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Does the E-Commerce City Pilot Reduce Environmental Pollution? Evidence From 265 Cities in China

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In order to promote the healthy and rapid development of e-commerce, China launched the construction of National E-commerce Demonstration Cities in 2009. This paper presents a feasible road to achieving sustainable development through the new urban development model. The paper employs the data of 265 cities in China from 2007 to 2016 as a research sample and uses the multiperiod difference-in-difference method to test the impact of National E-commerce Demonstration Cities pilots on urban environmental pollution. The basic result shows that urban environmental pollution is reduced by about 17.5% on average after becoming pilot cities, and the National E-commerce Demonstration Cities policy significantly reduces urban environmental pollution. We adopt a series of robustness tests, and all tests show that the basic result is still robust. Moreover, heterogeneity tests show that the pollution reduction effect of the National E-commerce Demonstration Cities policy in big cities is stronger than in small- and mid-sized cities, and there is no significant difference between the eastern cities and mid-western cities. The pollution reduction effect of the National E-commerce Demonstration Cities policy is more significant in cities with high human capital, low fiscal expenditure, and high information infrastructure. The empirical results of the spatial Dubin model show that the pilot city has no significant spatial spillover to neighboring cities. In the era of rapid development of e-commerce, this study provides a reference for developing countries to improve the urban environment and achieve sustainable development by using the new urban development model integrating e-commerce and urbanization.

Keywords: e-commerce demonstration cities, NEDC policy, urban environmental pollution, spatial spillover effect, siphon effect

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INTRODUCTION

Improving environmental pollution is an important issue related to the wellbeing of people all over the world. Many countries have increased attention to environmental protection by issuing strict regulations. For example, the United States has passed the American Climate and Energy Security Act; Japan has formulated the “Green Development Strategy”; the European Union has proposed the “2020 Strategy” and take green growth as its core strategy. As the world’s second largest economy, China has achieved rapid development by relying on extensive economic. But it has also brought heavy damage to the environment. According to the World Bank statistics, China’s economy accounts for 15.16% of the global economy, but the energy consumption accounts for 23.18% of the global energy consumption in 2017. The mismatch between economic development and energy consumption leads to a series of environmental problems and seriously damages the health of the population. In 2011, the Chinese Academy of Environmental Sciences noted that more than 20% of Chinese residents' medical expenditures are used to prevent diseases caused by environmental pollution. It can be seen that environmental pollution not only endangers the health of residents but also seriously damages the economic efficiency. Therefore, clarifying the factors causing environmental pollution and seeking ways to reduce environmental pollution are not only a research topic of environmental economics, but also an important starting point for the government to formulate environmental policies and improve the quality of economic development.

The world economy is currently undergoing a digital transformation. The e-commerce is one of the most active forms of the digital economy, and it has widely penetrated into various industries. According to the China E-commerce Report 2020 released by the Ministry of the People's Republic of China, China's e-commerce transactions reached ￥37.21 trillion (nearly $5.8 trillion) in 2020. The rapid development of e-commerce benefited from the support of the National E-commerce Demonstration Cities (NEDC) policy. In order to further play the role of e-commerce in the economy and society, the Chinese government implemented the NEDC policy and selected Shenzhen as the first pilot city. In the following years, the scope of the NEDC pilot was expanding. So far, 70 cities have become the NEDC pilots. The e-commerce demonstration city is a new urban development model explored by the Chinese government. The purpose is to "reduce energy consumption, develop a green economy; optimize resource allocation, improve industrial structure, and drive employment." Therefore, it plays an important role in improving urban environment pollution.

At present, scholars have studied the factors influencing environmental pollution from different perspectives. They found that international trade (Ang, 2009), foreign investment (Liang, 2014), environmental regulation (Lutsey and Sperling, 2008; Greenstone and Hanna, 2014), economic agglomeration (Ushifusa and Tomohara, 2013; Zhu et al., 2019), economic growth (Brajer et al., 2011), and urbanization (Liddle and Lung, 2010) are all important factors affecting environmental pollution. In addition, Information and Communication Technology (ICT) is an important factor affecting carbon emissions and environmental pollution (Raheem et al., 2020). Balsalobre-Lorente et al. (2021) believe that ICT has a significantly negative impact on carbon emissions or environmental pollution. This result was also confirmed by Magazzino et al. (2021). In these studies, urbanization is relevant to our study, but the relationship between urbanization and environmental pollution has not reached a consistent conclusion, and they are mainly divided into three views. The first view is that urbanization exacerbates environmental pollution. For example, Wang and Wang (2013) confirmed that urbanization would lead to environmental pollution, while Liu (2014) believed that urbanization would aggravate environmental pollution by exacerbating industrialization. The second view is that urbanization will alleviate the environmental pollution. Satterthwaite (1997) used the data from three developing countries and found that environmental pollution decreased with the expansion of the city scale. Deng and Zhang (2018) also confirmed that the city size has a significant inhibitory effect on environmental pollution. The third view is that there is a nonlinear relationship between urbanization and environmental pollution. The study of Wen and Wang (2017) shows that there is an inverted-U relationship between an urban population size and urban per capita pollution emissions. However, there is a lack of study about e-commerce and environmental pollution. Only a few studies have qualitatively analyzed the impact of e-commerce on the environment (Sui and Rejeski, 2002). These studies did not provide a reliable quantitative analysis.

