

The role of energy taxes and renewable energy consumption in achieving carbon neutrality: case of Sweden

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Abstract :

The primary aim of this research is to investigate the role of energy tax reforms, renewable energy use, and economic growth in terms of carbon dioxide (CO₂) emissions for Sweden. Using yearly data from 1995–2023, we have estimated a nonlinear autoregressive distributed lag (NARDL) model.

The findings portray the role of positive energy consumption trends of renewable sources and taxation in mitigating the adverse impacts of economic activities and boosting growth that degrade the environment, particularly with the ongoing use of fossil fuels, which enhances environmental degradation. Thus, Sweden's new environmental policy calls for continuity above all, as well as support and promotion of renewable utilization of energy in the majority of activities, with extra taxation than the existing rate to lead economic agents' conduct maximally towards sustainable activities. This will allow it to reach its carbon neutrality target.

Keywords: Renewable energy; Energy tax; CO₂ emissions; (NARDL) model; Sweden.

Jel Classification: Q5; Q48; H23; C22; O52

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1. Introduction.

The world has seen a number of environmental and climatic changes in recent decades, including a rise in CO₂ and other greenhouse gas emissions. As a result, stringent measures pertaining to the economy have been adopted. This is because the main source of these changes has been shown to be the significant energy consumption from fossil fuels, which coincides with the acceleration of industrial activities intended to promote economic expansion (Pranay Arora, 2024).

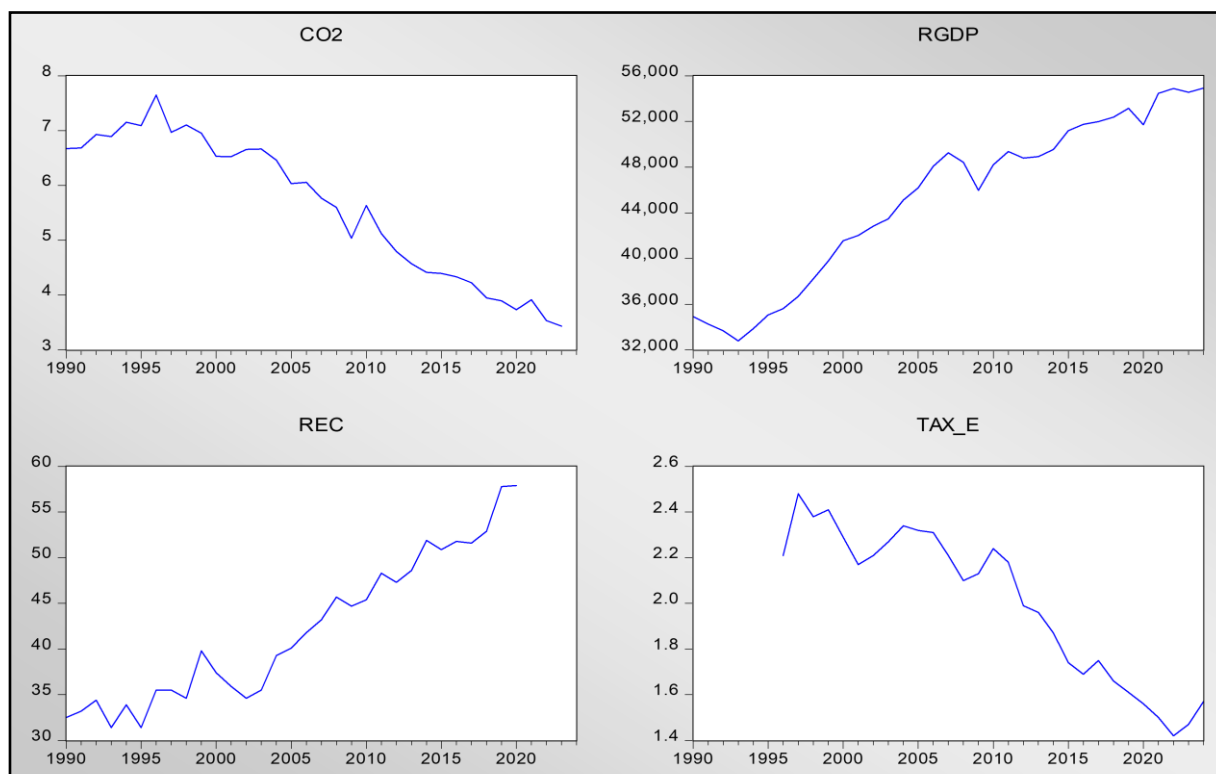
In order to achieve this and lessen the environmental harm, it was vital to create an economic, environmental, and energy policy that would allow nations to fulfill their environmental duties and commitments resulting from international conferences that emphasized the necessity of stepping up efforts to prevent environmental harm as much as possible. As a result (Leit.o, N.C., 2025), nations are focusing more on climate change and working to address sustainability's difficulties. Where are fiscal policy tools (such taxes) and renewable energy (energy transition) seen as the most important means of accomplishing the intended outcome?

