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Effects of Industrial Land Conveyance on Coastal Marine Pollution: An Spatial Durbin Econometric Analysis

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Abstract: Compared to inland areas, coastal areas display more frequent economic activity in China. Unfortunately, they also have the greatest impact on the coastal environment. Among the economic activities in coastal areas, industrial land conveyance not only has a profound impact on local economic growth, but also poses a greater threat to coastal water. Using panel data collected from 45 coastal cities during the period 2007–2017, this study constructed a spatial Durbin model to investigate the effects of industrial land conveyance on coastal marine pollution. Results show that the expansion of two-lagged agreement-based industrial land conveyance areas in a coastal city can increase coastal marine pollution. Meanwhile, the positive impacts of the two-lagged industrial land conveyance and the industrial land conveyance areas, through bidding, auction, and listing, on coastal marine pollution are statistically significant but economically insignificant. Furthermore, the two-lagged industrial land conveyance areas have a spatial spillover effect on coastal marine pollution. Specifically, the expansion of such areas from a coastal city can increase the marine pollution of other coastal cities.

Keywords: industrial land conveyance; spatial Durbin model; coastal marine pollution

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1. Introduction

Coastal areas represent the intersection between marine and land ecosystems, as they are the marine area closest to human activities and often face more serious pollution than other sea areas [1]. In China's coastal waters, 18.7% of the water quality of 417 monitoring points cannot be directly affected by humans, because of their Grade IV or lower classification [2]. Among 61 coastal cities, the water quality of coastal waters in 17 cities is poor or extremely poor, and 16 out of 44 bays with an area of over 100 km^2 are classified as having water quality below Grade IV [2]. China's coastal marine environmental protection mainly relies on coastal cities. However, these cities often have economic assessment goals that dominate the evaluation of officials who are up for promotion. Due to the emphasis on the assessment of economic indicators, coastal local governments tend to sacrifice the coastal water environment to ensure economic growth in cases when local economic growth and coastal marine environmental protection face conflicts [3–5]. In recent years, the central government has strengthened the supervision of local governments' coastal water environmental governance through the establishment of a central environmental protection inspector. Since then, the situation of coastal water environmental governance has been improved to some extent, but there are still some coastal local governments that only consider economic growth and ignore marine environmental protection [3]. For example, due to inadequate supervision, various chemical enterprises near the Jiaojiang River in Taizhou City secretly discharged wastewater, causing groundwater pollution and seepage through the embankment. The chemical oxygen demand and ammonia nitrogen concentration of the seepage water reached the highest levels at 23,800 mg/L and 175 mg/L, respectively; hence, the quality of the coastal waters of the Jiaojiang River in Taizhou City has been consistently below Grade IV throughout the years [6]. Given the current status of coastal environmental governance, it is particularly important to identify the conflict between coastal local governments' policies in promoting economic growth and coastal environmental protection.

Thus far, existing studies have investigated the impacts of coastal cities' economic development on coastal pollution from different perspectives. Some studies have focused on the impact of the marine economy on coastal marine pollution. Results show a non-linear relationship between marine economic growth and coastal marine pollution [7,8]. In addition to investigating the impact of the marine economy on coastal marine pollution from the perspective of the total marine economy, there are studies that have focused on coastal tourism and examined its impact on marine pollution. Their results show that the development of coastal tourism has produced serious marine pollution [9], which then affects water quality. The pollution caused by coastal tourism is mainly litter pollution. The rapid urbanization of coastal cities is another important factor [10,11]. The pollution generated by urbanization affects the quality of coastal waters through river input, urban runoff, and port discharge [12–14]. Wang et al. [15] proposed that the effects of coastal urbanization on the water quality of coastal waters depend on the stage of economic development. Their results show that urbanization harms the seawater quality recorded at Zhejiang and Shanghai, which are in the middle of the Environmental Kuznets Curve. Some studies have explored the causes of coastal marine pollution from the perspective of official promotion based on the real situation in China. In particular, local officials in coastal areas will promote rapid local economic growth by sacrificing the marine environment to achieve short-term political promotion [4,5,16]. In addition to the above factors, land reclamation is also an important economic activity in coastal cities. This phenomenon has brought serious environmental problems, such as loss of biodiversity in coastal waters, reduced water purification ability, and an increase in water pollution [17,18]. A study using data from Chinese coastal waters reported that tidal flat reclamation increased heavy metal pollution [19]. In China, coastal cities carry out large-scale industrial land conveyance to promote economic growth. However, the existing literature does not discuss the impact of this important economic activity on coastal pollution.

Among the policy tools used by coastal local governments to promote economic growth, industrial land conveyance policy is indispensable, and is also an important manifestation of the conflict between coastal water environment and economic development. China's land allocation is undergoing a transition from administrative allocation to market-based transactions. According to local practices, commercial and residential lands are mainly sold through bidding, which has basically achieved marketization, while most industrial land is still transferred in a non-transparent way, i.e., agreement-based conveyance [20,21]. Under the agreement-based conveyance, local governments can privately give industrial enterprises a variety of preferential conditions, such as extremely low-priced or free industrial land, tax incentives, and relaxation of environmental regulations, to encourage them to settle in the local area [22–24]. The above mentioned characteristics of the agreement-based conveyance tend to cause problems, such as low-efficiency land use, degradation of the ecological environment, and corruption [25]. Industrial land conveyance can also have a scale effect, which leads to an increase in industrial carbon emissions, while the agreement-based conveyance of industrial land can further increase these [26]. Agreement-based conveyance of industrial land may mean that investment projects have low quality, use backward technology and simple equipment, and have low environmental standards. Therefore, the introduction of these low-quality investment projects by local governments can cause serious environmental pollution [27]. The above mentioned literature mainly focuses on the impact of industrial land conveyance on the terrestrial environment and does not explore the impact of industrial land conveyance in coastal cities on coastal water environment. This study aims to explore the effects on coastal marine pollution of industrial land conveyance in coastal cities.

