Cuadernos de Economía (2023) Volume 46, Issue 131, 198-205

Asociación Cuadernos de economía

Cuadernos de economía

www.cude.es

ARTÍCULO

The Role of Carbon Pricing Mechanisms and Renewable Energy Technologies in Reducing Carbon Emissions: Evidence from the International Economy

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Jel Codes:

Keywords:
Carbon taxes, carbon cap and trade, renewable energy consumption, reducing carbon emission economic growth.

Abstract: The international community now places significant emphasis on achieving zero carbon emissions, requiring both new researchers and experienced policymakers to prioritise this goal. This article examines the effects of carbon taxes, carbon cap and trade, renewable energy (RE) production and consumption, and economic growth (EG) on carbon emission reduction in the United States, Japan, Canada, and Australia. The study collected secondary data from the World Development Indicators (WDI) secondary source spanning the years 1991 to 2022. The study examines the relationship between variables using the cross-sectionally augmented autoregressive distributed lag (CS-ARDL) approach. The findings indicate that carbon taxes, carbon cap and trade, RE production, RE consumption, and EG are all associated with a reduction in carbon dioxide (CO2) emissions in the United States, Japan, Canada, and Australia. The study provides guidance to regulators in developing regulations aimed at achieving zero carbon emissions. This includes implementing an efficient carbon tax system, effectively applying restrictions on carbon cap and trade, and maximising the use of renewable energy sources.

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https://doi.org/10.32826/cude.v46i131.1119

1. Introduction

The natural environment, which serves as a habitat for humans and a setting for various activities, exerts a significant impact on human social well-being, the economic advancement of nations, financial growth, and future progress. The health of living organisms, including humans, is influenced by environmental factors, which also define the quality of natural resources necessary for human utilisation. An environment that is clean, well-maintained, and abundant in high-quality natural resources promotes human health, vitality, and efficient functioning (Khan, Hou, & Le, 2021). The presence of robust human capital, characterised by high intellectual capacity and a strong labour force, along with the availability of healthy living resources (including animals, birds, plants, and fish) and high-quality non-living resources, plays a crucial role in bolstering the country's economy in the present and ensuring a sustainable future for economic development (Guo et al., 2021). Some polluting elements arise naturally, while others result from human activity related to society, the economy, or development. These elements have a detrimental impact on the efficiency of natural resources and human health and impede the growth of the country (Umar et al., 2021).

Carbon dioxide (CO2) emissions are a significant source of pollution and have a severe impact on environmental quality (Saidi & Omri, 2020). The generation of CO2 leads to the retention of heat in the Earth's atmosphere, resulting in an escalation of global warming. This disrupts the natural weather patterns and has detrimental effects on both human beings and the ecosystems in which they reside. CO2 emissions released into the atmosphere create a layer that obstructs sunlight and contributes to global warming. Consequently, the global temperature is experiencing a substantial increase. The geographical features, climate patterns, water availability, food, and natural resource quality, as well as the well-being of humans and other organisms, are expected to be impacted by the rising levels of CO2 emissions and subsequent global warming caused by these emissions (Xu, Schwarz, & Yang, 2020). The country's overall development is at risk due to the need for various resources such as a healthy environment, productive soil, clean water, bio-productivity, minerals, and human resources. To mitigate environmental concerns and associated hazards, it is imperative to decrease CO2 emissions (Aktar, Alam, & Al-Amin, 2021).

Human activities in residential, societal, and economic settings are the primary contributors to CO2 emissions, despite the presence of natural sources. This is typically due to human activities involving energy consumption and chemical usage, such as lighting, heating, cooling, operating electrical appliances, utilising various technologies in the manufacturing, construction, and service industries, transportation, information handling, and communication. Human activities disrupt the equilibrium of atmospheric CO2 levels. However, there are potential solutions, such as implementing carbon pricing mechanisms and utilising renewable energy technologies (Green, 2021). The carbon pricing mechanism encompasses carbon tax, carbon cap, and trade. The government imposes a carbon tax on individuals or entities engaged in carbon-emitting activities. The cost associated with carbon-emitting activities poses a financial burden and discourages individuals from engaging in such activities. Carbon cap and trade refers to government-imposed restrictions or limits on the use and trade of carbon-emitting products. The successful implementation of carbon pricing mechanisms leads to a reduction in CO2 emissions (Best, Burke, & Jotzo, 2020). RE technologies encompass both the production and consumption of renewable energy. RE production refers to the generation of energy from naturally occurring resources that can replenish themselves. Renewable energy sources, such as wind power, solar power, geothermal power, bioenergy, and biofuel, contribute to a decrease in carbon emissions. Similarly, RE consumption refers to the utilisation of energy derived from clean and sustainable resources and methods. Consumption decreases CO2 emissions (Jebli, Farhani, & Guesmi, 2020).