Sweden has successfully reduced its greenhouse gas emissions by 85% from 1990 levels, in line with its goal of achieving net-zero emissions by 2045. Currently, Sweden's most emission-intensive sectors are industry and transportation, but between 2005 and 2023, these and other sectors recorded a reduction in emissions (buildings 80%, electricity and heating 54%, transport 37%, and industry 25%), which had a significant impact on Sweden's overall net emissions. These results were not random; rather, they were the outcome of a purposeful climate policy that sought to control the causes of environmental deterioration by employing efficient tools.

The exploitation of the energy industry was one of the most important of these tools. Low emissions characterize Sweden's existing energy system, and the country is actively working to lessen its dependency on fossil fuels. By 2040, it aims to produce all of its electricity from fossil-free sources. The integration of a wide range of emission-free energy sources will help achieve this goal. Promoting nuclear and renewable energy sources is the key objective of Sweden's energy policy. With wind energy making up a growing portion of the country's energy mix, hydropower and nuclear energy provide the majority of Sweden's electricity supply, making up 67.8% of the total (IEA, 2024). Additionally, environmental taxes particularly energy and carbon taxes have been crucial in lowering greenhouse gas emissions. For the past 30 years, these tariffs have served as the cornerstone of Sweden's environmental policy. The 1991 tax reform includes the introduction of the carbon tax. Since then, the fee has steadily risen, and in 2020, it will be 123€ per ton of fossil carbon. The carbon tax now covers around 40% of greenhouse gas emissions and focuses mostly on fossil fuels used for motor fuel and heating, such as gasoline, diesel, gas, and electricity (S. Åkerfeldt & H. Hammar, 2015). Carbon tax revenues increased steadily until 2004, which coincided with the gradual increase in the carbon tax rate in the early years of its implementation. The money collected from the carbon tax was used to reduce other taxes in order to offset any negative effects of the tax (S. Jonsson & al, 2020) ; Lower carbon emissions over the last ten years have resulted in lower revenues and lower environmental taxes. An estimated 2% of Sweden's overall tax revenue comes from energy taxes (S. Åkerfeldt & H. Hammar, 2015).

With per capita GDP (real value) rising by more than 50% between 1990 and 2019, the Swedish economy has maintained a steady rate of economic growth thanks to these policies intended to direct and filter economic activities and processes. Therefore, it has been able to establish the best balance between lowering emissions and attaining consistent economic growth through a low-carbon energy mix and modest taxation, which has been beneficial (S. Jonsson & al, 2020).

Figure 1: Distribution of CO2 emissions, GDP per capita, energy taxes, and renewable energy consumption in Sweden



Source: Eviews11 output.

This study explores the global and European experience of reducing emissions through strict environmental and economic regulations, leading to a rise in renewable energy and environmental taxes. Sweden has developed a low-carbon economy, achieving carbon neutrality while maintaining economic expansion. The study evaluates the effects of these changes using renewable energy and environmental taxes. It evaluates existing research on energy use, economic growth, and energy taxes, presents data and standard methods, discusses estimation results, and offers findings and suggestions. The study aims to provide a comprehensive understanding of the impact of these changes.

2. Review of theoretical and empirical literature.

The literature on environmental degradation explores various causative factors, including economic growth, fossil fuel consumption, and foreign investment. It also examines mitigating elements, such as environmental taxes and energy derived from renewable sources. This multidimensional discourse offers a comprehensive empirical and theoretical framework for understanding environmental degradation.

2.1. Economic growth and energy consumption as key determinants of CO2 emissions:

The Environmental Kuznets Curve (EKC) serves as the foundation for examining the interplay between economic activity and environmental quality. It posits that, at lower per capita income levels, environmental degradation occurs, but once a specific income threshold referred to as the turning point is achieved, environmental quality begins to improve. This relationship is characterized by an inverted U-shape, correlating pollution levels with economic growth.

The EKC framework also connects environmental quality to various influencing factors, including governance, trade, foreign direct investment, and a range of social, political, and economic variables.

(Adeolu O. Adewuyi, 2016)

Consequently, the Environmental Kuznets Curve (EKC) hypothesis posits that as economies progress to advanced stages of growth, there will be a heightened awareness and concern regarding

environmental issues. This growing concern leads to the establishment of environmental regulations and policies aimed at compliance, which are crucial for achieving sustainable development in line with international agendas. However, prior to reaching this advanced stage, economic activities are primarily responsible for environmental degradation. (Leit.o, N.C., 2025)

2.2. Renewable energy, environmental taxes, and their role in achieving carbon neutrality:

Currently, both renewable energy and environmental taxes are considered factors that help mitigate environmental degradation. The discussion about the need to consume low- or zero-emission energy stems from the fact that the energy sector was one of the primary contributors to the 89% increase (Y. Nassar & M. Khalee, 2024).