The remainder of this paper is organized as follows. Methods and data, including the Global Moran's I statistic, spatial Durbin model, spatial weights matrix, variable selection, and data sources, are introduced in Section 2. The spatial-temporal distribution of industrial land transfer and coastal marine pollution, the estimation result of the effects of industrial land conveyance on coastal marine pollution, and spatial autocorrelation of coastal marine pollution are analyzed in Section 3. The discussion is provided in Section 4. Finally, conclusions are drawn in Section 5.

2. Methodology

2.1. Global Moran's I Statistic

Global Moran's I index can test the spatial correlation of a variable at the city level and provide preliminary evidence for the adoption of the spatial Dubin model. The formula of Global Moran's I index is expressed as follows:

$$Moran's\ I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\left(Y_i - \overline{Y}\right)\left(Y_j - \overline{Y}\right)}{S^2\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}},\quad (i \neq j) \tag{1}$$

$$S^2 = \sum_{i=1}^{n}\left(Y_i - \overline{Y}\right)^2/n$$

where Y is the measurement index. The range of Global Moran's I index is between 0 and 1. When Global Moran's I index > 0, it indicates that the variable Y has a positive spatial correlation. When Global Moran's I index < 0, it indicates that the variable Y has a negative spatial correlation. When Global Moran's I index = 0, there is no spatial correlation in Y, and the distribution of Y among coastal cities is random. W_{ij} is the spatial weight matrix.

2.2. Spatial Durbin Model

Under the promotion and assessment mechanism centered on GDP, China's local governments experience extensive economic competition [28], which makes cities imitate each other in the allocation of land elements between them. As the most economically developed region, coastal cities may interact more frequently in land allocation decisions. At the same time, coastal marine pollution may be spatially related because of the mobility of sea water. The estimation results based on the traditional panel data model are unreliable if the variables experience spatial interaction or correlation among coastal cities. Therefore, the spatial panel model needs to be used for parameter estimation. The spatial panel model includes the spatial Dubin model (SDM), spatial autoregression model (SAR), and spatial error model (SEM) [29]. The reason why SDM is adopted in this paper is to consider whether SDM can test the spatial spillover effect of industrial land conveyance on the pollution of offshore waters. SDM is constructed as follows:

$$Y_{it} = \rho\sum_{j=1}^{n} w_{ij}Y_{jt} + \alpha X_{it} + \beta\sum_{j=1}^{n} w_{ij}X_{jt} + \gamma Control_{it} + \theta\sum_{j=1}^{n} w_{ij}Control_{jt} + \lambda_i + v_t + \varepsilon_{it} \tag{2}$$

where Y_{it} represents the dependent variable, and the degree of coastal marine pollution is used as the dependent variable. $\sum_{j=1}^{n} w_{ij}Y_{jt}$ represents the spatial lag term of Y. ρ is the spatial autoregression coefficient, which can reflect the spatial correlation of Y. X_{it} is the independent variable, which includes the area of industrial land conveyance, the area of industrial land conveyance by agreement, and the area of industrial land conveyance by bidding, auction, and listing. $\sum_{j=1}^{n} w_{ij}X_{jt}$ represents the spatial lag term of X. In addition, to be able to obtain more accurate estimation results, the control variables and their spatial lag terms are also added to the model, denoted by $Control_{it}$ and $\sum_{j=1}^{n} w_{ij}Control_{jt}$ respectively.

λ_i is the city's fixed effects used to control the city's characteristics that do not change with time. v_t is the year fixed effects used to control the time trend and the influence of special events occurring in different years. The missing variable bias can be mitigated if we control city fixed effects and year fixed effects. ε_{ct} is an i.i.d disturbance term.

2.3. Spatial Weights Matrix

A suitable spatial weight matrix needs to be selected to measure the spatial relationship among cities before the SDM estimation. The spatial diffusion of coastal marine pollution may have a distance–decay effect, and the inverse geographic distance weight matrix can well reflect this. Therefore, the inverse geographic distance weight matrix is used to construct the spatial relationship among cities. The specific form of the inverse geographic distance weight matrix is as follows:

$$W_{ij} = \begin{cases} 1/d_{ij}, & i \neq j, \quad i = 1, \ldots, N; \; j = 1, \ldots, N; \\ 0, & i = j, \quad i = j, \quad i = 1, \ldots, ; \; j = 1, \ldots, N; \end{cases} \tag{3}$$

where d_{ij} represents the geographic distance between city i and city j. $1/d_{ij}$ decreases with geographic distance, so it can reflect the characteristics of distance–decay of coastal marine pollution diffusion with increased geographical distance.

3. Variable Selection and Data Source

This study uses data from 45 coastal cities in China from 2007 to 2017 to explore the impacts on coastal marine pollution of industrial land conveyance in coastal cities. In addition to coastal marine pollution and industrial land conveyance, this paper also controls other variables to obtain more accurate estimation results.

3.1. Coastal Marine Pollution

In this study, the inorganic nitrogen concentration in the sea area under the jurisdiction of coastal cities was used to measure the coastal marine pollution of coastal cities. Indicators currently used for measuring coastal marine pollution or water quality are mainly divided into three types. The first type consists of pollutant concentration indicators, such as concentration of heavy metals in sediments [30,31], concentration of organic pollutants [32], and concentrations of dissolved oxygen [33]. The second type is related to emissions, such as industrial wastewater directly discharged into the marine environment [8,34] and discharge of oily sewage [35]. The third type consists of indicators of the contaminated area, such as sea areas in which the water quality fails to reach the Grade I standard [7] and the proportion of an area demonstrating worse water quality than Grade V [36]. As far as the second type of indicator is concerned, the amount of pollution emissions cannot be equated with the degree of pollution. Due to the varying levels of pollution treatment technology, even the same pollution discharge can cause different consequences. Furthermore, the proportion of areas with poor water quality fails to reflect the average pollution level of coastal waters for the third type of indicator. The level of pollutant concentration can directly reflect the degree of water pollution for the first type of indicator, wherein the higher the pollutant concentration, the higher the pollution level.

