

# Empirical study on the effect of carbon tax on GHG emissions in select nations

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## Abstract

**Purpose** – This study aims to understand the impact of carbon pricing on greenhouse gas emissions. It is necessary to evaluate the effectiveness of the carbon pricing mechanism on the ground level; therefore, this study provides valuable input about the policies of carbon taxes in OECD countries.

**Design/methodology/approach** – This study examines the effects of carbon prices on greenhouse gas emissions in five OECD nations (Denmark, Finland, Sweden, Norway and Slovenia), for the sample period of 1990–2019. The research employs Karl Pearson's correlation and the Phillips–Perron Unit root test to analyze the relationship between carbon prices and greenhouse gas emissions across these countries.

**Findings** – This study explores the relationship between carbon tax and greenhouse gas emissions, revealing mixed outcomes. Carbon pricing has significantly reduced emissions in Finland, Slovenia, Sweden and Denmark but has been ineffective in Norway, where emissions increased, likely due to the country's expanding oil and natural gas sectors. These findings highlight the limitations of carbon pricing in certain contexts and emphasize the need for national carbon pricing policies tailored to each country's unique economic and environmental characteristics to ensure effectiveness.

**Originality/value** – This research highlights the need for tailored carbon pricing schemes that account for each country's unique environmental and economic conditions. It calls for further studies on the long-term impact of carbon pricing across sectors and regions. The study suggests combining technological innovation, behavioral economics and environmental policies to enhance carbon tax effectiveness, offering valuable insights for governments shaping carbon pricing strategies.

**Keywords** Carbon tax, Greenhouse gas emissions, Panel unit-root test

**Paper type** Research article

## 1. Introduction

According to economists, assigning a monetary value to carbon emissions, or carbon pricing, is an effective regulatory strategy for mitigating greenhouse gas emissions. This approach could potentially incentivize individuals and industries to adopt more environmentally sustainable practices (World Bank Group, 2019). Carbon pricing is a highly effective approach for promoting the adoption of sustainable practices among individuals and organizations. This pricing strategy serves as a powerful motivator, encouraging everyone to embrace cost-effective methods of reducing carbon emissions (Dong *et al.*, 2017).

The implementation of carbon pricing can be achieved through two primary mechanisms: the introduction of a carbon tax or the establishment of a greenhouse gas emissions trading system (ETS). Both mechanisms have distinct advantages and can contribute significantly to reducing carbon emissions. In the case of a carbon tax, the government sets the tax rate and identifies which emission sources are subject to taxation. This approach ensures fairness by imposing a larger tax burden on those who can afford to pay more (Musgrave & Musgrave, 1959). The extent of emission reduction depends on how these sources react to the tax. This study applied progressive tax theory to examine how carbon taxes impact GHG emissions, where tax rates increase with higher emissions or income.

## JEL Classification — G30, Q54

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On the other hand, the Pigouvian tax (an environmental economics concept) addresses negative externalities by charging polluters based on the environmental damage they cause. This tax incentivizes individuals and companies to adopt cleaner practices by internalizing the external costs of pollution (Wills, 2020). This study follows this Pigouvian tax theory to examine the relationship between carbon tax and greenhouse gas emissions.

Larger polluters or wealthier companies pay higher tax rates per ton of emissions, similar to progressive income taxes. This approach encourages greater reductions in GHG emissions while ensuring fair distribution of tax burdens (Fullerton & Heutel, 2017). The goal of carbon taxes is to reduce greenhouse gas emissions while ensuring equitable tax distribution. By internalizing these costs, carbon taxes aim to balance economic activity and environmental protection. Studies indicate (Hájek, Zimmermannová, Helman, & Rozenský, 2019; Dong *et al.*, 2017) that carbon taxes can effectively lower emissions while supporting economic growth through improved energy efficiency. However, these findings will not be applicable in all countries. Therefore, this study focuses on OECD countries to find the relationship between carbon tax and greenhouse gas emissions.

A carbon tax imposes a fee on carbon-based fuel usage to reduce dependence on fossil fuels and combat climate change. While it raises energy costs, it disproportionately affects lower-income households, raising fairness concerns. This progressive approach places greater responsibility on those with higher emissions or more financial means, encouraging them to reduce their impact. Higher tax rates incentivize large firms with significant resources to cut emissions (Pigou, 1920). Finland introduced the first carbon tax in 1990, valued at \$73.02 per ton by 2021, to reduce emissions and promote cleaner energy. Sweden and Norway followed suit in 1991, using market-based solutions to encourage renewable energy and cut fossil fuel use. Norway implemented a high carbon tax of \$69 per ton of CO<sub>2</sub> from gasoline to manage its oil and gas dependency and reduce pollution. Sweden and Norway's carbon taxes demonstrated their commitment to climate change mitigation and encouraged global adoption of green technologies (Zhang, Abbas, & Iqbal, 2021).

An idea in environmental economics known as the Pigouvian tax proposes charging actions that result in negative externalities at a rate equivalent to the external cost. By making the polluter accountable for the damage they cause to the environment, this tax internalizes the externality. According to Progressive Tax Theory, the tax rate may rise in proportion to the amount of emissions or the emitter's wealth, whereas a typical Pigouvian tax would impose a constant rate per unit of carbon emissions (Hennessy *et al.*, 2003).

