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Study on the Energy Saving and Emission Reduction Effect of Electric City Construction

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Abstract

Based on the data of China's prefecture-level city statistical yearbooks and environmental yearbooks from 2003 to 2018, the energy-saving and emission reduction effects of China's e-commerce model city construction are analysed using the multi-period double-difference method. It is found that the construction of national e-commerce model cities significantly reduces environmental pollution and energy consumption and significantly improves the structure of energy consumption, and that this effect is influenced by factors such as the level of marketisation, the degree of environmental regulation and the degree of informatisation. The estimation results of the mediated effect model show that the construction of national e-commerce demonstration cities promotes energy conservation and emission reduction mainly through the channel of industrial structure transformation and upgrading. The relevant policy implication is that the establishment of national e-commerce model cities is another important way to promote energy conservation and emission reduction, which helps to improve the quality of the ecological environment, reduce environmental risks, improve the level of ecological civilisation and develop a green economy.

Keywords

National e-commerce model city; energy saving and emission reduction; double difference.

1. Introduction

In 2020, guided by Xi Jinping's Thought of Socialism with Chinese Characteristics for a New Era, all regions and departments will implement Xi Jinping's Thought of Ecological Civilisation in depth, fully implement the spirit of the 19th CPC National Congress and the 2nd, 3rd, 4th and 5th Plenary Sessions of the 19th CPC National Congress, and successfully complete the phased target tasks of the Battle of Pollution Prevention and Control, and lay a solid foundation for completing the energy conservation and emission reduction targets of the 14th Five-Year Plan by successfully exceeding the nine binding ecological and environmental targets set in the Outline. On the basis of the successful overfulfillment of the nine binding ecological and environmental indicators set out in the "13th Five-Year Plan", we will make further efforts to complete the energy conservation and emission reduction targets of the "14th Five-Year Plan", and lay a solid foundation for the achievement of the carbon peak and carbon neutrality targets. To vigorously promote energy conservation and emission reduction, innovative environmental pollution prevention mechanisms and governance channels. 2009 National Development and Reform Commission and the Ministry of Commerce formally approved the establishment of Shenzhen as the first national e-commerce model city. Since 2011, the pilot e-commerce demonstration cities have been gradually and batch by batch promoted to other cities, and the scope of the work of creating demonstration cities has been expanding, and as of 2017, 70 cities have been approved as national e-commerce demonstration city pilots. According to the plan, the creation of national e-commerce demonstration cities is not only a strategic initiative to

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develop the market economy based on new trade methods of Internet technology, accelerate the pace of urban internationalisation and modernisation, and enhance the city's economic strength and, it is also an important initiative for China to carry out pollution prevention and development of a green and low-carbon economy and to achieve the goal of dual-carbon.

The rapid growth in the scale of e-commerce transactions is an innovation in the traditional business model. In the traditional business supply chain, the transfer of products from producers to consumers has to go through multiple layers of wholesalers, distributors and retailers, which is a very long circulation process and takes up a large amount of production factors such as manpower, capital and land. This has caused a certain degree of resource waste and environmental pollution. The application of e-commerce from the perspective of the supply chain to shorten the distance between the producer and the end user, reducing the intermediate links in the circulation, while changing the structure of the traditional market, so that producers and consumers can be directly interconnected to shorten the circulation time, so that the supply chain path shortened. At the same time, the clustering of logistics and unified high-volume distribution system, the use of advanced logistics technology planning and implementation of low-carbon logistics activities, logistics activities in the reduction of coal, oil and other high-carbon energy consumption and greenhouse gas emissions, to achieve the field of logistics of low-pollution, low-energy consumption and low emissions[1]. The rapid development of e-commerce will also change the payment method to stimulate the development of e-money and green finance. Compared with traditional cash payment, e-payment not only improves the convenience of transaction, but also directly avoids the considerable resources and manpower consumption in the manufacture, issuance, circulation and destruction of banknotes; it also indirectly promotes the obvious contraction of bank branches, and prompts banks and other financial institutions to expand their value-added businesses other than basic cash business, such as green finance and credit, etc.[1]. It has also indirectly contributed to the significant contraction of bank branches, prompting financial institutions such as banks to expand their value-added business beyond basic cash business, such as green finance and credit business [2], which can contribute to resource conservation and environmental protection.