The China Coastal Environmental Quality Bulletin comprehensively records the average concentration of inorganic nitrogen in the coastal waters under the jurisdiction of China's coastal cities. In the four oceans of China, inorganic nitrogen is the most important factor exceeding the water quality standard; thus, it can be used to reflect the pollution degree of China's coastal waters to a certain extent. In this measurement, the larger the average concentration of inorganic nitrogen, the more serious the coastal marine pollution.

3.2. Industrial Land Conveyance

The independent variables in this study are the area of industrial land conveyance, the area of industrial land conveyance by agreement, and the area of industrial land conveyance by bidding, auction, and listing. The China Land Market website contains transaction data on all urban land types, such as the city where the transaction land is located and the transaction time, price, and land type. We use crawler technology to crawl the land conveyance data from the China Land Market website, and sum up the area of each industrial land conveyance for each year in each coastal city to obtain the city's industrial land conveyance area for that year. Meanwhile, we distinguished between the agreement-based industrial land conveyance and industrial land conveyance under bidding, auction, and listing. On the basis of such information, we calculated the area of industrial land conveyance by agreement and the areas of industrial land conveyance by bidding, auction, and listing.

3.3. Control Variables

Based on Wang et al. [15], Zhou et al. [37], and Chen et al. [7] and considering the characteristics of China's coastal marine pollution, several control variables are selected. The first is GDP per capita (LNPERGDP), along with its quadratic term (LNPERGDP2). These two variables were added to test whether the environmental Kuznets curve existed. The second one is population density (LNDENSITY). A main source of pollution in coastal waters is sewage produced by human activity. In particular, the amount of sewage discharge increases when the population density increases, which can increase the water pollution in coastal waters. The third is urbanization rate (URBANIZATION), which is manifested in two aspects, namely, population and land urbanization. The advancement of population and urbanization in coastal cities reflects the expansion of economic activities, and pollution caused by economic activities will burden the marine environment. The process of land urbanization in coastal cities is typically accompanied by activities, such as sea reclamation, which can cause damage to the coastal water environment. The fourth is industrial structure (SECONDGDP), which we measured by using the proportion of the output value of the secondary industry in GDP. The increased proportion of the secondary industry indicates the increase in industrial production activities. The deployment of a large amount of industrial production on the coastline of coastal cities will directly affect the coastal marine environment. The fifth variable is marine economic activity (LNMGDP). Pollution is partly caused by this, such as resource exploitation, marine fishery, and marine transportation, which can directly affect the coastal marine environment. The sixth variable is watershed pollution (BASINPOLL). The pollution generated by the economic activities of inland cities can be transported to coastal waters through rivers. Therefore, we added watershed pollution to control the effects of inland cities on the pollution of coastal waters.

3.4. Data Resource

The panel data used in this study were collected from 45 coastal cities in China from 2007–2017. The actual sample size was 405 due to the missing data of some variables. The concentration of inorganic nitrogen in coastal waters was extracted from the CCEQB. The annual inorganic nitrogen concentration in coastal waters of cities in CCEQB was used as the average concentration obtained by monitoring three periods, namely, April to May (high-water period), July to August (common water period), and October to November (dry period), of the year. The data used to calculate the industrial land conveyance area of 45 coastal cities from 2007 to 2017 came from the China Land Market website. The amount of patent authorization in the current year was collected from the China Research Data Service Platform. GDP per capita, population density, urbanization rate, secondary industry output value, and GDP were all extracted from the China City Statistical Yearbook. The Gross Marine Product of coastal provinces was used instead of the Gross Marine Product of coastal cities, because the latter was significantly lacking. Data on the Gross Marine Product of coastal provinces came from the China Ocean Statistical Yearbook. Data on the watershed area proportion with worse water quality than grade V were collected from the China Environmental Statistics Yearbook. All currency variables were adjusted to 2006 constant prices using corresponding price indices. The descriptive statistics of all variables are listed in Table 1.

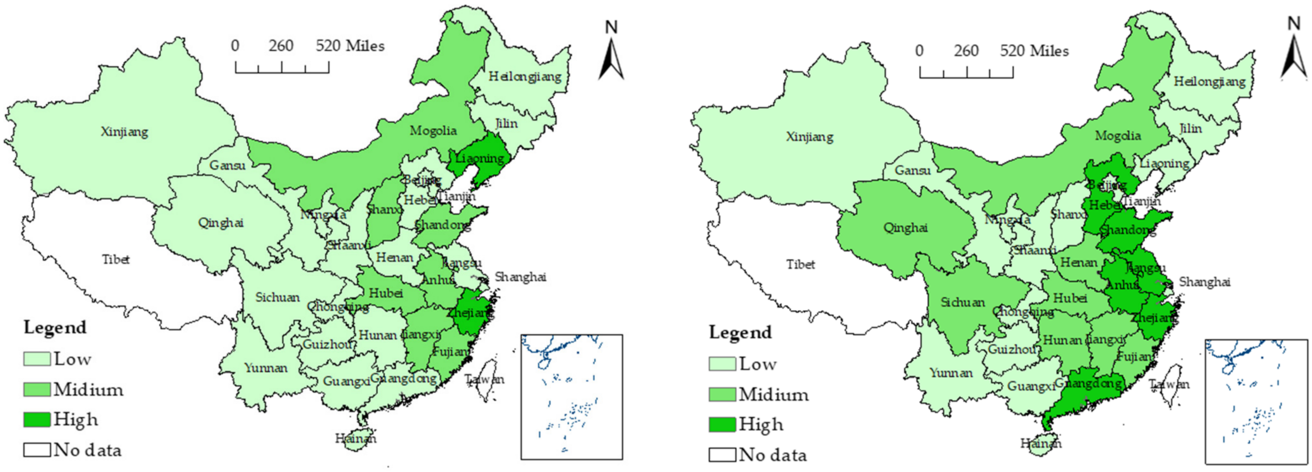
Table 1. Definition and descriptive statistics of variables.

