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Empirical Investigation on the Degree of Influence of Industrial Structure and Urbanization on Haze Pollution in China

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ABSTRACT

Haze pollution in China has become severe in recent years. This weather phenomenon is related to an unreasonable industrial structure and air pollution, which are induced by urbanization to a certain degree. A quantitative analysis of the influencing degree of industrial structure and urbanization on haze pollution in China is conducted in this study to further investigate the mechanism that influences haze pollution in China. A panel data regression model of Chinese provinces from 2000 to 2013 is established; haze pollution degree is regarded as an explained variable, and industrial structure and urbanization are regarded as explanatory variables. In the model, three control variables are introduced: gross regional domestic product and dummy variable of financial crisis and trade openness. Measurements and calculations are conducted on national and regional scales, and the regions are divided into coastal and inland regions to determine the degree of influence of industrial structures and urbanization level in these regions on haze pollution. Results show that industrial structure has a positive correlation with haze pollution, that is, increasing the proportion of industries in GDP, aggravates the degree of haze pollution and promoting urbanization has a positive influence on haze pollution. Gross regional domestic product has an obvious negative correlation with haze pollution, whereas the dummy variables of financial crisis and trade openness evidently have a positive correlation with haze pollution. The higher the urbanization level is, the greater the influence of industrial structure on haze pollution. The more unreasonable the industrial structure is, the greater the influence of urbanization on haze pollution. The positive effects of both industrial structure and urbanization on haze pollution in coastal regions are greater than those in inland regions. Hence, such methods as optimizing the industrial structure and controlling haze pollution in the process of accelerating urbanization and forming a collaborative and linkage effect mechanism between regions could realize the harmonious development of the economy, society, and environment.

INTRODUCTION

With the promotion of industrial structure optimization and urbanization, the resource utilization rate, total factor productivity, and household living quality in China have significantly improved. However, environmental problems accompanying urbanization and industrialization have also increased in severity. Particularly, haze weather, which has frequently occurred in recent years, seriously threatens the daily life and health of humans. The severity of haze pollution is closely linked to human life. Any organism needs to sustain its life through breathing; thus, the absence of air means the end of life. Haze is a weather phenomenon generated by the mixture of tiny particles, dusts, and aerosols in the air under a relatively steady state. Air pollution resulting from haze weather, especially severe dust haze weather, damages not only the biosphere but also human health. In recent years, China's cities have successively suffered from haze weather, which not only brings harm to people, animals, and plants but also impedes economic development and damages the ecological environment.

Numerous studies have shown that haze weather in China is mainly concentrated in North, Central, and Eastern China. It affects three major regions, namely, the Beijing "Tianjin" Hebei Region, Yangtze River Delta, and Pearl River Delta, which are also the centres of China's industry, particularly the heavy industry; these regions are also significant contributors to industrial waste gas emission. These factors would aggravate local air pollution and consequently result in haze weather once the purifying capacity of air itself is exceeded. The increasing proportion of industries in the gross regional domestic product would aggravate haze pollution. In recent years, the adjustments in and optimization of the industrial structure, as shown in Table 1, to transform traditional industries and promote low-carbon and clean production, have exerted a certain mitigation effect on air pollution through the use of modern technologies.

Currently, damaging atmospheric dispersion, combination of industrial and production areas, and highly centralized pollution caused by large-scale construction to accelerate urbanization (Fig. 1) are the main causes of urban haze

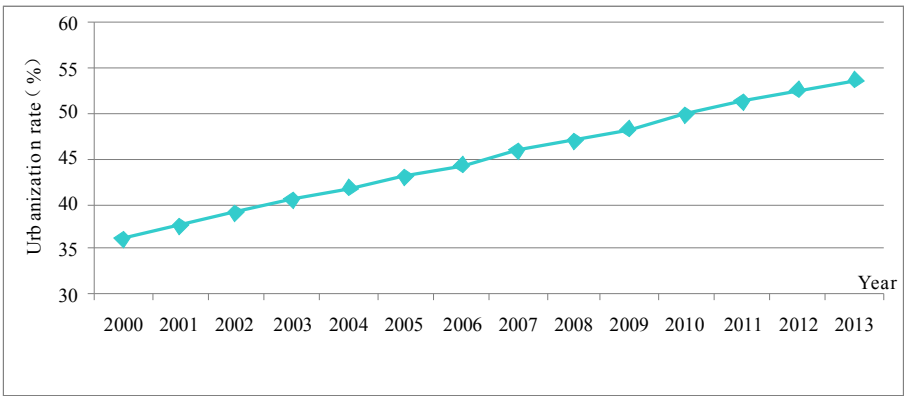

Fig. 1: Urbanization rate in China from 2000 to 2013.

