



The Synergistic Relationship between Rural Environmental Pollution and Industrial Structural Change in Heilongjiang, China

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ABSTRACT

Heilongjiang, a traditional agricultural province in China, is suffering from serious rural environmental pollution, which harms peasant health and hinders sustainable economic development. Rural environmental degradation is intensifying gradually, causing great harm to rural residents, the global agro ecological environment, and significant restriction of sustainable agricultural production. To further analyse the issues of rural environmental pollution in Heilongjiang and explore the dynamic relationship between rural environmental pollution and industrial structure change, this study analysed three problems related to rural environmental pollution based on the rural environmental data of Heilongjiang from 2000 to 2014. Municipal panel data were established for an empirical study on the relationship between rural environmental pollution and industrial structure change. Results demonstrated the following: Pesticide usage in Heilongjiang increased gradually, and domestic pollution emissions were high within the study period. A significantly positive correlation existed between rural industrialization and the intensity of pollutant emission. Industrial pollution emissions in rural areas were influenced by the industrial structure. The rural areas with higher proportions of industrial output to economic aggregate had poor environmental quality. Finally, some suggestions to improve rural environmental pollution in Heilongjiang were proposed. This study can serve as reference and has practical significance in comprehending the status of the rural environmental pollution in Heilongjiang in North China and the effects of industrial structure change on rural environmental pollution.

INTRODUCTION

China has devoted significantly less attention and investment on rural environmental management than on urban areas for a long time. The contradiction between the infrastructure of backward environmental management and increasing pollution loads becomes increasingly prominent, resulting in the serious and direct deterioration of rural environment. Accelerating rural environmental construction and improving environmental quality are not only the foundational requirements of current sustainable agricultural and rural development but are also important measures to realize the coordinated development of an urban-rural society and economy and to build a well-off society. Considering the increasing challenges confronting the rural environment and the shortcomings of rural environmental management in China, designing a feasible rural environmental management plan is an urgent and necessary task. This should strengthen the position of agriculture as the foundation of the economy, pursue a path of agricultural modernization that has distinctly Chinese characteristics, establish a long-term mechanism of promoting agriculture with the help of industries and urban areas, and form a new urban-rural integrated economic and social development pattern. Such plan should insist to pursue modern agricultural development and

rural economic boom as its primary tasks, strengthen the construction of rural infrastructure, perfect rural markets and the agricultural service system, and adhere to the basic state policy of resource conservation, environmental protection, and sustainable development in view of the interest of the public and society at large. The importance of constructing a resource-saving and environment-friendly society to an industrialization and modernization development strategy must be highlighted. A suggestion is to perfect the laws and policies that favour energy saving and ecological environmental protection, accelerate the formation of sustainable development systems and mechanisms, implement the responsibility system of energy conservation and emission reduction, develop and promote advanced and applicable technologies of energy saving, replacement, cycle utilization, and pollution management, develop clean and renewable energy sources, protect land and water resources, establish scientific and reasonable energy resource utilization systems, and increase energy utilization.

Heilongjiang is a traditional agriculture province, and its agricultural output increases year by year (Fig. 1). However, rural industrial products are characterized by single variety, low technical content, small added value, extensive production mode, and low resource utilization. Without a

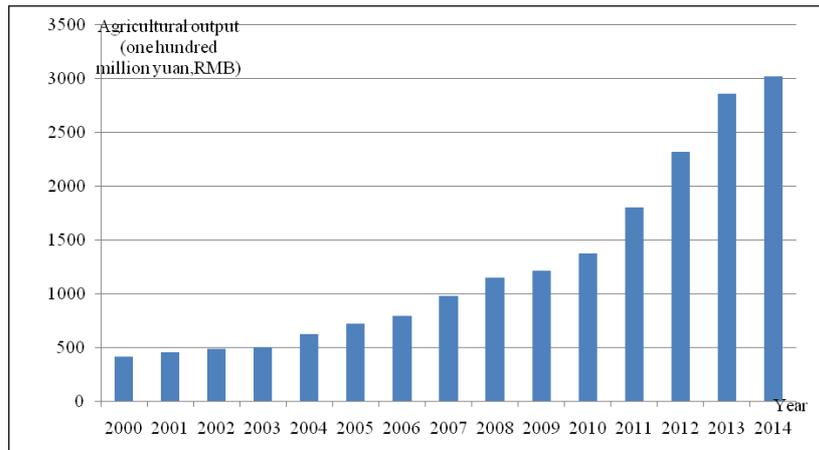


Fig. 1: Gross agricultural output of Heilongjiang from 2000-2014.