Most of the existing literature on e-commerce focuses on the economic field of cross-border e-commerce and rural e-commerce, and few of them involve the environmental field. For example, a wide range of scholars have carried out all-round research on cross-border e-commerce, exploring the relationship between cross-border e-commerce and regional economic development, and that improving the level of economic development can promote the development of cross-border e-commerce [3], and conversely the improvement of cross-border e-commerce level can significantly promote the development of trade economy and increase the scale of export trade [4]. Of course, some scholars[5]believe that small cross-border e-commerce inputs, on the other hand, have a certain degree of crowding out effect on the volume of China's import trade. More views recognise the positive synergies between cross-border e-commerce trade and economic development [6] and in the long run, cross-border e-commerce and cross-border logistics also show positive mutual promotion [7], as the development of cross-border e-commerce reduces the cost of production and fixed costs in trade [8], and the development of cross-border e-commerce reduces the transaction costs of service industries [9]. And the saving effect of e-commerce on transaction costs in the service sector is greater than that in the manufacturing sector, and the saving effect of external transaction costs is greater than that of internal control costs [9], which can promote the volume of China's export trade by lowering cross-border logistic costs and trade costs[10], reducing information costs and exploiting economies of scale[11] increases the probability of exporting and promotes the export expansion margin and the intensification margin[12].

In view of this, Unlike focusing on the economic benefits of the construction of national e-commerce demonstration cities, this paper is based on the quasi-natural policy experiment of

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the establishment of national business demonstration cities to explore the impact and mechanism of its energy conservation and emission reduction on the environment and energy . At present, there are fewer studies in China directly discussing the environmental benefits of e-commerce, but the initial purpose of the establishment of national e-commerce demonstration cities is not only to develop the Internet economy, but also to give full play to the role of e-commerce in optimising resource allocation, upgrading the industrial structure, and boosting employment, to promote the rapid development of regional e-commerce, to reduce energy consumption, and to develop a green economy. So it is necessary to verify its energy saving and emission reduction effect and transmission mechanism. Although scholars usually put their research perspectives on industrial structure, FDI and economic growth, a small number of scholars have focused on the green effects of the construction of national e-commerce demonstration cities, such as e-commerce on the macro level through industrial upgrading, factor agglomeration, and lowering the transaction costs to achieve green economic growth, and on the micro level through lowering the external market-type transaction costs and the internal managerial costs, realising the green technological innovation, and enhancing the enterprise market competitiveness [9]. These studies provide insights for understanding the green effects of e-commerce, but there is minimal research on the topic of the environmental pollution and energy saving and emission reduction effects of national e-commerce pilots. In particular, very little literature has directly focused on the role and importance of national business model city construction on environmental pollution and energy consumption. Therefore, this paper analyses the policy assessment effects of energy conservation and emission reduction by studying the construction of two batches of national e-commerce demonstration cities in China, the first batch of Shenzhen in 2009 and the two batches of 2011-2014, as exogenous policy shocks, and analyses whether energy conservation and emission reduction, in spatial terms, has a spillover effect on the neighbouring regions. It tries to innovate the mechanism of energy conservation and emission reduction from the perspective of e-commerce and provide new ideas for green economic development.

Compared with the established literature, the possible marginal contributions of this paper may be in the following three aspects: first, most of the existing studies focus on the economic benefits of the construction of national e-commerce demonstration cities, and this paper is based on the establishment of national business demonstration cities as a quasi-natural policy experiment to test the impact and mechanism of its energy conservation and emission reduction of environment and energy from the macro point of view of prefecture-level cities, which expands the research margins and the object of the study of this issue. Secondly, in terms of research content, the construction of national e-commerce model cities is taken as an exogenous policy shock, and the impact of urban e-commerce on energy conservation and emission reduction is examined by the multi-period double difference method, and the spatial spillover effect of energy conservation and emission reduction is verified by spatial double difference, which not only avoids the problem of endogeneity brought by the measurement error and reverse causality, but also expands the existing perspective of related researches. Thirdly, in terms of theoretical mechanism, an intermediary model is constructed to verify the path mechanism of national e-commerce demonstration city construction to achieve energy saving and emission reduction through industrial structure upgrading and consumption mode transformation to achieve cleaner production and consumption. This paper attempts to explore the energy-saving and emission reduction effects of e-commerce construction on the urban environment, so as to provide useful policy references for the realisation of the "dual-carbon" goal.

