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Analysis of The Effect of Carbon Tax on Fossil Fuels And Renewable Energy In European Countries In The Period 1996 – 2022

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Abstract. This study aims to analyze the impact of carbon tax implementation on fossil fuel consumption and renewable energy development in European countries over the period 1996-2022. The increasing use of fossil fuels has become a global issue as their carbon emissions trigger climate change and other negative impacts. As a solution, renewable energy is seen as a cleaner and more environmentally friendly alternative. A carbon tax is implemented as one policy to encourage the transition to renewable energy by imposing a surcharge on fossil fuels based on the amount of carbon emissions produced. This study uses panel data to measure the effect of carbon tax on fossil fuel consumption and renewable energy use in European countries in the period 1996 - 2022. The results of the analysis show that the implementation of carbon tax has no significant effect on fossil fuel use but can increase the use of renewable energy in the sample countries. The findings provide important insights for Indonesian policymakers in designing carbon tax policies to support a more sustainable energy transformation.

Keywords: Carbon Tax, Fossil Fuels, Renewable Energy, Environmental Tax

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Introduction

The increase in the use of fossil fuels is a global issue because the excess carbon emissions produced can trigger climate change globally (Hou et al., 2023). The rapid increase in fossil fuel consumption began with the first Industrial Revolution in 1760-1850 (Ritchie et al., 2023). At that time, fossil fuels became a major component in economic activity for the first time that led to prosperity for mankind (Pirani, 2020). Although its reserves are limited in nature, the use of fossil fuels continues to increase to date. Environmentalists advise minimizing the use of fossil fuels because of their adverse impact on nature, regardless of whether or not the fuel reserves are depleted(Abas et al., 2015).

In 2022, the result of burning fossil fuels produced 37.15 billion tons of CO2, which makes it the largest contributor to greenhouse gas emissions with a proportion of 75.01% (Ritchie et al., 2023). Growth in CO_2 concentrationThis rapid global has the potential to trigger climate change and sea level rise, which not only poses a threat to marine life but also affects human activities and survival (Qin et al., 2018). Climate change has resulted in a variety of serious threats such as increased frequency of natural disasters, ecosystem damage, disruption of food production, reduction in the quality and availability of clean water. as well as extreme heat waves and winters, all of which have an impact on human survival (Malihah, 2022).

Given the serious impact of fossil fuels that can cause environmental damage, the transformation to renewable energy is a crucial need. Renewable energy is seen as a sustainable, stable, clean, environmentally friendly, and efficient energy source that can reduce and neutralize global carbon (Sayed et al., 2021). Unlike fossil fuels that damage the environment, renewable energy does not produce harmful emissions and also offers long-term solutions that are renewable and do not damage the ecosystem (Ritchie et al., 2024). Therefore, the government needs to adopt various policies to encourage the use of renewable energy.

The use of carbon tax policies by the government is one of the key steps in supporting the transition to renewable energy by providing encouragement for encouraging industries to Immediately immediately use more environmentally friendly energy sources (Van Der Ploeg & Withagen, 2014). A carbon tax is imposed on fossil fuels based on the amount of carbon dioxide they produce (Brown, 2023). This tax will be collected from fuel suppliers, and the cost will be passed on to consumers in the form of price increases. electricity, gasoline, heating oil, and related goods and services (Parry, 2021).

Various studies have been conducted to assess the effectiveness of carbon tax policies. Results of the analysis (ESRI et al., 2019) shows that the combination of the elimination of fossil fuel subsidies with an increase in carbon taxes in Ireland could increase emissions reductions to 18.4%. Hájek et al., (2020) conducting research in five countries in the European Union revealed that an increase in the carbon tax rate of one Euro per ton can produce a relative impact in the form of a reduction in per capita greenhouse gas emissions of 11.58 kilograms per year.

Previous research on carbon taxes has tended to focus on their effectiveness in reducing carbon emissions. However, there have not been many studies that comprehensively examine the impact on changes in energy consumption patterns. Therefore, this study will bridge the knowledge gap by identifying how carbon taxes affect fossil fuel and renewable energy consumption in European countries in the period 1996–2022.

Literatur Review

Externality Theory

The formal study of externalities, or what is often referred to as the "spillover effect," was put forward by Alfred Marshall in 1890 and developed by Henry Sidgwick and Arthur C. Pigou (Boundreaux & Meiners, 2019). Externalities refer to the impact of economic activities that are not reflected in market prices, and this phenomenon arises when economic actors do not consider or are unable to force others to consider such external impacts in their decisions (Hayashi, 2021). In the face of this situation, government intervention through the implementation of subsidies and taxes is needed to narrow the gap between social and private costs, so as to correct market failures, and direct the allocation of resources towards more efficient conditions (Boundreaux & Meiners, 2019).

