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Impact of Chinese market segmentation on regional collaborative governance of environmental pollution: A new approach to complex system theory

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Abstract

The market segmentation among local governments under decentralization of China not only directly triggered the "fragmentation" of regional development, but also hindered collaborative actions in environmental governance. This study adopts a new method to calculate regional environmental collaborative governance using a synergy degree model of a complex system, and then it empirically analyzes the impact of Chinese market segmentation. We find that the regional environmental collaborative governance in China shows a growing trend during the period of investigation, but the level is still low. Market segmentation has significantly inhibited the regional collaborative governance of environmental pollution among local governments of China. The effect of market segmentation on the order of personnel input and capital input is significantly negative, while the effect on the order of policy input and organizational input is not significant. In the areas where the air pollution and water pollution are serious, the effect of market segmentation is also significantly negative. The conclusions are helpful to understanding the institutional factors that hinder regional environmental collaborative governance in China more comprehensively, and provide insights for improving the performance of environmental governance.

1 | INTRODUCTION

How to formulate more effective measures to improve the performance of environmental governance is an issue of social concern in China. Environmental pollution has natural and social attributes simultaneously: in terms of the natural attributes, the spatial spillover of pollutants leads to an impact of environmental pollution that is no longer limited to a single area, and the environmental pollution among different areas presents synchronicity, which will cause cross-border pollution (Copeland & Taylor, 1994). As far as social attributes are concerned, environmental pollution is non-exclusive and non-competitive due to the lack of property right definitions, and this will cause the “free-riding” of local government in environmental governance, which may worse the environmental pollution problem on the whole.

Therefore, the traditional environmental governance method, such as a Pigou tax, may fail in the implementation, while carrying out the regional environmental collaborative governance to strengthen the cooperation of local governments has become a broad consensus of society. Collaborative governance can overcome the fragmentation of the traditional method through the diversification of governance subjects, the synchronization of governance structure, and the collaboration of governance methods. So, regional environmental collaborative governance can be understood as a collective action among local governments to solve the problem of cross-border pollution by using a variety of ways to coordinate the governance of environmental pollution based on commonly determined rules.

However, according to the collective action theory proposed by Olson (1965), the collective interest is a public good, unless the number of people in the group is small or there is coercion to enable individuals to act in their common interest, and the rational individuals will not act to realize their common interests. Therefore, in the collective action, the constraint of self-interest maximization strengthens the incentive of “free riding,” which makes how to coordinate individual interests more effectively become the key to carry out collaborative governance activities. Especially for a transitional economy such as China's, after the tax sharing reform, the mismatch between the local governments' fiscal revenues and expenditures has become more serious. And expanding the source of fiscal revenue, reducing the scale of expenditure, and maximizing the economic interests have gradually become an important direction of local government. What is more, under the dual constraints of the local interest maximization and the flat regional administrative pattern in China, the relationship between local governments also presents a state of local protectionism (Bian et al., 2019; Poncet, 2005), which not only causes the market segmentation, but also becomes a key factor that restricts the regional environmental collaborative governance.

Specifically, on the one hand, the market segmentation in China under the decentralization is the direct result of local protectionism, and the local governments that implement local protectionism will reduce the expenditure on environmental governance as much as possible by adopting the “free-riding” strategy (Li et al., 2020). On the other hand, in order to attract enterprises with high tax creation ability to expand the source of fiscal revenue, the local government will also further deregulate the local area's environment and even carry out the “racing to the bottom” competition (Wu et al., 2020), which will not be conducive to the matching of different areas' environmental regulation. Besides, the regional “fragmentation” mode formed by the market segmentation cuts off the bridge of communication and consultation between local governments, which will also have a negative impact on the regional environmental collaborative governance. Figure 1 describes the research framework of this paper.

Therefore, this paper analyzes the key factors that affect the regional environmental collaborative governance in China from the perspective of Chinese market segmentation. Compared with the previous research, this paper embodies the innovation in the following aspects: First, this paper constructs a synergy degree model of a complex system for the first time, takes the provincial region as the subsystem, and selects the order parameter index to calculate the degree of regional environmental collaborative

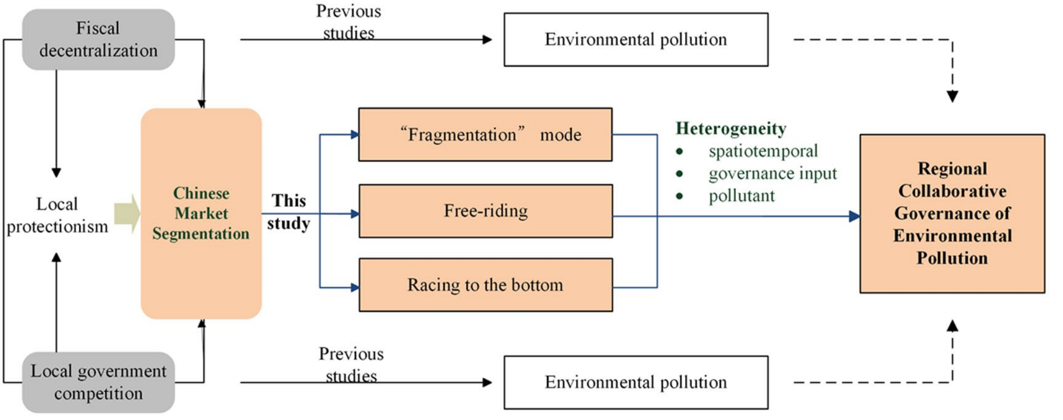

FIGURE 1 Research framework

governance of China. This method is the first to apply a complex system theory to the study of environmental pollution collaborative governance, which can more comprehensively reflect the internal mechanism of environmental pollution collaborative governance in different regions, more objectively measure the degree of regional collaborative governance of environmental pollution in China, and identify and analyze the key problems. Second, although previous studies have examined the role of local governments in the process of environmental pollution control under the fiscal decentralization system, they have not examined the impact of market segmentation among local governments of China on regional collaborative governance of environmental pollution. Compared with previous studies, this paper studies the impact of Chinese market segmentation on the regional collaborative governance of environmental pollution, which helps us to explore the key institutional factors restricting the regional environmental governance in China, and then, provide useful enlightenment for promoting the performance of environmental governance and improving environmental quality. Third, compared with previous studies, this paper further considers the spillover characteristics of environmental pollutants in examining the relationship between market segmentation and regional collaborative governance of environmental pollution. In fact, there are great differences in the spatial spillover between different environmental pollutants, which also makes the local governments implement different strategies for governing. Therefore, the analysis of the heterogeneous effects of different environmental pollutants in this paper will help us to understand more comprehensively the strategy choice of local governments in the process of regional collaborative governance of environmental pollution.

The remainder of this paper is arranged as follows: The second part is a review of the literature. The third part introduces the calculation method of regional collaborative governance of environmental pollution in detail. The fourth part constructs an econometric model and explains the selection of relevant indicators. The fifth part discusses the empirical research results, including the results of benchmark regression, the estimation results of different collaborative governance inputs, and the results of spatial–temporal heterogeneity analysis and a robustness test. The sixth part presents further research, considering the impact of spillover effects of different pollutants. The last part provides the conclusions and implications.

2 | LITERATURE REVIEW

The role of local government in environmental governance has always been one of the key issues in previous studies. Scholars have investigated whether decentralized governance or centralized governance is needed in environmental governance, and they have paid attention to the phenomenon of “racing to the bottom” and “racing to the top” about environmental regulation in local government competition. In addition, in recent years, some scholars have investigated the spillover effect of environmental pollution (i.e., cross-border pollution) and proposed to carry out regional collaborative governance of environmental pollution. Therefore, we will also review and sort out the previous research literature from the above aspects.

2.1 | Local government and environmental governance

2.1.1 | The theory of environmental decentralization and environmental centralization in environmental governance

Theoretically, whether the local government or the central government bears the responsibility of environmental governance mainly depends on the degree of spillover of environmental public goods and regional heterogeneity. Oates (1972) first proposed the optimal decentralization principle by analyzing the cost and benefit of environmental decentralization and argued that the marginal benefit of the local government's supply of public goods is equal to the marginal cost of its externality. However, the conclusions on the decentralization and centralization of environmental public goods supply are not completely consistent.

First, according to the environmental centralization theory, the provision of environmental public goods is mainly undertaken by the central government, because it can avoid the tragedy of the commons and prevent the lack of supply of environmental public goods caused by “free-riding,” with Stewart (1977) as the main representative. Moreover, the unified provision of environmental public goods by the central government can help to obtain the national scale economic benefits and overcome the pollution rent-seeking caused by the unequal political influence between environmentalists and environmental interest groups.

