

Industrial Carbon Emissions, renewable energy and Environmental Tax Revenue in China: A Bootstrap Quantile Regression Analysis.

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Abstract:

This study examines how environmental tax revenue, renewable energy use, and GDP growth affect industrial CO₂ emissions in China from 1995 to 2021. It uses bootstrap quantile regression at the 0.25, 0.50, and 0.75 levels. Environmental tax revenue shows a significant negative effect at median and upper quantiles. However, its impact is insignificant at the lower quantile. Renewable energy consumption reduces emissions consistently across all quantiles. GDP growth also has a negative effect on emissions in every quantile. Overall, both renewable energy and economic growth contribute to lowering emissions.

Keywords: Carbon Dioxide Emissions; Renewable energy; environmental tax; Quantile.

Jel Classification Codes: Q53, Q42, H23

1. INTRODUCTION

As the world community confronts the urgent task of attaining a zero-carbon future and restricting global warming to 1.5 °C, it is clear that swift, extensive, and revolutionary alterations across various sectors are necessary. Interconnected systems—comprising energy, technology, urbanization, finance, and economic development—are indispensable (qamruzzaman,2025). In 2015, the United Nations established 17 Sustainable Development Goals to combat climate change. Sustainable Development Goal 13 encompasses the objective of climate action: Adjusting to climate change and investing in low-carbon development (Hornberger and adams, 2022).

Climate change represents the most significant failure of the market economy and

Carbon emissions represent a substantial environmental hazard and an economic liability for all nations. It is anticipated that a worldwide GDP decline of 5% would ensue if greenhouse gas (GHG) reduction is not implemented. Consequently, both developed and developing nations should prioritize green growth policies by emphasizing green initiatives and low-carbon technologies (dhayal et al, 2025). Achieving these aims requires modifying developmental trajectories. Despite global agreement on reducing greenhouse gas emissions, national climate change initiatives are not implemented with adequate urgency (Caetano et al, 2020). Carbon dioxide emissions are the principal source of pollution. A burgeoning consensus has emerged among leading nations, environmental professionals, and legislators to establish new regulations and policy frameworks to address the environmental challenges posed by climate change (Doğan et al, 2022).

Many studies have been conducted to examine the impact of environmental tax revenue, renewable energy on carbon dioxide emissions in China and in other regions. Generally, greater environmental taxes correlate with decreases in CO₂ emissions, although effectiveness may differ by geography and policy design. Studies on G7 and European nations indicate that environmental taxes, particularly when revenues are augmented or tax rates are intensified, effectively diminish CO₂ emissions and promote cleaner production techniques, reinforcing the notion that environmental tax revenue can serve as a mechanism for climate mitigation (Wolde - Rufae et al. 2022; Aydın and Esen, 2018; Wang et al. 2023).

However, in many OECD countries, environmental taxes (as a share of total tax or GDP) are generally linked to lower emissions, but this is not always the case. Overall, environmental tax revenues often correlate with reduced CO₂ emissions, yet this relationship is shaped by policy design, regional economic conditions, and how funds are allocated—for example, to green technologies or research and development (Koval et al. 2022; Tang et al. 2024). This discrepancy in empirical results highlights the necessity for further investigation that includes other explanatory variables and

various econometric and theoretical models to accurately identify the factors influencing carbon emissions from industrial activities.

Furthermore, recent studies have examined the influence of ETR and REC on CO₂ emissions, rather than CDE, in a singular significant emitter like China. Prior studies have predominantly examined environmental taxes or renewable energy independently, providing little evidence on their joint impact on industrial emissions. Furthermore, the majority of current analyses depend on mean-based methodologies, neglecting the heterogeneity within the emissions distribution; thus, it remains ambiguous whether environmental tax revenue and renewable energy exert identical effects across low-medium-, and high-emission regimes.

The main objective of this study is to examine the impact of environmental tax revenue (ETR), renewable energy consumption as a part of total energy (REC) and gross domestic product growth (GDPG) on carbon dioxide emissions (CDE) in China for the period 1995- 2021, relying on bootstrap quantile regression. The structure of this paper is as follows; in addition to this introduction, the second part of the paper is the literature review, followed by the methodology section, the fourth section is the results of the study, and the last sections are the discussion and the conclusion.

2. Literature Review

This section reviews and summarizes studies on the nexus between carbon dioxide emissions and green finance through its components and mechanisms, such as environmental taxes. Additionally, the section shows the effect of renewable energy consumption on the carbon intensity.

