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Assessing the synergistic effect of "pollution and carbon reduction" and "economic growth": a perspective from bilateral trade between China and RCEP countries

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Introduction: With the accelerating process of globalization, trade activities have had profound impacts on both the environment and economic development.

Methods: This paper comprehensively evaluates the synergistic effect of bilateral trade on "pollution reduction" and "carbon mitigation," as well as "economic growth," utilizing panel data from China and RCEP countries spanning the period from 1997 to 2020.

Results: The empirical results reveal that bilateral trade significantly propels economic growth in RCEP countries and exhibits a positive "pollution reduction" effect, whereas its "carbon reduction" effect remains uncertain. To delve into the underlying reasons for bilateral trade's failure to effectively mitigate carbon emissions, this paper undertakes a mechanism test along two opposing paths. Notably, the influence of bilateral trade on economic growth and "pollution reduction" in RCEP countries varies regionally. Specifically, bilateral trade is more efficacious in fostering economic growth in ASEAN countries. Additionally, bilateral trade enhances environmental quality in ASEAN countries, yet it deteriorates in non-ASEAN countries. Furthermore, this paper examines the intricate relationship between bilateral trade, economic growth, and "pollution reduction" through the application of the PVAR model. It concludes that optimizing environmental quality in RCEP countries is conducive to both local economic growth and bilateral trade.

Conclusion: This study not only bears significant implications for understanding the complex interplay between economic growth, environmental quality, trade liberalization, and environmental policies, but also provides invaluable guidance for policy formulation and implementation aimed at achieving green transformation and fostering sustainable economic development.

KEYWORDS

bilateral trade, economic growth, environmental quality, carbon emission, RCEP

1 Introduction

The global economic landscape has been significantly impacted by the ongoing COVID-19 pandemic, with growth rates slowing across various economies. However, amidst this backdrop, bilateral trade between China and the members of the Regional Comprehensive Economic Partnership (RCEP) has demonstrated remarkable resilience and growth potential (Fang et al., 2022). As nations strive for economic revitalization and job creation through strategic measures such as investment promotion, innovation drive, and international cooperation, the nexus between economic growth and environmental sustainability has gained renewed significance (Li et al., 2023).

In recent years, the relationship between economic development and environmental quality has evolved from a perceived dichotomy to a mutually reinforcing one, with both objectives being achievable through innovative policies and practices (Li et al., 2020). China, as a global leader in climate action, has consistently emphasized green and low-carbon development as a strategic imperative for advancing ecological civilization and fostering sustainable development (Zhu and Lan, 2023; Bai et al., 2024). Despite the IEA's projection of a marginal increase in global CO_2 emissions from industrial processes and energy combustion in 2022, the rate of this growth remains lower than that of global GDP, signaling a modest improvement in energy-use intensity.

The international community has converged on the imperative of controlling pollution and carbon emissions, recognizing the severity of climate change and the urgency of addressing environmental challenges (Li and Li, 2020). Amidst this consensus, international cooperation has intensified, with agreements and mechanisms being formulated to jointly tackle climate change and enhance environmental stewardship (Schneider and La Hoz Theuer, 2019). The RECP, as one of the largest, most populous, and geographically widest-ranging free trade agreements in the world, not only aims to promote trade liberalization and economic integration among its member states but also holds the potential to deepen environmental cooperation and jointly address global environmental challenges. Hence, our motivation for selecting RECP countries as the subject of this study stems from the following aspects.

To start with, RECP member countries span economies in East Asia, Southeast Asia, and Oceania, which are interdependent in terms of economic development and face similar environmental challenges. Studying environmental cooperation among RECP countries can help reveal the positive impacts of regional economic integration on environmental governance, providing valuable insights for other regions. Then, while economic issues dominate the RECP agreement, member countries have also expressed their shared concern for environmental sustainability during the signing process. By examining environmental policy coordination and mechanism innovation within the RECP framework, we can gain insights into how to promote economic growth without compromising the environment, exploring green development models tailored to the region. Furthermore, the world is currently confronting grave environmental challenges such as climate change, biodiversity loss, and increasing pollution. As significant economies and natural resource users, RECP countries' environmental policies and practices significantly impact the global environment. By studying these countries, we can better understand how to foster global environmental cooperation and jointly tackle global environmental issues. Finally, RECP countries generally recognize and are committed to achieving the United Nations' 2030 Agenda for Sustainable Development, including numerous environmental-related goals such as environmental protection and climate action. By thoroughly analyzing RECP countries' efforts and achievements in pursuing these goals, we can provide valuable references and insights for other countries and regions, fostering sustainable development worldwide.

Given China's pivotal role within the RCEP and its substantial trade ties with other member nations, totaling 12.95 trillion yuan in 2022, a year-on-year increase of 7.5% and accounting for 10.7% of China's GDP (customs data), it is imperative to understand the multifaceted implications of bilateral trade for the region's environment and economy. Trade, as a catalyst for industrial development, technological advancements, and resource optimization, can propel economic growth while facilitating the dissemination of environmental protection technologies and best practices. This begs the question: Can bilateral trade between China and RCEP members achieve a harmonious balance between pollution and carbon reduction, on the one hand, and economic growth, on the other?

The motivation for this study stems from the pressing need to evaluate the intricate interplay between bilateral trade, environmental quality, and carbon emissions within the RCEP framework. By investigating this relationship, we aim to contribute to the following objectives: Firstly, providing a nuanced assessment of the environmental and economic implications of regional economic integration. Secondly, exploring the role of bilateral trade in mitigating pollution and carbon emissions across diverse economic and social contexts, thereby enhancing our understanding of trade-related channels and mechanisms for environmental protection. Thirdly, through a heterogeneity analysis, we seek to discern the differential impacts of bilateral trade on ASEAN and non-ASEAN countries, informing the formulation of targeted policies. Lastly, employing the Panel Vector Autoregression (PVAR) model to analyze the dynamic interactions among bilateral trade, environmental quality, and carbon emissions offers critical insights for fostering a positive synergy among these variables.

Moreover, this study contributes to the existing literature in several novel ways. Firstly, it fills a gap in the research on the environmental impacts of bilateral trade within the context of mega-regional free trade agreements, specifically the RCEP, which has yet to be thoroughly explored. Secondly, by focusing on both ASEAN and non-ASEAN member countries, our study offers a more comprehensive analysis of the differential impacts of bilateral trade on environmental outcomes across diverse economies and social contexts. Thirdly, the application of the PVAR model allows for a dynamic and intertemporal examination of the relationship between bilateral trade, environmental quality, and carbon emissions, providing a more nuanced understanding of the complex interactions among these variables. Finally, our findings offer practical implications for policymakers in RCEP countries, as well as other regions contemplating similar trade agreements, by highlighting the potential benefits and challenges associated with promoting economic growth while safeguarding environmental sustainability.

The structure of this paper unfolds as follows: Section 2 delves into the literature review and theoretical framework, Section 3 outlines the methodology and data sources, Section 4 presents the empirical findings and discussions, and Section 5 concludes with policy implications and future research directions.

2 Literature review and theoretical analysis

The implementation of RCEP in China has strengthened economic ties and cooperation with other members, promoted trade and investment liberalization, and thus driven economic growth and industrial upgrading (Chen and Chen, 2021). On the one hand, RCEP will reduce tariff and non-tariff barriers as well as trade costs among members, and simplify trade procedures and standards, making China's goods and services more competitive, stimulating export growth and import diversification (Peng et al., 2022). On the other hand, RCEP provides Chinese enterprises with broader market access opportunities in other members' markets (Zhang et al., 2023). In addition, enterprises from other members will have easier access to the Chinese market, which will expand the size of bilateral trade and encourage the growth of imports and exports. In addition, enterprises from other members will have easier access to the Chinese market, which will expand the size of bilateral trade and encourage the growth of imports and exports. So, is the bilateral trade between China and RCEP members effective in "reducing pollution and carbon emissions" and "economic growth"? From the existing literature, this article explains the following two aspects.

