CAN E-COMMERCE DEVELOPMENT DRIVE THE URBAN LOW-CARBON TRANSITION? EVIDENCE FROM CHINESE CITIES

XUE, Z. H.[1,2] – WANG, L. P.[3] – WAN, P. J.[4*] – ZHU, L.[5]

[1]*Northeast Asian Research Center, Jilin University, Changchun 130012, China*

[2]*Linyi People's Hospital, Linyi 276002, China*

[3]*College of Management, Ocean University of China, Qingdao 266100, China*

[4]*School of Public Administration and Policy, Shanghai University of Finance and Economics, Shanghai 200433, China*

[5]*The Discipline Inspection Commission and Supervision Commission of Lanshan District, Linyi City, Linyi 276002, China*

[*]*Corresponding author*
e-mail: m202210956@xs.ustb.edu.cn

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Abstract. In the era of the digital economy, the rapid development of e-commerce has profoundly influenced urban economic patterns and environmental dynamics. This study examines the impact of China's National E-commerce Demonstration Cities (NEDC) policy on urban carbon emissions. Using a dataset covering 265 cities from 2007 to 2023, we applied a progressive difference-in-differences model to assess the policy's effectiveness. The results demonstrate that the NEDC policy has significantly reduced urban carbon emission intensity by 23.1%. Mechanism analysis reveals that this reduction is primarily driven by improvements in energy utilization efficiency, promotion of green technological innovation, and enhancement of economic agglomeration effects. Further heterogeneity analysis indicates that the policy's impact is more pronounced in resource-based cities, and in those with a high proportion of clean energy, well-developed digital infrastructure, and a high degree of openness to external markets. Our study underscores the NEDC policy's efficacy in fostering low-carbon urban development and provides valuable insights for aligning digital economy initiatives with environmental sustainability goals.
Keywords: *e-commerce, carbon emissions, energy efficiency, green technology innovation, economic agglomeration*

Introduction

Against the backdrop of the escalating global climate crisis, greenhouse gas emissions primarily carbon dioxide continue to rise, emerging as a core challenge threatening the sustainable development of human society (Xu et al., 2025). Data from the World Meteorological Organization show that the global atmospheric CO_2 concentration reached 151% of pre-industrial levels in 2023 (WMO, 2024), triggering issues such as rising sea levels and frequent extreme weather events. These effects not only severely threaten ecological security but also pose direct risks to global economic and social stability (Wang et al., 2024). The United Nations' 2030 Agenda for Sustainable Development places climate governance at its core, in which "Climate Action" (SDG13) explicitly requires countries to take urgent measures to drastically reduce greenhouse gas emissions, while "Sustainable Cities and Communities" (SDG11) emphasizes the constructing of resource-efficient and environmentally friendly urban development models. The formulation of these goals reveals the close link between carbon emission

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governance and the achievement of global sustainable development objectives, highlighting the urgency and necessity of transitioning human society toward a low-carbon economy (Xing et al., 2023).

As the world's largest developing country and manufacturing base, China plays a pivotal role in the global carbon reduction process. While China's rapid economic growth over the past few decades has significantly improved living standards, it has also been accompanied by a rapid expansion of energy consumption and a continuous increase in total carbon emissions. Data show that industrial carbon emissions account for over 70% of China's total emissions. The extensive development model of traditional high-energy-consuming industries not only exacerbates domestic ecological and environmental pressures but also poses severe challenges to global climate governance (Lv and Chen, 2024; Liu and Wan, 2025). To proactively fulfill its responsibilities as a major power, China formally proposed the “dual carbon” goals in 2020, committing to peak carbon emissions before 2030 and achieve carbon neutrality before 2060. This strategic deployment marks a comprehensive transition toward green and low-carbon development in China's economic and social spheres. However, constrained by realities such as path dependence in traditional industries and unbalanced regional development, how to achieve emission reduction targets through innovation-driven approaches has become an urgent issue to be addressed (Feng et al., 2024; Lu et al., 2024).

In the wave of digital transformation, e-commerce, as a vital pillar of the digital economy, is reshaping China's economic landscape at an unprecedented pace (Xue, 2024; Gao and Kong, 2024). In 2023, China's online retail sales exceeded 15.42 trillion yuan, representing a 11.0% year-on-year growth, with its driving effect on consumption upgrading, optimizing impact on industrial structure, and enhancing role in economic efficiency becoming increasingly prominent (Qin et al., 2023). By breaking through spatial-temporal constraints via internet platforms, e-commerce has significantly reduced transaction costs and accelerated the circulation efficiency of goods and services (Ye et al., 2024). More importantly, the technological characteristics and industrial linkages of this new business model endow it with unique potential in carbon emission governance, triggering extensive attention from academia and policymakers (Xing et al., 2023). However, the rapid development of e-commerce has also brought new environmental issues, such as the surge in express packaging waste and the rise in logistics distribution carbon emissions, leaving its actual impact on urban low-carbon transition highly controversial (Yu et al., 2023a).

The existing studies on the environmental effects of e-commerce have not yet reached a consistent conclusion. Some studies suggest that e-commerce can substantially reduce energy consumption and carbon emissions in traditional business activities by reducing the construction of physical stores, optimizing logistics and distribution routes, and promoting the trading of second-hand goods (Pålsson et al., 2017). For example, consumers' online shopping behavior has decreased the need for travel to physical stores, thereby reducing carbon emissions in the transportation sector. However, other scholars argue that the rapid expansion of e-commerce has triggered exponential growth in the demand for express packaging materials and increased reliance on logistics vehicles. Without effective environmental protection measures, this could potentially exacerbate environmental pollution (Duan et al., 2019). Although current research has explored the correlation between e-commerce and carbon emissions, several limitations remain evident: First, the academic community has not formed a clear and systematic theoretical framework for the mechanism through which e-commerce affects carbon emissions.

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Second, limited by data availability, existing studies have paid insufficient attention to heterogeneities among cities in terms of resource endowments, infrastructure, energy structures, etc., making it difficult to accurately assess the differentiated impacts of e-commerce on urban low-carbon transitions.

To bridge this research gap, this study leverages the unique institutional context of China's National E-commerce Demonstration City Policy. Since 2010, the Ministry of Commerce has selected and cultivated 700 national e-commerce demonstration cities in multiple batches, promoting the rapid development of e-commerce industries in pilot cities through policy packages including tax incentives, infrastructure construction, and data openness. This quasi-natural experiment provides an ideal setting for evaluating the environmental effects of e-commerce development.

Compared with existing studies, the marginal contributions of this research are reflected in three dimensions:

First, against the backdrop that previous studies have not reached a consensus on the relationship between e-commerce development and urban carbon emissions, and it is difficult to accurately assess the impact due to data availability and endogeneity issues, this paper uses the panel data of 265 cities from 2007 to 2023 based on the unique institutional context of China's National E-commerce Demonstration City Policy, and constructs a progressive difference-in-differences (DID) model to provide new empirical evidence on the impact of e-commerce development on urban carbon emissions. This enriches the empirical literature on the environmental effects of e-commerce and helps academic circles deepen their understanding of the role of e-commerce in urban low-carbon transition. Second, this paper deeply analyzes the mechanism of e-commerce development affecting urban carbon emissions, and reveals the internal logic of reducing carbon emissions by improving energy use efficiency, promoting green technological innovation, and strengthening economic agglomeration effects. The systematic analysis of the action mechanism provides a clear theoretical framework for follow-up research. Third, we reveal the heterogeneous laws of policy effects from the dimensions of resource endowments, infrastructure, energy structure, and opening up, providing a scientific basis for the differentiated formulation of collaborative policies for digital economy and low-carbon development.

The remaining structure of this paper is as follows. Next, we systematically review two categories of literature closely related to this study. Subsequently, we introduce the institutional background and propose hypotheses. Then, we describe the methods, models, and data used in this research. After that, the empirical results are analyzed, followed by a heterogeneity analysis. Finally, we summarize the research findings and policy implications of this paper.