The Bator Classification integrates externalities into the theory of competitive equilibrium by identifying three types of market failures due to externalities, externalities of ownership which are unpaid factors of production, technical externalities, and externalities of public goods whose consumption by one person does not affect the consumption of others (Paniagua & Rayamajhee, 2023).

The Effect of Carbon Tax on Fossil Fuels

Negative externalities refer to the side effects or adverse impacts that economic activities have on other parties or the environment, without adequate compensation (Hayashi, 2021).

The intensive use of fossil fuels by industry gives rise to various negative externalities, especially in the form of carbon dioxide emissions that contribute significantly to global warming and climate change. This negative impact is not reflected in production costs, which are measured in *Private Marginal Cost (PMC)*. To address this problem, the government can implement a carbon tax, which functions as a *Marginal External Cost (MEC)* as an additional cost imposed on economic actors who use fossil fuels.

Based on the theory of negative externalities, the use of carbon tax as an MEC can make the price of fossil fuels more expensive so that it can reduce the quantity of production. This step directs the fossil fuel industry to a social optimum point, where the price of fossil fuels will not only become more expensive, but also reduce the amount of consumption and production.

H1: Carbon tax has a negative effect on fossil fuels

The Effect of Carbon Tax on Fossil Fuels

Positive externalities are activities that can provide benefits to others. External advantages arise as a result of these positive externalities, but those benefits are not reflected in market prices (Ratnawati, 2020).

The use of renewable energy by industry produces significant positive externalities, especially in the form of reducing greenhouse gas emissions and environmental sustainability. These benefits, while substantial, are often not recorded in the *Private Marginal Benefit (PMB)* received by the renewable energy industry. To maximize these benefits, the government can allocate carbon tax revenues obtained from the fossil fuel industry as corrective subsidies, which act as *Marginal External Benefit (MEB).*

Based on the theory of positive externality, when subsidies that act as MEBs are given to the renewable energy industry, it will lead the industry towards *social optimum*, this will reduce the price of renewable energy and increase the quantity of production. This step ensures that renewable energy is not only more affordable but also more widely produced. Thus, the use of carbon taxes that can make fossil fuels more expensive and the allocation of revenue from these taxes to subsidize renewable energy is an important strategy in supporting the transition to clean energy

H2: Carbon tax has a positive effect on renewable energy.

Research Methods

Data and Sample

This study aims to examine the long-term impact of carbon tax implementation, which is why the population selected consists of countries that were early adopters of this policy. Several European countries were pioneers in implementing carbon taxes, with Finland being the first in 1990, followed by Poland in the same year. Norway and Sweden adopted similar policies in 1991, followed by Denmark in 1992, and Slovenia in 1996. This study utilizes the Nonprobability Sampling method by applying a saturation sampling technique that includes all members of the population due to its relatively small size (Hikmawati, 2020). Saturated sampling was chosen because the study population only consists of six countries: Finland, Poland, Norway, Sweden, Denmark, and Slovenia.

The research period of 1996–2022 was selected because in 1996, for the first time, there were five countries that had already implemented carbon taxes. Meanwhile, 2022 was chosen as the end of the period because the latest data on fossil fuels and renewable energy is only available up to that year on the Our World In Data website. The selection of these countries allows for a comprehensive analysis of the long-term impact of carbon taxes on fossil fuel use and renewable energy transitions over an extended period.

Table 1. Sample Selection

Description	Observation Amount
Countries that have implemented a carbon tax in 1996-2022	6
Exclude: Missing data: CARBON TAX	(2)
Final observations	4

Variables Operationalization

In this study, the dependent variables consist of fossil fuel consumption and renewable energy consumption. Energy consumption is measured using *terawatt-hours (TWh)* which is equivalent to one *trillion watt-hours*. One *watt-hour* is equivalent to 3600 Joules of energy produced by one watt of power for one hour.

Carbon Tax is an independent variable in this study. Tax carbon is a government-set pricing mechanism that imposes a fee or tax on GHG emissions from the burning of fuels that cause global warming, including oil, gas, and coal (Iann Parry, 2023.). The tax is measured by the carbon tax rate based on every ton of carbon emissions produced (Omolere, 2024).

The choice of data source from Our World In Data is based on its reputation as a platform that provides global data with transparent methodologies and scientific research conducted by researchers at the University of Oxford, who are the main contributors of scientific content to the website. The platform also offers comprehensive and well-structured historical data, which is crucial for analyzing long-term trends, such as changes in the use of fossil fuels and renewable energy, which are the focus of this research

The World Bank was chosen as a data source for carbon taxes due to its high reputation for providing accurate and reliable global economic data. Additionally, World Bank offers very comprehensive data, including carbon tax revenues from all countries with a complete range of years, allowing for in-depth analysis of carbon tax policies across different countries.