There have been extensive empirical studies on the impact of ETR on CDE for example, (Al Shammre, 2023) conducted a study to examine the influence of various environmental tax categories on CO₂ emissions in 34 OECD countries for the period 1995-2019. The results indicated that all environmental tax categories reduce CO₂ emissions. Using a dynamic panel threshold regression (Aydin and Esen, 2018) inspected the influence of environmentally related taxes on carbon dioxide in the EU member states between 1995 and 2023. The results confirmed the asymmetrical

relationships and revealed that after exceeding the threshold level, the effect of becomes negative. (Mehta and Prajapati, 2024) investigated the effects of environmental tax and environmental spending on CO₂ emissions in 27 countries of the EU27 between 1995 and 2022. Using ARDL and NARDL models, the study revealed a symmetric and asymmetric long-term relationship, proving that CO₂ emissions are reduced when polluting activities are taxed. Another study of (Nudrat et al. 2023) employed PMG model to test the nexus between environmental-related technologies and ETR in 36 OECD countries spanning from 1990 to 2020. The empirical results demonstrated environmental-related tax revenues help in reducing CO₂ emissions.

It is noticeable that the majority of studies indicated that increased environmental tax revenue correlates with reduced CO₂ emissions; but, a minority of studies discovered scenarios where a positive correlation occurs, suggesting that as environmental tax money rises, CO₂ emissions also increase. This generally transpires in nations or eras when environmental taxes lack sufficient rigor to alter polluting conduct, or where tax augmentations are predominantly fiscal rather than environmentally motivated (Máté et al. 2023; Ebaidalla, 2023; Tang and Qin, 2024)

On the other hand, numerous authors examined the impact of environmental taxes on the carbon intensity over many countries and regions locally and globally. For example, Zhang et al. (2023) highlighted how environmental taxes affect environmental innovation and carbon intensity in China using the Quantile Autoregressive Distributed Lag (QARDL) model. Based on national data, the study demonstrated that higher environmental taxes significantly promote environmental innovation and reduce carbon intensity in both the short and long run. The study also showed the positive role of fiscal policy instruments in driving green technological advancement and carbon reduction, supporting China's path toward carbon neutrality. Furthermore, Zhong et al. (2024) investigated the impact of Environmental Protection Tax on carbon intensity using data from 282 Chinese cities and a difference-in-differences model. The study found that Environmental Protection Tax implementation reduced carbon intensity, mainly through

lower pollutant emissions and enhanced green innovation.

Overall, Environmental taxes are exposed to decrease carbon intensity by incentivizing cleaner production and consumption, especially when revenues are recycled into green R&D or renewable energy subsidies. The efficiency of environmental taxes is enhanced when combined with green finance and innovation policies (Sarpong et al. 2023; Bashir et al. 2020; Chien et al. 2021; Kafeel et al. 2023).

Likewise, numerous studies have surveyed the impact of renewable energy consumption on carbon intensity of GDP. Most of the studies confirmed the role of renewable energy consumption in reducing carbon intensity, for instance, (Ren et al. 2020; Sun et al. 2023; Rasoulinezhad & Taghizadeh-Hesary, 2022; Hao et al. 2020; Wu et al. 2023; Chen et al (2024); Zhu et al. 2024).

Research on the effect of GDP growth on CDE generally showed a positive relationship, meaning that an increase in GDPG consequently leads to an increase in (CDE) for example (Zheng et al. 2019, Wu et al. 2019; Du et al. 2022). While some regions and times show "weak decoupling" (emissions climb slower than GDP), significant negative relationships—where GDP grows and CO₂ emissions fall—are rare and mainly limited to specific industries or short periods. Due to its substantial use of fossil fuels, the secondary (industrial) sector still emits a lot, but the service sector has grown and advanced technologically. Long-term, environmental concerns and policy interventions may strengthen the negative relationship between GDP growth and CO₂ emissions, suggesting that sustainable economic growth without increased emissions is possible but not yet fully realized across all regions and sectors in China (Yang et al. 2021; Zou & Chau, 2023).