long-range unified planning and environmental protection system, the market-oriented short-sighted effect further intensifies the plunder of resources and pollution of the environment under agricultural development. In a way, rapid rural growth is achieved at the cost of high resource consumption and ecological environmental destruction. Influenced by the extensive development mode, decentralized structural layout, and transfer of urban industrial pollution sources, the contradiction between rural industrialization and the protection of resources, environment, and ecology becomes increasingly acute, accompanied with increasing pressures on rural areas with respect to territory, ecology, resources, and environment. These influence the sustainable development of rural modernization. The rural environmental pollution in Heilongjiang is mainly caused by the unreasonable usage of chemical products (e.g., fertilizers, pesticides, and agricultural films) and low multipurpose utilization of agricultural waste. Remarkable excessive fertilization also occurs; the average fertilization intensity is far higher than that in developed countries. Fertilizers absorbed by crops, released into the air, and retained in the soil account for only 1/3 of the total fertilizers. The rest are wasted and released into the environment, causing serious pollution. Pesticide utilization is generally low. Pesticides enter the soil, water, and air directly through various forms, and much of them float in the air, producing pesticide three-dimensional pollution. Agricultural film residues in soil increase continuously, thereby destroying the soil structure, affecting the air and water permeability of soils, hindering the air, water, and fertilizer absorption of crop roots, reducing soil fertility, and affecting the normal growth of crops. Pollution and eutrophication are also caused by the corrosion and decomposition of organic matters in faeces, as well as biological pathogenic bacteria pollution. The retention and accumulation of pollut-

ants from sewage irrigation in soils pollute underground water and influence biocenosis. Rural areas are characterized by multiple and extensive point and non-point industrial pollution sources, rapid increase of pollutant emissions, low processing rate and control rate of pollutants, and relative concentrated pollution scope.

STATE OF THE ART

According to the history of the industrialization of developed countries, environmental pollution intensified significantly when the GDP per capita increased from \$300 to \$1,000. Subsequently, environmental pollution has improved greatly because of the strengthening of economic power and annual increase in environmental investment. Given the highly intensive agricultural operation, massive use of chemical products, and highly centralized industrial layout, heavy resource waste and environmental pollution occur in foreign countries. Thus, foreign researches basically accept that rural areas have heavy environmental pollution. However, they emphasize how to establish a microscopic market transaction behaviour and macroscopic government guidance to manage agricultural and rural environments. For example, Daskalopoulos et al. (1998) analysed municipal solid wastes (garbage) and their adverse environmental effect. He proposed the better economic and more environment-friendly sustainable development measures for disposing municipal solid wastes. McCann estimated farmland demands for conservative cultivation by reducing the transaction costs of agricultural non-point pollution and proposed the corresponding solutions from the perspective of transaction cost and cost of emission reduction (McCann et al. 1999). Horan believed that the balance between the nutrient transaction point and non-point sources in Pennsylvania Hana River Basin can be achieved by providing two types