Second, the environmental decentralization theory mainly holds that the supply of environmental public goods should be undertaken by local governments. Due to the residents’ requirements for environmental quality, the influence of geographical location and technical conditions on the cost of environmental governance has regional heterogeneity, which may be ignored if the central government provides environmental public goods uniformly. Therefore, from the perspective of maximizing social welfare, the optimal environmental governance should consider the cost benefit relationship of each area and take a differentiated approach (Saveyn & Proost, 2004). Inman and Daniel (1997) found that the externality of environmental pollution can be solved through regional cooperation, rather than centralized governance. Ogawa and Wildasin (2009) also believed that although there is an obvious spillover effect, decentralized environmental governance can still produce effective resource allocation. Even if there is no superior government cooperation or “Coase negotiation” at all, and there are regional differences in consumer preferences and product technology, as long as the government has complete information and only cares about the local area's environmental quality, decentralized governance is still effective.

2.1.2 | “Racing to the top” and “Racing to the bottom” of environmental regulation

The hypothesis of “voting by feet” put forward by Tiebout (1956) holds that if residents can move freely, local governments will compete for better public services in order to attract them. The local governments tend to regard environmental quality as the main target and use the environmental regulation as the main method in the process of competition. The specific research viewpoints include two aspects:

First, in order to attract the mobile production factors, some local governments often adopt relatively loose environmental governance standards and reduce the environmental access threshold to attract enterprises to enter. And the spillover of environmental regulation will make some local governments adopt the "free-riding" strategy to decrease the environmental investment and eventually cause the deterioration of environment pollution. This is the "racing to the bottom," which has been verified by empirical studies (Peng, 2020). Second, if the local governments regard the improvement of environmental quality and the residents' living standards as the most important governance target, they will raise the threshold of environmental access and set more strict environmental regulations, so as to promote those polluting enterprises to move to other areas, which is the "racing to the top." The conclusions of Sigman (2003) support its existence.

2.2 | Cross-border pollution and regional collaborative governance

The previous literature also attached great importance to the spatial spillover of environmental pollutants and the cross-border pollution caused by the strategic behavior of local governments. Huang et al. (2016), Frutos and Martín-Herrán (2019), and Chang et al. (2018) built a game theory model of cross-border pollution and analyzed the environmental pollution problems caused by the strategic interaction between local governments. When analyzing the impact of air pollution on human health in China, Chen et al. (2017) found that air pollution in neighboring areas also had a negative impact on human health in this region. Huang et al. (2011) found that the pollution emission in developed regions significantly demonstrates the role-model effect on the remaining provinces, and the effect will weaken as the distance from the remaining provinces to three developed regions increases, which somewhat interprets the common trend of pollution emission among regions.

Therefore, it is difficult for polluters and victims to achieve effective governance unilaterally. Chen et al. (2019) found that spatial spillover characterizes China's haze pollution, and the industrial structure, dominated by heavy industry, will exacerbate haze pollution and further aggravate its spatial spillover. Therefore, they believed that in the formulation of haze pollution governance policies, full consideration must be given to the impact of spatial factors, strengthening the promotion and coordination between provinces and regions, and, ultimately, controlling pollution. The regional collaborative governance has become an important aspect of academic concern. Pi and Zhao (2017) constructed a dynamic game model considering cross-border pollution and found that, compared with unilateral governance, joint governance can reduce environmental pollution; although the latter can improve the overall and developed areas' welfare, it will reduce the social welfare of backward areas, so the developed areas should give the compensation to backward areas in joint governance.

Bodin (2017) argued that the collaborative environmental governance aligns human actions to ecosystem protection by proposing effective solutions through learning processes as well as coordination and cooperation by engaging public and private actors and stakeholders. Besides, synergies between multiple institutional and social realities facilitate sharing of different skills, knowledge, and resources, which can reach a new equilibrium in the balance between human agency and natural resources (Baggio & Hills, 2018; Li & Mauerhofer, 2016). From the perspective of practice, the coordination of interests among different areas is one of the important factors affecting the regional collaborative governance of environmental pollution. For example, the United States introduced the emission trading system in 1990, using market-oriented methods to coordinate the costs and benefits of different areas in terms of emissions, and established a strategy of combining intrastate joint prevention and regional coordination, relying on the federal environmental protection agency to maintain the relationship between states. Through the rights granted by laws such as the Clean Air Act and the agreements between states, the United States has carried out cross-regional environmental governance. In addition, Canada has also formed a relatively perfect coordination mechanism in the process of environmental governance. By introducing enterprises and non-governmental organizations and other departments, the interests of different departments are shared to avoid the emergence of sectoral protectionism. Some scholars also analyzed the dilemma of regional collaborative governance of environmental pollution in China and believed that the interest sharing of local governments is the key factor. Among them, Zhao and Zhou (2017) found that the main factors that cause the dilemma of regional collaborative governance include unclear responsibilities, dislocation, and absence of supervision, lack of regional coordination, and disordered competition. Yang et al. (2016) also argued that the local governments participating in the regional collaborative governance are mostly equal relations, and in the case of the public goods attribute of pollutants, the "free-riding" incentive makes the regional joint prevention easily fall into the collective action dilemma.

2.3 | A brief evaluation

The previous research has provided important references and enlightenments for us to understand the relationship between local government and regional environmental collaborative governance more comprehensively. Unfortunately, there are still some deficiencies:

1. The previous research either stays in the stage of factual description or simple theoretical analysis, or only studies the collaborative governance in a single region, lacking quantitative measurement of the current regional environmental collaborative governance. This is not conducive to a more objective understanding of the specific degree of regional collaborative governance of environmental pollution in China and the possible problems, and it hinders the further development of research in this field.
2. Previous studies have found that the interest sharing between local governments under the decentralization is the key to restrain the regional environmental collaborative governance; however, they have stopped here abruptly and ignored the impact of local protectionism and market segmentation. As mentioned above, the "free-riding" and the "racing to the bottom" competition of environmental regulation and the "fragmentation" development model in the context of domestic market segmentation may hinder the regional environmental collaborative governance. Neglecting this will not be conducive to a more comprehensive investigation of the key factors restricting the improvement of environmental quality in China.
3. The heterogeneity of different pollutants in the spillover effect has been ignored in previous research. These heterogeneities make the local government use different governance strategies, which will also have different effects on the regional environmental collaborative governance.

Therefore, in contrast to previous studies, this paper will build a measurement method based on the complex system theory for the first time to measure the degree of collaborative governance of environmental pollution among different regions in China and investigate its impact on regional collaborative governance of environmental pollution from the perspective of market segmentation between local governments under the decentralization. We also consider the heterogeneity of different pollutants in terms of spillover and investigate the impact of market segmentation on collaborative governance of pollutants with different spillover characteristics.

3 | THE MEASUREMENT OF REGIONAL ENVIRONMENTAL COLLABORATIVE GOVERNANCE: A SYNERGY DEGREE MODEL OF A COMPLEX SYSTEM

One of the important factors that hinders the deepening of the quantitative research on regional environmental collaborative governance is the lack of a scientific measurement method. Based on the synergetics theory, this paper regards the regional environmental collaborative governance among different local governments as a complex system, and each region (province) as the subsystem. By selecting the order parameter index and calculating the synergy degree of the complex system, we build a new method to measure the regional environmental collaborative governance.

3.1 | Methodology: Synergy degree model of a complex system

In the regional collaborative governance of environmental pollution, local governments play an important role, and their orderly cooperation will impact the overall governance effect. We assume that the complex system of regional environmental collaborative governance is S, the local governments forming the subsystem s, and $S = \left\{s_1, s_1, \ldots, s_n\right\}$, $n = 1, 2, \ldots, 31$; and

$$S = f\left(s_1, s_1, \ldots, s_n\right) \tag{1}$$

In Equation (1), f is the nonlinear function of S. The synergy of the regional collaborative governance system is to find an external action F, which makes the synergistic effect of the complex system greater than the simple sum of the actions of each subsystem. It can be expressed as:

$$E^g(S) = E\left\{F\left[f\left(s_1, s_1, \ldots, s_n\right)\right]\right\} = E\left[g\left(s_1, s_1, \ldots, s_n\right)\right] > \sum_{j=1}^{n} E^f\left(s_j\right) \tag{2}$$

There is more than one synergy mechanism of regional environmental collaborative governance, and we define an optimal synergy mechanism F^o, $\exists F^o \in \Gamma$. Under certain evaluation criteria, Equation (3) is established:

$$E\left\{F^o\left[f\left(s_1, s_1, \ldots, s_n\right)\right]\right\} = E\left[g^o\left(s_1, s_1, \ldots, s_n\right)\right] = optE^g(s) \tag{3}$$

Moreover, we define the order parameter e as the factor that influences the transformation of each subsystem from disordered to ordered:

$$e_j = \left(e_{j1}, e_{j2}, \ldots, e_{jn}\right) \tag{4}$$

In Equation (4), e_{ji} denotes the order parameter component. We define $\mu_j\left(e_{ji}\right)$ as the order degree of order parameter $j's$ component, and the value of $\mu_j\left(e_{ji}\right)$ is between 0 and 1; the larger the value is, the better the order parameter component can promote the ordered structure of the subsystem.