Table 1: Industrial structures of China from 2000 to 2013.

Year Industry	Primary Industry	Secondary Industry	Tertiary Industry
2000	15.1	45.9	39.0
2001	14.4	45.2	40.5
2002	13.7	44.8	41.5
2003	12.8	46.0	41.2
2004	13.4	46.2	40.4
2005	12.1	47.4	40.5
2006	11.1	47.9	40.9
2007	10.8	47.3	41.9
2008	10.7	47.4	41.8
2009	10.3	46.2	43.4
2010	10.1	46.7	43.2
2011	10.0	46.6	43.4
2012	10.1	45.3	44.6
2013	10.0	43.9	46.1

weather. Compared with areas with good air quality, those with heavy haze pollution exhibit a relatively higher urbanization level, larger urban size, higher population density, and higher municipal solid waste and transportation exhaust gas emissions.

STATE OF THE ART

Research on the different effects of the industrial structure and urbanization on environmental pollution, including haze, can be conducted mainly from two aspects: effects of industrial structure and effects of urbanization on environmental pollution. In both aspects, Grossman & Krueger (1994) conducted an extensive research and used the policy implementation of NAFTA (North American Free Trade Agreement) as the background to reveal the scale, structure, and technology effects of economic activities that influence the environment. He found that a reversed "U" relationship exists between environmental pollution and economic growth; his study provided significant contributions. Jan & Lourens (2007) believed that the industrial structure influences environmental pollution; the secondary industry, particularly its proportion of industrial output value, has a positive correlation with environmental pollution, whereas the proportion of the tertiary industry has a negative correlation with environmental pollution. Aaron et al. (2010) found that the haze weather in China is mainly concentrated in North, Central, and Eastern China and covers three major regions, namely, Beijing "Tianjin" Hebei Region, Yangtze River Delta, and Pearl River Delta; he believed that the greater the contribution of the secondary industry is, the more severe the pollution of haze weather would be. Brajer et al. (2011) challenged the previous finding and believed that the different forms of pollution play a major role in the relationship between the industrial structure and environmental pollution. They asserted that the reversed "U" relationship between environmental pollution and economic growth is not always be true. Steinberg & Shih (2012) believed that for cities principally occupied by large-scale industrial-type enterprises, the influence of urban pollution mainly derived from these highly polluting enterprises would be more obvious if the level of industrialization is too high. Fei Hu (2011) believed that China's industrialization has not been perfected yet, and the current upgrading of the industrial structure mainly presents an increasing proportion of the secondary industry but has a limited effect on relieving environmental pollution degrees in Central and Eastern China. In both aspects of urbanization and environmental pollution, Ehrhardt-Martinez et al. (2002) verified the relationship between urbanization development and deforestation rate and also found a reversed "U" relationship between the two. By conducting empirical research on 99 countries, Poumanyvong & Kaneko (2010) reported that urbanization could result in a reduction in energy consumption and carbon dioxide emission. The study conducted by Srivastava et

Table 2: Correlation coefficient matrix.

	URBA	STRU	STRU × URBA	LGDP	CRIS	OPEN
URBA	1					
STRU	0.211	1				
STRU × URBA	0.354	0.593	1			
LGDP	0.125	0.487	0	1		
CRIS	0.613	0.365	0.063	0.341	1	
OPEN	0.368	0.244	0.478	0.214	0.022	1

Table 3: Full-sample regression results.

