frontiers | Frontiers in Environmental Science

TYPE Original Research
PUBLISHED 26 February 2025
DOI 10.3389/fenvs.2025.1522197

OPEN ACCESS

EDITED BY
Jiachao Peng,
Wuhan Institute of Technology, China

REVIEWED BY
Tao Yu,
Harbin Institute of Technology, China
Fei Li,
Zhongnan University of Economics and Law, China
An Pan,
Zhongnan University of Economics and Law, China
Renjun Shen,
Central China Normal University, China

*CORRESPONDENCE
Lei Lei,
leilei3157@163.com

RECEIVED 04 November 2024
ACCEPTED 05 February 2025
PUBLISHED 26 February 2025

CITATION
Xu H, Wang S and Lei L (2025) Does institutional innovation improve environmental performance? — a quasi-natural experiment based on China's service trade innovative development pilot policy.
Front. Environ. Sci. 13:1522197.
doi: 10.3389/fenvs.2025.1522197

Does institutional innovation improve environmental performance? — a quasi-natural experiment based on China's service trade innovative development pilot policy

Han Xu[1,2], Siqi Wang[1,2] and Lei Lei[3]*

[1]School of Management, Hubei University of Chinese Medicine, Wuhan, China, [2]Research Center for the Development of Traditional Chinese Medicine, Key Research Institute of Humanities and Social Sciences of Hubei Province, Wuhan, China, [3]Quality and Education Teaching Supervision and Management Office, Wuhan Railway Vocational College of Technology, Wuhan, China

This study employs Chinese urban panel data and a staggered difference-in-differences (DID) model to investigate the effects of China's service trade innovative development pilot policy on environmental performance and its underlying mechanisms. The findings indicate that institutional innovation in the service trade sector substantially enhances regional environmental performance, and this conclusion remains valid after a series of validity tests and robustness tests. The mechanism test results show that institutional innovation can improve environmental performance mainly by promoting green innovation ability and industrial structure upgrading. Heterogeneity analysis found that regions with greater government support, a higher level of service industry development, and a higher degree of openness were more likely to rely on institutional innovation to improve their environmental performance. This research offers valuable policy insights for advancing institutional innovation in service trade and formulating pollution control strategies in China and other developing nations.

KEYWORDS

environmental protection, institutional innovation, service trade, environmental performance, green development

1 Introduction

In recent years, with the rapid development of global service trade, more and more countries have realized the key role of service trade in promoting economic growth, industrial transformation, environmental protection and so on. According to the World Trade Organization (WTO), global trade in services has continued to grow faster than trade in goods, especially in the areas of digital transformation and green economy, and the role of trade in services is becoming more prominent. As the world's second largest economy, China's service trade development history and achievements are particularly remarkable (Hu et al., 2022). In 2022, China's foreign trade in services reached a record high of 889.1 billion U.S. dollars, ranking second in the world for nine consecutive years. This achievement reflects the increasing status of China's service industry in the national economy, and service trade has become an important part of China's foreign economic cooperation and a new growth point. Especially in the field of green development and environmental protection, the role of China's service trade is becoming more and more prominent. According to the report of the International Energy Agency (IEA), China has witnessed significant growth in the import and export of green technologies and services, and the international market demand for green technology services provides new development opportunities for Chinese enterprises.

In China, the pilot policy for the innovation and development of trade in services, which was implemented in 2016, was deepened in 2018 and further expanded in 2020. It represents an important example of institutional innovation in trade in services and serves as a key experimental platform for promoting institutional opening-up in China. The policy leverages advantages in innovative capital, technology, the policy environment, and other resources. It attracts industrial agglomeration, promotes exchanges and cooperation among different industries and organizations, and accelerates technology spillovers and knowledge diffusion across related industries. While promoting industrial integration and the rise of emerging urban service industries and new economic sectors (Zeng et al., 2020), it also creates opportunities for the advancement of green technologies and the concentration of pollution control facilities within enterprises (Wu et al., 2020; Li et al., 2021). According to the Opinions on Promoting High-quality Development of Trade in Services through High-level Opening-up, issued by the General Office of the State Council in September 2024, China is promoting green and low-carbon development through institutional innovation in trade in services, particularly in the fields of energy conservation, environmental protection, and ecological governance. It strives to improve environmental performance and reduce pollution emissions by importing and exporting green technologies and services. These policies not only help promote the spread of green technology and optimize industrial structure but also provide new impetus for China's competitiveness in the field of international green service trade. Internationally, other economies are also attempting to promote green development through similar services trade policies. For example, under the framework of the "Green Deal," the EU supports the green transformation of its member states by deepening cross-border trade in green services and promotes the realization of green technologies and sustainable development goals. In contrast, the relationship between service trade innovation and environmental performance in China is still in the exploratory stage, and there is an urgent need to reveal the specific effects and mechanisms of policy implementation through systematic research.

Based on this, this paper focuses on the pilot policy of innovative development in the trade of services, which has been progressively implemented since 2016. By utilizing panel data from Chinese cities as a sample, the study employs the staggered difference-in-differences (DID) model to investigate the impact and mechanism of institutional innovation in China's service trade on environmental performance. It offers an in-depth analysis of the environmental effects resulting from institutional innovations and explores the varying outcomes of these effects across different groups. The study reveals that China's institutional innovation in the trade of services has a substantial positive impact on environmental performance, enhancing the pilot region's environmental metrics by 0.4544 percentage points. Secondly, institutional innovation enhances environmental performance primarily by fostering green innovation capabilities and facilitating the upgrading of industrial structures. Ultimately, regions that benefit from robust government backing, advanced service industry development, and a greater openness to international exchanges are more adept at leveraging institutional innovation to enhance the environmental performance of their pilot areas. The study's findings not only facilitate a rational evaluation of the efficacy of implementing institutional innovation, as exemplified by the pilot policy on the innovative development of trade in services, but also further the systematic liberalization of this sector. Additionally, they offer valuable empirical evidence and policy insights into the alignment and compatibility of institutional innovation in trade in services with the principles of green development. Moreover, they contribute to the advancement of innovative development within the trade in services sector and the formulation of anti-pollution strategies, particularly in developing nations such as China.

The marginal contributions of this paper are as follows:

First, this study focuses on the impact of institutional innovation in trade in services on environmental performance, which has significant theoretical and practical implications. In the context of global climate change and sustainable development, China has set dual carbon goals—carbon peak and carbon neutrality—which impose higher requirements for the green transformation of the service industry. Service trade is an essential part of the service sector, and its institutional innovation plays a crucial role in improving environmental performance. Therefore, this study not only responds to national strategic needs but also aligns with the global trend of green development.

Second, although pilot policies for the innovative development of trade in services have been implemented for many years, there is a lack of systematic assessment of their impact on environmental performance in the existing literature. Specifically, in research on the relationship between institutional innovation and environmental performance, few studies have used pilot policies in service trade innovation as a quasi-natural experiment to explore the specific impact of institutional innovation on environmental performance. This study fills this research gap and provides new perspectives and empirical evidence for future studies.

Third, this study makes significant contributions both theoretically and practically. At the theoretical level, using a staggered difference-in-differences model, it not only examines the impact of institutional innovation in service trade on environmental performance, but also explores the two mechanisms of green innovation capability improvement and industrial structure upgrading, providing a new theoretical framework for understanding the relationship between institutional innovation and environmental performance. At the practical level, this study reveals the varying environmental effects induced by institutional innovation across different regions and heterogeneous groups. It offers targeted policy recommendations for policymakers, particularly concerning government support, service industry development, and the degree of openness, while providing empirical evidence for optimizing policy design and implementation.

Fourth, in terms of research methods, this study employs two-stage difference-in-differences estimators to test the potential influence of heterogeneous treatment effects. This approach enhances the robustness of the research findings and provides methodological guidance for future studies. By using this method, this study can more accurately assess the impact of institutional innovation on the environmental performance of trade in services, offering a more reliable basis for policy evaluation and formulation.

2 Literature review

Institutions are gradually formed with the development of productive forces and the expansion of social communication (Lin and Liu, 2000) and are the rules of organizations, manifested in the structure of relationships and the form of rules (Liu et al., 2024). Institutional innovation refers to the transformation, optimization, or reconstruction of the existing institutional system to create a more efficient and fair social operation mechanism, covering dimensions such as the market system, science and technology system, financial system, innovation policy, and others (Liu et al., 2019). It involves the selection, creation, construction, and optimization of the social norm system, including the adjustment, improvement, reform, and replacement of the system. This paper will focus on the impact of institutional innovation in service trade on environmental performance. Existing studies mainly cover three aspects: first, the factors influencing environmental performance; second, the mechanisms through which institutional innovation influences environmental performance; third, the relationship between institutional innovation and environmental performance in service trade.

2.1 Influencing factors of environmental performance

Research on environmental performance generally focuses on two levels: regional and enterprise. At the regional level, factors affecting environmental performance mainly include national environmental audits (Li and Sun, 2019), government environmental audits (Zeng and Li, 2018), and coordinated efforts to promote pollution reduction and carbon emissions (Zheng and Zhang, 2024). These factors work together to enhance the environmental behavior of enterprises in the region and promote the implementation of green development policies. At the enterprise level, the main factors affecting environmental performance include the introduction of digital products (Shao and An, 2023), government environmental subsidies (Wang and Zheng, 2020), green human resource management (Zahid et al., 2020; Gill et al., 2021), and green innovation (Singh et al., 2020; Rehman et al., 2021). These factors improve environmental performance by optimizing production methods, enhancing resource utilization efficiency, and reducing pollution emissions.