Variables	Definition	Obs.	Mean	Std. Dev.	Min	Max
lnorgncon	Inorganic nitrogen concentration in coastal waters (mg/L)	495	0.292	0.296	0.120	2.271
lnagreearea	Logarithm of the area of industrial land conveyance by agreement	495	5.900	0.935	4.608	8.341
lnbidarea	Logarithm of the area of industrial land conveyance by bidding, auction, and listing	495	2.948	1.676	0.768	7.497
lnbalarea	Logarithm of the area of industrial land conveyance by bidding, auction, and listing	495	5.602	1.092	4.001	8.118
lnpergdp	Logarithm of GDP per capita (10^4 CNY)	495	10.556	0.500	9.916	12.784
lnpergdp2	Quadratic term of the logarithm of GDP per capita	495	111.673	10.693	98.326	163.418
lndensity	Logarithm of population density (person/km^2)	495	7.744	0.588	6.980	9.908
urbanization	Urbanization rate (%)	495	49.504	18.778	30.259	100.000
SecondGDP	Proportion of secondary industry to GDP (%)	495	49.940	7.067	41.090	76.530
lnMGDP	Logarithm of gross ocean product (108 CNY)	495	8.467	0.704	7.463	9.809
basinpoll	Watershed area proportion of water quality worse than grade V (%)	495	10.436	11.092	3.000	53.100

4. Results

4.1. Spatial-Temporal Distribution of Industrial Land Conveyance and Coastal Marine Pollution

Figure 1 shows the distribution of industrial land conveyance area at the provincial level in China. Figure 1a,b present this distribution in 2007 and 2017, respectively. In 2007, the provinces with the largest area of industrial land conveyance were Liaoning and Zhejiang, both of which were categorized as coastal provinces. By 2017, the provinces with the largest area of industrial land conveyance were Hebei, Anhui, Shandong, Jiangsu, Zhejiang, and Guangdong. Except Anhui, all the remaining locations were coastal provinces. Thus, whether in 2007 or 2017, the regions with the largest industrial land conveyance area were mainly located in coastal provinces.



(**a**) (**b**)

Figure 1. Spatial distribution of industrial land conveyance area. (**a**) Area of industrial land conveyance in 2007. (**b**) Area of industrial land conveyance in 2017.

Figure 2a,b show the distribution of inorganic nitrogen concentration in coastal provinces of China in 2007 and 2017, respectively. Several differences were observed in the concentration of inorganic nitrogen in coastal waters among provincial administrative regions. However, whether in 2007 or 2017, the provincial administrative regions with the highest concentration of inorganic nitrogen in coastal waters were always Zhejiang and Shanghai, whereas the concentration of inorganic nitrogen was consistently the lowest in Guangxi's coastal areas. For example, Guangxi and Zhejiang were the cities with the smallest and largest areas of industrial land transfer, respectively. These cities also had the lowest (Guangxi) and highest (Zhejiang) concentrations of inorganic nitrogen in coastal waters. Therefore, a positive correlation existed between the industrial land conveyance area and inorganic nitrogen concentration.

4.2. Spatial Econometric Regression Results

Table 2 shows the estimation results of the SDM. As shown, the industrial land conveyance area, agreement-based industrial land conveyance area, and industrial land conveyance area by bidding, auction, and listing all adopted the form of two-year lags. Such a result was observed because several years may be needed before industrial lands can be used for industrial production. It can be found that more than 50% of the project contract completion time presented in the national industrial land project transfer contract from 2007 to 2011 lasted for two years [23]. Thus, two years are needed for industrial land conveyance to have an impact on coastal marine pollution. The spatial autoregressive coefficient ρ in Columns (1)–(6) are all negative and statistically significant. This result means that a negative spatial correlation exists between coastal marine pollution in coastal cities. The increase in coastal marine pollution in a coastal city will spread to other coastal cities close to its geographical location, which in turn will reduce the city's coastal marine pollution; that is, the city's coastal marine pollution is diluted by other cities' coastal waters.

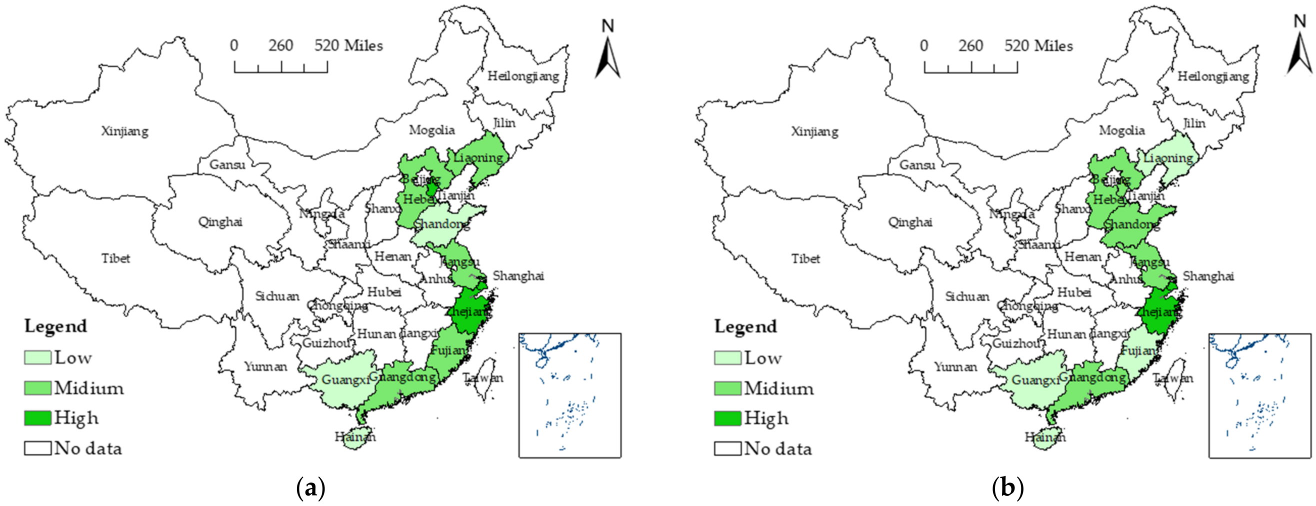


Figure 2. Spatial distribution of coastal marine pollution. (**a**) Coastal marine pollution in 2007. (**b**) Coastal marine pollution in 2017.

