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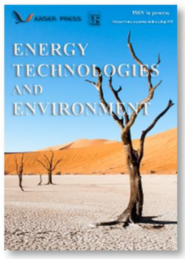

Potential Asymmetries in the International trade and Economic Growth in China: The Role of Emission Intensity

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ABSTRACT

This study delves into the complex relationship between China's international trade and economic growth, specifically focusing on emission intensity and its environmental ramifications within the context of energy efficiency. The primary objective is to provide a comprehensive understanding of how China's international trade dynamics influence economic growth, emphasizing emission intensity and employing a model that considers the nonlinear impact of trade on output. Through this model, structural breakpoints are identified, revealing distinct outcomes for China amidst positive and negative shocks from 1972 to 2021. The study uncovers the dual nature of the energy sector, acting both as a source of environmental degradation and a potential avenue for positive change through increased efficiency. Complex interplays among economic activities, inflation, and investment on carbon intensity are revealed. Additionally, the varying effects of export volume on carbon emissions intensity across lag thresholds underscore the significance of global trade dynamics for environmental sustainability. The study concludes by emphasizing the importance of balancing economic prosperity with environmental responsibility, advocating for carefully balanced policies that foster sustainable growth. Recommendations include considering the dual nature of the energy sector and implementing policies promoting increased efficiency. Policymakers are urged to adopt growth models prioritizing environmental responsibility, balancing economic activities, inflation, and investment to mitigate carbon intensity while acknowledging the diverse effects of global trade dynamics on environmental sustainability.

KEYWORDS

International Trade; Economic growth; Emissions; Environmental; Sustainability; China

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1. Introduction

Global economics is constantly evolving due to factors like technological advancements and geopolitical shifts. The environmental impact of economic activities, especially in the context of rising greenhouse gas emissions, is a pressing concern. As the world grapples with climate change consequences, it is crucial to examine the link between international trade, economic growth, and emissions, with a particular focus on major players like China. It has experienced significant economic growth in recent decades, reducing poverty for millions. However, this rapid development raises questions about its sustainability (Wang et al., 2021). Examining potential asymmetries in China's international trade and economic growth is crucial, especially considering the role of emission intensity, which links economic activities with environmental consequences.

The relationship between international trade and economic growth is intricate, involving competition, cooperation, and geopolitical factors. China's success in the global economy is attributed to its active participation in international trade, characterized by export-oriented strategies. However, this approach has led to rising pollution, deforestation, and high carbon emissions, highlighting the environmental impact of such a strategy. Emission intensity, the amount of greenhouse gas emissions per unit of economic output, is crucial in understanding China's environmental impact (Liu, et al., 2022). The challenge lies in balancing economic development with mitigating environmental effects. As China aims for carbon neutrality by 2060, emission intensity's role in international trade and economic growth is increasingly important (Zhao et al., 2022). China's status as the "world's factory" has led to a concentration of energy-intensive industries, contributing significantly to its carbon footprint. As global awareness of environmental issues grows, consumer preferences towards sustainably produced goods are shifting. This shift can create asymmetries in China's international trade, as nations that prioritize environmental considerations may scrutinize and restrict the import of goods with high emission intensity.

The global push towards environmental sustainability has led to the implementation of carbon tariffs, which aim to level the playing field by holding trading partners accountable for their carbon emissions. This complicates international trade dynamics and could potentially affect China's export-oriented economic model (Chen & Guo, 2017). The economic consequences of high emission intensity are becoming a key focus in shaping international trade relations.

China's economic growth trajectory is significantly influenced by emission intensity. The government's commitment to carbon neutrality necessitates a fundamental restructuring of the economy, transitioning from energy-intensive industries to green alternatives. This transition presents both challenges and opportunities, and potential economic growth asymmetries require careful consideration. China's transition to a low-carbon economy may cause disruptions in certain regions and industries, potentially leading to job displacements and economic disparities. Balancing economic growth with environmental sustainability is a delicate task, with emission intensity playing a critical role in shaping China's economic development trajectory. The shift towards cleaner technologies and practices is a delicate process.