2.1 Bilateral trade and economic growth

With the continuous deepening of international relations and economic integration, the relationship between trade openness and economic growth has become a hot topic of concern. From existing literature, the conclusion that trade openness contributes to economic growth has been supported by numerous studies (Schneider, 2005; Ma et al., 2019; Arvin et al., 2021; Zhuang et al., 2022). Trade openness can enable enterprises to gain broader markets, increase sales opportunities and potential consumers, and foster production and investment activities (Tiwari et al., 2022). At the same time, trade openness can also introduce more advanced products and technologies, increase production efficiency and competitiveness, thus helping to optimize resource allocation and facilitate economic efficiency (Chang et al., 2009). As economic globalization has deepened, the proportion of service trade in international trade has been gradually increasing. By opening up the service market, enterprises can provide a wider range of services, such as finance, transportation, education, tourism, etc. The growth of the service industry creates more employment opportunities and economic growth points for countries (Du and Liu, 2023).

As a globally populous country and the second largest economy, China's bilateral trade with RCEP members can expand the market size of these nations. China's vast consumer market and demand potential provide more development and export opportunities for enterprises in RCEP countries. Through bilateral trade with China, RCEP countries can benefit from China's technology and management experience. China has advanced technology and manufacturing capabilities in many fields, and trade with China can promote technology transfer and cooperation, raising the industrial level and innovation capabilities of RCEP countries. In addition, China offers more investment opportunities for RCEP countries via bilateral trade (Jiang and Yu, 2021). China is one of the world's largest sources of foreign direct investment, and trade with China can attract more foreign investment, boost the scale and production of enterprises in RCEP countries, and thus create jobs. According to the resource allocation theory, bilateral trade achieves optimal resource allocation. China meets its needs through imports, while RCEP countries utilize their resources and labor through exports. This optimization of resource allocation improves production efficiency and economic growth.

2.2 Bilateral trade, pollution and carbon reduction

There are two main theories about the relationship between trade openness and pollution and carbon reduction. One is the theory of trade benefits, which means that trade openness is beneficial for reducing environmental pollution and carbon emissions. Existing research also strongly supports this viewpoint. As Frankel and Rose (2005) argued, trade helps propel economic growth, and trade is negatively correlated with air pollution. Kim et al. (2019) found that trade openness has a significant inhibitory effect on carbon emissions in developed countries, as developed countries typically tend to develop high value-added and low intensity service, as well as knowledge intensive industries, while outsourcing high energy and carbon emission industries to developing countries. Cai et al. (2022) believed that trade liberalization encourages domestic trading enterprises to choose more proactive pollution reduction strategies, that is, signing the CAFTA helps reduce the pollution emissions of trading enterprises. Tan and Sheng (2022) used Chinese enterprise data to study that export trade significantly suppressed corporate pollution emissions. Some scholars have examined the influencing factors of sustainable development and environmental protection from the perspective of green trade.

Olasehinde-Williams and Folorunsho (2023) tested the validity of Porter's Hypothesis by examining the combined impact of green trade and tightened environmental policies on the sustainable development of the European Economic Area. Lee et al. (2023) found that both green trade and economic complexity have made positive contributions to environmental protection in 24 EU countries, and their interaction has reinforced their individual benefits. This indicates that promoting both green trade and economic complexity can effectively promote sustainable development, encouraging countries to increase local production capacity or utilize international green trade.

The other is the trade-harming theory, which means that trade openness will worsen environmental quality and increase carbon emissions. Its representative theories mainly include the "pollution paradise" hypothesis and the "race to the bottom line" hypothesis (Walter and Ugelow, 1979; Esty and Dua, 1997). Copeland and Taylor (1997) pointed out that free trade may lead to a negative cycle of low real income and environmental quality, and high pollution emissions. Li and Qi (2011) believed that trade openness has increased China's carbon emissions, and the environmental benefits of trade are smaller than the "race to the bottom line" influence. Wang and Xu (2015) found through their study of quarterly data in China that trade openness significantly encourages carbon emissions in the long term, meeting the "pollution paradise" hypothesis. Dai (2017) used the instrumental variables estimation method and found that trade openness will worsen environmental quality, of which export trade is the main reason for the deterioration of environmental. Khan et al. (2021) employed empirical evidence from the top ten manufacturing countries to show that commodity trade is positively related to economic growth and negatively related to environmental quality.

Bilateral trade between China and RCEP members could have an impact on the environmental quality and carbon emissions of RCEP countries through the following channels. Firstly, China has rich experience and advanced technology in clean energy, environmental protection technology, and sustainable development (Yu and Tsai, 2018). Through bilateral trade with China, RCEP countries can benefit from the spillover of Chinese technology, introduce and apply advanced environmental protection technologies, and thus facilitate the process of pollution and carbon reduction. Secondly, bilateral trade between China and RCEP countries can incentivize enterprises to adopt more environmentally friendly production methods and supply chain management, promoting the reduction of pollution and carbon emissions. Thirdly, China is one of the largest sources of foreign direct investment in the world. RCEP countries can attract more foreign investment and advance green development, pollution and carbon reduction projects and industries through bilateral trade with China.

As mentioned above, scholars have conducted extensive research on the relationship between trade openness, economic growth, as well as pollution and carbon reduction from different perspectives. Reviewing the existing literature, it is found that current research has mainly focused on the impact of trade openness on China's economic growth or environmental quality, while there is relatively little research has been done on the impact of bilateral trade with China on the economic growth or pollution and carbon reduction of other nations. Therefore, based on the Panel data of RCEP countries, this paper uses a combination of theoretical and empirical methods to evaluate the synergistic effect of "pollution and carbon reduction" and "economic growth" of bilateral trade.

3 Methodology and data

3.1 Model settings

In order to test the impact of bilateral trade between China and RCEP countries on economic growth and pollution and carbon reduction, a multivariate linear regression model is constructed in this paper. The balanced panel data for the RCEP countries from 1997 to 2020 is selected. The model is set up as shown in Equation 1:

$$y_{it} = \alpha_0 + \alpha_1 ctra_{it} + \sum_{j}^{T} \alpha_{j=2} control_{it}^{j} + \gamma_i + \delta_t + \varepsilon_{it} \quad (1)$$

where i and t represent country and year, respectively, y_{it} is the dependent variable of this paper, including economic growth ($pgdp_{it}$), environmental quality ($pm2.5_{it}$), and carbon emissions (pco_{it}), $ctra_{it}$ conveys the bilateral trade between China and RCEP countries, which is the core explanatory variable, $control_{it}^{j}$ is a set of control variables, including urbanization (urb_{it}), population density (pde_{it}), foreign investment openness (fdi_{it}), natural resource endowment (res_{it}), and government governance level (wgi_{it}), γ_i and δ_t represent national fixed effects and time fixed effects, respectively, ε_{it} is the random error term.

3.2 Variables

3.2.1 Dependent variables

The dependent variables include economic growth ($pgdp$), environmental quality ($pm2.5$) and carbon emissions (pco).

We adopt real *per capita* GDP as the proxy variable for economic growth, which is the most direct and widely accepted indicator to measure the level of economic development in a country or region (Zhang and Wang, 2023). The growth of *per capita* GDP reflects the overall scale of economic activity and the average living standard of residents, which is crucial for understanding how trade promotes or hinders economic growth.