2.2 The impact of institutional innovation on environmental performance

Institutional innovation affects environmental performance through multiple channels. For example, it can enhance resource allocation, strengthen environmental regulations, and improve government governance capacity, thereby fostering proactive involvement and synergy in environmental governance between enterprises and local governments (Han et al., 2023; Bai and Ding, 2023). In this process, the quality of institutions directly impacts the ability of economic entities to coordinate in their production and business activities, which in turn influences the improvement of environmental performance (Musa et al., 2021). Institutional innovation can also enhance environmental performance by optimizing the market system. China has long leveraged institutional innovation to foster enterprise development and refine the market economy system (Sun et al., 2024). providing enterprises with clearer environmental requirements and market incentives. These innovations have not only strengthened corporate environmental responsibility but also facilitated the widespread adoption and application of green technologies. Institutional innovation is also reflected in the collaborative cooperation among various stakeholders within a region. In regional environmental governance, a cooperation mechanism involving the government, enterprises, and social organizations has gradually taken shape, driving the joint achievement of pollution reduction and green innovation (Zheng and Zhang, 2024).

2.3 Institutional innovation and environmental performance in service trade

According to the environmental spillover effect theory of Copeland and Taylor (2004), international trade may affect national environmental protection policies through the "environmental spillover effect". The study of Assogbavi et al. (2023) shows that international trade not only directly affects the economic activities of various countries, but also indirectly affects the global distribution of carbon emissions. The open international market may push the country to strengthen environmental regulation to cater to the global market demand for green products. With the development of globalization and international trade, the role of service trade in promoting economic growth and environmental protection has received increasing attention. Zhao and Fang (2024) studied the practical effects of service trade innovation in China's A-share listed companies, focusing on energy conservation and emission reduction. Their research shows that service trade not only promotes the structural transformation of the economy, but also contributes to the achievement of energy conservation and emission reduction targets to some extent. Therefore, the role of international trade in promoting global environmental cooperation, especially how to reduce negative impacts through international agreements and green trade policies, is a direction worthy of further exploration.

Although existing studies have extensively explored the role of institutional innovation in environmental protection, there are relatively few studies on the relationship between institutional innovation and environmental performance in the field of service trade. Especially in China, with the promotion of "carbon peak" and "carbon neutral" goals, green transformation and sustainable development in the field of service trade have become urgent issues to be solved. China launched the service trade innovative development pilot policy in 2016, which is seen as an institutional innovation aimed at promoting the green development and international competitiveness of the service industry. Existing studies have shown that institutional innovation can promote the transformation and innovation of the service industry in environmental governance by improving the efficiency of resource allocation, optimizing industrial structure, and promoting the introduction of green technology (Dai and Ma, 2024). This provides a new perspective and practical basis for studying the impact of institutional innovation on environmental performance in the field of service trade. By studying the impact of service trade innovative development pilot policies on environmental performance, this paper hopes to fill the research gap on the relationship between institutional innovation and environmental performance in the field of service trade, and provide policy inspiration for the green development of service trade in China and even the world. Through quantitative and qualitative analysis, we hope to reveal the mechanism and path of institutional innovation in promoting green transformation and improving environmental performance. This study not only expands the research on the relationship between institutional innovation and environmental performance, but also provides a new theoretical basis for the interaction between service trade and green development.

3 Institutional innovation context and research hypotheses

3.1 Context of institutional innovation

The National Development and Reform Commission of China, in its "Outline for the Innovative Development of the Services Sector (2017–2025)," advocates for the acceleration of the innovative advancement of the services sector. This initiative aims to bolster the emergence of new growth drivers for the service economy, serving as a pivotal strategy to comprehensively enhance the nation's overall strength, international competitiveness, and capacity for sustainable development. In this context, to enhance China's service trade promotion system and establish a hub for service trade system innovation, in February 2016, the State Council endorsed the Pilot Program for Innovative Development of Trade in Services. This initiative approved the launch of pilot programs for the innovative development of trade in services across 15 regions (Specifically, these include: Tianjin, Shanghai, Hainan, Shenzhen, Hangzhou, Wuhan, Guangzhou, Chengdu, Suzhou, Weihai and Harbin New District, Nanjing Jiangbei New District, Chongqing Liangjiang New District, Guizhou Guian New District, and Shaanxi Xixian New District), including Tianjin. It also stipulated the exploration of policies and institutions tailored to foster the innovative development of the service trade sector. In June 2018, the State Council endorsed the "Comprehensive Plan for the Deepening Innovative Development of the Trade in Services Pilot Program." This initiative led to the inclusion of two new pilot zones in Beijing and the Xiong'an New Area, while also extending the scope of the existing pilot programs in Nanjing Jiangbei New Area and Harbin New Area to encompass the entire city. The directive aims to encourage these pilot zones to delve into the establishment of institutional mechanisms, policy measures, and opening strategies that are tailored to the innovative and developmental needs of the service trade sector. The ultimate goal is to foster the emergence of a new paradigm for comprehensive opening-up. The "Pilot Overall Program" has been expanded to encompass 28 regions, with a focus on fully leveraging the supportive role of the service trade sector in stabilizing foreign trade and foreign investment. It also aims to foster the transformation and upgrading of foreign trade, as well as to promote high-quality development.

After analyzing the policy documents, we found that once a city is selected as a pilot for the innovative development of service trade, a series of measures will be taken to promote green innovation and optimize the industrial structure. Specifically:

Combining financial innovation with policy support to ease financial pressure and incentivize green innovation: Pilot cities have implemented financial innovation measures and policy support to ease financing difficulties and incentivize green innovation. These measures include encouraging financial institutions to support service enterprises in pilot cities, particularly small and medium-sized enterprises that align with industrial policies, as well as providing financial support for key areas such as research and development, energy conservation, environmental protection, and environmental services. For example, after becoming a pilot city, Shanghai set up a service trade innovative development fund to attract private capital into key service trade areas. In 2018, Weihai relaxed the list of pilot enterprises for service trade branches, expanded the reach of cooperative banks, and increased financing channels for enterprises. Additionally, technologically advanced service enterprises and technology-based SMEs (small and medium-size enterprise) in the city can enjoy tax incentives that encourage the introduction of high-end service products and green technology R&D. After being selected, Chongqing Liangjiang New Area expanded the scope of technologically advanced service enterprises and technology-based SMEs, and provided tax incentives, implementing zero tax rates and tax exemptions for cross-border VAT (value-added tax) on services.

Fostering new industries and business models to promote industrial upgrading: The selected pilot cities actively adapt to emerging trends in service trade, strengthen cross-sectoral cooperation by deepening reforms and fostering continuous innovation, and cultivate new industries and business models to promote the upgrading of industrial structures. For example, Hainan leverages Haikou High-tech Zone and Hainan Ecological Software Park to build characteristic service outsourcing industrial clusters. Wuhan emphasizes the development of technology services, computer and information services, financial services, cultural services, and other emerging fields. Tianjin, by accelerating the construction of the "Double Innovation Special Zone," promotes the agglomeration of high-tech services and vigorously develops new business models such as cloud computing and big data.

3.2 Research hypotheses

Drawing on new institutional economics theory and green innovation theory, and considering the dual mechanisms of institutional innovation and industrial upgrading, this study explores how service trade innovative development pilot policies can enhance the environmental performance of pilot areas through green innovation and industrial upgrading. New institutional economics theory emphasizes the guiding role of institutions in economic behavior, arguing that institutional innovation is a key driver of economic growth and industrial upgrading. Particularly, service trade innovation policy, as a form of institutional innovation, can effectively change enterprise behavior and promote green innovation and industrial transformation by optimizing market rules, policy frameworks, and incentive mechanisms. These policies support green technology innovation by fostering technological advancements, capital flows, and market openness through institutional arrangements. Green innovation theory posits that technological innovation, especially green technological innovation, plays a crucial role in improving environmental performance and achieving sustainable development. Institutional innovation further supports the development and application of green technologies through knowledge spillover, technology diffusion, and policy incentives. Under the service trade innovative development pilot policies, regions can promote the innovation and application of green technologies by lowering technical barriers, accelerating technology transfer, and strengthening cross-border collaboration.

Combining these two theoretical perspectives, this study views service trade innovative development pilot policies as institutional innovation, which ultimately improves the environmental performance of pilot areas through two mechanisms: enhancing green innovation capabilities and promoting industrial upgrading.