The process of urbanization in China shows that environmental pollution mainly occurs in urban areas. We cannot help thinking whether the traditional urban development model is difficult to break the vicious circle of the resource curse. This requires us to explore a new urbanization model to improve the environment. As a new urban development model that integrates e-commerce and urbanization, can the national e-commerce demonstration city solve the environmental pollution caused by urban development? To answer this question, we take the execution of the NEDC policy as a quasi-natural experiment, using these cities that became NEDC pilots as the treatment and other cities as the control group, and adopt the multiperiod difference-in-difference (DID) method to conduct an empirical analysis on the impact of NEDC pilots on environmental pollution. In addition, we build a spatial Dubin model (SDM) to test whether pilot cities can bring pollution reduction benefits to neighboring cities.

The contributions of this paper are as follows. Firstly, from a new perspective of e-commerce, this paper empirically studies the effect of China's NEDC policy on urban environment pollution. The environment is an important issue that all countries are concerned about. Many countries are making efforts to improve their environment. However, the research on the impact of e-commerce on environmental pollution is insufficient. This paper enriches the studies on the factors affecting environmental pollution. The result has shown that the NEDC policy can reduce environmental pollution. Thus, we find a way to improve environmental pollution in developing countries. It helps developing countries take advantage of this new urbanization model to improve environmental quality and achieve sustainable development. In addition, this paper conducted a multifaceted heterogeneity test. It fits the countries with different development conditions and can be better applied to the pollution reduction work of other countries.

THEORETICAL FRAMEWORK

The NEDC policy not only promotes the development of e-commerce but also produces a green economic effect and reduces urban environmental pollution. We think that the NEDC pilot mainly reduces urban environmental pollution through the technical effect, economic agglomeration effect, industrial structure upgrading effect, and cost reduction effect (**Figure 1**). The detailed analysis of the influence channel is as follows.

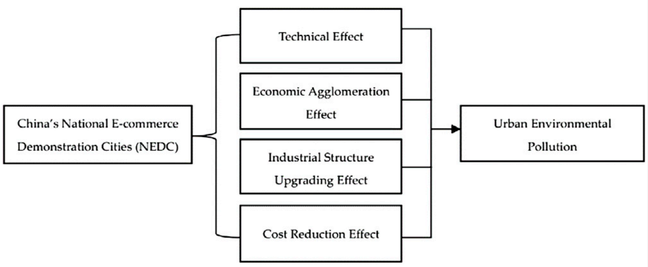

FIGURE 1 | The impact mechanisms of China's NEDC policy on urban environmental pollution.

First, the technical effect is the enterprises' main driving force to reduce pollution (Liu and Zhang, 2012). The NEDC pilot reduces environmental pollution through the technical effect. On the one hand, the development of e-commerce depends on the application of the internet. Under the pressure of high-intensity internet competition, enterprises will be forced to carry out technology innovation, accelerating the development of energy-saving technology and environmental protection technology. These energy-saving technologies and clean technologies are applied to energy systems and production systems, and it will improve the resource utilization efficiency of enterprises (Shi et al., 2018). On the other hand, technology innovation will enable enterprises to develop cleaner energy. The clean energy will replace traditional energy sources with high emissions and pollution. Technological innovation will reduce environmental pollution through the change of the energy consumption structure.

Second, in order to promote the development of e-commerce enterprises, the state will provide pilot cities with preferential policy support. This will attract the accumulation of the capital, labor, and other factors. In addition, infrastructure construction will be accelerated in the pilot cities, and the sharing effect of infrastructure will also attract the agglomeration of enterprises and production factors (Liu et al., 2021). With the increase of economic agglomeration, compact spatial distance and social network will facilitate the exchange and accumulation of knowledge between enterprises (Ni and Li, 2018). Therefore, the economic agglomeration effect contributes to the advancement of technology and improvement of production efficiency, saves unit energy consumption, and reduces pollution emissions. Therefore, the effect of economic agglomeration reduces urban pollution.

