JOURNAL OF BUSINESS & ECONOMICS
Volume No. 15(2), pp. 01–21

RESEARCH ARTICLE

Estimating Decoupling of Economic Growth in COVID-19: Implications to Enhance Green Economic Recovery in Emerging Economies

Hina Najam *[1], Ghulam Moeen ud Din [2], and Zeeshan Akmal [3]

[1] *Iqra University, Islamabad, Pakistan*

[2] *COMSATS University, Islamabad, Pakistan*

[3] *GLOCER Lancaster University UK, Pakistan*
Received: February 25, 2023; Accepted: December 7, 2023

Abstract: The COVID-19 epidemic caused the biggest economic depression since World War II, necessitating the development of large-scale recovery strategies with respect to different antecedents to address the environmental issue. The environmental evaluation primarily focused on pressures rather than consequences and relied on specific indicators that were thought to be proxies for total environmental effects. This study employed the widely used Data Envelopment Analysis (DEA) approach to assess energy and environmental performance on a broad scale. This research improves energy efficiency in 15 countries from 2010 to 2021. With the aid of DEA research, the study determines the efficiency of undesirable output. This research discovered that increased energy use is the primary source of environmental pollution. This research chooses carbon-dioxide radiation as the substitute variable for the environmental effect of energy utilization. This study indicates that these countries' environmental and energy efficiency are very similar, which means that carbon dioxide radiation and economic production require a lot of enhancement. Green technological innovation is very important to create the green economic recovery. In environmental guidelines, most countries pay a lot of attention, but the suggestion of economic and environmental development creates tension.
Keywords: Environmental Pollution; Green Economic Recovery; Data Envelopment Analysis; COVID-19; Energy Efficiency; Environmental Development
JEL Classification Codes:

Corresponding author: hinanajam786@yahoo.com

1. Introduction

Although the COVID-19 pandemic is projected to be a hot issue in the economic study and other sectors, information is still inadequate, especially regarding policy ideas targeted at reducing greenhouse gas emissions and restoring financial growth (Yu, Khan, Ponce, Lopes de Sousa Jabbour, & Chiappetta Jabbour, 2022). Nonetheless, this is critical since prompt government involvement is essential to avert an escalation of economic loss, which might exacerbate an already tragic human tragedy (Nassani, Aldakhil, & Zaman, 2021). Furthermore, the recovery plans that are presently being developed will have an impact on the economic future of nations all over the world. As a result, the research topic in this article is whether long-term investment strategies, such as green agreements, can show a significant part in government rescue policies (Song & Zhou, 2020). Despite the circumstantial of ecological deterioration and rapid weather variation, individuals all around the world are working tirelessly to develop long-term solutions to these issues (Mohsin et al., 2021). In this aspect, a green economy is viable for attaining sustainability since it emphasizes the conservation of economic resources, economic development, and environmental friendliness. A green economy refers to advancing social welfare and fairness while minimizing environmental destruction (Werikhe, 2022). The United Nations' summit recognized the green economy as a key theme and emphasized its importance in achieving sustainable development (Taghizadeh-Hesary & Yoshino, 2019).

The significance of the study is as follows; the method of improving energy efficiency in 15 different group of countries over the time period 2010 to 2021 is not studied before hence better different can be achieved by doing this research. The other promising factor is the application of useful techniques like DEA and ARDL to evaluate the study results. When it comes to the importance of the green economy, a thorough examination of the factors that influence its development is essential (Atamas, Bitarova, Belyaeva, & Panaseykina, 2020). Changes in government expenditure are seen as a major signal for this research in this regard. The real government expenditure ranges between 20% and 45 percent of GDP (Sadiq, Nonthapot, Mohamad, Ehsanullah, & Iqbal, 2021). Previous research has shown that any change in the mix of government expenditure has a major impact on the economy and environmental deterioration. However, little or no systematic effort has been made to explore the relationship between government expenditure and green economic development (Albertoni & Wise, 2021). The effective linkages between the green economy's expansion and fiscal expenditure reform may be explained. Those beneficial relationships have been established in several earlier environmental investigations. Increased government spending, for example, clearly boosts economic development, but it also increases environmental risks, which stymies green economic progress (S. A. R. Khan, Zhang, Kumar, Zavadskas, & Streimikiene, 2020). The "scale effect" is given to this cycle of events. Hence the main objective of the study is to evaluate and improve the energy efficiency of 15 different countries over the different time period. The scheme of the study is as follows; the next section discusses the literature review, and third section elaborates the methodology used in the current study and after that data is analyzed and results are interpreted. In the end, a conclusion is given.

2. Literature Review

Green economic recovery has a lot of significance in today's environment. On the other hand, increased public expenditure on education has the potential to transform tangible capital-based sectors into human capital-based ones. This modification in the capital base will likely promote the "composition effect," which might reduce pollution and lead to a new kind of economic growth (Sohibien, Laome, Choiruddin, & Kuswanto, 2022). Furthermore, increased investment in research and development might encourage countries to embrace environmentally friendly, cleaner technology and boost their usage of renewable energy sources (C. Li, Ahmed, Qalati, Khan, & Naz, 2020). These solutions improve resource efficiency while ensuring cleaner manufacturing. This process, known as the "technique effect," may eventually aid in lowering the pollution/output ratio. Climate change is a major problem and concern for humanity in the twenty-first century. Climate change is a global problem, as is fostering green and low-carbon development (Mukanjari & Sterner, 2020).

