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# Emissions Reduction Policies and Their Effects on Economy

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**Abstract:** The two broad carbon-reducing policies, carbon tax and cap-and-trade, have been implemented at various national and sub-national levels. This paper examines the relationships between emissions-reducing policies and their effect on the country's economic growth (GDP) using carbon tax and $CO_2$ emission as explanatory variables and population and R&D as control variables. The study employs Granger causality analysis (GCA) and panel data regression analysis to find the relationships between GDP, emissions, and carbon tax. GDP usually increases as a country's carbon emissions, carbon tax, R&D, and population increase. The analysis of carbon reduction policies, especially carbon tax and their general impact on a country's economy, is a unique contribution of this study. The applications of this study are to motivate governments to form a national carbon abatement policy and encourage corporate leaders to invest in clean technology to grow the economy.

**Keywords:** emissions; carbon tax; emissions policy; economic impact; environmental impact

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## 1. Introduction

The relationships between climate change, the rise in the earth's atmospheric temperature, and GHG emissions have been established. Gasses that absorb the sun's heat and radiate within the earth's atmosphere are called GHG, and carbon dioxide ($CO_2$) is the main component accounting for over 80% of GHG emissions (US EPA 2022). $CO_2$ levels have risen exponentially over the last 160 years. $CO_2$ build-up until the mid-18th century was roughly 280 ppm, which had jumped to 410 ppm by 2018 (Tvinnereim and Mehling 2018, p. 186).

The industrial revolution in the 18th century increased the demand for more goods and energy. These were met through fossil fuels, resulting in a massive release of $CO_2$ into the atmosphere. The demand for energy and goods increases with the increase in population, which also increases emissions. However, emissions depend on the changes in energy demand and energy sources rather than the changes in the population (Gurtu et al. 2016a, pp. 171–73). A study of the EU Members between 1960 and 2014 showed Granger causality relations between $CO_2$ emissions and GDP (Panait 2019). The population of a country has little impact on emissions. For instance, India and China have comparable populations. However, their emissions are not comparable. Another example is the USA's population being about one-quarter of India's population. In contrast, the USA's emissions are not one-quarter of India's emissions. This illustrates that energy consumption and the associated emissions are linked to industrialization rather than population (Gurtu and Goswami 2020). Vo et al. (2019) studied the relationship between carbon ($CO_2$) emissions, energy consumption, population growth, and economic growth for ASEAN countries between 1971–2014. They did not find a long-running relationship between the variables in the Philippines and Thailand. However, a relationship existed in Indonesia, Myanmar, and Malaysia.

The emissions in low-income countries are increasing due to non-clean sources and industrialization. Industrialization is rapidly increasing in low-income countries because high-income countries outsource their manufacturing activities (Gurtu et al. 2016b). This suggests using consumption-based accounting of national emissions (Gurtu et al. 2016a, 2016b, 2017, 2019).

Industrial growth throughout the 19th and 20th centuries caused an increase in GHG emissions, resulting in global warming. Public awareness of environmental problems in the 1960s led to the first environmental policy by the USA in the 1970s (Kamieniecki and Kraft 2012), inspiring governments in Europe and elsewhere to commit to laws, regulations, and other policy mechanisms concerning environmental issues.

Reducing global carbon emissions is a complex and challenging task for the scientific and business community, as well as for political leaders. It affects the economy, environment, and almost every part of society. The use of fossil fuels is the single largest cause of these emissions. However, due to it being the most prominent energy source and a critical growth engine, fossil fuel consumption cannot abruptly halt (BP 2021). There are two main approaches to reducing GHG emissions. One predominant approach is to encourage the use of renewable sources of energy, and the other is to discourage the use of fossil fuels through economic measures. Both are not necessarily mutually exclusive. For example, the International Solar Alliance of 75 countries is an effort to use solar energy to reduce fossil fuel consumption and, in turn, GHG emissions (ISA 2015). Many countries have used economic measures and devised various policies to reduce GHG emissions, such as cap-and-trade, a carbon tax, and other carbon abatement policies.

There is a lack of consensus on the most effective method of reducing GHG emissions to fight climate change. This paper addresses this gap in the literature. It investigates the relationships between emissions-reducing policies and their effect on the country's economic growth (GDP) using carbon tax and $CO_2$ emissions as independent variables and using R&D intensity and population as control variables. Country-specific policies are needed to limit climate change without affecting energy security and the economic situation. The authors highlight the effects of a national carbon abatement policy on the country's economy. They compare the effects of the different carbon abatement policies on various countries' economic growth and further try to establish a causal relationship between economic growth and carbon reducing policy by conducting a regression analysis using carbon tax as an explanatory variable. This is the first study to compare the long-term effects of a carbon-reducing policy on a country's GDP. The applications of this study are to motivate governments to form a national carbon abatement policy and encourage corporate leaders to invest in clean technology to grow the economy. The following section discusses the existing literature, including various emissions-reducing policies.

## 2. Literature Review

The paper intends to form a basis for more conclusive and empirical research. The paper analyzes the relationship between carbon-reducing policies and economic performance. A study on the use of renewable energy and its effects on emissions and economic growth in the EU found that green energy should be used in energy-intensive sectors, firstly to see a more significant impact on emissions (Nazarko et al. 2022).

Reducing GHG emissions is a global challenge that has gained momentum to mitigate environmental emissions and global warming. Since the beginning of the 20th century, climate scientists have anticipated that GHG would impact the earth's climate. Nevertheless, the understanding was insufficient to adopt GHG reduction policies. The Kyoto Protocol 1997 opened up an international market for allowances to emit GHG. The section briefly discusses various carbon reduction policies operational worldwide.

The exploratory analysis has been divided into sub-sections to discuss carbon abatement policies (Figure 1).