3.2.1 Enhancement mechanism for green innovation capacity

Innovation ability refers to an organization's capacity to generate, develop, and implement new ideas, technologies, products, or services. This process involves knowledge acquisition, research and development, innovation management, technology application, organizational learning, and market adaptation. The innovation of the service trade system has the potential to elevate the green technological innovation levels within pilot regions by facilitating factor substitution, policy incentives, knowledge spillovers, and technology diffusion. The pivotal role of green technology innovation in enhancing environmental performance and governance has been affirmed by numerous scholars (Zheng et al., 2022; Liu, 2023). Initially, regarding factor substitution, as the service industry's two-way opening intensifies and expands, pilot regions have the opportunity to lower barriers to entry for foreign suppliers. This facilitates the influx of foreign capital and high-end service sectors, thereby complementing and substituting for scarce local services or raw materials. Moreover, by outsourcing services, inefficient and non-core operations can be transferred, enhancing the enterprise's specialization level and fostering an increase in green innovation capabilities. Secondly, regarding policy incentives, the state aims to bolster and refine the support mechanisms for service enterprises in the pilot area to foster innovative development. Consequently, enterprises within the pilot zone are incentivized to proactively boost their investment in technological research and development. This encourages the reallocation of capital and other resources, advancing the development of clean energy and the creation of eco-friendly organizational and management structures. These initiatives are designed to enhance the productivity of the service industry within the pilot area and effectively enhance environmental performance. In conclusion, institutional innovation plays a pivotal role in fostering a liberalized trade environment for services. It not only accelerates the spatial mobility, agglomeration, and dissemination of knowledge and technology but also enhances opportunities for direct interactions among highly skilled professionals (Bai et al., 2020). For instance, the circulation and clustering of knowledge- and technology-intensive service components, including information and communication services, R&D, and design services, along with their interaction and integration with the manufacturing sector, can not only directly disseminate and diffuse advanced knowledge and technology across all facets of corporate production, but also afford enterprises the opportunity to learn from cutting-edge technology and managerial expertise, thereby fostering the accumulation of human capital and innovative knowledge within the pilot region.

3.2.2 Mechanism for upgrading industrial structure

The upgrading of industrial structure refers to the process by which the proportion of high-value-added and high-technology industries in a country's or region's industrial structure gradually increases, driven by economic development and changes in market demand, while the proportion of low-value-added and low-technology industries gradually decreases. Institutional innovation has introduced a range of favorable conditions, a more relaxed policy environment, and innovative resources to the pilot zones. This has effectively enhanced the industrial spatial layout and economic growth model of these areas. Consequently, it has facilitated the upgrading of the industrial structure by integrating industries and fostering market competition. Firstly, regarding the integration of the two sectors, the productive service industry and the manufacturing industry exhibit a profound technological interdependence and a symbiotic relationship in terms of intermediate supply and demand. Pilot regions can leverage policy incentives to expedite the aggregation of service components, thereby facilitating the refinement and upscale of service linkages. This approach not only offers distinctive, high-quality intermediate service products to manufacturing enterprises but also enhances industrial collaboration across various sectors and levels. It further strengthens the capacity of low-tech and traditional enterprises to evolve into high-tech and modern entities (Zhuang et al., 2021). Additionally, it establishes a solid foundation for enhancing their own environmental performance, creating favorable basic conditions. Secondly, regarding market competition, trade facilitation enhances the competitive landscape within the service sector, encourages the reallocation of production factors from less efficient industries to those with higher efficiency, and also fosters the transformation and upgrading of the manufacturing industry within the confined space and market conditions. And foreign-invested enterprises frequently possess advanced production technologies, abundant management expertise, and stringent environmental governance standards. These factors can stimulate domestic companies to align with international norms through competitive and exemplary effects, thereby propelling the industrial structure of the pilot region towards high-end sectors. The upgrading of the industrial structure can facilitate the transition of industrial development from being driven by factors to being driven by innovation, and from extensive to intensive, green, and low-carbon models. The upgrading of industrial structure can promote the transformation of industrial development from factor-driven to innovation-driven, and from extensive to intensive, green and low-carbon. The increase in the proportion of high-end producer services such as finance will accelerate the transformation of urban industrial structure from labor - and capital-intensive to knowledge - and technology-intensive (Jalil and Feridum, 2011), which can reduce the generation and emission of urban pollutants and improve environmental performance.

Therefore, the following research hypothesis is proposed: institutional innovation, exemplified by pilot policies aimed at the innovative development of the trade in services sector, can enhance the environmental performance of the pilot regions. This enhancement primarily occurs through two mechanisms: firstly, by bolstering green innovation capabilities, and secondly, by facilitating the upgrading of the industrial structure.

4 Data description and modeling

4.1 Data sources and sample selection

This study examines the institutional innovation of pilot policies for the innovative development of trade in services as a quasi-natural experiment. It designates regions with established pilot policies for the innovative development of trade in services as the treatment group, and regions without such policies as the control group. The study employs a staggered difference-in-differences methodology to assess the impact of these institutional innovations on environmental performance. Given the delayed initiation of the third batch of pilot regions, this paper primarily concentrates on the initial two groups, comprising a total of 17 regions. Taking into account the regulations aimed at reducing sulfur dioxide emissions and preventing and controlling air pollution during the "11th Five-Year" plan period, along with the significant amount of missing data for certain variables, and to mitigate the potential impact of the COVID-19 pandemic on various aspects of service trade and empirical outcomes (Mao and Guan, 2022; Li and Ma, 2023), the research period has been established from 2011 to 2019. Among them, the list of pilot regions and their respective implementation timelines are derived from the documents released by the Ministry of Commerce, as well as from each pilot region; the carbon emission data were obtained from the China Carbon Accounting Databases (CEADs); and other data were obtained from the database of the China Research Data Service Platform (CNRDS), the Statistical Yearbook of Chinese Cities, the Statistical Yearbook of each province, and the Statistical Yearbook of each city.

Before the empirical analysis, the samples were processed as follows: First, in order to ensure the comparability between the treatment group and the control group, 70 large and medium-sized cities and 12 port cities in China are used as the base samples. One reason is that the selection of pilot sites for the innovative development of trade in services across the nation is not entirely random. It primarily takes into account regions with a well-developed service industry and service trade, predominantly opting for regional central cities. Therefore, it is difficult for most cities to obtain pilot services trade innovation development (Chen, 2021). China's 70 large and medium-sized cities are basically national or regional center cities, with strong homogeneity among cities (Cao, 2020). The second reason is that the pilot zones are likely to be urban areas characterized by superior technological infrastructure and a higher degree of international integration.[1] Therefore, referring to the study conducted by Wang and Meng (2013), 14 new inland river ports and 17 coastal port cities are taken into consideration; however, only 12 port cities are actually added to the list, as some of them already fall within the category of the 70 large and medium-sized cities mentioned previously.[2] The final reason is that due to insufficient data, both Sanya and Dali are excluded from the list of 70 large and medium-sized cities. Consequently, the foundational research sample for this paper comprises 80 cities. Second, considering the availability of pilot data for state-level new areas and the heterogeneity of control policies, this paper excludes Harbin, Nanjing, Chongqing, Guiyang, and Xi'an from the original list of 80 cities. After screening, the final study sample was 75 cities, of which the treatment group was 11 cities: Tianjin, Shanghai, Haikou, Shenzhen, Hangzhou, Wuhan, Guangzhou, Weihai, Chengdu, Suzhou and Beijing.

4.2 Modeling and variable definition

Since the pilot policy on innovative development of trade in services has been implemented in stages, this study employs a staggered difference-in-differences approach and utilizes a two-way fixed-effects model to assess its impact on environmental performance. The econometric model is set as Equation 1:

$$\ln EP_{it} = \alpha + \beta did_{it} + \gamma Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \tag{1}$$

where i and t represent region and year, respectively. The explanatory variable $\ln EP_{it}$ is regional environmental performance. The core explanatory variable did_{it} indicates whether or not institutional innovation was implemented in region i in year t. The core explanatory variable is a control variable representing the series of other factors that may affect environmental performance. $Controls_{it}$ is a control variable representing a series of other factors that may affect environmental performance. μ_i represents the region fixed effect, which is used to control the factors of regional characteristics that do not change over time; λ_t represents the year fixed effect, which is used to control the factors such as macroeconomic fluctuations that do not change over time; ε_{it} is the error term. The focus of this paper is on the coefficient β, β should be significantly positive if institutional innovation improves environmental performance.

1 https://baijiahao.baidu.com/s?id=1674185459448881087&wfr=spider&for=pc

2 Wuhu, Nantong, Suzhou, Weihai, Jingzhou, Maanshan, Zhenjiang, Taizhou, Yingkou, Rizhao, Lianyungang and Shantou.

4.2.1 Explained variable

Regional environmental performance (lnEP). In this paper, the environmental performance is represented by GDP per unit of pollution emission (GDP/SO2), which can not only eliminate the impact of scale factors, but also meet the requirements of high-quality economic development in China at the present stage, that is, taking into account the optimal balance between social and economic development and environmental protection. In general, measuring environmental performance should take into account sulfur dioxide, carbon dioxide, PM2.5, solid waste, and other emissions. However, data on environmental pollution in China's service sector is currently scarce, as emissions from this sector tend to be more dispersed and difficult to quantify compared to those from the industrial sector. Therefore, considering that China's environmental pollution is mainly coal-smoke type air pollution, and SO_2 will bring acid rain and other associated pollution problems (Antweiler et al., 2001), especially in China's environmental statistical database, SO_2 data is the most complete and reliable. As a result, this paper chooses the proportion of regional GDP to industrial SO_2 emissions to measure regional environmental performance.