PM2.5 concentration is chosen as the measure of environmental quality due to its status as a primary component of air pollution that directly affects human health and environmental quality (Sahoo and Sethi, 2022). With the acceleration of industrialization and urbanization, PM2.5 pollution has become a global environmental concern, and its level changes can intuitively reflect the potential impact of trade activities on environmental quality.

Per capita carbon dioxide emissions serve as the proxy variable for carbon emissions, reflecting energy consumption and greenhouse gas emissions in economic activities (Liu et al., 2023). Trade activities often accompany the cross-border flow of goods and services, significantly impacting carbon emissions. Therefore, including carbon emissions in our study is essential for understanding the relationship between trade and climate change.

3.2.2 Core explanatory variable

The core explanatory variable is bilateral trade ($ctra$), with 1997 as the base period and the actual trade volume between China and RCEP members as the proxy variable for bilateral trade. Bilateral trade is chosen as the core explanatory variable because it is a crucial driver of economic interactions between nations (Wang and Tao, 2024). Given the focus of our study on China and RCEP countries, the volume of trade between these partners provides a direct measure of economic engagement. Changes in bilateral trade can significantly impact the economic growth prospects, environmental pressures, and carbon emissions of both parties.

3.2.3 Control variables

The control variables include several items. This paper draws on the research of Wang Q. et al. (2018), Khan et al. (2019), Hamid et al.

(2022), as well as Li and Zhang (2023), and selects the following indicators that will simultaneously affect economic growth, environmental quality, and carbon emissions as the control variables.

Urbanization (*urb*): The proportion of urban population to total population captures the process of urbanization, which is known to drive both economic growth and environmental changes. Rapid urbanization often leads to increased industrialization, consumption patterns, and resource use, all of which can affect both economic prosperity and environmental degradation. Therefore, urbanization is an essential control variable to account for its confounding effects.

Population Density (*pde*): Population density measures the distribution of people across a given area. High population density areas tend to experience greater environmental pressures due to increased demand for resources and services. At the same time, these areas also often exhibit higher levels of economic activity and potential for technological advancements that can mitigate environmental impacts. Including population density as a control variable ensures that the estimated effects of bilateral trade are not merely reflecting differences in population distribution.

Foreign Investment Openness (*fdi*): The proportion of actual utilization of foreign investment to GDP reflects a country's openness to and integration with the global economy. There is a notable relationship between a country's participation in global value chains and its carbon emissions (Olasehinde-Williams and Özkan, 2023). Meanwhile, FDI, as a vital means for multinational corporations to organize global production networks, contributes to enhancing the host country's participation in global value chains (Zhao et al., 2023). FDI can bring in capital, technology, and knowledge that contribute to economic growth but may also lead to the transfer of polluting industries, thereby affecting environmental quality and carbon emissions. Controlling for FDI is crucial to disentangle its potential confounding effects from those of bilateral trade.

Resource Endowment (*res*): Measured by the proportion of total natural resource rent to GDP, resource endowment captures a country's abundance of natural resources (Xiong and Wang, 2018). Resource-rich countries often rely heavily on resource extraction for economic growth, which can have adverse effects on the environment and lead to the so-called "resource curse." Including resource endowment as a control variable helps isolate the unique impact of bilateral trade on economic growth and environmental outcomes, net of the effects stemming from a country's natural resource base.

Government Governance (*wgi*): The World Governance Indicators (WGI) offer a comprehensive assessment of a country's governance quality across six dimensions: political stability, corruption control, government effectiveness, regulatory quality, rule of law, and voice and accountability. Effective governance is essential for sustainable economic growth and environmental protection. By averaging these six sub-indicators, we capture the overall level of government governance, which is crucial in shaping policies and institutions that influence economic outcomes and environmental behaviors (Yuan et al., 2018). Controlling for governance quality is essential to isolate the impact of bilateral trade from that of the broader institutional and political environment.

TABLE 1 Descriptive statistics.

Variables	Obs	Mean	Std. Dev	Min	Max
pgdp	336	7.935	2.197	3.743	10.967
pm2.5	336	21.797	10.258	5.903	44.056
pco	336	6.048	5.574	0.150	19.500
ctra	336	13.287	2.488	6.626	17.507
urb	336	3.956	0.517	2.894	4.605
pde	336	4.749	1.743	0.880	8.993
fdi	336	0.913	1.226	−4.742	3.471
res	336	0.083	2.988	−8.693	3.563
wgi	336	0.226	1.012	−1.752	1.865

3.3 Data and descriptive statistics

This article focuses on 14 RCEP members over the period 1997 to 2020. Per capita carbon dioxide emissions data were collected from the IEA database, bilateral trade data between China and other countries were sourced from the China Statistical Yearbook, government governance data were sourced from the WGI database, and other variable data were collected from the World Bank's WDI database. Individual missing data shall be filled with Linear interpolation method. The descriptive statistics of variables are shown in Table 1.

4 Results and discussion

4.1 Benchmark regression

This paper employs the stepwise law of return method to examine the impact of bilateral trade on economic growth, environmental quality and carbon emissions of RCEP countries. Drawing on the approach of Fang (2023), in order to control for the effects of factors that do not change over time, we adopt a bidirectional fixed effect model for regression. Columns (1), (3), and (5) of Table 2 show the results without the addition of control variables, while columns (2), (4), and (6) show the results with the addition of control variables. The results of columns (1)–(2) indicate that bilateral trade significantly promotes the economic development of RCEP countries. The results of columns (3)–(4) convey that the coefficient of bilateral trade is significantly negative, meaning that bilateral trade has suppressed the deterioration of environmental quality in RCEP countries. The results of columns (5)–(6) imply that the coefficient of bilateral trade is positive, but it did not pass the 10% significance level test, showing that the influence of bilateral trade on carbon emissions in RCEP countries is not significant. Based on the above results, although bilateral trade has stimulated the economic development of RCEP countries and suppressed their environmental quality deterioration, it has not had a significant impact on carbon emissions. This indicates that bilateral trade has played a synergistic effect of "pollution reduction" and "economic growth", and there is still uncertainty about the "carbon reduction" effect.

TABLE 2 Benchmark results.

Variables	pgdp		pm2.5		pco	
	(1)	(2)	(3)	(4)	(5)	(6)
ctra	0.229***	0.262***	−0.473***	−0.706***	0.173	0.218
	(9.40)	(10.76)	(-3.06)	(-4.50)	(1.26)	(1.59)
urb		−0.558***		−2.009**		3.797***
		(-4.09)		(-2.28)		(4.95)
pde		−0.915***		7.046***		−2.129
		(-3.61)		(4.32)		(-1.49)
fdi		0.036***		0.159*		−0.157**
		(2.74)		(1.89)		(-2.13)
res		−0.143***		0.239		−0.312**
		(-5.75)		(1.49)		(-2.23)
wgi		−0.059		−0.902**		1.032***
		(-0.89)		(-2.09)		(2.74)
Constant	5.285***	11.211***	27.786***	5.922	3.665**	−1.738
	(17.99)	(8.46)	(14.85)	(0.69)	(2.21)	(-0.23)
Country effect	Yes	Yes	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.7083	0.7499	0.7062	0.7421	0.1138	0.2490
N	336	336	336	336	336	336

Note: ****, **, *respectively indicate significant at the 1%, 5%, and 10% levels, and the values in () are the corresponding t-statistic.

TABLE 3 Robustness results.