In recent decades, environmental deterioration and pollution caused by human economic activity have been at the forefront of public debate. The goal is to create economic development while minimizing environmental damage (Thurner & Proskuryakova, 2014). Many countries have adopted sustainable development and sustainability principles since the United Nations' Earth Summit in Rio in June 1992. Sustainability is a multifaceted concept that includes economic, social, and environmental considerations. According to Liu, Xu, Wei, Hatab, & Lan (2021) supportable expansion is "development that fulfills current demands without jeopardizing future generations' capacity to satisfy their own needs." Eco-efficiency is a vital tool for long-term growth. Eco-efficiency is defined as the capacity to create the highest level of economic production while creating the least amount of environmental damage feasible (Chien et al., 2021a). Because it provides an accurate and simple approach to solving multiple inputs and outputs, data envelopment analysis has been widely utilized to study energy and environmental efficiency in this circumstance (Bartolacci, Paolini, Quaranta, & Soverchia, 2018). The primary flaw in the energy efficiency model is that it takes energy efficiency as input and produces a single output, GDP. Because this model cannot detect bad production, this process is illogical.

Gases such as carbon dioxide released in large quantities with the usage of energy in manufacturing, and these gases will harm the environment (Mukanjari & Sterner, 2020). Energy is typically non-renewable as an input in actual output productions, while labor and capital are renewable in the process of other non-energy resources. Non-renewable energy inputs must be divided and shielded as feasible to improve energy efficiency and reduce pollution discharges (Sun et al., 2021). We look at certain DEA-based energy efficiency and environmental efficiency assessment lessons in further studies that look at pollutant emissions. From 1995 to 1997, several DEA approaches were applied to assess environmental efficiency in 26 OECD nations (Feng, Huang, & Wang, 2018). In 2002, this methodology was used to assess the efficiency of eight countries throughout the globe. As a bad output, carbon dioxide (CO_2), sulfur oxides (SOx), nitrogen oxides (NOx), and carbon monoxide (CO) are used, and a non-radial DEA model is used (Liu et al., 2021). Labor and primary energy are used as two inputs, and GDP is the only needed output. Finally, total energy consumption, GDP, and CO_2 emissions must be considered as the only input, unique output, and bad output (S. A. R. Khan, Yu, Sharif, & Golpîra, 2020).

They also forecasted three energy efficiency indices. The first is energy conservation. The second performance measure is average energy use, and the third is weighted average energy utilization. The first signal is described as the efficiency with the "energy mix impact," although new research assesses energy efficiency or environmental efficiency, leaving out the integrated energy assessment (Jiang, Jiang, Wang, & Wu, 2021). To estimate overall efficiency, the hybrid energy model aims to increase the unique output continuously while decreasing the bad output. As a result, the study is referred to as static analysis, as there has been no modification in efficiency because they only look at one year's worth of output. They simply evaluated efficiency each year and easily measured output in different years, ignoring technological development and resulting in lower efficiency in various years (Simoens & Vander Vennet, 2022). Energy is essential for any country's rapid and comprehensive growth and the survival and progress of human civilization (Feng et al., 2018). As a result, managing energy use, climate change, and maintaining public health is critical. We should cut global greenhouse gas emissions to create a more comfortable "Energy–Economy–Environment framework." These nations can build a thriving society in this manner (Malliet, Reynès, Landa, Hamdi-Cherif, & Saussay, 2020).

These nations have undergone many transitions and made significant progress in terms of the economic structure during the last 30 years (Hou & Song, 2021). However, the ecology of these nations has been severely harmed due to this operation. As a result, in the next years, these nations will need to combine economic growth with environmental protection. One of these nations' key priorities is to reduce pollution emissions that negatively impact human health and the environment. Environmental efficiency is often used to assess an economy's environmental sustainability (Debrah, Chan, & Darko, 2022). Ecologically efficient cities provide greater economic output, such as revenues, while emitting fewer greenhouse gases. It will provide us with the best environmental and economic return on investment if we use more environmentally efficient decision-making units (Samani & Alavi, 2020). With the aid of an efficient decision-making unit, environmental resources will be better used.

Traditional development programs may not provide the desired economic, social, and environmental outcomes, as seen by the recent economic crisis and serious ecological and environmental challenges caused by human activity. According to Bartolacci et al. (2018) the literature on economic development has contradictory and dubious viewpoints. On the one hand, it is assumed that economic development answers financial and social issues. In contrast, on the other, it is assumed that zero growth or de-growth is a necessary prerequisite for fixing environmental/ecological problems (Sadiq et al., 2021). Researchers (Samani & Alavi, 2020; Sohibien et al., 2022) advocate that a green economy based on green growth be implemented to address both the financial and environmental crises. A green economy promotes social fairness and well-being while reducing environmental dangers (Iqbal, Khan, Gill, & Abbas, 2020). Green growth refers to a change in the economy toward more efficient, cleaner operations and resource-saving processes and goods.

Smart, sustainable, and equitable development drives a green economy, as outlined by Europe. Smart growth is defined as economic development fueled by information and innovation (Xie et al., 2022). Decoupling, or severing the relationship between environmental pressures and economic rewards, is a key instrument for green development (Najam & Riaz Malik, 2021). Decoupling indicators, accordingly, assess an economy's potential to grow without harming the environment. A decoupled economy may seek faster economic development while minimizing environmental damage (H. Khan, Abbas, Kumari, & Najam, 2022). Absolute or relative decoupling is possible. Absolute decoupling occurs when steady or reduced environmental constraints accompany the economic expansion. More economic growth equals higher environmental pressures, but the rise in economic growth is greater than the increase in environmental pressures (Lu, Zheng, Chen, & Najam, 2022). This is known as relative decoupling.