Literature review

The economic effects of e-commerce development

As a pivotal component of the digital economy, e-commerce is rapidly reshaping traditional economic operation models and business landscapes. Since its inception, it has exhibited remarkable penetration and driving capabilities, exerting extensive and profound impacts on economic growth, industrial structure, and corporate behavior. Consequently, e-commerce has emerged as one of the key engines propelling economic development, drawing significant attention and in-depth investigation into its economic effects from various sectors. E-commerce serves as a robust force for economic growth

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and macroeconomic stability. According to Prieger and Heil (2016), investment in information and communication technology (ICT), which underpins e-commerce, enables businesses to reduce operational costs and access new markets, thereby stimulating broader economic activity. This technology influences critical macroeconomic factors such as monetary and fiscal policies, as well as international trade, making e-commerce an integral part of modern economic systems. Similarly, Sharma (2005) highlights that ICT innovations have ignited a digital revolution, transforming how economies operate, learn, communicate, and conduct transactions, while driving socio-economic progress. The significance of e-commerce extends to its role in economic recoveries. Savrul and Kılıç (2011) analyzed the EU's recovery from the 2007–2009 recession and discovered that despite declines in trade volumes and turnover values, e-commerce turnover continued to grow. This suggests that e-commerce can provide an alternative pathway for economic recovery, offering resilience against disruptions in traditional trade and economic downturns. Such resilience is crucial for sustaining economic activity during periods of financial instability.

E-commerce has also become a key player in international trade, particularly in cross-border transactions. According to Zhang (2019), the coordinated development of China's cross-border e-commerce and manufacturing sectors reduces production and transaction costs, thereby facilitating international trade and industrial integration. Lei (2020) further investigates this relationship within the context of the Maritime Silk Road Economic Belt, demonstrating that optimizing logistics thresholds is crucial for enhancing the efficiency of cross-border e-commerce and manufacturing. Collectively, these studies highlight how e-commerce fosters global economic integration by mitigating international trade barriers and reducing costs.

Regional development and rural economic transformation have been profoundly impacted by the rise of e-commerce. Renolafitri (2020) investigates the emergence of Taobao villages in China, illustrating how rural e-commerce can revolutionize local economies by creating income opportunities and addressing social inequalities. This suggests that rural e-commerce acts as a potent tool for fostering economic inclusion, especially in developing countries like Indonesia, where rural communities exhibit unique industrial advantages. Likewise, Cao and Li (2025) employ a dataset from Chinese administrative villages to demonstrate that e-commerce alleviates rural poverty by strengthening collective action, enhancing market integration, and promoting participation in pension insurance programs. They find that, compared to rural areas without e-commerce, those with e-commerce experience a 4.68%–6.39% reduction in poverty levels.

E-commerce's influence extends to sustainability and environmental considerations. Mushtaq et al. (2024) identify a significant positive relationship between the construction of National E-commerce Demonstration Cities (NEDC) and urban economic resilience, highlighting that NEDC initiatives enhance economic resilience by increasing urban employment opportunities and boosting market dynamism. Ding and Gao (2023) examine the impact of urban e-commerce transformation on green total factor productivity (GTFP) through a quasi-natural experiment based on China’s national e-commerce demonstration cities. Specifically, they find that e-commerce development enhances urban GTFP by 1.4%.

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The environmental impact of the development of e-commerce

The environmental implications of e-commerce development have attracted significant scholarly interest, highlighting a nuanced balance between ecological benefits and challenges. On the one hand, e-commerce can alleviate environmental burdens by reducing reliance on physical retail infrastructure and associated transportation. For example, Chen and Yan (2020) demonstrated that the growth of e-commerce in China has contributed to a reduction in sulfur dioxide emissions. Conversely, Duan et al. (2024) warned that in underdeveloped regions of China, e-commerce might increase PM2.5 levels due to inefficient logistics systems, which result in higher emissions. Their estimation results indicated that after the implementation of the ECC policy, the participating counties experienced a 2.5% increase in the average annual mass concentration of PM2.5. Similarly, Biancolin and Rotaris (2024) emphasized that last-mile delivery is a critical phase where substantial environmental costs are incurred, primarily through the use of delivery vehicles and their associated emissions. This aspect of e-commerce logistics not only exacerbates air pollution but also contributes to increased traffic congestion and fuel consumption, thereby amplifying the ecological footprint. Yu et al. (2023a) conducted a comprehensive analysis of the relationship between e-commerce and environmental pollution in China, revealing a significant negative correlation between e-commerce development and air pollution—specifically, a 1% increase in per capita online transaction volume at the provincial level corresponds to a 0.509% decrease in per capita sulfur dioxide emissions. However, they also identified a concerning trend: e-commerce is associated with a 1.276% increase in per capita household waste generation for each 1% rise in online transactions, underscoring its adverse effects on waste pollution. These findings highlight the context-dependent environmental impact of e-commerce, reinforcing the necessity for assessments tailored to local developmental and infrastructural conditions.

One of the primary environmental concerns linked to e-commerce is the carbon footprint generated by transportation and logistics activities. Numerous studies emphasize that shipping and delivery processes are significant contributors to greenhouse gas (GHG) emissions. Empirical evidence illustrates a nuanced relationship: while e-commerce can reduce carbon emissions through efficiency gains, it may also intensify environmental pressures under specific circumstances. Using panel data from 30 Chinese provinces between 2011 and 2021, Liu et al. (2025a) reveal that the flourishing of e-commerce substantially curbs carbon emissions, mainly by lowering energy intensity and fostering technological innovation. Complementary research by Jiang et al. (2024a), conducted on 240 Chinese cities, utilizes the National E-commerce Demonstration City (NEDC) policy as a quasi-natural experiment. Their findings indicate that this policy improves carbon emission efficiency by 3.54% via industrial structure optimization, green technological advancement, and enhanced energy efficiency. However, the study also identifies a negative spatial spillover effect, where neighboring cities experience diminished carbon efficiency due to resource reallocation, highlighting the complexities of regional coordination in e-commerce-driven environmental governance.

Policy interventions and regional heterogeneity significantly influence the environmental outcomes of e-commerce. Du et al. (2024) assess the emission reduction effects of E-commerce Demonstration Zones (EDZs) across 276 Chinese cities, revealing that this policy reduces carbon emissions by 4.63%. Notably, the effects are more pronounced in western cities, larger urban areas, and resource-constrained regions. These findings resonate with the regional analysis conducted by Liu et al. (2025b), which

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underscores spatial disparities in the effectiveness of such policies. Marketization levels and logistics infrastructure emerge as critical moderators. For instance, Jiang et al. (2024a) demonstrate that e-commerce exhibits a stronger emission reduction effect in low-marketization areas, as it more effectively optimizes resource allocation in regions with inefficient traditional distribution systems. Similarly, cities with underdeveloped logistics infrastructure achieve a 31.2% reduction in unit transportation carbon emissions through improvements in e-commerce-driven distribution efficiency, surpassing the gains observed in well-developed regions.

Institutional background and research hypotheses

Institutional background

Following the 2008 global financial crisis, internet technologies accelerated their penetration, enabling e-commerce—a new business model—to achieve leapfrog growth in transaction scale within China. Against this backdrop, the Chinese government approved Shenzhen as the first National E-commerce Demonstration City in 2009, adding pilot cities in three subsequent batches (2011, 2014, and 2017), eventually forming a network of 70 pilot cities (Hu et al., 2025). The distribution of NEDC is shown in *Figure 1*. The policy's core lies in promoting the deep integration of e-commerce with traditional industries through comprehensive institutional design and resource investment.

