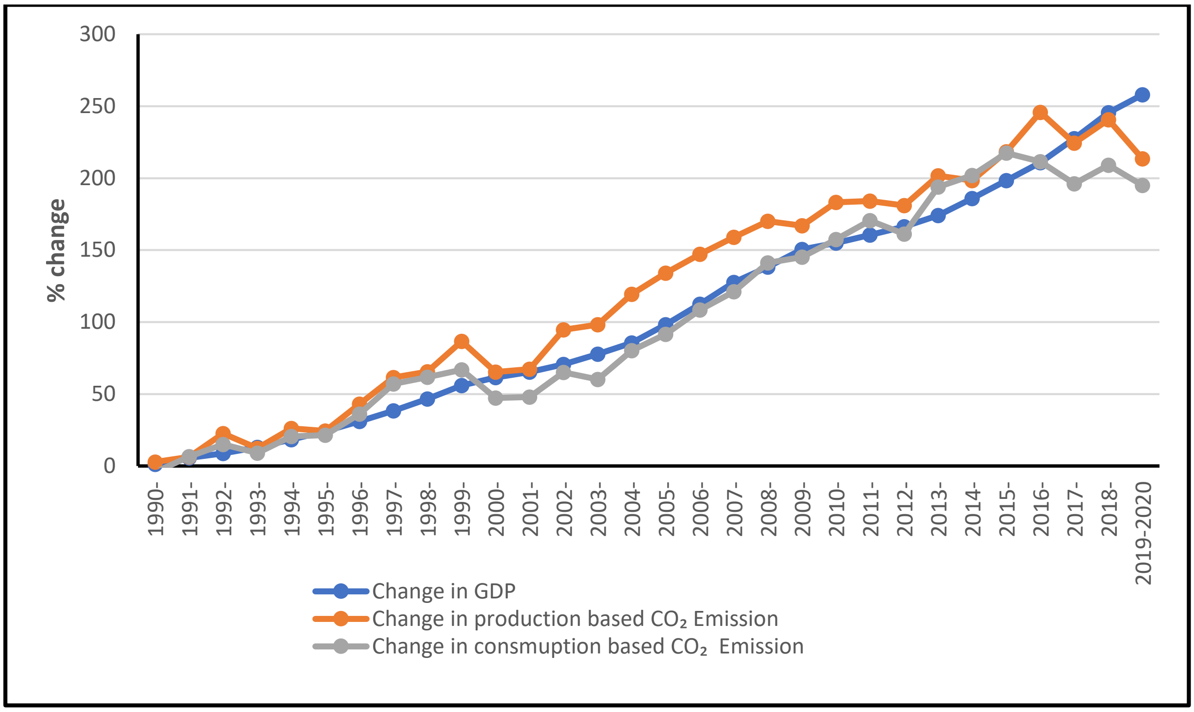
We seek to examine Egypt's economic growth since it is more straightforward to monitor compared to the complex factors influencing carbon dioxide emissions, which have a deficit of studies, and due to our study limitations, as we focused on general phenomena rather than inferring the cause of the relationship.

Starting in 1990, Egypt adopted IMF and World Bank-led reforms, transitioning to a liberal market economy, reducing government intervention, and boosting GDP. Unfortunately, this growth turned into a stagnant position in the period from 1997 to 2004, due to many international and local events negatively eroding the growth.

The period from 2004 to 2010 was the correction stage. Egypt's liberal government stimulated tourism, private sector growth, FDI especially in petroleum exploration and telecommunications, and remittances.

The period from 2011 to 2014 witnessed instability. The economic growth rates were low because of the two revolutions in Egypt, and the unemployment rate had risen. In the period 2014-2020, Egypt entered a new regime, implementing economic reform programmes that boosted economic growth again.

Figure 8.
Change in CO_2 emissions and GDP in Egypt (1990/1991-2019/2020)



Source: (World Bank, 2023a; World Bank, 2023b).

India

We found a limitation in finding papers that coincided with the phenomenon of GDP growth with CO_2 emissions and decided to find each aspect separately and see if the results encountered each other.