Third, the NEDC policy promotes the application and development of e-commerce. The development of e-commerce significantly increased the demand for employment (Biagi and Falk, 2017), especially in the service industry such as customer service, distribution, operation, technology, and so on. Meanwhile, it has obviously changed the original pattern of the service industry, expanded the proportion of service industry in the national economy, and promoted the upgrading of industrial structures. The energy consumption of the service industry, especially modern service industry such as knowledge-intensive industry, is obviously lower than that of resource-intensive industry (Cao et al., 2021). Obviously, the application and development of e-commerce will bring a "service-oriented" green transformation to the industrial structure (Shao et al., 2019). It contributes to the replacement of high-energy-consumption and high-pollution industries. Thus, the industrial structure upgrading effect can reduce urban pollution.

Lastly, the NEDC policy reduces business costs by promoting the application of e-commerce. This impact mechanism is mainly reflected in the following aspects: 1) e-commerce reduces the cost of information transmission through the application of the internet (Jensen and Miller, 2018). The characteristics of a paperless office, online product promotion, and sales reduce the non-productive costs of enterprises. Meanwhile, the reduction of additional expenses such as shop rentals reduces the management costs of enterprises (Cui et al., 2017). 2) E-commerce is characterized by the openness of the internet, and its application makes the information transmission between the market and product more smoothly, alleviates the information asymmetry among market players, and reduces the intermediate transaction costs (Cao et al., 2021). 3) Enterprises can timely communicate with suppliers and consumers, adjust supply-and-demand information, and reduce corporate inventory costs (Liu et al., 2021). The reduction of cost lessens energy consumption and resource allocation, which reduces pollution emissions. Therefore, the effect of cost reduction reduces urban pollution.

METHODS

Econometric Model

The NEDC policy as an external shock will have an impact on the environmental pollution of the pilot cities and then make the environmental pollution of the pilot cities and non-pilot cities different. In addition, after the implementation of the pilot policy, the environmental pollution is different from that before the implementation of the pilot. These two differences provide a good quasi-natural experiment opportunity for us to use the difference-in- difference (DID) method to evaluate the NEDC policy's pollution reduction effects. Currently, standard DID and multiperiod DID can conduct policy evaluation. However, standard DID methods cannot assess policy effects at multiple time points. Therefore, we draw on the setting method of Wang (2013) to establish a multiperiod DID model. His method can identify policy effects at multiple time points for empirical testing. The NDEC policy is implemented step by step in time and space. The method of Wang (2013) is consistent with the research in this paper. The model is built as follows:

$$pollution_{it} = \alpha_0 + \beta_1 DID_{it} + \lambda X_{it} + \mu_{it} + \vartheta_{it} + \varepsilon_{it} \tag{1}$$

where i is cities and t is years. The dependent variable $pollution_{it}$ is measured by the level of urban pollution. The independent variable is DID_{it}. The coefficient β_1 presents the standard DID estimator. and we can affirmatively infer with significantly negative β_1 that NEDC policy is effective for urban environmental pollution reduction. In addition, It represents a series of control variables. It includes economic agglomeration openness, urban economic development, urban innovation human capital, and industrial structure. The variables μ_{it} and ϑ_{it} respectively indicate year fixed effects and city fixed effects. ε_{it} is an independent and identically distributed error.

Existing studies often ignore the spatial correlation between regions when investigating the effect of the NEDC policy. To make up for this shortcoming, this paper introduces the SDM to test the spatial spillover effect of the NEDC policy on urban environmental pollution. We draw on the setting method of Li and Wang (2020) to establish the following model:

$$pollution_{it} = \rho Winno_{it} + \beta_1 DID_{it} + \lambda_1 X_{it} + \beta_2 WDID_{it} + \lambda_2 WX_{it} + \mu_{it} + \vartheta_{it} + \varepsilon_{it} \quad (2)$$

In model 2, W is the $N \times N$ geographic distance weight matrix. If $i = j$, $W = 0$. If $i \neq j$, $W = 1$. ρ is the spatial correlation coefficient, and other variable settings are consistent with model 1.

Measurement of Key Variables

Independent Variable

This paper uses the dummy variable (DID) of the NEDC policy as the core independent variable. The variable DID_{it} is the policy effect of the NEDC policy, consisting of the interaction item between $Treat_i$ and $Time_t$ dummy variables. $Treat_i$ equals 1 if this city is a pilot city; otherwise, it equals 0. $Time_t$ equals 1 for every year after this city as a pilot city; otherwise, it equals 0.