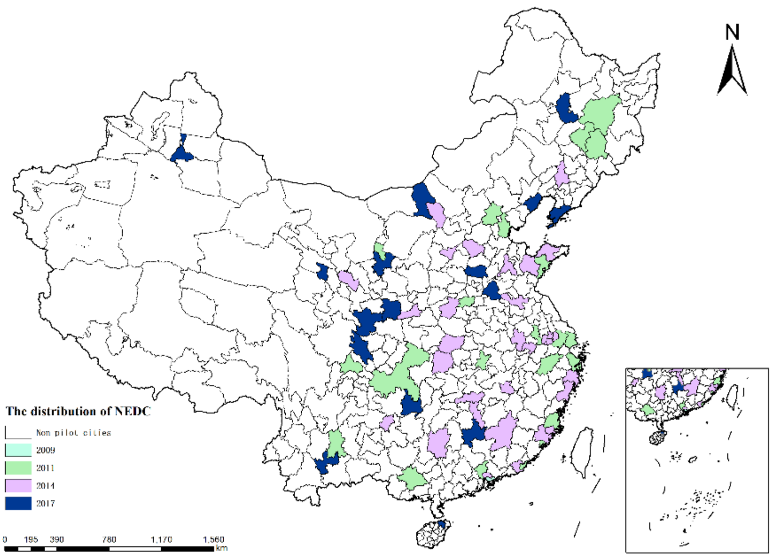

Figure 1. *The distribution of NEDC*

At the infrastructure level, the policy prioritizes the construction of information and communication technologies (ICT) such as broadband networks and mobile internet, providing technical support for e-commerce's efficient operation. Meanwhile, it actively fosters e-commerce platforms, encourages traditional enterprises to transform, and incubates new e-commerce models. Additionally, the policy advocates the construction of a green logistics system, enhancing logistics efficiency and reducing energy consumption and environmental pollution through measures like optimizing logistics

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networks, promoting intelligent technologies, and adopting green packaging. In terms of technological innovation, the policy incentivizes enterprises and research institutions to carry out green technology R&D through financial support and tax incentives, accelerating the application and transformation of green technologies in the e-commerce sector.

The policy and index evaluation system for the construction of NEDC exhibits a pronounced green preference, steering industries toward service sectors with lower energy consumption and emissions. It promotes the transformation of payment methods into "paperless" systems and encourages the application of high-tech innovations. This enhances enterprises' motivation to research and adopt new technologies, thereby increasing energy output per unit while reducing pollutant emissions. Specific guiding opinions include: "regulating the development of online payment resources such as online banking and online payment platforms," "promoting the application of advanced technologies like third-generation mobile communication networks, the Internet of Things, cloud computing, mobile Internet, and next-generation Internet" (2011), and "vigorously developing e-commerce in agriculture, manufacturing, and traditional service industries." Additionally, there are directives to "actively promote e-commerce in areas related to people's livelihood and cross-border e-commerce to facilitate economic transformation and upgrading" (2014), and "develop rural e-commerce, manufacturing e-commerce, etc., coordinate the construction of smart business districts, leverage e-commerce to drive the transformation and upgrading of traditional service industries, actively develop cross-border e-commerce, and expand new channels for international trade" (2017). Regarding the index evaluation system, taking Beijing's comprehensive evaluation index for national e-commerce demonstration bases as an example, it explicitly integrates a green development module. The specific indicators, along with their classifications and evaluation scales, are presented in the *Table 1:*

In practice, the NEDC policy has exerted a significant and far-reaching influence on the e-commerce ecosystems of the pilot cities and the nation as a whole. It has successfully facilitated the expansion of e-commerce transaction volumes in the pilot regions, thereby accelerating the growth of associated industries. The achievements of the demonstration cities have not only served as exemplary models for other cities but also propelled the nationwide enhancement of e-commerce capabilities, making tangible contributions to China's sustainable development objectives.

Research hypothesis

The development of e-commerce and urban carbon emissions

The impact of the development of e-commerce (NEDC policy) on urban carbon emissions can be analyzed from multiple perspectives. First, the growth of e-commerce streamlines supply chain management by eliminating redundant intermediary steps, which in turn reduces energy consumption and carbon emissions associated with logistics and transportation. E-commerce platforms integrate information across the supply chain, enhancing the efficiency of production, distribution, and consumption processes while minimizing energy waste during transportation (Teng et al., 2023). On the industrial side, the e-commerce pilot policy promotes industrial upgrading and resource optimization, thereby contributing to a reduction in carbon emissions (Lv and Chen, 2024). This transformation typically involves replacing energy-intensive processes with low-carbon alternatives. Moreover, the policy fosters the growth of service sectors such as

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information technology and logistics, which generally have lower carbon intensity compared to traditional manufacturing. Through the expansion of these low-carbon industries, the policy significantly mitigates the overall carbon footprint of a city's industrial structure.

Table 1. *Beijing's comprehensive evaluation index for national e-commerce demonstration*

Indicator	Classification	Evaluation Scale
Whether funds are allocated to support enterprise green development	Financial Support for Green Development	1 = Yes; 0 = No
Whether enterprises are organized or guided to implement digital operations	Digital Operation Management	1 = Yes; 0 = No
Whether green warehousing and distribution facilities are constructed	Green Infrastructure Construction	1 = Yes; 0 = No
Whether enterprise resource sharing mechanisms are established	Collaborative Resource Management	1 = Yes; 0 = No
Whether new energy or clean energy vehicles are utilized	Clean Energy Application	1 = Yes; 0 = No
Whether water-saving, electricity-saving, and gas-saving systems have been implemented	Energy-Saving Measures	1 = Yes; 0 = No
Whether garbage classification and other energy-saving and efficiency-enhancing supporting facilities are provided	Environmental Protection Supporting Facilities	1 = Yes; 0 = No

Secondly, the rise in e-commerce popularity has significantly boosted online transaction volumes while diminishing reliance on brick-and-mortar stores. The operation of physical stores entails substantial energy consumption, particularly for lighting, air conditioning, cooling, and other operational needs. As e-commerce continues to grow, consumers are increasingly shifting toward online shopping, which lessens their dependence on physical retail spaces and consequently reduces the overall energy consumption associated with commercial real estate. This shift in consumer behavior contributes to lower urban carbon emissions (Zhang et al., 2024a).

Furthermore, e-commerce has significantly propelled the growth of information consumption, which generally exhibits a lower carbon footprint compared to traditional material consumption (Xu et al., 2025). Information consumption primarily depends on digital infrastructure and electronic devices, with its energy consumption largely concentrated in the operation of data centers and network equipment. In contrast to traditional material consumption, the carbon emissions associated with the production, transportation, and use phases of information consumption are markedly reduced. From the perspective of green consumption, the rise of e-commerce has not only facilitated innovative payment methods such as mobile payment but also actively guided residents

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toward adopting green consumption patterns, thereby effectively promoting the green transformation of industries. For example, the widespread adoption of mobile payment platforms like Alipay and WeChat Pay has notably increased the likelihood of residents opting for public transportation during their commutes. Additionally, the “Ant Forest” initiative launched by Alipay, through an innovative incentive mechanism, has successfully encouraged residents to accumulate “green energy” via environmentally friendly lifestyle choices, thus fostering the development of a sustainable green consumption ecosystem (Qian et al., 2025).

The implementation of the NEDC policy has further accelerated the popularization and development of e-commerce in cities. Policy support has not only promoted the growth of e-commerce enterprises but also driven the digital transformation of traditional enterprises. With the in-depth development of e-commerce, the urban economic activity model has gradually shifted toward digitalization, networking, and intelligence, which helps improve energy use efficiency, reduce unnecessary energy waste, and thus lower the carbon emission intensity of cities. Additionally, the NEDC policy encourages enterprises to adopt green technologies and sustainable development practices through measures such as financial support and tax incentives, further enhancing e-commerce's contribution to urban carbon emission reduction.

Based on the above analysis, this paper proposes Hypothesis H1: The NEDC policy can reduce urban carbon emissions.