3. Data and Methodology

The aim of this study is to assess the effect of environmental tax revenue (ETR), renewable energy consumption (REC), gross domestic product growth (GDPG) on carbon dioxide emissions (CDE) in China for the period from 1995 to 2021. Equation (1) demonstrates the model used in the empirical analysis:

$$CDE = \beta_0 + \beta_1 ETR_t + \beta_2 REC_t + \beta_3 GDPG_t + \varepsilon_t \quad (1)$$

In this specification, CDE_t denotes industrial carbon emissions at time t , ETR_t is environmental tax revenue, REC_t is renewable energy consumption, and $GDPG_t$ represents the rate of economic growth. B_0 is the intercept term, while ε_t is the white-noise error term capturing all other factors not explicitly included in the model. The slope coefficients β_1 , β_2 , and β_3 measure the marginal effect (or sensitivity) of industrial carbon emissions to changes in environmental tax revenue, renewable energy consumption, and economic growth, respectively. All variables employed in this study are defined and described in detail in Table 1.

Table 1. Data Summary

Variables	Acronyms	Definitions	Hypothesis	Source
Carbon Dioxide Emissions from Industrial Process (Dependent Variable)	CDE	Carbon dioxide (CO ₂) emissions from Industrial Processes (Mt CO ₂ e)	/	World Bank
Environmental Tax Revenue (Independent variable)	ETR	Environmental tax revenue (% of GDP)	-	International Monetary Fund (IMF)
Renewable Energy Consumption (Independent variable)	REC	Renewable energy consumption (% of total final energy consumption)	-	World Bank
Gross Domestic Product Growth (Independent variable)	GDPG	Gross Domestic Product Growth %	+	World Bank

Source: by The Author

This study employed a Bootstrap Quantile Regression (BSQREG) to examine the impact of ETR, REC and GDPG on CDE in China between 1995 and 2021. Bootstrap Quantile regression provides better understanding of whether the effect is varying in different quantiles (Goswami, 2021). Moreover, Bootstrap is a straightforward yet potent estimate technique grounded in the principle of random sampling with replacement. Ridge regression utilizing a biasing parameter has emerged as a feasible alternative to the standard least squares regression model for analyzing data with collinear variables (Dar & Chand, 2024). Finally, Quantile regression is resilient to outliers and can represent varied effects throughout the distribution. A study on low-birth-weight modeling indicated that quantile regression "can accommodate non-normal errors as it is insensitive to heteroscedasticity and outliers (Yanuar et al. 2022).

4. Eonometric study findings

This study investigates the impact of ETR, REC, and GDPG in China between 1995 and 2021. Primary analyses employ the Bootstrap Quantile Regression (BSQR). the study also shows a descriptive statistic, a correlation matrix of the variables, co-variance between variables, and finally the diagnostic tests such as, heteroskedasticity test, and variance inflation factor (VIF).

4.1 Descriptive Statistics

Table 2 reports the descriptive statistics for all variables used in the analysis for China over 1995–2021. Average CO₂ emissions from industrial processes are about 953 Mt CO₂e, with a wide variation between roughly 377 and 1563 Mt, indicating strong growth and fluctuation in industrial emissions over time. Environmental tax revenue is relatively low, with a mean of 0.71% of GDP and a maximum of 1.44%. Renewable energy consumption represents on average about 18.9% of total final energy use, ranging from 11.3% to 30.5%. GDP growth is high on average, at 8.8% per year, but shows substantial variability, with a minimum of around 2.3% and a maximum above 14%.

Table 2. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
CDE	27	953.105	430.680	376.879	1562.902
ETR	27	0.708	0.363	0.150	1.440
REC	27	18.863	7.450	11.300	30.500
GDPG	27	8.787	2.289	2.340	14.150

Source: by The Author based on Stata 17 outcomes.

4.2 Correlation Matrix among the Variables

Table 3 presents the pairwise correlation coefficients among the variables. CDE is strongly and negatively correlated with (REC), with a value of (–0.893), suggesting that higher renewable energy use is associated with lower industrial CDE. CDE emissions are moderately and positively correlated with (ETR), with a value of (0.473), and moderately and negatively correlated with GDPG with a value of (–0.506). (ETR) is strongly and negatively correlated with REC, (–0.731). The Correlations between GDPG and the other variables are relatively weak, especially with ETR, (0.151) and REC (0.173). The strong correlation between (CDE) and (REC), and between (ETR) and (REC), may lead us to conduct the multicollinearity test.

Table 3. Correlation Matrix

Variable	CDE	ETR	REC	GDPG
CDE	1.000			
ETR	0.473	1.000		
REC	-0.893	-0.731	1.000	
GDPG	-0.506	0.151	0.173	1.000

Source: by The Author based on Stata 17 outcomes.