Variables	GDP	Ecological footprint	Carbon footprint
	(1)	(2)	(3)
ctra	0.257***	−0.176*	−0.032
	(10.50)	(-1.96)	(-0.58)
Control variables	Yes	Yes	Yes
Country effect	Yes	Yes	Yes
Time effect	Yes	Yes	Yes
R^2	0.8341	0.2461	0.1921
N	336	336	336

Note: ****, **, *respectively indicate significant at the 1%, 5%, and 10% levels, and the values in () are the corresponding t-statistic.

4.2 Robust test

To examine the reliability and robustness of the benchmark results mentioned above, this paper reconducts empirical estimation from the perspective of replacing the dependent variable. First, referring to the method of Huang et al. (2022), real GDP was used to characterize economic development. The results are shown in column (1) of Table 3. It can be found that the coefficient of bilateral trade on the economic development of RCEP countries is still significantly positive, conveying that the conclusion that bilateral trade can enhance the economic development of RCEP countries is robust. Then, drawing on the research of Aydin et al. (2019), ecological footprint can better measure the sustainability of the ecological environment. Therefore, we use ecological footprint as the proxy variable of environmental quality (Wang and Dong, 2019; Sui and Chen, 2021). The results are shown in column (2) of Table 3. Bilateral trade has substantially curbed the expansion of ecological footprints,

TABLE 4 Heterogeneity test results.

Variables	ASEAN countries			Non-ASEAN countries		
	pgdp	*pm2.5*	*pco*	*pgdp*	*pm2.5*	*pco*
	(1)	(2)	(3)	(4)	(5)	(6)
ctra	0.241***	−0.634***	0.197	0.237**	1.769**	−0.334
	(8.42)	(-3.51)	(1.37)	(2.25)	(2.62)	(-0.45)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Country effect	Yes	Yes	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.7402	0.7632	0.3163	0.9175	0.8739	0.7140
N	240	240	240	96	96	96

Note: ****, **, *respectively indicate significant at the 1%, 5%, and 10% levels, and the values in () are the corresponding t-statistic.

implying that bilateral trade is robust in curbing the deterioration of environmental quality. Finally, according to the research of Sun and Shen (2016), the carbon footprint index is employed to represent carbon emissions. The calculation of the carbon footprint is conducive to formulating targeted emission reduction strategies (Fenner et al., 2018). The results of column (3) in Table 3 show that the coefficient of bilateral trade is not significant, indicating that bilateral trade has no considerable influence on the carbon footprint of RCEP countries, which supports the robustness of the above benchmark results.

4.3 Heterogeneity test

The above empirical results suggest that, overall, bilateral trade significantly boosts economic growth and dampens environmental quality deterioration in RCEP countries, but does not play a role in reducing carbon emissions. Are there, then, differences in this result between different types of countries? To answer this question, this paper will examine the heterogeneous impact of bilateral trade on “pollution and carbon reduction” and “economic growth” from the perspective of location characteristics. The RCEP membership is made up of 15 countries, including China, Japan, South Korea, New Zealand, Australia and ten ASEAN countries. Given that this article focuses on bilateral trade between China and RCEP countries, the total sample is divided into ASEAN countries (10 countries) and non-ASEAN countries (4 countries) based on location and economic characteristics. Of these, all the countries in the ASEAN group, except Singapore, are developing countries, while the samples in the non-ASEAN group are developed countries.

Table 4 columns (1)–(3) report the estimated results of the ASEAN group of countries, while columns (4)–(6) state the results of the non-ASEAN group of countries. By comparing the coefficients of bilateral trade in columns (1) and (4), it was found that bilateral trade has a considerable positive effect on economic growth in both ASEAN and non-ASEAN nations. Bilateral trade has a greater economic growth effect in ASEAN countries compared to non-ASEAN countries. The possible reason is that ASEAN countries are still in the development stage in some industrial fields and have a high demand for technology and knowledge. As a leading country in manufacturing and technological innovation, China possesses advanced technology and professional knowledge. Through bilateral trade, China can transfer technology and knowledge to ASEAN countries, facilitating their industrial upgrading and economic development. In addition, there are certain similarities in cultural backgrounds and business habits between China and ASEAN countries, which helps both parties to establish and develop business cooperation relationships more easily (Ruan et al., 2022). The results of columns (2) and (5) reflect that bilateral trade has improved the environmental quality of ASEAN countries, while deteriorating the environmental quality of non-ASEAN countries. The explanation given in this article is that through trade cooperation with ASEAN countries, China can spread environmental protection technologies to ASEAN countries, helping them increase environmental quality. In addition, Chinese enterprises can also introduce advanced environmental protection equipment and technology into ASEAN countries to optimize their environmental governance level (Wang and Gao, 2019). Compared with developed countries, China’s environmental standards may be relatively low. If Chinese products cause more pollution to the environment during the production process, which leads to a deterioration of the environmental quality in developed countries. From the results of columns (3) and (6), it was found that the coefficients of bilateral trade did not pass the 10% significance level, indicating that bilateral trade did not have carbon reduction effects in both ASEAN and non-ASEAN groups.

4.4 Mechanism verification

The previous analysis shows that although bilateral trade has advanced economic growth and environmental quality in RCEP countries, it has no obvious impact on local carbon emissions. Considering that bilateral trade may reduce regional carbon emissions by technological innovation and encourage the level of information infrastructure, it may also increase regional carbon emissions by supporting industrialization. This paper aims to identify and examine these two pathways of action. Referring to

TABLE 5 Mechanism verification results.

Variables	Technological innovation	Information infrastructure	Industrialization
	(1)	(2)	(3)
ctra	0.154***	9.136***	2.144***
	(3.25)	(6.37)	(3.20)
Control variables	Yes	Yes	Yes
Country effect	Yes	Yes	Yes
Time effect	Yes	Yes	Yes
R^2	0.5995	0.8514	0.1624
N	336	336	336

Note: ****, **, *respectively indicate significant at the 1%, 5%, and 10% levels, and the values in () are the corresponding t-statistic.

the practices of Jiang and Luo (2022) and Zhang et al. (2023), Equation 2 is constructed for mechanism validation:

$$z_{it} = \beta_0 + \beta_1 ctra_{it} + \sum_{j}^{T}\beta_{j=2} control_{it}^{j} + \gamma_i + \delta_t + \varepsilon_{it} \quad (2)$$

where z_{it} is a mechanism variable, which is used to examine the relationship between mechanism and core explanatory variables, including technological innovation, information infrastructure and industrialization level. And separately adopt the number of patent applications, internet penetration rate, and industrial value added/ GDP as proxy variables for the above three. According to the existing literature, if β_1 is significant and the sign is positive, information infrastructure will restrain carbon emissions (Chen et al., 2023; Xie et al., 2023), and industrial development boost carbon emissions (Wang S. et al., 2018), it indicates that bilateral trade can affect carbon emissions of RCEP countries via z_{it}, but the direction of its impact is uncertain.

Table 5 reports the results of mechanism testing. It is not difficult to find that bilateral trade suppresses carbon emissions by stimulating technological innovation and information infrastructure in RCEP countries, while bilateral trade encourages carbon emissions via supporting industrialization in RCEP countries. Based on the analysis of the two opposite pathways mentioned above, it is once again evident that the "carbon reduction" effect of bilateral trade on RCEP countries is not significant.

4.5 Further discussion

4.5.1 Preliminary preparation of PVAR model

With the aim of studying the dynamic interaction among bilateral trade, economic growth and environmental quality, this paper constructs a panel vector autoregression (PVAR) for analysis. The PVAR model does not require presetting causal relationships between variables and distinguishing between endogenous and exogenous. Instead, all variables are treated as endogenous variables, and the interaction between each variable and the lagged term is analyzed. The model is set up as follows in Equation 3:

TABLE 6 Root of unity test results.