The remaining parts of this paper are arranged as follows: the second part combs the internal mechanism of e-commerce affecting the environmental effect; the third part is the description of relevant data and models; the fourth part is the test and mechanism analysis of the

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relationship between the construction of national e-commerce demonstration cities and the regional energy saving and emission reduction; and discusses the effect of the construction of national e-commerce demonstration cities in the regions with different degrees of marketisation, different strengths of environmental regulation, and different informatisation levels on the energy saving and emission reduction respectively; and finally the conclusion and policy implication. effects in regions with different degrees of marketisation, different intensities of environmental regulation, and different levels of informatisation, respectively; and finally, conclusions and policy implications.

2. Theoretical analysis and research hypotheses

2.1. Urban e-commerce transformation and industrial transformation

Industrial model is a process of continuous change influenced by systematic factors [13], and there is a significant positive correlation between the development of e-commerce and the optimisation and upgrading of industrial structure, and the development of e-commerce can significantly promote the optimisation and upgrading of industrial structure[14]. Some scholars believe that industrial transformation can inhibit pollution emissions through technological and structural effects, which are manifested in the following: technological progress can promote industrial differentiation, thus forming a comparative advantage in competitiveness, which will prompt some traditional type of polluting industries to transfer outside the agglomeration area, so as to achieve the goal of pollution reduction [15]. The transformation of the city's e-commerce will lead to the transformation of the city's industrial structure, and more and more production factors and infrastructures will slowly flow out of the secondary industry and into the rapidly developing high-end service industries, such as modern logistics, modern finance, information technology services, business exhibitions, health services, consulting services, scientific and technological services, and cultural creativity [16]. Pollution-intensive enterprises such as petrochemicals, iron and steel, non-ferrous metals, pharmaceuticals, and paper-making will be slowly phased out from e-commerce demonstration cities[17], and these high-energy-consuming and high-polluting industries will be shifted to non-e-commerce-enabled cities [18], which will reduce energy consumption and pollutant emissions in the region. It is not only a green transformation for the manufacturing industry, but also an important issue for the agricultural industry to promote the transformation of China's agriculture and the change of China's agriculture[19]. Therefore, it can reduce energy consumption and environmental pollution and improve production efficiency, thus promoting the green and high-quality development of the city. As for the city which itself takes the service industry as the pillar industry, the industrial structure caused by the application and development of e-commerce also presents the green transformation mode of "service-oriented". Therefore, through the analysis of the literature, the importance of industrial structure transformation and upgrading in the problem of e-commerce affecting regional energy saving and emission reduction effects is found.

From the industry perspective: the productive service industry plays a positive role in regulating the manufacturing industry's impact on pollution emission intensity, and can effectively reduce the pollution emission intensity in the process of manufacturing industry agglomeration[20]; manufacturing industry agglomeration will lead to an increase in regional carbon emissions, but the interaction between technology trading and manufacturing industry agglomeration is conducive to the reduction of carbon emissions[21]; As a core element of the modern economy, the financial industry not only promotes high-quality economic development, but also promotes energy conservation and emission reduction due to its "clean" characteristics, and promotes the green and sustainable development of the economy and society [22]. From a regional perspective, productive service industries can effectively reduce the intensity of

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pollutant emissions in the process of manufacturing agglomeration, and the extent of this reduction in pollutant emissions is greatest in the west, followed by the centre, and least effective in the east [23]. From the perspective of pollutant emissions, urban e-commerce can effectively reduce the emission intensity of industrial sulfur dioxide and industrial soot [24], and e-commerce, supported by the development of the Internet, also significantly reduces China's overall carbon intensity [25], and this environmental effect is the technical, configurational, and structural effects, respectively, through the use of modern information technology [26], and the second is to enhance the competitiveness of e-commerce enterprises by reducing the transaction costs of enterprises [27] so that enterprises will spend more money on improving green technology, increase green R&D investment, and form positive environmental externalities[28]. Therefore, some scholars have called on the relevant departments can start from industrial transformation, through various methods to reduce the demand for energy consumption, prompt industrial transformation and upgrading, to achieve the purpose of improving environmental pollution [29]. The development of urban e-commerce is another way of economic development in the new era, the fourth industrial revolution represented by digitalisation, grids and intelligence is the new direction of future industrial development, and digital has become a necessary element of modern economic development [30], and the environmental benefits behind the e-commerce economy can not be ignored [32]. However, based on the existing literature, few scholars have studied the direct effect of e-commerce on the environment, so it is crucial to make full use of the service industry advantage of e-commerce under the background of the dual-carbon target to promote the clean-up of the service industry, manufacturing industry, agriculture, and other industries, and to realise the upgrading of the industrial structure to lead the reduction of pollution and emission reduction.