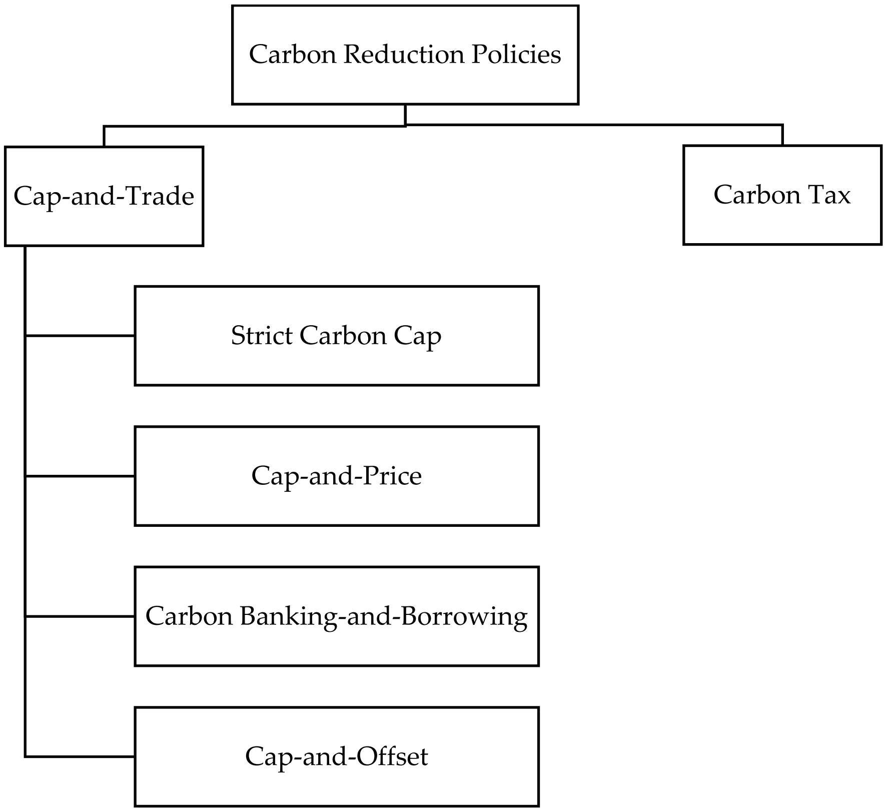


**Figure 1.** Popular carbon reduction schemes (Source: self-generated).

*2.1. Cap-and-Trade*

Carbon cap-and-trade, also known as emissions trading, is a market-based approach to reducing carbon emissions by providing economic incentives for reducing GHG emissions (Kosnik 2018; Milt and Armsworth 2017). This policy has perhaps been discussed the most. Many authors have written about this policy (Fuss et al. 2018; Gurtu et al. 2016a; Kosnik 2018; Milt and Armsworth 2017; Morehouse 2012; Schmalensee and Stavins 2017; Wittneben 2009). Under the cap-and-trade policy, each organization can generate carbon emissions up to a pre-determined limit called a cap. If an organization's emissions reach the cap, the organization must buy carbon credits from other organizations. An organization that has neither reached its annual emissions cap nor anticipates reaching its cap for the rest of the fiscal year can sell the leftover emissions credits to other organizations at a price. The market determines that price.

The policy puts a price on each unit, or credit, of carbon. The higher the demand for these credits, the higher the price for them; the higher the price for them, the higher the incentive for an organization to reduce its emissions. However, higher pricing can also hurt an organization's profitability because these prices are driven by market forces, very similar to the stock market. Therefore, a cap-and-trade policy should be accompanied by a viable emissions trading system (ETS). The trading aspect of a carbon cap-and-trade policy allows organizations to decarbonize while giving other organizations flexibility to manage it during the transition by purchasing carbon credits from the market (Schmalensee and Stavins 2017).

Many countries have a carbon cap-and-trade program called emissions trading system (ETS). ETS is gaining support as more proposed plans emerge every year. The European Union emissions trading system (EU ETS) is the most prominent. Even though many EU countries have had various decarbonization policies for quite some time, the EU now has an ETS policy. The EU ETS has been in place for over a decade, making it the world's first emissions trading system. The UK started its own ETS on 1 January 2021 (UK Gov 2021), leaving 27 member countries and three non-member countries to follow the EU ETS (European Commission 2018). It remains the most extensive greenhouse gas cap-and-trade system globally, accounting for over 75% of international carbon trading (Alper 2017). Thus, the EU ETS can provide an important and unique insight into the operations of its cap-and-trade programs. It can also give us an insight into the designs of globally emerging ETS.

Thirty-one countries are a part of the EU ETS. They account for an impressive 45% of all greenhouse gas emissions among the EU countries, with future phases set to cover even more (European Commission 2018). Phase 3 continued until 2020. The EU ETS had a fixed cap until 2017, updated in phases as the market matured.

The EU announced the rules for Phase 4 (2021–2030) in November 2017 and revised them in early 2018; this new phase replaces a fixed cap with one that is a function of market outcomes (Perino 2018). With this new strategy, the market dictates the price of carbon; as businesses become more efficient and decrease their emissions, the price of carbon increases over time. This is seen as an efficient way of cutting carbon emissions.

As discussed in the following four sub-sections, this policy has been modified in many ways. This policy's variations are cap-and-offset, cap-and-price, carbon banking-and-borrowing, and strict carbon cap. These policies provide greater flexibility for organizations while having a less stringent economic deterrent on exceeding the emissions cap. The variants of this policy are presented in the following four sub-sections:

#### 2.1.1. Strict Carbon Cap

Regulatory bodies provide a fixed carbon emissions limit to organizations known as a cap in this policy. The penalty for exceeding this cap is extensive and works as an economic deterrent (Chen et al. 2013). Therefore, organizations are forced to manage their emissions within the allowed limit to avoid harsh monetary penalties. This policy is considered the most stringent among all carbon policies and the most effective at reducing emissions quickly and significantly. Because there is no trading of carbon credits in this system, businesses and industries tend to suffer more because all entities are being held under a strict cap of emissions under the threat of a harsh penalty. This decarbonization policy is sparingly used, as it has much more detrimental effects on a country's economy. However, this policy has been considered in supply chain management for calculating economic order quantity (Ghosh et al. 2017). The following section discusses the direct tax policy.

#### 2.1.2. Cap-and-Offset

Offsets are investments for carbon-reducing projects, typically offered by a third party, to offset emissions above their specified cap. However, an organization does not benefit from emitting less than its specified cap (Chen et al. 2013). Carbon cap-and-offset programs are rarely used because organizations have less incentive to decrease carbon emissions. Instead of selling excess credits to other businesses, the money goes to low-carbon infrastructure and technology (Ghosh et al. 2017). If this policy could be tweaked to incentivize organizations to decrease emissions, investing in sustainable development and low-carbon technology would be an effective way to benefit the economy.

#### 2.1.3. Cap-and-Price

A cap-and-price policy occurs when a regulating agency encourages businesses to emit less than the cap by rewarding them and penalizing them for emitting more, effectively discouraging them from generating emissions. This can have a variety of forms, but in its simplest form, it consists of a reward (or penalty) per unit of emissions below (or above) the cap (Weber et al. 2019). This policy rewards an overachieving organization and penalizes an underachieving one (Chen et al. 2013).

#### 2.1.4. Carbon Banking-and-Borrowing

According to this policy, organizations can bank unused emissions for future use or borrow against future emissions in the present period (Li and Gu 2012). The difference between this policy and the cap-and-trade policy is that the former operates within the organization over a different time horizon and does not involve any financial transaction. In contrast, the latter operates across various organizations for a fixed time horizon, typically a year. There is usually a cost associated with trading carbon emissions.

### 2.2. Carbon Tax

The first significant emissions reduction policy that many countries have implemented and has a direct economic impact is a carbon tax. A carbon tax is a tax levied on the carbon content of fossil fuels, such as coal, oil, and gas (Hoeller and Wallin 1991). The carbon tax treats carbon emissions as a source of economic cost (Arslan and Turkay 2013). It is a financial penalty and linear with carbon emissions (Kosnik 2018). Nong et al. (2021) indicated that some carbon policies do not include non-carbon emissions and emphasize including non-carbon emissions, i.e., using carbon equivalent for a carbon tax, as the effect of non-carbon emissions is equally severe on health and the environment. However, a carbon tax can be progressive, regressive, and combine distinct features. This policy applies a specific percent tax to every unit of carbon emitted from an energy source, i.e., fossil fuel. There is no set limit on emissions; the emitter pays the tax rate on every unit of carbon generated.

The fundamental difference between carbon tax policy and cap-and-trade policies is that no matter how little carbon is emitted, the emitter pays the tax until the emissions are zero under the carbon tax policy. No other policy has the incentive to reduce their emissions to zero; they allow businesses to emit a certain amount of carbon without incurring any cost. A carbon tax is intended to generate funds to create new investment opportunities for green technology development (Labatt and White 2007). Economists agree that a carbon tax is a policy most effective at reducing GHG emissions without hurting a country's economy (Gaspar et al. 2019).