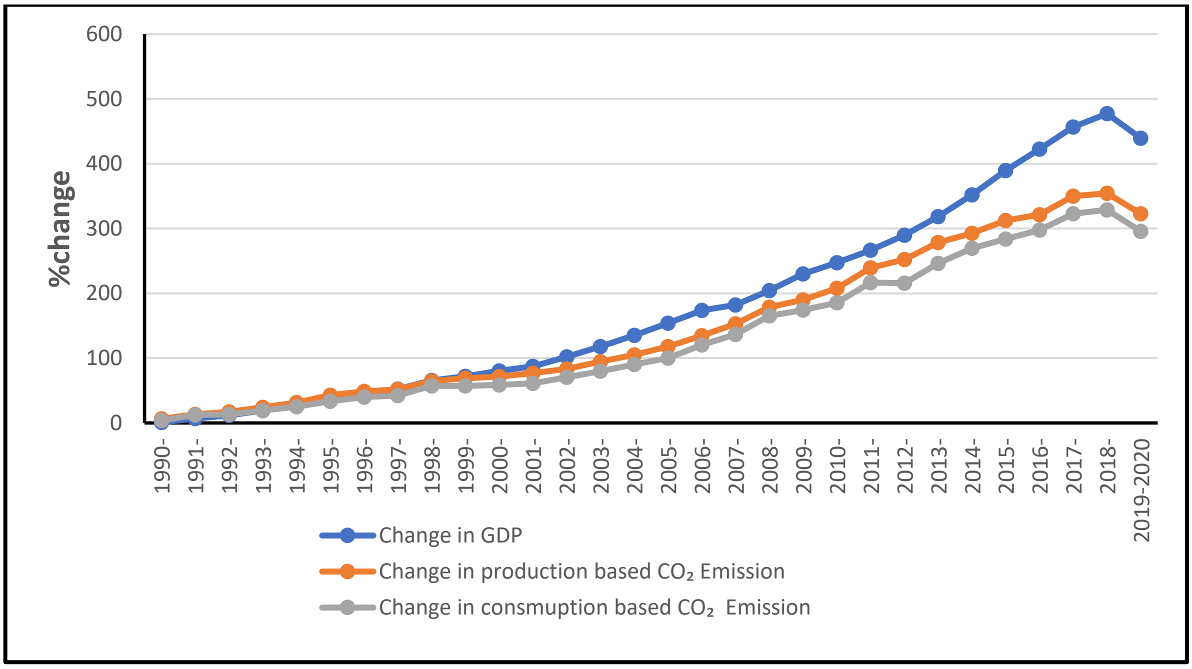
Between 1990 and 2013, India's CO_2 emissions increased at a compound annual growth rate (CAGR) of roughly 5%. Electricity generation, transportation, and the iron and steel industry provided 48%, 11.6%, and 7.9% of the 1897 Mt of CO_2 emissions, respectively. The estimations of the Indian economy's CO_2 emission intensity suggest an 11% decoupling of the increase in emissions and GDP from 2005 to 2013, indicating an increasing CO_2 intensity of the Indian energy sector, mainly due to enhanced coal use (Garg et al., 2017).

As opposed to its average emissions growth of 3.3% from 2015 to 2019, India's yearly CO_2 emissions decreased by 7% (or 160 Mt CO_2) in 2020. With over 1.4 billion Indians on complete lockdown in April 2020, emissions plummeted by an astounding 40% compared to April 2019, the highest drop in a single month experienced by any major economy. Yearly emissions from coal-fired power plants in India declined by 5% in comparison to 2019, owing to lower electricity consumption (IEA, 2021).

India's GDP growth decreased from 8.9% in 2011 to 4.5% in 2013, after increasing at an average pace of 6.3% for the previous three decades (1981–2011) (Patnaik & Pundit, 2014). According to Anand et al. (2014), the growth trend in India peaked at 8% before 2008 and then fell, while Mishra (2013) discovered that potential output increased the most from 2002 to 2007. Such a regression can be due to what Pritchett and Summers (2014) explained: it is to be expected that India will slow down after a time of rapid expansion because cross-country research reveals that after rapid growth, the slowdown is quite likely, signifying a decrease to the mean in the growth process. From 2010 to 2019, the relationship between GDP growth and CO_2 was volatile. Starting from 2019 to 2020, the correlation was clear as both took a hit and dropped by huge margins, as shown in Figure (9).

Figure 9.

Change in CO_2 emissions and GDP in India (1990/1991-2019/2020)



Source: (World Bank, 2023a; World Bank, 2023b).