4.2.2 Core explanatory variable

Institutional innovation (*did*), which is represented in this paper by the pilot policy for innovative development of trade in services. According to the list of pilot regions issued by the State Council to assign a value to *did*, if region *i* set up a pilot in year *t*, then region i in year t and the following years $did_{it} = 1$, otherwise $did_{it} = 0$. When defining the specific year for the establishment of pilot areas, it is considered that the implementation of pilot policies in each area is contingent upon the time when the plan is released in that particular area. Furthermore, the fact that the release time of the specific policy implementation content in some areas falls in the second half of the year poses a challenge, as it can hinder the policy from having a significant impact within that same year.

Therefore, June 30 is used as the cut-off point, and if the pilot program is announced before that date, it will be regarded as the implementation of the pilot policy in the same year; Otherwise, it is deemed to be implemented in the following year (Zhang and Tao, 2016). In the end, Chengdu and Suzhou were implemented in the current year, while the rest of the treatment group areas were implemented in the following year.

4.2.3 Control variables

The control variables include: the level of economic development (*lnpgdp*), measured by the regional GDP *per capita*; the level of foreign direct investment (*fdi*), measured by the ratio of the product of the amount of actual foreign investment utilized and the average exchange rate of the current year (US dollar to renminbi) to the regional GDP; and the level of financial development (*finance*), measured by the ratio of the financial institution's year-end loan balance to the regional GDP; The degree of government intervention (*lngovexp*), measured by the total government fiscal expenditure; and environmental regulation (*envreg*), measured by the ratio of completed investment in industrial pollution control to the value added of the secondary industry. The descriptive statistics of the main variables are shown in Table 1.

5 Empirical results and analysis

5.1 Baseline regression results

Table 2 reports the baseline results on the impact of institutional innovation in trade in services on regional environmental performance. Column (1) of Table 2 controls only for the core explanatory variables *did* and fixed effects, while column (2) further incorporates all control variables. From the regression results, it can be found that the coefficient of the institutional innovation in trade in services variable (*did*) is significantly positive at the 1% level regardless of the inclusion of control variables, which suggests that institutional innovation contributes to the environmental performance of the pilot regions. For instance, in column (2), it is observed that institutional innovation results in a 0.4635 percentage point enhancement in environmental performance within the pilot region relative to the control group. Consequently, this demonstrates that institutional innovation in the trade of services positively influences the environmental performance in the pilot region, thereby corroborating the research hypothesis.

5.2 Parallel trend test and dynamic effects analysis

The application of staggered DID requires the fulfillment of the parallel trend assumption, and there may be dynamic effects on the impact of institutional innovation in trade in services on environmental performance. Therefore, this paper draws on Liu and Mao (2019) to construct a model to test the parallel trend assumption and identify the differences in the impacts of different years of policy implementation on environmental performance by taking the previous year of institutional innovation implementation as the base period, and the model is set as Equation 2:

$$lnCi_{it} = \alpha + \beta_k \sum_{k=-8}^{k=3} did_{it}^k + \gamma Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

Where k = 0 in the year of institutional innovation implementation, β_k indicates the difference in environmental performance between the treatment and control groups in the *k*th year of institutional innovation implementation compared to the previous year of institutional innovation implementation. When $k < 0$, β_k is not significantly different from 0, it means that the parallel trend assumption is satisfied; when $k \geq 0$, β_k portrays the dynamic effect of institutional innovation. Due to the sample size problem, periods 8 and 7 before the implementation of institutional innovation are combined into period 6 before the implementation, and period 3 after the implementation of institutional innovation is combined into period 2. As illustrated in Figure 1, there is no significant difference between the environmental performance of the treatment group and the control group before the implementation of institutional innovation, which satisfies the parallel trend hypothesis. Due to the lag of policy effect, environmental performance was significantly improved only in the second year after the implementation of institutional innovation,

TABLE 1 Descriptive statistics of main variables.

Variable symbol	Variable name	Observed value	Average value	Standard deviation	Minimum value	Maximum values
lnEP	Environmental performance	664	−2.1631	1.4135	−4.6333	3.5107
did	Institutional innovation in trade in services	675	0.0489	0.2158	0.0000	1.0000
lnpgdp	Level of economic development	675	10.8510	0.4977	9.4841	12.7997
fdi	Level of foreign direct investment	675	0.0239	0.0201	0.0000	0.1134
finance	Level of financial development	675	1.2940	0.7587	0.2586	5.2007
lngovexp	Level of government intervention	675	15.1349	0.7780	13.3812	17.8829
envreg	environmental regulation	675	0.0026	0.0023	0.0001	0.0250
patapp	Green patent applications *per capita*	675	2.9842	4.6507	0.0283	50.9821
pataut	Green patents obtained *per capita*	675	1.5585	2.3109	0.0202	24.8992
Indstru	Upgrading of industrial structure	664	1.1579	0.6404	0.3905	5.2717

which verified the existence of environmental effects of institutional innovation in trade in services[3].

5.3 Heterogeneity treatment effect test

For the staggered DID model, the traditional two-way fixed effects estimator has been mostly used in the previous literature. The validity of these traditional two-way fixed effects estimators is based on the assumption of homogeneity of treatment effects. However, in the presence of heterogeneous treatment effects, the traditional two-way fixed effects estimators can be biased (De Chaisemartin and D'Haultfoeuille, 2020; Goodman-Bacon, 2021). To solve this problem, the existing literature puts forward three solutions (group-period average treatment effect estimator, interpolation estimator, and stacked regression estimator), each of which has its own advantages and disadvantages. The core idea, however, is to find a reasonable control group or use the control group to calculate a reasonable counterfactual result.

In this paper, the potential heterogeneous treatment effects may come from "bad control group" and "dynamic policy effect". First, due to the inconsistent implementation times of the service trade innovation development pilot, cities that set up the pilot earlier (such as Chengdu and Suzhou) may serve as the control group for cities that established the pilot later, which could lead to estimation bias. Second, in a dynamic context, the estimated coefficients for each phase may be cross-contaminated across periods, making them difficult to explain, which indicates that the pilot policy for the innovative development of trade in services exhibits significant temporal dynamics. Considering the small sample size of this paper, a large number of samples will be lost when calculating the group-period treatment effect, which may affect the estimation efficiency, and the stacked regression estimator may cause the problem of data reuse (Liu et al., 2022). Therefore, this paper uses the two-stage difference-difference method in the interpolated estimator to evaluate the impact of institutional innovation in trade in services on environmental performance (Gardner, 2022). Specifically, in the first stage, the city and year fixed effects are estimated using the unprocessed observation data ($did = 0$), as shown in Equation 3, and the parameters $\hat{\gamma}$, $\hat{\mu}_i$ and $\hat{\lambda}_t$ are estimated. In the second stage, the dependent variable with the fixed effects removed and the policy treatment variable are both used in regression to identify the average treatment effect, as shown in Equation 4, where θ is the robust estimator after correcting the estimation bias of the traditional bidirectional fixed effect difference-in-differences model.

$$lnCi_{it} = \alpha + \gamma Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (3)$$

$$ln\hat{C}i_{it} = lnCi_{it} - \hat{\gamma} Controls_{it} - \hat{\mu}_i - \hat{\lambda}_t = \theta did_{it} + \varepsilon_{it} \quad (4)$$

Based on Formulas 3, 4, the impact of institutional innovation in trade in services on environmental performance is evaluated. The regression results are shown in Table 3. It can be found that in the case of using the staggered differential robust estimator, regardless of whether the control variables are added, the institutional innovation of trade in services still significantly improves the environmental performance of the pilot area. It indicates that the heterogeneity treatment effect has limited impact on the estimation results, which verifies the reliability of the findings.

3 Unfortunately, missing data for 2020 and 2021 for some of the important variables makes the timeframe of this paper's study 2011–2019, which leads to only 2 periods after the implementation of the pilot policy in most of the treatment group districts, and does not allow us to see the change in the dynamic effects in the 3rd or even longer period after the implementation.

TABLE 2 Baseline regression results.

Variables	(1)	(2)
	lnEP	*lnEP*
did	0.4956***	0.4635***
	(0.1663)	(0.1575)
lnPgdp		0.2135
		(0.1428)
Fdi		1.6926
		(2.0088)
Finl		−0.1871**
		(0.0849)
lnGov		0.8443***
		(0.1808)
Er		8.5213
		(12.5468)
Constant	−2.1877***	−17.1032***
	(0.0083)	(3.0151)
City FE	Yes	Yes
Year FE	Yes	Yes
Observations	664	664
R-squared	0.9405	0.9476

Note: Robust standard errors for clustering at the district level are in parentheses, ***$p < 0.01$.