Carbon tax policies have many variations. Some examples of these variations are the tax rates based on the region, country, or states, changes in the rate of tax over time, rate of tax based on the types of fossil fuel, and collection and distribution of taxed money among regional, federal, state, and local governments. Appendix A provides a list of countries with national carbon tax schemes. Australia adopted a carbon tax in 2012 (Komanoff 2013); however, this was poorly received and withdrawn (Gurtu et al. 2016a). Another country not on this list is India, a signatory of the Paris Agreement. It pledged a 33–35% reduction compared to 2005 levels in its emissions intensity by 2030 (Timperley 2019). Massetti (2011) compared emissions without intervention in China and India with various carbon tax scenarios. The author found that a carbon tax (USD 10 per ton of $CO_2$) from 2020 would reduce emissions in China and India by 25% and 30%, respectively, in 2050. However, there is no global policy to reduce carbon emissions. Any two countries do not have the same standards and carbon tax policy.

Several authors have empirically examined climate change and GHG reduction policies; Hepburn (2007) examined the evolution and different aspects of carbon trading and reviewed the Kyoto mechanism. Andrew (2008) discussed some approaches to solve climate change by reducing GHG emissions, considering market failure, government failure, and externalities. Porter and Linde (1995) explained how an adequately designed emissions policy enhances environmental and economic aspects. Wittneben (2009) discussed that a cap-and-trade system might not be the most cost-efficient mechanism. Kim and Lim (2014) demonstrated that a cap-and-trade system for indirect emissions blended with a rate-based allocation system for direct emissions is an effective combination in the electricity sector. Cowan et al. (2014) depicted people's willingness to mitigate $CO_2$ emissions from India's road passenger transport sector. Similarly, Tong et al. (2022) explored the relationships between the tourism economy, emissions regulations, and emissions. Fuss et al. (2018) studied how the political process of making cap adjustments has formed market outcomes in the EU-ETS. The authors found high responsiveness of the market to political events. Hwang et al. (2017) developed a learning model to gauge the effect of learning on climate policy due to fat-tailed uncertainty on optimal policy. Most authors discussed different aspects of carbon trade, carbon tax/cost, policy, or both. Bernard and Kichian (2021) concluded that a revenue-neutral carbon tax does not negatively impact GDP.

## 3. Data and Methodology

This paper's objective is to explore the relationship between GDP, carbon-reducing policy, and specifically carbon tax in the presence of variables, such as carbon emissions, population, and R&D Intensity. Country-level data on carbon taxes, $CO_2$ emissions, GDP, and R&D Investment have been obtained from the World Bank (World Bank 2021a). Graphical analysis, Granger causality analysis (GCA), and panel data regression analysis used data from 1990 to 2019. We chose this time frame because the first carbon tax was introduced in 1990 in Finland. However, many countries have introduced a similar policy post-2000. The study has considered a time-series dataset for GCA and a panel dataset for regression analysis. Hence, it becomes essential to know that the data follow normality and stationarity assumptions for further analysis.

It is a recognized fact that many time series data are random walks or non-stationary time series and contain a unit root. Test of a unit root in the series is necessary as the presence of a unit root gives invalid inferences in the analysis. An augmented Dickey–Fuller (ADF) test is a popular test for unit root testing of time series data. Suppose $Y_t$ is the time series to be tested for unit root. In that case, the test statistic for ADF unit root testing will be given by $\tau$ statistics, which is the ordinary least squares (OLS) estimate of the coefficient of $Y_{t-1}$ in Equation (1), divided by its standard error:

$$\Delta y_t = \rho y_{t-1} + \mu + \lambda_t + \alpha_i \sum_{i=1}^{n} y_{t-1} + u_t \quad (1)$$

We tested the null hypothesis for the existence of a unit-root (non-stationary) against the alternative hypothesis of stationary variables using the augmented Dickey–Fuller (ADF) test. We employed the automatic selection of lags based on the Schwarz information criterion (SIC). A non-stationary process has an infinite memory as it does not show decay in a shock that takes place in the process. Every random shock carries away the process from its earlier level not to return to its original value unless random shock pushes it towards its previous level. The first differences in time series data were used to make the time-series data stationary. The ADF unit root test suggests that most of the series at the first differences were significant.

We first conducted the GCA on the data set to identify if there exists any causal relationship between the study variables of our interest. The analyses were conducted using the software STATA 14. We have conducted the lag selection test under vector autoregression diagnostics and test and found that analysis can be conducted with two lags. The following hypotheses were tested using GCA to understand the causal relationships between GDP, emissions, carbon tax, and population.

**H1 (null):** *GDP growth does not cause emissions growth.*

**H2 (null):** *Population growth does not cause emissions growth.*

**H3 (null):** *Carbon Tax does not cause GDP.*

**H4 (null):** *Carbon Tax does not cause emissions.*

To further investigate the impact of a carbon tax on economic performance, we conducted a pane data estimation. The sample comprises data between 1990 to 2019 for 22 countries from the Americas and Europe that have implemented carbon tax during this period. Accordingly, we formed an unbalanced panel for 22 cross-sectional units over 30 years, comprising 626 observations for the analyses.

Dependent Variable

- Natural log of GDP [Ln(GDP)] at constant prices is considered to measure the economic performance of the countries, which is a part of the analysis. GDP is considered the most widely used parameter for measuring the economic performance of countries.

Independent Variables

- Natural log of $CO_2$ emissions [Ln($CO_2$)]; higher emissions reflect more industrial activities contributing to higher GDP.
- Carbon tax (CT) rate is captured as a binary variable where 1 is the countries that have implemented the same and 0 otherwise.

Control Variables

- Natural log of the population [Ln(P)]; the larger the population, the higher the GDP as more people will be contributing to economic activities keeping other factors stationary.
- R&D intensity (RDI): R&D Intensity is captured using a ratio of R&D as a percentage of GDP. We have assumed that countries spending more on R&D must spend some amount on cleaner technologies in production. Hence, it will have an impact on GDP and emissions. However, it may not capture the direct impact.

Interaction Variable

- Interactions of $CO_2$ emissions and a carbon tax (Interact $CO_2 \times$ CT) explain the impact of a carbon tax on emissions. Interact $CO_2$ is a binary variable for a carbon tax to understand the impact of a carbon tax on GDP.

Using the above variables, we estimated the empirical model, specifying the regression model in the linear framework given by Equation (2).

$$\text{Natural log of GDP} = \text{f}(\text{CO}_2 \text{ emissions, population, carbon tax}) \quad (2)$$

The testable model is given in Equation (3).

$$\text{Ln}(\text{GDP}) = \beta_0 + \beta_1 \text{Ln}(\text{CO}_2)_{it} + \beta_2 \text{Ln}(\text{P})_{it} + \beta_3 (\text{CT})_{it} + \beta_4 (\text{Interact CO}_2)_{it} (\text{CT})_{it} + (\text{RDI})_{it} + u_{it} \quad (3)$$

where $i$ represents a country, $t$ represents a year, and $u_{it}$ is a random error term, assumed to be normally distributed with mean zero and constant variance.