Carbon taxation reduces greenhouse gas emissions by creating financial incentives for cleaner energy and sustainable practices, encouraging green technology development. It helps manage climate risks like extreme weather and promotes economic growth through energy efficiency and reduced fossil fuel dependence (Metcalf & Weisbach, 2009). Carbon taxes are usually charged at a fixed rate per ton of CO<sub>2</sub>, but a progressive tax approach could argue for higher taxes based on emission levels or the financial capacity of the emitters.

The article examines the impact of carbon taxes on greenhouse gas emissions in five OECD countries using advanced econometric methods like the Phillips-Perron Unit Root Test and Karl Pearson's correlation. This analysis ensures reliable time-series data for accurate modeling of the relationship between carbon taxes and emissions. The study applies Progressive and Pigouvian Tax Theories to analyze how carbon taxes reduce emissions by making polluters pay for environmental costs. It recommends a dynamic carbon tax system and suggests using revenues for renewable energy projects and public-private collaborations.

In four of the five studied countries, carbon taxes significantly reduced greenhouse gas emissions, except in Norway, where the relationship was positive and warrants further research. The research contributes to understanding carbon taxes' effects and highlights areas for future investigation. This research enhances existing literature by analyzing long-term carbon tax impacts (1990–2019) in five pioneering countries and testing Pigouvian and Progressive tax theories empirically. It highlights variations in efficacy due to policy design

and country-specific contexts, offering insights for tailored carbon tax policies. The findings align with key works in the field, bridging gaps in theoretical and empirical understanding.

This study's conclusions are further supported by (Alton *et al.*, 2014; Nong & Siriwardana, 2017), who explored the impact of carbon taxes on both economic performance and emissions reduction. The unique case of Norway, where emissions did not decline, mirrors the concerns discussed by (Van Heerden *et al.*, 2006; Freedman & Jaggi, 2009), who examined the challenges and complexities associated with implementing carbon taxes in different national contexts.

## 2. Literature review

The rationale behind conducting the research on the effect of carbon tax on greenhouse gas emissions is centered on understanding and evaluating the effectiveness of carbon taxation as a tool for mitigating climate change. The study is motivated by the need to assess how carbon taxes, implemented in various countries, influence the reduction of greenhouse gas (GHG) emissions. This is critical because carbon taxes are seen as a significant regulatory strategy for promoting environmental sustainability by incentivizing industries and individuals to adopt more eco-friendly practices. The research aims to evaluate the effectiveness of carbon taxes in reducing greenhouse gas emissions and mitigating climate change. It assesses how carbon taxes in different countries influence emissions reductions, highlighting their role in promoting environmental sustainability by encouraging eco-friendly practices. The research examines the effects of carbon taxes in Finland, Denmark, Norway, Slovenia and Sweden to provide empirical evidence on their impact on greenhouse gas emissions. The findings aim to guide other countries in crafting effective carbon tax policies and supporting global climate change efforts and sustainability.

Greenhouse gas (GHG) emissions, which include CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O and F-gases, have diverse origins and models are customized to accurately trace their sources. For instance, in the Global Trade Analysis Project (GTAP) database version 10 (Aguilar, Chepeliev, Corong, McDougall, & Van Der Mensbrugghe, 2019), CO<sub>2</sub> emissions specifically arise from the combustion of fossil fuels like coal, crude oil, natural gas and petroleum products. On the other hand, non-CO<sub>2</sub> emissions have various sources, including the combustion of fossil fuels, changes in land use, the use of livestock capital, chemical utilization and production processes. Modelers have the flexibility to configure their models to incorporate either CO<sub>2</sub> emissions, non-CO<sub>2</sub> emissions, or both. Over the past few decades, numerous studies have investigated the repercussions of climate change policies, taking into account both CO<sub>2</sub> and non-CO<sub>2</sub> emissions. Many of these studies encompass all GHG emissions, as demonstrated in works like (Reilly *et al.*, 1999; Adams, 2007; Meng, Siriwardana, & McNeill, 2013; Benavente, 2016; Renner, 2018; Tran, Siriwardana, Meng, & Nong, 2019; Nong, Nguyen, Wang, & Van Khuc, 2020). Some studies focus on specific gases, such as CO<sub>2</sub> and CH<sub>4</sub> in CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O in (Manne & Richels, 2001).

The study investigates how carbon impact information influences climate change decision-making, focusing on the CDP and the GHG Protocol as reporting frameworks. It concludes that diverse carbon disclosure methods improve the usefulness of climate change data (Andrew & Cortese, 2011) investigated the repercussions of the Kyoto Protocol on various countries, utilizing data collected from 282 firms through CDP questionnaires, alongside information from annual reports, social and environmental sustainability reports and websites. Their findings indicate that Canadian and Japanese firms disclose higher levels of GHG emissions in comparison to firms in EU countries, although disparities exist among EU firms (Freedman & Jaggi, 2009). Typically, assess the broader implications of climate change policies by employing computational general equilibrium (CGE) models (K. Zhang, Wang, Liang, & Chen, 2016).

Empirical evidence suggests that cost savings can vary significantly, up to 70%, when additional gases are considered (Reilly *et al.*, 1999; Tol, 1999; Manne & Richels, 2001). These

variations result in notably different outcomes, including an increase in poverty attributed to shifts in food prices (Renner, 2018).