We can see that the statement of Garg et al. (2017) coincides with the graph regarding CO_2 emissions being on the constant increase since 1990. With a huge decrease in 2020, the year when the pandemic started, we can see that between 2010 and 2015, GDP was characterised by a diminishing growth rate compared to the three decades before, which supports the findings of (Patnaik & Pundit, 2014).

Our findings indicate that there is a relationship between GDP growth rate and CO_2 emissions as they coincided in their growth in the last three decades and behaved the same way in the pandemic, not to mention that production in India is coal intensive and industry tends to use coal power plants as they are cheaper and more available to the masses (Mittal et al., 2012).

The USA

The decoupling index in the USA can be divided into two time periods: 1990–2005 and 2006– 2020. During the first period, the decoupling index appeared weak due to energy-related CO_2 emissions growing by an average of 1.0% per year. However, between 1990 and 2007, the transportation sector experienced an average annual rise in emissions of 1.4%, adding up to a total increase of 430 MMT. This expansion era, dominated by increased motor gasoline and diesel fuel use, began in tandem with a strengthening U.S. economy and ended with the recession.

The primary driver of the decline in energy-related carbon emissions was energy intensity, while economic scale was seen as the key impediment. Reduced energy-related carbon emissions were a result of increased R&D intensity and efficiency, as well as sectoral carbon intensity. Investment intensity came in second behind economic size. After investment intensity, population size also had a significant detrimental effect on the reduction of energy-related carbon emissions. The sectoral energy structure had a small but detrimental impact on the reduction of carbon emissions related to energy.

In the first period, R&D efficiency and intensity, as well as economics of scale were not able to offset the population size and investment intensity's significant negative impact on energy-related carbon emissions. Only the decoupling index in 2000–2001 and 2005–2006 had a negative value before 2007. This shows that carbon emissions increased along with economic growth.

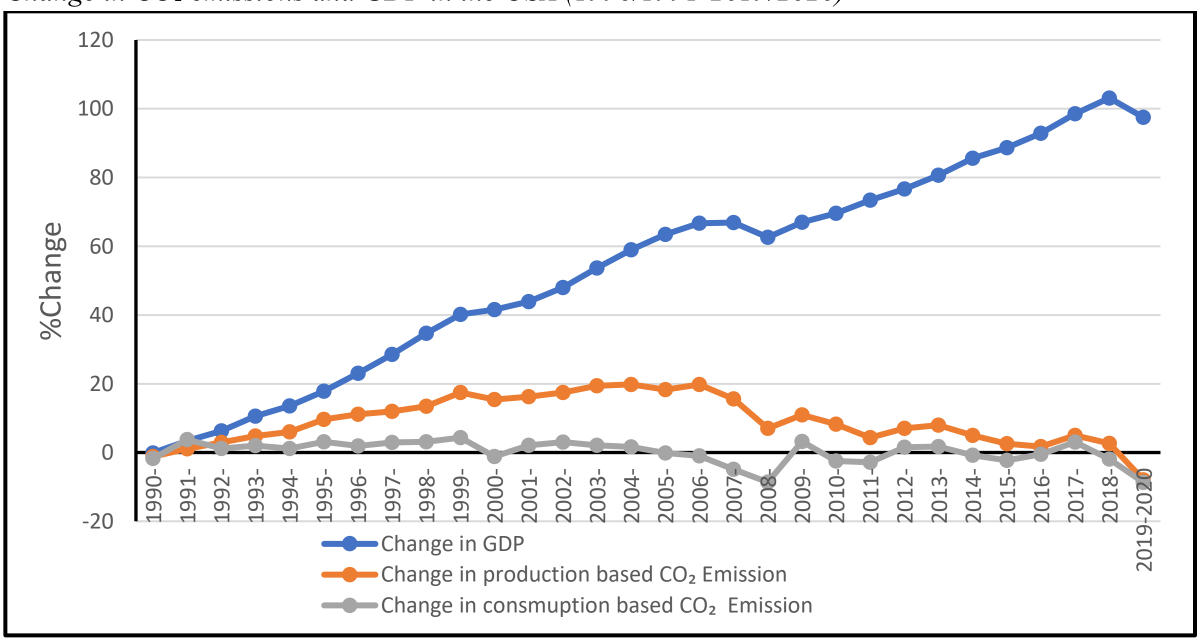
Concerning the second period, the decoupling index changed significantly. Although carbon emissions have been declining since 2007, a large decoupling was apparent in 2008 right away. The Great Recession began, and the decoupling state was not optimal enough because of the world economic crisis, resulting in recessive decoupling in 2008–2009 and expansive coupling in 2009–2010. The decoupling situation improved during the ensuing years, and a tendency for substantial decoupling emerged.