## 4. Results and Analysis: Relationship between Carbon Reduction Policies, $CO_2$ Emissions, and GDP

This section explores initiatives by various countries and regions in implementing carbon-reducing policies and their effectiveness, along with their impact on the economy. A detailed description and comparison of the different carbon tax policies are necessary to determine the best strategies depending on the country's situation. Cap-and-offset, cap-and-price, and banking-and-borrowing are different versions of the cap-and-trade policy. Pradhan et al. (2017) have grouped the various carbon reduction policies into the following three: (i) carbon tax, (ii) carbon cap-and-trade, and (iii) strict carbon cap. These three-carbon policies are also the most common carbon policies (Tsao et al. 2017). However, as stated earlier, a strict carbon cap is a variation of cap-and-trade where no trading is permitted.

So, we feel the two classes of policies are carbon tax and cap-and-trade. The countries in the various carbon abatement schemes are given in Appendix A. Since the data are at the country level and not all countries have a uniform policy, a continent-wide analysis is not possible. No country in North America and Asia (except Japan) has a national policy on emissions reduction. China is likely to introduce an ETS some time in 2021. Therefore, to further our analysis, we looked at the economies with a carbon reduction policy in the form of a carbon tax and its effect on GDP.

We first conducted a graphical analysis to identify if the implementation of carbon reduction policies impacts the economic performance of the respective country. Figures 2 and 3 show trends of emissions per unit of GDP (kg/2015 USD) and emissions per capita for select countries that implemented a carbon tax policy. Figure 2 is for countries that have maintained a carbon tax policy for over ten years, and Figure 3 is for countries that have implemented a carbon tax for ten years or less. The vertical line in each graph shows the year of adopting a policy. The graphical analysis indicates that carbon abatement policies positively impact $CO_2$ emissions reduction.

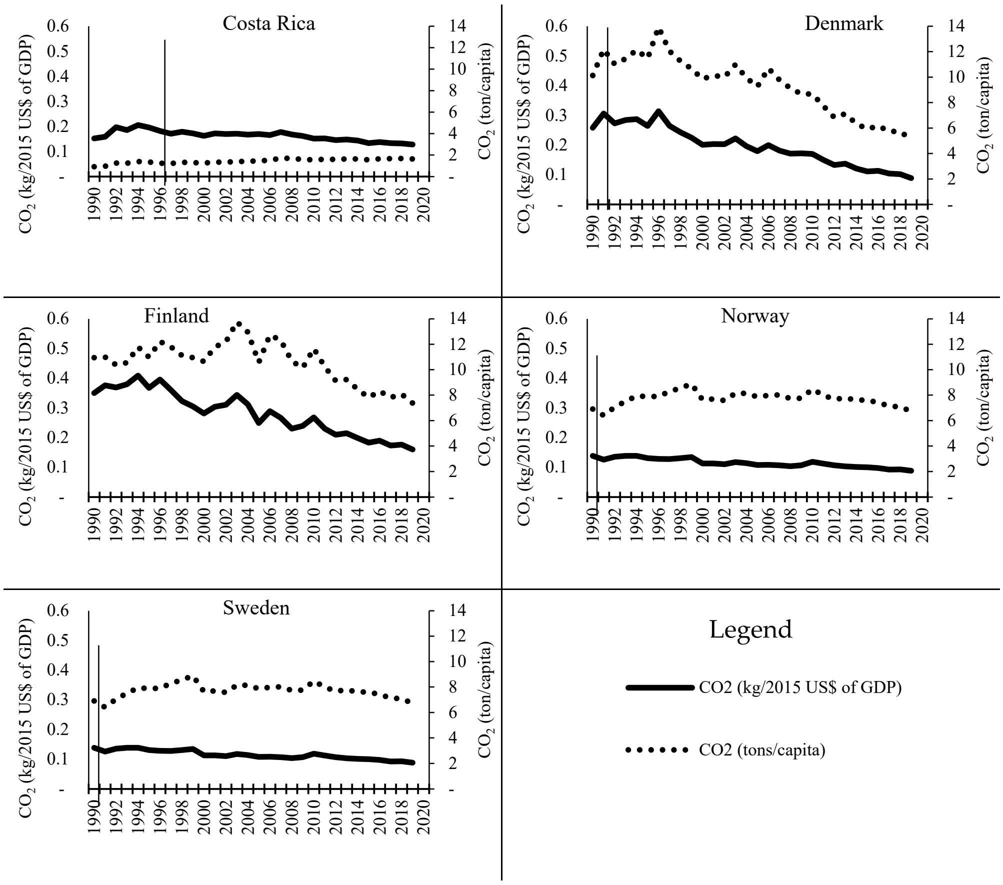


**Figure 2.** The effects of a carbon tax on the respective country, which had a carbon tax for over ten years (Source: self-representation of the data from the World Bank).

To gain a deeper understanding of the relationship between carbon tax policy and GDP, we conducted the GCA for 22 countries. Table 1 shows the relationships between GDP, $CO_2$ emissions, population, and carbon tax. These relationships between developed and developing countries are also not the same. Based on the results of GCA, there is an indication of a causal relationship (for some countries bi-directional as well) between $CO_2$ emissions and GDP. A unidirectional causal relationship exists between a carbon tax and GDP where a carbon tax has been implemented. It is interesting to note that the impact of a carbon tax on GDP can be more clearly seen in developing countries. In contrast, developed countries do not exhibit any Granger causality between a carbon tax and GDP. The results also indicate that for the majority of the countries, a unidirectional relationship has been observed between a carbon tax and $CO_2$ emissions (Appendix B). As mentioned earlier and confirmed by literature, our results also indicate a weak relationship between population and GDP.