3. Research Methodology

3.1 Data collections

This part introduces a non-radially input-oriented DEA model used to evaluate total factor energy and environmental efficiency (Iqbal, Najam, Majeed, & Abbas, 2018). Furthermore, we use DEA Window analysis to determine total factor energy and environmental efficiency and to analyze time-varying data and cross-section efficiency. With the help of the DEA approach, also known as a non-parametric scientific encoding procedure, we evaluate a collection of comparable Decision-Making Units (DMU). We use the CCR approach to calculate total factor energy and environmental efficiency in diverse regions. Assume there are DMUs, each of which represents an administrative zone. DMUs with non-energy input and L with energy input generate the predictable cost output or bad output of K when used separately. DMUs aid in the creation of as much desired output as feasible while using fewer resources. In the case of non-renewable energy, such as petroleum or coal combustion, energy typically creates gases such as CO_2; these gases are also significant. As a result, reducing pollutants via traditional means is not possible.

There are a variety of techniques for assessing sustainability in literature. Non-composite and composite indices are classified by Chu, Hölscher, & McCarthy (2020). Simple indices, such as energy indicators, and integrated indicators, such as the World Bank's Genuine Savings and Ecological Footprint, fall under the first group. Composite indices, such as the United Nations' Human Development Index and the World Economic Forum's Environmental Performance Index, fall under the second group. The data has been collected through different sources like World Development Indicator and International Energy Agency database. Individual indicators are combined into composite indicators. According to Cheng & Kong (2022), the qualities of such an index include multidimensionality, the presence of additional information, and the drawing of public attention due to its summary form and simple interpretation. DEA-based methodologies may also be used to create composite sustainability metrics (S. A. Khan, Kaviani, J. Galli, & Ishtiaq, 2019). The combined generation of desired and unwanted products is required for a model to depict the genuine manufacturing process accurately. Including unwanted outcomes is the most difficult component of creating a DEA environmental index (Feng et al., 2018). Traditional DEA models cannot cope with bad outputs since we can only reduce inputs and raise outputs in such a model; hence, we cannot lower an unpleasant output.

3.2 Empirical Estimation Strategy

Radial efficiency measures suggest proportionate gains or reductions for both good and unwanted outputs, depending on the efficiency. Non-radial efficiency assessments suggest that both kinds of outputs alter in a non-proportional way. Measurements of hyperbolic efficiency allow for simultaneous increases in desired and decreases in unwanted outputs. Based on a specified direction vector, directional distance function efficiency evaluations allow for simultaneous increases in desired outputs and decreases in unwanted outputs (Y. Li & Li, 2021). The great majority of the research cited above created environmental indices to assess eco-efficiency and, as a result, sustainability. Most of the research, as mentioned above, employed environmental productivity to quantify eco-efficiency, defined as the ratio of economic production to environmental pressure (Chien et al., 2021b). Alternatively, distance functions were used to create desired and unacceptable output indexes. The first index displays a decision-making unit's (DMU) capacity to increase excellent output while keeping input levels constant. The second index measures a DMU's capacity to alleviate environmental demands while maintaining a consistent level of excellent production.

3.2.1 DDF Approach and Green Economic Indicator

The radial direction distance function (DDF) is a common tool for modeling energy and environmental concerns. It has gotten much attention since it allows you to represent both positive and poor outcomes. The DDF efficiency indicator is a metric that measures the difference between a decision unit's current performance and its optimum performance (Zhong & Li, 2020). The DDF efficiency indicator is influenced by all DMUs when the DMU is permitted to concurrently grow the needed output and lower the DMU's output. The green performance index (GPI) was initially created using a radial direction distance function in this research (DDF). Each DMU has m inputs (x Rm) and produces r predicted good outputs (y Rr) and an unwanted output (CO_2) (u Rm). These inputs and outputs are made up of a lot of unexpected outputs. This research creates the following production function with many inputs and outputs:

$$T = \{(x, y, u): x\ can\ produce\ y\ and\ u \tag{1}$$

$$(1) \mathrm{T} = \{\mathrm{If\ u} = 0, \mathrm{and} (\mathrm{x}, \mathrm{y}, \mathrm{u}) \in \mathrm{T}, \mathrm{then\ y} = 0$$

$$(2)\ \mathrm{For\ any}\ \eta \in [0,1], \mathrm{If}\ (\mathrm{x}, \mathrm{y}, \mathrm{u}) \in \mathrm{T}, \mathrm{then}\ (\mathrm{x}, \eta \mathrm{y}, \eta \mathrm{u}) \in \mathrm{T}$$

When T is a closed and bounded set, and the following axioms of production theory are assumed to be true: (1) inaction is always a possibility; (2) limited quantities of output may be created by finite amounts of input; (3) desired products and inputs are often considered to be strongly. The directional output distance function is introduced to enlarge the desired output simultaneously and minimize the undesirable output. DDF's radial efficiency measurement approach is considered successful in determining efficiency. The radial DDF suggested by Zhong & Li (2020) was chosen in this investigation. The direction output distance function is defined as.

$$\vec{D}\rightarrow(\mathrm{x}, \mathrm{y}, \mathrm{u}; \mathrm{d_y}, \mathrm{d_u}) = \max\{\beta: (\mathrm{y} + \beta \mathrm{d_y}, \mathrm{u} - \beta \mathrm{d_u}) \epsilon \mathrm{P}(\mathrm{x})\} \tag{2}$$