Test	$ctra_{it}$		*pgdp*		*pm2.5*	
	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
LLC	−0.51	−9.80***	−0.47	−9.19***	1.41	−7.41***
IPS	−0.47	−8.29***	−3.87***	−9.28***	1.89	−9.26***
HT	−2.57***	−21.48***	−6.69***	−20.73***	−0.26	−30.13***
ADF	34.89	202.90***	47.57**	197.68***	9.09	153.51***

Note: ****, **, *respectively indicate significant at the 1%, 5%, and 10% levels.

$$Y_{it} = \alpha_0 + \sum_{j=1}^{k}\alpha_j Y_{i,t-j} + \beta_i + \gamma_t + \quad (3)$$

where Y_{it} is a column vector that includes bilateral trade, economic growth, and environmental quality, α_j represents the coefficient matrix of the lagging variable, β_i is the country effect column vector, reflecting individual differences in cities, γ_t represents a dummy variable of time effect, reflecting the impact of time changes on different cities, ε_{it} is a random perturbation term.

To ensure the accuracy of model estimation and avoid the phenomenon of "pseudo regression", we conducted stationarity tests on three variables: bilateral trade, economic growth, and environmental quality. Referring to the research of Wang and Xiang (2022), this paper selects LLC test, IPS test, HT test and ADF test to investigate whether there is a Root of unity in variables. See Table 6 for the results. It can be seen that bilateral trade, economic growth, and environmental quality cannot be completely significant at the 10% level, conveying that all three variables are unstable. However, after first-order difference processing, all variables passed the 1% significance test, indicating that bilateral trade, economic growth, and environmental quality are in a first-order single integer sequence. In order to further test whether there is a long-term stable equilibrium relationship among the three variables, this article employs the Kao test to conduct cointegration tests on the data after the first-order difference of all variables. The Kao test results reply that the t-statistic value

TABLE 7 Selection of optimal lag order.

Lag order	CD	J	J *p*-value	MBIC	MAIC	MQIC
1	0.999	49.559	0.005	−101.195[a]	−4.441	−43.311[a]
2	0.999	30.787	0.030	−69.716	−5.213[a]	−31.127
3	0.999	15.336	0.082	−34.915	−2.664	−15.621

Note: [a]represents the optimal lag order selected based on MBIC, MAIC, and MHQIC, criteria.

TABLE 8 GMM estimation results of PVAR model.

Variables	h_Dctra	h_Dpgdp	h_D pm2.5
L.h_Dctra	0.943***	0.221***	−0.080***
	(22.50)	(6.07)	(-3.52)
L.h_Dpgdp	0.067	0.202	0.089
	(0.48)	(1.15)	(0.79)
L.h_Dpm2.5	0.012	−0.037*	1.122***
	(1.02)	(-1.85)	(29.68)

Note: ***, **, *respectively indicate significant at the 1%, 5%, and 10% levels. The data in () is the z-statistic.

of ADF is −10.832, and the P-value is 0.000, which rejects the original hypothesis, meaning a stable equilibrium relationship between bilateral trade, economic growth, and environmental quality.

Before conducting PVAR model estimation, it is necessary to determine the optimal lag order of the model. Drawing on the approach of Yan and Wu (2016), this article uses MBIC, MAIC, and MQIC to determine the lag order. According to the results in Table 7, the first order PVAR model has the smallest MBIC and MQIC, while the second order PVAR model has the smallest MAIC. Therefore, the lag order of the PVAR model is determined to be 1 through comprehensive evaluation.

4.5.2 GMM estimation results

After determining the root of unity test and the optimal lag order, this paper studies the relationship between bilateral trade, economic growth and environmental quality based on generalized method of moments (GMM). GMM estimation is a parameter estimation technique used to estimate the parameters within a PVAR model. The GMM estimation method for PVAR models enables the precise estimation of autoregressive coefficients, cross-correlation coefficients, and their corresponding confidence intervals for each variable, thereby uncovering the immediate and long-term dynamic relationships among variables. Furthermore, it captures the long-run equilibrium trends of the model, providing a solid foundation for forecasting the future states of variables. Additionally, the models constructed using this estimation method serve as potent instruments for economic simulations and policy impact analyses. Table 8 reports the estimated results of GMM. The results show that bilateral trade with a lag of one order has a substantial boosting effect on its current level, implying that the increase in bilateral trade has a certain inertia. When economic growth is taken as the dependent variable, lagged first-order bilateral trade has a considerable positive influence on current economic growth. However, the higher the PM2.5 value of lagged first-order, the less conducive it is to economic growth, indicating that the improvement of lagged first-order environmental quality is conducive to increasing the current economy. The development of environmental protection industries can create more job opportunities (Panwar et al., 2011). For example, developing renewable energy, clean technology, and environmental monitoring, so as to attract a large number of highly skilled and value-added employment opportunities and propel economic growth. When PM2.5 is used as the dependent variable, the coefficient of lagged first-order bilateral trade is significantly negative, indicating that the previous period's bilateral trade improved the current environmental quality. The lagging first-order PM2.5 has a considerable promoting effect on the current PM2.5, indicating that the optimization of environmental quality has a sustained characteristic. Environmental problems are often the result of long-term accumulation and impact. Only through continuous environmental protection measures, monitoring, and management can we achieve continuous improvement of environmental quality and sustainable development.

4.5.3 Impulse response analysis

To visually display the response mechanism between bilateral trade, economic growth, and environmental quality, we adopt pulse response graphs for analysis. The impulse response approach is to characterize the current and future dynamic response of a standardized shock on the error term of one variable against another, while keeping the other variables under control. The pulse response function is shown in Figure 1. It can be observed that all impulse response plots exhibit a convergence trend, indicating that the model has stability.

