Exploration on Inter-relation of Environmental Regulation, Economic Structure, and Economic Growth: Provincial Evidence from China.

Ye Tian[1]，Qian Wan[1]，Yao Tan[2]*

（1.School of Economics and Management，Hubei University of Technology, Wuhan, China 430068；2. CRCC Financial Leasing Company，Tianjin, China 300457）

Abstract： The potential effect of implementing environmental regulations on economic growth is a controversial issue for a long time. Various explanations were given from different empirical findings with contradictory arguments. As portrayed by Porter hypothesis, environmental regulations may impact on economic growth by reconstructing the economic structure. A number of previous literature proved the connections between the above three parties and proposed a series of mechanisms how these three parties effected one another. Studies on single mutual relation between any pair of two parties is valuable to outline the working mechanism, however may not be enough to to explore the nature of environmental regulations' effect on economic growth by considering three parties as a whole. With the intention of exploring the nature of this mechanism, it is important to understand the internal inter-relation of the three parties, requiring data from a large economy experiencing the transition in economic structure. As the largest developing country, provincial data of China provide a good empirical example for observing the inter-relation of the three parties. By constructing a panel containing data from 30 Chinese provinces over 10 years (2008-2019), this paper investigate the dynamic inter-relation of the three parties by introducing Panel Vector Autoregression (PVAR) model. PVAR model builds a vector by taking all three parties as endogenous factor, and examines the internal dynamic relation under the integrated vector. With the analysis of mutual Granger Tests between three parties, results from PVAR model not only display the inter-relation of any pair of two parties, but also illustrate the dynamic inter impulse and response. In this paper, the findings reveal that environmental regulations give a "U" shaped impact to economic growth. In return, economic growth promotes the development of economy with a weakening strength. In addition, results also support

the hypothesis that economic structure is the intermediate of economic growth and environmental regulations, since both uni-lateral effecting relations were found in economic growth to economic structure and economic structure to environmental regulations. There is a rooftop for the effect of economic structure to environmental regulations. The rooftop may signify the best optimization of primary structure.

Keywords : Environmental Regulations; Economic Structure; Economic Growth; PVAR Model

1.Introduction

The conflicts between environmental protection and economic development has been one of the primary topics for developing countries. Unlike in developed countries, the driven forces of economy in developing countries are industries relying on low cost of human and natural resources, which generates significant environmental problems. Policy makers are always cautious about imposing national-wide environmental regulations with concern about the potential negative effects on economic. Environmental governance is the inescapable step for developing countries on the path to developed phase. Recalling the processes developed countries have gone through, the optimization of economic structure constitutes an important change in the improvement of environment. There are broad implications for exploring the intrinsic mechanism between environmental regulations, economic development, and the evolution of economic structure. However, the transformation of economic structure in most developed countries occurred at or before the turn of the 20th century. The environmental issues human have and associated technologies changes considerably after a century of development. It is better to select cases in progress than the old one. China is the ideal case, where the environment improves with an ongoing national-wide upgrading of industries. As one of largest developing countries, the analysis of the impact of environmental regulations on industrial modernization in China provides empirical lessons to other developing countries.

Previous research has examined the relations between environmental regulations, economic structure, and economic growth. Evidences illustrate that the economic structure contribute both positive and negative impact to the economic growth. Majority research support that environmental regulations promotes the economic development. As it is observed that environmental regulations significantly shapes the economic structure, this suggests that environmental regulations can raise the level of the economy in developing countries by rebuilding industries. It is necessary to

include the three factors in the research scope in order to understand how environmental regulations work on the economic structure and subsequent economic growth. Few previous studies did so. In addition, most previous studies merely investigate the unidirectional causality between the three factors, missing the potential two-way causality. In this paper, panel vector autoregression (PVAR) was employed to explore the dynamic mechanism of the above three factors with two-way causality tests, based on a data panel of 30 Chinese provinces for 2008-2019.