This study examines CO2 emissions in the global economy, focusing on four countries: the USA, Japan, Canada, and Australia. The expansion of the market leads to significant CO2 emissions. Based on empirical data from 2019, the United States was responsible for emitting 14.64 metric tonnes of CO2 into the atmosphere (Bilgili et al., 2021). Canada is a developed nation with a well-developed mixed economic system. The population of the area is 40,097,761 individuals. The country's nominal GDP for 2023 is $2.118 trillion, positioning it as the tenth-largest economy. According to the latest data in 2021, Canada's emissions amount to 545.6 million metric tonnes, primarily attributed to the extensive utilisation of fossil fuels and the growth of industrial activities. The data indicates a 2% increase compared to the previous year (Rahman & Vu, 2020). Japan possesses a sophisticated social market economy, commonly referred to as the East Asian model. With a nominal GDP of $4.231 trillion, it ranks as the fourth-largest economy globally. Japan's CO2 emissions in 2022 amounted to 1.08 billion metric tonnes (Dou et al., 2021). Australia's economy is characterised by a mixed and highly advanced structure. In 2023, Australia's nominal GDP will be $1.688 trillion, making it the 14th largest national economy in terms of nominal GDP. Australia emitted 463.9 million metric tonnes of CO2 in 2022 (Adebayo & Acheampong, 2022). To mitigate CO2 emissions and protect the environment, these economies require efficient initiatives. This study focuses on strategies to mitigate CO2 emissions, addressing the existing demand for such solutions.

This study has made substantial contributions to the existing body of literature. This study aims to analyse the effectiveness of carbon tax and carbon cap and trade as mechanisms for reducing CO2 emissions. Furthermore, previous research has primarily focused on discussing the role of renewable energy (RE) in relation to environmental quality. This article contributes significantly to the existing literature by examining the production and consumption of renewable energy (RE) separately while also evaluating the levels of CO2 in the atmosphere. The article examines various aspects of carbon taxation, carbon cap and trade systems, renewable energy production and consumption, and the role of environmental governance in reducing global CO2 emissions.

The article is divided into five sections. The second section involves conducting a literature review to examine the correlation between the chosen factors. The third section outlines the study methodology, while the fourth section presents the research findings. Subsequently, the final section encompasses a discussion, implications, conclusion, and limitations.

2. Literature Review

Various articles have examined the effectiveness of carbon tax, carbon cap and trade, renewable energy production,

renewable energy consumption, and energy generation in mitigating CO2 emissions. This study conducts a literature review to examine the relationship between carbon tax, carbon cap and trade, renewable energy (RE) production, RE consumption, and environmental governance (EG) in the context of reducing CO2 emissions.

Carbon taxation involves the categorization of economic units and individuals, with taxes imposed on those responsible for emitting carbon into the atmosphere. The financial burden incurred by individuals is a consequence of their choices, leading to pollution. The imposition of significant carbon taxes prompts individuals to modify their behaviour and embrace carbon-neutral resources and practices due to the financial burden they experience. Consequently, they were able to reduce carbon dioxide (CO2) emissions (Pretis, 2022). Nong, Simshauser, and Nguyen (2021) conducted a study to examine the impact of carbon taxes on emissions reduction. The GTAP-E-PowerS model was utilised to analyse global climate change policy. Data were collected from both developed and developing countries. The research focused on the following developing countries: Iran, Kazakhstan, Australia, the United States, South Africa, China, India, Russia, Mexico, and Indonesia. Firms may be deterred from non-compliance with carbon taxes due to the potential legal consequences and associated penalties imposed by the government, according to this study. Consequently, carbon-intensive activities are reduced, leading to a decrease in CO2 emissions Ghazouani et al. (2020). examine the impact of carbon taxation on the reduction of CO2 emissions. The contextual evidence was gathered from European countries that have implemented and not implemented taxes. The research analysis utilised the Covariate Balance Summary Test and Kernel Density Test to obtain findings. The study suggests that implementing carbon taxation on business firms in an economy results in reduced usage of fossil fuels and chemicals, thereby leading to a decrease in CO2 emissions.