E-commerce development, energy utilization efficiency and carbon emissions

In the modern economic system, improving energy use efficiency is a key factor in achieving low-carbon development. The NEDC policy significantly enhances urban energy use efficiency through multiple mechanisms, thereby effectively reducing carbon emissions. From the perspective of factor allocation, e-commerce platforms leverage digital technologies to dismantle information barriers in traditional markets, achieving precise supply-demand matching via big data algorithms. This not only substantially reduces transaction costs but also mitigates resource misallocation (Yang et al., 2024). Such efficiency gains can minimize redundant energy consumption in production and circulation processes. At the production stage, enterprises can adopt a “sales-driven production” model based on real-time order data, thereby reducing warehouse energy waste caused by excessive inventory. In the circulation phase, intelligent logistics systems optimize routes to decrease transportation mileage and empty loading rates, significantly lowering per-unit logistics energy consumption. This micro-level resource optimization directly enhances the overall energy efficiency of urban systems (Wang et al., 2023).

In the dimension of industrial structure, according to the Petty-Clark theorem, the e-commerce development promoted by the NEDC policy will accelerate the service-oriented transformation of urban industrial structures (Qian et al., 2025). As a low-energy-consuming and high-value-added emerging industry, the increasing proportion of e-commerce and its derivative digital economy formats (such as cloud computing and digital finance) in urban economies will replace the share of traditional high-energy-consuming manufacturing industries. This “structural dividend” is reflected in two aspects: First, the energy consumption per unit of output in the service sector is significantly lower than that in manufacturing, and the softening of industrial structure directly reduces the overall energy consumption intensity of cities (Zhao et al., 2022). Second, the penetration of digital technologies into traditional industries (such as industrial internet transformation) can enhance the fine-grained level of energy

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management in manufacturing, reducing energy waste through process optimization and real-time monitoring (Li et al., 2024).

In summary, this paper proposes Hypothesis H2a: The NEDC policy reduces urban carbon emissions by improving energy use efficiency.

E-commerce development, green technology innovation and carbon emissions

Green technological innovation has emerged as the core driving force for advancing the low-carbon development of cities. The NEDC policy has successfully fostered an ecosystem conducive to innovation, thereby effectively promoting the research and application of green technologies and reducing urban carbon emissions. On the one hand, the rise of e-commerce has expanded the pathways for technology dissemination, enhancing inter-city knowledge flows (Dong et al., 2023). With NEDC policy support, a robust cooperation and communication mechanism among cities has been established, significantly accelerating the diffusion and sharing of green technologies. E-commerce platforms have facilitated the rapid dissemination of green technological innovations across the entire industrial chain, encouraging related enterprises to absorb and apply new technologies (Hu et al., 2025). For example, certain e-commerce platforms now offer online display and trading services for green technologies, enabling innovative solutions to reach a broader range of potential users and expediting their market penetration.

On the other hand, the NEDC policy has fostered a market environment that stimulates innovation, drawing high-end talents and research institutions to the demonstration cities. These talents and institutions have introduced cutting-edge technological concepts and R&D capabilities, thereby providing intellectual support for the city's green technological innovation. To facilitate the development of national e-commerce demonstration cities, pilot cities have successively implemented a series of preferential policies aimed at supporting the growth of e-commerce enterprises and related industries. This has contributed to creating a “policy magnet effect” in the pilot regions, attracting the concentration of factors such as labor and capital. Such an agglomeration effect not only enhances the city's innovation capacity but also fosters collaborative innovation among various entities, leading to the emergence of more green technological achievements with practical application value.

In addition, the development of e-commerce has facilitated the commercialization of green technologies by amplifying market demand. As consumer environmental awareness continues to rise, the demand for green products and services is expanding significantly. Enterprises backed by the NEDC policy are better positioned to perceive these market trends, thereby increasing their investment in green technological innovation and developing more competitive low-carbon products. Through e-commerce platforms, enterprises can effectively promote energy-saving products and environmental protection technologies, achieving both their own sustainable development and catalyzing the green transformation of the entire industrial chain.

To summarize, this paper proposes Hypothesis H2b: The National E-commerce Demonstration City (NEDC) policy mitigates urban carbon emissions by fostering green technological innovation.

E-commerce development, economic agglomeration and carbon emissions

The economic agglomeration effect is a critical feature of urban economic development. By facilitating the spatial concentration and efficient allocation of resources, it significantly enhances production efficiency and innovation capacity. The

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NEDC policy has effectively mitigated urban carbon emissions by optimizing urban spatial layouts, improving resource allocation, and reinforcing the economic agglomeration effect. First, the NEDC policy has facilitated the formation and growth of industrial clusters. The rise of e-commerce has enabled related enterprises to concentrate geographically and form industrial clusters (Ding and Gao, 2023). Through incentives such as the establishment of e-commerce industrial parks and preferential policies, the NEDC policy has guided the creation of e-commerce clusters, offering opportunities for the integration and co-development of e-commerce and traditional industries. This agglomeration not only reduces enterprise operating costs but also enhances resource utilization efficiency through shared infrastructure and public services, thereby lowering carbon emissions per unit of output (Liu et al., 2023).

Second, the NEDC policy has facilitated the reallocation of production factors towards high-productivity sectors. The adoption of e-commerce platforms has decreased consumers' information search costs and transportation costs, thereby enhancing their utility levels and improving the efficiency of supply-demand information matching. This process generates a “local market effect,” which stimulates market demand expansion. The resulting increase in market demand attracts additional capital and labor to concentrate in high-productivity sectors, creating a positive agglomeration effect. Given that high-productivity sectors typically exhibit higher energy efficiency and lower carbon emission intensity, the reinforcement of economic agglomeration contributes to reducing the overall carbon emission level of the city.

Furthermore, the NEDC policy amplifies the positive externalities of economic agglomeration by fostering knowledge spillovers and technological innovation among cities (Liu et al., 2023). Within demonstration cities, enterprises share green technologies and environmental protection strategies via e-commerce platforms, driving the low-carbon transformation of the entire region.

Finally, the NEDC policy enhances the functional layout of cities by improving their comprehensive carrying capacity. With policy support, cities have achieved significant advancements in infrastructure development, public service delivery, and ecological environment protection. This improvement in comprehensive carrying capacity not only boosts urban resource utilization efficiency but also attracts more people and industries to cluster, thereby fostering economies of scale. The economies of scale enable cities to either maintain or reduce carbon emission levels per unit of output while expanding their economic scale. Additionally, the external spillover effects and symbiotic relationships generated by economic agglomeration have improved the efficiency of factor utilization, such as information and energy, minimized resource waste and by-product generation, and consequently reduced greenhouse gas emissions, including carbon dioxide, during urban energy consumption.

Based on the aforementioned analysis, this paper puts forward the hypothesis that the H2c: NEDC policy can reduce urban carbon emissions by enhancing economic agglomeration effects.

Materials and methods

Econometric model

Given that the NEDC policy was implemented in batches, with four rounds of pilots conducted in 2009, 2011, 2014, and 2017, this paper treats the national e-commerce demonstration city policy as an exogenous shock. Based on the pilot timelines, we

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designate cities included in the NEDC policy as the treatment group and those not covered as the control group, constructing a progressive difference-in-differences (DID) model to examine the policy's impact on urban carbon emissions. The econometric model is specified as follows:

$$CO2_{it} = \alpha_0 + \alpha_1 ECD_{it} + \alpha_c Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad \text{(Eq.1)}$$

In *Eq.1*, $CO2_{it}$ denotes the carbon dioxide emission intensity of cities. Ecd_{it} is a dummy variable for e-commerce development, taking the value of 1 if city i is included in the NEDC program in year t, and 0 otherwise. $Controls_{it}$ represents a set of control variables. μ_i and λ_t denote city fixed effects and time fixed effects, respectively, while ε_{it} is the random error term. Additionally, standard errors are clustered at the city level to account for potential within-city serial correlation.

Variable definitions

Dependent variable (CO2)

Following the measurement approach of Wei and Wan (2025), we calculate the total carbon dioxide emissions for each city based on electricity consumption, total consumption of artificial coal gas and natural gas, and liquefied petroleum gas (LPG) consumption. The carbon dioxide emission intensity is then obtained by dividing total emissions by the city's GDP, and we take the logarithm of this intensity value for empirical analysis.