Based on the above analyses, this paper proposes the following research hypotheses:

Hypothesis 1: Other things being equal, the construction of national e-commerce model cities has an energy-saving and emission reduction effect.

Hypothesis 2: The construction of national e-commerce demonstration cities achieves energy saving and emission reduction through industrial structure transformation and upgrading.

Hypothesis 3: There may be spatial spillovers of this energy saving and emission reduction effect to neighbouring areas.

3. Research design and data description

3.1. Model design and variable setting

3.1.1. Multi-period double-difference modelling

Based on the panel data of 275 prefecture-level cities used in this paper, this paper wants to verify whether the level of urban e-commerce can have energy-saving and emission reduction efficacy on the environment, while the national e-commerce demonstration cities were set up in three times in 2009-2014.The first pilot city, Shenzhen, was set up in September 2009; 22 prefecture-level cities, including Beijing, were set up in November 2011; and 30 prefectural cities, such as Dongguan, were set up in March 2014. The first pilot city was Shenzhen in September 2009, 22 prefectures including Beijing in November 2011, and 30 prefectures including Dongguan in March 2014. These 53 demonstration prefecture-level cities are the focus of this paper's policy implementation, because the e-commerce demonstration cities set up in 2017 are too short, and the impact of the radiation of the policy may not be obvious, so they are not included in this paper's research scope for the time being. Since the e-commerce demonstration cities are not established at a uniform point in time, a multi-period double-difference model is used to do the preliminary regression test by controlling for individual and time fixed effects at the same time. According to the actual meanings of the regression

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coefficients to verify whether urban e-commerce has an energy saving and emission reduction effect on the city.

$$lnE_{it} = \beta_0 + \beta_1 did_{it} + \gamma X_{it} + \lambda_t + \mu_i + \varepsilon_{it} \quad (1)$$

$$lnP_{it} = \beta_0 + \beta_1 did_{it} + \gamma X_{it} + \lambda_t + \mu_i + \varepsilon_{it} \quad (2)$$

where E is energy consumption, F is environmental pollutant emissions, i is the region, and t denotes the year. did is a policy dummy variable where did takes the value of 1 if the city is a national e-commerce demonstration city and the year is after the implementation of the policy, otherwise it takes the value of 0. X is a set of control variables that affect environmental pollution and energy consumption.λ_t Denotes time fixed effects;μ_i Denotes individual fixed effects;ε_{it} denotes a random error term.

3.1.2. Samples and data

In this paper, the panel data of 275 prefecture-level cities in China from 2003 to 2018 are selected as the research sample. During the sample period 53 cities were approved as national e-commerce demonstration cities in 2009 (Shenzhen), 2011, and 2014, and the information of the demonstration cities is mainly obtained through the websites of the National Development and Reform Commission (NDRC) and the Ministry of Science and Technology (MOST), and the websites of the governments of provinces (municipalities and autonomous regions) and other public reports. Other relevant data were mainly obtained from the China Urban Statistical Yearbook, the China Environmental Statistical Yearbook and the Business Data Centre of the Ministry of Commerce of China in previous years.

3.2. Variable setting and measurement

1. National e-commerce model city policy (*DID*). Assign a value of 1 to pilot cities in the year following the implementation of the policy and a value of 0 in all other cases.

2. Energy conservation and emission reduction. In studies of environmental pollution, it is common to measure pollutant emissions by the three industrial wastes [33], including industrial sulphur dioxide emissions, industrial wastewater emissions, and industrial solid waste emissions. In view of the completeness and availability of data, the "emission reduction" in this paper is measured by per capita industrial sulfur dioxide emissions from the "three industrial wastes". In addition, since the development of urban e-commerce and logistics industry are complementary[34], the construction of e-commerce model cities may have an impact on air quality, so the rastered data of the Atmospheric Compositional Analysis Group of Dalhousie University[35] are used as a proxy for the mean concentration of the 275 prefectural-level cities to ensure the robustness of the empirical results. robustness of the results.