Carbon cap and trade is a regulatory approach that establishes a maximum limit on the usage and trading of carbon-emitting products as a means of carbon pricing. It significantly influences individuals' patterns of consumption and trading, leading to a notable reduction in carbon emissions. There has been a decrease in CO2 emissions (Holtsmark & Weitzman, 2020). Putra (2021) analyses the effectiveness of carbon tax, carbon cap, and trade mechanisms in reducing CO2 emissions. The authors employed normative legal research for this study. The research aimed to gather secondary data on the implementation of the carbon tax, carbon cap, and trade in Indonesia by examining relevant laws, regulations, and legal theories. The research employed interviews and literature reviews as data collection methods. The research findings indicate a positive correlation between carbon cap and trade policies and the reduction of CO2 emissions. The adoption of carbon cap and trade has led to a significant reduction in CO2 emissions Pan et al. (2019). examines the association between carbon emission reverification, carbon cap and trade policy, and the reduction of CO2 emissions. This study examines the implementation of a cap-and-trade system in Shenzhen, China. This study presents a three-player game model to analyse the actions of the government, emission-generating companies, and third-party verifiers in the context of Shenzhen's cap and trade system. The study asserts that implementing legally enforceable carbon caps and trade measures in the economy leads to reduced CO2 emissions Zhang, Tian, and Han (2022). investigate the impact of carbon caps on recycling mode selection, carbon abatement decisions, and CO2 emission reductions. The data was obtained from China. The study suggests that carbon cap and trade policies discourage the introduction of carbon-emitting products into the economy, resulting in a reduction of CO2 emissions.

Renewable energy (RE) refers to the generation of energy using natural resources or the utilisation of natural processes. The process of production is characterised by its spontaneous nature, serving to promote the growth of vegetation and effectively manage waste disposal sites. It can absorb carbon dioxide from the atmosphere and mitigate the production of additional CO2 (Awodumi & Adewuyi, 2020). Razmjoo et al. (2021) conducted empirical research to investigate the impact of renewable energy (RE) production on the mitigation of carbon dioxide (CO2) emissions. The objective of this study was to evaluate various sustainable hybrid renewable systems for electricity generation in Iran. The authors thoroughly examined environmental issues. The data was obtained from the Meteorological Organisation, and the authors conducted a techno-economic evaluation using HOMER software. The authors found that the hybrid electric system developed for renewable energy production yields cleaner energy compared to that derived from fossil fuels. As a result, the hybrid electric system developed for renewable energy production reduces the amount of CO2 emissions Magazzino, Mele, and Schneider (2021). conducted research on the correlation between renewable energy (RE) production, fossil fuel consumption, gross domestic product (GDP), and the reduction of carbon dioxide (CO2) emissions. RE production is assessed using two indicators: solar and wind energy production, while fossil fuel consumption is gauged through coal consumption. The research data were collected from three economies: China, India, and the USA, spanning the years 1990 to 2017, 1986 to 2017, and 1983 to 2017, respectively. The study suggests that increased renewable energy production is associated with a reduction in atmospheric carbon levels and a decrease in CO2 emissions from the economy Chen, Wang, and Zhong (2019). examine the relationship between renewable and non-renewable energy production, foreign trade, GDP, and per capita CO2 emissions. The data were collected in China between 1980 and 2014. The study found that an increase in renewable energy (RE) production is associated with a decrease in carbon dioxide (CO2) emissions in the economy.

RE consumption acts as a deterrent to reliance on fossil fuel combustion and reduces the emission of CO2 Kirikkaleli, Güngör, and Adebayo (2022). examine the interplay between renewable energy (RE) consumption, financial development, electricity consumption, economic growth (EG), and consumption-based carbon dioxide (CO2) emissions in their research. The research focuses on Chile as its primary subject of analysis. The study suggests that the adoption of renewable energy by businesses and individuals leads to a decrease in the use of fossil fuels and the associated emissions of carbon dioxide Dong, Dong, and Jiang (2020). conducted a study to examine the effects of renewable energy consumption on carbon dioxide emissions in various countries. A global panel of 120 states was used to analyse the relationship between renewables, economic growth, and emissions. The data was collected