Regression Formula	(1) *WMWR*	(2) *WMWR*	(3) *WMWR*	(4) *WMWR*
STRU	2.735***(7.964)	0.697***(2.978)	0.478**(2.784)	0.389**(2.473)
URBA		0.568**(2.454)	0.578**(2.963)	0.469***(1.976)
LGDP		-0.069**(-2.973)	-0.097**(-3.748)	-0.075**(-3.697)
CRIS			0.081**(3.978)	0.071***(3.978)
OPEN				0.047**(2.368)
Constant Term	2.964**(17.684)	4.789**(7.685)	5.987**(8.974)	8.674(9.637)
Adjusted R^2	0.784	0.697	0.845	0.841
F Statistical Magnitude	78.647	87.456	74.684	72.684
Haussmann value		23.698	29.685	27.658

Notes: ***, ** and * respectively represent 1%, 5%, and 10% significance levels. The numerical values in parentheses are the T statistical values.

al. (2014) revealed that urbanization, industrialization and economic growth in developing countries are always accompanied by enhanced generation of urban solid waste pollution. Koshy et al. (2014) investigated the urbanization progress in Asia and the Pacific Ocean and pointed out that metropolis is not the permanent development theme; climate-adapting cities demonstrate more flexibility and could better realize sustainable development. Liddle & Lung (2010) utilized the STIRPAT model to reveal that differences exist among different age groups in developed countries in terms of the influence they exert on urban pollution.

Studies on the industrial structure and environmental pollution show that the influence of the industrial structure on environmental pollution is obvious, and different industries have different influencing degrees on the environment. Thus, it is necessary to conduct an analysis at different time points and with different objects. Studies on urbanization and environmental pollution demonstrate that in the context of urbanization, an obvious difference exists in the environmental pollutant emissions of different administrative regions. As urbanization reaches a high level, urban pollutant emission initially increases and then decreases in a U-type pattern. The aforementioned studies deepened our understanding of the relationship among industrial structure, urbanization, and environmental pollution to a certain degree, but the interactive relationships and influencing degrees of these three factors have not been totally resolved yet. Thus, this study, which is based on the panel data of provinces in China, analyses the influencing degrees of industrial structure and urbanization on haze pollution in the hope to provide advisory opinions on how to adjust countermeasures of environmental governance in different provinces.

RESEARCH METHODS

Model setting: The following measurement model was constructed to inspect the relationship among haze pollution, industrial structure, and urbanization.

$$WMWR_{it} = \alpha_0 + \alpha_1 URBA_{it} + \alpha_2 STRU_{it} + \sum_{k=1}^{n} \gamma_k C_{it} + \varphi_i + \varepsilon_{it} \quad ...(1)$$

Where, i is the province, t is the year, $WMWR_{it}$ is the haze pollution state, $URBA_{it}$ is the urbanization level, $STRU_{it}$ is the industrial structure, C_{it} is the corresponding control variable, φ_i is the individual effect of each province, and ε_{it} is the influence of specific factors in a province and is expressed as a random error.

Variable declaration: Explained variable (haze pollution state expressed by $WMWR$): In this study, $WMWR$ was obtained from the research of Zhao Chen et al. (2004), who employed the annual average population weighted concentration of PM 2.5 to characterize the pollution levels of the provinces (cities and municipalities).

Explanatory variable 1 (urbanization expressed by *URBA*): Since the implementation of the reform and opening-up policy, which resulted in the continuous and rapid growth of the economy of China, urbanization and industrialization in the country have unavoidably resulted in environmental pollution problems, as proven to a certain degree by the recent frequent occurrence of haze pollution. In this study, the proportion of non-agricultural population in the total population was adopted to measure the urbanization level.

Explanatory variable 2 (industrial structure expressed by *STRU*): The adjustment in the industrial structure influences environmental pollution, and the industrial production of China mainly relies on resources such as coal, which is a major pollutant. The pollutants emitted by industries, such as chemical engineering, metallurgy, and electricity generation, are the main causes of haze weather. In this study, the proportion of industrial output value in the gross regional domestic product was selected to measure the industrial structure level of China.