There have been a large number of studies on "energy conservation", and fossil energy sources mainly include coal, oil, natural gas, and so on. Zhou et al. use the total provincial energy consumption minus non-fossil energy consumption as the total fossil energy consumption, and use the per capita energy consumption (total fossil energy consumption/total population of each province) as a proxy indicator of energy consumption[36]. The total energy consumption has also been measured using 10,000 tonnes of standard coal and the amount of GDP energy consumption[37]. In this paper, we use per capita industrial electricity consumption as a proxy variable for "energy consumption", and also consider the intensity of industrial energy consumption, which is measured by the proportion of total energy consumption to the value-added of the secondary industry, in order to verify that the sustained decline in coal use in the demonstration cities mainly stems from the reduction of coal use in the industrial sector after the serviceisation of the industrial structure as well as the reduction of coal use in the industrial sector after the serviceisation of the industrial structure, and the decrease of coal use in the model cities. related energy policies, investment in technology development, and industrial

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structure transformation. The paper also controls for other factors affecting energy saving and emission reduction:

Including the level of regional economic development, expressed in terms of the square term of real per capita GDP; population density, expressed in terms of the number of household population per unit of regional administrative area; capital-labour ratio, expressed in terms of the ratio of fixed-asset investment to the average number of on-the-job employees; the level of tertiary education, expressed in terms of the percentage of students enrolled in ordinary tertiary education schools in the total number of the population; the urbanisation rate, expressed in terms of the proportion of the urban population in the total household population; the degree of openness to foreign Foreign direct investment as a percentage of regional GDP; regional investment in science and technology as the proportion of science and technology expenditures to public financial expenditures; and environmental regulation (using the cumulative frequency of words related to environmental protection in the government work report of prefecture-level municipal government information disclosure).Details are in Table 1 below:

Table 1 Descriptive statistics of variables

	N	average value	variance	minimum value	maximum values
SO2	4,400	4.553	1.185	0	7.981
PM2.5	4,400	7.179	0.908	0	11.18
PCE	4,400	7.03	1.615	0	11.81
EI	4,400	0.177	0.177	0	3.248
DID	4,400	0.0752	0.264	0	1
ECO	4,400	104.7	17.39	0	245.7
POP	4,400	2.068	1.011	0	3.425
LAB	4,400	4.56	1.751	0	6.058
EDU	4,400	0.016	0.022	0	0.131
URB	4,400	49.97	17.36	0	100
OPE	4,400	0.00309	0.00388	0	0.115
P&G	4,400	0.0244	0.0488	1.79E-07	0.414
ER	4,400	4.512	1.173	0	6.802

4. Analysis of empirical results

4.1. Baseline regression results

Table 2 presents the results of the baseline regression of the dampening effect of national e-commerce model cities on environmental pollution and energy consumption, with the estimated coefficients of did in each column being negative and significant at the 1 per cent level. In particular, columns (1) and (2) denote the effect of the policy on environmental pollutant emissions, and columns (3) and (4) denote the effect of the policy on energy consumption. It is not difficult to find that, after controlling for individual city fixed effects and time fixed effects, the estimated coefficients of the national e-commerce demonstration city policy are significantly negative regardless of whether control variables are added to the model or not, indicating that the energy-saving and emission reduction effects of this e-commerce demonstration policy are all significant, and are generally conducive to the reduction of pollutant emissions and energy consumption, which implies that the e-commerce demonstration policy exerts the expected energy-saving and emission reduction effects, and confirms hypothesis H1.This result coincides with the established literature, which all affirm the positive effects of national e-commerce model city construction on environmental

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protection. For example, e-commerce in cities can significantly increase green total factor productivity through urban green technological innovation [9]and urban industrial structure enhancement and rationalisation.

Table 2 Base regression results

	emission reduction		energy-saving	
	(1)	(2)	(3)	(4)
DID	-0.252***	-0.218***	-0.304***	-0.250***
	(0.039)	(0.041)	(0.070)	(0.073)
Constant	4.570***	5.187***	6.267***	5.491***
	(0.030)	(0.203)	(0.054)	(0.362)
Control	YES	YES	YES	YES
Individual fixed effect	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES
R^2	0.459	0.466	0.267	0.277
N	275	275	275	275

Note: ***, ** and * denote significance levels of 1 per cent, 5 per cent and 10 per cent, respectively, with robust standard errors in parentheses, clustered to the city level.