Between 2013 and 2019, there was volatility in amounts and percentages of CO_2 emissions in the USA, with changes in emissions each year being around -2.5% and 2%. This period also witnessed a steady increase in GDP levels between 2–3 percentage points per year, keeping the country in a steady state of strong decoupling.

The COVID-19 pandemic had a significant impact on the global economy, energy markets, and CO_2 emissions in 2020. The total CO_2 emissions caused by energy in the United States fell by 11% in 2020, or by 570 million metric tons (MMT). Emissions have decreased nine out of the last thirteen years since they peaked in 2007.

Figure 10.

Change in CO_2 emissions and GDP in the USA (1990/1991-2019/2020)



Source: (World Bank, 2023a; World Bank 2023b).

Japan

A brief overview of the CO_2 emissions and economic growth in Japan in the period of the study (1990–2020) shows that in 1990–1995, CO_2 emissions increased relatively higher than in previous years; the CO_2 emissions increased from 1,107,610 kt in 1993 to 1,160,780 kt in 1994; in 1998, Japan's estimated CO_2 emissions were 58 MMT of GDP (in 1995 prices), and Japan's energy use accounted for almost 90% of CO_2 emissions.

When observing Japan's CO_2 emissions by industry in the first interval, the research used decomposition analysis from the demand and supply sides. The factors observed from the demand side were changes in environmental technologies, demand for intermediate input, imports, exports, domestic final demand, and output (Yabe, 2004).

Changes in domestic final demand and output increased emissions by 51.0% and 121.1%, respectively. The intermediate input factors cut emissions by 32.2%. ETC (intensities of CO_2 emissions as measured by producer's prices on the demand side) was responsible for the second-largest reduction in emissions, which was 28%. As the Japanese economy was in a bubble during this time, domestic final demand and output both increased, significantly contributing to an increase in CO_2 emissions.

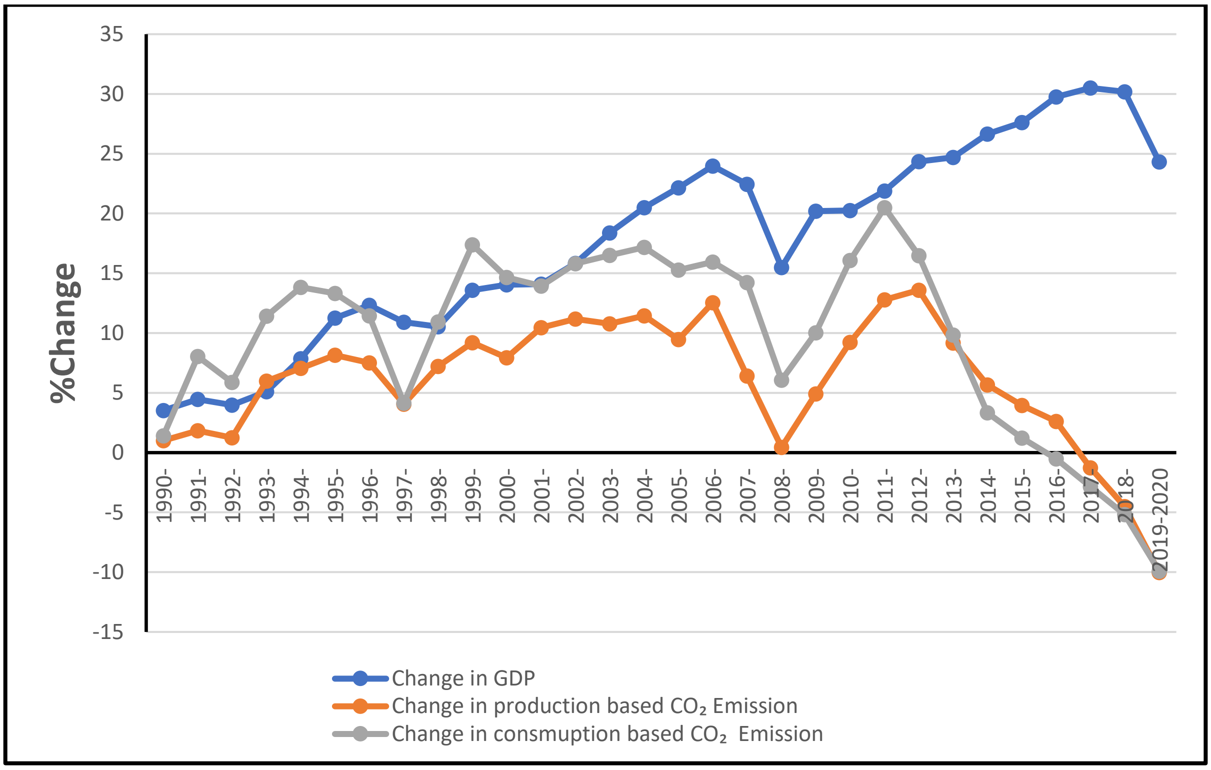
Changes in imports and exports reflected variations in the number of CO_2 emissions that were embodied in traded goods; the overall reduction in CO_2 emissions due to trade was around 11.9%.