2.Background

2.1Mechanism of Environmental Regulations on Economic Growth

Various previous studies discussed the relation between environmental regulations and economic development. Economic structure was believed as an intermediate factor, forcing regional economy to react to environmental regulations. It was found that the consequence of environmental regulations to economic development relies on the economic structure. Positive consequence comes up with robust economic structure [1,2,3]. Several explanations were provided to elaborate the mechanisms how environmental regulations working on economic development by changing the economic structure [4,5]. The early explanation considered environmental regulations as a raising cost to production, which obviously limit the development of economy [6,7]. Thereafter, led by "Porter Hypothesis" [8], some scholars proposed a positive mechanism by empirical studies, where environmental regulations performed as an incentive to manufacturers in upgrading their current structure [9]. Pollution intensive firms had to either upgrade their technology to reduce pollution or shift to other areas with liberally regulations in accordance with pollution haven hypothesis. With implementation of more technological upgradation in manufacture sector, massive firms were going to turn to tech-driven business from resource-driven business, which indicated a upcoming reconstruction of economic structure. During the reconstruction, most resource-firms with outdated technologies were going to diminish as failed to collect enough profits for upgradation or transformation after the implementation of environmental regulations [10]. This may not happen with the existence of strict environmental regulation as only external compulsory measures could raise firms' attentions to environmental cost [11]. Reference to the past success of industrial evolution, tech-firms always occupied the profitable positions in global industrial chain, bringing more income to regional economy and accelerating the growth of service business. In addition, tech-firms

usually sustained higher environmental standards. These standards not only could satisfy the requirement of environmental regulations, but also make up shadow entry barriers of market for contenders outside economy. Most firms surviving the reconstruction would obtain more resilience power to counter the instability and risk from fluctuations in future market [12]. This phenomenon was concluded as "Innovation Compensation", a fact appearing only under intensive regulation [13].

After major driven force changed from manufacture to service sector, economy would rise significantly on the reconstruction of economic structure [14]. However, there was a disputed issue in this speculation, whether environmental regulations could stimulate the change from resource-firms to tech-firms. It was argued that this transformation under stimulation would occurs only under certain conditions, where environmental regulations was appropriate and effective for the reality of economic structure [15]. This means the effects of environmental regulations would present heterogeneity for different regions with various economic conditions, which was displayed by the results of Du et al 2021 [11]. Others proposed the non-linear effect of economic reconstruction on the economic growth, since some empirical studies found that industrial upgradation would be harmful rather than beneficial to economic growth [16]. The above contradictory findings were suggested as the early stage of a "U" shape relation between industrial upgradation and economic growth [17,18]. The "U" shape speculation was supported by finding that economic growth would only take place after passing a certain threshold [19], which was suggested as a turning point of regional income per capital at 8000 USD by World Bank in 1992 [20].

A number of empirical studies partially proved above speculations. After sacrificing environmental quality for economic development for a long time, the emerging impairment to Chinese economy was found. This finding supported the impose of sustainable environmental regulations, which would provide more benefits rather than loss in economic development [21]. Zhang et al. [22] illustrated the benefits of environmental regulations on improvement of economic structure with time lags. Heavy manufacture industries, such as steel industry, would elevate productivity with the implementation of environmental regulations [23]. The cost of environmental regulations could be classified as one component of natural capital [24], which generates inclusive growth of regional economy along with other potential determinants [25,26].

Most previous literature tried to approach the nature of mechanism by figuring out the process how environmental regulations worked on economic structure or how

environmental regulations effected on economic growth. Few focused on building an integrated mechanism by including all three parties, environmental regulation, economic structure, and economic growth.

2.2 Environmental Regulations

Environmental regulations refer to laws and policies employed by government to regulate the pollution from activities in society as well as measures adopted by local authorities [27]. After the "Earth Summit" on global environment and development in 1992, majority nations consider environment protection as one of the basic duties in administration. Environmental regulations are fundamental measures to treat pollution and other hazardous behaviors [28]. Since the pollution reduction may not be spontaneously occur with the growth of economy, additional measures are need to be imposed to constrain the spreading pollution during the expansion of industrial sector in economic structure. Environmental regulations are such policy and law measures widely designed for curbing the pollutant emissions and polluting behaviors. In accordance with the Kuznets Curve (EKC) proposed by Grossman and Kreuger [29], the implementation of environmental regulations could help regional economy reached the peak of Kuznets Curve earlier at a relative lower pollution level.