4.2. Robustness tests

By replacing the explanatory variables with per capita PM2.5 emissions and industrial energy consumption intensity, respectively, artificially advancing the time point of policy implementation to 2008 and 2010, and excluding outliers, other robustness tests are conducted, and the regression results are shown in Table 3: the implementation of the policy significantly reduces the per capita PM2.5 emissions by 5.64%, and the intensity of industrial energy consumption is also significantly reduced by 1.68%, again verifying the reasonableness of the original hypothesis. The did regression coefficients after advancing the time point of policy implementation by 2 or 4 years are not significant, which means that it implies that the energy saving and emission reduction of the experimental group and the control group are not caused by the random factors at the time level. For the reliability of the data and to reduce the interference of outliers, the paper shrinks the data by 1% and finds that the conclusions remain robust.

Table 3 Robust type test

	Substitution of variables		counterfactual		1 per cent treatment of indentations	
	(1)	(2)	(3)	(4)	(5)	(6)
DID	-0.056***	-0.017*	-0.111	0.027	-0.160***	-0.148*
	(0.008)	(0.009)	(0.098)	(0.091)	(0.039)	(0.081)
Constant	7.526***	0.342***	0.937**	0.977**	4.802***	3.896***
	(0.040)	(0.046)	(0.452)	(0.452)	(0.253)	(0.523)
Control	YES	YES	YES	YES	YES	YES
Individual fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
N	275	275	275	275	275	275
R2	0.562	0.182	0.212	0.212	0.53	0.272

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Note: ***, ** and * denote significance levels of 1 per cent, 5 per cent and 10 per cent, respectively, with robust standard errors in parentheses, clustered to the city level.

4.3. Heterogeneity test

Generally speaking the level of e-commerce development in cities varies according to the level of market economic development, government intervention in the business environment, and regional infrastructure, showing differences in different dimensions. In this paper, we mainly consider the differences in the level of marketisation, the differences in regional government intervention, and the differences in regional informatisation. In view of this, this paper follows three different ideas: first, for the degree of marketisation. First, for the degree of marketisation, the sample cities are divided into two groups of high and low degree of marketisation according to the median province of the marketisation index in the "China Sub-Provincial Marketisation Index Report (2020)", and all the cities are divided into two groups of high and low degree of marketisation according to the provinces they belong to. Second, for government intervention differences, according to the government work report on energy saving and emission reduction of environment-related words accounted for the proportion of the total number of words to measure the regional government's attention to the environment and the degree of intervention, and in accordance with the median will be divided into the region of strong government intervention and weak government intervention. Third, for regional informatisation. This paper measures the degree of city informatisation according to the number of Internet broadband access users, and divides the sample cities into two parts: high degree of informatisation and low degree of informatisation.

Table 4 Heterogeneity analysis of emission reduction effects

	Level of marketisation		Level of government intervention		Information	
	lower	higher	lower	higher	lower	higher
	(1)	(2)	(3)	(4)	(5)	(6)
DID	-0.035	-0.246***	-0.145**	-0.228***	1.493***	-0.192***
	(0.096)	(0.046)	(0.073)	(0.055)	(0.533)	(0.044)
Constant	5.057***	5.183***	5.118***	5.177***	5.546***	4.913***
	(0.391)	(0.256)	(0.328)	(0.298)	(0.458)	(0.309)
Control	YES	YES	YES	YES	YES	YES
Individual fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
N	275	275	275	275	275	275
R2	0.344	0.518	0.073	0.588	0.154	0.633

Note: ***, ** and * denote significance levels of 1 per cent, 5 per cent and 10 per cent, respectively, with robust standard errors in parentheses, clustered to the city level.

Through the heterogeneity analysis, it can be seen that the lower degree of marketisation of the region's lower level of economic development, logistics and transportation network is not developed, the innate conditions for the development of e-commerce is not good, so as the regression results show that the establishment of a national e-commerce demonstration city in the lower degree of marketisation of the underdeveloped areas of the energy saving and emission reduction effect is not significant. On the contrary, in the higher degree of marketisation in developed areas such as Shanghai, Jiangsu Province, Zhejiang Province and

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other areas with high marketisation level, both online e-commerce commodity trading and offline traditional commodity trading turnover is much larger than the marketisation of underdeveloped areas, commodity trading is developed, energy saving and emission reduction effect is significant. Governmental command, incentive or environmental regulation of cities can have a profound impact on the green development of cities [39], and in columns (3) and (4) of Table 5, respectively, the abatement effects of varying degrees of regional governmental intervention in the environment are presented: column (4) shows that the estimated coefficient of -0.228 for did is larger than that of column (3), which is -0.145 and is significant above the 1% level, indicating that the greater the intensity of government intervention, the more obvious the effect of energy saving and emission reduction. It indicates that the government should strengthen its attention to the ecological environment and use government administrative orders to reduce environmental pollution.