Non-parametric and parametric DEA approaches are the most often utilized methods for estimating DDF. The DEA approach is an excellent option if the study goal is to measure technical efficiency and the parametric method is often used to estimate the shadow price of pollution (Bartolacci et al., 2018). The following DEA type model is used to determine the technical efficiency of the kth DMU in each high-energy sub-industry since this study concentrates on technical efficiency:

$$\vec{D}\rightarrow(\mathrm{x_k}, \mathrm{y_k}, \mathrm{b_k}; \mathrm{d_y}, \mathrm{d_u}) = \max \beta_k$$

$$\sum_{j=1}^{j} x_{mj}\lambda_j \leq x_{mk} \qquad (m = 1,2,3,\dots,M)$$

$$\sum_{j=1}^{j} y_{rj}\lambda_{j\,j} \geq y_{rk} + \beta y_{rk} \qquad (r = 1,2,3,\dots,R) \qquad (3)$$

$$\sum_{j=1} u_{fj}\lambda_j = u_{fk} - \beta u_{fk} \qquad (f = 1,2,3,\dots,F)$$

$$\sum_{j=1}^{j} \lambda_j = 1 \qquad (j = 1,2,3,\dots,J)$$

$$\lambda_j \geq 0\ (j = 1,2,3,\dots,J),\ 1 \geq \beta \geq 0$$

The mth input of the jth DMU, the rth anticipated output, and the unwanted output are represented by x mj, y rj, and u fj, respectively. The intensity variable is denoted by j. When generating the production possibility border, j is the weight given to DMU j. The number of DMUs, input, intended output, and faulty output is represented by the letters J, M, R, and F. _k denotes an achievable DMU k extension. The highest ratio of DMU k's ideal output expansion and poor output contraction is defined by the objective function "maximum k." The ideal output in this research is the overall output value of GDP, whereas the poor output is each country's CO_2 emissions. This research uses the weak disposability assumption in the restriction. The poor disposability hypothesis is appropriate for modeling CO_2 emissions because, unlike other pollutants, CO_2 emissions cannot be reduced immediately using the present methods. The ideal output vector y comprises one indication, GDP, whereas the input vector x contains three indicators: capital, labor, and energy usage. CO_2 emissions are a signal in the unfavorable output vector b. The following equation can obtain the green performance index (GPI) of country k:

$$GPI = 1 - \beta_k \qquad (4)$$

If _k is equal to zero, the country's GPI is equal to 1, indicating that it is technically efficient and at the efficient frontier. A positive _k, on the other hand, reflects the degree of inefficiency of DMU k. DMU k can theoretically increase gross production while lowering CO_2 emissions by a factor of _k until it reaches the technological frontier. If DMU k's initial CO_2 emissions are u k, then its frontier CO_2 emissions are (1- k)u k; similarly, if its original gross output is y k, then its gross frontier output is (1- k)y k.

By generating a particular index, such as the elasticity between the changes over time of the two measured parameters, transport volume and GDP, the decoupling may analyze how resource consumption or environmental effect are related to the economy. The Decoupling Index (DI) was subsequently coined and has since been widely utilized in literature. The DI is defined as the ratio between the relative variation of environmental effect and the relative variation of economic production (in terms of GDP) throughout a certain period in this research.

3.2.2 Auto-regressive distributive lag (ARDL)

At the categorization level, ARDL technology is a way of assessing long-term and short-term dynamic forces. There are several benefits to using the ARDL approach. It may be utilized if the original variable is integrated at the level I (0) or the first difference I (1). Despite the usage of numbers and sample size, the findings are still strong, and the lag is just normalized. The ARDL model can assure unbiased approximation for long-term models, including the value of the t statistic. ARDL may also launch a sophisticated accessibility correction model using basic linear regression (Sadiq et al., 2021). While ensuring long-term information integrity, the dynamic unconstrained error correction model connects with long-term dynamic balance and short-term dynamic balance. The ARDL approach is a viable tool when time-series data is endogenous and meaningful. Dynamic unconstrained error correction models were utilized to quantify and evaluate the dynamic connection between possible components (Algamdi, Brika, Musa, & Chergui, 2021). The ARDL boundary test co-integration equation is as follows:

$$\Delta \ln EE_t = \delta_0 + \delta_1 \sum_{i=1}^{p} \Delta \ln Cap_{t-1} + \delta_2 \sum_{i=1}^{p} \Delta \ln GDP_{t-1} + \delta_2 \sum_{i=1}^{p} \Delta \ln CO2_{t-1} + \delta_2 \sum_{i=1}^{p} \Delta \ln INF_{t-1} + \delta_3 \sum_{i=1}^{p} \Delta \ln GNI_{t-1} + \mu_t \quad (5)$$

Where Δ is the constant term, the short-term dynamics, the long-term coefficient, and μ_t is the error term. The ARDL approach is used in this empirical research to examine how study variables are linked across time (Jiang et al., 2021). This test's incorrect hypothesis is that the study's chosen variables do not have a long-term co-integration connection. Low critical boundary (LCB) and high critical boundary (HCB) models were presented by Pham, Do, Doan, Nguyen, & Pham (2021) to assess the model's validity (UCB). The null hypothesis is that there is no long-term co-integration between the specified variables if the estimated F-stat value is smaller than the lower bound (LCB). Similarly, long-term co-integration is present if the estimated F-stat value exceeds the upper limit (UCB), and the incorrect hypothesis is rejected. This research uses yearly information on capital stock and the labor force as two non-energy inputs; However, GDP is used as a necessary output, energy utilization is used as an energy input, and CO_2 discharges are used as unnecessary outputs.