of transaction systems (Horan et al. 2002). O'Shea declared the necessity of frequently adjusting the input in non-point pollution control and proposed application measures of the single import duty policy (O'Shea 2002). Runkel pointed out that the actual benefits and costs of all related stakeholders and management activities should be considered in environmental pollution control and suggested setting up ecosystem management (Runkel 2003). Gutrich deemed that the experiences and lessons learned from projects in Hawaii, the South Seas, Africa, and continental United States can be applied to the partnership between Hawaii and other watersheds (Gutrich et al. 2005). Korhonen proposed four principles of rural sustainable development, which can be used to analyse sustainable development system and study important features of all complex systems (Korhonen 2007). Based on the five typical pollution cases in Sweden, Renberg analysed lake acidification, eutrophication, biodiversity, landscape dynamics, and protection of extensive benefits, which provide us with a broad research perspective (Renberg et al. 2009). Ryan believed that individual management philosophy, responsibility, commitment, and feasibility are the most important motivations to implement the optimal management practice in fostering among farmers the awareness of environmental protection against agricultural pollution (Ryan 2009).

Moreover, only few studies discuss the effects of rural environmental pollution on industrial structure. However, some research results on environmental pollution and industrial structure change have been achieved. Reviewing many studies, Grossman found that, against the background of the North American Free Trade Agreement (NAFTA), economic activities influence the scale effect, structural effect, and technological effect of environment. He also found an inverted U-shaped relationship between environmental pollution and economic growth (Grossman et al. 1994). Aaron found that haze mainly occurs in North China, Central China, and East China, covering the Beijing-Tianjin-Hebei Region, the Yangtze River Delta, and the Pearl River Delta. He concluded a positive correlation between the contribution of the secondary industry and haze intensity (Aaron et al. 2010). Steinberg thought that the large-scale industrial enterprises that are the main support in various cities are the primary dischargers of urban pollution, when the proportion of industrialization is very high (Steinberg et al. 2012). Srivastava pointed out that urbanization, industrialization, and economic growth in developing countries are always accompanied with a high output of urban solid pollution (Srivastava et al. 2014).

Undeniably, foreign studies on industrialization and rural industrialization provide certain guidance to industrial

development in a specific historical stage. They can provide us with important references and suggestions. In the present study, the status of the rural environmental pollution in Heilongjiang is analysed using related theories, and its effect on industrial structure change is estimated. Corresponding countermeasures and suggestions are also proposed from different perspectives.

ISSUES OF RURAL ENVIRONMENTAL POLLUTION IN HEILONGJIANG

Heavy agricultural pollution: Although Heilongjiang possesses a vast territory and abundant resources, its rural land per capita and production areas are limited. Land resources have been almost fully developed and used. With the continuous general use of chemical products, such as pesticides and fertilizers (Fig. 2), crop yields (e.g., fruits, vegetables, and grains) increase significantly. Peasants can obtain more fruits with less labour efforts and higher economic benefits in the short run. Thus, traditional organic fertilizers and farming modes are replaced gradually. To increase agricultural output and control crop diseases, chemical fertilizers and pesticides have been widely used in Heilongjiang, causing serious air and water pollution and threatening the safety of the lives of peasants. Moreover, most pesticides are retained in soil and crops, thereby intensifying soil pollution and deteriorating agricultural product quality. Crops with excessive pesticide content cause great harm to human health. With the popularization of greenhouse agriculture and plastic film mulching technology, crop output has increased significantly, providing farmers outstanding economic benefits and accelerated agricultural development. However, plastic film pollution has been intensifying at the same time. Given that most plastic films are made of polyethylene, they are characterized by difficult degradation, low recovery rate, and difficult unified disposal. Film residues in soil increase year by year, which goes against the air permeability of soils, water flow in soils, and full nutrient and water absorption by crops, thereby resulting in crop output reduction and direction economic losses.