The COP 28 conference identified fossil fuels as the main cause of climate change, prompting the call for decarbonizing the energy system, emphasizing a transition away from fossil fuels (Pranay Arora, 2024). This shift is pivotal for establishing a modern, low-emission energy framework that can prevent further environmental damage from traditional energy reliance. To attain sustainable development goals, it is essential to promote energy transition in economies, ensure energy comes from clean and reliable sources, and focus on advancement and innovation within this sector (S. Oluklulu & S. Kasal, 2025).

Other key measures for mitigating environmental degradation include environmental taxes, which align economic and financial activities with ecological goals. Their primary aims are to improve climate risk management and to steer capital flows towards sustainable investments, thereby decreasing carbon intensity and expediting the shift to a low-carbon economy (P. D'Orazio & Anh-Duy Pham, 2025). Environmental taxes are considered among the most prominent factors adopted by most countries in their environmental policies. Environmental taxes come under various names, such as carbon taxes, energy taxes, transport taxes, and pollution taxes. These taxes aim to regulate and direct productive, consumptive, and investment economic activities towards an approach that protects the environment as much as possible (B. altay Topcu, 2023).

, It is expected to contribute positively to improving the situation. Perhaps the most prominent proposal currently being put forward is the introduction of a carbon tax with gradually increasing rates, so that its sustainable impact is reflected in stimulating innovation for the transition to a low-carbon economy (Y. W-Rufael & E. M-weldemeskel, 2022). However, their implementation can lead to "double dividend" effects: the 'green return' denotes environmental benefits from reduced emissions, whereas the 'blue return' highlights potential adverse impacts on economic growth, as increased production costs can undermine competitiveness and affect pricing, particularly for sectors heavily reliant on pollution-generating practices (Y, A. B., Dahmani, & Mabrouki, M, 2023).

2.3. Empirical studies.

Several studies have investigated environmental degradation, focusing on various contributing factors. Some researchers analyzed the relationship between economic growth, fossil fuel consumption, and degradation, identifying multiple other factors exacerbating environmental issues. Additionally, other studies assessed the potential positive effects of renewable energy consumption and governmental interventions, such as implementing taxes on activities harmful to the environment, as strategies aimed at fostering environmental protection.

Based on an evaluation of Kuznets' hypothesis, numerous research studies have attempted to validate it; the majority concur that it is valid in both developed and developing nations. According to studies (M. Ben Jebli et al, 2013) (J. P. Vallejo Mata et al, 2024) (E. dogan & F. seker, 2016), when economic growth reaches advanced stages and per capita income rises, changes in the structure of economic activity will take place that will improve the environment. In contrast, the resurgence of economic activity in the early stages of development particularly in heavy industries with significant energy consumption will worsen environmental degradation. As stated by (M, M Rahman & al, 2023), depending on the growth rate or threshold, the different effects of economic activity and the use of dirty energy continue to vary. Once this threshold is reached, economies try to incorporate clean

technology and other environmental protection strategies, like diversifying their energy sources and establishing stringent environmental regulations. On the other hand, along with economic growth, current research has placed a strong emphasis on the connection between taxes, renewable energy, and environmental damage. These elements have become powerful instruments for reducing the adverse impacts of economic activity. Their beneficial effects have been acknowledged by the majority of investigations (Yongfeng Zhu et al, 2023),(Y W-Rufael & E. M.-Weldemeskel, 2022).

demonstrating that in Latin America and the Caribbean, renewable energy and environmental taxes can both be useful instruments for enhancing environmental quality and lowering the use of non-renewable energy. supports this opinion (Buhari Dogan et al, 2022), as the G7 nations have demonstrated that enforcing stringent environmental regulations has led businesses to switch to cleaner production practices and increase their use of renewable energy. As a result, emissions in the countries under study decreased. It was suggested that tax income be redirected to sustainable technology research and development programs in order to boost the tax tool's efficacy. According to (Y, A. B., Dahmani, & Mabrouki, M, 2023), environmental taxes serve to encourage clean technology and activities while lowering emissions from polluting operations. As indicated by (D.Mehta & V. Derbeneva, 2024), taxes are an effective tool for combating polluting activities and contributing to reducing emissions. The solution lies in relying on this factor is achieve a balance between economic development and environmental sustainability. The solution lies in encouraging the use of cleaner alternative energy sources to achieve both goals. This viewpoint has also been supported by (O'Ryan R & al, 2023), who contend that environmental taxes and renewable energy sources have the power to change patterns of production and consumption, guide both domestic and foreign investment toward eco-friendly technologies, and lower carbon emissions. likewise, it shows that the existing level of environmental stringency is low in comparison to the levels needed to meet climate change targets (O'Ryan R & al, 2023) . He found that the more stringent environmental regulations, energy taxes, and transportation tariffs are, the more carbon dioxide emissions are reduced in his study, which covered 20 European nations. Therefore, it is anticipated that the benefits of environmental taxes will persuade decision-makers to raise them in the future.