Table 2. Estimation results of SDM.

VARIABLE	Dependent Variable: Inorganic Nitrogen Concentration in Coastal Waters					
	(1)	(2)	(3)	(4)	(5)	(6)
l2_lnindarea	0.0007 (0.0141)			0.0282 ** (0.0115)		
l2_lnagreearea		0.1654 *** (0.0260)			0.6055 *** (0.185)	
l2_lnbalarea			0.0682 (0.0742)			0.0183 ** (0.0088)
lnpgdp				−2.2321 *** (0.5814)	−1.8822 *** (0.5561)	−2.0080 *** (0.5709)
lnpgdp2				0.1043 *** (0.0268)	0.0889 *** (0.0257)	0.0941 *** (0.0263)
lnpopden				0.1332 *** (0.0222)	0.1257 *** (0.0224)	0.1300 *** (0.0223)
urbanrate				0.0025 *** (0.0008)	0.0023 *** (0.0008)	0.0027 *** (0.0008)
Second_GDP				0.0072 *** (0.0021)	0.0065 *** (0.0021)	0.0068 *** (0.0021)
lnmarGDP				−0.2458 (0.2076)	−0.2072 (0.2069)	−0.2444 (0.2085)
basinwpoll				−0.0061 * (0.0033)	−0.0061 * (0.0032)	−0.0063 * (0.0033)
W*l2_lnindarea	0.0545 (0.0392)			0.0910 (0.0714)		
W*l2_lnagreearea		0.2172 ** (0.0854)			1.0545 ** (0.481)	
W*l2_lnbalarea			0.3749 (0.2873)			0.0387 (0.0390)
W*lnpgdp				−1.6822 (2.4787)	−1.0135 (2.4925)	−0.4974 (2.4608)
W*lnpgdp2				0.0686 (0.1135)	0.0440 (0.1143)	0.0157 (0.1130)

Table 2. *Cont.*

VARIABLE	Dependent Variable: Inorganic Nitrogen Concentration in Coastal Waters					
	(1)	(2)	(3)	(4)	(5)	(6)
W*lnpopden				−0.0667	−0.0218	−0.0768
				(0.0943)	(0.0986)	(0.0951)
W*urbanrate				−0.0039	−0.0041	−0.0028
				(0.0029)	(0.0028)	(0.0029)
W*Second_GDP				0.0289 ***	0.0232 **	0.0252 **
				(0.0107)	(0.0105)	(0.0105)
W*lnmarGDP				−0.2757	−0.4280	−0.1328
				(0.4562)	(0.4630)	(0.4508)
W*basinwpoll				0.0133 *	0.0093	0.0139 *
				(0.0073)	(0.0072)	(0.0076)
ρ	0.4473 ***	0.3025 **	0.4566 ***	−0.2927 *	−0.2983 *	−0.2794 *
	(0.1152)	(0.1290)	(0.1138)	(0.1651)	(0.1656)	(0.1651)
Province Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	405	405	405	405	405	405
R^2	0.0042	0.0614	0.0022	0.4414	0.4170	0.5476

Note: Figures in () are standard error. ***, **, and * indicate the statistical significance at the 1%, 5%, and 10% levels, respectively.

The estimation result in Column (1) shows a positive correlation between industrial land conveyance area and coastal marine pollution. However, the result is statistically insignificant. This result may be due to the other variables that were not considered. Column (4) further adds control variables based on Column (1). After adding the control variables, the estimation coefficient of l2_lnindarea remained positive and statistically significant at the 5% level. The results suggest that the two-lagged industrial land conveyance area has a positive effect on coastal marine pollution. To test the impact of different industrial land conveyance methods on coastal marine pollution, this study divided industrial land conveyance area into two types. The first type is the agreement-based area. The agreement-based conveyance is private, and it is the manner by which industrial enterprises and the local government privately negotiate industrial land conveyance. In addition, the specific content is not disclosed to the public. The second type is the area for bidding, auction, and listing. Bidding, auction, and listing are open, and matters related to industrial land conveyance can be revealed to the public. Columns (2) and (3) show that without the addition of control variables, the estimation coefficients of l2_lnagreearea and l2_market were positive, but only l2_lnagreearea exhibited statistical significance. After adding the control variables, the sign and statistical significance of l2_lnindarea showed no change, and the estimation coefficient of l2_lnbalarea became negative and statistically significant at the 1% level. This result implies that the expansion of the two-lagged agreement-based conveyance area and the two-lagged conveyance area by bidding, auction, and listing will increase coastal marine pollution in the current period. However, the estimation coefficient of the former is about 33 times that of the latter.

Table 2 also reports the estimation results of the spatial spillover effects of industrial land conveyance on coastal marine pollution. In the estimation results without added control variables, the estimation coefficients of W*l2_lnindarea, W*l2_lnagreearea, and W*l2_lnbalarea were all positive, but only W*l2_lnagreearea was statistically significant. After adding the control variables, the estimation coefficient size changed, but the coefficient direction and statistical significance remained the same. The above results revealed that the expansion of the two-lagged agreement-based conveyance area had a positive spatial spillover effect on coastal marine pollution, i.e., the expansion of the two-lagged agreement-based conveyance area in one city will increase the coastal marine pollution of other cities.

The SDM estimation results in Table 2 cannot directly reflect the marginal effects of industrial land conveyance area and control variables on coastal marine pollution [38].