The intricate relationship between international trade, economic growth, and emission intensity, particularly within China's global economic role, necessitates a nuanced understanding to effectively address climate change challenges. This study fills a critical gap in the literature by examining China's emission intensity through time series data, shedding light on how variations impact international trade patterns and economic growth. The unique contribution of this research lies in its exploration of potential asymmetries in China's trade relations and economic growth, offering innovative insights and policy approaches crucial for a sustainable future. To address the gap highlighted, the study specifically delves into the impact of carbon tariffs on trade dynamics, assessing asymmetries, and proposing measures to counteract their effects on trade patterns and economic development. This distinctive focus on China's context distinguishes the study from others, emphasizing the need for a tailored understanding of the intricate connections between emission intensity, international trade, and economic growth. The research, therefore, not only contributes to the existing body of knowledge but also advances the field by providing a more comprehensive perspective on the complex dynamics at play, essential for informed decision-making and effective policy formulation.

Figure 1, shows that trade of environmental goods of china during 1994-2021. It indicates that since year 2000, there has been an extraordinary increase in the trade of environmental goods, particularly, the increase in exports. The negative initial trade deficit converted into surplus after year 2011. Increase in environmental goods exports over a decade or so, by now has been attributed to green technology and energy efficiency, i.e., decrease in energy intensity in the same period (Figure 2). However, carbon intensity initially increased but remained constant for few years in early this century, then it started reducing after 2010. This also confirms the presence of green economy initiatives in China.

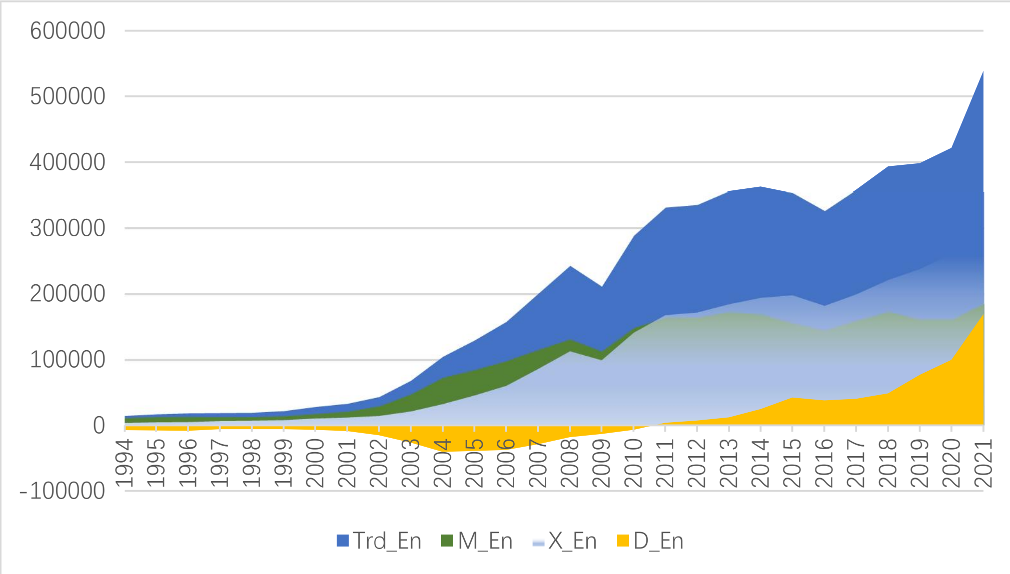

Figure 1. Trade of Environmental Goods: China.