Besides, the ordered structure is realized through the integration of $\mu_j\left(e_{ji}\right)$. This paper uses the linear weighted method to express it, and the order degree of each subsystem can be obtained:

$$\mu_j\left(e_j\right)=\sum \omega_i \mu_j\left(e_{ji}\right),\ \omega_i \geq 0,\ \sum \omega_i=1 \tag{5}$$

Finally, if the order degree of each subsystem is $\mu_j^0\left(e_j\right)$ at the initial time t_0, and $\mu_j^1\left(e_j\right)$ is the order degree of each subsystem at t_1, the overall synergy degree of the complex system of collaborative governance of environmental pollution in the t_0-t_1 can be expressed as follows:

$$\mathrm{DWS}=\theta \sum \lambda_j\left[\left|\mu_j^1\left(e_j\right)-\mu_j^0\left(e_j\right)\right|\right] \tag{6}$$

In Equation (6), the value range of the synergy degree DWS of the complex system of regional environmental collaborative governance is [−1, 1], and the larger the value is, the higher the synergy of the complex system is. λ is the weight of each subsystem in the complex system, and $\lambda_j \geq 0$, $\sum \lambda_j=1$.

According to the synergetics theory, if one subsystem in the complex system has not developed in an orderly direction, the complex system may be in a nonsynergistic state. And if the order degree of one subsystem is greatly improved and that of other subsystems is only slightly increased or even decreased, then, the complex system is still not in a good synergistic state. This is consistent with the reality of regional environmental collaborative governance; that is, the collaborative governance activities among different local governments depend on their joint actions. If any of the local governments adopt the “free-riding” strategy or do not participate in the collaborative governance, it may lead other local governments to adopt similar strategies, which will cause a nonsynergistic effect of the complex system and make it difficult to achieve good environmental performance.

3.2 | Order parameter index

The synergy of the complex system depends on the driving of order parameters, which played a decisive role in the system evolution. Generally, the behaviors of local government in the environmental pollution governance mainly include the input of personnel, capital, policy, and organization. We will also construct the order parameter index of the regional environmental collaborative governance complex system from these four dimensions.

First, this paper selects the total number of personnel in environmental protection departments, which include the environmental administrative and supervision departments, environmental and radiation monitoring stations, scientific research institutions, publicity and education institutions, and emergency institutions in each province, to measure the personnel input. Second, in terms of capital input, we choose the industrial pollution governance investment of each province as the measurement index during the investigation period, and a GDP deflator was used to convert it into constant price with 2002 as the baseline year. Third, we adopt the total number of environmental protection organizations in each province as the proxy index of organizational input. The original data above mainly come from the *China Environmental Yearbook* of each year. Fourth, as for the policy input, we use the number of the policies and regulations about environmental protection issued by each province from 2002 to 2015 to measure it, and the relevant original data are mainly obtained from the *Fabao of Peking University*. Table 1 shows the specific contents of the order parameter index.

TABLE 1 Order parameters index

Subsystem	Order parameters	Secondary indicators	Unit
Environmental governance subsystem i	Personnel input	Number of personnel of environmental protection departments	People
	Capital input	Industrial pollution governance investment	10,000 yuan
	Policy input	Number of policies and regulations about environmental protection	Piece
	Organization input	Number of environmental protection organizations	1

Besides, this paper uses the CRITIC of objective weighting method to measure the weight of each index, and it uses the mean-standard deviation method to standardize the data. According to the above equations and order parameter index, we can calculate the order degree of each subsystem and the synergy degree of the complex system of regional environmental collaborative governance.

3.3 | Result, analysis, and discussion

Figure 2 shows the time trend of the regional environmental collaborative governance, and Figures 3–7 show the spatial distribution of each order parameter's order degree from 2002 to 2015. During the investigation period, the overall synergy degree of the complex system of regional environmental collaborative governance is greater than 0, which indicates that the complex system shows the transformation from disorder to order. The degree of coordination among different regions in the collaborative governance of environmental pollution is increasing. However, the absolute level of it is lower (0.136) and still far away from the best front. This shows that although the regional environmental pollution governance in China presents a certain collaborative trend, its overall situation is not optimistic. Moreover, according to the spatial distribution shown in Figure 3, the degree of regional collaborative governance of environmental pollution in the eastern area is significantly higher than that in the middle and western areas, especially in the Beijing-Tianjin-Hebei region, the Yangtze River Delta region, and the Pearl River Delta region. These regions have a higher degree of regional economic integration in China, and the relationship between local governments is closer. In terms of the order degree of different inputs shown in Figures 4–7, their spatial distribution also follows the same law; that is, the order degree of personnel input, capital input, policy input, and organizational input of local governments in the eastern area is relatively higher.

4 | MODEL SPECIFICATION AND DATA SELECTION

4.1 | Model specification

To empirically study the impact of Chinese market segmentation on regional collaborative environmental governance, this paper proposes to build a Dynamic Panel Econometric Model as follows:

$$\text{Collaboration}_{it} = \alpha_0 + \tau \text{Collaboration}_{i,t-1} + \beta \text{Segmentation}_{it} + \gamma_j X_{jit} + \varepsilon_{it} \tag{7}$$

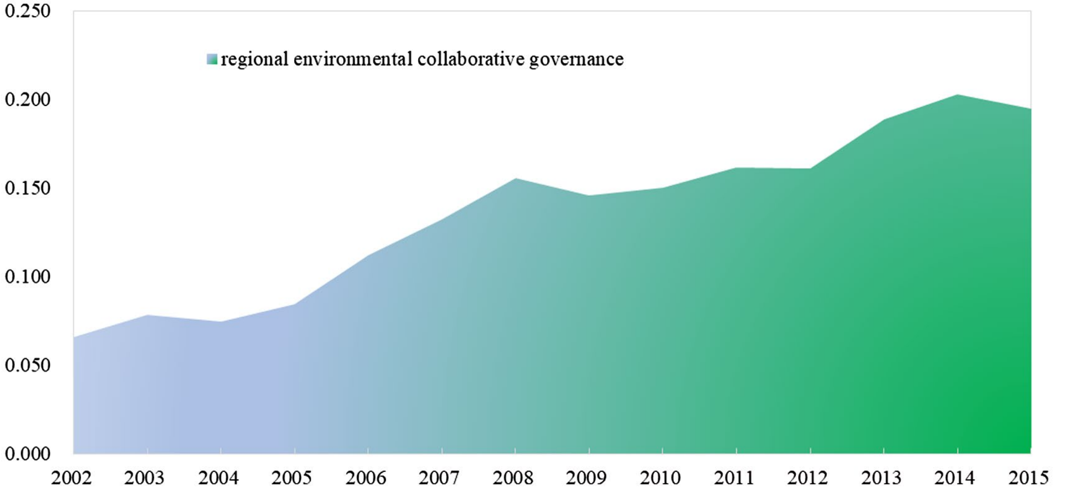

FIGURE 2 Mean of the regional environmental collaborative governance in 2002–2015

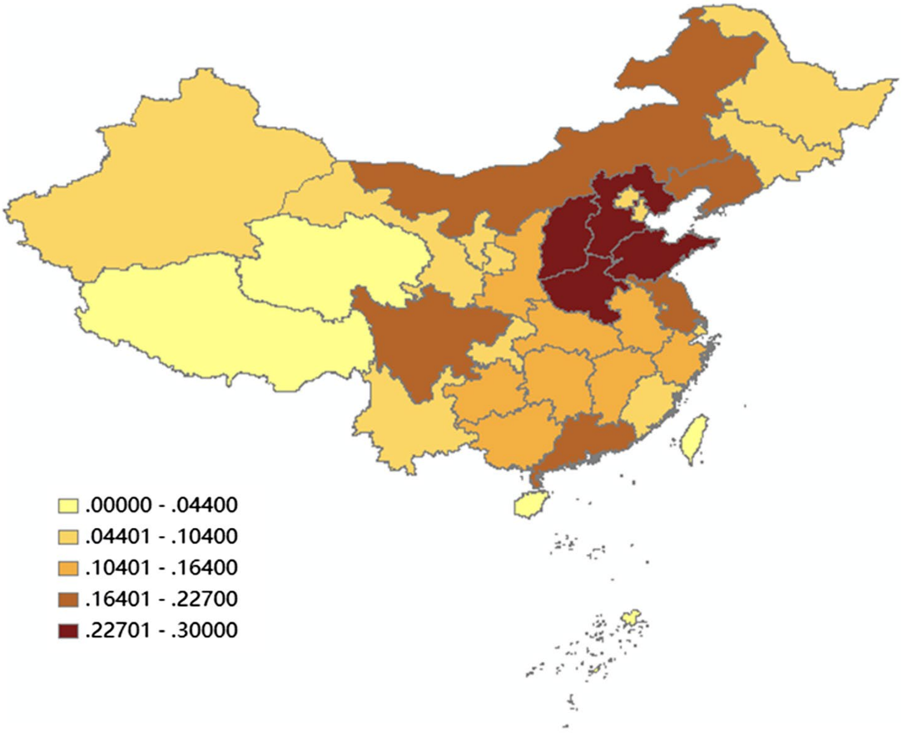

FIGURE 3 Spatial distribution of the regional environmental collaborative governance

In Equation (7), i and t denote the number of cross-sections and the number of periods; *Collaboration* denotes the degree of regional environmental collaborative governance; α is a constant term; τ is the time lag coefficient; *Segmentation* denotes the Chinese market segmentation, with the β as its estimated coefficient; Z denotes a series of control variables, γ is the respectively estimated coefficient; and ε is the random error term.