Table 2. Variable Operationalization

Variable	Measurement	Source
Dependent variable		
Fossil Fuels (FF)	Coal + Natural Gas + Petroleum	Our World In Data
Renewable Energy (RE)	Hydropower + Tenaga Surya + Energi Angin + Bioenergi + Biofuel + Energi Panas Bumi	Our World In Data
Independent Variable		
Carbon Tax (CT)	Carbon x Ton Co2 Tax Rate	The World Bank

Empirical Models

This study utilizes panel data regression analysis to evaluate the effect of carbon tax on fossil fuel consumption, shown in equation 1, and the effect of carbon tax on renewable energy, shown in equation 2.

$$FF = a + \beta 1PK + \varepsilon \quad (1)$$

$$RE = a + \beta 1PK + \varepsilon \quad (2)$$

Results and Discussions

Descriptive Statistics

Table 3. Descriptive Statistics

	FF	RE	CT
Mean	1.565	5.821	1.187
Median	1.675	4.122	9.129
Maximum	2.835	1.554	4.323
Minimum	4.547	2.080	1.368

The results of descriptive statistical analysis show that the country with the lowest fossil fuel is Slovenia, which occurred in 2020 with a total of 45.47 TWh. Meanwhile, the highest value reached 283.55 TWh found in Denmark in 1996. The country with the lowest renewable energy is Denmark, which occurred in 1996 with a total of 2.08 TWh. Meanwhile, the highest value reached 155.46 TWh in Norway in 2007. The country with the lowest carbon tax is Slovenia, which occurred in 1997 with an amount of 13.68 million dollars. Meanwhile, the highest value reached 4,323.29 million dollars found in Sweden in 2010.

Classical Assumption Test

Table 4. Classical Assumption Test

	Autokorelasi Test	Heteroscedacity Test	Normality Test
	Breusch-Godfrey Test	Glejser Test	Jarque-Bera Test
Equation 1	0.6239	0.9366	0.121591
Equation 2	0.753	0.4080	0.196012

The classical assumption test in this study does not use a multicollinearity test because equations 1 and 2 only use one independent variable, namely the carbon tax. Based on table 4, the results of the autocorrelation, heteroscedasticity, and normality tests showed that the significance values in each test were more than 0.05, so that the models in equations 1 and 2 passed the classical assumption test.

Panel Data Regression Model Selection

Table 5. Regression Model Selection Test

Test	Prob.	Equation 1	Equation 2
Chow Test	cross-section F	0,0000	0,0000
Hausman Test	cross section random	0,0000	0,0641
LM Test	cross section Breusch –pagan	-	0,0000

Based on the regression model selection test in table 5, the probability value of equation 1 in the Chow test and the Hausman test is 0.0000 < 0.05, so the model chosen for equation 1 is the Fixed Effect Model. For equation 2, the probability value in the Chow test is 0.0000 < 0.05, while in the Hausman test it is 0.0641 > 0.05. Because there are differences in the two tests, the LM test is carried out as a follow-up test to choose the CEM and REM models. In the LM test, it can be seen that the value of Breusch's cross section – pagan equation 2 is 0.0000 < 0.05, so the most suitable model is the Random Effect Model.

Panel Data Linear Regression

Based on the regression equation estimation model selection test in table 5, the model chosen for equation 1 is the Fixed Effect Model and equation 2 is the Random Effect Model.

Table 6. Panel Data Regression – Equation 1

Fixed Effect Model			
Variable	Coefficient	t-Statistic	Prob.
C	153.1537	3.641825	0.0004
HP	0.528486	0.080143	0.9363
R-squared		0.822274	
S.E. of regression		29.69683	
S.D. dependent var		69.11.326	

Based on table 6, a regression line is obtained which can be formulated as follows:

BBF = 153,1537 + 0,528486PK + 6,594263

The regression equation above shows that the value of the α constant is 153.1537, which indicates that if the Carbon Tax (PK) variable is considered constant, then the value of Fossil Fuel (BBF) will be 153.1537. The PK regression coefficient of 0.528486 indicates that every increase of one unit in the carbon tax variable will cause an increase of 0.528486 in the fossil fuel variable, assuming the other independent variables remain constant.

Table 6 shows that carbon tax does not have a significant effect on fossil fuels, this is because the significance value in table 6 is 0.9363 > 0.05, so this hypothesis is not supported empirically, so it is concluded that carbon tax does not have a negative effect on fossil fuels, so the H1 hypothesis is rejected.