Control variable 1 (gross regional domestic product expressed by *LGDP*): The larger the economic scale in a region is, the more resources needing input will be and the higher the emission of pollutants will be. As a result, environmental problems will become aggravated. For regions with a high economic growth level, the government will have sufficient capital to intensify environmental governance, thus mitigating environmental pollution problems. In this study, the GDP values of 30 provinces were selected.

Control variable 2 (dummy variable of financial crisis expressed by *CRIS*): The financial crisis in 2008 involved China, and the economy of the country was influenced to a certain degree. To maintain a sustainable and stable economic growth, the government has formulated a series of policies to expand investments, which also exert a certain influence on the environment. Thus, in this study, year 2008 was set as a dummy variable to control the influence of the financial crisis on the environment; year 2008 was set to 1, and the other years were set to 0.

Control variable 3 (trade openness expressed by *OPEN*): The rapid development of the international trade on the one hand can render a region capable of increasing the environmental protection input by boosting the economic growth; consequently, environmental pollution problems are reduced to a certain degree. On the other hand, export products in international trade are mainly from domestic production, and pollutants emitted by energy consumption aggravate environmental pollution in China. In this study, the ratio of gross export to gross regional domestic product was used to measure the trade openness of all regions.

Data declaration: In consideration of the availability and consistency of data, 30 provinces (cities and municipalities) (the data set on Chongqing were incorporated into the data set of Sichuan Province for processing and those of HK, Macao and Taiwan were not included) of China from 2000 to 2013 were selected as research objects. For data involving value form, with year 2001 as the base period, corresponding indices were adopted to reject the influence of price factor. Except for PM 2.5 data, other data were derived from the Statistical Yearbook of China (2001-2014), Yearbook of Environmental Statistics in China (2001-2014), Yearbook of Energy Statistics in China (2001-2014), and Wind Database.

EMPIRICAL RESEARCH

Correlation coefficient test: The correlation coefficients between major variables were calculated to determine whether a serious multicollinearity problem exists between variables. The specific results are shown in Table 2. All correlation coefficients between variables are less than 0.613; thus, no multicollinearity problem is present. Calculation of the variance inflation factors of the variables shows that the average value of the inflation factors of the model is 1.71, which is less than 2; the maximum value is 2.04, which is also far less than the empirical value of 10. Thus, no serious multicollinearity problem exists in the model. In this study, the natural logarithm of variables with large variance was adopted to eliminate the heteroscedasticity in the model and consequently improve the reliability of the conclusion.

Full-sample regression: The type of data employed in this study is panel data, and the test methods for panel data models have mixed, random, and fixed effects. For the mixed-effect and random-effect models, the Lagrange multiplier (LM) test rejected the null hypothesis; the mixed-effect model was adopted at 1% significance level. For the random-effect and fixed-effect models, the Haussmann test rejected the null hypothesis; the random-effect model was adopted at 1% significance level. Hence, the fixed-effect model was used to conduct a regression analysis.

Table 3 shows that model (1), without other control variables added, independently generated the fixed-effect regression results of the relationship between industrial structure level (*STRU*) and haze pollution (*WMWR*). The results show that the influence of industrial structure level on haze pollution is positive and is at 1% significance level. Given that China has long implemented the development strategy "put more emphasis on the heavy industry than the service industry," much irrationality is evident in the industrial structure. Particularly, the proportion of industry is too large and has an extensive economic growth pattern. The industrialization

Table 4: Regional regression results.

Explanatory Variable	Inland Regions			Coastal Regions		
	(1) *WMWR*	(2) *WMWR*	(3) *WMWR*	(1) *WMWR*	(2) *WMWR*	(3) *WMWR*
STRU	0.606***(2.678)	0.325**(2.247)	0.248**(2.697)	0.704***(3.945)	0.697**(2.105)	0.697**(2.674)
URBA	0.468**(2.687)	0.307**(2.301)	0.367***(1.921)	0.497**(2.974)	0.674**(2.674)	0.478***(1.367)
LGDP	-0.074**(-2.651)	-0.073**(-3.684)	-0.069**(-3.698)	-0.097**(-2.674)	-0.084**(-3.634)	-0.0.75**(-3.674)
CRIS		0.064**(3.684)	0.004***(2.941)		0.067**(3.697)	0.0974***(3.874)
OPEN			0.069**(2.684)			0.067**(2.974)
Constant term	4.638**(7.671)	7.945*(10.684)	9.228**(9.637)	5.621**(9.674)	6.745**(12.354)	10.974(19.974)
Adjusted R^2	0.701	0.634	0.841	0.711	0.697	0.794
F Statistical Magnitude	90.684	96.354	72.684	97.632	97.148	97.485
Haussmann value	174.684	168.478	127.658	179.364	168.964	187.942