from 1995 to 2015 and organised into four income-based subpanels. This approach allowed us to examine variations in slope and cross-sectional dependence. The study asserts that the growing utilisation of renewable energy sources effectively mitigates energy waste, thereby reducing the release of CO2 emissions, a significant contributor to environmental contamination Zafar et al. (2019). investigate the impact of renewable energy consumption, stock market development, and banking sector development on the reduction of CO2 emissions. This study investigates the EKC hypothesis using data from N-11 and G-7 countries between 1990 and 2016. The study utilised second-generation unit root tests to analyse the integration properties of the variables. The authors utilised the Lagrange Multiplier bootstrap panel co-integration method to validate the existence of a long-term equilibrium relationship among the variables. The study suggests that an increase in renewable energy consumption leads to a decrease in the overall usage of fossil fuels and nuclear energy. Consequently, there is a reduction in CO2 emissions.

Economic expansion typically leads to increased CO2 emissions due to the utilisation of energy, machinery, technology, and the generation of substantial economic waste. If an economy is effectively managed and experiences sustained growth, it has the potential to foster technological, financial, and managerial advancements. Improved management can enable effective control of CO2 emissions (Anwar, Younis, & Ullah, 2020a, 2020b). Namahoro et al. (2021), and Xu, Schwarz, and Yang (2020) check the influences of EG, RE consumption, and energy intensity on CO2 emissions across multiple regions in the world. The data were collected from 50 African countries over the period of 1980–2018, and these countries were selected based on income level. The study claims that when an economy is emerging rapidly, it has high financial performance and develops the ability to have access to advanced energy-efficient technologies. As a result, the control of CO2 emissions is possible.

3. Research Methods

This article examines the effects of carbon taxes, carbon cap and trade policies, renewable energy (RE) production and consumption, and energy generation (EG) on carbon emission reduction in the United States, Japan, Canada, and Australia. The study utilised secondary data from the World Development Indicators (WDI) as a source, spanning the years 1991 to 2022. The study established the equation provided below:

$$CO2E_t = \alpha_0 + \beta_1 CT_t + \beta_2 CCT_t + \beta_3 REP_{it} + \beta_4 REC_t + \beta_5 EG_t + e_t \quad (1)$$

Where

CO2E = Carbon Dioxide Emission

t = Time Period

i = Countries

CT = Carbon Taxes

CCT = Carbon Cap and Trade

REP = Renewable Energy Production

REC = Renewable Energy Consumption

EG = Economic Growth

The study focused on CO2 emissions as the primary variable and measured them in metric tonnes per capita. The study employed two predictors, namely carbon taxes measured as a percentage of revenue from environmental taxes and carbon cap and trade measured as a percentage of trade in carbon intensity. The study employed three control variables: RE production, measured as a percentage of total energy output; RE consumption, measured as a percentage of total energy consumption; and EG, measured as the annual GDP growth rate. Table 1 presents the measurements.

Table 1: Variables with Measurements

S#	Variables	Measurement	Sources
01	Carbon Dioxide Emission	CO2 emissions (Metric ton per capita)	WDI
02	Carbon Taxes	Environmental taxes (% of revenue)	WDI
03	Carbon Cap and Trade	Carbon intensity (percent of trade)	WDI
04	Renewable Energy Production	RE output (% of total energy output)	WDI
05	Renewable Energy Consumption	RE consumption (% of total energy consumption)	WDI
07	Economic Growth	GDP growth (annual percentage)	WDI

This study employs descriptive statistics to examine the specific details of the constructs. Descriptive statistics provide information such as the average, minimum and maximum values, number of observations, and standard deviations. Furthermore, the study examines the correlation between constructs by utilising a correlation matrix. Additionally, this study investigates cross-sectional dependence (CSD) and applies a model using a CSD test. The equation for the test is provided below:

$$CSD_{IT} = \left[\frac{IT(T-1)}{2}\right]^{\frac{1}{2}} \hat{\rho}_T \quad (2)$$

In above equation, $\hat{\rho}_T$ exposed the coefficient correlation, while T exposed the time, and I exposed the cross-sections. In addition, the cross-sectionally augmented IPS (CIPS) unit root test is used to find out if there are any unit roots in the constructs so that the right model can be chosen. Panel data is an effective research method. The equation for the approach is provided below:

$$\Delta W_{i,t} = \emptyset_i + \emptyset_i X_{i,t-1} + \emptyset_i \bar{X}_{t-1} + \sum_{l=0}^{p} \emptyset_{il} \Delta \bar{W}_{t-1} + \sum_{l=0}^{p} \emptyset_{il} \Delta W_{i,t-1} + \mu_{it} \quad (3)$$