Heavy domestic pollution: Rural areas have poor infrastructure conditions. Without a designated waste-yard and environmental protection equipment (e.g., waste treatment plants, assorted trash cans, and toilets), household wastes are scattered around in most rural spaces, such as roads, rivers, farmlands, and channels, thereby generating a huge quantity of solid wastes (Fig. 3). In rural areas, water is an indispensable resource for agricultural production and daily life. With the increase in the living standard and population in rural areas, daily water consumption increases greatly. At the same time, domestic sewage emission becomes an important pol-

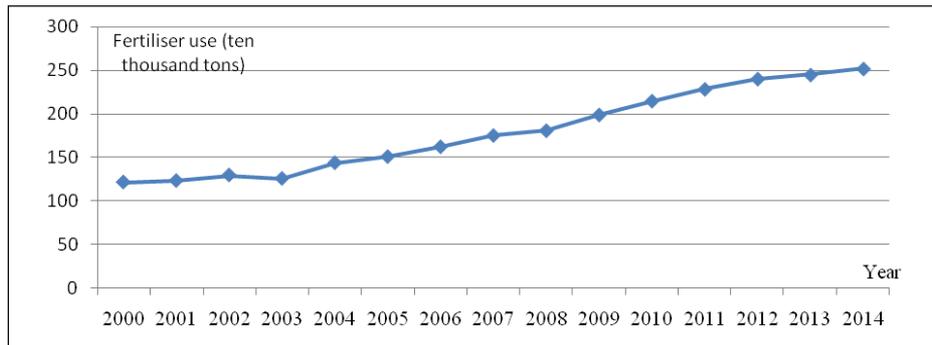


Fig. 2: Fertilization in Heilongjiang from 2000-2014.

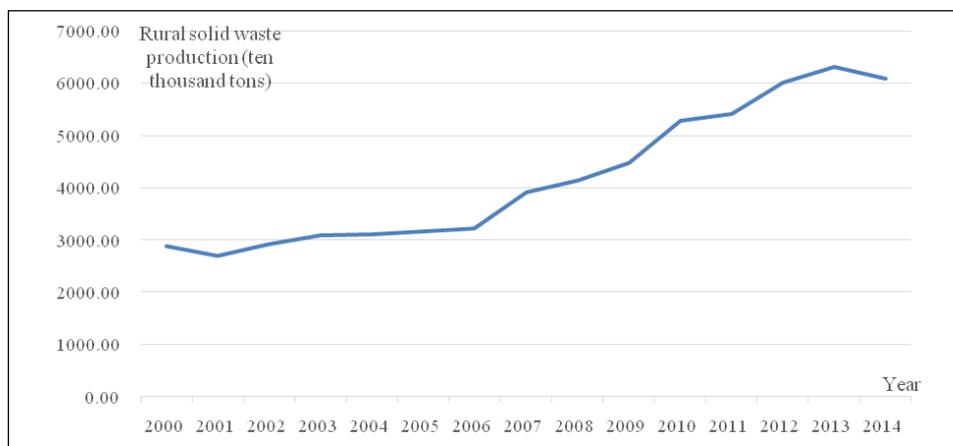


Fig. 3: Production of solid wastes in rural areas from 2000-2014.

lution source in rural areas. Given the extensive rural territory, domestic sewage pollution in rural areas is characterized by broad and scattered non-point sources, diversified sources, and quick growth. Such domestic sewage mainly include washing wastewater, kitchen wastewater, wastewater produced by human and animal excreta, and wastewater produced by the rain-washing of domestic garbage. Without corresponding sewage treatment equipment and given the peasants' habit of free emission of domestic sewage over the years, these domestic sewages have accumulated and penetrated into the surrounding environments, thereby threatening the safety of drinking water and physical health of peasants. Furthermore, most domestic sewages are discharged into rivers directly without any treatment, causing river pollution and the large-scale deaths of fish and prawn. Polluted water is used for agricultural irrigation, reducing crop yields. Most rural areas in China have limited living standard and survival conditions and prominent fuel problems. Straws, including corn stalk, rice straw and wheat straw, are unique resources in rural areas. Particularly, straws are widely used for cooking and heating in winter in North China. Straw

masses are placed on both road-sides and water channels randomly or are burned at will, especially during the crop harvest season. Straw burning not only wastes energy resources, but also releases much smoke, increasing the smoke and particles in the air significantly and causing serious air pollution. Moreover, diffuse smoke lowers atmospheric visibility, which in turn decreases the safety of highway and railway transportation.