Therefore, LeSage and Pace [39] proposed direct, indirect, and total effects. The direct effects represent the magnitude of influence, which includes feedback effects, of an independent variable in a certain city on a dependent variable, i.e., the influence on other cities will correspondingly affect the city. The direct effects are equal to the sum of the SDM coefficient and the feedback effect. Indirect effects, also known as spatial spillover effects, can be explained as the effect of a city's independent variable on other cities' dependent variable or the effect of other cities' independent variable on a city's dependent variable. The total effects are the sum of the direct and indirect effects, which can be understood as the average effect of a city's independent variable on dependent variable of all cities. Table 3 reports the estimation results of the direct, indirect, and total effects.

First, the direct effects of l2_lnindarea, l2_lnagreearea, and l2_lnbalarea were all significantly positive. Specifically, if the two-lagged industrial land conveyance area increases by 1%, the inorganic nitrogen concentration in coastal waters will increase by about 0.0003 mg/L, which accounts for approximately 0.10% of the average concentration of inorganic nitrogen. An additional 1% increase in two-lagged agreement-based conveyance area is associated with an approximately 0.0060 mg/L increase in inorganic nitrogen concentration, which accounts for approximately 2.05% of the average concentration of inorganic nitrogen. A 1% increase in two-lagged conveyance area by bidding, auction, and listing will approximately generate 0.0002 mg/L increase in inorganic nitrogen concentration, which accounts for approximately 0.07% of the average concentration of inorganic nitrogen. In general, the direct effects of the two-lagged agreement-based industrial land area were the strongest. Second, the indirect effect of l2_lnagreearea was significantly positive at the 5% level, whereas the indirect effects of l2_lnindarea and l2_lnbalarea were also positive but not statistically significant. These results imply that only the two-lagged agreement-based industrial land area has a spatial spillover effect on coastal marine pollution. On average, for every 1% increase in the two-lagged agreement-based conveyance area for a city, the inorganic nitrogen concentration in the coastal waters of other cities will increase by about 0.0071 mg/L, which accounts for approximately 2.43% of the average concentration of inorganic nitrogen. Therefore, compared with the total area of industrial land conveyance and the conveyance area by bidding, auction, and listing, the spatial spillover effect of the agreement-based industrial land conveyance area on coastal marine pollution is more economically significant. In addition, the direct effects of l2_lnindarea and l2_lnagreearea were all significantly positive, whereas that of l2_lnbalarea was statistically insignificant.

For the control variables. the estimation results of direct effects showed that the estimated coefficients of lnpgdp and its quadratic term were negative and positive respectively, and both were statistically significant at the 1% level. This result implies the "inverted U−shaped" relationship between per capita GDP and coastal marine pollution. The estimated coefficients of lnpopden, urbanrate, and Second_GDP were all positive and statistically significant at the 1% level. Thus, the increase in population density, urbanization rate, and proportion of secondary industry to GDP in a city are positively correlated with coastal marine pollution. The watershed area proportion of the water quality that is poorer than Grade V was negatively correlated with coastal marine pollution. In addition, the indirect and total effects of most control variables were statistically insignificant.

Table 3. Decomposition results of direct, indirect, and total effects of SDM.

VARIABLE	Dependent Variable: Inorganic Nitrogen Concentration in Coastal Waters								
	Direct Effects			Indirect Effects			Total Effects		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
l2_lnindarea	0.0270 **			0.0655			0.0925 **		
	(0.0117)			(0.0424)			(0.0446)		
l2_lnagreearea		0.5951 ***			0.7065 **			1.3016 ***	
		(0.1896)			(0.3343)			(0.4301)	
l2_lnbalarea			0.0180 **			0.0265			0.0445
			(0.0089)			(0.0320)			(0.0346)
lnpgdp	−2.2432 ***	−1.8979 ***	−2.0385 ***	−0.8971	−0.4297	−0.0179	−3.1403	−2.3276	−2.0564
	(0.5584)	(0.5283)	(0.5470)	(2.0678)	(2.0616)	(2.0588)	(2.2076)	(2.1819)	(2.1772)
lnpgdp2	0.1051 ***	0.0898 ***	0.0958 ***	0.0335	0.0168	−0.0058	0.1386	0.1066	0.0900
	(0.0257)	(0.0244)	(0.0252)	(0.0948)	(0.0947)	(0.0947)	(0.1010)	(0.1002)	(0.1001)
lnpopden	0.1351 ***	0.1266 ***	0.1320 ***	−0.0849	−0.0462	−0.0917	0.0503	0.0804	0.0403
	(0.0212)	(0.0218)	(0.0213)	(0.0714)	(0.0762)	(0.0729)	(0.0774)	(0.0802)	(0.0787)
urbanrate	0.0025 ***	0.0024 ***	0.0028 ***	−0.0037	−0.0039 *	−0.0029	−0.0012	−0.0015	−0.0001
	(0.0007)	(0.0007)	(0.0007)	(0.0023)	(0.0023)	(0.0023)	(0.0025)	(0.0026)	(0.0026)
Second_GDP	0.0067 ***	0.0061 ***	0.0063 ***	0.0218 **	0.0173 **	0.0192 **	0.0285 ***	0.0234 **	0.0255 ***
	(0.0020)	(0.0019)	(0.0020)	(0.0088)	(0.0084)	(0.0086)	(0.0098)	(0.0094)	(0.0096)
lnmarGDP	−0.2432	−0.2006	−0.2446	−0.1715	−0.3054	−0.0609	−0.4147	−0.5060 *	−0.3056
	(0.2238)	(0.2238)	(0.2247)	(0.4294)	(0.4414)	(0.4243)	(0.2709)	(0.2833)	(0.2625)
basinwpoll	−0.0065 **	−0.0064 *	−0.0067 **	0.0121 *	0.0089	0.0126 *	0.0055	0.0025	0.0059
	(0.0033)	(0.0033)	(0.0033)	(0.0065)	(0.0065)	(0.0068)	(0.0043)	(0.0043)	(0.0046)

Note: Figures in () are standard error. ***, **, and * indicate the statistical significance at the 1%, 5%, and 10% levels, respectively.