Dependent Variable

The dependent variable of this paper is urban environmental pollution (pollution). At present, relevant research uses a specific indicator to measure environmental quality. Sheng and Lv (2012) think that air pollution is the determinant of environmental pollution, Sulfur dioxide and $PM_{2.5}$ are major sources of air pollution (Yang, 2005). Therefore, this paper measures environmental pollution from two aspects of sulfur dioxide and $PM_{2.5}$. Firstly, this paper uses the urban per capita sulfur dioxide emissions to measure urban environmental pollution ($pollution_1$). Secondly, this paper refers to the method of Cole et al. (2005) and uses the $PM_{2.5}$ concentration of the urban unit Gross Domestic Product (GDP) to measure environmental pollution ($pollution_2$).

Control Variables

Economic agglomeration (aggl). Economic agglomeration is an important variable that affects urban pollution. We use the location quotient to measure economic agglomeration (Zeng et al., 2019). The calculation formula of the location quotient is $LQ_{it} = (E_{it}/\sum (E_{it})/(E_t/\sum (E_t)$. $E_{it}/\sum E_{it}$ represents the ratio of the number of people employed in the secondary and tertiary industries to the urban total employment, and $E_t/\sum E_t$ represents the ratio of the number of people employed in the secondary and tertiary industries to the total employment in China.

Openness (open). The "pollution refuge hypothesis" (Keller and Levinson, 2002; Bhujabal et al., 2021) and the "pollution halo hypothesis" (Antweiler et al., 2001) show that openness plays an important role in urban environmental pollution. This paper uses the proportion of the foreign direct investment in GDP to measure openness.

Urban economic development (pgdp). This paper employs the natural logarithm of the urban per capita GDP to control the impact of urban economic development (Zhang and Wang, 2014).

Urban innovation (inno). We use the natural logarithm of the number of patent applications to measure urban innovation (Yuan and Xie, 2015).

Human capital (human). Human capital is an important force to promote technological progress and plays an important role in improving environmental pollution. This paper uses the ratio of college students to urban employed population to measure human capital (Yu and Jin, 2021).

Industrial structure (stru): This paper employs the proportion of the output value of the tertiary industry in GDP to measure an industrial structure.

Date

The balanced panel data of 265 cities in China from 2007 to 2016 are chosen as the research sample in this paper. During the sample period, the sample mainly includes the first batch and second batch of pilot cities. The dates are mainly taken from the China City Statistical Yearbook (2007–2017) and Atmospheric Composition Analysis Group of Dalhousie University. **Table 1** presents the descriptive statistics of our main variables that we used.

EMPIRICAL RESULTS

Baseline Model Estimations

In order to identify the impact of the NEDC policy on urban environmental pollution, this paper uses the multi-period DID that controls the time fixed effect and city fixed effect for regression analysis. **Table 2** shows the regression results of model 1. Column (1) and column (2) are the regression results when the dependent variable is $pollution_1$. The estimation coefficient of DID is significantly negative. Column (3) and column (4) are the regression results when the dependent variable is $pollution_2$. The estimation coefficient of DID is still significantly negative at the significant level of 1%. From the column (2), the urban environmental pollution reduces by about 17.5% on average after becoming NEDC pilots. This result shows that the NEDC policy can significantly reduce the environmental pollution of pilot cities. The conclusion is similar to the research of Chen and Yan (2020). As mentioned in the theoretical framework, the NEDC policy will reduce urban environmental pollution through the technical effect, economic agglomeration effect, industrial structure upgrading effect, and cost reduction effect.

Robustness Test

Common Trend Test

Using the DID method, we need to satisfy the common trend hypothesis. Without the policy shock, the changing trend of the outcome variable in the two groups should be consistent.

TABLE 1 | Descriptive statistics.

Variables	Observations	Mean	Std. Dev	Min	Max
$pollution_1$ (tons/person)	2,650	4.5793	0.9332	1.2809	7.5019
$pollution_2$	2,600	−3.3180	0.9385	-6.7408	−0.9579
aggl	2,650	1.3618	0.0950	0.6464	1.3947
Pgdp (yuan/person)	2,650	10.7278	0.5047	9.4801	12.2413
Open (dollar/yuan)	2,650	0.2650	0.2516	0.0013	1.4209
Tech (piece/person)	2,650	7.4682	1.4522	4.6052	11.4112
Labor (%)	2,650	4.6894	1.0906	1.2349	7.1653
Stru (%)	2,650	0.4090	0.0882	0.2417	0.7965

TABLE 2 | baseline results.