Table 7. Panel Data Regression – Equation 2

Random Effect Model			
Variable	Coefficient	t-Statistic	Prob.
C	2.155973	2.933113	0.0041
HP	0.528486	2.189023	0.0308
R-squared		0.042323	
S.E. of regression		0.375863	
S.D. dependent var		0.382280	

Based on table 7, a regression line is obtained which can be formulated as follows:

ET = 2,15973 + 0,176295PK + 0,080536

The regression equation above shows that the value of the α constant is 2.15973, which indicates that if the Carbon Tax (PK) variable is considered constant, then the value of Renewable Energy (ET) will be 2.15973. The PK regression coefficient of 0.176295 indicates that every increase of one unit in the carbon tax variable will lead to an increase of 0.176295 in the renewable energy variable, assuming the other independent variables remain constant.

Table 7 shows that carbon tax has a significant effect on renewable energy with the significance value in table 4.17 being 0.0308 < 0.05, so it is concluded that carbon tax has a positive effect on renewable energy, so the H2 hypothesis is accepted.

The t-test in this study showed that carbon taxes had no effect on fossil fuels, so H1 which stated "carbon taxes have a negative effect on fossil fuels" was rejected. Based on the theory of negative externalities, the implementation of a carbon tax as a Marginal External Cost (MEC) will increase the price of fossil fuels and reduce the quantity of their production. However, in this study, the carbon tax was not able to reduce the quantity of fossil fuels in 4 sample countries, namely Denmark, Sweden, Slovenia, and Norway. This indicates that carbon taxes may not be implemented at a significant enough level to encourage behavioural change among both producers and consumers.

In some sectors in the four countries, the high dependence on fossil fuels has led to their energy needs still having to be met by fossil fuels, despite carbon taxes. In addition, these countries still provide significant subsidies for fossil fuels, which could neutralize the effects of carbon taxes.

Another thing that causes the carbon tax to not be able to reduce the use of fossil fuels is because its application does not cover all fossil fuels. In Denmark, the carbon tax covers only 35% of all greenhouse gas emissions, in Sweden 40%, in Slovenia 52%, and in Norway 63% (Mengden, 2023). This limited coverage means that most fossil fuels are not subject to a carbon tax, thus reducing the incentive to lower overall fossil fuel consumption. However, keep in mind that the more complex a tax system is, the more dishonest it is in tax reporting, which can reduce the effectiveness of carbon taxes (Airawaty & Widarjo, 2021)

The results of the t-test show that renewable energy has a positive influence on fossil fuels, so H1 stating that "carbon tax has a positive effect on renewable energy" was accepted. This is in line with the theory of positive externality, where the government can collect carbon tax revenues obtained from the fossil fuel industry as corrective subsidies, which act as Marginal External Benefit (MEB). Based on the theory of positive externalities, when subsidies that act as MEBs are given to the renewable energy industry, it will direct the industry towards *Social Optimum*. This will lower the price of renewable energy and increase the quantity of its production. The results of this study are also in line with the research (Ghazouani et al., 2021) which revealed that environmental regulations, taxes, and energy-related policies can be an effective tool to increase the use of renewable energy.

Conclusion

The carbon tax had no effect on fossil fuel use in the sample countries (Denmark, Slovenia, Norway, and Sweden) during the period 1996-2022. This is due to dependence on fossil fuels in some sectors, the implementation of a carbon tax that does not cover all types of fossil fuels, and the provision of subsidies on fossil fuels.

Carbon taxes had a positive effect on the use of smelly energy in four sample countries (Denmark, Slovenia, Norway, and Sweden) during the period 1996-2022.

Suggestion

For countries that implement carbon taxes, several measures can be considered to increase the effectiveness of carbon tax policies. First, expanding the scope of the carbon tax to cover all types of fossil fuels and significant industrial sectors in greenhouse gas emissions will provide more equitable and effective incentives for the transition to renewable energy. Second, carbon tax revenues can be used to fund renewable energy infrastructure projects and clean technologies, thereby reducing dependence on fossil fuels. Third, countries can gradually reduce and phase out fossil fuel subsidies to increase the effectiveness of carbon taxes in encouraging the transition to clean energy. Finally, gradually increasing the price of carbon taxes can also provide stronger economic incentives for producers and consumers to reduce the use of fossil fuels

The sample in this study is only four countries and there are no control variables, so for future researchers it is recommended to expand the country sample, include relevant control variables such as economic development level, energy policy, and demographic factors, and consider the use of different analysis methods such as difference in difference, time series analysis or spatial analysis to provide more comprehensive insights.

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