Core explanatory variable (ECD)

The core explanatory variable is the level of e-commerce development (*ECD*), measured as a binary dummy variable. Specifically, if a city is officially listed as a National E-commerce Demonstration City in year t, *ECD* takes the value of 1 for that city in year t and all subsequent years; otherwise, it is 0.

Mediating variables

1. Energy Use Efficiency (EE)

Energy use efficiency is measured by the output value per unit of energy consumption. Given that urban electricity consumption constitutes the primary source of energy use, this study employs urban electricity usage to represent total energy consumption. A higher output value per unit of electricity consumption indicates a stronger efficiency in converting energy into economic value.

2. Green Technological Innovation (GTI)

Drawing on research by Yu et al. (2023b), green technological innovation capacity is measured by the logarithmic value of per capita green patent applications in each city. This study focuses on green technological innovation (measured by green patent applications) because it reflects the core capacity of cities to generate new low-carbon technologies, which is directly incentivized by the NEDC policy’s support for R&D and digital infrastructure. While green technology adaptation is also important for emission reduction, it is often a downstream outcome of innovation. Given data availability and

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the policy's direct focus on technological upgrading, this study prioritizes innovation as a key mechanism, with adaptation considered a potential extension for future research.

3. Economic Agglomeration (EA)

Economic agglomeration level is commonly characterized by output density or economic density, defined as the economic output per unit of land area (Ciccone and Hall, 1993). This study measures economic agglomeration as the ratio of GDP to urban construction land area.

Control variables

To minimize bias from omitted variables in evaluating the NEDC's impact on urban carbon emissions, we control for the following variables based on existing research:

Industrial structure (*Ind*): Measured by the ratio of tertiary to secondary industry output (Jiang et al., 2024b). The secondary industry referred to in this paper includes: mining industry, manufacturing industry, production and supply of electricity, gas and water, and construction industry. The tertiary industry refers to other industries except the primary and secondary industries. It includes: transportation, storage and postal services; information transmission, computer services and software industry; wholesale and retail trade; accommodation and catering industry; financial industry; real estate industry; leasing and business services; scientific research, technical services and geological prospecting industry; water conservancy, environment and public facilities management industry; residential services and other services; education; health, social security and social welfare; culture, sports and entertainment industry; public administration and social organizations; and international organizations.

Economic development level (*Pgdp*): Represented by the logarithm of per capita GDP (Jiang and Jiang, 2024).

Financial development level (Fin): Calculated as the ratio of year-end deposits and loans balance of financial institutions to GDP (Zhang et al., 2024b).

Urbanization (*Urban*): Measured by the proportion of non-agricultural population.

Human capital (*Hc*): Represented by average years of education in each city.

Population size (*Pop*): Measured by the logarithm of urban population (Jiang et al., 2023).

Sample selection and data sources

Considering data availability, after removing samples with severe missing values, this study retains 265 Chinese cities from 2007 to 2023 as the research sample. Regarding the processing of missing values in the sample data, the following criterion was adopted: city samples were excluded if they had 20% or more missing values. Specifically, when the proportion of missing values in a city's sample reached 20% or higher, that city sample was removed from the dataset to ensure the reliability and validity of the analysis results.

The data primarily derive from the China City Statistical Yearbook and the EPS database. For minor missing values in some variables, linear interpolation is used for imputation, resulting in a final dataset of 4,505 observations. *Table 2* reports the descriptive statistics for each variable.

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Table 2. *Descriptive statistics*

Variable	N	Mean	SD	Min	Max
CO2	4505	2.911	0.762	0.366	6.933
ECD	4505	0.133	0.340	0	1
Pgdp	4505	10.502	0.724	4.595	13.064
Urban	4505	54.171	15.961	6.491	121.684
Ind	4505	1.301	0.721	0.187	10.601
Hc	4505	0.020	0.027	0	0.193
Fin	4505	2.330	1.176	0.560	21.302
Pop	4505	5.873	0.697	2.868	8.136
EA	4505	17.221	11.730	0.153	228.814
GTI	4505	3.468	1.897	0	9.978
EE	4505	0.029	0.028	0.001	0.320

Results

Baseline regression analysis

Table 3 reports the baseline regression results of NEDC's impact on urban carbon emissions. To verify the robustness of the findings, we adopt a stepwise regression approach, sequentially incorporating control variables such as industrial structure, economic development level, urbanization, human capital, financial development, and population size. The results in columns (1)-(7) show that the regression coefficient of the core explanatory variable *ECD* remains consistently negative and passes the 1% significance level test in all specifications. Compared with non-pilot cities, the policy promoting e-commerce development reduces the carbon emission intensity of cities by 23.1%. Hypothesis 1 is thus validated.

Table 3. *Benchmark regression results*

Variables	(1) CO2	(2) CO2	(3) CO2	(4) CO2	(5) CO2	(6) CO2	(7) CO2
ECD	-0.267***	-0.261***	-0.271***	-0.260***	-0.256***	-0.258***	-0.231***
	(0.028)	(0.028)	(0.028)	(0.027)	(0.027)	(0.027)	(0.027)
Ind		-0.072***	-0.053***	-0.043**	-0.045***	-0.046***	-0.039**
		(0.016)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
Pgdp			-0.119***	-0.218***	-0.223***	-0.167***	-0.181***
			(0.035)	(0.036)	(0.036)	(0.038)	(0.038)
Urban				0.017***	0.017***	0.017***	0.016***
				(0.002)	(0.002)	(0.002)	(0.002)
Hc					-0.139	0.004	-0.699
					(0.750)	(0.749)	(0.763)
Fin						-0.049***	-0.043***
						(0.012)	(0.012)
Pop							-0.472***
							(0.103)
_cons	2.947***	3.039***	4.267***	4.360***	4.433***	3.738***	6.707***
	(0.007)	(0.022)	(0.365)	(0.360)	(0.357)	(0.395)	(0.760)
City FEs	YES	YES	YES	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES	YES	YES	YES
N	4505	4505	4505	4505	4505	4505	4505
R^2	0.754	0.756	0.756	0.763	0.761	0.762	0.764

Note: Standard errors clustered at the city level are reported in parenthesis; ***, ** and * indicate statistical significance at the levels of 1%, 5%, and 10% respectively

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Parallel trend test

The parallel trend assumption is the cornerstone of the difference-in-differences (DID) model for identifying causal effects. It aims to test whether the treatment group and the control group exhibited similar trends in carbon emission changes prior to policy implementation. If this assumption holds, it indicates that the evolution of carbon emissions in both groups before the policy was driven solely by common macro factors. This ensures that any differences observed post-policy can be reasonably attributed to the NEDC pilot policy, rather than pre-existing group differences or other confounding factors. Violation of the parallel trend assumption would introduce selection bias into the estimation results, undermining the validity of policy effect identification. Therefore, examining the dynamic differences in carbon emission intensity between the treatment and control groups across all pre-policy periods serves as a critical prerequisite for validating the reliability of causal inference in this study.

Figure 2 illustrates the dynamic changes in carbon emission intensity between the treatment group and the control group before and after the implementation of the NEDC policy. The horizontal axis denotes the relative time of policy implementation (negative values indicate pre-policy periods, while positive values indicate post-policy periods); the vertical axis represents the influence coefficient of the NEDC pilot policy on urban carbon emission intensity; the dashed lines depict the 90% confidence interval. As shown in the figure, prior to policy implementation, there is no significant difference in carbon emission intensity between the treatment and control groups ($p > 0.1$), with the coefficient estimate fluctuating around zero. This suggests that there is no substantial divergence in the carbon emission change trends between pilot and non-pilot cities before the policy, thereby satisfying the parallel trend assumption.