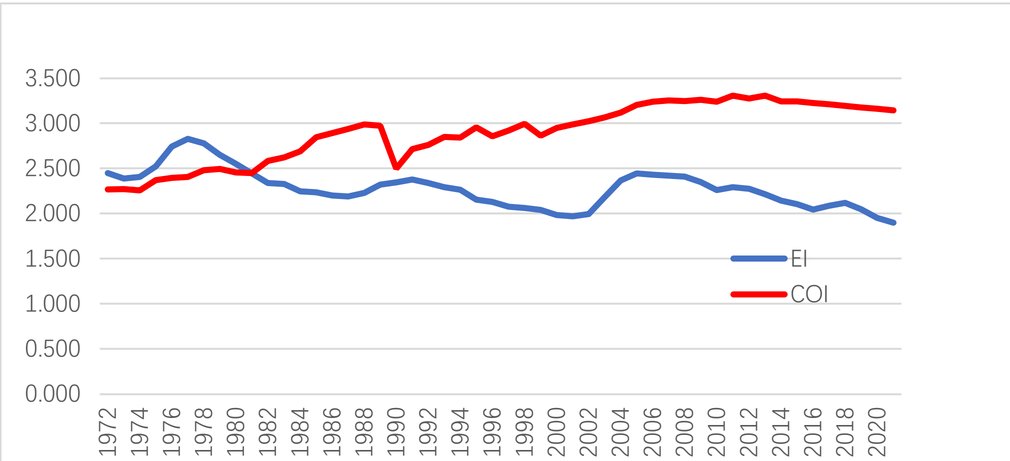

Figure 2. Energy Intensity (EI) and Carbon Intensity (COI).

2. Literature Review

This literature review provides a comprehensive overview of studies on potential asymmetries in China's foreign trade and economic growth, focusing on the impact of emission intensity, in the context of the complex interplay between international trade, economic growth, and environmental sustainability. The link between international trade and environmental repercussions has received a great deal of attention since Grossman and Krueger (1995) who pioneered the Environmental Kuznets Curve (EKC) idea, which proposed an inverted U-shaped link between environmental deterioration and income levels. However, further research has called into doubt the curve's universality and emphasized the relevance of commerce and trade activities in shaping environmental consequences. Emission intensity, defined as the amount of greenhouse gas emissions produced per unit of economic output, emerges as a crucial metric in understanding the environmental implications of economic activities. Xu and Nagurney (2012) argue that considering emission intensity provides a more nuanced understanding of the environmental impact of economic growth, allowing for the assessment of progress in decoupling economic development from environmental degradation. Studies have shown that international trade has a positive long-term relationship with economic growth, as seen in ASEAN countries (Wang, 2011) and the Economic Community of West African States (ECOWAS) (SALAZAR, 2015). However, there are also potential asymmetries in the global trading system, both on a global, regional, and bilateral level (Tsoulfidis, et al., 2019). These asymmetries can be directly or indirectly linked to international trade processes. To address these asymmetries and promote economic development, suggestions have been made to modernize the global trading system, improve the effectiveness of the World Trade Organization, and enhance government policies that support international trade (Tananaiko, et al., 2023). Additionally, the issue of unequal exchange and transfer of values in international trade has been raised, highlighting the importance of considering productivity, wage differentials, and purchasing power parity in assessing economic advantages (Deng, 2017). Labor subsidy can lead to higher TFP growth in manufacturing sector and Quality of exported goods is bimodally distributed within sectors (Hollstein, 2018). Most studies support the gains of trade and recognize the contributions of GATT/WTO. The macroeconomic evidence supports the positive effects of trade on output and growth. Difficult to disentangle effects of trade policies from other macroeconomic policies. Trade is one of several catalysts of productivity and growth (Maurer, 1998).

The environmental effect of China's foreign trade operations, as a pioneer in export-led growth, cannot be understated. The industrial sector's growth in exports has resulted in a concentration of energy-intensive businesses within the country (Zhang et al., 2014). These high-emission industries contribute considerably to China's carbon footprint, raising worries about the environmental viability of the country's economic model. Recent studies have delved into the nuances of emission intensity, considering variations across industries and regions within China. By examining sector-specific emission intensity, scholars have identified hotspots of environmental concern, offering valuable insights for policymakers aiming to balance economic growth with environmental sustainability (Liu et al., 2017). The global push towards sustainable development has introduced new dimensions to international trade dynamics, potentially creating asymmetries for nations heavily reliant on high emission intensity industries. As consumers and governments worldwide prioritize eco-friendly products, there is a discernible shift in demand towards sustainably produced goods. Notably, this shift has prompted discussions on the imposition of carbon tariffs as a means of holding trading partners accountable for their carbon emissions.