In numerous national and global contexts, a noticeable trend is the prevalence of studies that primarily concentrate on CO<sub>2</sub> emissions when evaluating climate change policies through CGE models. To illustrate (Alton *et al.*, 2014), employed a dynamic national CGE model to assess the repercussions of implementing a carbon tax in South Africa. This model provides in-depth insights into electricity generation technologies, encompassing both fossil fuels and renewable sources. However, its exclusive focus was on CO<sub>2</sub> emissions. The study's outcomes suggested that implementing a \$30 carbon tax would result in a reduction in South Africa's real GDP ranging from 1% to 1.23% by 2025 under various scenarios.

Similarly, (Nong & Siriwardana, 2017) utilized a global CGE model named GTAPE-Powers to investigate the consequences of a recently introduced \$9.15 carbon tax in South Africa. When the model considered only CO<sub>2</sub> emissions, it projected a 1.34% decline in real GDP. However, when non-CO<sub>2</sub> emissions were factored in, the reduction became more pronounced, at 1.59%. Several other studies concerning carbon taxes in South Africa, including those conducted by (Van Heerden *et al.*, 2006, 2016; Devarajan, Go, Robinson, & Thierfelder, 2011; Winkler, 2017), also focused exclusively on CO<sub>2</sub> emissions within their models. Additionally, (Clarke, Fraser, & Waschik, 2014) utilized a global CGE model known as GTAP-E to assess the potential reductions in emissions achievable through reverse auctions funded by the Australian Emission Reduction Fund (valued at A\$2.55 billion). When the analysis considered only CO<sub>2</sub> emissions, it concluded that this budget could cover 50% of the required emissions reductions to meet Australia's Kyoto target of reducing emissions to 5% below 2000 levels by 2020. However, a contrasting viewpoint was presented by (Nong & Siriwardana, 2017), who argued that when both CO<sub>2</sub> and non-CO<sub>2</sub> emissions were integrated into the model (using GTAP-E), this budget could potentially enable Australia to achieve 85% of its 2020 emissions target.

The study evaluates the effects of a carbon tax on greenhouse gas emissions in Finland, Denmark, Norway, Slovenia and Sweden. The primary goal of the tax is to decrease dependence on environmentally damaging sources like coal and fossil fuels (Kerr, 2010; Van der Ploeg & Withagen, 2012). The research assesses the impact of carbon taxes on greenhouse gas emissions in Finland, Denmark, Norway, Slovenia, and Sweden, measuring the success of these countries in emission reductions. It aims to promote sustainability and reduce the adverse effects of GHG emissions. The study hypothesizes a negative correlation between carbon taxes and GHG emissions trends in these countries. Integrated assessment models (IAMs) are key tools in environmental research for evaluating the economic and ecological effects of policies like carbon taxes. They integrate data from economics, environmental science and technology to assess the impact of policy choices on economic and climate outcomes.

IAMs simulate the long-term effects of carbon taxes on greenhouse gas emissions, economic growth and environmental issues by exploring various scenarios. They assess how carbon taxes impact GDP, energy consumption and technological innovation, reflecting the interplay between the economy and the environment (Nordhaus, 1992). This aids in comprehending the carbon tax's wider effects. These models aid in the assessment of the trade-offs between the advantages of lower emissions and averted climate damage and the costs of enacting carbon taxes (Weyant, 1999). This is essential for figuring out the ideal tax rate that strikes a balance between environmental and economic objectives.

### 2.1 Problem statement

The study investigates the effectiveness of carbon taxation in reducing greenhouse gas (GHG) emissions across five selected OECD countries: Finland, Denmark, Norway, Slovenia and Sweden. The core objective is to evaluate the impact of carbon tax policies on mitigating climate change by analyzing the correlation between carbon tax rates and GHG emissions over the period from 1990 to 2019. The research is particularly focused on understanding whether

carbon taxes serve as a viable and effective mechanism for reducing GHG emissions, thereby contributing to global climate change mitigation efforts.

## 2.2 Research questions

The study aims to investigate how carbon taxes affect greenhouse gas emissions in Finland, Denmark, Norway, Slovenia and Sweden. It explores whether carbon tax laws have significantly reduced emissions, examines differences in tax effectiveness among these countries and identifies causes for these discrepancies, such as policy variations and economic conditions. Additionally, it assesses whether the reductions in GHG emissions are sustained over time to evaluate the long-term effectiveness of carbon tax policies.

*H0.* There is no relationship between carbon tax and greenhouse gas emissions.

*H1.* There is some relationship between carbon tax and greenhouse gas emissions.

## 3. Data and research methodology

The study relies on secondary data from the World Bank, covering carbon prices and greenhouse emissions from 1990 to 2019. This approach ensures the use of accurate and up-to-date information. The Phillips–Perron Unit Root test is employed to validate the reliability of the time series data (Adams, 2007). The study has also utilized Karl Pearson’s correlation coefficient to determine the relationship between carbon tax and greenhouse emissions (Fairbrother *et al.*, 2021). The Phillips–Perron (PP) test is a statistical method used to determine if a time series has a unit root, indicating whether the series is stationary. Applying this test to research on carbon taxes and greenhouse gas emissions helps ensure the validity of the econometric analysis by confirming the reliability of the time series data (Phillips, 1988).