In above equation, $\bar{W}$ exposed the mean "cross-section" and mentioned below:

$$W^{i,t} = \emptyset^1 \overline{CT}^{i,t} + \emptyset^2 CCT^{i,t} + \emptyset^3 \overline{REP}^{i,t} + \emptyset^4 REC^{i,t} + \emptyset^5 \overline{EG}^{i,t} \quad (4)$$

So, the CIPS is given below:

$$\widehat{CIPS} = N^{-1} \sum_{i=1}^{n} CADF_i \quad (5)$$

Where, the CADF exposed the cross-sectionally augmented dickey fuller test.

Furthermore, the study investigates the requirement of co-integration for the application of the model. This is assessed using the co-integration test developed by Westerlund and Edgerton (2008). The equation for the approach is as follows:

$$llog(L) = \alpha_0 - \frac{1}{2}\sum_{i=1}^{N}\left(Tlog(\sigma_{i.t}^2) - \frac{1}{\sigma_{i,t}^2}\sum_{t=1}^{T} eit^2\right) \quad (6)$$

The study examines the relationship between variables using the CS-ARDL approach. It establishes relationships between constructs in both the long and short term. In addition, this method addresses issues related to endogeneity, the common support and density (CSD) assumption, and heterogeneity. The equation is mentioned below:

$$\Delta Y_{it} = \varphi_i + \sum_{l=1}^{p} \varphi_{it} \Delta Y_{i,t-1} + \sum_{l=0}^{p} \varphi'_{il} X1_{s,i,t} + \sum_{l=0}^{1} \varphi'_{il} \overline{X2}_{i,t-1} + \varepsilon_{it} \quad (7)$$

So, the study established the CS-ARDL equation using the under article constructs as under:

$$\Delta CO2E_{it} = \varphi_i + \sum_{l=1}^{p} \varphi_{it} \Delta CO2E_{i,t-1} + \sum_{l=0}^{p} \varphi'_{il} CT_{s,i,t} + \sum_{l=0}^{p} \varphi'_{il} CCT_{s,i,t} + \sum_{l=0}^{p} \varphi'_{il} REP_{s,i,t} + \sum_{l=0}^{p} \varphi'_{il} REC_{s,i,t} + \sum_{l=0}^{p} \varphi'_{il} EG_{s,i,t} + \varepsilon_{it} \quad (8)$$

4. Research Findings

The study employs descriptive statistics to examine the specific details of the constructs. This includes calculating the average, minimum, and maximum values, as well as determining the number of observations and standard deviations. The findings revealed that the average per capita CO2E value was 14.829 metric tonnes, with CT at 4.083 percent and CCT at 2.491 percent. Furthermore, the findings revealed that the average value of REP was 24.060%, REC was 10.660%, and EG was 2.085%. Table 2 presents the values.

Table 2: Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
CO2E	128	14.829	3.674	7.401	20.470
CT	128	4.083	4.914	-0.280	18.675
CCT	128	2.491	0.393	1.896	3.262
REP	128	24.060	22.098	6.784	64.708
REC	128	10.660	6.875	3.340	23.911
EG	128	2.085	2.003	-5.693	5.945

In addition, the study examines the correlation between constructs by utilising a correlation matrix. The results indicate that carbon taxes, carbon cap and trade, renewable energy (RE) production, RE consumption, and energy generation (EG) are positively associated with carbon emission reduction or negatively associated with CO2 emissions in the USA, Japan, Canada, and Australia. Table 3 presents the values.

Table 3: Matrix of correlations

Variables	CO2E	CT	CCT	REP	REC	EG
CO2E	1.000					
CT	-0.823	1.000				
CCT	-0.115	-0.016	1.000			
REP	-0.093	-0.061	-0.696	1.000		
REC	-0.208	-0.207	-0.603	0.969	1.000	
EG	-0.445	-0.375	0.135	0.004	0.061	1.000

Further, this study investigates the use of the CSD model in the context of CSD testing. The results showed that the t-values exceeded the threshold of 1.96, indicating statistical significance, while the p-values fell below the threshold of 0.05, indicating statistical significance as well. The value of CSD is non-existent. These values are given in Table 4.