The prospect of carbon tariffs introduces an additional layer of complexity to international trade relations, with potential implications for China's export-oriented economic model. Research by Levinson (2009) underscores the need for a careful examination of the economic consequences and potential retaliatory measures that may arise from the implementation of carbon tariffs. Transitioning to a low-carbon economy is a formidable challenge for China, and the role of emission intensity becomes particularly salient on the domestic front. Government commitments to achieve carbon neutrality by 2060 necessitate a fundamental restructuring of the economy, with implications for regional development and employment.

A study by Shi et al. (2020) explores the regional disparities in China's green transition, highlighting potential asymmetries in economic growth as certain regions bear the brunt of the shift away from carbon-intensive industries. The research underscores the importance of targeted policies to mitigate regional inequalities and ensure an equitable transition to a more sustainable economic paradigm. As China grapples with the challenge of balancing economic growth and environmental sustainability, the literature emphasizes the importance of well-crafted policies and international cooperation. Policy instruments such as carbon pricing and emissions trading systems are proposed as effective tools to incentivize emission reductions without stifling economic growth (Hepburn et al., 2018). Furthermore, the literature emphasizes the need for collaboration between nations to address the global challenge of climate change. International efforts, such as the Paris Agreement, aim to foster cooperation in mitigating greenhouse gas emissions and transitioning towards sustainable development. However, the literature also acknowledges the complexities of international negotiations and the challenges in achieving a collective commitment to environmental stewardship.

Research by Meng et al. (2018) explores the relationship between emission intensity and China's industrial upgrading. The study investigates how upgrading industries to higher value-added activities may influence emission intensity, shedding light on the potential trade-offs and synergies between economic growth and environmental sustainability. Technological Innovation and Emission Intensity: A study by Tang and Zhang (2017) investigates the role of technological innovation in mitigating emission intensity in China. By examining the adoption of cleaner technologies across industries, the research provides insights into how innovation can be a driving force in achieving both economic development and environmental goals.

The phenomenon of emission outsourcing, where developed countries' demand for goods results in increased emissions in developing nations, is explored by Su and Ang (2018). This research delves into the role of China in global value chains and how emission-intensive production processes may be relocated across borders, impacting both international trade dynamics and environmental sustainability. Investigating the link between consumer preferences and emission intensity, Liu and Wen (2020) analyze the role of sustainable consumption patterns in shaping China's economic development. The study considers the influence of consumer choices on the demand for environmentally friendly products, providing implications for industries and policymakers.

Zhu and Zhang (2019) examine the relationship between emission intensity and financial performance of Chinese firms. This research explores how companies that proactively manage and reduce their emission intensity may experience enhanced financial performance, contributing to the broader discourse on the business case for sustainability. Policy Effectiveness and Emission Reduction Targets: Evaluating the effectiveness of environmental policies, Wang et al. (2021) assess China's progress towards emission reduction targets. The study provides insights into the impact of policy measures on emission intensity, highlighting the need for robust policy frameworks to achieve environmental goals while sustaining economic growth.

Social Equity and Green Transition: Addressing the social dimension of emission intensity reduction, Yang and Shi (2019) analyze the implications of China's green transition for social equity. The research considers how policies aimed at reducing emission intensity can be designed to ensure a fair distribution of benefits and burdens across different segments of society. In the context of global efforts to address emissions, a study by Wang and Liu (2018) focuses on the potential for international collaboration in carbon capture and storage technologies. The research explores how collaborative initiatives can facilitate emission reduction without compromising economic growth, emphasizing the importance of shared technological advancements.

Despite the growing body of literature on the interplay between international trade, economic growth, and emission intensity in the context of China, there remains a notable gap that requires further exploration. The existing research has primarily focused on overarching relationships and broad trends, leaving certain critical aspects insufficiently addressed. The literature gap includes:

While some studies have delved into emission intensity at a macroeconomic level, there is a need for more granular analysis at the sectoral level. Understanding how different industries contribute to overall emission intensity and how this affects trade dynamics and economic growth is a nuanced aspect that merits closer examination. The literature has hinted at the potential implications of carbon tariffs on China's international trade, but a comprehensive exploration of how these tariffs might create asymmetries, both in terms of trade patterns and economic growth, is lacking. This is particularly crucial given the global shift towards environmentally conscious trade policies.