4.3. Robustness Test

The previous estimation results were all based on the inverse geographic distance weight matrix. To ensure the robustness of the estimation results of the independent variables in Table 3, Table 4 reports the estimation findings based on the inverse economic distance weight matrix. The results show that the direct effects of two-lagged industrial land conveyance area, agreement-based industrial land conveyance area, and industrial land conveyance area by bidding, auction, and listing on coastal marine pollution remained significantly positive. Among the results of indirect effects, only the positive impact of the expansion of the two-lagged agreement-based industrial land conveyance area on coastal marine pollution can be established, consistent with the results in Table 3. Although the estimated coefficients of the independent variables in Table 4 differ from those in Table 3, the relative sizes were the same, that is, the direct and indirect effects of the two-lagged agreement-based industrial land conveyance area on the coastal marine pollution were the largest among the three independent variables.

As presented in Table 3, this study used the average concentration of inorganic nitrogen in coastal waters under the jurisdiction of coastal cities to measure coastal marine pollution. As shown in Table 5, the average concentration of inorganic nitrogen was replaced by the average concentration of active phosphate in coastal waters under the jurisdiction of coastal cities for a robustness test. The results revealed that the direction of the direct and indirect effects of the three independent variables were consistent with the findings in Table 3, and the statistical significance showed no significant change. Therefore, if the average concentration of active phosphate is used to measure coastal marine pollution, the conclusion on the three independent variables remains unchanged.

Table 4. Results based on the inverse economic distance weight matrix.

VARIABLE	Dependent Variable: Inorganic Nitrogen Concentration in Coastal Waters								
	Direct Effects			Indirect Effects			Total Effects		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
l2_lnindarea	0.0110 **			0.0065			0.0176 *		
	(0.0051)			(0.0196)			(0.0092)		
l2_lnagreearea		0.6117 ***			0.3980 ***			1.0097 ***	
		(0.1384)			(0.1109)			(0.1874)	
l2_lnbalarea			0.0017 *			0.0041			0.0058
			(0.0009)			(0.0141)			(0.0173)
lnpgdp	−2.5025 ***	−2.4224 ***	−2.4061 ***	5.9227 ***	5.8575 ***	6.0684 ***	3.4202 ***	3.4351 ***	3.6623 ***
	(0.4496)	(0.4156)	(0.4386)	(1.2474)	(1.2140)	(1.2245)	(1.2619)	(1.2095)	(1.2160)
lnpgdp2	0.1207 ***	0.1173 ***	0.1162 ***	−0.2688 ***	−0.2666 ***	−0.2753 ***	−0.1482 **	−0.1493 ***	−0.1591 ***
	(0.0206)	(0.0191)	(0.0201)	(0.0588)	(0.0573)	(0.0578)	(0.0595)	(0.0573)	(0.0575)
lnpopden	0.1092 ***	0.0951 ***	0.1064 ***	0.1772 ***	0.2074 ***	0.1673 ***	0.2864 ***	0.3025 ***	0.2737 ***
	(0.0155)	(0.0158)	(0.0155)	(0.0441)	(0.0447)	(0.0434)	(0.0528)	(0.0528)	(0.0524)
urbanrate	0.0019 ***	0.0017 ***	0.0019 ***	0.0014	0.0010	0.0014	0.0032 ***	0.0027 **	0.0033 ***
	(0.0005)	(0.0005)	(0.0005)	(0.0010)	(0.0010)	(0.0010)	(0.0012)	(0.0012)	(0.0012)
Second_GDP	−0.0011	−0.0010	−0.0011	0.0029	0.0024	0.0025	0.0018	0.0014	0.0014
	(0.0013)	(0.0012)	(0.0012)	(0.0021)	(0.0020)	(0.0021)	(0.0027)	(0.0025)	(0.0026)
lnmarGDP	−0.2543 *	−0.2895 *	−0.2334	−0.0179	−0.0619	−0.0272	−0.2723 **	−0.3514 ***	−0.2605 **
	(0.1529)	(0.1486)	(0.1533)	(0.2055)	(0.2049)	(0.2048)	(0.1288)	(0.1328)	(0.1254)
basinwpoll	0.0040 *	0.0035	0.0039	−0.0031	−0.0033	−0.0030	0.0009	0.0002	0.0008
	(0.0024)	(0.0024)	(0.0024)	(0.0037)	(0.0036)	(0.0037)	(0.0026)	(0.0026)	(0.0026)

Note: Figures in () are standard error. ***, **, and * indicate the statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 5. Results of coastal marine pollution measured by active phosphate.

VARIABLE	Dependent Variable: Active Phosphate								
	Direct Effects			Indirect Effects			Total Effects		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
l2_lnindarea	0.0010 **			−0.0007			0.0003		
	(0.0004)			(0.0013)			(0.0013)		
l2_lnagreearea		0.0120 *			0.0031 ***			0.0151 ***	
		(0.0068)			(0.0005)			(0.0011)	
l2_lnbalarea			0.0002			−0.0013			−0.0011
			(0.0003)			(0.0010)			(0.0010)
lnpgdp	−0.0473 **	−0.0360 *	−0.0381 *	0.1200 *	0.1291 **	0.1210 *	0.0727	0.0931	0.0829
	(0.0198)	(0.0189)	(0.0194)	(0.0631)	(0.0645)	(0.0629)	(0.0668)	(0.0677)	(0.0657)
lnpgdp2	0.0022 **	0.0017 *	0.0018 **	−0.0054 *	−0.0058 *	−0.0054 *	−0.0033	−0.0041	−0.0036
	(0.0009)	(0.0009)	(0.0009)	(0.0029)	(0.0030)	(0.0029)	(0.0031)	(0.0031)	(0.0030)
lnpopden	0.0033 ***	0.0029 ***	0.0032 ***	−0.0040 *	−0.0026	−0.0044 *	−0.0008	0.0003	−0.0012
	(0.0007)	(0.0008)	(0.0008)	(0.0023)	(0.0025)	(0.0023)	(0.0024)	(0.0026)	(0.0024)
urbanrate	0.0001 ***	0.0001 ***	0.0001 ***	−0.0003 ***	−0.0003 ***	−0.0003 ***	−0.0002 **	−0.0002 **	−0.0002 **
	(0.0000)	(0.0000)	(0.0000)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Second_GDP	0.0001 **	0.0002 **	0.0002 **	0.0000	−0.0000	−0.0000	0.0002	0.0001	0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0003)	(0.0003)	(0.0002)	(0.0003)	(0.0003)	(0.0003)
lnmarGDP	−0.0114	−0.0099	−0.0116	−0.0054	−0.0098	−0.0039	−0.0169 **	−0.0197 **	−0.0155 **
	(0.0081)	(0.0082)	(0.0082)	(0.0142)	(0.0148)	(0.0140)	(0.0082)	(0.0087)	(0.0079)
basinwpoll	−0.0003 **	−0.0003 **	−0.0003 **	0.0004 *	0.0004 *	0.0003	0.0001	0.0001	0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0001)