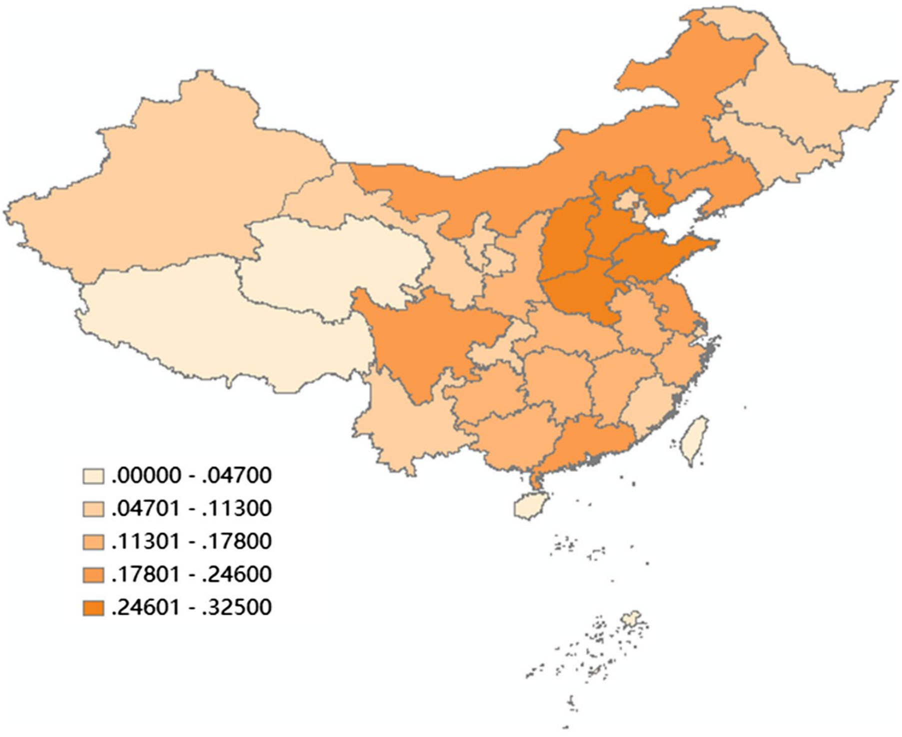

FIGURE 4 Order degree of personnel input

For the Dynamic Panel Econometric Model shown in Equation (7), the lag term of the dependent variable is included as an independent variable, which can further control the endogenous bias caused by the missing variables and improve the accuracy of the research results. However, although the time effect is included, it is difficult to deal with the unobservable individual fixed effect; moreover, if the lag term is related to the random error term, the ordinary least squares (OLS) estimator of the lag term will be seriously biased up, the OLS estimator of the fixed effect will be seriously biased down, and the generalized least squares (GLS) estimator of the random effect will also be biased. At this time, if the traditional estimation method is used to estimate the Dynamic Panel Econometric Model, biased, and inconsistent estimation parameters will be produced. Therefore, Arellano and Bond (1991) and Arellano and Bover (1995) proposed to use Generalized Method of Moments (GMM) to overcome the above problems. And considering the advantages of the two-step System GMM (SYS-GMM), we will use this method to estimate the Dynamic Panel Econometric Model.

Samples in the empirical study are the panel data of 31 provinces (excluding Chinese Taipei, Hong Kong, and Macau due to missing data) during 2002–2015. The original data are obtained from the *China Statistical Yearbook* and the *China Statistical Yearbook for Regional Economy*.

4.2 | Variables selection

4.2.1 | Chinese market segmentation

The measurement methods of Chinese market segmentation mainly include production method, trade method, price method, economic cycle method, and questionnaire method in previous studies. Among

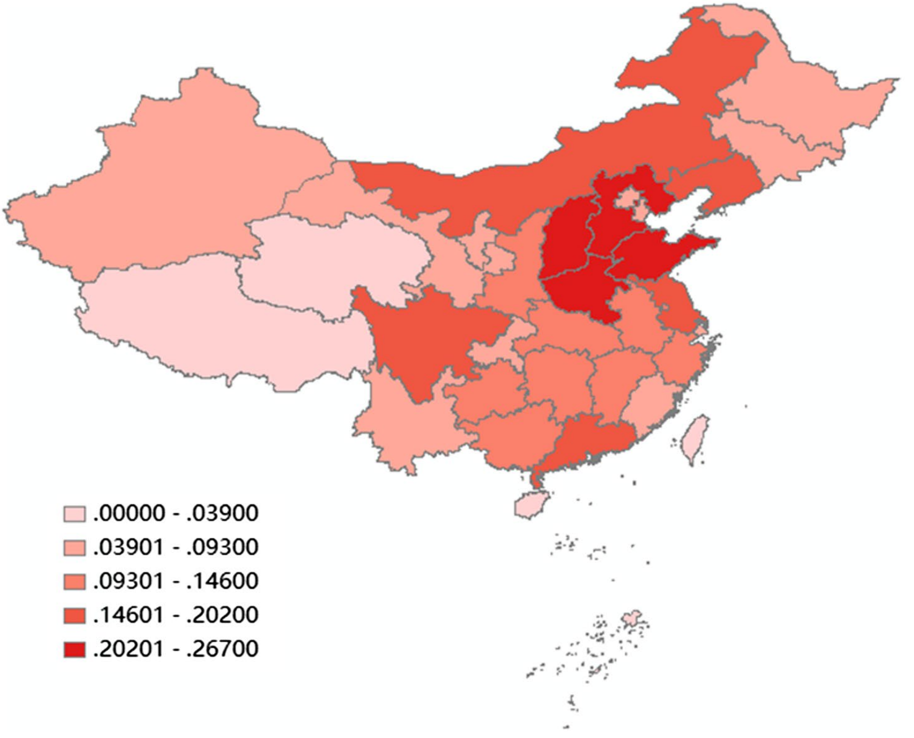

FIGURE 5 Order degree of capital input

them, the price method has a solid theoretical foundation (*one price law* and *glacier cost model*), which has become the choice of this paper. If there is a statistical convergence of commodity prices among different areas, it means that the degree of market integration is increased, and the market segmentation is decreased.

According to the glacier cost model, due to the existence of transaction costs, the value of the commodity will be "melted" partly in the trade, which cause the prices of the commodity in the *m* area and *n* area, and P_m and P_n cannot be completely equal. The trade between the two areas will be formed when the arbitrage is profitable only if P_m (1-c)> P_n or P_n (1-c)> P_m. c ($0 < c<1$) denotes the ratio of the size of the "melted" per unit price. We use the first-order difference to calculate it:

$$\Delta Q^k_{mnt} = \ln\left(P^k_{mt}/P^k_{nt}\right) - \ln\left(P^k_{mt-1}/P^k_{nt-1}\right) = \ln\left(P^k_{mt}/P^k_{mt-1}\right) - \ln\left(P^k_{nt}/P^k_{nt-1}\right) \tag{8}$$

where k denotes the commodity category, and P is the price of k (including *food*, *cigarettes and alcohol*, *clothing*, *household equipment*, *medical and health care*, *transportation and communication tools*, *entertainment*, *education and cultural goods*, *and residential-related products and services*). Besides, the systematic errors caused by random factors such as commodity characteristics, α^k, and market environment, μ^k_{mnt}, are eliminated by the de-mean method. Referring to Parsley and Wei (2001), we calculate the mean of $\left|\Delta Q^k_t\right|$ for a certain type of commodity in a given year to eliminate α^k, and we use $\left|\Delta Q^k_{mnt}\right|$ to subtract it:

$$\left|\Delta Q^k_{mnt}\right| - \left|\Delta Q^k_t\right| = \left(\alpha^k - \overline{\alpha^k}\right) - \left(\mu^k_{mnt} - \overline{\mu^k_{mnt}}\right) \tag{9}$$