This is particularly true in light of the fact that environmental taxation policies are crucial to preserving economic equilibrium and advancing sustainability in EU member states. (Buket Savranlar & al, 2024). Similarly, the EU experience demonstrates how green taxes have encouraged the adoption of environmentally friendly technology, demonstrating the efficacy of these taxes in accomplishing emissions reduction objectives (Koval, V., & al, 2022).

Even if earlier research highlights the benefits of environmental fees, economic activity may be adversely affected. Despite lowering carbon dioxide emissions, (E, D, Gemechu & al , 2013) demonstrated that it has had adverse effects on industries with comparatively low environmental footprints that are subject to environmental tax rates. This has led to an increase in production prices, which will eventually be reflected in the consumer price index for goods in those industries. Future rate increases could make it more challenging for nations to simultaneously meet their economic and environmental objectives. The report suggested using the money raised to compensate persons who were adversely impacted by the tax in order to resolve this. The report suggested using the money raised to compensate persons who were adversely impacted by the tax in order to resolve this. (Mürşit Recepoğlu, 2020) mentioned this effect. Environmental taxes have specific economic costs that, if they do not result in a decrease in output, will raise prices even when they aid in reducing environmental harm. Therefore, in addition to environmental regulations, governments need also undertake corresponding fiscal policies.

Based on the analysis of existing literature, the Kuznets hypothesis underscores the challenge of achieving economic growth while minimizing environmental pollution. It advocates for the integration of environmental considerations into economic development strategies, primarily through the phased elimination of polluting energy sources. Key components of an effective environmental policy include the promotion of renewable energy and the implementation of environmental taxes,

both of which are essential for balancing environmental sustainability with economic growth. However, the success of these initiatives is contingent upon various factors. The advancement of renewable energy relies heavily on robust research, innovation, financial investment, and international collaboration. Furthermore, environmental taxes have been shown to effectively reduce pollution if designed primarily for environmental protection, with proceeds earmarked for ecological purposes. Nonetheless, potential adverse effects must also be considered, necessitating comprehensive research and analysis during the formulation of environmental policies.

3. Data and methods of analysis.

3.1. Data.

We used annual data for Sweden for the period 1995–2023, relating to carbon dioxide emissions, measured in metric tons per capita, as an indicator of environmental degradation (the dependent variable) co_2 . The explanatory variables in the model were per capita gross domestic product (RGDP), energy taxes (% of GDP) (tax-e)—considered the most important environmental taxes, including the carbon tax—and the level of renewable energy consumption (REC) (% of total energy consumed). We obtained this data from the World Bank (<https://data.worldbank.org/>, 2025) and the Organization for Economic Co-operation and Development (OECD) (<https://data-explorer.oecd.org/>, 2025).

Table 1. Description and sources of data used in this study

Variable Symbols	Data description	Source
co2	CO 2 emissions per capita	EDGAR : https://edgar.jrc.ec.europa.eu/
RGDP	GDP per capita (constant 2015 US\$)	World Bank : https://data.worldbank.org/
REC	Renewable energy consumption (% of total final energy consumption)	World Bank : https://data.worldbank.org/
tax-e	Energy taxes as % of GDP	OECD : https://data-explorer.oecd.org/

Source: Authors construction

The relationship between emissions, domestic product, taxes and renewable energy can be expressed mathematically as follows:

$$co_2 = f(RGDP, REC, TAX - E) \quad (1)$$

1- Methodology

The NARDL methodology is one of the standard ways of dealing with the issue of non-linearity of economic relationships and the unevenness of effects in the long and short term. It is based primarily on the ARDL (autoregressive distributed lag) model developed by (Shin, Yongcheol & al, 2013); this methodology assesses the impact of both positive and negative shocks to independent variables (Sibusiso Khoza & Mduduzi Biyase, 2024, p. 6). If $B^+ \neq B^-$ —this means that, the long-term impact of negative changes on unity (x) differs from the positive impacts on unity (x) (Shin, Yongcheol & al, 2013) and is expressed as follows:

$$x_t^+ = \sum_{j=1}^t \Delta x_j^+ = \sum_{j=1}^t \max(\Delta x_j; 0); \quad x_t^- = \sum_{j=1}^t \Delta x_j^- = \sum_{j=1}^t \min(\Delta x_j; 0)$$