Japan's CO_2 emissions increased in the following periods until drastically declining in the fourth interval from 1,225,070 kt in 2007 to 1,100,980 kt in 2009 due to the global financial crisis, then increasing rapidly in the next interval, reaching a new peak of 1,262,780 kt in 2013. In 2015, the manufacturing industries accounted for almost one-quarter of Japan's CO_2 emissions.

When examining the emissions in the 47 prefectures, Matsumoto et al. (2019) deduced that CO_2 emissions decreased in 36 of the 47 prefectures in the period (1990–2013); Osaka and Tokyo accounted for the largest reductions, with -31.3% and -58.9%, respectively, relative to 1990. On the other hand, when examining GDP growth, Japan's GDP declined from 5.03 trillion in 2007 to 4.68 trillion, however, the GDP increased with CO_2 emissions to reach a peak of 5.28 trillion in 2019.

Figure 11.

Change in CO_2 emissions and GDP in Japan (1990/1991-2019/2020)



Source: (World Bank, 2023a; World Bank,2023b).

Conclusion and policy implications

The paper examined the decoupling phenomenon between CO_2 emissions and economic growth in two developed countries (the USA and Japan) and two developing countries (Egypt and India) in six time periods from 1990 to 2020. It started by mentioning the Environmental Kuznets Curve (EKC) theory and the following related theories, including Brundtland's curve and the Daly curve, to examine the relationship between economic growth and environmental degradation and how the EKC identified the relationship between per capita income and carbon dioxide concentration and how they are connected to a certain point. Brundtland's curve also showed that poor countries are initially responsible for a great part of environmental degradation due to their lag in putting environmental protection first, and then damages declined as countries develop until reaching a tipping point at which environmental degradation started to increase. Then, the paper indicated the studies on which the methodology was based and the model used to determine the decoupling state in each country, mainly relying on the elasticity values dividing the decoupling and non-decoupling states into eight different types, depending on the Tapio (2005) decoupling model presented in his research.

The state of decoupling differs among countries and across different time periods. The analysis revealed that weak decoupling and expansive coupling were the most common states, especially in developing countries. However, weak decoupling has also occurred multiple times in developed countries. We can infer that developing countries are heading in a similar direction. Strong decoupling is found in the USA and is moving towards stabilisation, especially after the shift from weak to strong at the onset of the new decade. The decoupling states in Japan were fluctuating from expansive, to weak, to recessive; no clear trend emerged.

Exhibiting the direction of the decoupling states based on the EKC, Brundtland's curve, and Daly curve in each country to detect the difference between developed and developing countries shows that the USA achieved a level of decline in CO_2 emissions while maintaining positive GDP growth rates, which is the same direction as in the EKC. In Japan, the level of decoupling can be best described by Daly curve in the first couple of periods.