5.4 Endogeneity analysis

Considering that the selection of cities for the implementation of institutional innovations in trade in services may not be completely random, this part uses two-stage least squares (2SLS) and PSM-DID to test the possible endogeneity of the policy variables. Firstly, combining with existing research, the interaction term of geographic centrality and the lagged one-period value added of the tertiary industry is adopted as an instrumental variable to conduct the 2SLS estimation (Guo and Lan, 2021)[4]. In general, cities with higher geographical centrality have more accessible regional networks, better urban openness, and are more likely to implement institutional innovation. Moreover, the geographical index is strictly exogenous, does not affect regional environmental performance, and meets the requirements of relevance and exclusivity. The results in column (1) of Table 4 show that the estimation results of the first stage. The K-P LM and K-P Wald F tests indicate that the model is identified and the instrument variables are strong. The instrumental variable (DistanceStr3) is a strong and significant predictor of the policy variable. Column (2) shows the estimation results of the second stage. The coefficient of the core explanatory variable remains significantly positive. Secondly, in order to make the characteristics of the pilot and non-pilot areas as consistent as possible, there is put-back sampling according to 1:2 caliper nearest-neighbor matching, which matches the pilot areas on a year-by-year basis. The reason for using 1:2 matching is that 1:2 matching strikes a balance between bias, efficiency, and robustness while ensuring that the sample size remains sufficient for meaningful analysis. The regression results using the PSM-DID method are presented in Table 4, Column (3), and show that the coefficients on the core explanatory variables remain significantly positive. It can be seen that institutional innovation can still significantly improve the environmental performance of the pilot districts after further mitigating potential endogenous problems.

4 The calculation is based on the nearest distance from each city to the top ten ports, which are: Dalian Port, Tangshan Port, Tianjin Port, Qingdao Port, Lianyungang Port, Shanghai Port, Ningbo Port, Xiamen Port, Guangzhou Port and Qinzhou Port.

5.5 Robustness tests

5.5.1 Placebo testing

Drawing on the existing literature (Li et al., 2016), this paper adopts a random sampling method to construct a false treatment and control group, as a way to obtain a new sample re-estimation. In order to improve the reliability of the placebo test, the above process is repeated 500 times, thus generating the corresponding 500 estimated coefficients to obtain Figure 2, where the vertical dashed line indicates the correct estimated coefficients. Theoretically, if the benchmark regression result is indeed brought about by institutional innovation, then the estimated coefficient of the policy variable should not be significantly different from 0. The estimation results in Figure 2 show that the estimated coefficients of the policy variable did follow a normal distribution and have a mean value around 0. Therefore, the possibility that the impact of institutional innovation in trade in services on environmental performance stems from other factors is low, indicating that the policy effects derived from the benchmark regression are relatively robust.

5.5.2 Excluding other contemporaneous policy effects

Given the predominant implementation of institutional innovations in regional centers or highly open cities, these pilot regions are often subject to multiple national-level policies that can potentially influence their environmental performance. In order to exclude other contemporaneous policy influences, this paper mainly considers: first, the Pilot Free Trade Zone policy (*did01*). The 11 pilot regions of service trade system innovation in this paper have successively set up free trade pilot zones, so this policy may bring some interference to the environmental performance of the region. Second, National-level New Zone policy (*did02*). Among the 11 service trade system innovation regions, four cities (Guangzhou, Chengdu, Tianjin and Shanghai) have been affected by the National-level New Zone policy before the implementation of system innovation, and it is necessary to exclude the impact of this policy on environmental performance. Therefore, this paper further incorporates the dummy variables of the Pilot Free Trade

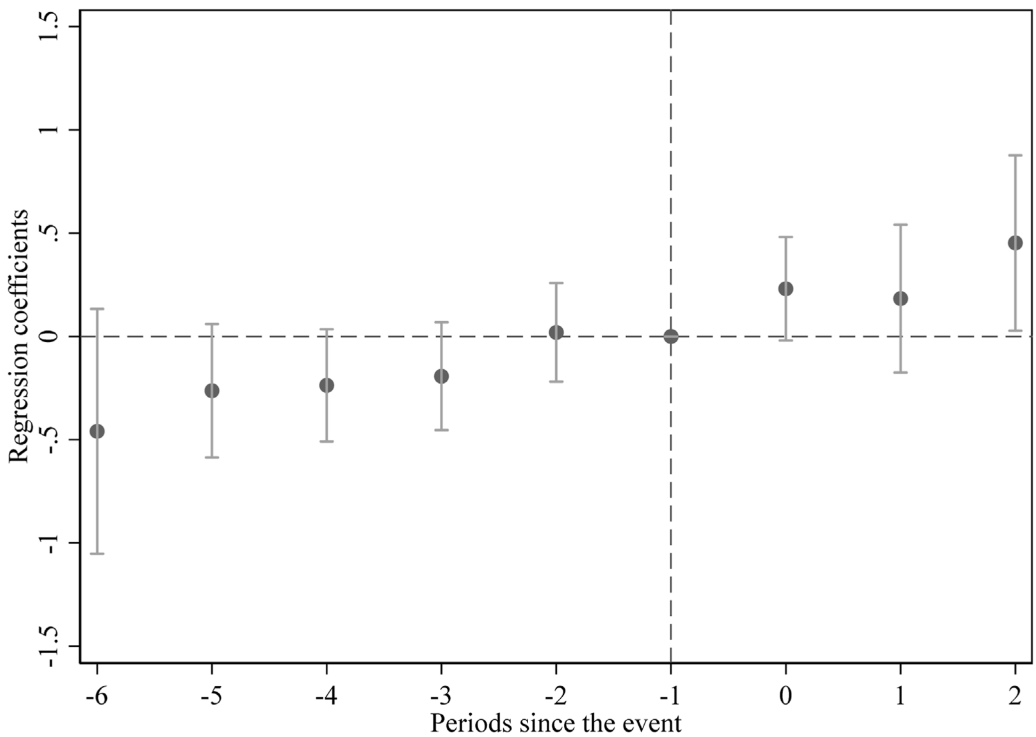

FIGURE 1
Parallel trends and dynamic effects test.

Zone policy and the National-level New Zone policy on the basis of model (1), the construction method is similar to that of the core explanatory variables, and the estimation results are reported in Table 5. It can be seen that the estimated coefficients of the core explanatory variable *did* are all significantly positive, which suggests that, after the exclusion of the effects of the Pilot Free Trade Zone policy and the National-level New Zone policy, the institutional innovation of trade in services still can significantly improve environmental performance, indicating that the research findings are robust.

5.5.3 Adjustment of the study sample

Two main kinds of robustness tests are mainly conducted: First, full sample regressions[5]. Column (1) of Table 6 reports the regression results for the sample of 275 districts. Second, the inclusion of cities belonging to new national-level districts[6]. Column (2) of Table 6 reports regression results for 81 regions, including 75 basic research samples and six cities, Chongqing, Guiyang, Anshun, Xi'an, Xianyang and Baoding. Combining columns (1) to (2) of Table 6, it can be found that the estimated coefficients of the core explanatory variable did remain significantly positive, further validating the robustness of the findings.

5.5.4 Replacement of explanatory variables

In this paper, environmental performance is mainly expressed in terms of GDP realized per unit of industrial SO_2, but other pollutants are also emitted in the process of regional development. Under the constraint of the "double carbon" goal of carbon peak and carbon neutrality, reducing carbon emissions is an important task for China to realize sustainable development. Therefore, in order to more fully examine the impact of institutional innovation on environmental performance, based on data availability, this paper selects the share of regional GDP in CO_2

5 The full sample of 285 cities, excluding Dali, Sanya, Harbin, Nanjing and the cities belonging to the Xixian New Area, the Two Rivers New Area, the Gui'an New Area, and the Xiong'an New Area, leaves 275 cities.

6 The cities of Nanjing and Harbin are not added here to control for the policy's own heterogeneity

TABLE 3 Results of the heterogeneity treatment effect test.

Variables	(1)	(2)
	lnEP	*lnEP*
did	0.4665***	0.4303***
	(0.1698)	(0.1612)
Controls	No	Yes
City FE	Yes	Yes
Year FE	Yes	Yes
Observations	664	664

Note: Robust standard errors for clustering at the district level are in parentheses, ***$p < 0.01$.

TABLE 4 Results of endogeneity analysis.

Variables	(1)	(2)	(3)
	First stage	Second stage	
	did	*lnEP*	*lnEP*
did		1.4971***	0.2844**
		(0.5162)	(0.1382)
DistanceStr3	0.0251*** (0.0058)		
Controls	Yes	Yes	Yes
City FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	589	589	328
R-squared	—	0.8496	0.9460
K-P LM statistic	9.748 [0.00]		
K-P Wald F statistic	18.629 [16.38]		

Note: Values in parentheses in the K-P LM, statistic correspond to p-values; values in parentheses in the K-P Wald F statistic correspond to critical values at the 10% level of the Stock-Yogo test; ***$P < 0.01$, **$P < 0.05$; and clustering robust standard errors at the district level are in parentheses. The first-stage results estimated using the xtivreg2 command do not report the R-squared, hence it is denoted by "—".

emissions (*lngco2*) as a new regional environmental performance indicator. The carbon dioxide emissions data are sourced from the China Emissions Accounts and Datasets (CEADs). As of 4 January 2025, the database has released carbon emission data for 290 Chinese cities from 1997 to 2019. The results in column (3) of Table 6 show that the estimated coefficients of the core explanatory variable did are significantly positive, indicating that after taking into account the different pollution emission behaviors that regions may have due to different pollutants, institutional innovation in trade in services still has an uplifting effect on environmental performance, which further supports the findings of the study.