Industrial pollution: Township enterprises also produce increasingly serious rural environmental pollution, especially some typical small heavy pollution industries, such as papermaking plants, chemical engineering plants, and electroplate factories. This is related to their unreasonable layout, simple and outdated equipment, backward technology, absence of pollution control facilities, and others. Under the profound impact of rural natural economy, most township enterprises have no idea of overall planning and have neglected rural ecological environmental protection and management since their foundation. In practical production and operation, they pursue economic benefits blindly, reduce the budget for pollution control, dispose solid wastes randomly,

and occupy tremendous farmlands. These wastes cannot be treated promptly and further pollute surrounding water and soils after they are washed and soaked by rains. Industrial waste gas and sewage are discharged into rivers directly (Fig. 4), causing river pollution and the large-scale deaths of fish and prawns. These harm the lives and health of local peasants directly. To safeguard and enrich non-staple foods to urban residents and accelerate the improvement of living standard, livestock and poultry farms have developed rapidly in rural areas, from scattered cultivation into large-scale intensive cultivation. They offer diversified animal products to urban residents and bring huge economic benefits to peasants. Nevertheless, they also cause great environmental pressure and produce new rural environmental pollution. Most livestock and poultry farms are equipped with no pollution prevention and control devices. The excrement and sewages of livestock are discharged randomly rather than through centralized disposal, and only few of them are applied to farmland after treatment. The rest are exposed to air and influence air and underground water sources significantly. Meanwhile, the excrement of livestock become the breeding place of many pathogens and the infection source of diseases, thereby threatening the physical health of peasants and influencing the rural survival environment and new rural construction significantly.

EFFECT OF RURAL ENVIRONMENTAL POLLUTION ON INDUSTRIAL STRUCTURE OF HEILONGJIANG

Model establishment: Many researchers have shown that environmental pollution is the combined consequence of economy of scale, emission intensity, and industrial structure. In the empirical test of rural environmental pollution in Heilongjiang, attention was given on how to choose the appropriate indexes to measure these factors and data acquisition. The model is expressed as follows:

$$\ln E_{it} = \alpha_i + \beta_1 \ln GDP_{it} + \beta_2 \ln I_{it} + \beta_3 STR_{it} + v_{it} \quad \dots(1)$$

Where E_{it} represents the industrial waste emissions of

the i^{th} city in t years, specifically the industrial SO_2 and COD. α_i and β_i are estimated parameters; GDP_{it} is the GDP of the i^{th} city in t years; I_{it} is the SO_2 and COD discharge intensity of the i^{th} city in t years; STR_{it} is the proportion of the added value of the secondary industry to the GDP of the i^{th} city in t years; v_{it} is a random disturbance term.

Data processing: Environmental pollution covers air pollution, water pollution, solid waste pollution, and others. In the empirical study, no uniform standard for index selection exists. According to data availability, this study chooses industrial SO_2 emissions and industrial COD emissions as explanatory variables, rural GDP as the variable representing the economy of scale, discharge intensity of rural industrial pollution as the discharge intensity, and the proportion of added value of the secondary industry to the GDP as the variable of output structure. All the data are collected from the Statistical Yearbook of Heilongjiang Province, and the environmental data from Environmental Statistical Yearbook of Heilongjiang Province. The test samples are rural areas at all prefecture cities in Heilongjiang, covering the period 2000 to 2014.

Effect of industrial structure change: The fixed effect model is chosen based on the estimation equation (1), calculation with Eviews7.0, and verification. The estimated results are listed in Table 1. All the regression coefficients are significant at a 1% significance level.

Table 1 leads to the following conclusions: Rural industrialization has a scaled effect on environmental pollution. It influences industrial pollutant emissions significantly. SO_2 increases by 0.813% and COD increases by 0.784% when rural GDP increases by 1%, indicating the significant negative effect of rural industrialization on rural environmental quality.