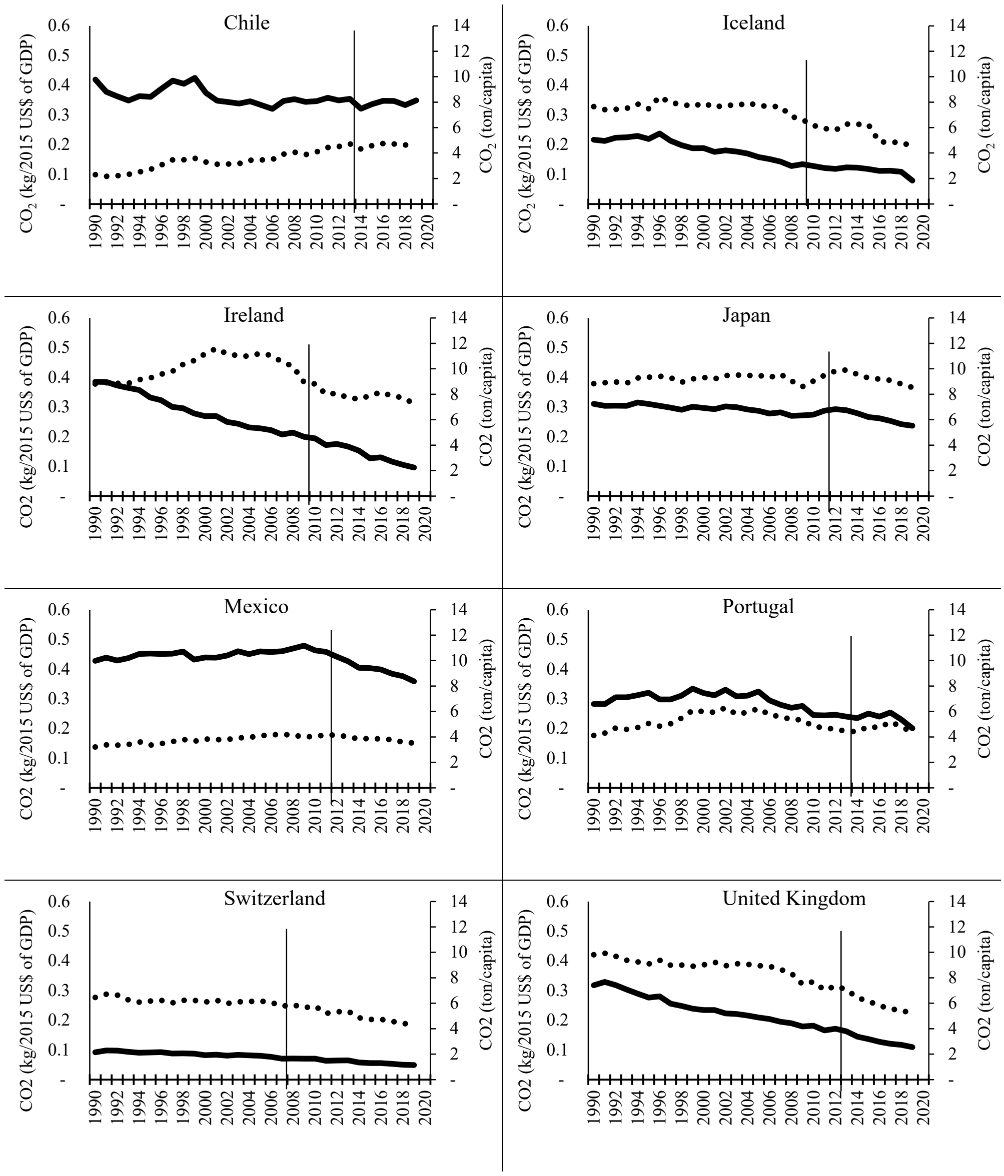


**Figure 3.** The effects of a carbon tax on the respective country, which had a carbon tax for ten years or less (Source: self-representation of the data from the World Bank).

**Table 1.** Relationships from GCA.

| | Accept | Reject | Grand Total |
|---|---|---|---|
| Carbon Tax does not Granger cause $CO_2$ emissions | 9 | 8 | 17 |
| Carbon Tax does not Granger cause GDP | 12 | 4 | 16 |
| $CO_2$ emissions do not Granger cause GDP | 4 | 17 | 21 |
| $CO_2$ emissions do not Granger cause Carbon tax | 14 | 3 | 17 |
| GDP does not Granger causes carbon tax | 15 | | 15 |
| GDP does not Granger cause $CO_2$ emissions | 15 | 6 | 21 |
| GDP does not Granger cause Population | 17 | 4 | 21 |
| Population does not Granger cause GDP | 17 | 4 | 21 |

The causal analysis supplements the graphical analysis results. It establishes a relationship between GDP, carbon tax, and $CO_2$ emissions, thus implying that carbon abatement policies impact economic performance. We conducted a panel data regression analysis to strengthen the analysis and the hypothesis.

Further, Table 2 presents the regression results of both pooled and static panel data models. The insignificant chi-squared value of the Hausman test indicates that the random-effects model is to be chosen over the fixed effects model. However, it can be observed from the table that the results of both fixed effects and random effects are similar. These results show that economic performance (GDP) is significantly influenced by carbon-reducing policies and other control factors after controlling for individual heterogeneity. After estimating the robust random-effects model, we tested its validity against the pooled OLS model by employing the Breusch–Pagan Lagrange multiplier (B-P LM) test. The chi-squared value of this test is statistically insignificant at a 5% level, implying that the pooled OLS model should be chosen over the robust random-effects model. Thus, the results of pooled OLS have been considered. Nevertheless, the analysis shows similar results in both cases. It can be observed from both pooled OLS and random-effects model that carbon tax, population, and $CO_2$ emissions positively and significantly affect GDP; however, the interaction term of the carbon tax and $CO_2$ emissions negatively and significantly impact the GDP of the countries levying carbon taxes.

**Table 2.** Regression results.

| Variables | Pooled OLS | Static Panel Data Estimation | |
|---|---|---|---|
| | | **Fixed Effects** | **Random Effects** |
| Ln($CO_2$) | 0.676<br>(3.32) *** | 0.582<br>(4.54) *** | 0.589<br>(5.12) *** |
| CT | 4.851<br>(7.62) *** | 1.477<br>(3.41) *** | 1.495<br>(3.49) *** |
| (Interact $CO_2$) × (CT) | −0.415<br>(−7.30) *** | −0.106<br>(−3.12) ** | −0.108<br>(−3.91) *** |
| Ln(P) | 0.162<br>(5.27) *** | 0.193<br>(4.58) *** | 0.193<br>(4.52) *** |
| RDI | 0.252<br>(9.92) *** | 0.108<br>(5.39) *** | 0.109<br>(5.41) *** |
| Constant | 15.762<br>(13.35) *** | 16.445<br>(12.71) *** | 16.377<br>(14.94) *** |
| No. of observations | 626 | 626 | 626 |
| F Statistics/Wald $X^2$ | 931.699 *** | 41.88 *** | 245.92 *** |
| $R^2$ | 0.788 | 0.762 | 0.762 |
| Hausman Test | $X^2$ = 3.14, Prob > chi square = 0.542 (RE chosen over FE) | | |
| B-P LM test for random effects | $X^2$ (01) = 0.01 Pr > $\overline{\chi}^2$: 0.461 (Pool OLS have chosen over RE) | | |

Notes: ***, ** represents statistically significant at 1% level and 5% level, respectively; t-statistics are corrected for heteroscedasticity and reported in parentheses.

The analyses of the panel data on 22 countries for three decades indicate that the imposition of a carbon tax significantly impacts the economic performance of the countries. A carbon tax is commonly assumed to impact the economy negatively. However, that is not the case when a carbon tax is designed appropriately, communicated to the public clearly, and applied correctly. Another important observation from the above results is the interaction variable between carbon emissions and carbon tax. The negative and significant results indicate that once the carbon tax is levied on firms producing high carbon emissions, the immediate effect will be a low economic activity to adjust for additional taxes, and thus negatively impact the country's economic performance. Further, the impact of the $CO_2$ emissions is, as expected, positive and significant on the economic performance of the country, representing a high degree of industrial activity. The impact of control variables, population, and R&D intensity is also expected to be positive and significant. Higher R&D

investments will lead to higher economic activity. It could be expected that some of the investment might be going to cleaner energy innovations.

## 5. Conclusions and Policy Implications

This paper explored existing policies that discourage carbon emissions at the regional, national, and international levels. This is the first study to compare the long-term effects of a carbon-reducing policy on a country's GDP. The overall analysis presents a valid argument that carbon tax can significantly reduce emissions without negatively impacting GDP.

We analyzed the impact of carbon taxes on GDP, and the regression results indicated that a carbon tax does not have any negative impact on the economic performance of the country. Moreover, the interaction of $CO_2$ emissions and carbon tax specifies that the economic activities of firms on which carbon tax is imposed will reduce initially. However, further, these firms can rebound back using cleaner technologies. The other control variables have a significant and positive impact on the economic performance of a country.