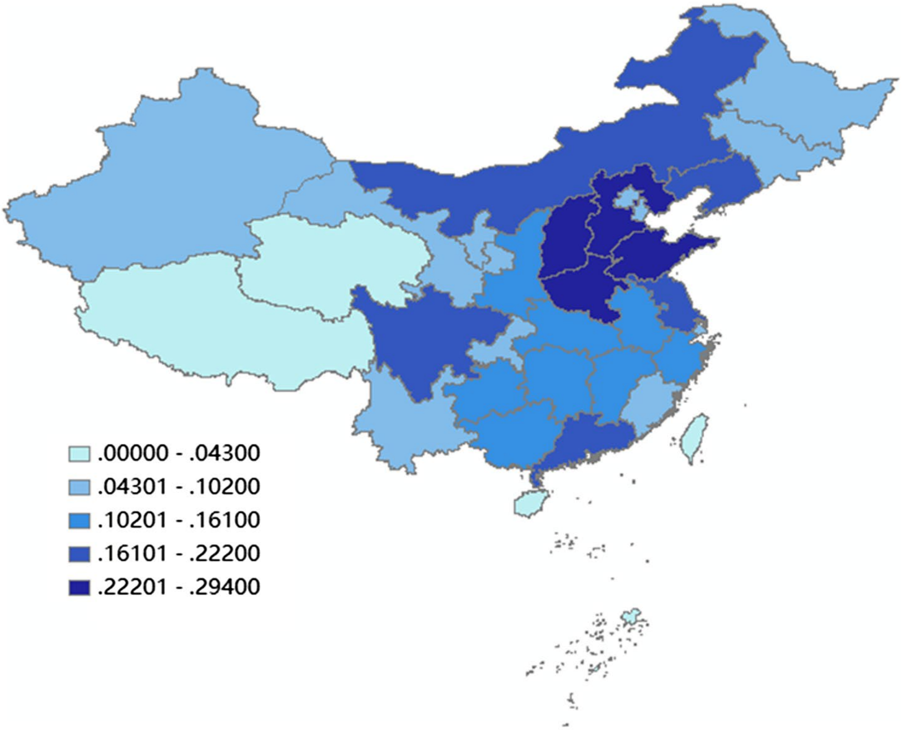

FIGURE 6 Order degree of policy input

Therefore, the difference of price of k between m and n is:

$$q_{mnt}^{k} = \mu_{mnt}^{k} - \overline{\mu_{mnt}^{k}} = \left|\Delta Q_{mnt}^{k}\right| - \overline{\left|\Delta Q_{mnt}^{k}\right|} \tag{10}$$

The variance of q_{mnt}^{k} is calculated to measure the market segmentation of China. We use Figure 8 to describe the degree of Chinese market segmentation in the period of 2002–2015. Although the degree of market segmentation experienced a declining trend in China, there are typical characteristics of segmentation during the investigation period.

4.2.2 | Control variables

In this study, other control variables that may affect regional collaborative governance of environmental pollution are selected, which include environmental pollution situation, economy growth, industry structure, openness level, technical innovation, human capital, urbanization level, and population density.

1. Environmental pollution (*Pollution*). Environmental pollution is the direct factor leading to collaborative governance. So in areas where environmental pollution is more serious, the possibility of regional collaborative governance of environmental pollution by local governments is higher. This paper constructs an environmental pollution index, including wastewater, waste gas (sulfur dioxide, smoke dust, PM2.5), and solid waste, to measure the environmental pollution.[1]

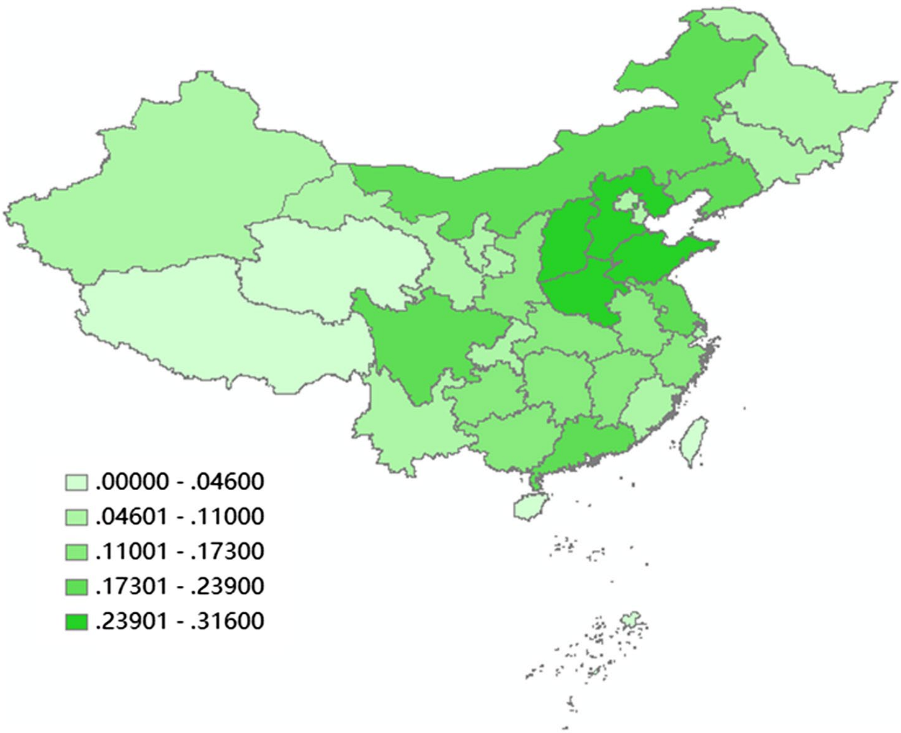

FIGURE 7 Order degree of organization input

2. Economy growth (*Economy*). According to the Environmental Kuznets Curve, there is a significant inverted U-shaped relationship between economic growth and environmental pollution (Grossman & Krueger, 1995). Better economic growth can provide a material basis for environmental governance, but at the same time, regional differences in economic growth also constitute an important factor affecting regional collaborative governance of environmental pollution. We select the per capita GDP of each province during the period 2002–2015 as the proxy indicator, and we use CPI to convert it into constant price per capita GDP with 2002 as the baseline year.
3. Industry structure (*Structure*). Unreasonable industrial structure is one of the sources of environmental pollution, and the optimization of industrial structure is also conducive to the smooth progress of environmental governance. We use the proportion of the secondary industry output to the regional GDP to measure it.
4. Openness level (*Open*). Although opening to the outside world helps to obtain advanced technology from developed countries and improve their environmental quality, the pollution paradise hypothesis also holds that enterprises in developed countries will transfer those highly polluting enterprises to developing countries to avoid their strict environmental regulations, thus, aggravating environmental pollution in developing countries. Therefore, the degree of openness is also an important factor affecting the degree of environmental pollution and the degree of regional collaborative governance of environmental pollution. It is denoted by the total investment of per foreign-funded enterprises, and the investment amount is converted into CNY using the exchange rate between CNY and USD of the corresponding year. The GDP deflator is used to convert the amount into constant price investment with 2002 as the baseline year.
5. Technology innovation (*Technology*). Technological innovation helps to optimize the production process and promote the R&D of clean technologies, which helps to reduce environmental

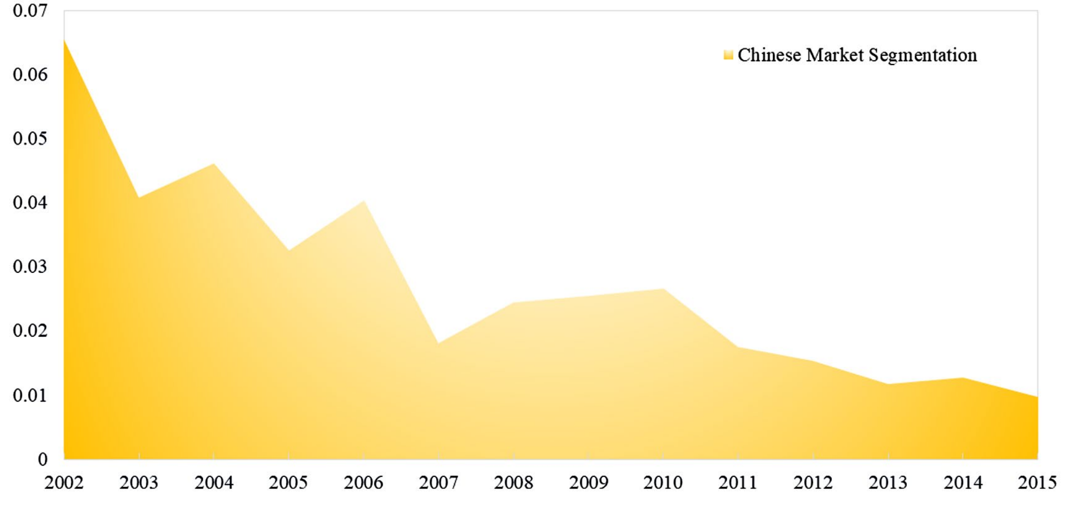

FIGURE 8 Chinese market segmentation in 2002–2015

pollution and promote regional collaborative governance of environmental pollution. We choose the weighted form of granted patents in each province during the period 2002–2015 as the proxy indicator by assigning weights of 0.5, 0.3, and 0.2 to invention patent, utility patent and design patent, respectively, according to their level of innovation.