Notes: ***, ** and * respectively represent 1%, 5%, and 10% significance levels. The numerical values in parentheses are the T statistical values.

tendency of the heavy industry in the industrial structure contributes to the rapid development of high-pollution industries, such as chemical engineering, metallurgy, and cement manufacturing, which have a large demand for energies with low utilization rate. The pollutants emitted in the production process are the major reason for the formation of haze. The estimation results of the standard model (4) show that urbanization level (*URBA*) at 10% significance level has a positive influence, indicating that haze pollution in China is inseparable from the promotion of urbanization. On the one hand, the urban infrastructure in China is relatively complete, and cities are featured by great market scale and large population density, which result in an increasing demand for urban living fire coal and cars and consequently an increasing amount of domestic pollution and transportation tail gas pollution. On the other hand, the development of urbanization has increased the housing demand, and housing buildings are closely related to such industries as metallurgy and cement manufacturing; thus, the amount of dust in construction sites is increased, and the pollutants emitted by metal and cement industries further deteriorate the air quality. Gross regional domestic product (*LGDP*) is negative at 5% significance level. This result may be due to the fact that the living quality of residents improves with economic development, which in turn elevates their demand for environmental quality. The government has sufficient funds to intensify the governing force against environmental pollution, thereby improving environmental quality to a certain degree. The coefficient of the dummy variable of financial crisis (*CRIS*) is positive and passed the 1% significance level test, which means that the Chinese government has successfully implemented a series of measures to expand its investment to cope with the financial crisis in 2008. Within a short time, the number of construction projects has significantly increased. This development aggravates the haze pollution in China to a certain degree. Trade openness (*OPEN*) is positive at 5% significance level because export products are mainly produced in China; as a result, domestic resources are consumed, and emitted pollutants exert great pressure on the domestic environment.

Regional regression results: Differences exist in economic development level and geographic position of different provinces (cities and municipalities); thus, estimation and examination must be conducted by region to analyse the effects of the industrial structure and urbanization on haze pollution. According to the results of the LM test and Hausman test, regional estimation still adopts the individual fixed-effect model. In this study, the 30 provinces (cities and municipalities) in China were divided into coastal and inland regions. The specific regression results for different regions are shown in Table 4.

The results in Table 4 indicate that the positive influences of industrial structure and urbanization, on haze pollution in the regional models are basically identical to those in the full-sample model. The results further verify that the positive influences of industrial structure and urbanization on haze pollution are steady. Notably, the influence of urbanization level in inland regions on haze pollution is positive but not significant, probably because the urbanization level in inland regions is relatively low and exerts limited positive influence on haze pollution; as a result, the industrial structure in these regions exerts an insignificant positive influence on haze pollution. By contrast, significant positive influences of industrial structure and urbanization on haze pollution exist in coastal regions, indicating that a regional difference exists in the influences of industrial structure and urbanization on haze pollution. Such a regional difference may be attributed to the fact that the industrialization and urbanization levels in coastal regions are higher than

those in inland regions, resulting in greater positive influences of industrial structure and urbanization in coastal regions on haze pollution.