Table 5 Heterogeneity analysis of energy saving effects

	Level of marketisation		Level of government intervention		Level of regional informatisation	
	lower	higher	lower	higher	lower	higher
	(1)	(2)	(3)	(4)	(5)	(6)
DID	-0.005	-0.048**	0.001	-0.033***	-0.239*	-0.030***
	(0.010)	(0.021)	(0.032)	(0.009)	(0.136)	(0.008)
Constant	0.407***	0.170*	0.167*	0.057	0.043	0.156***
	(0.056)	(0.087)	(0.095)	(0.109)	(0.119)	(0.055)
Control	YES	YES	YES	YES	YES	YES
Individual fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
N	174	101	275	274	241	263
R2	0.191	0.186	0.171	0.363	0.158	0.358

Note: ***, ** and * denote significance levels of 1 per cent, 5 per cent and 10 per cent, respectively, with robust standard errors in parentheses, clustered to the city level.

Analysing column (1)(2) of the heterogeneity of energy-saving effects, it can also be found that the establishment of e-commerce demonstration cities set up in regions with a high degree of marketisation produces more significant energy-saving effects than in regions with a low degree of marketisation, and the e-commerce economy has become an important asset for the competitive advantage of the region, and a major manifestation of the level of marketisation in the region. Regional e-commerce demonstration city construction for both e-commerce enterprises and offline suppliers have a strong attraction, the low degree of marketability of the region less attractive to enterprises, so in the low marketability of the city to vigorously advocate e-commerce construction is not as good as in the high degree of marketability of the economically developed areas of energy saving and emission reduction, but also can not deny that the e-commerce can alleviate the backward areas of the product stagnant sales. Columns (3) and (4) show that the implementation of policies in regions with a high degree of government intervention is more effective, because green GDP is an important indicator of government performance assessment, and the formulation of strict environmental regulation policies can effectively reduce regional environmental pollution. （Columns (5) and (6) show

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that e-commerce transactions tend to be more frequent and more active in areas with a high degree of urban informatisation[40], and that e-commerce has a significant positive effect on the rationalisation of industrial structure under the development of the Internet [41], and that the integration of e-commerce, the Internet economy, and the city gives full play to e-commerce's environmental mitigation effect. effect. Therefore, it is necessary to grasp the new opportunities of e-commerce development, build a regional economic layout of high-quality development, and reduce the energy consumption of cities and regions.

4.4. Mechanism testing

4.4.1. Model construction

In order to explore the mediating effect of e-commerce demonstration cities on energy conservation and emission reduction, this paper draws on the mediating effect of the three-step model for step-by-step testing, and the model is set as follows:

$$M_{it} = \beta_0 + \beta_1 did_{it} + \gamma X_{it} + \lambda_t + \mu_i + \varepsilon_{it} \quad (3)$$

$$P_{it} = \beta_0 + \beta_1 did_{it} + \beta_2 M_{it} + \gamma X_{it} + \lambda_t + \mu_i + \varepsilon_{it} \quad (4)$$

$$E_{it} = \beta_0 + \beta_1 did_{it} + \beta_2 M_{it} + \gamma X_{it} + \lambda_t + \mu_i + \varepsilon_{it} \quad (5)$$

4.4.2. Analysis of results

The estimated coefficients of did in columns (2)(3) of Table6 are significantly negative, indicating that the construction of e-commerce demonstration cities reduces the emission of industrial pollutants and air pollutants in cities. The estimated coefficients of did in columns (4)(5) are significantly negative, indicating that in addition to the emission reduction effect, the e-commerce pilot can also bring energy saving effect to the city, saving industrial electricity consumption and reducing the intensity of industrial energy consumption. Meanwhile, the estimated coefficient of industrial structure upgrading in columns (2)(3) of Table 6 combined with the results in column (1) of Table 6 is significantly positive, and the indirect effect of industrial structure transformation on per capita sulfur dioxide emissions is calculated to be -0.0158, with the indirect effect accounting for 7.73% of the total effect. The indirect effect on per capita PM2.5 emissions is -0.0026, and the indirect effect accounts for 4.24% of the total effect. In addition, columns (4) and (5) of Table 6 combined with column (1) of Table 6 show that the indirect effects of industrial structure transformation on per capita electricity consumption and industrial energy consumption intensity are -0.0257 and -0.0103 respectively, with the indirect effect accounting for 10.29% and 3.63% of the total effect. All of them show that the construction of national e-commerce model cities can promote energy conservation and emission reduction through industrial structure transformation and upgrading.