The Phillips-Perron test checks if a time series, such as economic indicators or carbon emissions, is stationary or has a unit root. Stationarity means that statistical properties like mean and variance remain constant over time, which is crucial for accurate econometric analysis. Nonstationary data, indicated by a unit root, can lead to unreliable regression results if traditional methods are used (Hamilton, 2020). The Phillips–Perron (PP) test, like the Augmented Dickey–Fuller (ADF) test, detects unit roots in time series data. However, the PP test adjusts for heteroskedasticity and serial correlation in the error terms, offering greater reliability when the ADF test may be inadequate (Enders, 2008).

Karl Pearson’s correlation coefficient was used to analyze the relationship between carbon taxes and greenhouse gas emissions, determining the effectiveness of taxes in reducing emissions. A strong positive correlation suggests that higher carbon taxes are effective, guiding policymakers to set appropriate levels. Targeted taxes in specific sectors could enhance emission reductions, and businesses can use this insight to evaluate financial impacts and invest in cleaner technologies (Metcalf, 2019; Andersson, 2019).

The study analyzes five OECD countries – Finland, Denmark, Norway, Slovenia and Sweden – chosen for their commitment to carbon pricing and sustainability. Covering 1990 to 2019, the research uses World Bank secondary data to ensure accuracy in assessing carbon taxes and greenhouse gas emissions. This timeframe allows for a detailed comparison of the evolution and impact of carbon taxes in these countries. Finland’s early adoption in 1990 offers long-term insights, Denmark’s innovative practices and renewable investments are notable, Norway’s high carbon tax provides lessons for oil economies, Slovenia’s newer adoption reflects EU policy impacts and Sweden’s high rates demonstrate effective emissions reductions. These steps by OECD countries provide us with the scenario to analyze the effectiveness of carbon tax in these countries.

The duration of the study varies from country to country, reflecting the most recent imposition of the carbon tax in each country. The study used E Views and SPSS software tools, which are widely recognized for their accuracy and reliability.

#### 4. Data analysis

The Phillips-Perron Unit Root Test was used to analyze the time series data of greenhouse gas emissions and carbon taxes in Finland, Denmark, Norway, Sweden and Slovenia. With a truncation lag of 2 to address autocorrelation, the test results showed  $p$ -values below 0.01 for all countries. This indicates rejection of the null hypothesis of a unit root, confirming that the data is stationary. The Dickey-Fuller  $Z(\alpha)$  statistics supported the findings of stationarity, with substantial negative values ranging from  $-22.491$  to  $-33.423$  across the countries studied. These results reinforce the absence of unit roots, confirming that the greenhouse gas emissions and carbon tax data are stationary. This confirmation is crucial for reliable time-series modeling. The Phillips-Perron Unit Root Test results confirm the stability and nonexplosive nature of the GHG emissions and carbon tax data for the studied countries. This stability enhances the study's methodological rigor and informs the development of effective and resilient policy recommendations for environmental sustainability and carbon taxation.

Table 1 outlines the unit root test results for various countries and variables, including GHG emissions and carbon taxes. Column 1 lists the countries and specific variables analyzed. Column 2 shows a truncation lag parameter of 2, used for all tests. Column 3 displays  $p$ -values, indicating the likelihood of a unit root; lower  $p$ -values suggest rejecting the null hypothesis. Column 4 presents the Dickey-Fuller  $Z$  statistics, supporting the test results.

Table 1 shows very low  $p$ -values (0.01 or 0.0115), indicating strong evidence against a unit root in the time series data. This suggests that the data for the specified variables in the countries examined are stationary. This stationarity is beneficial for accurate statistical analysis and modeling.

Figure 1 initial visual aid, shows Finland's greenhouse gas emissions over time, while Figure 2 secondary visual aid, depicts carbon tax rates from 1990 to 2019. The carbon tax started at \$1.75 in 1990, with emissions at 69,660, and rose to over \$22.24 by 2004, with emissions increasing to 81,130. By 2011, the tax rate had surged to \$42.42, and emissions decreased to 66,770, further dropping to 57,030 with a tax rate of \$64.75 in 2016. In 2019, the tax rate reached \$69.66, with emissions at 51,480.

Table 2 analyzes the correlation between carbon tax and greenhouse gas emissions in Finland from 1990 to 2019. The correlation coefficient of  $-0.743$ , significant at the 0.01 level, indicates a strong negative relationship between the two variables. This suggests that higher carbon taxes are effective in reducing greenhouse gas emissions. The result highlights the effectiveness of carbon tax policies in emission reduction and is relevant for stakeholders involved in climate change mitigation.