Variables	Dependent variable: $pollution_1$		Dependent variable: $pollution_2$	
	(1)	(2)	(3)	(4)
DID	−0.1705*** (0.0549)	−0.1753*** (0.0550)	−0.0475*** (0.0178)	−0.0760*** (0.0150)
aggl		−0.9658*** (0.2681)		0.4735*** (0.0726)
pgdp		0.1924* (0.1005)		−0.6674*** (0.0273)
open		−0.1135 (0.0737)		0.0790*** (0.0200)
tech		−0.0730** (0.0335)		−0.0872*** (0.0091)
labor		0.0940*** (0.0257)		−0.0036 (0.0070)
stru		-0.0090** (0.0037)		0.0032*** (0.0010)
_cons	−13.5617*** (0.033)	−13.5118*** (1.089)	−2.6134***	3.5092***
			−0.0107	−0.296
Year fixed effects	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes	Yes
Observations	2,650	2,650	2,600	2,600
R-squared	0.228	0.241	0.865	0.907

*Note: ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively.*

TABLE 3 | Robustness test.

Variables	Common trend	Substitution variable	Eliminate disturbing policies	Traditional DID
DID		−0.214*** (0.055)	−0.161*** (0.058)	−0.181** (0.076)
pre2	0.014 (0.121)			
pre1	−0.168 (0.121)			
current	−0.143 (0.120)			
post1	−0.197 (0.121)			
post2	−0.269** (0.121)			
Low-carbon city pilot policy			Control	
Innovative city pilot policy			Control	
Smart city pilot policy			Control	
Carbon emission trading pilot policy			Control	
Control variables	Yes	Yes	Yes	Yes
Constant	−13.947*** (1.180)	10.535*** (1.081)	−13.866*** (1.102)	−13.835*** (1.176)
Year fixed effects	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes	Yes
Observations	2,420	2,650	2,650	2,420
R-squared	0.224	0.555	0.243	0.223

*Note: ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively.*

Therefore, we put the interaction item of the dummy variable of the pilot city and dummy variable of each year in the model for regression. If the coefficient of DID is not significant before the implementation of the policy, the common trend hypothesis is satisfied. If the coefficient of DID is significant, the common trend hypothesis is not satisfied. Column (1) of **Table 3** shows that the coefficient of DID is not significant before the implementation of the policy, and it became significant 2 years after the policy was implemented. The result shows that the common trend hypothesis is satisfied, and there is a time lag in the pollution reduction effect of the NEDC policy.

Other Measures of Urban Innovation

In the previous article, we used per capita sulfur dioxide emissions to measure environmental pollution. In order to ensure the robustness of the results, this paper further uses sulfur dioxide per unit output value as a substitute variable for urban environmental pollution. The result is shown in column (2) of **Table 3**. The coefficient of DID is still significantly negative at the significant level of 1%. The baseline result of this paper is robust.

Eliminate Disturbing Policies

During the promotion of the NEDC policy, China has successively implemented the low-carbon city pilot policy (Khanna et al., 2014; Cheng et al., 2019), innovative city pilot policy (Nie et al., 2021), smart city pilot policy (Zhan and Li, 2021), and carbon emission trading pilot policy (Speed, 2009). These policies will have an impact on urban environmental pollution. In order to eliminate these disturbing policies and accurately identify the net effect of the NEDC policy, this paper adds the time dummy variables of other policy pilots to control the influence of other policy factors on urban environmental pollution. The result is shown in column (3) of **Table 3**. The coefficient of DID is negative and significant at the 1% level. It shows that the NEDC policy can significantly reduce the urban environmental pollution of the pilot city.

Traditional DID Test

The basic regression in this article uses the multiperiod DID method, and the research samples are mainly the first and second batches of pilot cities. In order to ensure the robustness of the result, this paper further uses the standard DID for regression. The second batch of demonstration cities is more than the first batch. Thus, we use the second batch of pilot time as the policy time point and remove the first batch of pilot cities from the research sample. The result is shown in column (4) of **Table 3**, the regression result of using standard DID is consistent with the basic regression result.

Instrument Variable Approach

The previous result shows that the NEDC policy will significantly reduce urban environmental pollution. However, there may be a reverse causal relationship between the choice of pilot cities and urban environmental pollution. The problem of variable omission may also lead to the deviation of the estimated result. Therefore, this paper uses the instrumental variable (IV) method to solve the possible endogeneity problem. This paper chooses the Ming Dynasty post station[1] as the IV of the NEDC policy. As an ancient national mail and post transportation system, the post station in Ming Dynasty has a certain correlation with modern communication infrastructure. Therefore, the regions with post stations in history have better development in information, logistics, and other aspects, and they are more likely to be selected as pilot cities. There is a correlation between the Ming Dynasty post station and the pilot city. In addition, as a historical data, the post station in Ming Dynasty has no direct relationship with the current urban environment. In this paper, we structure the interaction term of the Ming Dynasty post and time dummy variables as IVs to perform a two-stage least squares estimation. The estimation result is shown in **Table 4**. The first stage in column (1) shows that the selected IV is highly correlated with pilot cities, and the IV has passed the weak IV test, which verifies the effectiveness of IVs in this paper. The result shows that the coefficient of DID is significantly negative, which is consistent with the baseline conclusion that the NEDC policy significantly reduces the urban environmental pollution.