Table 6 Results of testing the mechanism of industrial structure transformation

	(1) industrial structure	(2) so2 emissions per capita	(3) PM2.5 emissions per capita	(4) Per capita electricity consumption	(5) Industrial energy intensity
DID	-2.007***	-0.189***	-0.059***	-0.224***	-0.027***
	(0.371)	(0.043)	(0.008)	(0.073)	(0.009)
Constant	25.38***	5.049***	7.559***	5.167***	0.470***
	(1.846)	(0.216)	(0.041)	(0.370)	(0.047)
Control	YES	YES	YES	YES	YES

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Individual fixed effect	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES
N	275	275	275	275	275
R-squared	0.363	0.449	0.564	0.28	0.212

Note: ***, ** and * denote significance levels of 1 per cent, 5 per cent and 10 per cent, respectively, with robust standard errors in parentheses, clustered to the city level.

5. Conclusions and policy implications

In this paper, using the panel data of 275 prefecture-level cities from 2003 to 2018, based on the theory related to e-commerce and environment, and taking the pilot policy of national e-commerce demonstration city construction as a policy shock, the energy saving and emission reduction effect of e-commerce demonstration city construction in China is analysed by using multi-period double-difference method and spatial double-difference method. It is found that the construction of national e-commerce demonstration cities significantly reduces environmental pollution and energy consumption, and significantly improves the structure of energy consumption, and this effect is influenced by the level of marketisation, the degree of government intervention and the degree of regional informatisation. It is further analysed that the construction of national e-commerce model cities promotes energy conservation and emission reduction mainly through two channels, namely industrial structure transformation and upgrading and consumption mode transformation. In addition, this paper analyses the spatial spillover effect of energy conservation and emission reduction based on the spatial Durbin model. To a certain extent, it enriches the research related to environmental pollution and energy consumption. The above findings are useful for China to further improve the construction of e-commerce demonstration cities and expand the pilot scope. Give full play to the energy saving and emission reduction policy effect of the e-commerce pilot has important policy insights, and provide innovative ideas for China's energy saving and emission reduction practice.

First, pay attention to the synergistic development of the real economy and the e-commerce economy, and actively promote the construction of the e-commerce city. With the high degree of development of computer Internet information technology, the entity economy can not abandon the independent development of the e-commerce economy, the e-commerce economy is also precisely the entity economy is a necessary guarantee for the development of sound development development. Especially in the context of the new crown epidemic, the development of the real economy is facing serious challenges, and active transformation and restructuring has been inevitable. The results of the study show that e-commerce not only has significant economic benefits, but also can help China to achieve energy saving and emission reduction, change the mode of economic development, vigorously develop the green economy, and make an important contribution to the realisation of the dual-carbon goal.

Secondly, the industrial structure should be optimised, green logistics and supply chain systems should be fostered, and consumption patterns should be transformed. Heavy industrial industries with high energy consumption and strong pollution should be transferred in an orderly manner, and green industries should be actively introduced to produce green consumer goods. Establish a sound green supply chain system of green procurement, green credit, green taxation and green products. It is of great significance to boost green consumption demand, co-ordinate the planning of e-commerce economic development, fully explore potential green consumer groups, and further release the potential of e-commerce energy saving and emission reduction.

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Thirdly, expanding the pilot scope of e-commerce in market-oriented developed areas can expand the energy-saving and emission reduction effects. At the same time, it is important for the government to increase environmental protection publicity and strengthen the development of incentive-based environmental regulatory policies, and command-based environmental protection systems, in order to deepen its role in guiding green production and consumption. At the same time, it can raise the public's awareness of environmental protection, and uphold the concept of environmental protection while consuming both online and offline. Strengthen the construction of Internet and 5G communications, promote the iterative upgrading of Internet-related infrastructures, improve network access coverage and penetration, etc., raise the level of regional informatisation, promote the development of the online economy, give full play to the energy-saving and emission-reduction effects of e-commerce demonstration cities, and raise the level of ecological civilisation construction and green economic development.

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