Environmental regulations could be categorized into three general groups by driven forces [30]. The first groups are mandatory regulations published by authorities, e.g. policies laws, rules, standards, and other measures listed by authorities' mandates, which are designed for controlling the pollution by imposing negative consequences and extra cost to polluting sources. U.S. Clean Air Act and Chinese Environmental Protection Law are typical mandatory regulations in this group. Regulations in this groups are clear in targets, operational procedures, evaluation standards, and punishments after violations [31]. These distinct contents are straightforward for officers to execute and for society to understand. The drawback of mandatory regulations is expensive cost while implementation and difficult to be quantified directly. Similar to taxation, a large number of people and a big investment for enforcement equipment are necessary to ensure the effect of mandatory regulations [32]. Further expenditure is continuously required to sustain a expanding systematic network of monitoring, reporting, and verification (MRV), since the entities in economy increase with economic development. The intensity of mandatory regulation may not be able to quantified by analyzing the descriptive text in the documents, but may indirectly to be measured by counting the enforcement cases or the amount of violation fines.

The second group are those market instrument with profit driven. In the opposite of mandatory regulation, market instrument provides a scheme to allow entities to gain extra income by cutting the potential emissions [33], a positive consequence for pollution reduction. The market instruments are designed following by the theory proposed by Pigou [34], in which polluters were hypothesized to prefer controlling the pollution with minimum marginal cost of pollution reduction. These instruments are substantiated in many forms, e.g. emission trading and subsidies for pollution reduction [35], which are widely proved effective in market practice. Established in 2005, European Union Emission Trading Scheme (EU ETS) is one renowned example of successful market instruments efficiently reducing large quantity of greenhouse gas (GHG) emissions as well as other pollutants. Associated with EU ETS, Clean Development Mechanism (CDM) under United Nations Framework Convention for Climate Change (UNFCCC) promoted the largest proactive GHG reduction in developing countries by providing incentive compensations from carbon market. The advantage of market instruments is the low cost for society and environmental administrations with high enthusiasm in reduction actions for polluters. The low cost of market instruments refers only to the directly expenditures for firms and government, however, the operation of such instruments always needs extra big investment to sustain a network of MRV. The prominent drawback is the ambiguous reduction result since the total expected reduction from market may fluctuate as individual entity's decision is random and cannot be predicted accurately. This vague target may not meet the need of policy makers when a certain and explicit number of reduction is set by obligation.

The third group are those voluntary standards proposed by industries and their associations in purpose of obtaining competitive advantages. Standards from mandatory regulations are the bottom lines in environmental governance, which have to be executed thoroughly by any entity in the economy. Large firms with advanced technologies reserved usually benefits from these standards due to the limited cost compared to income, while small firms may have to spend a large proportion of income on fulfilling the standards. Firms benefiting from the standards would like to enhance their competitive advantages by raising the standards higher. In this case, voluntary standards are designed by unions or associations of these firms. The validation of voluntary standards in market competition is under various forms, such as product label, production certification, and other propaganda movements. Voluntary standards cost little but contribute little correspondingly, generating limited

impact on pollution reduction.

3.Status quo

3.1Analysis of the current situation of environmental regulations

The most direct and effective way to regulate environmental issues is to combat environmental pollution, which requires adequate capital investment. At the national level, during the period 2008–2019, the annual average value of total investment in environmental pollution control as a share of GDP in China reached 1.4, indicating the importance and determination of the Chinese government to ensure capital investment to effectively curb the deterioration of environmental pollution. After 2014, with the gradual improvement of China's environmental quality and the accelerated pace of economic structural upgrading, the share of total investment in environmental pollution control to GDP started to decline and stabilized at around 1.2%.

Figure1 Total national investment in environmental pollution control as a share of GDP(Unit: %).

Note: Data come from China Environmental Statistics Yearbook.

Looking at the regional level, during the period 2008–2019, the investment amounts in industrial pollution and environmental treatment in the three major regions of China (East, West, and Northeast) all basically showed a trend of first increasing and then decreasing, with only four provinces in the central region (Shanxi, Anhui, Henan, and Jiangxi) showing fluctuating growth in investment. In eastern coastal areas, due to the transfer of polluting industries to the central region, the amount of industrial pollution control investment decreased. The western and northeastern regions are mainly due to the significant increase in government environmental regulations and environmental governance. This makes industrial environmental pollution reduction difficult. The amount of investment in governance has decreased. The four provinces of Shanxi, Anhui, Henan, and Jiangxi in the central region have taken over the transfer of some polluting industries, as well as their own industrial structures, relying excessively on heavy industries such as energy extraction, resulting in the difficulty of regional industrial pollution and environmental treatment, and the investment amount has shown a fluctuating increase. This shows that China attaches great importance to the environmental pollution problems brought about by rapid economic development, and all regions have invested a lot of money in industrial pollution control, and most provinces have achieved certain results in industrial

pollution control.