Overall, a carbon tax slightly edges over other carbon abatement programs due to its relative simplicity in implementation, low cost to regulators, and the benefits seen within economies from revenues made by the tax. The tax rate will incentivize utility companies, industries, and consumers to decarbonize. A critical aspect of implementing this tax to make it successful is reducing other energy taxes. One advantage of a carbon tax over an ETS is that it can easily be implemented in any geographic area from a city, state or province, country, or region, such as the EU.

Despite a proven record of success with a carbon tax in reducing GHG emissions, it has failed to gain traction in countries with the most GHG emissions. Moreover, the idea of a carbon tax has been resisted in many of the world's wealthiest countries, including the United States, Russia, and China, which have favored carbon cap-and-trade markets or the ETS.

However, carbon cap-and-trade programs and variations of ETS could become the prominent carbon policy, especially with significant emitters, due to its ability to act as a market policy and its ability to include several groups of states and countries together in the same policy (Huisingh et al. 2015). The ETR can revise the entire country's tax structure with two objectives: (1) focus on environmental protection, particularly the reduction in carbon dioxide and other greenhouse gasses, and (2) reduce labor costs and increase employment (Beuermann and Santarius 2006).

Ultimately, there are two possibilities for a global carbon decarbonization policy. Either (1) all countries work together for a low carbon policy system, similar to how they came together for the Paris Agreement, which could come in the form of a carbon tax or ETS or a combination of the two, or (2) countries independently decide what policy or combination of policies are best for their countries. However, after researching the literature, there seems to be a consensus on working towards a low-carbon society, as discussed in the Kyoto Protocol and the Paris Agreement.

Although we recommend implementing carbon tax policies to make the quickest and deepest cuts in carbon emissions, countries can also implement ecological tax reform (ETR), including a carbon tax. However, suppose a state, province, or country is looking to join a decarbonization program with other states or countries. In that case, some version of an ETS could work, albeit not as effectively. This two-fold approach is another way of incentivizing a reduction in carbon emissions and supporting a growing economy. Ultimately, each country must specify clear economic goals and emissions targets for the future. Each country should explore the policy option listed in this paper and choose what works best with their economy and national political framework, along with public support.

The applications of this study are to motivate governments to form a national carbon abatement policy and encourage corporate leaders to invest in clean technology to grow the economy.

This research paper has some limitations too. One of the limitations is that it has not covered every country. Another limitation is that it has not examined states within a country implementing a carbon tax policy, such as California (USA) and British Columbia (Canada). This study can be taken forward in a few ways. It can be extended by studying the sector-wise effect of carbon policies on emissions. Further, this study did not examine countries that reverted to a non-carbon tax regime after implementing a carbon-reducing policy.

The exploratory research in the paper indicates that a carbon tax is the best policy for quickly and effectively reducing carbon emissions. However, countries looking to form a coalition with other countries or become a part of a regional or an international decarbonization system would find developing an alternate policy cap-and-trade system more convenient. Hopefully, with the U.N. and international collaborations in the future, the world will be able to lower emissions in time to avoid the adverse effects of anthropogenic climate change without negatively impacting the economic growth performance of the countries.

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## Appendix A

**Table A1.** Carbon tax schemes in various countries.

| Country | Year Adopted | Tax Rate |
|---|---|---|
| Chile | 2014 | USD 5 per $tCO_2e$ (2018) |
| Costa Rica | 1997 | 3.5% tax on hydrocarbon fossil fuels |
| Denmark | 1992 | USD 31 per $tCO_2e$ (2014) |
| Finland | 1990 | EUR 35 per $tCO_2e$ (2013) |
| France | 2014 | EUR 7 per $tCO_2e$ (2014) |
| Iceland | 2010 | USD 10 per $tCO_2e$ (2014) |
| Ireland | 2010 | EUR 20 per $tCO_2e$ (2013) |
| Japan | 2012 | USD 2 per $tCO_2e$ |
| Mexico | 2012 | MXN 10–50 per $tCO_2e$ (2014) * |
| Norway | 1991 | USD 4–69 per $tCO_2e$ (2014) ** |
| Portugal | 2014 | EUR 5 per $tCO_2e$ (2015) |
| South Africa | 2016 | ZAR 120/$tCO_2$ (Proposed tax rate for 2016) *** |
| Sweden | 1991 | USD 168 per $tCO_2e$ (2014) |
| Switzerland | 2008 | USD 68 per $tCO_2e$ (2014) |
| United Kingdom | 2013 | USD 15.75 per $tCO_2e$ (2014) |

* Depending on fuel type; ** Depending on fossil fuel type and usage; *** Tax is proposed to increase by 10% annually until the end of 2019. Source: (World Bank 2021b).