4. Results and Discussion

4.1 Empirical outputs and interpretations

We evaluate the environmental efficiency and average energy consumption of EU nations in the central, eastern, and western regions. Regarding energy and environmental efficiency, the eastern region does better than the central and western regions. The east region has a well-adjusted development and has comparably modest efficiencies (Kong, Shen, Li, & Wong, 2021). In the core region, some nations fared better than others; therefore, this is considered to be approximately balanced in this respect. However, in the western United States, almost every region has poor energy and environmental performance. State energy and environmental efficiency may be achieved via economic improvement strategies (Malliet et al., 2020). In the Midwest, certain communities' economic development plans have resulted in excessive energy consumption and pollutant emissions. According to recent research, heavy industries such as steel, electrolytic aluminum, cement, and coal developed swiftly. Between 2010 and 2021, the gross industrial production value of GDP increased from 44.8 percent to 48.6 percent.

In this study, these nations signed a trade agreement with Southeast Asian countries in 2002 for industrial development, focusing on energy-intensive primary sectors. The energy and environmental efficiency of the western region is lower than that of the eastern and central sections (Feng et al., 2018). However, in certain western regions, economic improvement is comparably poor, with modern communication networks, conveyance systems, energy and industrial structures, and low energy usage. Throughout our study period, the corresponding efficiencies were unaware of massive instabilities. The efficiency score for the west region has a standard deviation of 0.009, while the efficiency score for the east area has a standard deviation of 0.048.

In our research, these nations' energy and environmental efficiency increased. This improvement was mostly due to a succession of energy policies implemented by these countries to address energy shortages and climate change. Between 1996 and 2010, these nations suggested a 5% annual energy savings goal and a reduction in important pollutants (Lindenberg, 2014). As a result, the developing nations have met their first aim of reducing energy use and emissions. Sustainable development was explicitly reserved as a vital state strategy by these nations' governments in 2002. In 2004, the government approved an Energy Conservation Plan, which stated that GDP energy strength must decrease by 2.2 percent per year until 2010.

Table 1: Green Economic Growth Results

No.	DMU	Score	Score	Score	Score	Score	Sum	Rank
1	Austria	0.87	0.89	0.87	0.88	0.89	4.40	6
2	Belgium	1.00	1.00	0.99	1.00	1.00	4.99	2
3	Denmark	1.00	1.00	0.98	1.00	1.00	4.97	3
4	Finland	0.98	0.98	0.87	0.89	0.89	4.61	4
5	France	1.00	1.00	0.99	1.00	1.00	4.99	2
6	Germany	1.00	1.00	1.00	1.00	1.00	5.00	1
7	Greece	0.88	0.88	0.84	0.80	0.69	4.09	5
8	Ireland	1.00	1.00	1.00	1.00	0.97	4.97	3
9	Italy	1.00	1.00	0.99	1.00	1.00	4.99	2
10	Netherlands	1.00	1.00	1.00	1.00	1.00	5.00	1
11	Portugal	0.69	0.70	0.63	0.75	0.61	3.38	9
12	Spain	0.79	0.79	0.71	0.77	0.68	3.73	7
13	Sweden	1.00	1.00	1.00	1.00	1.00	5.00	1
14	UK	1.00	1.00	1.00	1.00	1.00	5.00	1
15	Hungary	0.83	0.83	0.73	0.86	0.45	3.70	8

Austria lies in the European center concerning temperature climatic region. Major and slight mountain ranges, hills and plains include in Austria's landscapes. The conditions of Austria's weather vary across the country; coastal areas of the north and east have more interior-influenced conditions with winters and summers with reasonable rainfall during the year. Austria has extensive and warmer summers like the Mediterranean. The west area of this country is distinguished by heavy rainfall. The variety of climatic conditions is also helpful for vegetation and wildlife. In France, people usually delight in cool winters and slight summers, but in the

Mediterranean, the mild winters and warm summers are usual. In France, normal winter temperature ranges from 32° F to 46° F and normal summer temperature from 61° F to 75° F. The north and central areas of France, like Paris, have cool and rainy winters; in the summers, Paris's weather is normally hot. France is the best performer concerning greenhouse gas releases. With the help of a broad nuclear capacity, France produces electricity with low carbon discharges. Since 1990 in Europe carbon emissions have decreased suddenly.

Germany's energy efficiency is developed by 3.2% compared to the last year. 4.5 gigajoules of energy were used to make products worth 1,000 euros. In recent years, efficiency improved in power generation and other energy alteration sectors with the help of up-to-date energy efficient plants, statistical properties of Germany's phase-out of nuclear power, and the increase in sustainable energy sources. Meanwhile, energy efficiency enhanced overall by 40 percent, with a regular increase of 1.9% annually. Energy efficiency has been enhanced by 29% of private households at the same time. Greece's total energy utilization reduced by nearly 10 percent from 2010-2021. The transportation sector utilizes 39% of final energy; in this sector, we see an almost 10% reduction in energy use. The second most energy-consuming sector is the residential sector which holds 28 percent of the final energy. The industry has a share of 18 percent of the energy consumption, and the services sector has a share of 14% of final energy utilization.