Regarding Egypt and India, unlike Brundtland's argument in his research, the relationship between environmental degradation and economic growth was not best described by his curve, and the Daly curve described most of the time frame as carbon emissions tend to rise alongside GDP growth, but the rate of decoupling fluctuates from weak decoupling to expansive coupling. They can also be characterized by the initial part of the Environmental Kuznets Curve (EKC), and with certain environmental incentives, they can reach a turning point where emissions decrease.

Thus, based on the previous results, we can mention different policies and show their implications, aiming to reach strong decoupling:

- Less reliance on CO_2 as an energy source will be required for economic progress by correcting price distortions to remove subsidies for fossil fuels. Fiscal ecological reforms can be implemented by shifting taxes to resource usage to promote energy efficiency and moving to clean, renewable energy sources like solar, wind, and nuclear power.

  In this context, Egypt has launched the National Strategy for Climate Change 2050, aiming to improve the quality of life for its citizens, foster sustainable economic growth, and protect natural resources. Despite contributing only a small share of global CO_2 emissions (<0.6%), Egypt is highly vulnerable to climate change negative impacts across various sectors, including agriculture, water resources, and infrastructure. The Strategy includes plans to adapt to climate change, identify problems in affected sectors, and enhance societal resilience. Egypt is also preparing a national adaptation plan, an interactive map to pinpoint vulnerable areas, and has issued green bonds worth US$750 million to support its green economy goals in the face of global challenges like climate change and COVID-19.

- It is critical to invest in the creation of energy-saving and carbon-reduction technology while eliminating coal energy plants that are being used in some of the discussed countries.

- Implementation of a comprehensive plan for greening jobs, skills, and education that incorporates sustainability goals, identifying labour market instruments, mobilising funds, encouraging the exchange of best practices, and promoting public awareness and participation involves several key steps:

  1. Assessing and planning the current state and sustainability goals.
  2. Developing supportive policies and regulations.
  3. Enhancing green job skills through training programs.

4. Integrating sustainability education into formal systems.
5. Using labour market instruments to promote green job hiring.
6. Mobilising funding from public and private sources.
7. Promoting the exchange of best practices.
8. Increasing public awareness and participation.
9. Continuously monitoring and evaluating progress.
10. Scaling up successful initiatives.

The total cost varies based on the economy's size and specific initiatives, with funding from various sources, including government budgets, private investments, and international aid. The economic benefits of sustainability can offset costs over time.

- State authorities, private organizations, and businesses should measure progress and report on their actions, with constant monitoring from the concerned parties - including the Ministry of Environment, non-governmental organizations like the Egyptian Environmental Affairs Agency, local communities, academic and research institutions, international organizations such as the United Nations Environment Programme, and environmental activists and advocacy groups - on achieving a specific set of environmental goals..
- Creating a network to share best practices, standardised procedures, and direction on topics like life cycle costing techniques and the usage of labels could benefit municipalities and administrations in engaging in green public procurement (GPP).
- Developing new indicators to better understand resource utilisation in production and improving existing indicators, including carbon, land, and water footprints. These indicators aim to provide clarity to policymakers, businesses, and the public regarding resource usage. The focus is on enhancing metrics for large factories and heavy industries, mainly in the private and non-governmental sectors. The overall goal is to offer better tools and data for managing resource utilisation and its environmental impact, informing policies, promoting sustainability in businesses, and increasing public awareness about environmental consequences of resource consumption.

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Appendix

Table 1
GDP Data

Year	Egypt	India	The USA	Japan
1990	3416.8	15833.8	100988.1	40558.1
1991	3455.2	16001.1	100878.8	41987.1
1992	3609.8	16878.3	104432.1	42365.2
1993	3714.5	17680.2	107305.9	42170.7
1994	3862.1	18857.5	111629	42627.6
1995	4041.4	20285.8	114625.4	43749.1
1996	4243	21817.3	118949.7	45120.1
1997	4476	22700.9	124239.6	45562.9
1998	4725.6	24104.8	129807.3	44984.1
1999	5011.6	26237.1	136030.9	44833.9
2000	5330.9	27244.8	141577.1	46073.3
2001	5519.3	28559.1	142928.2	46251.2
2002	5651.2	29645.5	145352.2	46270.6
2003	5831.7	31975.7	149416.5	46981
2004	6070.3	34509.1	155172.9	48008
2005	6341.8	37243.4	160577.9	48874
2006	6775.8	40245.5	165046.5	49544.8
2007	7256.1	43328.7	168364.7	50280
2008	7775.3	44666.1	168570.5	49664.4
2009	8138.7	48177.7	164187.8	46836.9
2010	8557.6	52271.6	168635.4	48756.2
2011	8708.6	55011.3	171249.1	48767.8
2012	8902.5	58012.9	175154.8	49438.3
2013	9097.1	61717.7	178380.9	50429.6
2014	9362.3	66291.1	182461.9	50578.9
2015	9771.6	71591.9	187400	51368.3
2016	10196.4	77502.8	190524.8	51755.5
2017	10622.7	82769.4	194796.2	52622.6
2018	11187.2	88111.2	200533.7	52929.9
2019	11808.9	91404.7	205134.8	52802.7
2020	12230.5	85375.6	199457.1	50423