## Appendix B

**Table A2.** Country-wise results of Granger causality analysis.

| Country | Null Hypothesis | Chi-Square Statistics | Prob. | Decision |
|---|---|---|---|---|
| Argentina | $CO_2$ Emissions do not Granger cause GDP | 8.2106 | 0.016 | Reject |
| Argentina | GDP does not cause $CO_2$ emissions | 6.3478 | 0.042 | Reject |
| Argentina | Population does not cause GDP | 3.6333 | 0.163 | Accept |
| Argentina | GDP does not cause Population | 2.2166 | 0.33 | Accept |
| Argentina | A Carbon Tax does not cause GDP | 0.93152 | 0.628 | Accept |
| Argentina | GDP does not cause a Carbon Tax | 4.1118 | 0.128 | Accept |
| Argentina | $CO_2$ emissions do not cause a Carbon Tax | 648.65 | 0 | Reject |
| Argentina | A Carbon Tax does not cause $CO_2$ emissions | 10.538 | 0.005 | Reject |
| Canada | $CO_2$ Emissions do not Granger cause GDP | 0.13589 | 0.934 | Accept |
| Canada | GDP does not cause $CO_2$ emissions | 0.96564 | 0.617 | Accept |
| Canada | Population does not cause GDP | 0.43633 | 0.804 | Accept |
| Canada | GDP does not cause Population | 2.2182 | 0.33 | Accept |
| Canada | A Carbon Tax does not cause GDP | NA | NA | NA |
| Canada | GDP does not cause a Carbon Tax | NA | NA | NA |
| Canada | $CO_2$ emissions do not cause a Carbon Tax | NA | NA | NA |
| Canada | A Carbon Tax does not cause $CO_2$ emissions | NA | NA | NA |
| Chile | $CO_2$ Emissions do not Granger cause GDP | 12.058 | 0.002 | Reject |
| Chile | GDP does not cause $CO_2$ emissions | 9.1148 | 0.01 | Reject |
| Chile | Population does not cause GDP | 3.363 | 0.186 | Accept |
| Chile | GDP does not cause Population | 6.6681 | 0.036 | Reject |
| Chile | A Carbon Tax does not cause GDP | 4.7232 | 0.094 | Reject |
| Chile | GDP does not cause a Carbon Tax | - | - | - |
| Chile | $CO_2$ emissions do not cause a Carbon Tax | 9.7734 | 0.008 | Reject |
| Chile | A Carbon Tax does not cause $CO_2$ emissions | 390.5 | 0 | Reject |
| Colombia | $CO_2$ Emissions do not Granger cause GDP | 33.318 | 0 | Reject |
| Colombia | GDP does not cause $CO_2$ emissions | 5.2206 | 0.074 | Reject |
| Colombia | Population does not cause GDP | 5.9142 | 0.052 | Reject |
| Colombia | GDP does not cause Population | 0.19033 | 0.909 | Accept |
| Colombia | A Carbon Tax does not cause GDP | 5.4695 | 0.065 | NA |
| Colombia | GDP does not cause a Carbon Tax | - | - | - |
| Colombia | $CO_2$ emissions do not cause a Carbon Tax | 3.2868 | 0.193 | Accept |
| Colombia | A Carbon Tax does not cause $CO_2$ emissions | 421.08 | 0 | Reject |
| Costa Rica | $CO_2$ Emissions do not Granger cause GDP | 8.2106 | 0.016 | Reject |
| Costa Rica | GDP does not cause $CO_2$ emissions | 6.3478 | 0.042 | Reject |
| Costa Rica | Population does not cause GDP | 3.6333 | 0.163 | Accept |
| Costa Rica | GDP does not cause Population | 2.2166 | 0.33 | Accept |
| Costa Rica | A Carbon Tax does not cause GDP | 0.93152 | 0.628 | Accept |
| Costa Rica | GDP does not cause a Carbon Tax | 4.1118 | 0.128 | Accept |
| Costa Rica | $CO_2$ emissions do not cause a Carbon Tax | 648.65 | 0 | Reject |
| Costa Rica | A Carbon Tax does not cause $CO_2$ emissions | 10.538 | 0.005 | Reject |
| Denmark | $CO_2$ Emissions do not Granger cause GDP | 6.1507 | 0.046 | Reject |
| Denmark | GDP does not cause $CO_2$ emissions | 1.4929 | 0.474 | Accept |
| Denmark | Population does not cause GDP | 1.3908 | 0.499 | Accept |
| Denmark | GDP does not cause Population | 3.2439 | 0.198 | Accept |
| Denmark | A Carbon Tax does not cause GDP | 0.22421 | 0.894 | Accept |
| Denmark | GDP does not cause a Carbon Tax | 2.4844 | 0.647 | Accept |
| Denmark | $CO_2$ emissions do not cause a Carbon Tax | 1.6834 | 0.431 | Accept |
| Denmark | A Carbon Tax does not cause $CO_2$ emissions | 3.0526 | 0.217 | Accept |
| Finland | $CO_2$ Emissions do not Granger cause GDP | 12.477 | 0.002 | Reject |
| Finland | GDP does not cause $CO_2$ emissions | 0.6814 | 0.711 | Reject |
| Finland | Population does not cause GDP | 2.6028 | 0.272 | Accept |
| Finland | GDP does not cause Population | 0.98397 | 0.611 | Accept |
| Finland | A Carbon Tax does not cause GDP | 6.0124 | 0.049 | Reject |
| Finland | GDP does not cause a Carbon Tax | 5.0905 | 0.278 | Accept |
| Finland | $CO_2$ emissions do not cause A Carbon Tax | 1.9885 | 0.37 | Accept |
| Finland | A Carbon Tax does not cause $CO_2$ emissions | 8.534 | 0.014 | Reject |

**Table A2.** *Cont.*

| Country | Null Hypothesis | Chi-Square Statistics | Prob. | Decision |
|---|---|---|---|---|
| France | $CO_2$ Emissions do not Granger cause GDP | 84.445 | 0 | Reject |
| France | GDP does not cause $CO_2$ emissions | 0.32609 | 0.85 | Accept |
| France | Population does not cause GDP | 3.423 | 0.181 | Accept |
| France | GDP does not cause Population | 0.51664 | 0.772 | Accept |
| France | A Carbon Tax does not cause GDP | 1.6658 | 0.435 | Accept |
| France | GDP does not cause a Carbon Tax | 2.3012 | 0.681 | Accept |
| France | $CO_2$ emissions do not cause A Carbon Tax | 0.13981 | 0.932 | Accept |
| France | A Carbon Tax does not cause $CO_2$ emissions | 4.9053 | 0.086 | Reject |
| Iceland | $CO_2$ Emissions do not Granger cause GDP | 1.6598 | 0.436 | Accept |
| Iceland | GDP does not cause $CO_2$ emissions | 0.29303 | 0.864 | Accept |
| Iceland | Population does not cause GDP | 0.61628 | 0.735 | Accept |
| Iceland | GDP does not cause Population | 0.02472 | 0.988 | Accept |
| Iceland | A Carbon Tax does not cause GDP | NA | NA | NA |
| Iceland | GDP does not cause a Carbon Tax | NA | NA | NA |
| Iceland | $CO_2$ emissions do not cause A Carbon Tax | NA | NA | NA |
| Iceland | A Carbon Tax does not cause $CO_2$ emissions | NA | NA | NA |
| Ireland | $CO_2$ Emissions do not Granger cause GDP | 0.82113 | 0.663 | Accept |
| Ireland | GDP does not cause $CO_2$ emissions | 2.4029 | 0.301 | Accept |
| Ireland | Population does not cause GDP | 2.6568 | 0.265 | Accept |
| Ireland | GDP does not cause Population | 1.4608 | 0.482 | Accept |
| Ireland | A Carbon Tax does not cause GDP | 4.6515 | 0.098 | Reject |
| Ireland | GDP does not cause a Carbon Tax | 18.341 | 0.72 | Accept |
| Ireland | $CO_2$ emissions do not cause A Carbon Tax | 0.65586 | 0.72 | Accept |
| Ireland | A Carbon Tax does not cause $CO_2$ emissions | 0.46979 | 0.791 | Accept |
| Japan | $CO_2$ Emissions do not Granger cause GDP | 15.454 | 0 | Reject |
| Japan | GDP does not cause $CO_2$ emissions | 0.8175 | 0.664 | Accept |
| Japan | Population does not cause GDP | 2.5384 | 0.281 | Accept |
| Japan | GDP does not cause Population | 10.856 | 0.004 | Reject |
| Japan | A Carbon Tax does not cause GDP | 2.2478 | 0.325 | Accept |
| Japan | GDP does not cause a Carbon Tax | 0.59025 | 0.744 | Accept |
| Japan | $CO_2$ emissions do not cause A Carbon Tax | 0.96169 | 0.618 | Accept |
| Japan | A Carbon Tax does not cause $CO_2$ emissions | 1.1893 | 0.552 | Accept |
| Mexico | $CO_2$ Emissions do not Granger cause GDP | 19.007 | 0 | Reject |
| Mexico | GDP does not cause $CO_2$ emissions | 0.68407 | 0.71 | Accept |
| Mexico | Population does not cause GDP | 0.67885 | 0.712 | Accept |
| Mexico | GDP does not cause Population | 0.68407 | 0.71 | Accept |
| Mexico | A Carbon Tax does not cause GDP | 0.66916 | 0.716 | Accept |
| Mexico | GDP does not cause a Carbon Tax | 6.2272 | 0.183 | Accept |
| Mexico | $CO_2$ emissions do not cause A Carbon Tax | 4.2193 | 0.121 | Accept |
| Mexico | A Carbon Tax does not cause $CO_2$ emissions | 4.9897 | 0.083 | Reject |
| Norway | $CO_2$ Emissions do not Granger cause GDP | 14.284 | 0.001 | Reject |
| Norway | GDP does not cause $CO_2$ emissions | 0.86477 | 0.649 | Accept |
| Norway | Population does not cause GDP | 11.625 | 0.003 | Reject |
| Norway | GDP does not cause Population | 0.1561 | 0.925 | Accept |
| Norway | A Carbon Tax does not cause GDP | 3.0999 | 0.212 | Accept |
| Norway | GDP does not cause a Carbon Tax | 8.2498 | 0.128 | Accept |
| Norway | $CO_2$ emissions do not cause A Carbon Tax | 1.9002 | 0.387 | Accept |
| Norway | A Carbon Tax does not cause $CO_2$ emissions | 1.7274 | 0.422 | Accept |
| Poland | $CO_2$ Emissions do not Granger cause GDP | 66.478 | 0 | Reject |
| Poland | GDP does not cause $CO_2$ emissions | 3.9667 | 0.138 | Accept |
| Poland | Population does not cause GDP | 3.9543 | 0.138 | Accept |
| Poland | GDP does not cause Population | 2.465 | 0.292 | Accept |
| Poland | A Carbon Tax does not cause GDP | 2.3717 | 0.305 | Accept |
| Poland | GDP does not cause a Carbon Tax | 1.457 | 0.834 | Accept |
| Poland | $CO_2$ emissions do not cause A Carbon Tax | 0.95056 | 0.622 | Accept |
| Poland | A Carbon Tax does not cause $CO_2$ emissions | 0.51505 | 0.773 | Accept |
| Portugal | $CO_2$ Emissions do not Granger cause GDP | 60.574 | 0 | Reject |