As with the ARDL model, the NARDL model is applied to variables that are constant at level or first difference $I(0)$, $I(1)$, or a combination thereof, provided that none of these variables are $I(2)$ (Hassan Chikri & al, 2021, p. 2). From the above, the following NARDL formula can be written:

$$\Delta y_t = \rho y_{t-1} + \theta^+ x_{t-1}^+ + \theta^- x_{t-2}^- + \sum_{j=1}^{p-1} \varphi_j \Delta y_{t-j} + \sum_{j=0}^{q-1} (\pi_j^+ \Delta x_{t-j}^+ + \pi_j^- \Delta x_{t-j}^-) + \varepsilon_t \quad (2)$$

The long-run parameters of the symmetric relationship are denoted by ρ, θ^+, θ^- , and the short-run asymmetric parameters are denoted by $(\pi_j^-; \pi_j^+, \varphi)$ respectively.

Similar to the ARDL approach, Shin et al. introduced a boundary test within the micro-concept of asymmetric cointegration in the nonlinear context of the NARDL model based on Shin and Smith (2001). The model is also subject to the same statistical criteria for determining model quality: functional form, CUSUM and CUSUMSQ tests to ensure the reliability and stability of the NARDL model, in addition to the WALD test for testing the symmetry and asymmetry of the effect under the null hypothesis $-\frac{\theta^+}{\rho} = -\frac{\theta^-}{\rho}$. For the long term, and $\sum_{j=0}^{q-1} \pi_j^+ = \sum_{j=0}^{q-1} \pi_j^-$ for short-term coefficients. (Le Hoang Phong & al, 2019, p. 8)

3. Results and discussion.

3.1. Statistics description and stationarity of variables.

Table 2 show descriptive statistics for the study variables.

Table 1. Descriptive statistics of the variables

	LCO2	LRGDP	LREC	LTAX E
Mean	1.693851	10.73902	3.778131	0.724913
Median	1.728387	10.78321	3.799974	0.779325
Maximum	2.034425	10.881	4.058717	0.908259
Minimum	1.317469	10.48024	3.543854	0.444686
Std. Dev.	0.217036	0.115541	0.166553	0.139211
Skewness	-0.22354	-0.81042	0.037309	-0.70889
Kurtosis	1.713884	2.592782	1.741256	2.148278
Jarque-Bera	1.931231	2.909304	1.656254	2.849483
Probability	0.380749	0.233482	0.436867	0.240571
Sum	42.34627	268.4754	94.45327	18.12283
Sum Sq. Dev.	1.130512	0.320395	0.665759	0.465116
Observations	25			

Source: Eviews11 output.

Using the augmented Dickey-Fuller test (ADF) and the Phillips & Perron test (PP), we determined the degree of stability of the variables included in the study. Based on the results shown in Table 2, we see that, except for CO2, which is integrated at level I0, the remaining variables, RGDP, REC, and TAX_E are stable at level I1. This result allows us to apply the NARDL model.

Table 2. ADF & PP Test Results

UNIT ROOT TEST TABLE (PP) : At Level				
Variable	CO2	RGDP	REC	TAX_E
t-Statistic	-3.454	-1.934	-2.8327	-1.518412
Prob.	0.0615	0.615	0.1974	0.1186
	*	n0	n0	n0
UNIT ROOT TEST TABLE (PP) : At First Difference				
Variable		d(RGDP)	d(REC)	d(TAX_E)
t-Statistic		-5.5089	-7.6954	-6.062183
Prob.		0.0001	0.0000	0.0000
		***	***	***
UNIT ROOT TEST TABLE (ADF): At Level				
Variable	CO2	RGDP	REC	TAX_E
t-Statistic	-3.2858	-1.8129	-2.9438	-1.988106
Prob.	0.0862	0.6763	0.1639	0.5814
	*	n0	n0	n0
UNIT ROOT TEST TABLE (ADF): At First Difference				
Variable		d(RGDP)	d(REC)	d(TAX_E)
t-Statistic		-5.4524	-2.6376	-5.187624
Prob.		0.0001	0.0996	0.0000

		***	*	***
Notes: (*)Significant at the 10%; (**)Significant at the 5%; (***) Significant at the 1%. and (no) Not Significant				

Source: Eviews11 output.