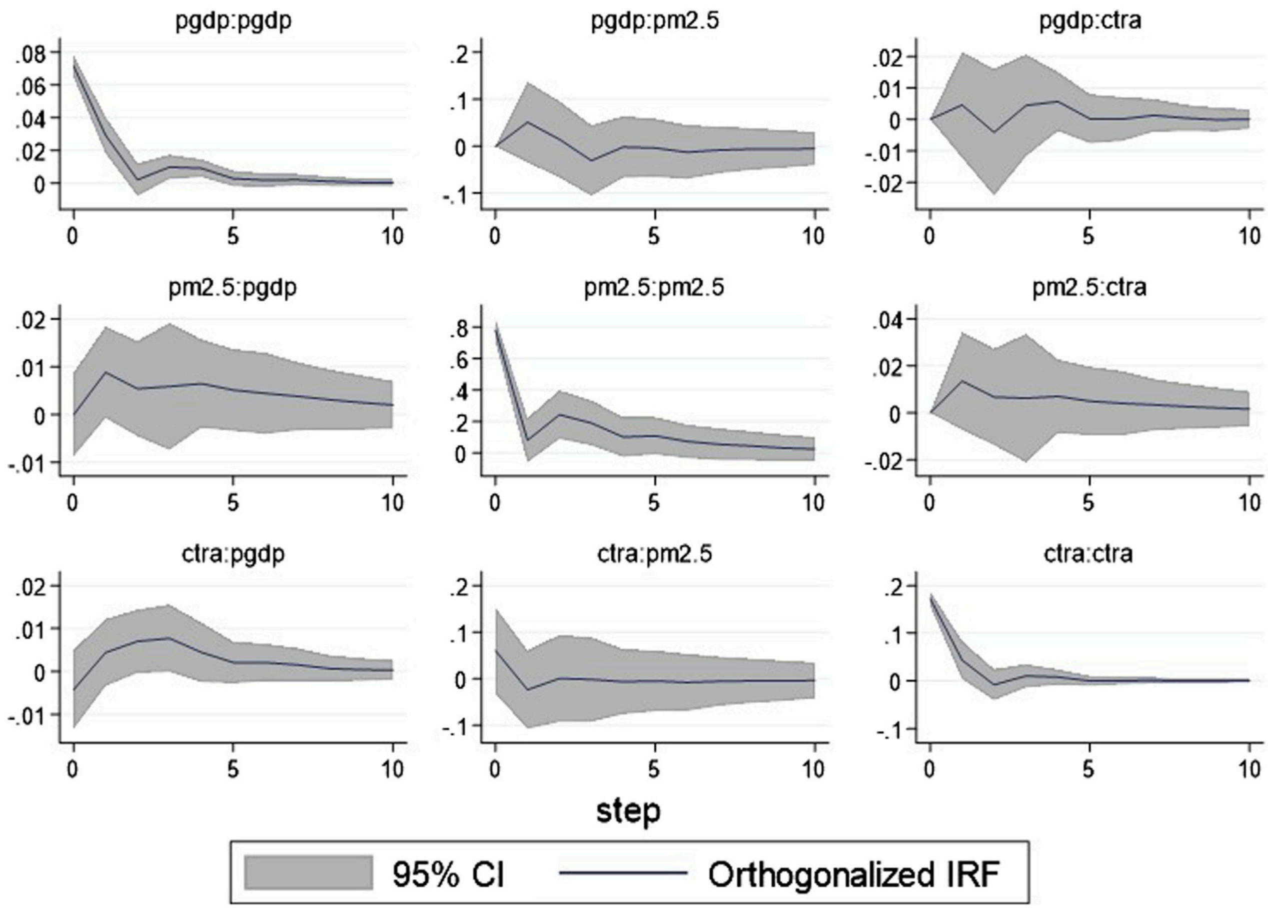

FIGURE 1
Pulse response diagram.

When economic growth is affected by one standard deviation, it can exhibit an obvious positive impact on itself, followed by a rapid decline. In the third period, there is a weak fluctuation around the zero axis, until the influence on itself approaches zero in the fifth period. After being impacted by the standardization of economic growth, PM2.5 experienced a strong positive reaction in the first phase, with the reaction intensity reaching its maximum. Later, it drops to the third phase and becomes a negative response, fluctuating around the null axis. In the sixth phase, the effect largely disappears, meaning that economic growth initially causes environmental deterioration, and over time, economic growth improves environmental quality. Bilateral trade showed a weak positive response when affected by economic growth, then decreased to a negative response in the second period, and rapidly increased to a positive response in the third period, until the impact in the fifth period basically disappeared, which implies that economic growth has a sustained effect on environmental quality and bilateral trade in the long run.

When PM2.5 is influenced by a standard deviation, it promptly exhibits a strong positive effect on itself, with the impact value reaching its maximum, and then rapidly decreasing to become negative. In the second phase, there is a small increase followed by a gradual decrease until it approaches 0 in the sixth phase. When economic growth and bilateral trade are affected by PM2.5, the reaction is mostly consistent. In the first phase, there is a positive reaction, and the reaction intensity reaches its maximum. It then decreases to the second phase and stabilizes, and gradually decreases to the null axis in the fourth phase. This denotes that improving environmental quality is not conducive to economic growth and bilateral trade in the initial stage, while over time, environmental quality will have a positive effect on both.

When bilateral trade is affected by a standard deviation, it speedily shows an obvious positive impact on itself, followed by a rapid decline. In the third period, it begins to fluctuate weakly around the null axis, until the effect on itself approaches zero in the fifth period. When economic growth is impacted by bilateral trade, it straightaway exhibits a negative response, and then rapidly increases to a positive influence in the first period. By the third period, the positive response reaches its maximum and begins to decline until the effects of the fifth period disappears. When PM2.5 is influenced by bilateral trade, it instantaneously shows a positive response, and then rapidly decreases to a negative impact in the first phase. In the second phase, it shows a slight increase and approaches zero, indicating that the influence of bilateral trade on environmental quality is relatively short-lived.

5 Conclusions and policy recommendations

5.1 Conclusions

The parallel pursuit of "pollution and carbon reduction" alongside "economic growth" not only aligns with sustainable development goals but also fosters green economic transformation, enhancing resource efficiency, innovation, and international competitiveness. Employing panel data from China and RCEP member countries, this study examines the intricate interplay between bilateral trade, economic growth, and environmental quality. The key conclusions are:

(1) Bilateral trade significantly boosts economic growth and environmental quality in RCEP nations, yet its impact on carbon emissions is nuanced. It curbs emissions through technological innovation and information infrastructure improvements but exacerbates them via industrialization. Thus, the net "carbon reduction" effect hinges on the balance of these competing forces.
(2) The effects of bilateral trade vary across RCEP regions. Trade with ASEAN nations more robustly drives economic growth, while environmental benefits are concentrated in ASEAN, with non-ASEAN countries experiencing deterioration. Both regions show minimal direct impact on carbon emissions from trade.
(3) The PVAR model reveals inertia in bilateral trade's growth-enhancing and environmental quality-improving effects. Lagged bilateral trade and environmental improvements positively influence current economic growth, underscoring the need for sustained efforts.
(4) Pulse response analysis indicates that initial economic growth can temporarily compromise environmental quality, but over time, it improves environmental outcomes. Conversely, while initial environmental gains may not immediately bolster trade or growth, they eventually do so. Bilateral trade's environmental impact is relatively short-lived, necessitating continuous attention.

5.2 Policy recommendations

Building on these findings, the following practical implications and recommendations aim to guide decision-making, managerial practices, and policy development in RCEP countries:

(1) Harmonized Environmental Standards. Recognizing the win-win potential of environmentally friendly trade, RCEP partners should establish uniform environmental standards and certification mechanisms. This includes promoting technologies that reduce pollution, enhance energy efficiency, and foster circular economies. Strengthening environmental information sharing and communication will facilitate joint efforts to tackle environmental challenges and ensure trade aligns with sustainability goals.
(2) Technological Cooperation and Digital Transformation. China and RCEP countries should collaborate on technological innovation, particularly in low-carbon and environmentally friendly technologies. Policy incentives such as financial support, intellectual property protection, and tax benefits can spur R&D cooperation. Digitalization and internet infrastructure upgrades can improve efficiency, reduce emissions, and support sustainable trade practices. Establishing rigorous carbon management systems, including emission standards and monitoring, is crucial to mitigating industrialization's carbon footprint.
(3) Tailored Cooperation Strategies. Given regional heterogeneity, China and ASEAN should deepen trade ties beyond traditional sectors, focusing on high-value environmental technologies, green agriculture, and renewable energy. China can offer environmental technology assistance, transfers, training, and financial support to ASEAN, fostering bilateral cooperation and addressing shared environmental challenges. Encouraging corporate social responsibility projects in ASEAN will further strengthen sustainable trade ties.