6. Human capital (*Human*). Human capital is an important factor affecting the quality of economic growth. The higher the human capital is, the lighter the environmental pollution is. Moreover, higher human capital can also help to provide intellectual support for regional collaborative governance of environmental pollution. We use the average years of education of the population, which are calculated by the weighted form based on the population with different academic qualifications, as the proxy indicator for human capital.[2]
7. Urbanization level (*Urbanization*). Both theoretical research and practical experience show that the rapid development of China's urbanization process is an important factor affecting environmental pollution, which also determines the necessity of regional collaborative governance of environmental pollution. The indicator we used is the proportion of built-up area to the whole area.
8. Population density (*Population*). Similarly, since the Industrial Revolution, the high concentration of population is an important factor leading to environmental pollution, which also puts forward the necessary requirements for the regional collaborative governance of environmental pollution in population-concentrated areas. We choose the proportion of the regional total population at the end of the year to the administrative area as the final indicator. Table 2 reports the descriptive statistical results of the above variables.

5 | RESULTS AND DISCUSSIONS

5.1 | Results of benchmark regression model

We use *Stata* to estimate the Dynamic Panel Econometric Model shown in Equation (7). In order to further reduce the autocorrelation between the control variables and the core independent variable, we lag the control variables for one period to ensure that the control variables occur before the

TABLE 2 Descriptive statistical results of variables

Variable name	Unit	Obs	Mean	Standard deviation	Maximum	Minimum
Coordination	1	434	0.136	0.088	0.447	0.003
Segmentation	1	434	0.028	0.021	0.164	0.006
Pollution	1	434	1.000	0.536	2.500	0.023
px_1	10,000 tons	434	190,282.893	159,379.021	911,523.000	1,079.000
px_2	10,000 tons	434	71.032	45.155	200.300	0.100
px_3	10,000 tons	434	52.083	38.746	181.700	0.200
px_4	μg/m^3	434	45.385	22.565	108.273	3.464
px_5	10,000 tons	434	6,988.383	7,232.830	45,575.830	5.000
Economy	yuan	434	23,443.423	15,339.092	75,332.896	3,240.631
Structure	1	434	0.463	0.084	0.664	0.197
Open	10,000 yuan	434	2,566.907	1,520.192	12,890.567	532.378
Technology	piece	434	5,678.729	11,004.860	72,813.800	2.000
Human	year	434	9.276	0.863	13.335	7.344
Urbanization	1	434	0.016	0.030	0.172	0.000
Population	person/km^2	434	433.875	659.210	4,182.759	2.174

Note: In the later estimation process, the above variables are all logarithmic, and the proportional variable uses log (1 + original value).

core independent variable. In addition, based on the comparability, we also report the results of the pool OLS, panel data fixed effect model (FE), and SYS-GMM with and without control variables, as shown in columns (1)–(6) of Table 3. We use *Sargan statistics* to test the validity of instrumental variables and adopt the first and second serial correlation tests *AR (1)* and *AR (2)* of the first-order difference transformation equation to test the serial correlation of residuals.

We will select the results based on the SYS-GMM, as shown in (6), for discussion. The results of *Sargan* statistics indicate that instrumental variables with first-order lag are effective. The *AR* (1) is significant at 1%, and *AR* (2) is not significant at 10%, which show that the residual term first-order serial correlation exists, but the second-order serial correlation does not exist. The time lag coefficient of regional environmental collaborative governance is significantly positive at 1%, which indicates that the regional collaborative governance activities have a time-locked feature. The effect of Chinese market segmentation (*Segmentation*) on the regional environmental collaborative governance is significantly negative at 1%, and the market segmentation of China can significantly inhibit the coordination of regional environmental pollution governance. Under the fiscal decentralization, Chinese market segmentation may lead to the "free-riding" of environmental governance, urge local governments to reduce environmental standards, and cause the "racing to the bottom" competition. Moreover, the fragmentation formed by market segmentation also hinders the communication between local governments, which will have a negative impact on the regional environmental collaborative governance.

As for the results of control variables shown in column (6), the effect of environmental pollution situation (*Pollution*) on regional collaborative governance is significantly positive, indicating that the higher the environmental pollution is, the greater the efforts of collaborative governance among local governments are. As far as the economic development (*Economy*) is concerned, it also plays a significant role in promoting the regional collaborative governance of environmental pollution.

TABLE 3 Results of benchmark regression model

	Pool OLS		Panel FE		SYS-GMM	
	(1)	(2)	(3)	(4)	(5)	(6)
Lag_1	0.870*** (0.009)	0.748*** (0.159)	0.735*** (0.014)	0.619*** (0.023)	0.956*** (0.000)	0.807*** (0.011)
Segmentation	−0.042 (0.047)	−0.158*** (0.045)	−0.224*** (0.046)	−0.074 (0.049)	−0.121*** (0.002)	−0.096*** (0.017)
Pollution	–	0.036*** (0.005)	–	−0.005 (0.011)	–	0.031*** (0.009)
Economy	–	0.001 (0.002)	–	0.027*** (0.005)	–	0.023*** (0.004)
Structure	–	0.011 (0.012)	–	−0.042 (0.026)	–	−0.029* (0.016)
Open	–	0.005*** (0.001)	–	0.010*** (0.002)	–	0.019*** (0.001)
Technology	–	0.002** (0.001)	–	−0.001 (0.002)	–	0.004*** (0.001)
Human	–	−0.010 (0.013)	–	−0.008 (0.017)	–	0.012** (0.005)
Urbanization	–	0.001 (0.037)	–	0.302* (0.157)	–	−0.608 (0.601)
Population	–	−0.002** (0.001)	–	−0.010 (0.013)	–	−0.001 (0.005)
Constant	0.016*** (0.002)	−0.030 (0.027)	0.038*** (0.003)	−0.196** (0.087)	0.017*** (0.002)	−0.389*** (0.043)
R-square	0.968	0.977	0.918	0.934	–	–
Wald test	–	–	–	–	500,000.56 (0.000)	45,144.85 (0.000)
Observations	403	403	403	403	403	403
AR (1)	–	–	–	–	0.000	0.000
AR (2)	–	–	–	–	0.216	0.154
Sargan	–	–	–	–	30.784 (1.000)	29.856 (1.000)

Note: ***, **, and * denote a significance level of 1%, 5%, and 10%, respectively; standard errors are reported in parentheses; the results in AR (1) and AR (2) statistics are the corresponding *p*-value.

The economic development has a strong correlation with environmental pollution itself, and higher economic development also provides material guarantee for the collaborative governance. Industrial structure (*Structure*) has a significantly negative impact on the regional environmental collaborative governance. Although the secondary industry has always been an important source of environmental pollution, this paper does not find a significant relationship between industrial structure and regional collaborative governance. The relationship between the opening-up (*Open*) and the regional environmental collaborative governance is significantly positive, indicating that the degree of opening to the outside world is conducive to promoting the enthusiasm and strength of the local government to participate in the collaborative governance. Foreign enterprises attach great importance to environmental pollution, and in order to attract foreign investment, local governments will have enough motivation to carry out environmental pollution governance and strengthen cooperation with surrounding governments. Technology innovation (*Technology*) and human capital (*Human*) are also helpful to promote regional environmental collaborative governance. Finally, the empirical results show that the effect of urbanization level (*Urbanization*) and population size (*Population*) on the regional environmental collaborative governance is not significant at 10%.

5.2 | Impact of Chinese market segmentation on different collaborative governance inputs

We construct the order parameter index of each subsystem from the perspective of input in environmental pollution governance, which mainly includes personnel input, capital input, policy input, and organization input. There may be some differences in the impact of Chinese market segmentation on the different environmental collaborative governance inputs because personnel input and capital input are relatively explicit, direct, and quick in effect, while policy input and organization input are relatively implicit, indirect, and slow in effect.