6 Further analysis

6.1 Test of action mechanism

The results of the previous study show that the innovation of trade in services system can significantly improve the environmental performance of the pilot region, while what is the acting mechanism behind it needs to be further examined. According to the research hypothesis, the mechanism of action may include both green innovation capacity enhancement and industrial structure upgrading, and the mechanism testing model is set as Equation 5:

$$M_{it} = \beta_0 + \beta_1 did_{it} + \gamma Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (5)$$

M_{it} denotes the mechanism variable. Green innovation capacity is measured by the number of green patent applications per 10,000 people (*patapp*) and the number of green patents obtained per 10,000 people (*pataut*), and the data are obtained from the database of China Research Data Service Platform (CNRDS). Industrial structure upgrading is measured by the ratio of value added of tertiary industry to value added of secondary industry (*Indstruc*) (Gan et al., 2011). The coefficient β_1 indicates the impact of institutional innovation on the improvement of regional green innovation capacity and industrial structure upgrading.

6.1.1 Green innovation capacity enhancement mechanisms

Table 7 reports the results of the test of the mechanism of action. Among them, the results in columns (1) and (2) show that the innovation of the services trade system can significantly increase the number of green patent applications and acquisitions per 10,000 people in the pilot region, and promote the improvement of green innovation capacity. The service industry is more environmentally friendly and resource-saving industry, and manufacturing agglomeration brings more environmental pollution problems (Levinson, 2010). Institutional innovation has attracted large-volume service industry agglomeration, which can reduce pollution control in manufacturing industry through clean outsourcing services and incentivize manufacturing enterprises to innovate low-carbon emission reduction technologies. In addition, the coordinated interaction between manufacturing and service industries can not only enable the sharing and dissemination of advanced production technologies and scarce resource elements within the pilot region, generating technological externalities, but also improve the resource utilization efficiency of the pilot region by strengthening the rational allocation of resources, reducing the consumption of intermediate inputs, reducing the cost of technological innovation, and jointly promoting the enhancement of green innovation capacity.

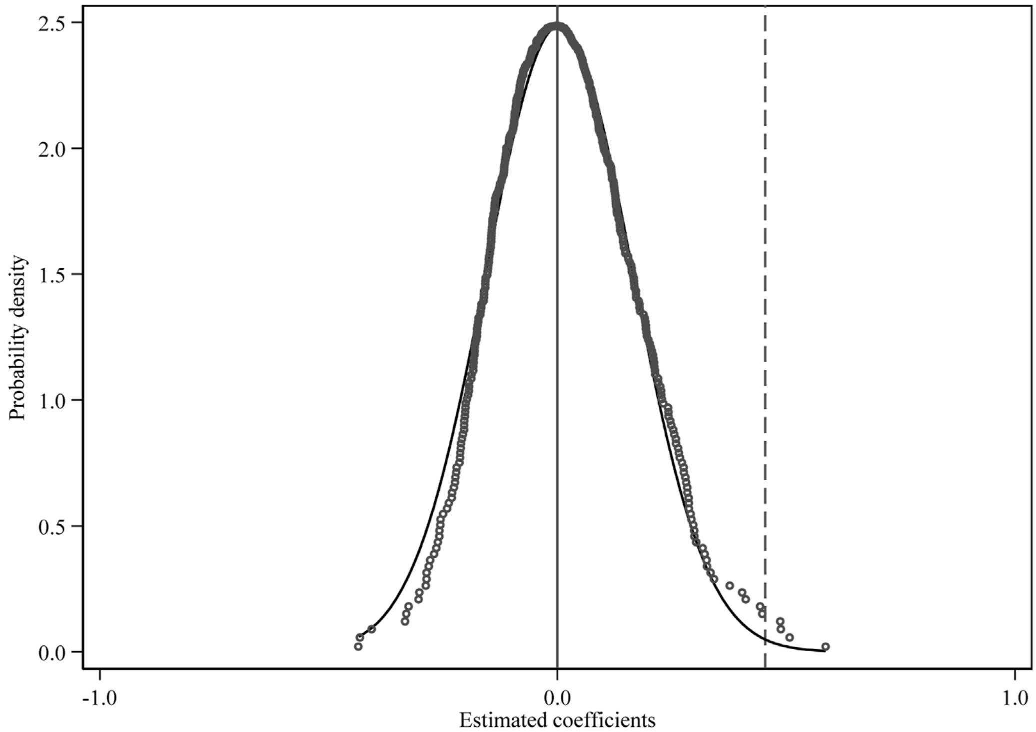

FIGURE 2
Placebo test.

TABLE 5 Test results excluding the effects of other contemporaneous policies.

Variables	(1)	(2)	(3)
	lnEP	*lnEP*	*lnEP*
did	0.4703***	0.4656***	0.4719***
	(0.1604)	(0.1574)	(0.1603)
did01	−0.0536		−0.0503
	(0.0849)		(0.0856)
did02		0.0955	0.0914
		(0.1135)	(0.1118)
Controls	Yes	Yes	Yes
City FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	664	664	664
R-squared	0.9476	0.9477	0.9478

Note: Robust standard errors for clustering at the district level are in parentheses, ***$p < 0.01$.

6.1.2 Mechanisms for upgrading the industrial structure

The results in column (3) of Table 7 show that institutional innovation in trade in services can also improve environmental performance by influencing the upgrading of regional industrial structure. For a long time, China's industrial development has mainly relied on scale expansion, with a relatively crude model, low energy utilization, high resource and environmental costs, and serious challenges to the development of a green economy. Systematic innovation in trade in services can promote the

TABLE 6 Results of other robustness tests.

Variables	(1)	(2)	(3)
	lnEP	*lnEP*	*lngco2*
did	0.5635***	0.4617***	0.0746*
	(0.1507)	(0.1707)	(0.0437)
Controls	Yes	Yes	Yes
City FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	2,250	718	598
R-squared	0.9209	0.9441	0.9630

Note: Robust standard errors for clustering at the district level are in parentheses, ***$P < 0.01$, *$P < 0.1$. The first column reports regression results for a sample of 275 regions, and the second column shows regression results for 81 regions.

TABLE 7 Results of mechanism of action tests.

Variables	(1)	(2)	(3)
	patapp	*pataut*	*indstru*
did	4.4738***	1.6380***	0.1510*
	(1.4717)	(0.5562)	(0.0804)
Controls	Yes	Yes	Yes
City FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	675	675	675
R-squared	0.8892	0.9184	0.9443

Note: Robust standard errors for clustering at the district level are in parentheses, ***$P < 0.01$, *$P < 0.1$.

transformation and development of trade in services by virtue of preferential policies and a facilitated business environment, and provide a better platform for industrial upgrading in pilot regions. As an integrated carrier of innovative development and a frontline of cooperation in science and technology innovation, the pilot regions will see the innovative factors and resources triggering changes in the mode of production and organization and continuously penetrating into various industrial fields, accelerating the transformation and upgrading of the traditional industries while emerging new industries. In addition, the advanced knowledge and technology of the service industry can also affect the manufacturing industry through the spillover effect, and promote the upgrading of the entire industrial structure through the integration and coordinated development of the two.

6.2 Heterogeneity analysis

6.2.1 Heterogeneity in the degree of government support

Mechanism analysis shows that innovation in the trade in services system can significantly improve environmental performance by promoting the green innovation capacity of pilot regions. However, there are some differences in government support in different regions, which leads to a large gap between the absorption and transformation capacity of advanced resources in each region, and the lower absorption capacity will inhibit the pilot regions from realizing their own green development by means of advanced service products and clean and green technologies. Therefore, this paper adopts the proportion of government expenditure on education, science and technology to GDP to measure government support (*govsu*). When government support is higher than the mean, *govsu* is assigned a value of 1, and when government support is lower than the mean, *govsu* is assigned a value of 0. Then *govsu* and its interaction term with institutional innovation ($did \times govsu$) are incorporated into the model, and the estimation results are reported in column (1) of Table 8. It can be seen that the coefficient of the interaction term is significantly positive, indicating that regions with stronger government support are more able to improve environmental performance through institutional innovation. The reason behind this result may be that regions with greater government support can provide more resources and policy backing for green innovation, thus enhancing the R&D capacity and technology absorption capabilities of innovation entities. Specifically, higher government support can not only directly improve the efficiency of green

TABLE 8 Results of heterogeneity analysis.

Variables	(1)	(2)	(3)
	lnEP	*lnEP*	*lnEP*
did_govsu	0.7433***		
	(0.2110)		
govsu	−0.1857***		
	(0.0583)		
did_serlev		0.3701**	
		(0.1653)	
serlev		0.1196*	
		(0.0657)	
did_open			0.3133*
			(0.1624)
open			0.2285***
			(0.0829)
did	0.1970	0.1593	0.2100
	(0.1546)	(0.1838)	(0.1508)
Controls	Yes	Yes	Yes
City FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	664	664	664
R-squared	0.9502	0.9483	0.9497

Note: Robust standard errors for clustering at the district level are in parentheses, $^{***}P < 0.01$, $^{**}P < 0.05$, $^{*}P < 0.10$.

technology research, development, and promotion, but also optimize resource allocation through policy guidance, thereby promoting the transformation and application of innovative results. In this context, institutional innovation can more effectively enhance the green innovation capacity of pilot areas, further improving environmental performance. Therefore, government support, as a key factor, plays an important role in promoting green development and environmental improvement, particularly in areas where resources and technology are relatively scarce. In these regions, government support has become a crucial driving force behind the green transformation.