Although there is recognition that transitioning to a low-carbon economy may lead to regional economic disparities, there is a lack of in-depth analysis regarding the specific regions most affected and the socio-economic implications. Understanding the regional nuances of China's green transition is vital for formulating targeted policy interventions.

The influence of consumer preferences for sustainably produced goods on China's international trade remains an area that demands more attention. Exploring how shifts in global consumer preferences may affect China's export patterns and the subsequent impact on economic growth can provide valuable insights for policymakers.

3. Model and Methodology

To accomplish the objectives of this study, we assume following growth model generated from usual Cobb-Douglas production function,

$$Y_t = A_t K_t^{\alpha} L_t^{\beta} \tag{1}$$

We divide both sides by L and get Output per capita, the per capita capital stock and all else is adjusted in intercept term and take log of it.

$$lnGDP_t = lnA_t + \alpha lnK_t + \epsilon_t \tag{2}$$

Here lnGDP is log of GDP per capita. We assume that CO2 emissions cause a damage to the economy through (i) depreciating capital by amount γ and (ii) with by reducing energy efficiency of the output. We sum both effects in one place and hold that international trade affects the output through increase/decrease in environmental trade as well. Thus the final growth equation will be of the shape;

$$lnGDP_t = \alpha_0 + \alpha_1 lnK_t + \alpha_2 ltx_{en_t} + \alpha_3 X_{t_t} + \alpha_4 COI_t + \alpha_5 EI_t + \epsilon_{1t} \tag{3}$$

And for carbon Intensity

$$COI_t = \beta_0 + \beta_1 lnK_t + \beta_2 ltx_{en_t} + \beta_3 X_{t_t} + \beta_4 LGDP_t + \beta_5 EI_t + \epsilon_{2t} \tag{4}$$

Although this model is log linearized, but the impact of trade on green output is assumed to have both linear and nonlinear impact due to the nature of the variable: (i) both positive and negative of trade balance affect output, but their direction and magnitude of impact cannot be same on output; (ii) In time-series certain threshold value of output respond differently to the state variable, i.e., trade balance of environmental goods. To address these issues, in this study we use the Smooth Transition Autoregressive (STAR) Model which is a nonlinear time series investigation technique that incorporates regime-dependent linear auto-regression provisions in a smooth transition nonlinear regression (STNR) structure, resulting in smooth regime switching when a variable crosses undetected thresholds.

The paper uses the STR modeling approach to test nonlinearity, as it is more comprehensive and concrete, as it doesn't require a specific order of integration for individual series, unlike NARDL which can only be used with different order of integration and dependent variable integration.

$$LGDP_t = \sum_{j=0}^{m-1} 1_j\ (s_t; c, \pi). Z_t'\delta_j + X_t \propto + \mu_t \tag{5}$$

Here π is slope parameter of the threshold, c is indicator of thresholds (one or more), $\boldsymbol{s_t}$ is observed variable in this case strong candidate is ltx_en, and lx_t, Z variable(s) with varying coefficients across regimes (in this case it is ltx_en and COI), X variables with invariant coefficients: inflation and investment in this case. The m=2 and for exactly one j we can write equation (7) as

$$\begin{aligned} LGDP_t &= 1_0\left(ltx_{en_t}; c, \pi\right). Z_t'\delta_0 + 1_1\left(ltx_{en_t}; c, \pi\right). Z_t'\delta_1 + X_t \propto + \mu_t \\ &= (1 - 1_1\left(ltx_{en_t}; c, \pi\right)). Z_t'\delta_0 + 1_1\left(ltx_{en_t}; c, \pi\right). Z_t'\delta_1 + X_t \propto + \mu_t \end{aligned} \tag{6}$$

To build a two-regime STR model, the indicator function is replaced with a continuous transition function G, which has value between 0 and 1;

$$LGDP_t = \sum_{j=0}^{m-1} 1_j\ (s_t; c, \pi). Z_t'\delta_j + X_t \propto + \mu_t \tag{7}$$

In Equation (7) the key modeling choices including selection of transition function with threshold. For a chosen/observed value of ltx_en and G, we can estimate parameters (δ0, δ1, αs and βs) whereas the threshold values c and slope π, using nonlinear OLS. Furthermore, for a given list of choice variables for ltx_en, by applying model selection method one can select a threshold variable. Given the assessment of a two-regime STR model, we would want to see whether there is any further un-modeled asymmetry. The similar process is held for equation 3 & 4. The asymmetry is tested through policy variable carbon tariff or environmental tax!