4.3 Co-variance Between Variables

Table 4 reports the covariance matrix for the variables used in the study. The diagonal elements represent the variances of each variable, which are consistent with the standard deviations reported in the descriptive statistics. The positive covariance between CDE from industrial processes and (ETR) indicates that these two variables tend to move in the same direction over time. In contrast, the negative covariance between (CDE) and (REC), and between (CDE) and (GDPG), suggests that higher renewable energy use and higher growth are generally associated with lower industrial CO₂

emissions industrial processes. The signs of the covariances are consistent with the correlation matrix in Table 3, but the magnitudes depend on the scale of each variable.

Table 4. Co-variance Between Variables

Variable	CDE	ETR	REC	GDPG
CDE	185485.000	73.894	-2865.650	-498.705
ETR	73.894	0.132	-1.978	0.125
REC	-2865.650	-1.978	55.508	2.955
GDPG	-498.705	0.125	2.955	5.238

Source: by The Researcher based on Stata 17 Outcomes

4.4 Bootstrap Quantile Regression Results for CDE ($\tau = 0.25$)

Table 5 reports the bootstrap quantile regression results for the 0.25 quantile of (CDE) from industrial processes in China. At the lower end of the emissions distribution, (REC) has a large and statistically significant negative effect on (CDE): a one–percentage-point increase in (REC) is associated with a reduction of about 50 Mt CO_{2e}, holding other factors constant. GDPG also shows a significant negative effect, indicating that higher growth is linked to lower industrial (CDE) at the 0.25 quantile, which may reflect efficiency gains or structural changes in the economy.

In contrast, the coefficient on (ETR) is negative but statistically insignificant, suggesting that at this quantile there is no clear evidence that (ETR) is associated with changes in industrial (CDE). The constant term is positive and highly significant, capturing the baseline level of emissions when all regressors are zero. Overall, the results indicate that renewable energy consumption and (GDPG) are key drivers of lower emissions in the lower part of the (CDE) distribution.

Table 5. Bootstrap Quantile Regression ($\tau = 0.25$)

Variable	Coefficient	Bootstrap Std. Error	t- statistic	p- value	95% CI (Lower)	95% CI (Upper)
ETR	-103.507	111.967	-0.92	0.365	-335.129	128.115
REC	-49.986***	5.524	-9.05	0.000	-61.414	-38.559
GDPG	-75.015***	18.848	-3.98	0.001	-114.006	-36.025
_cons	2549.496***	154.252	16.53	0.000	2230.401	2868.591

Source: by The Researcher based on Stata 17 Outcomes

Dependent variable: *CDE* (CO₂ emissions from industrial processes, Mt CO₂e).
Quantile: $\tau = 0.25$. Number of observations = 27. Bootstrap replications = 1000. Pseudo $R^2 = 0.8006$.
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

4.5 Bootstrap Median Regression Results for CDE ($\tau = 0.50$)

Table 6 presents the bootstrap median regression results for industrial (CDE) in China. At the median of the emissions distribution, all three explanatory variables are statistically significant and have negative effects. (ETR) significantly reduces median CDE: a one–percentage-point increase in (ETR, as a share of GDP) is associated with a decrease of about 205 Mt CO₂e.

(REC) has a strong and highly significant negative impact: a one–percentage-point increase in (REC) is linked to a reduction of about 54 Mt CO₂e. (GDPG) also shows a significant negative coefficient, suggesting that higher growth is associated with lower median industrial emissions, possibly reflecting improvements in energy efficiency and technological progress.

The constant term is large and highly significant, capturing the baseline level of emissions when the regressors are zero. Overall, the median regression results indicate that (ETR) , renewable energy consumption, and (GDPG) all play an important role in reducing CO₂ emissions at the center of the emissions distribution.

Table 6. Bootstrap Median Regression Results for CDE ($\tau = 0.50$)

Variable	Coefficient	Bootstrap Std. Error	t-statistic	p-value	95% CI (Lower)	95% CI (Upper)
ETR	-204.542**	76.564	-2.67	0.014	-362.926	-46.158
REC	-54.093***	4.137	-13.08	0.000	-62.651	-45.535
GDPG	-58.806***	12.727	-4.62	0.000	-85.133	-32.478
_cons	2637.414***	133.899	19.70	0.000	2360.422	2914.405

Source: by The Researcher based on Stata 17 Outcomes
Dependent variable: *CDE* (CO₂ emissions from industrial processes, Mt CO₂e).
Quantile: $\tau = 0.50$ (median regression). Number of observations = 27. Bootstrap replications = 1000. Pseudo $R^2 = 0.8271$.
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

4.6 Bootstrap Quantile Regression Results for CDE ($\tau = 0.75$)

Table 7 shows the bootstrap quantile regression estimates for the upper part of the CDE distribution ($\tau = 0.75$). At this quantile, all coefficients are negative. (REC) has a strong and highly significant negative effect: a one–percentage-point increase in (REC) is associated with a reduction of about 59 Mt CO₂e, holding other factors constant. (GDPG) also significantly reduces (CDE), with an estimated effect of about 50 Mt CO₂e per one–percentage-point increase in growth.