6.2.2 Heterogeneity in the level of development of services

As institutional innovation in services trade to promote industrial structure upgrading is another channel to improve its environmental performance, are regions with a higher level of services development more able to rely on institutional innovation to improve their environmental performance? This paper adopts the proportion of added value of the tertiary industry to GDP to measure the development level of the service industry (*serlev*). When the level of service industry development is higher than the mean, *serlev* is assigned a value of 1. When the level of service industry development is lower than the mean, *serlev* is assigned a value of 0. Then *serlev* and its interaction term with institutional innovation ($did \times serlev$) are incorporated into the model, and the estimation results are reported in column (2) of Table 8. It can be seen that the coefficient of the interaction term is significantly positive, indicating that regions with higher levels of services development are more able to improve their environmental performance through institutional innovation. This may be because the service sector itself has strong green development potential. Compared with traditional manufacturing, service industries such as finance, information technology, consulting, and modern logistics not only have lower resource consumption and pollution emissions, but can also promote green transformation through technological innovation and industrial upgrading. For example, the financial industry can promote the implementation of green projects through green financing, environmental protection investment, and other means, while the information technology industry can improve resource use efficiency and reduce carbon emissions through digital means. As a result, the development of the service sector offers greater scope and potential to drive sustainable improvements in environmental performance. In addition, the service industry is usually more flexible than traditional industries and can quickly adapt to market demand and policy

10.3389/fenvs.2025.1522197

changes, which makes the implementation cost of institutional innovation in the service industry lower and its effect more significant. Regions with high service levels are generally better able to respond to and take advantage of changes in environmental policy and market demand, thereby promoting green innovation and the adoption of green technologies. With the gradual introduction and application of green technologies, these regions can achieve greater progress in reducing resource waste and improving energy efficiency, thus significantly improving environmental performance.

6.2.3 Heterogeneity in openness to the outside world

Accompanied by the deepening of institutional innovation, the expanding two-way openness of the service industry, and the increasing availability of advanced service products, regions relying more on openness to the outside world may be able to realize more effective green development. This paper adopts the proportion of the amount of FDI actually utilized by the region to the regional GDP to measure the degree of openness to the outside world (*OPEN*). When the degree of openness to the outside world is higher than the mean, *open is* assigned a value of 1, and when the degree of openness to the outside world is lower than the mean, *open is* assigned a value of 0. Then *open* and its interaction term with institutional innovation ($did \times open$) are incorporated into the model, and the estimation results are reported in column (3) of Table 8. It can be seen that the coefficient of the interaction term is significantly positive, implying that the more open to the outside world a region is, the more it can improve its environmental performance through institutional innovation. First, regions with a higher degree of openness to the outside world can improve the efficiency of applying green technologies by introducing and absorbing advanced external resources, based on institutional innovation, thus enhancing environmental performance. Second, such regions generally enjoy more policy support and market opportunities. In the context of globalization, they can participate in more international green trade and cooperation, promoting the development of green industries. Institutional innovation provides a more flexible policy environment, encouraging these regions to adopt and innovate green technologies more actively, thus supporting sustainable development. Additionally, market competition resulting from openness to the outside world can also be an important factor. In more open regions, the competitive pressure between companies and governments may be greater, incentivizing them to improve efficiency and green performance through innovation. In this competitive environment, institutional innovation can not only optimize resource allocation but also encourage enterprises to focus more on environmental protection and the introduction and implementation of green technologies. Therefore, the degree of openness to the outside world has become a key factor in promoting green development, especially in areas reliant on external resources. The improvement in openness provides more opportunities and impetus for institutional innovation, making it more likely to achieve a win-win outcome for both environmental protection and green development.

7 Conclusion and policy suggestion

Focusing on institutional innovation in service trade characterized by the development of innovative systems, this paper examines the impact of institutional innovation on environmental performance based on panel data from 75 cities in China between 2011 and 2019 using a staggered difference-in differences model. The main findings are as follows: first, institutional innovation in China's trade in services significantly improves environmental performance, raising the average environmental performance of pilot regions by 0.4635 percentage points, and the conclusion still holds after a series of validity tests and robustness tests. The result is consistent with existing research (Zheng and Zhang, 2024), further demonstrating the positive role of institutional innovation in promoting green development and enhancing environmental performance. Second, institutional innovation improves the environmental performance of the pilot regions mainly by promoting the improvement of green innovation capacity and industrial structure upgrading. This finding is consistent with the research of Musa et al. (2021), emphasizing the role of institutional quality and innovation capability in promoting environmental performance. At the same time, it aligns with Sun et al. (2024), who argues that optimizing the market economy system and promoting technological innovation can effectively drive the implementation of corporate environmental responsibility. Third, regions with stronger government support and higher levels of service industry development and openness to the outside world are better able to rely on institutional innovation to improve their environmental performance. This result echoes the findings of Han et al. (2023), indicating that government governance capacity and the degree of market openness are important factors in driving environmental governance.

As a core component of the service industry, institutional innovation in service trade has a profound impact on improving environmental performance. Although innovation policies for trade in services have been implemented in many regions for years, systematic assessments of their environmental performance remain inadequate. This paper explores the relationship between institutional innovation and the environmental performance of service trade using a staggered difference-in-differences model and a quasi-natural experiment. The study analyzes the mechanisms through which improvements in green innovation capability and industrial structure upgrading affect environmental performance, and reveals the heterogeneous effects of policy implementation across different regions and groups. These findings not only enrich the theoretical framework regarding the relationship between institutional innovation and environmental performance, but also provide a new perspective for the academic community, filling gaps in the existing literature. Furthermore, the study offers both a theoretical foundation and practical guidance for policymakers, particularly regarding the specific impacts of service trade system innovation on environmental performance, which holds significant practical implications.

The conclusions can provide valuable policy insights for promoting the innovative development of trade in services and pollution reduction in developing countries such as China. Firstly, we should further expand the opening-up of the service industry and deepen the innovative development of service trade. The first step is to broaden the scope of opening up in the service industry, allowing for unrestricted flow of technology-intensive and environmentally friendly service factors. The second step involves continuously summarizing and promoting institutional innovation experiences in pilot regions, while exploring a policy system that aligns with the innovative development of trade in services. Secondly, establish a platform that integrates industry, academia, and research to optimize the environment for green technological innovation. This can be achieved by gradually formulating innovation policies, increasing investment in science and technology as well as education, and providing corresponding financial support for green technological innovation. Additionally government departments should encourage collaboration between schools and enterprises while building an innovative platform that combines production, learning, and research to continuously enhance the capacity for green technology innovation, Thirdly, implement differentiated development strategies to promote the upgrading of regional industrial structures. On the one hand, while phasing out heavily polluting and underperforming industries, it is imperative to encourage and guide increased investment in clean service sectors. On the other hand, for emerging green enterprises, it is crucial to fully leverage innovative and preferential policies as guiding mechanisms, fostering deep integration between emerging and traditional industries, thereby propelling sustainable development.

8 Research limitations and future prospects

Although this paper provides useful insights into the impact of institutional innovation in trade in services on environmental performance, some limitations remain.

First, the analysis is based on panel data from 75 cities in China. While the data set is large, the generalizability of the results may be affected to some extent by regional differences. Therefore, future studies could consider expanding the sample to include data from additional countries or regions to enhance the external validity of the conclusions.

Additionally, future research should focus on the dynamic effects of institutional innovation in service trade and its long-term impacts. Since the effects of policies tend to accumulate gradually, short-term data may not fully capture their long-term impact on environmental performance. Consequently, future studies could extend the time span of the research to more thoroughly assess the long-term effects of policy implementation.

With the continuous advancement of the global green development initiative, the interaction between institutional innovation in trade in services and other international environmental protection policies, progress in green technology, and the global supply chain warrants further exploration. Future research could broaden the international perspective and further analyze the mechanisms through which transnational institutional innovation affects environmental performance.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

HX: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Resources, Software, Supervision, Writing–original draft, Writing–review and editing. SW: Formal Analysis, Investigation, Software, Writing–review and editing. LL: Data curation, Investigation, Methodology, Resources, Supervision, Writing–review and editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This work was funded by the Philosophy and Social Science Research Project of Hubei Provincial Department of Education (Grant No. 23Y085).

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.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

References

Antweiler, W., Copeland, B. R., and Taylor, M. S. (2001). Is free trade good for the environment? *Am. Econ. Rev.* 91 (4), 877–908. doi:10.1257/aer.91.4.877

Assogbavi, K. K., and Dées, S. (2023). Environmental policy and the CO2 emissions embodied in internationa ltrade. *Environ. Resour. Econ.* 84 (2), 507–527. doi:10.1007/s10640-022-00734-6

Bai, J. H., and Ding, S. B. (2023). Institution-based openness, business environment, and total factor productivity: a quasi-natural experiment based on China's pilot free trade zone. *China Econ.* (02), 14-45+349–352.

Bai, Y., Qian, Q., Jiao, J., Li, L., Li, F., and Yang, R. (2020). Can environmental innovation benefit from outward foreign direct investment to developed countries? *Environ. Sci. Pollut. Res.* 27 (12), 13790–13808. doi:10.1007/s11356-020-07819-z

Cao, Q. F. (2020). The driving effect of state-level new zones on regional economic growth: empirical evidence based on 70 large and medium-sized cities. *China Ind. Econ.* 7, 43–60. doi:10.19581/j.cnki.ciejournal.2020.07.014

Chen, Z. (2021). Policy evolution and promotion ideas for innovative development of trade in services. *China Dev. Monit.* 24, 63–65.