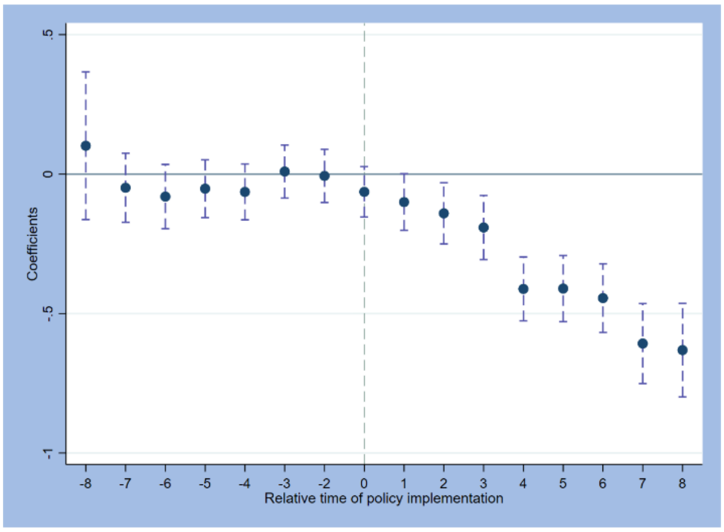

Figure 2. *Parallel trend test*

Placebo test

To further validate the robustness of baseline regression results and rule out the possibility of unobserved confounding factors interfering with policy effect estimation, this paper conducts a placebo test. This method constructs fake treatment groups or pseudo policy shocks to simulate scenarios without actual policy intervention. If a

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significant policy effect still emerges, it indicates potential bias in baseline results; conversely, insignificant coefficients in fake scenarios support the baseline reliability. To be specific, we performed random assignment of treatment status to cities, constructing 1,000 placebo treatment groups and conducting separate regressions for each. The results show that most coefficient estimates of the placebo policy variables failed to pass statistical significance tests, with their distribution centered around zero (*Figure 3*). This distribution markedly deviates from the true estimate of -0.231 (denoted by the red vertical line), confirming that the significant policy effect in baseline regressions is not attributable to random factors or unobserved confounders.

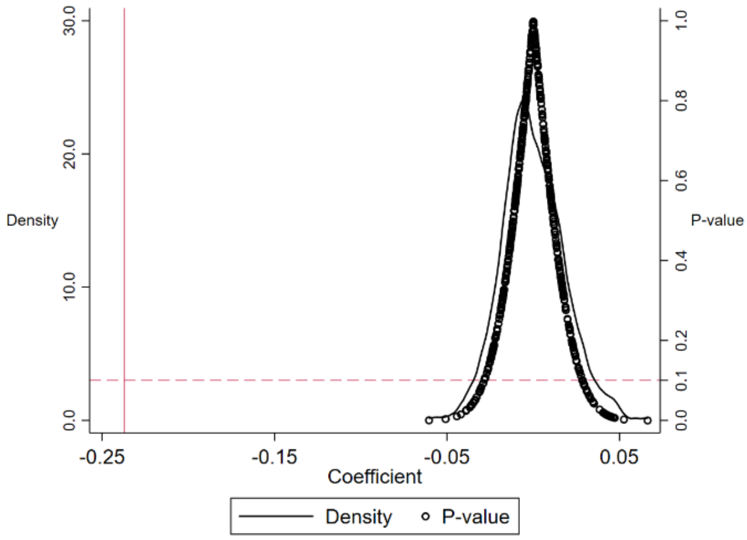

Figure 3. *Placebo test*

Bacon decomposition

In multi-period difference-in-differences (DID) models, staggered policy interventions across treatment groups may lead to bias in the two-way fixed effects model (de Chaisemartin and D'Haultfoeuille, 2023). To ensure the accuracy of NEDC policy effect estimation, this paper decomposes the average treatment effect of the multi-period DID using the method proposed by Goodman-Bacon (2021), aiming to identify the contribution of different treatment groups and timing to the overall estimate and assess potential bias.

Table 4 presents the weighting results from the Bacon decomposition. The “Timing_groups” reflect differences arising from varying policy implementation times, i.e., disparities between treated and control units at different treatment timings. In this study, Timing_groups account for only 6.4% of the total weight, indicating limited impact on the overall estimation. Additionally, the weighted sum of DID estimators across different classification groups is -0.231 (see *Figure 4*), consistent with the baseline result in *Table 3*, column (7). This confirms that the progressive DID model exhibits minimal bias and robust reliability in estimating the NEDC policy's impact on urban carbon emissions.

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Table 4. *Bacon decomposition weight results*

Control group classification	Estimator	Total Weight
Timing_groups	0.174	0.064
Never_v_timing	-0.277	0.899
Within	0.187	0.037

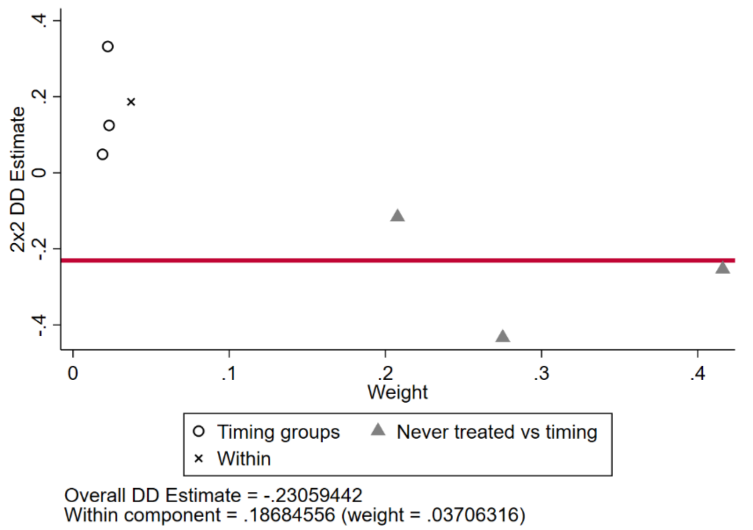

Figure 4. *Bacon decomposition weight distribution*

Other robustness tests

PSM-DID

To address potential sample selection bias, this study employs propensity score matching-difference-in-differences (PSM-DID) for robustness testing. Specifically, we use all control variables from the baseline regression (industrial structure, economic development, etc.) as covariate characteristics, estimate each city's propensity score for NEDC inclusion via a Logit model, and match treatment and control groups using radius matching (radius = 0.05). Matching results show that standardized biases for all covariates are reduced to within 15% (*Figure 5*), indicating significantly improved pre-policy characteristic balance between groups and effective mitigation of sample selection bias.

Re-estimating the model with the matched sample (*Table 5*, column 1), the core explanatory variable *ECD* yields a coefficient of -0.265, consistent with the baseline regression in both direction and significance level. This result confirms that the NEDC policy's inhibitory effect on urban carbon emission intensity remains significant even after strict control of sample selection bias, validating the robustness of baseline conclusions.

Exclude the samples from the epidemic period

To exclude the interference of the COVID-19 pandemic's exogenous shock on policy effect estimation, this study further conducts a robustness test by excluding samples from 2020 to 2023. During the pandemic, urban economic activity patterns underwent drastic changes (e.g., widespread adoption of remote work, logistics disruptions, supply chain

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interruptions), non-policy factors that could cause abnormal fluctuations in carbon emission intensity and thus confound the true effect of the NEDC pilot policy.