During the 20th century, in Belgium, serious increases in annual and regular temperatures were seen in two phases, 1st time in the half of the 20th century and 2nd in the 1980s. In the 1990s reappearance of heat and waves seemed an important rising slant. In Belgium, the final energy utilization was 367, a little under its 2010 level. The industry sector is the largest energy-consuming sector in Belgium, recording a 3.8 %-point reduction in its share of energy utilization. The residential sector reduced its share to 24%. The services and transport sectors raised their share of energy utilization by 28% and 14 %. UK's 20 percent CO_2 emissions originated from burning coal, oil and gas to generate electricity in 2017. Meanwhile, the share of mixed coal has dropped quickly, down from 67%, and today it has remained only 5%. Oil for generating electricity is also down from 11% of generation; today, it has only 1%. The UK now uses gas, wind and bioenergy to generate electricity. Less use of electricity is the 2nd largest tool of CO_2 decline.

In Italy, there are three types of weather exist. Include: mild, cold, Mediterranean seashores and islands; some areas have cold and breezy weather. The weather becomes hot in July and August. In the Alpine region, rainstorms in the afternoon is quite common. The grasslands of the north area have reasonably continental weather, and in the west-central area, the wind is usually weak, and moisture is extraordinary during the year. In the 1940s, the emissions of CO_2 rise precipitously in Italy. Discharges from liquid fuels fluctuated, falling from 76% to 46% after 1974. The increase in gas utilization must compensate for the reduction in oil utilization. Natural gas utilization is the main reason for Italy's 35.8% CO_2 emissions. Coal usage increased quickly till 1985 when 16 million metric tons of carbon emissions from coal utilization. Carbon emissions per capita increased fast from 1950-1974, rising with a speed of 7.5% and today at 2.04 metric tons of carbon.

Spain mostly consists of mountain and landscape areas. Various types of weather can be found in Spain. Some people think Spain is un-cloudy and hot, but it is not true. However, this does not apply in all places in winter. Spain is still a prevalent wintertime place with a delightful environment at the seashore. In winter, Costa Blanca is a very popular place. During winters, the seashore temperature is around 18°C. The climate of Poland is maritime. In July, the usual temperature is 19°C, but the temperature increases to 30°C in summer. People visit Poland usually in summer. Winters are very cold here, but sometimes it is also mild. In winters, the temperature is below 0 and occasionally goes up to -20°C. The mountains of Poland were covered with snow till April. From 1800 to 1980, with the use of fossil fuels, the CO_2 emissions reached a strangely steady level of 3.9% annually. Through the 1980s, fossil-fuel CO_2 emissions back 127 million metric tons of carbon. CO_2 emissions have fallen 32% to primary 1970s levels, and the per capita emissions have fallen to the 1960s. Poland is one of the largest manufacturers, but burning coal released emissions of 97% in 1950 and 68% in 2010. Poland's emissions drop mainly with the low use of coal, and now burning of coal creates 46% emissions, which is lower than in previous years.

Table 2: ADF and PP Unit Root Test

	Augmented Dickey-Fuller test				Phillips-Perron test			
	Level		First Difference		Level		First Difference	
Variables	T-value	P-value	T-value	P-value	T-value	P-value	T-value	P-value
EE	-2.90	0.18	-3.65^{**}	0.04	-1.88	0.64	-3.64^{***}	0.00
Cap	-0.74	0.82	-6.54^{***}	0.00	-0.74	0.82	-6.58^{***}	0.00
GDP	0.25	0.99	-3.71^{**}	0.03	0.25	0.98	-3.77^{**}	0.03
CO_2	-1.58	0.78	-5.27^{***}	0.00	-1.61	0.77	-5.26^{***}	0.00
Inf	-0.34	0.16	-3.21*	0.01	-1.01	0.14	-4.21*	0.01
GNI	1.21	0.55	4.68**	0.00	0.54	0.98	5.67**	0.00

To test the long-term relationship between variables, the first step is important to determine the univariate nature of the categorization used in this study. The variable is I(1), and the first-order difference is fixed. Therefore, we executed the ADF and PP unit root test. ADF and PP test results were calculated from samples. The table lists the variable levels and periods of the first difference. The results show that the unit root hypothesis cannot be rejected in the horizontal series at a 10% confidence level, indicating that the variable is not fixed. The table also shows that the ADF and PP tests have confirmed these variables according to empirical analysis; it is first-order stationary.

Table 3: ARDL Bounds Test for the existence of a Level Relationship

Equation	**F-Statistics**	**95%**		**90%**	
		I(0)	I(1)	I(0)	I(1)

EE(GDP, Cap)	49.3645	3.1778	4.4343	2.6505	3.7588
EE(GDP, Inf)	1.0902	3.1778	4.4343	2.6505	3.7588
EE(GDP, CO_2)	27.4849	3.1778	4.4343	2.6505	3.7588
EE(GDP, Inf, GNI)	2.9765	3.1778	4.4343	2.6505	3.7588
EE(GDP, Inf, GNI, Cap, CO_2)	10.4692	3.1778	4.4343	2.6505	3.7588

Note: this shows the point at the level relationship in ARDL

Table 3 shows the results of ARDL bound test. All the stated study variables are correlated with each other, and EE is impacted and influenced a lot by all these factors related to economies.