3.2. NARDL model estimation :

We will follow the approaches and findings of previous relevant studies in evaluating the factors that play a decisive role in climate change policies in Sweden. (B. altay Topcu, 2023) , (D.Mehta & V. Derbeneva, 2024), (Leit.o, N.C., 2025)

We will use the NARDL approach to evaluate the asymmetric effects of renewable energy and taxation, two factors that are thought to restrict environmental degradation. In order to prevent problems with data heteroskedasticity, we convert all variables to log form in addition to the impact of economic growth. Our NARDL model is written as follows:

$$\Delta lco2_t = \rho lco2_{t-1} + \theta_1 lrgdp + \theta_2^+ LREC_{t-1}^+ + \theta_3^+ LREC_{t-2}^+ + \theta_4^+ LTAX_{E,t-1}^+ + \theta_5^+ LTAX_{E,t-2}^+ + \sum_{j=1}^{p-1} \phi_j \Delta lco2_{t-j} + \sum_{j=1}^{q-1} \pi_1^+ \Delta lrgdp_{t-j} + \sum_{j=0}^{q-1} (\pi_j^+ \Delta LREC_{t-j}^+ + \sum_{j=0}^{q-1} (\pi_j^- \Delta LREC_{t-j}^- + \sum_{j=0}^{q-1} (\pi_j^+ \Delta LTAX_{E,t-j}^+ + \sum_{j=0}^{q-1} (\pi_j^- \Delta LTAX_{E,t-j}^- + \varepsilon_t \quad (3)$$

a. Diagnostic tests:

The results of the diagnostic tests reflect that the model is free from standard problems such as heteroscedasticity, functional form, and the Jarque-Bera test on normality, where the null hypothesis was rejected and the alternative hypothesis was accepted.

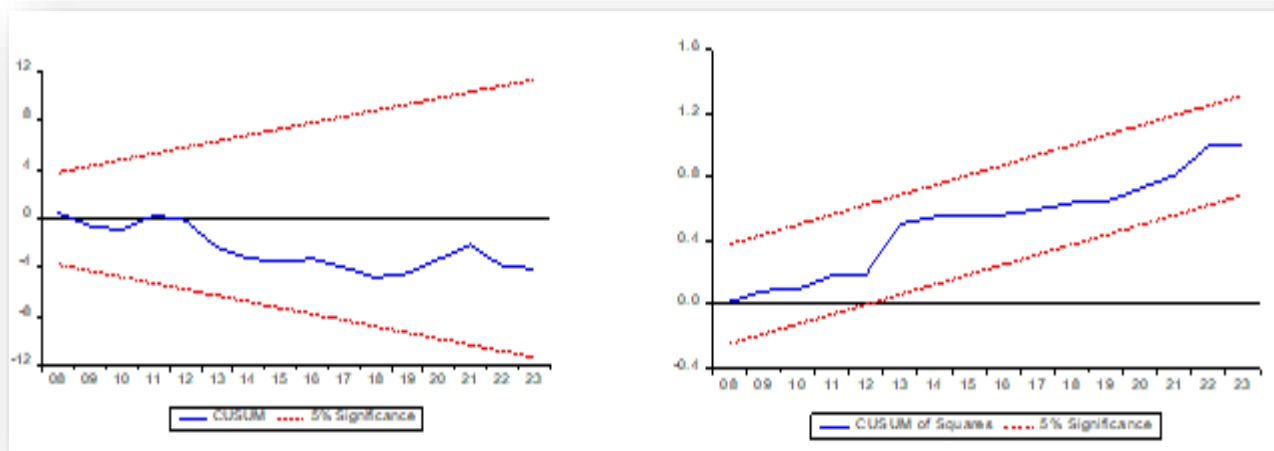
Table 3 Diagnostic result

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	1.193938	Prob. F(2,14)	0.3321
Obs*R-squared	3.788457	Prob. Chi-Square(2)	0.1504
Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	2.111588	Prob. F(10,15)	0.0926
Obs*R-squared	15.20143	Prob. Chi-Square(10)	0.1249
Scaled explained SS	3.854869	Prob. Chi-Square(10)	0.9537
Ramsey RESET Test			
	Value	Df	Probability
F-statistic	0.133427	(2, 14)	0.8762

Source: Eviews11 output

The CUSUM and CUSUMSQ tests also indicate that the model is stable at a significance level of 5%.

Figure 2. Plot of CUSUM and CUSUMSQ tests



Source: Eviews11 output

b. Cointegration test in the NARDL model

To determine the asymmetric joint integration between variables, using statistical values for the Bounds Test and comparing them with the upper and lower limits at different significance levels, the statistical values tBDM and Fpss showed a long-term non-linear relationship between CO2 emissions and explanatory variables: economic growth, energy taxes, and renewable energy consumption.