Source: (World Bank, 2023b).

Table 2

CO_2 Emissions in KT

Year	Egypt	India	The USA	Japan
1990	87745.4	563575.4	4844517	1090508
1991	89369.5	607224	4807497	1103961
1992	90903.6	626293.3	4879626	1115035
1993	92661.9	651351.1	4995210	1107587
1994	87900.8	685903	5066803	1160755
1995	93722.3	737856.4	5117037	1170985
1996	98940.1	774070.2	5273486	1184647
1997	106057.6	819268.8	5543349	1172604
1998	110982.4	836269.9	5590536	1130281
1999	116535.3	901325.2	5609017	1168955
2000	114614.4	937858.4	5775807	1184425
2001	126704.4	953537.3	5748262	1172340
2002	129441.2	985453.3	5593024	1206760
2003	133020.4	1011771	5658992	1213930
2004	144503.9	1085667	5738286	1207286
2005	162217.1	1136466	5753493	1215474
2006	170745	1215205	5653081	1193043
2007	183395.7	1336737	5736319	1227991
2008	189935.2	1424383	5558379	1158836
2009	197660.5	1564881	5156425	1102386
2010	200313.3	1659983	5392109	1157242
2011	205767.3	1756744	5173591	1213776
2012	215000.9	1909442	4956053	1254319
2013	213856.4	1972429	5092097	1267376
2014	219121.1	2147107	5107209	1217307
2015	226283.6	2158023	4990704	1178349
2016	235425.8	2195249	4894499	1164869
2017	244540.5	2308804	4819365	1150835
2018	237983	2458176	4975300	1111115
2019	217908.3	2423951	4817710	1073645
2020	210752.3	2200836	4320533	1014065

Source: (World Bank, 2023a).

Table 3.
Production base CO_2 emissions

Year	Egypt	India	The USA	Japan
1990	75217530	577996540	5122496000	1158129400
1991	77295850	615365500	5064987000	1169777700
1992	79939880	655447550	5175220000	1179504300
1993	92277976	677299800	5274363000	1172487300
1994	84555820	716268600	5365579000	1227513600
1995	94890390	761449200	5427798500	1239909400
1996	93568660	825200830	5616430600	1252447000
1997	107512840	858935100	5691864600	1245139500
1998	121465780	876952060	5737129500	1205249900
1999	124496184	950950850	5810331600	1241835500
2000	140349710	978103800	6016350700	1264594600
2001	124293720	991731700	5911988000	1249988500
2002	125782376	1022175200	5952699000	1279362300
2003	146462660	1058725300	6015804400	1287691900
2004	149143330	1124517800	6117963000	1283076600
2005	165043680	1184926500	6137603600	1290599400
2006	176019060	1258643300	6057163300	1267624000
2007	185907330	1356953100	6135287300	1303362000
2008	194764000	1461518300	5918868500	1232480800
2009	203169680	1611416200	5482978000	1163375100
2010	200841470	1676495000	5681392000	1215058000
2011	213026640	1778472600	5546629000	1265034900
2012	213733500	1962594300	5345454000	1306182500
2013	211418900	2037415600	5480926000	1315568800
2014	226899340	2187343000	5528871000	1264413200
2015	224479730	2270766000	5376578000	1223605100
2016	239385570	2383816000	5251757600	1203888100
2017	260110600	2434868000	5210957300	1188359000
2018	243907870	2600446500	5376657400	1143411800
2019	256140160	2626459400	5259144000	1106015500
2020	235819780	2445012000	4715691000	1042224000

Source: (World Bank, 2023a).