Specifically, faced with increasingly serious environmental pollution, local governments have gradually recognized the need to strengthen regional collaborative governance, and the central government also has emphasized the elimination of local protectionism and the promotion of market integration. However, on the one hand, under the decentralization, local governments may take some strategic actions to protect the enterprises' interests of the local area, such as only strengthening the input of labor and capital, but not implementing the adjustments in policy, organizational arrangements, and other institutional aspects. On the other hand, since the policy and organization input are indirect, slow, and difficult to adjust, some local governments are not willing to strengthen the policy and organization input to carry out the regional environmental collaborative governance. Therefore, this paper will further investigate the impact of Chinese market segmentation on the different inputs of collaborative governance of environmental pollution. The estimation results based on the Dynamic Panel Econometric Model are shown in columns (7)–(10) of Table 4.

From the results shown in Table 4, it can be seen that the impact coefficients of Chinese market segmentation on the order of personnel input and capital input in the environmental collaborative governance are significantly negative, which show that market segmentation is not conducive to the improvement of the order of personnel input and capital input in the collaborative governance of environmental pollution by local governments. Moreover, Chinese market integration between different areas can improve the order of personnel input and capital input in the regional collaborative governance. However, the results in columns (9) and (10) show that the relationships between Chinese market segmentation and the order of policy input and organization input are not significant, which indicate that market segmentation has no significant impact on the policy coordination and organization

TABLE 4 Results of the different collaborative governance Inputs

	(7) Personnel input	(8) Capital input	(9) Policy input	(10) Organization input
Lag_1	0.781*** (0.012)	0.419*** (0.009)	0.706*** (0.008)	0.366*** (0.008)
Segmentation	−0.171*** (0.026)	−0.299*** (0.041)	0.045 (0.028)	0.042 (0.042)
Constant	−0.130*** (0.052)	−1.546*** (0.111)	−0.291*** (0.046)	0.515*** (0.056)
Control variables	Yes	Yes	Yes	Yes
Wald test	32,363.82 (0.000)	24,994.03 (0.000)	84,635.28 (0.000)	8,262.98 (0.000)
Observations	403	403	403	403
AR (1)	0.003	0.000	0.000	0.000
AR (2)	0.174	0.441	0.413	0.224
Sargan	30.424 (1.000)	30.048 (1.000)	30.120 (1.000)	29.873 (1.000)

coordination of local governments in the process of regional collaborative governance of environmental pollution.

5.3 | Spatial and temporal heterogeneity analysis

Using an econometric model to test the spatial and temporal heterogeneity is helpful to understand the relationship between Chinese market segmentation and regional collaborative governance of environmental pollution more comprehensively, and it is also an expansion and deepening of the previous analysis. In fact, market segmentation in China shows a temporal feature, in the years with higher degree of market segmentation, and it may have a restraining effect on the regional environmental collaborative governance. In the years with a lower degree of market segmentation, its impact may be relatively small. Therefore, this paper will further investigate the temporal characteristics of Chinese market segmentation affecting the environmental collaborative governance. The differences of the impact of market segmentation on the regional collaborative governance of environmental pollution in Period I (2002–2007) and Period II (2008–2015) are investigated empirically, and the results are shown in columns (11) and (12) of Table 5.

Besides, it can be seen from the results shown in Figures 3–7 that there is typical spatial heterogeneity in regional collaborative governance of environmental pollution in China during the investigation period, and the degree of collaborative governance among provinces in the eastern area is significantly higher than that in the middle and western areas. Then, is there spatial heterogeneity in the effect of market segmentation on regional collaborative governance of environmental pollution? In addition, due to the gradient pattern of China's regional economic development, the research on China's regional economy cannot ignore the regional differences among the eastern, the middle, and the western areas. Therefore, we will also further investigate the spatial heterogeneity of the impact of Chinese market segmentation on the regional environmental collaborative governance and divide the samples into the eastern, middle, and western areas. The estimated results are shown in columns (13), (14), and (15) of Table 5, respectively. It should be noted that after the regional processing, the number of cross-sections of each sample is less than the number of periods, which does not meet the requirements of SYS-GMM. Therefore, the estimation method used here is the two-way fixed effect model of panel data.

TABLE 5 Results of spatial and temporal heterogeneity

	Temporal heterogeneity		Spatial heterogeneity		
	(11)	**(12)**	**(13)**	**(14)**	**(15)**
Lag_1	1.007^{***} (0.036)	0.597^{***} (0.014)	–	–	–
Segmentation	-0.120^{***} (0.018)	-0.083^{***} (0.031)	0.159 (0.123)	-1.098^{***} (0.285)	-0.083^{***} (0.029)
Constant	-0.651^{***} (0.028)	0.042 (0.045)	1.254^{**} (0.506)	-1.208^{*} (0.631)	0.159 (0.216)
Control variables	Yes	Yes	Yes	Yes	Yes
Cross fixed effect	No	No	Yes	Yes	Yes
Time fixed effect	No	No	Yes	Yes	Yes
Wald test	16,759.16 (0.000)	7,993.12 (0.000)	–	–	–
Observations	155	248	143	104	156
AR (1)	0.000	0.000	–	–	–
AR (2)	0.130	0.120	–	–	–
Sargan	28.997 (1.000)	30.642 (1.000)	–	–	–

TABLE 6 Results of robustness tests

	Robustness test 1		Robustness test 2
	(1)	(2)	(3)
Lag_1	–	–	0.561^{***} (0.007)
IV	0.359^{***} (0.038)	–	–
Segmentation	–	-0.382^{**} (0.192)	-0.037^{*} (0.022)
Constant	0.014^{***} (0.001)	0.829^{***} (0.236)	-0.136^{***} (0.051)
Control variables	Yes	Yes	Yes
R^2	0.9146	0.846	–
Wald test	–	–	49,753.71(0.000)
Observations	403	403	372
AR (1)	–	–	0.000
AR (2)	–	–	0.124
Sargan	–	–	28.881 (0.1483)

From the results of temporal heterogeneity in Table 5, during 2002–2007, the effect of Chinese market segmentation on the regional environmental collaborative governance is significantly negative, indicating that market segmentation significantly inhibited the collaborative governance activities between local governments of China. And during 2008–2015, the impact of Chinese market segmentation is still significantly negative, but the coefficient is lower than that in the previous stage due to the lower market segmentation. In terms of the results of spatial heterogeneity, the impact of market segmentation on the regional environmental collaborative governance in the eastern area is not significant, which may be due to the relatively high degree of market integration, while in the middle and western areas, market segmentation can significantly worsen regional environmental collaborative governance.

5.4 | Robustness tests

1. Instrumental Variables Method of Panel Data. The Dynamic Panel Model used in the previous paper is helpful to further control the endogenous bias. Here, we will use the instrumental variables method of panel data to control the possible two-way causality in the process of Chinese market segmentation impact on the regional environmental collaborative governance. The instrumental variable selected here is the first-order lag term of market segmentation, which belongs to the historical variable and satisfies the exogenous constraints. The degree of Chinese market segmentation in the early stage will have an important impact on the current period, and it also satisfies the correlation conditions. The results of the instrumental variable method estimated by the two-stage least square method (2SLS) are shown in Table 6, in which column (1) and column (2) represent the results of the first stage and the second stage, respectively.
2. DIF-GMM method. For the Dynamic Panel Model, there are two kinds of estimation: the DIF-GMM and SYS-GMM, and the latter has been used in the benchmark model. Here, we will further

TABLE 7 Results of the further study

	px_1	px_2	px_3	px_4	px_5
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
Panel A: High-pollution area					
Lag_1	0.868*** (0.023)	0.759*** (0.016)	0.797*** (0.029)	0.829*** (0.019)	0.705*** (0.023)
Segmentation	−0.169* (0.094)	−0.094*** (0.029)	−0.491*** (0.070)	−0.209*** (0.047)	−0.266 (0.749)
Constant	−0.423 (0.433)	−0.494*** (0.044)	−0.245*** (0.067)	−0.423*** (0.087)	−0.476 (1.221)
Control variables	Yes	Yes	Yes	Yes	Yes
Wald test	24,049.46 (0.000)	19,650.05 (0.000)	19,598.65 (0.000)	30,932.53 (0.000)	27,857.25 (0.000)
Observations	231	264	243	242	245
AR (1)	0.000	0.000	0.000	0.000	0.000
AR (2)	0.130	0.114	0.257	0.130	0.117
Sargan	20.584 (1.000)	22.457 (1.000)	22.357 (1.000)	27.004 (1.000)	23.456 (1.000)
Panel B: Low-pollution area					
	(6)	(7)	(8)	(9)	(10)
Lag_1	0.979*** (0.078)	0.871*** (0.065)	0.706*** (0.071)	0.515 (0.333)	0.790*** (0.104)
Segmentation	−0.152*** (0.049)	−0.028 (0.023)	−0.028 (0.025)	−0.067 (0.064)	−0.009 (0.016)
Constant	−0.446** (0.217)	−0.139 (0.155)	0.161 (0.158)	−0.202 (0.363)	−0.280*** (0.081)
Control variables	Yes	Yes	Yes	Yes	Yes
Wald test	7,016.29 (0.000)	1592.38 (0.000)	511.71 (0.000)	3,925.67 (0.000)	21,214.03 (0.000)
Observations	172	139	160	161	158
AR (1)	0.014	0.012	0.004	0.014	0.009
AR (2)	0.135	0.100	0.360	0.189	0.370
Sargan	12.321 (1.000)	14.838 (1.000)	16.151 (1.000)	10.765 (1.000)	17.104 (1.000)

use the DIF-GMM to estimate the Dynamic Panel Model shown in Equation (7), and the estimation results are shown in column (3) in Table 6.