Table 4. Bounds Test

F-Bounds Test F_{pss}		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	25.04506	10%	1.81	2.93
k	5	5%	2.14	3.34
		2.50%	2.44	3.71
		1%	2.82	4.21
t-Bounds Test T_{BDM}		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
t-statistic	-7.9823	10%	-1.62	-3.49
		5%	-1.95	-3.83
		2.50%	-2.24	-4.12
		1%	-2.58	-4.44

Source: Eviews11 output

c. Long and short-term transaction analysis:

The estimation results presented in Table 5 illustrate the impacts of both positive and negative changes in energy taxes, renewable energy consumption, and economic growth over both the short and long term. The error correction coefficient of -0.90339 is statistically significant and negative, indicating a long-term equilibrium between the variables. This implies that approximately 90% of any deviation from the long-term equilibrium is correct within each period.

As for transactions, starting with the indicator that reflects economic growth, which is per capita GDP (RGDP), it has a positive impact in the short and long term, respectively (0.941286 and 0.200695). The result reflects an important part of Kuznets' hypothesis, which considers economic growth to be one of the factors that increase environmental degradation. It indicates that economic activities in Sweden are still positively correlated with emissions, as activities that consume fossil fuels will have a direct impact on emissions. However, in the long term, the impact will decrease, which points to the second part of the hypothesis, which states that achieving high growth rates will lead to a shift towards environmentally friendly activities. This is consistent with (B. altay Topcu, 2023) (Leit.o, N.C., 2025)(M.Ben Jebli et al, 2013)

About renewable energy consumption, its negative and positive changes in the long term have effects that reduce carbon dioxide emissions and thus improve environmental quality. A 1% increase and decrease in renewable energy consumption will lead to changes of 0.19763 and -0.36818, respectively. Although its impact is somewhat weak, this finding aligns with expectations; Therefore. The use of this energy will affect the behavioral approach towards the environment by economic agents, as it encourages the gradual abandonment of fossil fuels, which leads to emission reductions even when consumption decreases. which reflects the effectiveness and importance of this factor within the environmental policies currently in place and their consideration as key factors determining environmental sustainability. These results are consistent with the findings of (Leit.o, N.C., 2025)(Y. W-Rufael & E. M-weldemeskel, 2022)(Buhari Dogan et al, 2022).

As for energy taxes, estimates indicate that positive changes in these taxes have a statistically significant negative impact on emissions, with a 1% increase leading to a reduction in emissions (mitigation of environmental degradation) of (-1.39481). This effect is evident even in the short term, where the impact is estimated at -0.82344. This positive effect of taxes on the environment is greater than the effect of renewable energy consumption, and this result is consistent with (Y. W-Rufael & E. M-weldemeskel, 2022)) D.Mehta&V. Derbeneva(2024).

Conversely, a 1% decrease in energy taxes leads to a statistically significant increase in CO₂ emissions of 0.56723. This reflects that negative changes in tax rates can have an adverse environmental impact. (Leit.o, N.C., 2025) reducing taxes out of concerns about increased costs affecting economic activities and the competitiveness of local goods may result in a negative impact on the environment. These findings are supported by (Y. W-Rufael & E. M-weldemeskel, 2022)(D.Mehta & V. Derbeneva, 2024)

Since energy taxes have a significant and obvious impact on environmental quality by influencing the production and consumption behavior of individuals and institutions as well as by raising environmental awareness, their expected impact and both positive and negative changes suggest how this factor should be addressed. If environmental objectives are prioritized within the overall strategy, then these tax rates should be raised above their current levels.

This increase would facilitate a shift from environmentally harmful economic behaviors to more environmentally friendly practices, thereby enhancing the effectiveness of this policy tool in the transition toward a low-carbon economy (B. altay Topcu, 2023)(Buhari Dogan et al, 2022)

Table 5. Estimation of the long and short run coefficients in the NARDL model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LRGDP	0.200695	0.003532	56.82416	0.0000
LREC_POS	-0.19763	0.120335	-1.64236	0.12
LREC_NEG	-0.36818	0.110468	-3.3329	0.0042
LTAX_E_POS	-1.39481	0.373838	-3.73105	0.0018
LTAX_E_NEG	0.567229	0.079555	7.13	0.0000
ECM Regression				
Case 1: No Constant and No Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LRGDP)	0.941286	0.144684	6.505823	0.0000
D(LREC_NEG)	0.330302	0.197446	1.672869	0.1138
D(LTAX_E_POS)	-0.82344	0.192508	-4.27744	0.0006
D(LTAX_E_POS(-1))	1.230929	0.240715	5.113639	0.0001
CointEq(-1)*	-0.90339	0.064326	-14.0439	0.0000

Source: Eviews11 output

d. Asymmetry in the NARDL model

The asymmetry test and the Wald test, according to the F statistic and Prop values, indicate that for negative and positive changes in renewable energy in the long term, their effect is symmetrical on environmental degradation at a significance level of 5%. This differs for the energy tax variable, where in the long term, the effects of the changes are asymmetric, i.e., the increasing and decreasing effects are not symmetrical. This confirms that tax reductions may lead to negative effects, which may hinder the performance of environmental policy in Sweden, and that raising energy taxes above the current level will improve the quality of the environment.