To estimate the model (eq. 3 & 4) with specification (eq. 7) annual data from various sources including WDI and NBS China are used. The data range 1972 to 2021. Some variables for example environmental trade variables are extrapolated for some initial years. The major variables and their descriptions are given in table 1 below.

Table 1. Description of the Variables.

Variable Name	Unit	Source
LGDP	GDP per capita, USD Million Log data are used for analysis	WDI
LTrd_en	Total trade in environmental goods. USD Million Log data are used for analysis	IMF
LX_en	Exports of environmental goods. USD Million Log data are used for analysis	IMF
LM_en	Imports of environmental goods. USD Million Log data are used for analysis	IMF
LTX_en	Carbon tax or environmental tax (policy variable	WDI
GFCF: Gross fixed capital formation	Taken as proxy for capital flow USD Million, Log taken	WDI
LT_t	Total trade, USD Million, Log	WDI
LX_t	Total exports, USD Million, Log	WDI
LM_t	Total imports USD Million, Log	WDI
COI	Carbon Intensity	WDI
EI	Energy Intensity	WDI

4. Results

Table 2 presents the staitionarity check of each series and we found that all variables are integrated of order one, which means there is possibility of a long run stable relationship among these variables. Based on these results, it is now obvious to prefer STAR model over NARDL, because the later requires different order of integration of the non-threshold variables. The results are reported in table 3 & 4 below.

Table 2. Stationarity Diagnostics.

Variable Name	ADF Stat	Order
LGDP	-5.99	I(1)
LTrd_en	-4.94	I(1)
LX_en	-3.42	I(1)
LM_en	-3.97	I(1)
LTX_en	-2.07	I(1)
LK	-4.78	I(1)
LT_t	-5.23	I(1)
LX_t	-3.29	I(1)
LM_t	-3.17	I(1)
COI	-5.07	I(1)
EI	-3.99	I(1)

As discussed in section 3 above, we are using environmental tax and energy intensity as threshold affecting GDP and Carbon intensity in both ways (linear and non-linear). In Table 3 model for GDP is presented for 10, 18 and 27 lags of GDP to set as thresholds. At 10 lags the energy intensity affects the GDP per capita both linearly and non-linearly. However, the carbon tariff only affects nonlinearly in 10 and 18 lags case whereas linear effect in 27 lags threshold. The nonlinear affects only lasts for 18 lags at most by both threshold variables with varying parameters. Investment affects positively with elasticity greater than one, showing increasing returns to capital and confirms the accelerator principle for Chinese economy. The slopes are significant for 18 lags (2003) and 27 lags (1994). It mean that non-linearity prevails since 1994. The diagnostics suggest that there are rare chances of serial correlation and lag 27 has minimum standard error of regression. As found in the literature in this study we find the carbon intensity to affect the GDP negatively and significantly in all three cases. Total exports exert positive effect in relatively less lag threshold period as compared to longer ones. For 18 and 27 lags, the effect of exports become negative and insignificant. Inflation affects only in 18-lag threshold models.

Table 3. Nonlinear Threshold Estimation Growth Model.