TABLE 4 | Instrument variable test.

Variables	NEDC	Pollution
IV: Ming Dynasty post	0.585*** 0.008	
DID		−0.169*** (0.057)
Constant	0.990*** (0.364)	−14.664*** (1.528)
Control variables	Yes	Yes
Year fixed effects	Yes	Yes
City fixed effects	Yes	Yes
Cragg–Donald Wald F statistic	5,405.17***	
Observations	1,750	1,750
R-squared		0.775

*Note: ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively.*

Heterogeneity Test

Although this paper has verified that the NEDC policy can significantly reduce urban environmental pollution, there are still different implementation effects between different cities. The discussion of this heterogeneity will help us to have a deeper understanding of the regional applicability of the NEDC policy and regional characteristics of the pollution reduction effect and provide some empirical basis for decision-makers to conduct classified guidance and local policies. We test the heterogeneity of policy effects in the aspect as follows.

Heterogeneity of Urban Size

In order to investigate the heterogeneity impacts of the NEDC policy on urban environmental pollution in different urban sizes, we divide sample cities into big cities and small- and mid-sized cities according to the "*Notice on Adjusting the Criteria for City Scale Classification*" issued by the State Council of China in 2014. The results are shown in column (1) and column (2) of **Table 5**. The coefficients of DID are negative and significant at the 5% level in the two regressions, but the estimated coefficient in the sample of big cities is obviously larger than small- and mid-sized cities. In other words, the NEDC policy's pollution reduction effect is remarkable in large cities. Compared with small- and medium-sized cities, big cities are more attractive to talents. The sharing effect and learning effect produced by the agglomeration of talents and innovation elements are stronger than those of small- and mid-sized cities; the resulting improvement in resource utilization efficiency has a stronger effect on pollution reduction in large cities.

[1]The data of Ming Dynasty post comes from the data provided by Wordmap of the Geographical Analysis Center of Harvard University. The website is worldmap.harvard.edu.

TABLE 5 | City size and location heterogeneity test.

Variables	Small and mid-sized cities	Large cities	Mid-western cities	Eastern cities
DID	−0.169** (0.067)	−0.287** (0.131)	−0.180** (0.079)	−0.173** (0.077)
Constant	4.476*** (1.132)	12.933*** (4.851)	3.341** (1.514)	5.096*** (1.866)
Control variables	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes	Yes
Observations	2,440	210	1,670	980
R-squared	0.237	0.442	0.241	0.264

*Note: ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively.*

TABLE 6 | Urban characteristics heterogeneity test.

Variables	High human capital	Low human capital	High financial expenditure	Low financial expenditure	High industrial transformation	Low industrial transformation
DID	−0.126** (0.061)	−0.203 (0.163)	−0.087 (0.137)	−0.166*** (0.058)	−0.195*** (0.052)	0.478 (0.312)
Constant	−14.069*** (1.591)	-14.399*** (1.701)	−15.138*** (1.770)	−9.249*** (1.587)	−11.475*** (1.674)	−14.216*** (1.794)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,330	1,320	1,330	1,320	1,330	1,320
R-squared	0.302	0.195	0.186	0.359	0.356	0.191

*Note: ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively.*

Heterogeneity of Urban Location

China has a vast territory, and there are great regional differences. Therefore, the development difference among regions is obvious. The eastern region has obvious agglomeration advantages because of its coastal location advantages, which facilitate the development of innovative resources. Technological progress improves the efficiency of resource utilization and reduce pollution emissions. The mid-western regions are less attractive to innovative resources than the eastern regions because of the disadvantage of geographical location. This difference may lead to different pollution reduction effects. We divide sample cities into eastern cities and mid-western cities to explore the difference in pollution reduction effects, and the results are shown in column (3) and column (4) of **Table 5**. There is no significant difference in the coefficient between the two types of cities. The possible reason is that China has made some achievements in coordinated regional development. The mid-western regions can get more preferential policies, such as the western development strategy and plan for the rise of the central region, which make up for its disadvantages and reduce the difference in the pollution reduction effect. Therefore, the pollution reduction effect of the NEDC policy in the mid-western cities and eastern cities is significant, and there is no significant difference.