(ETR) has a relatively large negative coefficient (around –247 Mt CO₂e), but it is only weakly significant at the 10% level ($p = 0.065$). This suggests some evidence that higher (ETR) is linked to lower emissions at the 0.75 quantile, but the effect is less precisely estimated compared with (REC) and (GDPG). The constant term is positive and highly significant, reflecting the high baseline level of emissions when the explanatory variables are zero. Overall, the 0.75 quantile results confirm that (REC) and (GDPG) play an important role in reducing CDE even at higher emission levels, while the effect of (ETR) is weaker and less robust.

Table 7. Bootstrap Quantile regression results for CDE ($\tau = 0.75$)

Variable	Coefficient	Bootstrap Std. Error	t-statistic	p-value	95% CI (Lower)	95% CI (Upper)
ETR	-247.010*	127.624	-1.94	0.065	-511.021	17.001
REC	-58.522***	7.260	-8.06	0.000	-73.539	-43.504
GDPG	-49.513***	13.406	-3.69	0.001	-77.246	-21.779
_cons	2708.828***	239.703	11.30	0.000	2212.964	3204.692

Source: by The Researcher based on Stata 17 Outcomes

Dependent variable: *CDE* (CO₂ emissions from industrial processes, Mt CO₂e).
Quantile: $\tau = 0.75$. Number of observations = 27. Bootstrap replications = 1000. Pseudo R² = 0.7802.

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

4.7 Heteroskedasticity Test

Table 8 reports the Breusch–Pagan/Cook–Weisberg test for heteroskedasticity in the regression model of CO₂ emissions. The test statistic is $\chi^2(1) = 1.83$ with a p-value of 0.176. Since the p-value is higher

than conventional significance levels (1%, 5%, or 10%), we fail to reject the null hypothesis of constant variance. This means there is no statistical evidence of heteroskedasticity, and the assumption of homoskedastic errors appears to be reasonable for this model.

Table 8. Breusch–Pagan test for Heteroskedasticity

Test	χ^2 statistic	df	p- value	Null hypothesis
Breusch–Pagan / Cook–Weisberg test	1.83	1	0.176	Constant variance (homoskedasticity)

Source: by The Researcher based on Stata 17 Outcomes

Notes: Assumption: normal error terms. Variable: fitted values of *CDE*

4.8 Variance Inflation Factors (VIF) for the explanatory variables

Table 9 reports the variance inflation factors (VIFs) for the explanatory variables in the (CDE) model. All VIF values are relatively low: 2.61 for (REC), 2.59 for (ETR), and 1.24 for GDPG. The mean VIF is 2.15. Since all VIFs are well below common thresholds (such as 5 or 10), there is no evidence of serious multicollinearity among the regressors. This suggests that the estimated coefficients are not seriously distorted by linear dependence between the explanatory variables.

Table 9. VIF Test

Variable	VIF	1/VIF
REC	2.61	0.3827
ETR	2.59	0.3856
GDPG	1.24	0.8042
Mean VIF	2.15	/

Source: by The Researcher based on Stata 17 Outcomes

5. Discussion

The main objective of this study is to assess the impact of (ETR), (REC) and (GDPG) on (CDE) in China over the period 1995-2021 using a bootstrap quantile regression. Across the first part of distribution The study revealed that all the variables are statistically significant and have a negative effect on (CDE) except (ETR). The study also demonstrated the same results across second and the third part of distributions ($\tau = 0.50$ and τ

= 0.75). The strong negative relationship between (REC) on (CDE) across all the quantiles indicates that increasing the share of (REC) is an important channel to decrease industrial emissions in China. This result is in line with many studies such as, (Hao et al. 2020; Wu et al. 2023; Chen et al 2024; Zhu et al. 2024).

the negative but insignificant results of (ETR) at the ($\tau = 0.25$), can reveal that (ETR) does not have a clean effect on (CDE) from industrial sector when emissions are low, but it becomes more effective in reducing emissions at the middle and upper parts of the emissions. In other words, when industrial emissions are in a low-emission regime ($\tau = 0.25$), other factors such as the energy mix, technology, or general economic conditions may be more important than environmental taxes in explaining emission levels. In this case, the existing level of environmental taxation in China may be too weak to generate a measurable response from firms, or the variation in tax revenue is not large enough to show a clear effect.