Some study limitations must be considered when interpreting our findings. Firstly, while we have initially explored the varied impacts of bilateral trade on economic growth and environmental pollution in different regions within RCEP countries (such as ASEAN and non-ASEAN countries), this analysis has not delved into more specific country-level or industry-level details. Secondly, in examining the potential mechanisms behind why bilateral trade has not effectively reduced carbon emissions, we have utilized a mechanism test encompassing two pathways, but there may still be other complex factors or pathways that have been overlooked. In our future research, we will firstly refine our analysis further to delve into the specific impacts of bilateral trade on economic growth and environmental pollution across different countries and industries, as well as the underlying reasons behind these impacts. Secondly, we will introduce additional variables and pathways, such as technology spillover effects, the intensity of environmental regulations, and changes in consumer preferences, to more comprehensively reveal the complex mechanisms through which bilateral trade affects carbon emissions reduction.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

YW: Conceptualization, Methodology, Project administration, Resources, Writing–review and editing. RS: Software, Supervision, Writing–review and editing. CG: Conceptualization, Data curation, Methodology, Software, Writing–original draft. SY: Funding acquisition, Resources, Visualization, Writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Arvin, M. B., Pradhan, R. P., and Nair, M. (2021). Uncovering interlinks among ICT connectivity and penetration, trade openness, foreign direct investment, and economic growth: the case of the G-20 countries. *Telematics Inf.* 60, 101567. doi:10.1016/j.tele.2021.101567

Aydin, C., Esen, Ö., and Aydin, R. (2019). Is the ecological footprint related to the Kuznets curve a real process or rationalizing the ecological consequences of the affluence? Evidence from PSTR approach. *Ecol. Indic.* 98, 543–555. doi:10.1016/j.ecolind.2018.11.034

Bai, C., Xie, D., and Zhang, Y. (2024). Industrial land transfer and enterprise pollution emissions: evidence from China. *Econ. Analysis Policy* 81, 181–194. doi:10.1016/j.eap.2023.11.029

Cai, X., Liu, Q., and Peng, Q. (2022). International environmental regulation, trade liberalization, and enterprise pollution reduction: evidence from China. *Front. Ecol. Evol.* 10, 965484. doi:10.3389/fevo.2022.965484

Chang, R., Kaltani, L., and Loayza, N. V. (2009). Openness can be good for growth: the role of policy complementarities. *J. Dev. Econ.* 90 (1), 33–49. doi:10.1016/j.jdeveco.2008.06.011

Chen, F. L., and Chen, A. Z. (2021). Research on the development mechanism of RCEP regional industrial chain—on the upgrading path of China's industrial chain. *Economist* (06), 70–80. doi:10.16158/j.cnki.51-1312/f.2021.06.008

Chen, X., Rahaman, M. A., Murshed, M., Mahmood, H., and Hossain, M. A. (2023). Causality analysis of the impacts of petroleum use, economic growth, and technological innovation on carbon emissions in Bangladesh. *Energy* 267, 126565. doi:10.1016/j.energy.2022.126565

Copeland, B. R., and Taylor, M. S. (1997). The trade-induced degradation hypothesis. *Resour. Energy Econ.* 19 (4), 321–344. doi:10.1016/s0928-7655(97)00015-8

Dai, L. H. (2017). How trade openness affects PM2. 5—causal effect studies based on heating policy differences between the two sides of Huai River. *Manag. Rev.* 29 (05), 237–245. doi:10.14120/j.cnki.cn11-5057/f.2017.05.022

Du, S. Y., and Liu, Y. P. (2023). Service sector opening, resource misallocation, and value chain upgrading—empirical study based on Chinese manufacturing micro-enterprises. *J. Int. Trade* (06), 34–51. doi:10.13510/j.cnki.jit.2023.06.005

Esty, D. C., and Dua, A. (1997). Sustaining the Asia Pacific miracle: environmental protection and economic integration. *Asia Pac. J. Environ. Law* 3 (1), 150–152. doi:10.1111/0017-4815.00107

Fang, D. L. (2023). Impact of digital economy on energy utilization efficiency of Chinese cities from the perspective of technology empowerment and spillover. *Resour. Sci.* 45 (02), 296–307. doi:10.18402/resci.2023.02.05

Fang, J., Ou, J., and Yao, S. (2022). On COVID-19 pandemic and China's foreign trade. *World Econ.* 45 (11), 3507–3533. doi:10.1111/twec.13269

Fenner, A. E., Kibert, C. J., Woo, J., Morque, S., Razkenari, M., Hakim, H., et al. (2018). The carbon footprint of buildings: a review of methodologies and applications. *Renew. Sustain. Energy Rev.* 94, 1142–1152. doi:10.1016/j.rser.2018.07.012

Frankel, J. A., and Rose, A. K. (2005). Is trade good or bad for the environment? Sorting out the causality. *Rev. Econ. Statistics* 87 (1), 85–91. doi:10.1162/0034653053327577

Hamid, I., Alam, M. S., Kanwal, A., Jena, P. K., Murshed, M., and Alam, R. (2022). Decarbonization pathways: the roles of foreign direct investments, governance, democracy, economic growth, and renewable energy transition. *Environ. Sci. Pollut. Res.* 29 (33), 49816–49831. doi:10.1007/s11356-022-18935-3

Huang, Z. H., Song, W. H., Ye, C. H., and Hu, W. B. (2022). The county economic growth effect of government support for migrant workers to return home for entrepreneurship: an examination based on the pilot policy of returning home for entrepreneurship. *Chin. Rural. Econ.* 2022 (01), 24–43.

Jiang, H., and Yu, M. (2021). Understanding RCEP and CPTPP: from the perspective China's dual circulation economic strategy. *China Econ. J.* 14 (2), 1–18. doi:10.1080/17538963.2021.1933055

Jiang, T., and Luo, Z. B. (2022). LOC102724163 promotes breast cancer cell proliferation and invasion by stimulating MUC19 expression. *China Ind. Econ.* 23 (05), 100–120. doi:10.3892/ol.2022.13220

Khan, H. U. R., Zaman, K., Usman, B., Nassani, A. A., Aldakhil, A. M., and Qazi Abro, M. M. (2019). Financial management of natural resource market: long-run and inter-temporal (forecast) relationship. *Resour. Policy* 63, 101452. doi:10.1016/j.resourpol.2019.101452

Khan, I., Hou, F., Le, H. P., and Ali, S. A. (2021). Do natural resources, urbanization, and value-adding manufacturing affect environmental quality? Evidence from the top ten manufacturing countries. *Resour. Policy* 72, 102109. doi:10.1016/j.resourpol.2021.102109

Kim, D. H., Suen, Y. B., and Lin, S. C. (2019). Carbon dioxide emissions and trade: evidence from disaggregate trade data. *Energy Econ.* 78, 13–28. doi:10.1016/j.eneco.2018.08.019

Lee, C. C., Olasehinde-Williams, G., and Gyamfi, B. A. (2023). The synergistic effect of green trade and economic complexity on sustainable environment: a new perspective on the economic and ecological components of sustainable development. *Sustain. Dev.* 31 (2), 976–989. doi:10.1002/sd.2433

Li, J., and Li, S. (2020). Energy investment, economic growth and carbon emissions in China—empirical analysis based on spatial Durbin model. *Energy Policy* 140, 111425. doi:10.1016/j.enpol.2020.111425

Li, K., and Qi, S. Z. (2011). Trade openness, economic growth and carbon dioxide emission in China. *Econ. Res. J.* 46 (11), 60–72+102.