Figure2 Environmental treatment of industrial pollution in the four major economic regions(Unit: dollars).

Note: Data come from China Environmental Statistics Yearbook.

In terms of specific provinces, the report of the 19th National Congress of the Communist Party of China clearly puts forward "accelerating the reform of the ecological civilization system and building a beautiful China", which puts forward more stringent requirements for the environmental governance performance of each province. From the average value of the total investment in environmental pollution control as a percentage of GDP in each province from 2008 to 2019, Xinjiang, Ningxia, and Inner Mongolia three provinces have the largest share of total investment in environmental pollution control, Shanxi and Beijing have the second largest share of total investment in environmental pollution control, and Guangdong Province has the lowest share of total investment in environmental pollution control. This may be due to the fragile ecological environment of Xinjiang, Ningxia, and Inner Mongolia, the high cost of environmental pollution control, and the fact that the Chinese government has placed a high priority on ecological control in its western development strategy and has invested a lot of labor, material, and financial resources in environmental pollution control and ecological environmental protection; Shanxi Province originally developed a resource-based economy, and its industrial structure was severely tilted, and excessive resource exploitation led to ecological damage and serious environmental pollution. Shanxi Province has started to focus on ecological civilization construction and significantly increase the intensity of environmental regulation in the province. Beijing, due to its rapid economic development and the large proportion of high energy-consuming enterprises, has led to serious air pollution, and the government pays attention to ecological environment improvement and increases the management of related pollution. From the above analysis, it is clear that the intensity of environmental regulations in each province is highly related to the ecological and environmental conditions, economic growth, and structural characteristics of the province.

Figure3 Total investment in environmental pollution control as a share of GDP by province(Unit: %).

Note: Data come from China Environmental Statistics Yearbook.

3.2Analysis of the current situation of economic structure reconstruction

With the continuous development of China's economy, the process of economic restructuring, transformation, and upgrading is also gradually advancing. The current status of China's economic structure reconstruction can be comprehensively analyzed by using three indicators: the output value of the three major industries; the ratio of output values of the three major industries; and the ratio of employed persons in the three major industries.

According to Figure4, it can be seen that the three major industries in China developed well and were in growth during 2008–2019. Among them, the tertiary industry developed particularly rapidly, from an output value of 196,9.31 billion dollars in 2008 to 776,2.71 billion dollars in 2019, a total increase of 3.9 times, higher than the growth rate of the primary and secondary industries; the secondary industry developed at the second fastest rate, from a fluctuating output value of 215,8.21 billion dollars in 2008 to 551,9.61 billion dollars in 2019, a total increase of 2.5 times; the primary industry output value grew relatively slowly, with an increase of 2.2 times from 467.24 billion dollars in 2008 to 102,1.81 billion dollars in 2019. This indicates that in recent years, with the accelerated pace of economic restructuring and industrial upgrading, China has shown a trend of high growth in the tertiary industry and steady progress in the primary and secondary industries in terms of economic structure.

Figure4 National value added of the three major industries (Unit: billion dollars).

Note: Data come from EPS database.

The tendency of China's economic structure reconstruction is more prominent in terms of the share of three major industries in GDP. As can be seen from Figure 5, both the share of primary and secondary industries are in a declining trend, while the share of tertiary industries is on a rapid rise. Specifically, the proportion of output value of the secondary industry was the highest from 2008 to 2012, followed by the tertiary industry, and the primary industry accounted for a smaller proportion. From 2012 to 2019, the proportion of the tertiary industry exceeded that of the secondary industry and became the industry with the highest proportion. And after 2015, the proportion of the tertiary industry all exceeded 50%. It can be seen that China's economic structure reconstruction has achieved remarkable results and gradually shifted from the original secondary industry as the leading industry to an economic structure supported by the tertiary industry.