**Table A2.** *Cont.*

| Country | Null Hypothesis | Chi-Square Statistics | Prob. | Decision |
|---|---|---|---|---|
| Portugal | GDP does not cause $CO_2$ emissions | 0.47996 | 0.787 | Accept |
| Portugal | Population does not cause GDP | 1.1788 | 0.555 | Accept |
| Portugal | GDP does not cause Population | 3.833 | 0.147 | Accept |
| Portugal | A Carbon Tax does not cause GDP | 1.8702 | 0.393 | Accept |
| Portugal | GDP does not cause a Carbon Tax | 3.0723 | 0.215 | Accept |
| Portugal | $CO_2$ emissions do not cause A Carbon Tax | 0.40092 | 0.818 | Accept |
| Portugal | A Carbon Tax does not cause $CO_2$ emissions | 3.9024 | 0.142 | Accept |
| South Africa | $CO_2$ Emissions do not Granger cause GDP | 120.03 | 0 | Reject |
| South Africa | GDP does not cause $CO_2$ emissions | 4.4186 | 0.352 | Accept |
| South Africa | Population does not cause GDP | 17.271 | 0.002 | Reject |
| South Africa | GDP does not cause Population | 10.962 | 0.027 | Reject |
| South Africa | A Carbon Tax does not cause GDP | NA | NA | NA |
| South Africa | GDP does not cause a Carbon Tax | NA | NA | NA |
| South Africa | $CO_2$ emissions do not cause a Carbon Tax | NA | NA | NA |
| South Africa | A Carbon Tax does not cause $CO_2$ emissions | NA | NA | NA |
| Spain | $CO_2$ Emissions do not Granger cause GDP | 69.869 | 0 | Reject |
| Spain | GDP does not cause $CO_2$ emissions | 3.6909 | 0.158 | Accept |
| Spain | Population does not cause GDP | 1.7574 | 0.415 | Accept |
| Spain | GDP does not cause Population | 4.0514 | 0.132 | Accept |
| Spain | A Carbon Tax does not cause GDP | 3.2777 | 0.194 | Accept |
| Spain | GDP does not cause a Carbon Tax | 3.3761 | 0.497 | Accept |
| Spain | $CO_2$ emissions do not cause A Carbon Tax | 2.5027 | 0.286 | Accept |
| Spain | A Carbon Tax does not cause $CO_2$ emissions | 11.537 | 0.003 | Reject |
| Sweden | $CO_2$ Emissions do not Granger cause GDP | 5.8116 | 0.055 | Reject |
| Sweden | GDP does not cause $CO_2$ emissions | 2.8163 | 0.245 | Accept |
| Sweden | Population does not cause GDP | 2.5932 | 0.273 | Accept |
| Sweden | GDP does not cause Population | 1.7684 | 0.413 | Accept |
| Sweden | A Carbon Tax does not cause GDP | 3.9837 | 0.136 | Accept |
| Sweden | GDP does not cause a Carbon Tax | 0.59677 | 0.963 | Accept |
| Sweden | $CO_2$ emissions do not cause A Carbon Tax | 0.23204 | 0.89 | Accept |
| Sweden | A Carbon Tax does not cause $CO_2$ emissions | 1.5131 | 0.469 | Accept |
| Switzerland | $CO_2$ Emissions do not Granger cause GDP | 30.602 | 0 | Reject |
| Switzerland | GDP does not cause $CO_2$ emissions | 4.8329 | 0.089 | Reject |
| Switzerland | Population does not cause GDP | 1.8377 | 0.399 | Accept |
| Switzerland | GDP does not cause Population | 14.594 | 0.001 | Reject |
| Switzerland | A Carbon Tax does not cause GDP | 12.344 | 0.002 | Reject |
| Switzerland | GDP does not cause a Carbon Tax | 5.7673 | 0.217 | Accept |
| Switzerland | $CO_2$ emissions do not cause A Carbon Tax | 0.992 | 0.609 | Accept |
| Switzerland | A Carbon Tax does not cause $CO_2$ emissions | 1.7385 | 0.419 | Accept |
| Ukraine | $CO_2$ Emissions do not Granger cause GDP | 1.2373 | 0.539 | Accept |
| Ukraine | GDP does not cause $CO_2$ emissions | 2.1411 | 0.343 | Accept |
| Ukraine | Population does not cause GDP | 12.194 | 0.002 | Reject |
| Ukraine | GDP does not cause Population | 0.24094 | 0.887 | Accept |
| Ukraine | A Carbon Tax does not cause GDP | 1.9846 | 0.371 | Accept |
| Ukraine | GDP does not cause a Carbon Tax | 4.0877 | 0.394 | Accept |
| Ukraine | $CO_2$ emissions do not cause A Carbon Tax | 0.23849 | 0.888 | Accept |
| Ukraine | A Carbon Tax does not cause $CO_2$ emissions | 0.39178 | 0.822 | Accept |
| UK | $CO_2$ Emissions do not Granger cause GDP | 89.732 | 0 | Reject |
| UK | GDP does not cause $CO_2$ emissions | 0.30143 | 0.86 | Accept |
| UK | Population does not cause GDP | 1.4386 | 0.487 | Accept |
| UK | GDP does not cause Population | 0.36131 | 0.835 | Accept |
| UK | A Carbon Tax does not cause GDP | NA | NA | NA |
| UK | GDP does not cause a Carbon Tax | NA | NA | NA |
| UK | $CO_2$ emissions do not cause A Carbon Tax | NA | NA | NA |
| UK | A Carbon Tax does not cause $CO_2$ emissions | NA | NA | NA |

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