However, In the median and high-emission regimes ($\tau = 0.50$ and $\tau = 0.75$), decreasing industrial CO₂ emissions are associated with higher environmental tax revenue (ETR coefficients are negative and significant). This may suggest that environmental taxes work better when emissions are high because large polluters and enterprises are more susceptible to the levy and more motivated to change their behavior, adopt cleaner technologies, or improve energy efficiency. The data show that Chinese environmental fees reduce emissions more among medium and high emitters but not low-emission scenarios. This result is consistent with (Sarpong et al. 2023; Bashir et al. 2020; Chien et al. 2021; Kafeel et al. 2023).

The results also highlighted a statistically significant negative relationship in all quantiles (0.25,0.50 and .075) between (GDPG) and (CDE) in China during the period of the study. This negative link between GDP growth and CO₂ emissions aligns with a growth model characterized by industrial enhancement, improvements in energy efficiency, and green investments, rather than just expansion of energy-intensive, polluting output. This substantiates the notion that, during the examined timeframe, China's

industrial expansion has increasingly become more environmentally sustainable, and that economic advancement does not inherently result in elevated emissions. This result is consistent with the outcomes of (Yang et al. 2021; Zou & Chau, 2023).

The findings indicate that renewable energy use and economic growth correlate with reduced industrial CO₂ emissions throughout the emission distribution, whereas environmental tax revenue mostly decreases emissions at the median and upper quantiles. The findings indicate that a policy combination of enhanced environmental taxes, increased renewable energy, and assistance for green industrial advancement can facilitate China's industrial decarbonization while maintaining economic growth.

Despite the contribution of this study, it has several limitations that must be highlighted. First, the annual data used in this study for a single country, China over a short period of 27 years. Second, the analysis focused on the emissions of industrial sector only. While emissions from other sectors such as transport, buildings, and agriculture are not involved. Therefore, the results express only part of the full emissions. Third the empirical model includes a limited explanatory variable (ETR, REC, GDPG). Other important factors, such as energy prices, trade openness, green finance indicators, credit to the green sector, environmental regulation stringency, or technological innovation, are not explicitly controlled for. Finally, quantile regression is a static method; it does not capture dynamic adjustment, feedback effects, or causality directions, which might be important for policy analysis.

6. Conclusion

This study aimed to examine the effect of (ETR, REC, GDPG) on (CDE) in China, using annual data over the period 1995-2021. Using a bootstrap quantile regression across three parts of the emissions distributions (0.25, 0.50, and 0.75 quantiles). The main results of the study showed that (REC) and (GDPG) have statistically significant negative relationship on (CDE) during the period of the study and over all Quantiles. However, (ETR) has no impact over the first quantile in contrast to the second and the third

quantiles where the results demonstrated a negative effect on CDE but its impact is weaker and less stable. (GDPG) also revealed a negative and significant impact on emissions across all quantiles, suggesting that, over the sample period, growth in China has been associated with improvements in energy efficiency and cleaner production in the industrial sector.

This research contributes the field in several ways. The study primarily focuses on industrial CO₂ emissions, which make up a large fraction of China's total emissions but are often evaluated with other sectors. Second, it uses bootstrap quantile regression instead of mean-based methods. This allows the research to show how environmental tax revenue, renewable energy, and growth affect low, moderate, and high emission levels. Third, by integrating tax, energy, and growth variables, the analysis provides a general view of policy and economic factors affecting Chinese industrial emissions.

However, the study had major limitations. The sample includes one country and 27 annual data, limiting long-term structural change detection and statistical power. The model only considers three main explanatory variables, disregarding energy cost, green finance, technical innovation, trade, and environmental regulation robustness. The static study does not include dynamic impacts or causation; therefore, policy changes or structural breaks may affect the outcomes.

Future research may expand on this. Initially, adding measurements of green financing, innovation, and regulation would help explain how taxes and renewable energy affect emissions. Second, dynamic models and causality tests can assess long-term and short-term consequences and whether emissions affect policy and economic growth. Third, sectoral or regional statistics in China may show whether industries or provinces respond better to environmental levies and renewable energy projects. Comparison analysis using panel data across various nations would allow China's experience to be compared to that of other major polluters, providing further policy insights.

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