Copeland, B. R., and Taylor, M. S. (2004). Trade, growth, and the environment. *J. Econ. Literature* 42 (1), 7–71. doi:10.1257/002205104773558047

Dai, X., and Ma, H. W. (2024). Has systemic liberalization promoted export quality and efficiency. *Int. Trade* (01), 66–76. doi:10.14114/j.cnki.itrade.2024.01.012

De Chaisemartin, C., and D'Haultfoeuille, X. (2020). Two-way fixed effects estimators with heterogeneous treatment effects. *Am. Econ. Rev.* 110 (9), 2964–2996. doi:10.1257/aer.20181169

Gan, C. H., Zheng, R. G., and Yu, D. F. (2011). Impact of industrial structure change on economic growth and volatility in China. *Econ. Res.* 46 (5), 4–16+31.

Gardner, J. (2022). Two-stage differences in differences. arXiv preprint arXiv:2207.05943.

Gill, A. A., Ahmad, B., and Kazmi, S. (2021). The effect of green human resource management on environmental performance: the mediating role of employee eco-friendly behavior. *Manag. Sci. Lett.* 6, 1725–1736. doi:10.5267/j.msl.2021.2.010

Goodman-Bacon, A. (2021). Difference-in-differences with variation in treatment timing. *J. Econ.* 225 (2), 254–277. doi:10.1016/j.jeconom.2021.03.014

Guo, J., and Lan, Y. F. (2021). Evolution and mechanism analysis of the effect of domestic market potential in promoting urban economic growth. *Econ. Rev.* 6, 118–135. doi:10.19361/j.er.2021.06.08

Han, S. C., Li, M., and Li, X. Z. (2023). Research on the impact of institutionalized openness of service industry on regional green innovation: a quasi-natural experiment based on the construction of service outsourcing demonstration cities. *Technol. Econ.* 42 (09), 12–23.

Hu, Z. B., Zhu, M. J., and Zhang, Y. Y. (2022). Sources of total factor productivity growth dynamics in the service sector: based on the ternary margin of service export growth. *J. Changsha Univ. Technol. Soc. Sci. Ed.* 37 (5), 49–66. doi:10.16573/j.cnki.1672-934x.2022.05.006

Jalil, A., and Feridun, M. (2011). The impact of growth, energy and financial development on the environment in China: a cointegration analysis. *Energy Econ.* 33 (2), 284–291. doi:10.1016/j.eneco.2010.10.003

Levinson, A. (2010). Pollution and international trade in services. *Int. Environ. Agreements-Politics Law Econ.* 10, 93–105. doi:10.1007/s10784-010-9115-9

Li, K. W., and Ma, T. J. (2023). External demand shocks and trade downturns: an empirical analysis based on the perspective of global value chain reconstruction. *Int. Financ. Stud.* 1, 40–51. doi:10.16475/j.cnki.1006-1029.2023.01.009

Li, L., and Sun, W. (2019). Research on the role mechanism of state audit in promoting environmental performance: analysis based on provincial panel data from 2008-2014. *Ecol. Econ.* 35 (06), 175–181+205.

Li, P., Lu, Y., and Wang, J. (2016). Does flattening government improve economic performance? *J. Dev. Econ.* 123, 18–37. doi:10.1016/j.jdeveco.2016.07.002

Li, S., Sun, B., Hou, D., Jin, W. J., and Ji, Y. (2021). Does industrial agglomeration or foreign direct investment matter for environment pollution of public health? China. *Front. Public Health* 9, 711033. doi:10.3389/fpubh.2021.711033

Lin, G., and Liu, Y. C. (2000). North and marx: a comparison of two explanations on the origin and nature of institutions. *Econ. Res.* 06, 58–65+78.

Liu, C., Sha, X. K., and Zhang, Y. (2022). Interleaved double differencing: treatment effect heterogeneity and estimation method selection. *Res. Quantitative Tech. Econ.* 39 (9), 177–204. doi:10.13653/j.cnki.jqte.20220805.001

Liu, Q., Li, X., Li, Y., Luo, Q., Fan, Q., Lu, A., et al. (2024). Technology empowerment, institutional innovation, and behavior reshaping: how does the "decentralization, regulation, and service" reform optimize the business environment? *Nanjing Soc. Sci.* 19 (06), 36–46. doi:10.1186/s13020-024-00896-z

Liu, S. M., Zhang, S. J., and Zhu, H. D. (2019). Research on the measurement of national innovation driving force and its effect on high-quality economic development. *Quantitative and Tech. Econ.* 36 (04), 3–23. doi:10.13653/j.cnki.jqte.2019.04.001

Liu, Y., and Mao, J. (2019). How do tax incentives affect investment and productivity? Firm-level evidence from China. *Am. Econ. J. Econ. Policy* 11 (3), 261–291. doi:10.1257/pol.20170478

Liu, Y. G. (2023). Green technology innovation leads the high-quality development of basin industry and economy. *People's Forum* 17, 83–85.

Mao, J., and Guan, X. (2022). The effect of local government bailout policies: evidence from listed companies. *Econ. Res.* 57 (9), 82–98.

Musa, M. S., Jelilov, G., Iorember, P. T., and Usman, O. (2021). Effects of tourism, financial development, and renewable energy on environmental performance in EU-28: does institutional quality matter? *Environ. Sci. Pollut. Res.* 28 (38), 53328–53339. doi:10.1007/s11356-021-14450-z

Rehman, S. U., Kraus, S., Shah, S. A., Khanin, D., and Mahto, R. V. (2021). Analyzing the relationship between green innovation and environmental performance in large manufacturing firms. *Technol. Forecast. Soc. Change* 162, 120481. doi:10.1016/j.techfore.2020.120481

Shao, C. Y., and An, A. (2023). How imports of digital products affect firms' environmental performance. *Nankai Econ. Res.* (08), 101–118. doi:10.14116/j.nkes.2023.08.006

Singh, S. K., Del Giudice, M., Chierici, R., and Graziano, D. (2020). Green innovation and environmental performance: the role of green transformational leadership and green human resource management. *Technol. Forecast. Soc. Change* 158, 119762. doi:10.1016/j.techfore.2019.119762

Sun, L., Xu, H., Song, J., Yang, X., Wang, X., Liu, H., et al. (2024). OsNAC103, a NAC transcription factor, positively regulates leaf senescence and plant architecture in rice. *China Mark.* 17 (01), 15–18. doi:10.1186/s12284-024-00690-3

Wang, L., and Meng, H. (2013). Efficiency comparison between inland river ports and coastal ports in China: a study based on common boundary and sequential SBM-DEA. *Soft Sci.* 27 (3), 90–95.

Wang, X. F., and Zheng, J. (2020). Impact of government environmental subsidies on environmental performance under the macro and micro perspectives. *East China Econ. Manag.* 34 (07), 18–27. doi:10.19629/j.cnki.34-1014/f.200303017

Wu, S., Zhou, Y., and Yan, W. (2020). Coastal service industry, industrial structure optimization and environmental governance: an empirical analysis based on Chinese coastal cities. *J. Coast. Res.* 109, 114–120. doi:10.2112/jcr-si109-019.1

Zahid, H., Khan, I. U., Islam, T., Sheikh, Z., and Naeem, R. M. (2020). Do green HRM practices influence employees' environmental performance? *Int. J. Manpow.* 41 (7), 1061–1079. doi:10.1108/ijm-08-2019-0407

Zeng, C. L., and Li, J. T. (2018). Government environmental auditing and environmental performance improvement. *Auditing Res.* (04), 44–52.

Zeng, G., Geng, C., and Guo, H. (2020). Spatial spillover effect of strategic EemergingIndustry agglomeration and green EconomicEfficiency in China. *Pol. J. Environ. Stud.* 29 (5), 3901–3914. doi:10.15244/pjoes/116443

Zhang, K. Z., and Tao, D. J. (2016). Economic distributional effects of transportation infrastructure: evidence from the opening of high-speed rail. *Econ. Dyn.* 6, 62–73.

Zhao, S. L., and Fang, H. (2024). The energy conservation and emission reduction effects of service trade innovation development: evidence from A-share listed companies. *Issues Int. Trade* 37 (5), 49–66.

Zheng, Y., Lv, Q., and Wang, Y. (2022). Economic development, technological progress, and provincial carbon emissions intensity: empirical research based on the threshold panel model. *Appl. Econ.* 54 (30), 3495–3504. doi:10.1080/00036846.2021.2009760

Zheng, Y. W., and Zhang, Q. F. (2024). Synergistic evolution of energy and environmental performance of Chinese textile industry towards pollution reduction and carbon reduction in a systems theory perspective. *J. Syst. Manag.*, 1–26.

Zhuang, R., Mi, K., and Feng, Z. (2021). Industrial co-agglomeration and air pollution reduction: an empirical evidence based on provincial panel data. *Int. J. Environ. Res. Public Health* 18 (22), 12097. doi:10.3390/ijerph182212097