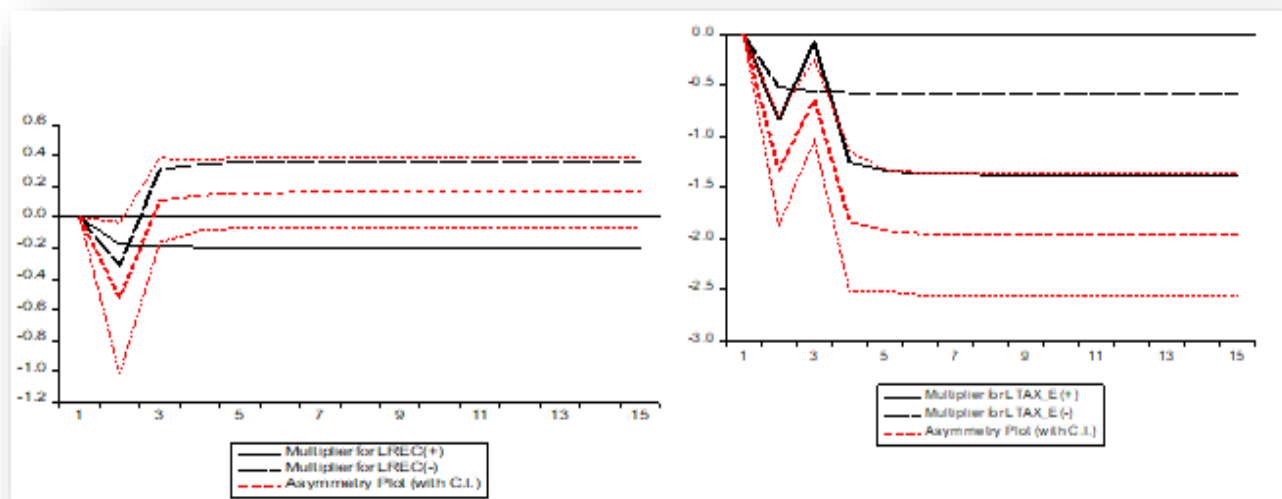
Table6. Asymmetry test and Wald test

Exog.var.	Long-run effect [+]			Long-run effect [-]		
	Coefficient	- F-stat	PROP	Coefficient	- F-stat	PROP
REC	-0.150281	-0.17853	0.2528	-0.368667	5.805407	0.0276
TAX E	-1.223370	13.83886	0.0017	0.526432	25.65777	0.0001
Wald Test : Long-run asymmetry						
	F-stat			Prob		
REC	1.465131			0.2427		
TAX E	25.36846			0.0001		

Source: Eviews11 output

The dynamic multiplier reflects the amount of change in the emissions volume variable resulting from a 1% positive and negative shock change in renewable energy and energy taxes, and their long-term equilibrium during the study period.

Figure3. The asymmetric dynamic relationships between the variables.



Source: Eviews11 output

The negative response to the dynamic multiplier indicates a positive shock to energy taxes (tax increase) and a negative shock (tax decrease), respectively. To varying degrees, the effect is asymmetrical, with the reaction to the positive shock being greater than the reaction to the negative shock, confirming that continuing to reduce energy taxes in Sweden compared to raising energy taxes will hurt the quality of the environment and the important progress that has been achieved.

As for renewable energy, a negative shock will lead to an immediate reduction in emissions, and within period 3, its impact will be positive. Conversely, a positive shock (increased consumption of renewable energy) will lead to a significant and sustained reduction in emissions during the period, supporting the hypothesis that the use of this energy should be promoted.

4. Conclusion.

As part of the European Union's strategy to mitigate greenhouse gas emissions, countries like Sweden have implemented successful environmental policies that promote economic growth while minimizing ecological degradation. Central to these strategies is the integration of renewable energy sources into the overall energy mix, achieving over 50% reliance for various activities, alongside the introduction of carbon taxes and other fossil fuel taxes. This research paper examines the influence of these key environmental policy components in Sweden, focusing on their role in fostering economic stability and achieving carbon neutrality. Utilizing the NARDL model, the study spans from 1995 to 2023 and assesses the relationship between economic growth and emissions. The analysis highlights both positive and negative changes in renewable energy adoption and the effects of energy taxation. The findings indicate that increases in renewable energy and favorable adjustments in energy taxation significantly contribute to emission reductions, serving to mitigate the adverse impacts of economic activities on the environment. Consequently, these factors are pivotal for Sweden's successful environmental policy, enabling a balance between carbon neutrality and economic advancement within a sustainable development framework.

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