Figure5 The proportion of GDP and the proportion of employees in the three major industries(Unit: %).

Note: Data come from EPS database.

From the perspective of the employment ratio of the three major industries, the employment ratio of the primary industry gradually decreased from the highest of 39.6% in 2008 to the lowest of 24.7% in 2019, and the labor force continuously flowed out of the primary industry. The employment ratio of the secondary industry showed a trend of rising and then declining with the stage of industrial restructuring, remaining in the range of 25%–30%, as the labor force flowed out of the primary industry and gradually shifted to the secondary industry, while the proportion of employed people in the tertiary industry showed rapid growth, from 33.2% in 2008 to 47.1% in 2019, gradually approaching 50%. With the rapid development of the tertiary industry, the employment attractiveness of the tertiary industry has also risen rapidly, and has now become the main industry of employment in China.

4Methodology

4.1 Data and Variables

4.1.1 Environmental Regulations (ENR).There are two major approaches to quantify the level of regional environmental regulations:

Use the emission intensity of pollutants as an alternative indicator. It implies that strict environmental regulations reduce the emissions intensity of pollutants. The more severe regulations are, the less emissions produced.

Use the investment in pollution control as an alternative indicator. The investment refers to the money from both public and private sectors, partially implying the local's aspiration against pollution and responding measures to local environmental regulations.

In this paper, investment in pollution control is selected to measure the level of local environmental regulations.

4.1.2 Economic Structure Reconstruction (STR). The reconstruction of regional economic structure is a dynamic process of evolution, difficult to be measured by any single indicator. According to Gan et al. [36], we build an entropy to estimate the general level of reconstruction of economic structure under following steps:

(1) Calculate the Theil Index for yield and labor in any industry. Prior to estimating the entropy of industrial reconstruction, the level of industrial development

and the degree of coordination of each industry must be measured. Theil index is the indicator to measure the rational proportion of labor to associated yield in each industry, illustrating how coordinate the current economic structure is. Theil index is given by the equation (1).

$$TL = \sum_{i=1}^{n} \left(\frac{Y_i}{Y}\right) \ln \left(\frac{\frac{Y_i}{L_i}}{\frac{Y}{L}} \right) \quad (1)$$

Where, TL is short for Theil Index, Y is the industrial yield in RMB (Chinese Currency), and L stands for labor.

(2) Calculate the reconstruction potential of regional industries. In accordance with the process developed countries went through, economic grows with increased service sector's proportion and decreased manufacture sector's proportion. The ratio of the industrial yield from service sector to the yield from manufacture sector implies the potential of adjustment in structure, given as below.

$$RP = {Y_s}/{Y_m} \quad (2)$$

Where, RP is reconstruction potential, Y_s is yield from service sector, and Y_m is yield from manufacture sector.

(3) Calculate the entropy of the reconstruction of economic structure. Since the value from a specific industry may vary greatly in number and unit, it is required to standardize the value to avoid the disturbance. Weights for indicators are given by the extent of polarization to specific indicator.

For positive values：

$$y_{ij}^{'} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - min(x_j)} \quad (3)$$

(4) Where x refers to indicator's value, y refers to standardized value, j stands for the evaluation index, and i stands for region.

(5) For negative values：

$$y_{ij}^{'} = \frac{max(x_i) - x_{ij}}{max(x_j) - min(x_j)} \quad (4)$$

To avoid that the "0" value generated after standardization cannot be calculated subsequently, make $y_{ij} = y_{ij}^{'} + 10^{-4}$, then calculate the proportion of the evaluation index *j* of region *i*.

$$p_{ij} = {y_{ij}}/{\sum_{i=1}^{n} y_{ij}} \quad (5)$$

Where P is the proportion value.

For the entropy of the reconstruction of economic structure and the associated

redundancy:

$$e_j = -\frac{1}{ln(n)}\sum_{i=1}^{n} p_{ij} ln(p_{ij}) \quad (6)$$

$$d_j = 1 - e_j \quad (7)$$

Where *e* is the entropy, and *d* is the redundancy.

For the weights by redundancy in a given sector:

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \quad (8)$$

Where *w* stands for weight.