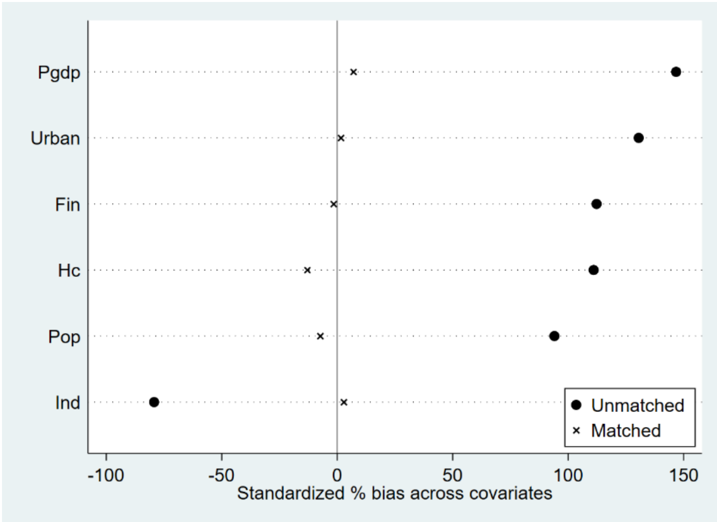

Figure 5. *Balance test*

Table 5. *Other robustness tests*

Variables	**(1)** **CO2**	**(2)** **CO2**	**(3)** **CO2**	**(4)** **CO2**
ECD	-0.265***	-0.162***	-0.129***	-0.241***
	(0.033)	(0.027)	(0.036)	(0.037)
_cons	3.694***	3.964***	3.848***	6.268***
	(0.262)	(0.430)	(0.410)	(0.572)
Controls	YES	YES	YES	YES
City FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
N	3896	3445	3604	2468
R-squared	0.672	0.826	0.772	0.800

Table 5, column (2) presents regression results after excluding pandemic-period samples. The regression coefficient of the core explanatory variable *ECD* remains significantly negative, indicating that the NEDC policy's effect in reducing urban carbon emission intensity remains robust after removing pandemic interference. This further validates the reliability of this study's conclusions: the NEDC pilot policy significantly promotes urban low-carbon transitions, and this conclusion is unaffected by exceptional events like the pandemic.

Exclude special city samples

In China, provincial capital cities and sub-provincial cities typically enjoy special status and policy preferences in political, economic, and resource allocation spheres, which may lead to significant differences in development models and policy responses compared to ordinary prefecture-level cities. For example, these special cities often possess higher fiscal autonomy, more sophisticated infrastructure, and stronger

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capabilities to attract investment and talent—characteristics that could cause their carbon emission trends to diverge from other cities. To ensure research findings are not confounded by the atypical characteristics of these cities and to accurately assess the NEDC pilot policy's general impact on ordinary cities, this paper conducts a robustness test excluding provincial capitals and sub-provincial cities.

Table 5, column (3) reports regression results after excluding special cities. The core explanatory variable *ECD* yields a coefficient of -0.129, remaining significantly negative. This indicates that the NEDC's inhibitory effect on urban carbon emissions remains robust after removing provincial capitals and sub-provincial cities. The results confirm the generalizability of our conclusions: the NEDC's promotion of urban low-carbon transition is not driven by a few special cities but applies universally to cities of all types.

Exclude interference from other policies

To more accurately assess the independent impact of the NEDC pilot policy on urban carbon emissions, this study further conducts a robustness test excluding interference from other policies. Previous studies have shown that China's low-carbon city pilot policy and smart city pilot policy may also affect urban carbon emissions (Lv et al., 2024; Dong et al., 2024; Li et al., 2025).

Table 5, column (4) presents regression results after excluding samples influenced by low-carbon city and smart city pilot policies. The core explanatory variable *ECD* yields a coefficient of -0.241, which is significantly negative at the 1% level. This indicates that the NEDC pilot policy's inhibitory effect on urban carbon emissions remains robust after removing interference from other policies.

Mechanism analysis

To uncover the internal pathways through which the NEDC pilot policy influences urban carbon emissions, this study selects energy efficiency (*EE*), green technological innovation (*GTI*), and economic agglomeration (*EA*) as mediating variables and constructs a mediation effect model for mechanism testing. The regression results are presented in *Table 6*.

Table 6. *Mechanism test results*

Variables	(1) EE	(2) GTI	(3) EA
ECD	0.041***	0.090**	0.272***
	(0.006)	(0.037)	(0.061)
_cons	0.363***	-0.891*	-37.220***
	(0.082)	(0.528)	(8.633)
Controls	YES	YES	YES
City FEs	YES	YES	YES
Year FEs	YES	YES	YES
N	4505	4505	4505
R-squared	0.674	0.733	0.615

Column (1) of *Table 6* indicates that the estimated coefficient of NEDC on energy efficiency (*EE*) is 0.041, which is statistically significant at the 1% level with a positive sign. This finding demonstrates that the NEDC policy has effectively improved urban energy efficiency. Such improvement can be attributed to e-commerce optimizing supply

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chain management, promoting efficient resource allocation, and facilitating corporate digital transformation, thereby reducing redundant energy consumption links and achieving more efficient energy utilization. As such, Hypothesis H2a is supported.

Column (2) shows that the coefficient of NEDC is statistically significant at the 5% level with a positive sign, indicating that the NEDC policy has significantly promoted green technological innovation (*GTI*). The development of e-commerce provides enterprises with broader market reach and richer information resources, incentivizing them to increase investments in green technology R&D. Meanwhile, the technological innovation demands of e-commerce platforms themselves drive progress in related fields such as green logistics and digital energy management—these technological innovations further reduce urban carbon emission intensity. Accordingly, Hypothesis H2b is validated.

The results in Column (3) show that the coefficient of NEDC on economic agglomeration (*EA*) is significantly positive at the 1% level, indicating that the NEDC pilot policy effectively enhances economic agglomeration, thereby further facilitating the low-carbon transformation of cities. The growth of e-commerce has not only stimulated the spatial agglomeration of economic activities but also increased the economic density and industrial concentration of cities. This agglomeration effect fosters knowledge spillovers and technology diffusion while reducing energy consumption per unit of economic output through economies of scale, thus contributing to the effective control of carbon emissions. Hypothesis H2c is therefore supported.

Heterogeneity analysis

The baseline regression results demonstrate that the National E-commerce Demonstration Cities (NEDC) pilot policy significantly curbs urban carbon emissions, and this conclusion has been validated through multiple robustness tests. Nevertheless, given China's extensive geographical expanse, cities vary considerably in terms of resource endowments, energy structures, infrastructure, and other dimensions. In light of these disparities, a more pertinent question emerges: Does the low-carbon effect of the NEDC policy exhibit differential performance depending on variations in urban resource endowment characteristics, energy consumption structures, information infrastructure levels, and degrees of openness? To further explore the heterogeneous impacts of policy implementation, this section conducts a detailed heterogeneity analysis of the baseline regression results across four dimensions: urban resource endowment types (resource-based vs. non-resource-based), cleanliness of energy consumption structures, completeness of information infrastructure, and degree of openness.

Resource endowment

Based on the “Notice of the State Council on Issuing the National Sustainable Development Plan for Resource-based Cities (2013–2020,” we categorized the sample cities into resource-based and non-resource-based cities to investigate the heterogeneous emission reduction effects of the NEDC pilot policy under varying resource endowments. The regression results in columns (1) and (2) of *Table 7* indicate that in resource-based cities, the emission reduction effect of the NEDC policy is more pronounced, with the corresponding coefficient being -0.325 and significant at the 1% level. In contrast, in non-resource-based cities, the NEDC coefficient was -0.174, which only passed the significance test at the 10% level. The difference between the two groups was significant at the 1% level.

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Table 7. *Heterogeneity analysis based on resource endowment and energy structure*

Variables	(1) Resource-based Cities	(2) Non-resource-based Cities	(3) Low Energy Cleanliness	(4) High Energy Cleanliness
	CO2	**CO2**	**CO2**	**CO2**
ECD	-0.174*	-0.325***	-0.127*	-0.242***
	(0.097)	(0.061)	(0.069)	(0.085)
_cons	2.905**	5.096***	3.407***	5.208***
	(1.170)	(1.226)	(0.818)	(1.411)
Controls	YES	YES	YES	YES
City FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Test for Group Differences	0.151***		0.115***	
N	1826	2675	2231	2254
R-squared	0.760	0.778	0.820	0.802

This outcome may be attributed to the following context and mechanisms: Resource-based cities typically face challenges such as strong resource dependence, industrial structures dominated by heavy industry, and low energy efficiency, which are often accompanied by higher carbon emission intensities during the transition process. The development of e-commerce provides new growth drivers and transformation opportunities for resource-based cities. Through e-commerce platforms, these cities can expand market boundaries, promote deep processing and high-value-added transformation of resource-based products, and thus drive industrial restructuring towards diversification and upgrading. Meanwhile, the digital management tools and information technologies of e-commerce also help improve energy management in resource-based enterprises, optimize resource allocation, reduce energy waste, and thereby achieve more substantial carbon emission reductions.