From the robustness test results shown in Table 6, whether the instrumental variables method of panel data or the DIF-GMM method is used, the estimation coefficients are all significantly negative, which indicates that Chinese market segmentation is not conducive to promoting regional environmental collaborative governance among local governments. This is consistent with the estimation result of the benchmark regression model, and the conclusions of this paper have good robustness.

6 | FURTHER STUDY CONSIDERING THE SPILLOVER OF ENVIRONMENTAL POLLUTANTS

In investigating the relationship between Chinese market segmentation and regional environmental collaborative governance, the diversity of pollutants is worthy of attention. The diffusion feature of each pollutant and the external factors that affect them are not the same, which means the governance measures adopted by local government for different environmental pollutants may be different.

Specifically, for the five pollutants selected in this paper, the spillover of waste gas is the strongest, followed by wastewater, while the spillover of solid waste pollution is the lowest. These differences among different pollutants may also affect the decision making of local governments: in the collaborative governance of strong spillover pollutants, such as waste gas, regional collaborative governance is necessary, and it is also more vulnerable to the adverse impact of market segmentation; for the pollutants with poor diffusion, such as wastewater and solid waste, they often depend on the local government's unilateral governance. Therefore, due to the difference in the spillover among different pollutants, the impact of market segmentation on the regional collaborative governance of different environmental pollutants may have differences. We will further test this phenomenon.

According to the mean value of different pollutants, we divide five pollutants into high-pollution area and low-pollution area, and we investigate the impact of Chinese market segmentation on the regional environmental collaborative governance in the two areas. The results are shown in Table 7, where Panel A and Panel B represent samples of high-pollution area and low-pollution area, respectively.

From the results shown in Table 7, it can be seen that in areas with high emissions of waste gas such as sulfur dioxide (px_2), smoke and dust (px_3), PM2.5 (px_4), and wastewater (px_1), the effect of Chinese market segmentation is significantly negative, indicating that market segmentation mainly inhibits regional environmental collaborative governance in these areas; however, for the areas with large solid waste (px_5) emissions, the impact of Chinese market segmentation is not significant. For the waste gas and wastewater pollutants with strong spillover, it is necessary to strengthen the collaborative action of different local governments. Market segmentation will be bound to have a negative impact on regional collaborative governance activities, and for the pollutants with strong spillover, the impact of Chinese market segmentation is more obvious. For the governance of low spillover and diffusion pollutants, such as solid waste, it often depends on the local government for unilateral governance, and for these areas, the impact of Chinese market segmentation may not be obvious.

7 | CONCLUSIONS AND IMPLICATIONS

The dual attributes of environmental pollutants determine the necessity of regional collaborative governance, which may be impacted by Chinese market segmentation under fiscal decentralization. Based on combing the previous research literature, this paper calculates the regional environmental collaborative governance by provinces in China from 2002 to 2015, and then, uses the Dynamic Panel Econometric Model to empirically analyze the impact of Chinese market segmentation. The main conclusions and implications are as follows:

First, the order of personnel input, capital input, policy input, and organization input of each subsystem shows a transformation from disorder to order, and the synergy of the complex system of regional environmental collaborative governance also experienced an upward trend, but they are still at a low level. Second, Chinese market segmentation has a negative effect on the regional environmental collaborative governance, which indicates that the protectionist behavior among local governments has significantly inhibited the regional environmental collaborative governance. Third, Chinese market segmentation restrains the order of personnel input and capital input in the regional environmental collaborative governance, but it has no significant impact on the order of organization input and policy input. Fourth, the impact of Chinese market segmentation on regional environmental collaborative governance is large in 2002–2007; because of the low degree of Chinese market segmentation, the effect in the eastern area is not significant. Fifth, in areas with high emissions of waste gas and wastewater, the effect of Chinese market segmentation is significantly negative, while for areas with large emissions of solid waste, the effect is not significant.

The policy implications of this study are as follows: Under the fiscal decentralization, the interest differentiation caused by the imbalance of regional economic development is the key factor that hinders regional collaborative governance of environmental pollution. Therefore, in the environmental governance, how to design a more scientific interest-sharing mechanism has become an important issue. And a "mutually beneficial" pattern, which considering the "interest difference" of each area, will help stimulate the enthusiasm of local governments to participate in collaborative governance. Specifically,

1. establishing an institutionalized mechanism and strategy of regional collaborative governance of environmental pollution. As for the central government, it is necessary to establish a unified coordination organization, which is responsible for coordinating the regional collaborative governance of environmental pollution and the relationship between different areas and building a sound collaborative governance strategy and development goals. The local government should also closely focus on the actual situation of local areas' environmental pollution, carry out collaborative governance with the surrounding local governments, and establish bilateral collaborative governance strategy and implementation rules, as well as a collaborative governance scheme suitable for the actual situation of the region.
2. Establishing a more scientific and inclusive compensation mechanism for ecological interests. Although many local governments are also trying to establish an ecological compensation mechanism, it has not fundamentally eliminated the differences in ecological protection motivation between developed areas and backward areas. The gap between local governments in economic development is still the root cause of the local protectionism, and the current interest compensation is also difficult to completely solve this problem. Therefore, in the future, the establishment of the ecological interest compensation mechanism needs to establish a more long-term concept and implement the industrial ecological compensation mechanism.
3. Improving the external institutional system is the key to coordinate the benefits of different local governments. Many regional collaborative strategies are non-substantive, which are reflected in their illegality and fuzziness. For example, many regional collaborative behaviors are only temporary actions for some major activities or event and a lack of long-term mechanism and higher level supervision. Some collaborative strategies no have detailed description and supporting measures, and there are no mandatory and legal provisions in the establishment of collaborative groups.

Therefore, it is very important to establish a more operational, targeted, and legitimate regional collaborative strategy.

On the whole, based on the theory of a complex system, we construct the model of synergy degree model, adopt a new method to measure the regional collaborative governance of environmental pollution, and investigate the effect of Chinese market segmentation on it. However, it is undeniable that there are some defects in the above-mentioned method. For example, the results calculated by this method mainly reflect the order and coordination degree of collaborative governance between different regions (subsystems), but they cannot fully show the real governance behavior and cooperation degree between them. Therefore, in the future, we will further explore new methods and data to measure regional collaborative governance of environmental pollution in China more scientifically.

CONFLICT OF INTEREST

1. All authors of this manuscript have directly participated in planning, execution, and/ or analysis of this study.
2. The contents of this manuscript have not been copyrighted or published previously.
3. The contents of this manuscript will not be copyrighted, submitted, or published elsewhere while acceptance by the *Growth and Change* is under consideration.
4. There are no directly related manuscripts or abstracts, published, or unpublished, by any authors of this manuscript.
5. I am one author signing on behalf of all co-authors of this manuscript, and attesting to the above.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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ENDNOTES

[1] The environmental pollution index can be expressed as $\boldsymbol{Polluton_i}=(\boldsymbol{px_{i1}} + \boldsymbol{px_{i2}}+\boldsymbol{px_{i3}} + \boldsymbol{px_{i4}}+\boldsymbol{px_{i5}})/5$, where $\boldsymbol{px_{ij}}$ refers to the relative emission scale of the $\boldsymbol{j}$ pollutants in region $\boldsymbol{i}$. This paper mainly selects five pollutants: wastewater ($\boldsymbol{px_{i1}}$), sulfur dioxide ($\boldsymbol{px_{i2}}$), industrial smoke and dust ($\boldsymbol{px_{i3}}$), PM2.5 ($\boldsymbol{px_{i4}}$), and solid waste ($\boldsymbol{px_{i5}}$). They are measured by each province's wastewater discharge, sulfur dioxide discharge, industrial smoke (powder) dust discharge, PM2.5 surface concentration mean value, and solid waste discharge.

[2] The equation can be expressed as follows: $H_i = \sum T_n \cdot P_{in}$. $\boldsymbol{T_n}$ denotes the years for the $\boldsymbol{n}$ education type (primary school, junior high school, senior high school, and university school), and we assumed that the year of primary school is 6, the junior high school is 9, the senior high school is 12 and the university school is 16. $\boldsymbol{P_{in}}$ denotes the number of populations with $\boldsymbol{n}$ education type in $\boldsymbol{i}$ area.

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