A significantly positive correlation exists between rural industrialization and pollution discharge intensity. SO_2 increases by 0.013% and COD increases by 0.014% when the discharge intensity increases by 1%. This reflects that com-

Table 1: The estimates of the explained variables.

| Explanatory variables | In SO_2 | | In COD | |
|-------------------------|-------------|---------|-------------|---------|
| | Coefficient | T value | Coefficient | T value |
| Constant term | 2.412*** | 3.98 | 2.473*** | 4.98 |
| In GDP | 0.813*** | 9.07 | 0.784*** | 8.94 |
| LnI | 0.013*** | 16.94 | 0.014* | 1.93 |
| STR | 1.981*** | 5.97 | 1.221* | 1.89 |
| Adjusted R ² | 0.996 | | 0.997 | |
| F value | 169.74 | | 394.75 | |

(Note: *** means significant at a1% significance level; * means significant at a 10% significance level)

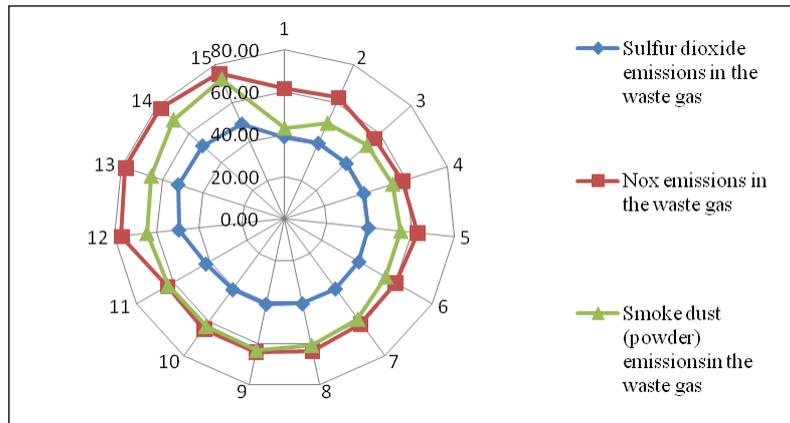


Fig. 4: Emissions of main pollutants in the air in rural areas from 2000-2014.

prehensive environmental pollution management is beneficial to improving environmental quality. However, different technologies have different characteristics and influence environment differently at different stages of the economic development. In the early or middle period of rural industrialization, extensive technologies with high investment and low output are employed widely, whereas in late rural industrialization, environment-friendly technologies are adopted. In late industrialization or post-industrialization, the social production mode and consumption mode are all developed toward environmental protection. Thus, technologies of low energy consumption and pollution are extensively used.

Rural environmental pollution is positively related to industrial structure changes. SO_2 increases by 1.981% and COD increases by 1.221% when the proportion of the added value of the secondary industry to GDP increases by 1%. This demonstrates that rural environment deteriorates as the proportion of industrial output to the economic aggregate increases. Industrial structure adjustment influences the total pollution emissions, which reveals that the state and changes of the industrial structure are decisive factors of the total pollution emission. In Heilongjiang, pollution caused by the secondary industry affects the industrial structure more than that caused by the tertiary industry.

POLICY SUGGESTIONS

Promote the transformation of the agricultural production mode, and increase agricultural science and technology inputs: Change agricultural production mode and promote agricultural modernization. At present, China still pursues extensive agricultural development. Continuing to adopt such energy-consuming development mode will further intensify agricultural environmental pollution and hinder ag-

ricultural modernization. This study suggests enhancing the supervision and control use of chemical products (e.g., pesticides and fertilizers) strictly, prohibiting the production and purchase of unqualified fertilizers and pesticides, guide peasants to use them scientifically and reasonably, use low-toxicity and degradable plastic films, promote organic fertilizers and farm manures, and encourage straw mulching. Straws and wasted films should be recycled and treated promptly, and agricultural production wastes should be used reasonably as resources. The study also suggests increasing agricultural science and technology inputs, developing ecological agriculture vigorously, and focusing on technologically innovative agriculture. Great efforts should be made to develop ecological agriculture and conservative agriculture, substitute technologies of pesticide and fertilizers, and accelerate R&D and application of new technologies. Furthermore, ecological development, which conforms to China's agricultural development trend, should emphasize the protection of the agro ecological environment, as well as the harmonious development of the economy, society, and environment. These efforts should be directed to realizing a balanced development between production and ecology and must assume an irreplaceable role in agricultural environmental protection.