Li, Y., Zhang, T. B., and Qi, P. F. (2020). Research on the impact of the local government's environmental protection constraint target on economic growth. *China Environ. Sci.* 40 (10), 4617–4630. doi:10.19674/j.cnki.issn1000-6923.2020.0513

Li, Y. Y., and Zhang, S. (2023). Spatio-temporal evolution of urban carbon emission intensity and spatio-temporal heterogeneity of influencing factors in China. *China Environ. Sci.* 43 (06), 3244–3254. doi:10.19674/j.cnki.issn1000-6923.20230104.001

Li, Z., Huang, Z., and Su, Y. (2023). New media environment, environmental regulation and corporate green technology innovation: evidence from China. *Energy Econ.* 119, 106545. doi:10.1016/j.eneco.2023.106545

Liu, Y., Zhang, J., and Geng, Y. (2023). Exports and carbon emissions from the perspective of global value chains: Re-examination of the inverted U-shaped relationship. *J. Int. Trade* (01), 90–107. doi:10.13510/j.cnki.jit.2023.01.005

Ma, J., Shi, J., Luo, D., and Che, Y. (2019). Effect of trade openness on regional economic growth in China: revisiting the discussion. *Appl. Econ. Lett.* 26 (16), 1313–1316. doi:10.1080/13504851.2018.1558331

Olasehinde-Williams, G., and Folorunsho, A. (2023). Environmental policy, green trade and sustainable development in Europe: new perspective on the Porter hypothesis. *Energy and Environ.*, 0958305X231193870. doi:10.1177/0958305x231193870

Olasehinde-Williams, G., and Özkan, O. (2023). A consideration of the environmental externality of Turkey's integration into global value chains: evidence from dynamic ARDL simulation model. *Environ. Sci. Pollut. Res.* 30 (11), 29154–29163. doi:10.1007/s11356-022-24272-2

Panwar, N. L., Kaushik, S. C., and Kothari, S. (2011). Role of renewable energy sources in environmental protection: a review. *Renew. Sustain. Energy Rev.* 15 (3), 1513–1524. doi:10.1016/j.rser.2010.11.037

Peng, Y., Ding, B. L., and Yang, B. Z. (2022). Simulation of the impact of RCEP cross-border data flow rules on China's economy. *J. Quantitative and Tech. Econ.* 39 (12), 69–89. doi:10.13653/j.cnki.jqte.2022.12.004

Ruan, W. X., Yu, X., Wang, S. Y., Zhao, T. C., and Liu, Y. Z. (2022). Exploration of China–ASEAN trade relations in the context of sustainable economic development—based on the Lotka–Volterra model. *Sustainability* 15 (1), 517. doi:10.3390/su15010517

Sahoo, M., and Sethi, N. (2022). The dynamic impact of urbanization, structural transformation, and technological innovation on ecological footprint and PM2.5: evidence from newly industrialized countries. *Environ. Dev. Sustain.* 24 (3), 4244–4277. doi:10.1007/s10668-021-01614-7

Schneider, L., and La Hoz Theuer, S. (2019). Environmental integrity of international carbon market mechanisms under the Paris Agreement. *Clim. Policy* 19 (3), 386–400. doi:10.1080/14693062.2018.1521332

Schneider, P. H. (2005). International trade, economic growth and intellectual property rights: a panel data study of developed and developing countries. *J. Dev. Econ.* 78 (2), 529–547. doi:10.1016/j.jdeveco.2004.09.001

Sui, J. L., and Chen, H. (2021). Research on the coordinated development path of ecological environment and economic growth coupling from the perspective of ecological footprint. *Finance and Trade Econ.* 42 (06), 54–70. doi:10.19795/j.cnki.cn11-1166/f.20210604.009

Sun, Y. Z., and Shen, L. (2016). Bibliometric analysis on research progress of four footprint methodologies in China. *J. Nat. Resour.* 31 (09), 1463–1473.

Tan, Y., and Sheng, D. (2022). Untangling the mechanism of how trade affect firm pollution: cleaner production or post-pollution abatement. *Nankai Econ. Stud.* (01), 39–55. doi:10.14116/j.nkes.2022.01.003

Tiwari, A. K., Nasreen, S., and Anwar, M. A. (2022). Impact of equity market development on renewable energy consumption: do the role of FDI, trade openness and economic growth matter in Asian economies? *J. Clean. Prod.* 334, 130244. doi:10.1016/j.jclepro.2021.130244

Walter, I., and Ugelow, J. L. (1979). Environmental policies in developing countries. *Ambio*, 102–109.

Wang, B., and Gao, K. (2019). Forty years development of China's outward foreign direct investment: retrospect and the challenges ahead. *China and World Econ.* 27 (3), 1–24. doi:10.1111/cwe.12278

Wang, J., and Dong, K. (2019). What drives environmental degradation? Evidence from 14 Sub-Saharan African countries. *Sci. Total Environ.* 656, 165–173. doi:10.1016/j.scitotenv.2018.11.354

Wang, M. C., and Xu, K. N. (2015). Trade openness, economic growth and CO2 emission in China: a GVAR analysis. *China Popul. Resour. Environ.* 25 (11), 52–58.

Wang, Q., Su, M., and Li, R. (2018). Toward to economic growth without emission growth: the role of urbanization and industrialization in China and India. *J. Clean. Prod.* 205, 499–511. doi:10.1016/j.jclepro.2018.09.034

Wang, S., Li, G., and Fang, C. (2018). Urbanization, economic growth, energy consumption, and CO2 emissions: empirical evidence from countries with different income levels. *Renew. Sustain. Energy Rev.* 81, 2144–2159. doi:10.1016/j.rser.2017.06.025

Wang, S. F., and Xiang, Y. Y. (2022). Urban sprawl, private traffic and haze pollution. *Chin. J. Environ. Manag.* 14 (02), 95–103. doi:10.16868/j.cnki.1674-6252.2022.02.095

Wang, Y., and Tao, Y. (2024). The effect of fluctuations in bilateral relations on trade: evidence from China and ASEAN countries. *Humanit. Soc. Sci. Commun.* 11 (1), 32–13. doi:10.1057/s41599-023-02525-w

Xie, H., Tan, X., Li, J., Qu, S., and Yang, C. (2023). Does information infrastructure promote low-carbon development? Evidence from the "Broadband China" pilot policy. *Int. J. Environ. Res. Public Health* 20 (2), 962. doi:10.3390/ijerph20020962

Xiong, B., and Wang, M. J. (2018). Study on the influencing factors of Chinese OFDI in countries along the "Belt and Road": based on spatial perspective. *J. Int. Trade* (02), 102–112. doi:10.13510/j.cnki.jit.2018.02.014

Yan, S. Q., and Wu, Q. (2016). Incoordination between urban expansion and urban population growth and their interaction. *China Popul. Resour. Environ.* 26 (11), 28–36.

Yu, H. C., and Tsai, B. Y. (2018). Environmental policy and sustainable development: an empirical study on carbon reduction among Chinese enterprises. *Corp. Soc. Responsib. Environ. Manag.* 25 (5), 1019–1026. doi:10.1002/csr.1499

Yuan, Q. G., Gao, C., and Yan, S. L. (2018). African governments' governance level and the location selection of Chinese enterprises' OFDI. *World Econ. Stud.* (10), 121–134+137. doi:10.13516/j.cnki.wes.2018.10.010

Zhang, Q., Qiu, B., and Sun, S. Q. (2023). Trade and welfare effects of liberalisation of trade in services under the RCEP. *J. World Econ.* 46 (06), 3–30. doi:10.19985/j.cnki.cassjwe.2023.06.001

Zhang, X. J., and Wang, Y. (2023). Prospects for economic growth under the long-range objective of socialist modernization: based on the measurement of the potential economic growth rate. *Soc. Sci. China* (04), 4–25+204.

Zhao, Y., Wang, S., Liu, X., and Tang, X. (2023). Effect of the logistics industry on the promotion of China's position in the global value chain: an international trade perspective. *Int. Rev. Econ. and Finance* 86, 834–847. doi:10.1016/j.iref.2023.03.029

Zhu, Y., and Lan, M. (2023). Digital economy and carbon rebound effect: evidence from Chinese cities. *Energy Econ.* 126, 106957. doi:10.1016/j.eneco.2023.106957

Zhuang, J. L., Chen, W., and Yang, X. (2022). International trade, place-based policies and long-term regional economic growth: a study into the "Third Front Construction" area. *Econ. Res. J.* 57 (11), 65–83.