POLICY SUGGESTIONS

Changing the economic development mode and adjusting the industrial structure: The era that emphasizes the economic development scale must be terminated, and the construction scale must be transformed from rapid expansion into stable development. Resource consumption, environmental damage, and ecological benefit should be incorporated into the evaluation systems of economic and social development. Objective systems, assessment methods, and reward and punishment mechanisms that meet the requirement for an ecological civilization should be established. Emphasis should be placed on improving economic development quality, appropriately adjusting the industrial structure, enabling the moderate development of economic growth rate, expanding the proportion of final consumption in the structure of economic dynamics, gradually alleviating immoderate reliance on investment and export, relieving the large amount of stress on the development of the heavy industry, and vigorously developing and establishing a "resource-saving and environment-friendly" society. Cleanliness should be considered the objective; key industries should be reconfirmed; industries with backward productivity, high pollution, and heavy emission should be eliminated; strategic new industries featured by energy conservation and environmental protection should be developed; national industrial distribution should be optimized; the development of a circular economy should be emphasized.

Transforming the development concept of urbanization and conducting a comprehensive measurement of urbanization progress: Urbanization, which is an irresistible trend of economic and social development, is a great impetus to improve economic and social development. The concept of urbanization should positively and stably promote urbanization and emphasize the improvement of urbanization quality according to the requirements of urbanization. During urbanization progress, urban and rural development should be balanced by properly promoting the transfer of rural surplus population to urban areas and practically solving the 'Three Rural Issues'. The development of the tertiary industry should be boosted, and urbanization quality should be elevated by virtue of the advantages of the tertiary industry, which attracts labour resources and innovates agglomeration, thus promoting economic development. A reasonable urban size should be developed by considering resource endowments and advantages as well as the bearing capacity of the ecological environment in specific regions. The relationship between urban development planning and environmental protection should be coordinated, air pollution should be reduced, and inputs for governing haze pollution should be increased while vigorously boosting urbanization progress to realize sound and harmonious development between urbanization and environmental protection.

Rigorously implementing policies on ecological environmental protection and strengthening law enforcement and supervision of law enforcement: Laws and regulations on ecological environmental protection should be practically implemented. Negative externality during the process of urbanization and industrial structure adjustment would exert a certain negative influence on the ecological environment, and this negative influence can be corrected through laws and regulations. The existing laws and regulations on ecological environmental protection in China are encompassing, but their operational level is far from being complete. Considering tax resource and economic growth indices, many local governments have relaxed their supervision of enterprises that negatively affect the ecological environment; as a result, ecological environmental quality continuously deteriorates. Hence, law enforcement and the supervision force of law enforcement should be intensified, and the negative externality effect on ecological and environmental quality should be corrected by legal means during urbanization progress.

Implementing cooperative governance and forming a collaborative and linkage effect mechanism between regions: Haze pollution is a public issue characterized by high permeability and inalienability. For the public governance of haze pollution, regional cooperation allows for a more powerful technical and financial support and environmental governance. Regional cooperation can also realize learning effect, information sharing, and multi win-win situation; it can also reduce the transaction cost and increase social total welfare. The establishment of a collaborative and linkage effect mechanism between regions with joint defence and governance results in a centripetal force in work; increases the weights of evaluation indices, such as resources, environment, and ecological benefits; guides local governments to form a behavioural pattern that emphasizes ecological civilization step by step; and constructs the joint defence and control system of air pollution governance in China. The central government should improve its ability to implement macroeconomic regulation and control and duly handle specific matters on benefit sharing and responsibility bearing between local governments.

CONCLUSIONS

In this study, the interaction mechanism among the three factors of industrial structure, urbanization, and environmen-

tal pollution was examined, and the influence degrees of China's industrial structure and urbanization development on haze pollution were analysed. The results show that the greater the urbanization level is, the greater the influence of the industrial structure on haze pollution will be. The more irrational the industrial structure is, the greater the influence of urbanization on haze pollution will be. Gross regional domestic product has a significant negative correlation with haze pollution, whereas the dummy variable of financial crisis and trade openness has a significantly positive correlation with haze pollution. A healthy air environment is a necessary condition for human survival and sustainable development. Hence, the industrial structure should be adjusted by transforming the economic development mode, transforming the concept of urbanization development, and conducting a comprehensive measurement of urbanization progress. Policies for ecological environmental protection should be rigorously implemented, and law enforcement and supervision should be intensified. Cooperative governance and a collaborative and linkage effect mechanism must be implemented between regions to effectively control haze and finally realize harmonious development between the environment and economy.

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