Heterogeneity of Urban Characteristics

In the previous theoretical analysis, the NEDC policy is mainly used to promote the development of e-commerce. However, the development of e-commerce needs the support of people (human capital), finance (financial expenditure), and material (information infrastructure), so people, finance, and material are important to the pilot cities. This paper carries out a heterogeneity test from the above three aspects. This paper uses the ratio of college students to the employed population in urban; the proportion of government expenditure in GDP; and the natural logarithm of the number of internet broadband access users to measure human capital, financial support, and information infrastructure. We divided these three variables into the high group and low group by median, and the regression results are shown in **Table 6**.

In cities with low human capital, the pollution reduction effect of the NEDC policy is not obvious, while in cities with high human capital, the pollution reduction effect is significant. This shows that human capital has a strong supporting role in the NEDC policy and greatly improves the pollution reduction effect of pilot cities. The information age puts forward higher demands for people, and the development of e-commerce depends on the application of the internet. Therefore, high human capital can better serve the construction of pilot cities and give full play to its pollution reduction effect. The pollution reduction effects in the cities with high human capital are significant than in the cities with low human capital. In terms of financial support, compared to the high financial expenditure group, the pollution reduction effect is significant in the low financial expenditure group. The reason is that the financial support measured by the financial expenditure index represents the government's intervention degree in the construction of pilot

TABLE 7 | Model selection.

Test	Statistics	P
LR_spatial_lag	39.78	0.00
Wald_spatial_lag	39.98	0.00
LR_spatial_error	39.89	0.00
Wald_spatial_erro	39.88	0.00

cities. When a city pursues only economic growth, it will abandon long-term environmental protection and industrial transformation goals, so the pollution reduction effect is smaller when government intervention is strong. In terms of material support, the NEDC policy depends on the application of the internet. Only when the information infrastructure construction is perfect can it provide a material guarantee for urban pollution reduction. Therefore, the pollution reduction effect is more significant in cities with higher information infrastructure.

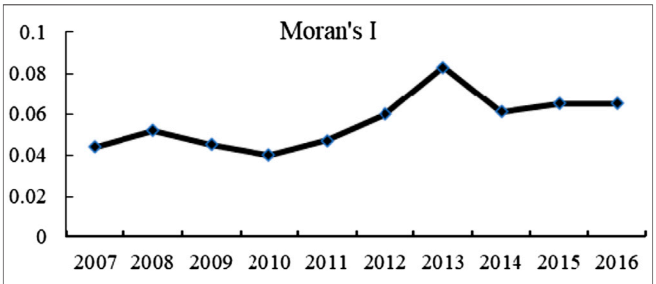

FIGURE 2 | Moran index distribution.

FURTHER DISCUSSION

Spatial Measurement Model

Before regression, we need to perform a spatial autocorrelation test to verify whether there is spatial correlation. The result is shown in **Figure 2**. The Moran index (Moran's I) is greater than 0, and the *p*-values are all less than 0.01; it indicates that there is a strong spatial correlation. Moreover, we need to test whether the SDM degenerates into the spatial lag model and spatial error model. The estimation result is shown in **Table 7**. Both the likelihood ratio (LR) test and Wald test reject the null hypothesis at the 1% significance level. It shows that the SDM cannot be degenerated into a spatial lag model and a spatial error model, so we choose the SDM for empirical testing.

Regression Results of Spatial Dubin Model

Table 8 shows the result of model 2. Column (1) and column (2) are regression results without and with control variables. The results of the SDM model show that the ρ is positive at the significance level of 1%, indicating that there is a significant positive spatial correlation between urban environmental pollution. Environmental pollution has the characteristic of spreading, which happens often across cities and forms the phenomenon of "transboundary pollution." It makes the principle of "who pollutes, who controls" ineffective. Therefore, environmental governance requires cooperation between cities (Lv and Gao, 2021). The coefficient of DID is significantly negative, indicating that the NEDC policy will significantly reduce the environmental pollution. Because the coefficient of W*DID cannot directly reflect the impact on the environmental pollution of neighboring cities, this paper further estimates the direct effect, indirect effect, and total effect. The coefficient of indirect effect is not significant, indicating that the NEDC policy has not produced significant spatial spillover effects on neighboring cities. The reasons are as follows. On the one hand, pilot cities will have a spatial spillover effect on neighboring cities. On the other hand, when e-commerce demonstration cities gather innovative resources, they may cause the loss of innovative resources in neighboring cities. Pilot cities rely on taxation and other policies to form policy depressions, attract surrounding cities' innovative resources to gather there, and then have a siphon effect on neighboring cities. As a result, the pilot cities did not produce a significant spatial spillover effect on the environmental pollution of neighboring cities.

TABLE 8 | Regression results of SDM.