Figure 3 shows Denmark's total greenhouse gas (GHG) emissions, while Figure 4 depicts the carbon tax rates from 1992 to 2019. The carbon tax was introduced in 1992 at \$15.58, with

**Table 1.** Phillips-Perron unit root TestValues

| Country WithVariable   | Truncation lag<br>parameter | $p$ -value | Dickey-<br>Fuller $Z$<br>( $\alpha$ ) |
|------------------------|-----------------------------|------------|---------------------------------------|
| GHG of Finland         | 2                           | 0.01       | $-30.61$                              |
| Carbon Tax of Finland  | 2                           | 0.01       | $-28.756$                             |
| GHG of Denmark         | 2                           | 0.01       | $-32.748$                             |
| Carbon Tax of Denmark  | 2                           | 0.01       | $-26.284$                             |
| GHG of Norway          | 2                           | 0.01       | $-29.747$                             |
| Carbon Tax of Norway   | 2                           | 0.01       | $-25.369$                             |
| GHG of Sweden          | 2                           | 0.01       | $-33.423$                             |
| Carbon Tax of Sweden   | 2                           | 0.0115     | $-22.491$                             |
| GHG of Slovenia        | 2                           | 0.01       | $-22.625$                             |
| Carbon Tax of Slovenia | 2                           | 0.01       | $-27.169$                             |



Figure 1. Greenhouse gas emission in Finland



Figure 2. Carbon tax in Finland

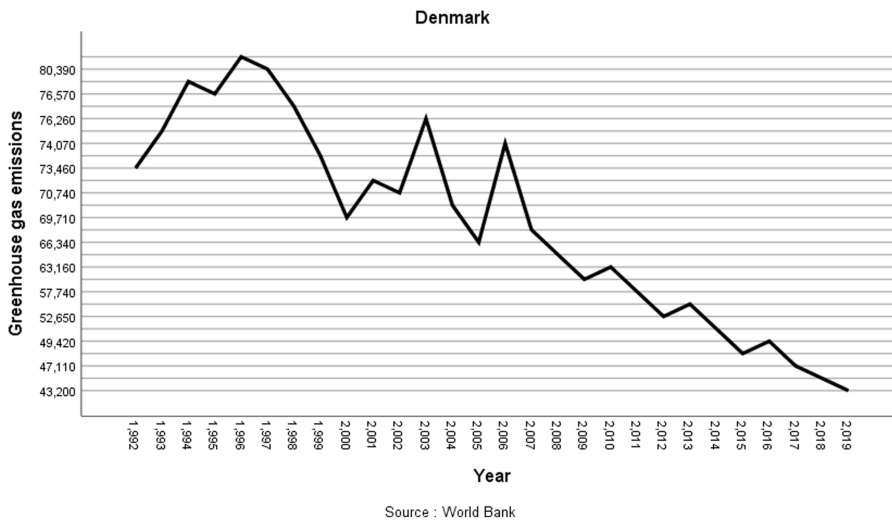
GHG emissions at 73,460. By 2008, the tax had risen to over \$31.50 and GHG emissions had been reduced to 65,770. In 2010, the tax was \$27.96 with GHG at 63,160, and by 2019, the tax was \$26.39 with emissions dropping to 43,200. Since 1992, carbon taxes have increased by 69%, while GHG emissions have decreased by 41.19%.

Table 3 analyzes the correlation between Denmark’s carbon tax and greenhouse gas emissions from 1992 to 2019. The correlation coefficient of  $-0.765$ , significant at the 0.01 level, indicates a strong negative relationship between the two variables. This suggests that higher carbon taxes have effectively reduced greenhouse gas emissions in Denmark.

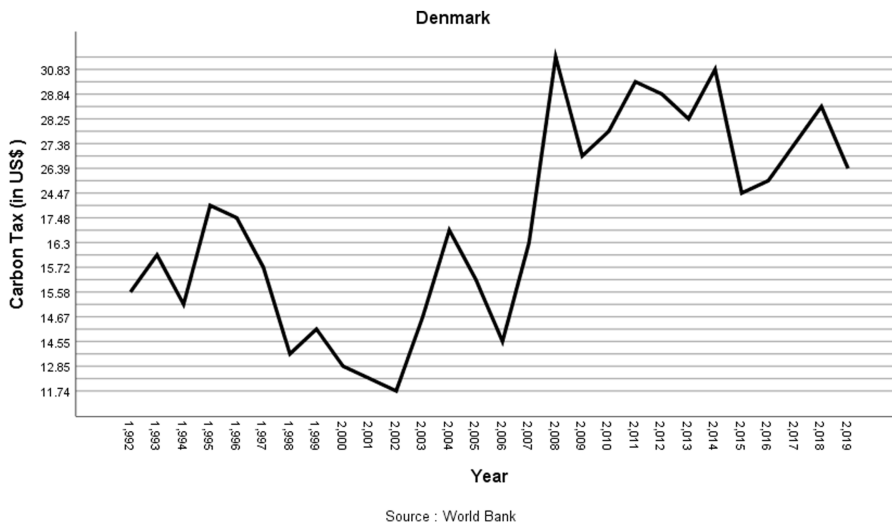
**Table 2.** Correlation for Finland

|            |                     | Greenhouse Emissions |
|------------|---------------------|----------------------|
| Carbon Tax | Pearson Correlation | −0.743***            |
|            | Sig. (two-tailed)   | 0.000                |
|            | N                   | 33                   |

**Note(s):** \*\*\*Correlation is significant at the 0.01 level (two-tailed)



**Figure 3.** Greenhouse gas emission in Denmark



**Figure 4.** Carbon tax in Denmark

Table 3. Correlation for Denmark

|                                                                       |                     | Greenhouse Emissions |
|-----------------------------------------------------------------------|---------------------|----------------------|
| Carbon Tax                                                            | Pearson Correlation | −0.765***            |
|                                                                       | Sig. (two-tailed)   | 0.000                |
|                                                                       | N                   | 28                   |
| Note(s): ***Correlation is significant at the 0.01 level (two-tailed) |                     |                      |

The finding underscores the effectiveness of carbon tax policies in emission control and provides valuable insights for policymakers and stakeholders developing climate change strategies.