Table 4.
Consumption-based CO_2 emissions

Year	Egypt	India	The USA	Japan
1990	81895850	575239550	5047884300	1317659000
1991	78313540	596627600	4962092500	1336395900
1992	87351330	646377600	5148217300	1423634800
1993	94125060	651706430	5208202000	1395227100
1994	89228580	684846700	5310463500	1468174800
1995	98724570	719422700	5371032000	1499940200
1996	99485630	768698600	5538584000	1493182000
1997	111580410	803935400	5643258400	1468469900
1998	128585190	820290050	5807569400	1372156700
1999	132505900	903167360	5985869000	1461891000
2000	136710240	905620000	6244750300	1546829000
2001	120575800	913154300	6168974000	1510765200
2002	121077300	928201200	6295762000	1501378700
2003	135220620	981077100	6488179700	1525949000
2004	131211050	1035427800	6623224000	1535019300
2005	147495890	1095645600	6729185000	1543864800
2006	156796960	1151739900	6716711000	1518880800
2007	170806980	1268807200	6651804700	1527833300
2008	181162980	1360786000	6327503000	1505146000
2009	197411340	1525794600	5784664600	1397639700
2010	200813300	1577571600	5971111400	1449777000
2011	210836370	1642312700	5822865400	1529670500
2012	221573870	1820424000	5656314400	1587669100
2013	213902750	1815656000	5743123000	1534877700
2014	240688420	1992492800	5842337300	1447222900
2015	247172820	2125896400	5795042300	1361484700
2016	259990640	2208969700	5663945000	1333812600
2017	255120860	2289075200	5635312000	1310950100
2018	242432060	2431702800	5804677600	1280274400
2019	253132050	2467513000	5692483600	1249506700
2020	241614200	2276880600	5197398000	1187140900

Source: (World Bank, 2023a).

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تصدر عن مركز المعلومات ودعم اتخاذ القرار

فحص ظاهرة الانفصال بين النمو الاقتصادي وانبعاثات ثاني أكسيد الكربون.. دراسة قياسية حول أربع دول خلال الفترة (1990 – 2020)

المستخلص

في ظل القلق المتزايد من التغير المناخي وضرورة الحد من التدهور البيئي، أصبحت العلاقة بين انبعاثات ثاني أكسيد الكربون والنمو الاقتصادي محل اهتمام. وتسعى هذه الورقة إلى بحث عملية فك الارتباط (Decoupling) بين انبعاثات ثاني أكسيد الكربون والنمو الاقتصادي، وترصد هذه الظاهرة في بلدين متقدمين، هما الولايات المتحدة الأمريكية واليابان، وبلدين ناميين هما مصر والهند. وقد تم الاعتماد على المنهج الكمِّي؛ لحساب القيم المحتسبة لعملية فصل الارتباط لكل دولة على مدى ست فترات زمنية تمتد من 1990 إلى 2020. وتناقش الورقة أيضًا أسباب حالة فصل الارتباط في كل بلد، وتستكشف أسباب بعض زيادات انبعاثات ثاني أكسيد الكربون مع ثبات النمو الاقتصادي، وفي بعض الحالات تراجع النمو الاقتصادي. وفي الخاتمة تقدم الورقة البحثية أشكال فصل الارتباط في كل بلد، استنادًا إلى منحنى Kuznets البيئي، وBrundtland، ومنحنى Daly. وقد حققت الولايات المتحدة الأمريكية مستوى من الانخفاض في انبعاثات ثاني أكسيد الكربون، مع الحفاظ على معدلات نمو إيجابية للناتج المحلي الإجمالي. وفي اليابان، يمكن وصف مستوى الانفصال بشكل أفضل من خلال منحنى Daly في الفترتين الأوليين. وبالنسبة لمصر، عبَّر منحنى Daly عن الفترتين الأوليين فقط. ويمكن لمنحنى Brutland أن يصف الوضع في الهند. واستنادًا إلى هذه النتائج، تم اقتراح بعض التوصيات المهمة.

الكلمات الدالة: النمو الاقتصادي، انبعاثات ثاني أكسيد الكربون، الفصل، مرونة الفصل، البلدان النامية، طريقه تحليل Tapio للمرونة