For the coordinate indicator in a given region.

$$y_i = \sum_{j=1}^{n} w_j \times y_{ij} \quad (9)$$

4.1.3. Economic Growth (PGDP). Most previous studies use domestic gross production (GDP) or GDP per capital to measure the level of economic growth. Given the level difference of individual region, GDP per capital is used.

4.2 Data Source

Data were selected from annual provincial statistics, annual environmental statistics, and Express Professional Superior (EPS) database, covering 30 major provinces in China from 2008 to 2019. Missing values are supplanted by averaging neighbour values. All values are treated to logarithmic form with price deduction. Statistical results are below:

Table 2 Descriptive Statistics

4.3 Quantitative Model

Panel vector autoregression (PVAR) is a dynamic model with advantages from both panel data and vector autoregression. All variables are treated endogenously, avoiding the potential problems of missing variables. The model provides relatively robust estimations of mutual relations between variables by allowing individual difference. A quantitative model is constructed below to describe the dynamic mutual relations between environmental regulations, economic structure, and economic growth.

$$y_{it} = \alpha_0 + \sum_{j=1}^{p} \beta_{i,j}\, y_{i,t-j} + \gamma_i + \theta_t + \varepsilon_{it} \quad (10)$$

Where, i is province, t is year, p stands for lag order, y_{it} is a three dimensional vector consisted of $\ln ENR$, $\ln STR$, and $\ln PGDP$, α_0 is constant, $\beta_{i,j}$ is coefficient matrix, γ_i stands for individual effect, θ_t stands for time effects, and ε_{it} is the residuals.

5 Empirical Analysis

5.1 Panel Stationary

To minimum the potential effects of spurious regression, both of Harris-Tzavalis test and Levin-Lin-Chu test were applied to examine the existence of unitroot. Given any unitroot, all variables were tested another round after first-order difference. PVAR model was operated on the condition that test results of all variables significantly rejected the null hypothesis of unitroot existence at 1% level.

Table 3 Unitroot Test.

5.2 Granger Causality

The mutual relation between environmental regulations, economic structure, and economic growth is measured by Granger Causality. The results are below.

Table 4 Granger Causality Test

Results from the above table exhibit the potential strong mutual causality between environmental regulations and economic growth by rejecting the null hypothesis at 1% significant level. Economic structure exert unidirectional relation of Granger causality to the environmental regulations. The same unidirectional relation was found between economic growth and structure change, where economic growth is the cause.

Generalized method of moments (GMM) is employed to explore the dynamic relation between environmental regulations, economic growth, and economic structure by impulse response and variance decomposition.

5.3 Lag Order

One important precondition is optimization of lag order selection. There are three primary types of information criterion for GMM lag setting, i.e. Minimum Bayesian Information Criterion (MBIC), Minimum Akaike Information Criterion (MAIC), and Minimum Quasi Information Criterion (MQIC) . After comparing results of all three types of criterion within 3 lag order, lag order sets to 2 for a better fit in most criterion, i.e. MAIC and MQIC. In contrast, lag order 1 provides a good fit only in MBIC and lag order 3 has none.

Table5 Lag Order Selection

5.4 Stationary Test

Since the stationary of GMM model is required for executing detailed analysis by impulse response, a stationary test was applied to the eigenvalues of dynamic matrices in PVAR model. As shown in figure 1, magnitudes of all eigenroots are within the 1 unit radius circle, which indicates the PVAR model is stationary with a good fit at lag order 2.

Figure 1 Stationary Test for Impulse Response

5.5 GMM Estimation

The potential individual effect and fixed effect are excluded by Helmert procedure. Table 6 describes the results from GMM estimations at lag order 2 with

data of 30 provinces in China.

Table 6 GMM Estimations

From the results, environmental regulation s suppress itself with one period lag but exert minor suppression with two period lag. Two period lag of economic growth imposes significantly positive effect on environmental regulations. Significantly positive values are found in economic structure's self-interference at one period lag while negative found at two period lag. Economic growth present a significantly self-driven attribute with positive values at both one and two period lags. Given the all negative numbers in values of environmental regulations to economic growth, it infers that environmental regulations hamper the growth of economic.

5.6 Impulse Response

Estimations by GMM display the static relations between variables, ignoring the potential dynamic interactions. In purpose of further exploring the dynamic interaction, a 6 period impulse response is conducted through 200 times simulation of variables' change by Monte Carlo method. Results are shown in figure 2.