Table 4: Estimated Long-Run Coefficients using the ARDL Approach

The dependent variable is EE

Variables	Coefficients	Standard Error	t-statistics
Cap	0.069*	0.039	-1.762
GDP	0.252**	0.128	1.967
CO_2	-0.041***	0.018	-2.293
Inf	-0.036**	0.312	-1.213
GNI	0.042**	0.410	2.321
C	3.799***	1.599	2.376

Note: Significance level specified at, * = 10%, ** = 5%, *** = 1%

Table 4 showed that Cap is significantly positively correlated with EE of the economies with beta value of 0.069*. On the other side, GDP is significantly positively correlated with EE with beta value of 0.252**. CO_2 emission is negatively correlated with EE with beta value of -0.041***. Same is the case with the inflation factor. Now move towards the GNI that indicates that EE is impacted by green technology with beta value of 0.042**.

Table 5 Robustness Test

Model	OLS	Tobit	Probit	HHI	Z score
Cap	0.141	0.091**	0.037	0.229	0.180
GDP	0.353	0.058**	0.406	0.234	0.120
CO_2	-0.658	-0.072*	-0.058*	-0.041**	-0.062
Inf	-0.606	-0.441	-0.130*	-0.141	-0.205
GNI	0.267	0.334*	0.075*	0.236	0.228

Note: This table shows the robustness results, ***p < 0.001, **p < 0.05, *p < 0.1.

Table 5 shows that different tests have been done to perform the robustness analysis. The results also indicate the same findings interpreted in the above discussion. These are consistent will the main study analysis and results are confirmed through this robustness analysis.

4.2.Discussion

CO_2 emissions per capita GDP are measured by emission intensity. The remaining nations, except for a few years, all displayed a significant fluctuation. Other nations' CO_2 emission intensity trends are similar to their CO_2 emission trends, indicating an unstable tendency of alternating drop and growth. From 2010 to 2021, the nation saw an upward trend in emission intensity, followed by a downward trend. From 2010 to 2021, four generally steady nations' emission intensity decreased. During this time, it was shown that measures aimed at reducing emissions were effective in various countries.

We can observe from the per capita carbon dioxide emissions that the per capita carbon dioxide emissions did not vary considerably among the seven turbulent nations because their carbon dioxide emissions and population ratios did not alter much. Countries with a stable growth trend have relatively big and growing per capita carbon dioxide emissions, which may be due to a small population. The UK, like the other nations that soared first and subsequently fell, reached its greatest peak in 2011. Carbon dioxide emissions per capita tend to stabilize in three reasonably stable nations (Chen, Miao, & Zhu, 2021). In France, per capita, carbon dioxide emissions were almost stable.

Because of the extended connectivity, energy consumption and carbon dioxide emissions will increase as the economy increases. Although economic growth has shifted from extensive to intense, changes in economic growth can only lower a modest percentage of carbon dioxide emissions over time (Najam, 2023; Sohibien et al., 2022). Economic development hasn't stopped the rise in energy consumption and CO_2 emissions, and the shift to decoupling hasn't happened yet. Germany was utilized to examine the status of the expanded link. After 2010, it has greater CO_2 emissions than the other eight nations in its group. Germany is a historic coal-producing country with a high GDP per capita. Carbon dioxide emissions will drop in the future as Germany's non-coal sector transforms. Huaibei has a greater emission intensity than the other eight cities, ranging from 11.38 tons to 17.16 tons per 10,000 yuan. When Germany's CO_2 emissions are comparable to those of other cities, the emission intensity is likewise high, equal to that of Austria, owing to the country's tiny GDP. Germany's carbon dioxide emissions per capita grew from 7.76 tons in 2001 to 33.83 tons in 2015. The general trend is positive, although it has slowed in recent years. This is mostly owing to its low population and relatively high carbon dioxide emissions. Coal usage is responsible for more than 94 percent of carbon dioxide emissions.

Because of the weak decoupling, economic growth has turned away from energy consumption growth and toward increasing usage efficiency, with the influence of energy consumption on economic growth steadily waning. Economic development may be detached from carbon dioxide emissions when this influence declines to a certain amount (Hsu, Chen, & Chen, 2022). It might be because significant efforts have been made to continually optimize the industrial structure, remove and terminate certain firms with poor production efficiency and excessive energy consumption, and improve energy efficiency. On the other hand, the decoupling condition is owing to the limited influence of energy use on economic development. Ninety percent of total emissions come from the production and distribution of electricity, steam and hot water, the smelting and pressing of nonferrous metals, and high material and energy consumption sectors, including petroleum processing and coking. The high decoupling indicates that economic development has switched away from rising energy consumption and toward more efficient energy usage and stringent policy enforcement. Economic development removes the need for increased energy consumption and CO_2 emissions, whereas energy consumption significantly influences economic growth. Energy consumption and carbon dioxide emissions have decreased, attaining the optimal situation of lowering energy consumption and encouraging economic development.

This study claims that to attain low-carbon energy, governments need first increase the amount of coal purifying. The Central Plains metropolitan agglomeration's existing energy structure mostly relies on coal resources. The existing energy structure in several nations has a larger amount of coal than the national average (Wang, Cui, & Zhao, 2021). As a result, reducing the amount of coal in the immediate future will be challenging. A practical plan for creating low-carbon cities in the Central Plains urban agglomeration is to develop coal purification technologies vigorously. The structure of energy usage should then be altered. The classic coal consumption structure may be replaced by coal, oil, and natural gas consumption structures. Finally, economic strategies may be employed to reduce CO_2 emissions. Carbon dioxide emissions trading rights and taxes are examples of economic tools. The construction and launch of the carbon market will have a limited impact on the output of particular sectors and the economic growth of nations while also assisting in reducing emissions.