Note: Figures in () are standard error. ***, **, and * indicate the statistical significance at the 1%, 5%, and 10% levels, respectively.

5. Discussion

An important result obtained in Table 3 is that the expansion of two-lagged agreement-based industrial land conveyance area in a coastal city will increase its coastal marine pollution. In addition, the positive impacts of the two-lagged industrial land conveyance area and the industrial land conveyance area by bidding, auction, and listing on coastal marine pollution were statistically significant, but economically insignificant. China has primary and secondary land markets. The primary market is monopolized by the government, whereas local governments obtain extra-budgetary income through land conveyance [40,41]. In the primary market, coastal local governments mainly transfer land use rights to enterprises through agreement, bidding, auction, and listing. Agreement-based conveyance is the land conveyance acquired through private negotiations between coastal local governments and enterprises, and the operation is non-public. The land conveyance through bidding, auction, and listing is market-oriented, and its operation is open. Although China's land conveyance is generally operating toward marketization, industrial land is still mainly attained through agreement-based conveyance [20]. Under agreement-based land conveyance, coastal local governments have strong incentives to use below-market price, or even free land as a bargaining chip to attract industrial enterprises to settle in [42,43]. The industrial enterprises that are attracted to settle in are often inefficient, which will cause considerable pollution [27]. In addition, agreement conveyance provides opportunities for coastal local governments and industrial enterprises to collude. To attract industrial enterprises to settle in, coastal local governments may relax environmental supervision [4]. Industrial land conveyance through bidding, auction, and listing can make land transactions between coastal local governments and industrial enterprises public, thereby avoiding the entry of low-efficiency enterprises and the emergence of government-enterprise collusion.

Another important finding in this study is that the two-lagged industrial land conveyance area exhibited a spatial spillover effect on coastal marine pollution. The expansion of a two-lagged industrial land conveyance area by a coastal city will increase the coastal marine pollution in other coastal cities. For a long time, the central government's assessment of local officials has focused on economic growth [3,44]. Under this system, to promote economic growth, coastal local governments launched fierce competition by adopting various preferential policies to attract industrial enterprises to invest locally [45]. As one of the most critical production factors, land is used by coastal local governments as an important tool to attract investment from industrial enterprises. Coastal local governments use industrial land as a bargaining chip to carry out investment competition, and agreement-based conveyance is an important means to achieve this. Coastal local governments compete to reduce land prices through agreement-based conveyance of industrial land in order to attract investment from industrial enterprises [22]. As a result, coastal local governments have a significant spatial interaction in agreement-based industrial land conveyance. In this case, when a coastal city increases the supply of agreement-based industrial land, other coastal cities may also implement the same measures, and the increase in these coastal cities' supply of agreement-based industrial land will increase their coastal marine pollution. As a result, agreement-based industrial land conveyance in coastal cities induces a spatial spillover effect on coastal marine pollution.

Coastal marine pollution in China was investigated from a new perspective of industrial land conveyance in this study. However, limitations were still observed. First, with regard to the measurement of coastal marine pollution, although the concentration of inorganic nitrogen can reflect the degree of pollution in the coastal waters to a certain extent, it is a single indicator and cannot fully measure the degree of pollution. Second, limited by the data, this study failed to analyze the pollution discharge problem at the industrial enterprise level. If we can obtain pollution emission data at the industrial enterprise level in coastal cities in the future, we will be able to conduct an in-depth analysis of the emission behavior of industrial enterprises that obtain land under the agreement-based conveyance and conveyance by bidding, auction, and listing conveyance.

6. Conclusions and Policy Implications

Among the economic activities in coastal areas, industrial land conveyance has a profound impact on local economic growth, and poses a greater threat to the coastal marine environment. However, no literature has studied the coastal marine pollution in China from the perspective of industrial land conveyance. This study divided industrial land conveyance into agreement-based conveyance and bidding, auction and listing conveyance and tested the impact of the two types of industrial land conveyance on coastal marine pollution. The results showed that the expansion of two-lagged agreement-based industrial land conveyance area in a coastal city increases its coastal marine pollution. In addition, the positive impacts of the two-lagged industrial land conveyance area and industrial land conveyance area through bidding, auction, and listing on coastal marine pollution were statistically significant but economically insignificant. The two-lagged industrial land conveyance area showed a spatial spillover effect on coastal marine pollution. Specifically, the expansion of a two-lagged industrial land conveyance area by a coastal city will increase the coastal marine pollution of other coastal cities.

These findings have significant policy implications. On the one hand, the central government should formulate relevant laws and regulations to prevent coastal local governments from transferring industrial land through agreement and accelerate the marketization of industrial land conveyance. On the other hand, in the design of the incentive mechanism for local officials, not only local economic development factors must be considered but also coastal marine environmental factors. The design of the incentive mechanism should consider the sustainable development of the economy and weaken the requirements for economic growth in order to prevent coastal local governments from ignoring the coastal marine environment in the supply of land. The concentration of coastal marine pollutants should be included in the assessment of local officials.

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