Table 4: CSD analysis

Variable	Test Stat (prob-values)
CO2E	5.487*** (0.000)
CT	3.292*** (0.000)
CCT	4.776*** (0.000)
REP	4.986***(0.000)
REC	6.594*** (0.000)
EG	4.333*** (0.000)

Additionally, this study investigates the presence of a unit root among the constructs by employing the cross-sectionally augmented IPS (CIPS) unit root test to determine the appropriate model to apply. The results indicate that the variables CO2E, CT, CCT, and EG exhibit stationary behaviour at the level, while REP and REC exhibit stationary behaviour at the first difference. Table 5 presents the outcomes.

Table 5: Unit Root Test

	I (0)		1st Difference I(1)	
Variables	CIPS	M-CIPS	CIPS	M-CIPS
CO2E	-4.938***	-4.859***	----	----
CT	-4.399***	-4.390***	----	----
CCT	-5.654***	-4.887***	----	----
REP	----	----	-5.430***	-3.884***
REC	----	----	-5.049***	-4.392***
EG	-4.381***	-4.885***	----	----

Furthermore, this study also investigates the requirement of co-integration for the application of the model, which is assessed using the Westerlund and Edgerton (2008) co-integration test. The results show that the t-values exceed the threshold of 1.96, indicating statistical significance, while the p-values fall below the threshold of 0.05, suggesting statistical significance. The results indicate the presence of co-integration. Table 6 presents the outcomes.

Table 6: Co-integration Test

Test	Without break	Mean shift	Regime shift
	Explained Variable: CO2E		
$Z_{\varphi}(N)$	-4.377***	-5.473***	-4.493***
P_{value}	0.000	0.000	0.000
$Z_{\tau}(N)$	-5.392***	-5.442***	-4.463***
P_{value}	0.000	0.000	0.000

The study examines the relationship between variables using the CS-ARDL approach. The results indicate that carbon taxes, carbon cap and trade, renewable energy production, renewable energy consumption, and environmental governance are associated with a reduction in carbon emissions or have negative correlations with CO2 emissions in the United States, Japan, Canada, and Australia. Table 7 presents the associations.

Table 7: CS-ARDL Short run and long run analysis

Long Run findings			
Variables	Coeff	t-stat	Prob
Explained Variable: CO2E			
CT	-0.784*	2.101	0.043
CCT	-2.190***	4.849	0.000
REP	-1.292**	2.682	0.016
REC	-3.281**	2.223	0.029
EG	-3.001***	4.109	0.000
CSD-Statistics	-	0.054	0.323
Short Run Results			
CT	-1.884***	4.392	0.000
CCT	-3.291***	8.101	0.000
REP	-1.454*	2.001	0.048
REC	-3,464**	2.643	0.019
EG	-1.281**	2.548	0.023
ECT (-1)	-0.774***	-5.492	0.000

5. Discussions

The results indicate a positive correlation between the implementation of a carbon tax and the reduction of CO2 emissions. These findings align with Andersson (2019) research, which suggests that implementing high carbon taxes and enforcing stringent penalties for non-compliance can effectively motivate the public to adopt more environmentally friendly behaviours and reduce carbon emissions. Consequently, there is a decrease in carbon dioxide (CO2) emissions. The results of Domon et al. (2022) further corroborate the effectiveness of carbon taxation in mitigating CO2 emissions. The study suggests that increasing the carbon tax leads to commercial units attempting to avoid carbon-

intensive activities, resulting in a decrease in carbon emissions. The findings indicate a positive correlation between carbon cap and trade policies and the reduction of CO2 emissions. These findings align with the research conducted by Astanti, Daryanto, and Dewa (2022), which suggests that when a government prioritises environmental quality for the well-being of its citizens and implements a carbon cap and trade policy, the number of carbon-emitting products available for trade decreases. The reduction in the trade of carbon-intensive goods leads to a decrease in the aggregate volume of carbon dioxide (CO2) emissions released into the atmosphere, thereby contributing to atmospheric purification Akulker and Aydin (2023). further corroborate the findings of this study by explaining the decline in the trade and consumption of carbon-intensive energy resources in economies where traders are subject to government-imposed carbon caps and trade restrictions. In the present scenario, the economic entities exhibit a reduced level of carbon dioxide emissions.