Energy consumption structure

To further explore the impact of energy consumption structure on the emission reduction effect of the NEDC policy, cities were categorized into high-energy cleanliness and low-energy cleanliness groups based on the proportion of coal consumption. Specifically, the classification was determined by measuring the ratio of coal consumption to total energy consumption in each city. Cities with a relatively lower proportion of coal consumption were classified as high-energy cleanliness cities, while those with a relatively higher proportion were classified as low-energy cleanliness cities. Among the samples, there are 133 cities in the high-energy cleanliness category and 132 cities in the low-energy cleanliness category.

The regression results in Columns (3) and (4) of *Table 7* show that the NEDC policy exhibits a more significant emission reduction effect in cities with high energy cleanliness, with a coefficient of -0.242 significant at the 1% level. In contrast, the coefficient for low-energy-cleanliness cities is -0.127, only passing the 10% significance test, and the coefficient difference between the two groups is significant at the 1% level.

This finding reflects the critical role of energy consumption structure in the NEDC policy's implementation effect. In cities with high energy cleanliness, the energy structure features a low proportion of high-carbon energy sources like coal and a high share of clean energy (e.g., natural gas, hydropower, wind power), leading to relatively low carbon

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emissions during energy use. E-commerce development further optimizes their energy consumption structures, improves energy efficiency, and drives green technological innovation—thereby achieving more pronounced carbon emission reductions. The widespread use of clean energy may also enhance environmental awareness among enterprises and the public, amplifying policy effectiveness. In contrast, cities with low energy cleanliness have a high proportion of high-carbon energy sources (e.g., coal) in their energy structures, resulting in relatively high carbon emission intensities. Although the NEDC policy still demonstrates some emission reduction effects in these cities, its implementation effectiveness is relatively weak due to the inherently high-carbon nature of the energy structure.

Digital infrastructure

With the rapid development of the digital economy, digital infrastructure has emerged as a critical determinant in facilitating the growth of e-commerce and driving the low-carbon transformation of cities. The adequacy of digital infrastructure directly influences the operational efficiency and technological application level of e-commerce, which in turn may moderate the effectiveness of New Energy Development and Carbon Reduction (NEDC) policies. To further investigate the role of digital infrastructure in enhancing the emission reduction effects of NEDC policies, this paper uses the optical cable density of cities as an indicator to assess the level of digital infrastructure across different cities. Cities are categorized into two groups based on the median value: those with well-developed digital infrastructure and those with underdeveloped digital infrastructure.

As shown in *Table 8*, column (1) and columns (2), the regression results indicate that in cities with better digital infrastructure, the emission reduction effect of NEDC policies is more pronounced, with a corresponding coefficient of 0.191, significant at the 1% level. In contrast, in cities with poorer digital infrastructure, the NEDC coefficient was not statistically significant. Moreover, the difference between the regression coefficients of the two groups is significant at the 1% level.

Table 8. *Heterogeneity analysis based on digital infrastructure and degree of openness*

Variables	**(1)**	**(2)**	**(3)**	**(4)**
	Worse Digital Infrastructure	**Better Digital Infrastructure**	**Low Openness**	**High Openness**
	CO2	**CO2**	**CO2**	**CO2**
ECD	-0.048	-0.191***	-0.062	-0.272***
	(0.155)	(0.056)	(0.134)	(0.064)
_cons	4.151***	5.530***	5.050***	2.827**
	(1.109)	(1.166)	(1.310)	(1.378)
Controls	YES	YES	YES	YES
City FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Test for Group Differences	0.143***		0.210***	
N	2221	2251	2250	2236
R-squared	0.771	0.821	0.793	0.788

This finding highlights the critical role of digital infrastructure in the implementation of the NEDC policy. In cities with better digital infrastructure, high-speed and stable network environments provide a solid foundation for e-commerce development, enabling

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more efficient operation of various e-commerce applications. This not only facilitates online transactions and information sharing among enterprises but also drives the digital transformation of corporate management—thereby improving energy efficiency and reducing carbon emissions. In contrast, in cities with poor digital infrastructure, issues such as insufficient network coverage and unstable signals may limit the development potential of e-commerce, thereby weakening the emission reduction effect of the NEDC policy.

Conclusions and policy recommendations

Conclusions

The National Electronic Commerce Demonstration Cities (NEDC) policy in China has been instrumental in reducing urban carbon emissions. Based on our analysis using a staggered difference-in-differences model applied to 265 cities from 2007 to 2023, the following findings are revealed: (1) The NEDC policy has significantly decreased urban carbon emission intensity, with empirical evidence indicating a 23.1% reduction attributable to the policy. (2) The NEDC policy facilitates carbon emission reductions primarily through three mechanisms: improving energy efficiency, encouraging green technological innovation, and reinforcing economic agglomeration effects. (3) The effectiveness of the policy varies across city types, with more significant carbon reduction outcomes observed in resource-based cities, cities with cleaner energy structures, better digital infrastructure, and higher levels of openness. These findings underscore the NEDC policy's role in advancing urban low-carbon development and offer key insights for aligning digital economy policies with environmental sustainability.

Practical recommendations

Given that the emission reduction effect of the NEDC policy is more pronounced in resource-based cities, priority should be given to driving e-commerce-led transformation in these cities to break free from carbon lock-in. This aligns with Li et al. (2024)'s observation that digitalization can mitigate the high-carbon path dependence of resource-dependent industries. Concrete steps include establishing special funds to support the integration of e-commerce with traditional resource sectors, such as developing online trading platforms for deep-processed mineral products to reduce redundant intermediate links and associated carbon emissions. Additionally, drawing on Beijing's green development module, which emphasizes resource sharing and clean energy adoption, resource-based cities should incorporate energy efficiency indicators into the evaluation of e-commerce industrial parks.

Cities with higher energy cleanliness demonstrate more pronounced emission reduction effects under the NEDC policy, which supports the findings of Liu et al. (2025a). For these cities, policies should focus on synergizing e-commerce development with clean energy transitions. E-commerce platforms can be incentivized to prioritize suppliers using renewable energy, as Yu et al. (2023b) noted that green technology diffusion is accelerated through digital platforms. Moreover, integrating carbon footprint data of logistics vehicles into e-commerce supervision systems, consistent with the clean energy application indicator in our evaluation system—can further reduce carbon emissions from transportation, a key source of urban carbon footprints.

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The critical role of digital infrastructure is underscored by the finding that cities with superior digital infrastructure exhibit a significant reduction in emissions, whereas others do not. To address this disparity, underdeveloped regions should allocate e-commerce development funds toward optical fiber and 5G infrastructure, as enhanced connectivity can improve the operational efficiency of e-commerce platforms and accelerate enterprise digital transformation. Drawing on Ding and Gao (2023), who found that digital transformation reduces unit energy consumption, tiered subsidy policies for small and medium enterprises can be designed accordingly: providing greater support for digital operation upgrades in cities with low digital density, with subsidies gradually decreasing in high-density areas. This approach aims to promote balanced digital infrastructure development and fully realize the low-carbon benefits of e-commerce.

Mechanism analysis confirms that economic agglomeration mediates the emission reduction effect, consistent with Ciccone and Hall (1993)'s theory on agglomeration economies. Therefore, policies should promote economic agglomeration through the development of e-commerce industrial clusters. Urban master plans can designate specific zones for e-commerce clusters and mandate shared logistics infrastructure to minimize redundant energy consumption, which aligns with the resource-sharing mechanism identified in our study. Introducing "carbon intensity per unit land area" as a core assessment indicator for e-commerce parks—set with annual reduction targets based on our estimated relationship between economic agglomeration and carbon emissions—can further enhance resource-use efficiency. Moreover, fostering cross-city e-commerce alliances within major urban agglomerations, such as the Yangtze River Delta and Pearl River Delta, can help mitigate adverse spatial spillovers and amplify the low-carbon benefits of economic agglomeration.

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