Threshold Variables (linear part)			
Variable/Coefficients	Threshold LGDP(-10)	Threshold LGDP (-18)	Threshold LGDP (-27)
LTX_en: δ_{01}	0.0673 (0.0518)	-0.0188 (0.181)	0.359* (0.117)
EI: δ_{02}	-.199* (0.117)	-0.0754 (0.0701)	-0.347 (0.122)
Threshold Variables (nonlinear part)			
LTX_en: δ_{11}	1.0672* (0.4626)	-0.225* (0.101)	-0.074 (0.09)
EI: δ_{22}	0.771* (0.236)	0.271* (0.201)	0.042 (0.09)
Non-Threshold Variables			
LK	1.509*(0.121)	1.2702* (0.107)	1.278* (0.085)
INF	0.01 (0.04)	-0.0053* (0.002)	0.010 (0.006)
COI	-0.19* (0.101)	-0.3649* (0.178)	0.443* (0.214)
LX_T	0.394* (0.11)	-0.0928* (0.114)	-0.141 (0.111)
Slopes			
SLOPE:π	30.3714 (35.531)	7.576* (2.44)	11.61* (4.85)

Thresholds			
THRESHOLD: c	13. 02* (0.087)	12.70* (0.071)	12.24* (0.061)
Fitness and Diagnostics			
R-squared	0.998	0.999	0.999
S.E. of regression	0.031	0.044	0.029
Durbin-Watson stat	1.486	1.83	1.82

Note: Standard Errors in parenthesis. indicates statistically significant parameters at least at 10% or below.*

In table 4 the results for carbon intensity are presented. It is noteworthy that the carbon tariff affect the carbon intensity positively and significantly in case of 27-lag threshold only in linear model. However, the environmental taxes pose significantly negative effect on the carbon intensity for 10 and 18 lags thresholds, indicating that the efforts to control carbon though protection can lead to green effects. Energy intensity affects negatively in linear part of the model, but the response of carbon intensity to energy intensity is positive and significant in non-linear model. It means that there is increase in carbon intensity due to inefficiency in the energy sector. However, if the energy sector improves its efficiency, the effect would be productive for the economy. There is positive effect of inflation and investment on carbon intensity, which shows that for the robust economic activities increase the chances of pollution. Inflation also seems to be affecting the environment through over production. The slopes of 10 and 27 lags are insignificant. Export volume decrease the carbon emissions intensity in 10 and 18 lags threshold, whereas it increases it in the 27 lags thresholds.

Table 4. Nonlinear Threshold Estimation Carbon Intensity Model.

Threshold Variables (linear part)			
Variable/Coefficients	Threshold LGDP(-10)	Threshold LGDP (-18)	Threshold LGDP (-27)
LTX_en: δ01	0.0673 (0.0518)	-0.049 (0.104)	0.393* (0.110)
EI: δ02	-.199* (0.117)	-0.185* (0.096)	0.326* (161)
Threshold Variables (nonlinear part)			
LTX_en: δ11	-1.0672* (-0.4626)	-0.394* (0.114)	-0.171 (0.217)
EI: δ22	0.771* (0.236)	0.768* (0.295)	0.443* (0.211)
Non-Threshold Variables			
LK	0.281 (0.28)	0.371* (0.22)	-1.003* (196)
INF	0.010* (0.004)	0.003 (0.01)	-0.006* (0.003)
LGDP	-0.006 (0.011)	-0.081 (0.19)	0.849* (0.155)
LX_T	-0.086 ((0.11)	-0.014 (0.214)	0.152* (0.093)
Slopes			
SLOPE:π	316.4 (506.76)	20.27* (12.13)	9.26 (9.85)
Thresholds			
THRESHOLD: c	2.95. * (0.01)	2.74* (0.063)	2.73* (0.091)
Fitness and Diagnostics			
R-squared	0.868	0.946	0.963
S.E. of regression	0.091	0.055	0.0297
Durbin-Watson stat	1.09	2.18	2.30

Note: Standard Errors in parenthesis. indicates statistically significant parameters at least at 10% or below.*