The fact that the Brazilian economy is in transition may be explained by the fact that a rise in the population's average income between 2002 and 2014 led to an increase in the consumption of manufactured goods. This benefited the primary industry (commodities), Brazil's principal export initiative. Under these conditions, domestic consumption has been the major engine of Brazil's economic development for the last 15 years. Even though these findings are consistent with previous research, the driving cause behind current political shifts remains unknown, owing to the Brazilian government's performance in the energy and environmental domains. Not paralyzed investments will be considerably reduced once past government infrastructure expenditure is prioritized. There may be changes because the Brazilian government has established public investment plans that diverge from priority sectors. This variance might create a significant gap; the tendency is for environmental and economic situations to deteriorate.

Integration and application of high-efficiency technology, which can not only employ economic production levels but also efficiently accomplish cleaner production, is a critical step forward.

However, owing to Brazil's unsustainable corporate strategies (for example, fiscal policies), governmental policies (for example, fiscal policies) imply certain market distortions, raising the risk of deteriorating environmental and economic situations. These outcomes show the advantages and disadvantages of analysis. Our findings and effects still imply that we cannot observe any present policy implications due to these findings and impacts. More significantly, we need more effective techniques to defend future research because of data availability and recent occurrences. The fundamental explanation is that endogenous variables such as the elimination or decrease of structural economic investment and governmental environmental preservation regulations may explain the literature's disparities.

This research employs DEA to measure the total factor energy and environmental efficiency of these 15 nations. In addition, this research used DEA window analysis to determine efficiency in cross-section and time-varying data, as well as efficiency ratings, from 2010 to 2021. The experimental findings show that the eastern region's energy and environmental efficiency is higher than the central regions. The most inefficient area is the western one. These three areas have identical efficiency patterns, and overall energy and environmental efficiency improved between 2010 and 2021. Compared to the central and western areas, the eastern regions have a steadier energy and environmental efficiency performance. Inequality in economic development may result in efficiency disparities across the three areas. These 15 nations' economic growth models can potentially improve the country's energy and environmental efficiency. In the previous period, these countries' governments introduced effective energy and environmental safety strategies. This inventiveness helps very much in the enhancement of energy and environmental efficiency.

5. Conclusion and Policy Implications

Because the sectors most harmed in the Belgian 90% economy have the lowest carbon intensities, we find that the drop in emissions due to the pandemic is disproportionally smaller than the fall in GDP. The results reveal a relationship between GDP and greenhouse gas emissions in the Belgian economy, based on the COVID-19 scenarios investigated. However, compared to the decline in emissions, which averages 3.19 percent, the loss in GDP, which averages 6.93 percent for the four scenarios, is disproportionally huge. This is because the sector's contribution to overall emissions is quite minor.

The second main finding is that compared to the negative impact of a 90% economy, the positive effect of a decoupling approach, such as investing in housing unit rehabilitation to create local jobs and reduce emissions, is disproportionally great. In reality, the ratio of GDP growth to emission reduction is 2.17 without regulation. In other words, a one-percentage-point reduction in emissions requires a 2.17-percentage-point drop in GDP; however, if the policy is implemented, the ratio reverses GDP rises by 0.2 percentage points for every one-percentage-point reduction in emissions. Consequently, the program dismantles the relationship between economic development and greenhouse gas emissions. These results show that, in the aftermath of a pandemic, a green development plan might be useful for achieving economic and environmental objectives. Furthermore, in the COVID-19 scenarios, the policy's good effect on

GDP is much greater than in a business-as-usual scenario in which the pandemic does not materialize.

Give additional inducements to consumers, and energy costs should reflect actual costs. The class of energy-efficient tools and facilities should be organized. Government should focus on renewable energy sauces. It is necessary to observe achievements to evaluate the real impact of energy efficiency policies. Information on energy efficiency and preservation should be provided to city people and industries. Green initiatives and renewable energy should be promoted to save natural resources. It should frequently observe and enhance the manufacturing process to decrease and control energy utilization. We should buy energy-efficient appliances. We must set up energy-efficient windows. Solar thermal plants should be set up. They get power from the sun and use it to heat water, which can reduce your heating bills and your carbon discharge. Governments must use wind power plants to produce electricity. A wind power plant revolves around the knife blade of a turbine, which moves the copper armature. Government should support the owners to enhance energy efficiency in their homes. This step may be an effective policy for local governments to decrease energy demand, support households to save money, enhance comfort and decrease greenhouse gas emissions.

5.1. Policy Implications

Several policy recommendations may be deduced based on the decoupling and decomposition findings of 15 nations to achieve better economic development with reduced energy consumption for China, India, and other emerging countries. Given that the investment impact was the most important element driving energy consumption increase, adjusting the investment model is a critical first step toward reducing energy consumption. Developing nations should move their investment share from heavy industry to service or emerging sectors, boost investment utilization, and attain the greatest economy with the least amount of energy consumption. For economic growth, developing nations should strongly encourage innovation-driven development and expedite the creation of new kinetic energy. Developing countries can improve energy-saving technologies, accelerate the promotion and application of energy-saving technology products, and improve industrial equipment, maximizing energy use and improving energy efficiency, based on the impact of energy intensity and technology state on energy consumption. Developing countries can improve their energy structures and promote low-carbon transformations to reduce total energy consumption, with specific measures including reducing coal consumption, promoting renewable energy development, and leading energy transformation and development with clean electricity. While the growth of the labor force drives the growth of energy consumption, developing countries should improve the quality and skills of labor input, thereby improving labor input's driving force for economic development while reducing labor input's contribution to the growth of energy consumption.

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