Impulse from economic growth. The initial self-impulse of economic growth reaches maximum while shock decreases with time, indicating a lagged development in economic. Economic growth brings negative shock to economic structure with the max one at period 2. One possible explanation for this is that the structure of economic may not automatically adjust to the perfect balance with the growth of economic. The growth may be the result of aggregate productions from unbalanced industries. The inverted "U" positive impact of economic growth on environmental regulations was in line with the previous studies [37,38,39], showing that the stage of economic development determines the intensity of environmental regulations. Intensive pollution always comes up with the early stage of economic development as the primary driven force generated from heavy and resource reliable industries. To alleviate the deterioration of environment, the strength of regulations has to be

increased corresponding to the pollution accumulation. After economy grows over a certain threshold [19], 8000 USD per capital income by World Bank [20], economic structure is reconstructed to service oriented industries with less resource consumption and pollution, which can be treated well under relative loose regulations. The falling intensity of environmental regulations after the threshold implies less cost and potential precise measures with higher efficiency. Similar threshold point is found in the afterwards "U" shape performance by impulse from economic growth to economic structure. Considering the decreasing trends displayed in the result of economic growth's self-impulse, it is inferred that market capital tends to invest to heavy and resource reliable industries until the marginal return falls to the a certain level, proposed as the threshold point. In that case, economic structure may become progressively worse with economic development. After passing over the threshold point, market capital would incline to invest industrial upgradation, which initiates the reconstruction of economic structure.

Impulse from economic structure. The max self-shock appears at the beginning of economic structure impulse and shock continuously shrinks to a stable level. Economic structure produces an "N" type impact on the intensity of environmental regulations. It shows a positive shock before period 1 as well as negative one at period 2, and turns to positive shock thereafter with a declining route. Economic structure concludes a long time positive impact on environmental regulations with some fluctuations in near future. Fluctuation may be the consequence of uncertainty in early industry's evolution. In accordance of the results shown in the impulse of economic growth, it is assumed that the satisfied return in the investment to heavy and resource reliable industries induces hesitations when firms are about to make decisions on whether to upgrade their equipment or invest to the current business. Different choices may correspondingly lead to divergent environmental regulations under various intensity. The randomly diversified decisions on this issue may be the origin of the early fluctuated response in environmental regulations. The response of economic development to economic structure grows over time and finally weakens to a certain level. The response of economic growth indicates a potential rooftop exiting for effects from the reconstruction of economic structure. Most economy may not be able to keep the developing rate after the finish of industrial upgrading.

Impulse from environmental regulations. The response of economic growth to environmental regulations is negative for the early three periods contrast to the positive ones after period 4. This may suggest a potential significant scale effect of

environmental regulations on economic growth. After the implementation, firms are forced to pay extra cost to meet the new and higher standards of environmental regulations during the early period. This additional expenditure to environment results in a weaker competitiveness in market and reduction in revenue, which restrains the growth of economy. In line with the above description of the impulse from economic growth, with time goes, the enforced regulations urge firms to provide services and products with higher environmental standards. These standards are going to become labels of products and entering barriers for outside competitors, which award domestic firms extra competitiveness, resulting in economic growth. The response of economic structure reaches the peak value at period 1, implies a potential rooftop existing, matching the findings given in the above description of the impulse from economic structure. The maximum negative self-shock of environmental regulations appears at period 1 and turns to positive at period 2 with weakening signals afterwards.

Figure 2 Impulse Response

5.7 Variance Decomposition

Contribution of each variable to endogenous variable's fluctuation can be measured by variance decomposition, which further discloses the mutual influences of variables.

By analyzing the variance decomposition of environmental regulations, it is found that environmental regulations has the largest contribution to its own variance decomposition results, with more than 50% in phase 5, 10 and 20, which are highly dependent on itself. In the stable state, the contribution rates of industrial restructuring and economic growth will reach 15.8% and 31.0% respectively.

According to the variance decomposition results of economic structure adjustment, economic structure exerts the greatest impact on itself, reaching 81.0% in a stable state, while the contribution rate of economic growth has reached 11.4%, indicating that economic growth has a certain impact on the change of economic structure in the long run.