5. Discussion

Notably, the positive and significant impact of carbon tariffs on carbon intensity at the 27-lag threshold, as revealed in the linear model, adds importance to the ongoing discourse on the effectiveness of such tariffs in mitigating carbon emissions. Conversely, the negative effect of environmental taxes on carbon intensity for 10 and 18 lags thresholds underscores the potential success of regulatory measures aimed at fostering environmentally friendly practices. The negative association between energy intensity and carbon intensity in the linear model suggests that inefficiencies in the energy sector contribute to increased carbon emissions. However, the positive and significant response in the non-linear model implies that improvements in energy sector efficiency can be a catalyst for environmental sustainability. Moreover, the positive effects of inflation and investment on carbon intensity raise concerns about the environmental effects of robust economic activities. These findings match with literature highlighting the delicate balance between economic growth and environmental protection (for example, Ang 2004; Deng 2017; Tsoulfidis, et al., 2019, Salazar, 2015). The impact of export volume on carbon emissions intensity, varying across lag thresholds, further emphasizes the complexity of global trade dynamics and their implications for environmental outcomes. Overall, the results contribute valuable hints to the ongoing discussions regarding policy interventions and economic strategies aimed at achieving sustainable and environmentally conscious development. As China navigates the path towards carbon neutrality, the literature highlights the importance of adaptive policies that balance economic imperatives with environmental responsibilities, ensuring a sustainable future for the nation and the global community. Research has consistently demonstrated a positive long-term correlation between international trade and economic growth, evident in regions such as ASEAN countries (Wang, 2011) and the economies of West African States (Salazar, 2015). However, the global trading system exhibits potential asymmetries on global, regional, and bilateral scales (Tsoulfidis, et al., 2019). These asymmetries, directly or indirectly linked to international trade processes, prompt the need for addressing issues to foster economic development. Suggestions for this include the modernization of the global trading system, improved efficacy of the World Trade Organization, and bolstered government policies supporting international trade (Tananaiko, et al., 2023). Moreover, concerns about unequal exchange and the transfer of values in international trade underscore the importance of considering productivity, wage differentials, and purchasing power parity in evaluating economic advantages (Deng, 2017; Hollstein, 2018). While trade serves as a catalyst for productivity and growth (Maurer, 1998), the discussion should be refined to specifically align with the study's findings and compare them with other pertinent literature from the same geographical regions. This restructuring ensures a more focused and relevant exploration of the study's outcomes within the context of existing research.

6. Conclusion

This study delves into the intricate dynamics of carbon intensity and economic development, investigating the impacts of various factors and policy interventions on environmental sustainability. The findings contribute significant insights to the existing literature on the complex relationship between economic activities and environmental outcomes. Notably, the study challenges conventional wisdom by highlighting the positive influence of carbon tariffs on carbon intensity at specific lag thresholds, suggesting the potential efficacy of tailored tariff measures in shaping environmentally conscious practices. Conversely, the negative impact of environmental taxes on carbon intensity underscores the potential effectiveness of regulatory frameworks in fostering green practices. The dual nature of the energy sector, serving as both a source of environmental degradation and a potential avenue for positive change through increased efficiency, is elucidated through the relationship between energy intensity and carbon intensity. The study also underscores the complex interplay of economic activities, inflation, and investment on carbon intensity, emphasizing the necessity for carefully balanced policies promoting sustainable growth.

Beyond academic discourse, this study offers practical guidance for policymakers, businesses, and environmental advocates. It implies that policymakers can leverage insights into the impacts of carbon tariffs and environmental taxes to design targeted and effective environmental protection measures. The study emphasizes the need for energy sector efficiency to reduce carbon emissions, urging policymakers to invest in cleaner technologies. Additionally, it suggests adopting sustainable growth models prioritizing environmental considerations and balancing export-oriented strategies with economic growth. To enhance clarity and relevance, the conclusions are revised, incorporating specific policy recommendations tailored to the target sample, recognizing that general policies may lack practical utility in scholarly articles. Furthermore, the study acknowledges its limitations and provides future research directions, suggesting the use of a computable general equilibrium (CGE) model for environmental degradation and protection, along with a more dynamic stakeholder analysis of the policies. This comprehensive approach strengthens the study's contents, ensuring clarity for readers and offering valuable insights for policymakers and scholars alike.

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Conflict of interest

All the author claims that the manuscript is completely original. The author also declares no conflict of interest.

Author contributions

Conceptualization: Atul Kumar Singh; Investigation: Atul Kumar Singh; Methodology: Atul Kumar Singh; Formal analysis: Atul Kumar Singh; Writing – original draft: Atul Kumar Singh; Writing – review & editing: Atul Kumar Singh.

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