Figures 5 and 6 illustrate greenhouse gas emissions and carbon tax trends in Norway from 1991 to 2019. The carbon tax, introduced at \$38.98 in 1991, was later adjusted to \$34.10 in 2001 and \$59.22 in 2019. Greenhouse gas emissions decreased to 45,900 in 2019, indicating the effectiveness of Norway’s carbon tax policy. Since 1991, the tax has increased by 51%, reflecting the government’s ongoing commitment to emission reduction. These trends demonstrate Norway’s progress in mitigating greenhouse gas emissions.

Table 4 shows a positive correlation of 0.216 between carbon tax and greenhouse gas emissions in Norway from 1991 to 2019, but this result is not statistically significant. This suggests that the relationship between these variables is weak. Further research is recommended to explore this relationship in more detail and to identify additional factors affecting emissions. Such analysis could help in developing more effective policies for reducing greenhouse gas emissions.

Figures 7 and 8 graphs show that Sweden’s carbon tax, introduced early and increased over the years, has been effective in reducing greenhouse gas (GHG) emissions. The consistent rise in the tax rate and the corresponding decline in emissions highlight the positive environmental impact of this policy. While there is room for further improvement, Sweden’s approach demonstrates a strong commitment to sustainability. This successful model could serve as a valuable example for other countries in their climate change mitigation efforts.

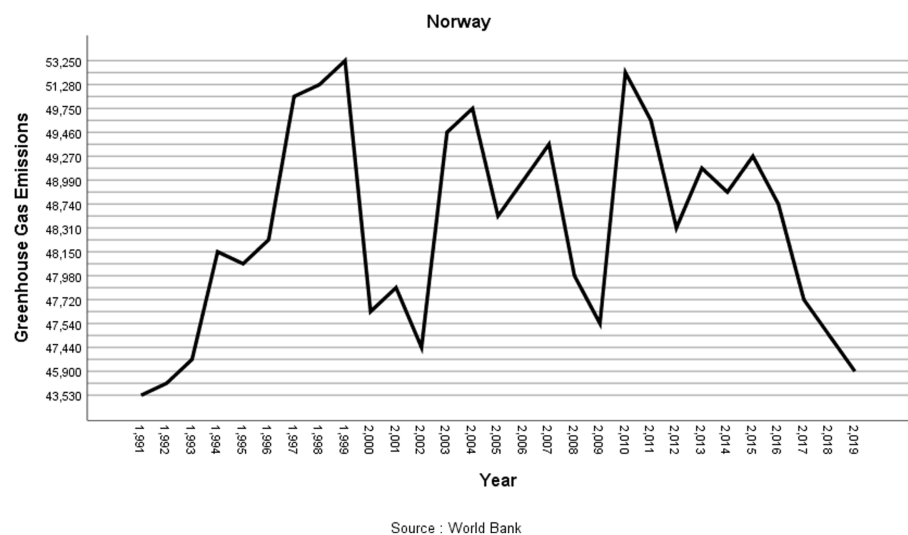
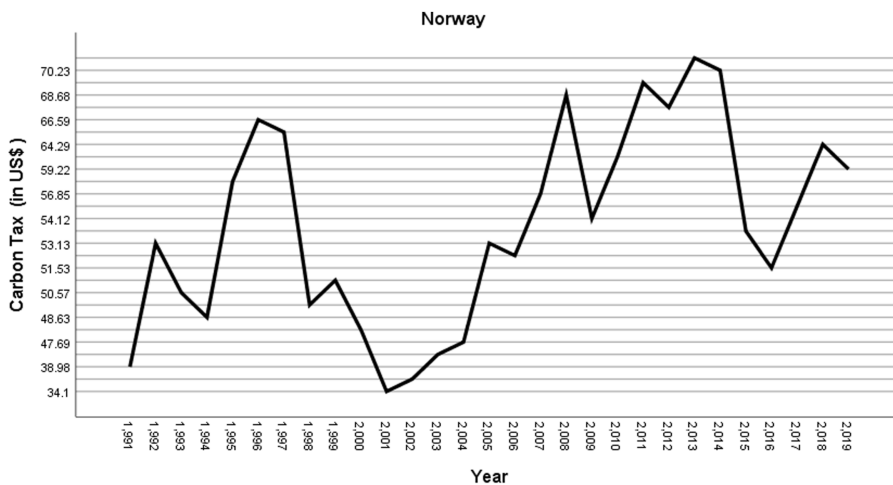