Results indicate a positive correlation between renewable energy production and the reduction of CO2 emissions Pata (2021). conducted research that illuminates the role of renewable energy production in mitigating CO2 emissions. The study asserts that increasing the production of renewable energy resources, such as wind power, geothermal power, hydroelectricity, bioenergy, and biofuel, leads to a decrease in the emission of harmful gases, such as CO2, into the atmosphere Qin et al. (2021). also support these findings, emphasising that the establishment of renewable energy (RE) production power plants significantly contributes to the economy by providing a substantial supply of RE. The increased utilisation of renewable energy sources effectively mitigates carbon dioxide emissions. The findings indicate a positive correlation between the consumption of renewable energy (RE) and the reduction of carbon dioxide (CO2) emissions. The research conducted by Khan, Khan, and Binh (2020) suggests that promoting renewable energy sources leads to a greater adoption of cleaner energy compared to fossil fuels. Consequently, there is a reduction in carbon dioxide (CO2) emissions Khan et al. (2020). corroborate these findings, asserting that businesses utilising renewable energy sources experience reduced energy waste and environmental harm, such as CO2 emissions.

The results indicate a positive correlation between EG and the reduction of CO2 emissions. These findings align with Lin et al. (2021), who argue that countries with stronger economic growth tend to have the financial capacity to invest in clean energy resources and address CO2 emissions Li and Haneklaus (2021). also found evidence supporting the relationship between an increase in the EG rate, financial development, and the utilisation of green finances. It results in a decrease in carbon dioxide (CO2) emissions.

6. Implications

The study guides the researchers by providing valuable literary contributions. This study investigates the impact of carbon pricing mechanisms, such as carbon tax and carbon cap and trade, as well as renewable energy (RE) technologies, specifically RE production and RE consumption, on the reduction of CO2 emissions. The study also considers the control factor of energy generation (EG). This study examines the issue of CO2 emissions, a prevalent environmental concern across all economies. The significance of this is relevant to all economies. The article offers a comprehensive framework for economic regulators to effectively manage and mitigate carbon dioxide (CO2) emissions. The study suggests that the implementation of carbon taxes by the government and environmental regulators is necessary to effectively control CO2 emissions from individuals and economic entities within the country. The study suggests that implementing carbon cap and trade as a carbon pricing mechanism can help address CO2 emissions and recommends that economic and environmental regulators adopt this approach. The guideline also emphasises the need for regulators to implement stringent measures to promote renewable energy production, thereby facilitating a reduction in CO2 emissions. There is a suggestion that motivating the public is necessary for promoting renewable energy consumption. This would help in mitigating atmospheric CO2 emissions. Additionally, the study indicates that economic growth is necessary to support the advancement of environmentally sustainable initiatives and the regulation of CO2 emissions. The study assists regulators in formulating regulations to achieve zero carbon emissions through the implementation of an efficient carbon tax system, the effective application of restrictions on carbon cap and trade, and the optimal utilisation of renewable energy resources.

7. Conclusion

The authors sought to assess the effects of carbon pricing mechanisms, such as carbon tax and carbon cap and trade, as well as renewable energy technologies, specifically renewable energy production and consumption, on the reduction of CO2 emissions. Additionally, the authors examined the impact of EG on the mitigation of CO2 emissions. This study investigates the interplay of the aforementioned factors in the global economy, utilising data from the United States, Canada, Japan, and Australia. The research findings indicate a positive relationship between carbon tax, carbon cap and trade, renewable energy (RE) production and consumption, energy generation (EG), and the reduction of carbon dioxide (CO2) emissions. The results indicate that the implementation of a carbon tax in each country leads to effective regulation of carbon-emitting activities and a reduction in CO2 emissions. When a government implements a carbon cap and trade policy, it restricts certain activities and the use of carbon-emitting substances. The study found that increasing renewable energy production processes can effectively mitigate carbon emissions and contribute to environmental cleanliness. As a result, carbon emissions decrease. The study findings indicate that the growing utilisation of renewable energy sources alleviates the reliance on fossil fuels for energy generation, resulting in a notable reduction in carbon dioxide emissions.

8. Limitations

The present study has certain limitations that warrant further attention from scholars to enhance its quality. The study focused on analysing the impact of selected factors, including the carbon pricing mechanism and renewable energy technologies, on the reduction of CO2 emissions. Additional research is required to examine the influence of green financial factors and managerial factors in the realm of environmental protection. Secondly, this study examines the influence of the carbon pricing mechanism and renewable energy (RE) technology on the reduction of CO2 emissions in the global economy. However, the study only includes evidence from four countries: the USA, Canada, Japan, and Australia. As a result, the study lacks comprehensiveness and has limited implications. It is necessary to increase the number of countries for data collection.

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