Enhance the education of peasant with regard rural environmental protection, and increase awareness of environmental protection: Enhance the education of peasants with regard environmental protection. Most rural areas in China are characterized by lag in economic development, accompanied with a low living standard and education background. Peasants have traditional conservative ideas and backward concepts. They are unaware of the surrounding environmental problems and most of them even believe that rural areas ought to be like this. Thus, environmental pro-

tection education among primary and secondary school students in rural areas must be enhanced. Consciousness of environmental protection should be heightened, and the public should be encouraged to participate in rural environmental protection. To address environmental pollution in new rural construction, local governments must assume the role of organizing, instructing, and enhancing ecological environmental protection consciousness and the ability of the public through education and propaganda. Local environmental protection departments can resort to the countryside to promote environmental protection knowledge, increase the public's cognition and consciousness of environmental protection, hold propaganda of green civilization by stages, and offer basic knowledge training activities in rural environmental pollution control. A column of rural environmental protection can be created by making full use of broadcasts and blackboard in towns, villages, and streets, aiming to help peasants be aware of the serious consequences of environmental pollution and increase their consciousness of environmental protection. Rural environmental quality is closely related to peasants' benefits. The government should instruct peasants to establish a non-governmental environmental protection organization, which can make them teach and discipline themselves through participation, increase their consciousness of environmental protection, and advocate a civilized ecological lifestyle.

Construct a legal system for rural environmental protection, and perfect the mechanism for ecological compensation: Accelerate the formulation of a legal system for rural environmental protection, and strengthen law enforcement efforts. Laws and regulations concerning rural environmental pollution (including specific laws and regulations related to agricultural production pollution, rural domestic pollution, and pollution caused by township enterprises) should be established and perfected. The perfection of the basic law and regulation systems of rural environmental protection must be accelerated, including related regulations, management system, and supporting systems. Associated local sectors should establish a relatively perfect and independent legal system of rural environmental protection according to local actual situations and economic development, enlist rural environmental pollution management in the legal system, enhance rural ecological environmental protection, implement related laws and regulations fully, and intensify implementation and supervision. Establishing and perfecting an ecological compensation mechanism are conducive to a new rural environmental protection in China. An ecological compensation mechanism involves all aspects of rural environmental protection and many rural interested parties. Thus, it should be further promoted in new rural construction, including specific compensation stand-

ards, compensation object and scope, means of compensation, and others. Specific rural compensation forms, such as an organic fertilizer compensation mechanism, should be further explored and perfected, with the aim to form a comprehensive ecological compensation system.

CONCLUSIONS

Rural industrialization in Heilongjiang drives rural economic development. The industrial shift from cities to rural areas and decentralized industrial layout in rural areas cause heavy environmental pollution. Based on the environmental data on rural areas of Heilongjiang from 2000 to 2014, this study analyses three problems of rural environmental pollution and then establishes municipal panel data for an empirical study of the relationship between rural environmental pollution and industrial structure change. This study makes the following conclusions: (1) Pesticide usage in Heilongjiang has increased gradually, and domestic pollution emissions are high within the study period. (2) A significantly positive correlation exists between rural industrialization and intensity of pollutant emission. (3) Industrial pollution emissions in rural areas are influenced by the industrial structure. The rural areas with higher proportions of industrial output to economic aggregate have poor environmental quality. This study has great significance in relieving the increasingly serious industrial pollution in rural areas, halting the deterioration of the rural ecological environment, and reducing the threats to rural sustainable development and peasants' health. Given that China is suffering from heavy rural environmental pollution but has no perfect rural environmental planning systems, further studies on the spatial and regional distribution of rural environmental pollution and suggestions concerning the theoretical, legal, administration, technological, and management systems are needed.

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