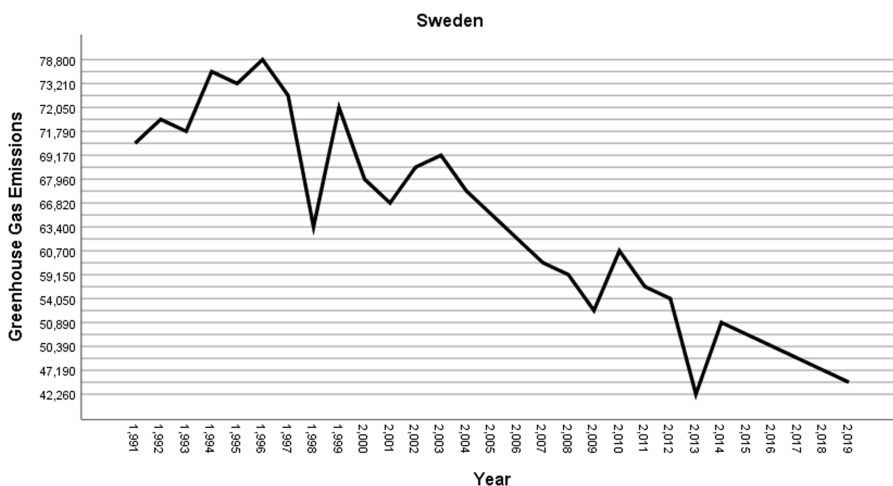
Figure 5. Greenhouse gas emission in Norway



Source : World Bank

**Figure 6.** Carbon tax in Norway**Table 4.** Correlation for Norway

| Greenhouse Emissions |                     |       |
|----------------------|---------------------|-------|
| Carbon Tax           | Pearson Correlation | 0.216 |
|                      | Sig. (two-tailed)   | 0.259 |
|                      | N                   | 29    |



Souece : world Bank

**Figure 7.** Greenhouse gas emission in Sweden



Figure 8. Carbon tax in Sweden

Table 5 shows a strong negative correlation of  $-0.814$  between carbon tax and greenhouse gas emissions in Sweden from 1991 to 2019, with statistical significance at the 0.01 level. This indicates that the carbon tax has been highly effective in reducing GHG emissions. The findings underscore the positive impact of carbon tax policies on climate change mitigation. This evidence is valuable for policymakers and researchers focused on environmental sustainability and achieving sustainable development goals.

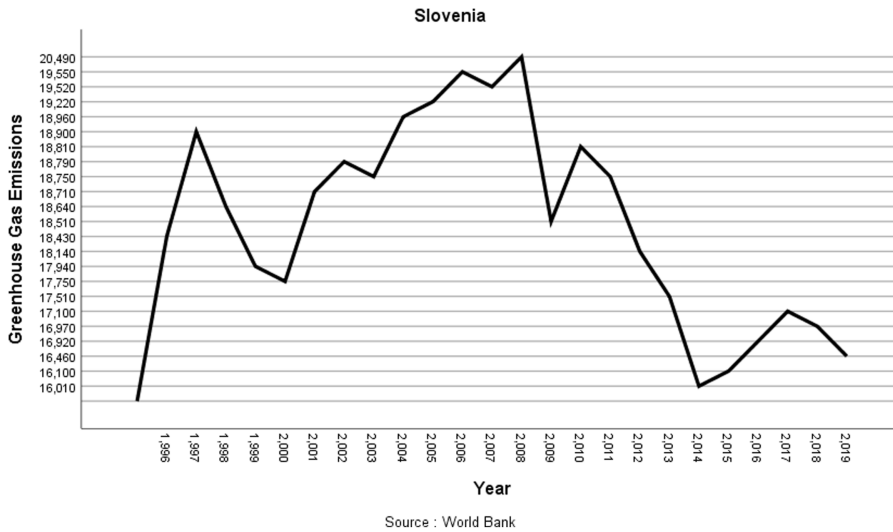
Figures 9 and 10 show that Slovenia, having introduced a carbon tax in 1996, has experienced a notable reduction in greenhouse gas emissions over the years. Despite the carbon tax rate rising significantly – by 160.58% since its inception – GHG emissions have continuously decreased. In 2015, an increase in the carbon tax to USD 18.58 led to a 12.64% reduction in emissions. These trends highlight the effectiveness of carbon taxation in mitigating climate change impacts.

Table 6 shows a significant negative correlation between carbon tax and greenhouse gas emissions in Slovenia from 1996 to 2019, indicating that higher carbon taxes are associated with reduced emissions. This result, significant at the 5% level, underscores the effectiveness of Slovenia's carbon tax in curbing greenhouse gases. The findings support the adoption of similar measures to promote sustainability and can be valuable for stakeholders and researchers studying carbon tax effectiveness.

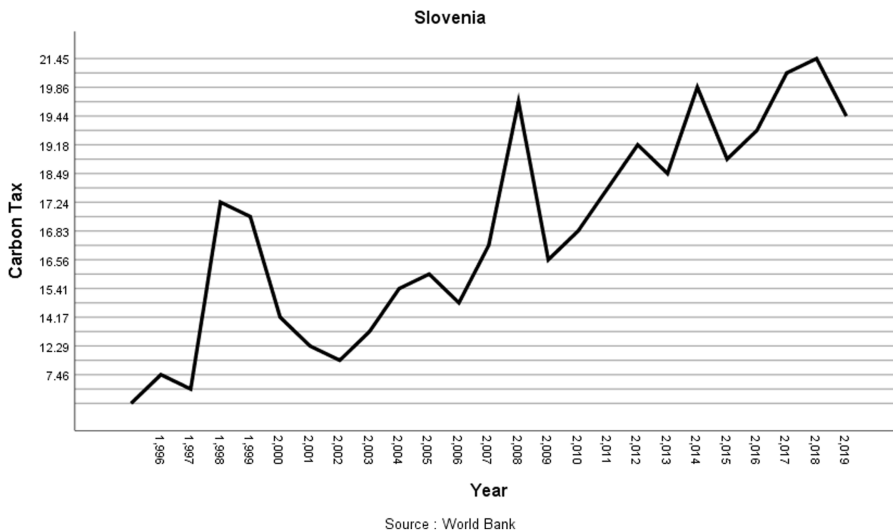
The study reveals that carbon taxes significantly reduced GHG emissions in Finland, Sweden, Slovenia, and Denmark, aligning with Progressive and Pigouvian Tax Theories. Progressive Tax Theory suggests that higher emissions or income should incur higher taxes,