Variables	(1)	(2)
ρ	0.863*** (0.041)	0.838*** (0.048)
DID	−0.167*** (0.050)	−0.145*** (0.051)
W*DID	−0.525 (0.651)	0.179 (0.704)
Direct effect	−0.188*** (0.059)	−0.143** (0.057)
Indirect effect	−5.731 (5.749)	0.260 (4.604)
Total effect	−5.919 (5.777)	0.118 (4.627)
Control variables	No	Yes
Year fixed effects	Yes	Yes
City fixed effects	Yes	Yes
Observations	2,650	2,650
R-squared	0.114	0.055
Log L	-1,846.81	-1,855.96

*Note: ***, **, and *denote significance levels at 1%, 5%, and 10%, respectively.*

DISCUSSION

At present, the impact of e-commerce on the environment has been preliminarily explored. However, the relevant researches are only qualitative analysis, the lack of quantitative analysis, and empirical evidence. For example, Sui and Rejeski (2002) qualitatively analyzed the impact of e-commerce on the environment from both positive and negative aspects. Tiwari and Singh (2011) also qualitatively analyzed the impact of e-commerce on the environment from these two aspects. In terms of environmental impact, they see e-commerce as a double-edged sword. However, qualitative analysis cannot determine whether the positive impacts outweigh the negative impacts and therefore cannot clearly define the ultimate impact of e-commerce on the environment. Is the ultimate impact of e-commerce on the environment positive or negative? In order to further verify the impact of e-commerce on the environment, this paper adopts the method of quantitative analysis and uses the quasi-natural experiment of national e-commerce demonstration city construction. The purpose of the national e-commerce demonstration city construction is to promote the rapid and healthy development of e-commerce. Therefore, the construction of e-commerce demonstration cities is bound to promote the development of e-commerce and further affect the urban environment. Taking the construction of e-commerce demonstration cities as a quasi-natural experiment can effectively verify the impact of e-commerce on environmental pollution. Compared with the existing researches, the use of data and empirical testing methods makes the results of this paper more convincing, and this paper concludes that e-commerce has a significant positive impact on environmental pollution. The result is more accurate. In addition, the e-commerce demonstration city is a new urbanization development model, and exploring its influence on neighboring cities is also beneficial to provide a reference for the government to choose the demonstration city. This also enriches the current researches.

CONCLUSION

E-commerce pilot cities are essentially the product of the integration of e-commerce and urbanization. As a new urban development model, it is an important path to reduce urban environmental pollution. Based the mechanism analysis of the NEDC policy implementation, this paper employs the data of 265 cities in China from 2007 to 2016 as a research sample and uses the multiperiod DID method to test the policy shock of the NEDC pilots on the urban environmental pollution. The basic result shows that urban environmental pollution reduces by about 17.5% on average after becoming pilot cities, and the NEDC policy has significantly reduced urban environmental pollution. We adopt different methods to test the robustness of the basic results. Firstly, we test whether the common trend hypothesis is satisfied. Secondly, we use other indicators to measure urban environmental pollution. Thirdly, we eliminate the disturbing policy during the sample period, such as the low-carbon city pilot policy, innovative city pilot policy, smart city pilot policy, and carbon emissions trading pilot policy. Fourthly, we use the standard DID method to test. Finally, we use the post station in the Ming Dynasty as the instrument variable to solve the endogenous problems. All tests show that the basic results are extremely robust. In heterogeneity analysis, the pollution reduction effect of the NEDC policy in big cities is stronger than that in small- and mid-sized cities, and there is no significant difference between eastern cities and mid-western cities. Further, the pollution reduction effect of the NEDC policy is more significant in cities with high human capital, low fiscal expenditure, and high information infrastructure. Furthermore, we found that the pilot cities did not have a significant spatial spillover effect on neighboring cities because of the siphon effect.

This study has practical significance for the sustainable development of developing countries. Firstly, E-commerce pilot cities are a new urban development model explored by China. The certification results show that the NEDC policy can significantly reduce environmental pollution. It indicates that this urbanization model is effective in developing countries and can be promoted in developing countries. Therefore, this study provides a new urban development model for developing countries to improve environmental quality. Secondly, this study confirmed that the pilot cities did not bring space spillovers to neighboring cities because of the siphon effect, which also provided a reference for the government in the construction of resource coordination and other aspects. Finally, the study conducts heterogeneity tests from many aspects to provide a reference for developing countries to make decisions.

Although this paper confirms that e-commerce has a significant pollution reduction effect, it is undeniable that the development of e-commerce also brings negative effects. However, these issues are not addressed in this paper. In future research, the negative impact of e-commerce will also be an important research direction. At the same time, how to solve these negative effects is also an important research topic.

AUTHOR CONTRIBUTIONS

ZZ: Conceptualization. ZS: writing-original draft preparation. HL: data curation.

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