Table 5. Correlation

|                                                                       |                     | Greenhouse Emissions |
|-----------------------------------------------------------------------|---------------------|----------------------|
| Carbon Tax                                                            | Pearson Correlation | $-0.814^{***}$       |
|                                                                       | Sig. (two-tailed)   | 0.000                |
|                                                                       | N                   | 29                   |
| Note(s): ***Correlation is Significant at the 0.01 Level (two-tailed) |                     |                      |



**Figure 9.** Greenhouse gas emission in Slovenia



**Figure 10.** Carbon tax in Slovenia

motivating reductions in emissions. This supports the effectiveness of carbon taxes in driving environmental improvements (Musgrave & Musgrave, 1959; Metcalf & Weisbach, 2009). Similarly, Pigouvian Tax Theory supports imposing taxes that match the external costs of pollution, aiming to internalize environmental damage and promote emission reductions (Pigou, 1920).

The study supports the effectiveness of carbon taxes in reducing GHG emissions, aligning with Progressive and Pigouvian Tax Theories. Most countries saw emissions decrease, but Norway's unexpected positive correlation suggests specific national policies or exemptions

Table 6. Correlation

|            |                     | Greenhouse Emissions |
|------------|---------------------|----------------------|
| Carbon Tax | Pearson Correlation | −0.413**             |
|            | Sig. (two-tailed)   | 0.045                |
|            | N                   | 24                   |

Note(s): \*\*Correlation is Significant at the 0.05 Level (two-tailed)

may impact effectiveness. Further analysis is needed to understand these anomalies (Nordhaus, 1992; Weyant, 1999). The research confirms that well-designed carbon taxes effectively reduce GHG emissions and mitigate climate change. It emphasizes the need for balanced policies that integrate both environmental and economic considerations to maximize their impact.

5. Finding and conclusion

The study confirms that carbon taxes have significantly reduced greenhouse gas emissions in Finland, Sweden, Slovenia and Denmark, aligning with prior literature. However, Norway’s case shows a positive but not statistically significant correlation, suggesting potential issues like industry exemptions that may affect tax effectiveness. The research highlights the importance of balancing business protection with environmental goals to enhance carbon tax policies. Using Karl Pearson’s correlation and the Phillips-Perron Unit Root Test, the study found significant negative correlations between carbon tax rates and emissions in most countries, indicating the effectiveness of these taxes. Nevertheless, Norway’s unique situation underscores the need for further investigation into how specific national policies impact tax efficacy. Overall, while carbon taxes are generally effective, their success can vary depending on country-specific conditions and policy implementation.

6. Implications and Suggestions

Carbon taxes can significantly reduce greenhouse gas emissions and promote renewable energy, despite potential financial burdens. Finland’s successful model offers valuable insights for developing nations, while Norway’s example underscores the need for eliminating environmentally harmful practices and supporting renewable energy. Early adopters of carbon taxes provide a useful benchmark for others, emphasizing the importance of global cooperation in transitioning to sustainable energy sources. The research recommends enhancing carbon tax policies by incentivizing renewable energy investments through tax credits, grants and low-interest loans for advanced technologies. Allocating carbon tax revenues to renewable energy projects can create a self-reinforcing system that reduces emissions and supports green infrastructure. Additionally, targeted tax rebates for high-efficiency projects, including smart grid technologies and energy storage, are advised to optimize carbon reduction.

The study highlights the importance of public-private partnerships (PPPs) in scaling renewable energy, especially in developing regions, and recommends government support through clear guidelines and risk-sharing mechanisms. It advocates for a dynamic carbon tax system that adjusts rates based on real-time data and suggests educational campaigns to enhance understanding and support for renewable energy and carbon taxes. These measures aim to turn research findings into effective policies for carbon reduction and sustainable development.

## 7. Limitations of the study

This study has a few limitations. Access to data is the major issue due to the inconsistencies in reporting greenhouse gas emissions, carbon tax rates and economic indicators. Variations in regional and sectoral impacts of carbon taxes within a country have been overlooked. External factors like technological advancements, which can affect the result, have not been included in this study due to the unavailability of such data.

## 8. Future Research Directions

Future research can focus on analyzing industry-specific responses to the carbon tax implementation. Comparative studies of different regional taxation models can identify success factors in a country. Exploration of the role of technological innovation, if data is available in the future, can help the policymaker in the better implementation of such policies. Integrating insights from other environmental policies will help in creating a cohesive policy framework. These approaches will enhance current research and improve climate change mitigation strategies.

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