According to the variance decomposition results of economic growth, economic growth is most affected by itself, which once again verifies that economic growth has strong inertia characteristics. When it reaches a stable state, the contribution rate of economic growth to itself is 68.1%, while the contribution rate of environmental

regulations is 8.8%, which shows that in addition to its own contribution, environmental regulations will promote economic growth to a certain extent.

Table 7 Variance Decomposition

5.8 Robustness tests

Since the above impulse response and variance decomposition results are very dependent on the order of variables, the results of other variable orders need to be examined to ensure the robustness of the above results. In this paper, we refer to Hao Jin and Yuja Li [40] and swap the orders of the two variables with the highest residual correlation, i.e., the order of environmental regulation and economic growth. The results show that the GMM estimation results and impulse response plots do not change fundamentally, except for a slight change in the variance decomposition results, so the model passes the robustness test and the results obtained from the analysis are reliable.

6 Conclusion

The impact of environmental regulations on economic growth is a widely discussed issue. The short-term negative expectations from regulations on economic provoke anxiety of those concerning wealth accumulation rather than sustainable future. Although a number of literature elucidates the existence of potential mechanism on which environmental regulations cause the growth of economic, our research is the first to elaborate the mechanism by constructing a trio-lateral relation as introducing economic structure. A further novelty we have in this research is the Granger Causality tests for all three factor in one another pair, providing a possible explanation on the interactions of environmental regulations and economic. The final

novelty is the dynamic structure build for examining how trio-relation varies over time by PVAR model with GMM estimations, which reveals the dedicated proportions of each factor to another.

Samples from 30 provinces in China over 10 years are used in our research. From Granger Causality tests, we found a logic chain justifying the possible process how environmental regulations promoted economic. Test results show that environmental regulations cause the evolution of economic structure which leads to the growth of GDP finally. The detailed steps of this process exhibit in the dynamic analysis in PVAR model. According to the GMM estimation, environmental regulations may not contribute economic growth directly with negative coefficients for all lags. In line with the test result from Granger Causality, environmental regulations presents significant dedications to the improvement of economic structure, which eventually contributes to the economic development. This proposed process is also supported by the results come up with impulse response, where the early impulse generated by environmental regulations produces positive to economic structure but negative to economic growth. Given structure's long time positive shock to economic growth, it indicates that environmental regulations promote the economic by shaping the long-term structure, which matches the findings in the previous two tests. Furthermore, the "U" shape shock from economic growth discloses a possible route, through which economic growth feed the environmental regulations after finishing the upgrading of industries.

Above findings suggest that it is not a dilemma issue between environment and economic for developing countries, especially for those experiencing the transition of major industries from manufacture to service. The continuous improvement of environmental regulations ultimately leads to a better economic.

Acknowledgments

The authors are thankful to the editor and the anonymous reviewers for their helpful comments on the paper. This work was supported by the National Social Science Fund of China [grant number 19CJY019]

Reference：

1. Chen, L.; Ye, W.; Huo, C.; James, K. Environmental Regulations, the Industrial Structure, and High-Quality Regional Economic Development: Evidence from China. Land 2020, 9, 517. https://doi.org/10.3390/land9120517

2. Sun, Y., Mu, H., F, H., Hou, X., Zhang, Z., 2020. Research on the heterogeneous linkage effect of environmental regulations on the upgrading of industrial structures. J. Ind. Technol. Econ. 39, 89–95.

3. Guoxing, Z., Peide, Z., Zhe George, Z., Jiexun, L., 2019. Impact of environmental regulations on industrial structure upgrading: An empirical study on Beijing-Tianjin-Hebei region in China. J. Clean. Prod. 238, 117848-117848.

4. Burton, D.M.; Gomez, I.A.; Love, H.A. Environmental regulation cost and industry structure changes.Land Econ. 2011, 3, 545–557.

5. Chong, Z.; Qin, C.; Ye, X. Environmental regulation, economic network and sustainable growth of urban agglomerations in China. Sustainability 2016, 8, 467.

6. Kneller, R., Manderson, E., 2012. Environmental regulations and innovation activity in UK man ufacturing industries. Resour. Energy Econ. 34 (2), 211–235. https://doi. org/10.1016/j.reseneeco.2 011.12.001.

7. Yang, S., Chen, Z., Umar, M., Khursheed, A., 2022. Environmental regulation and highquality s ustainable development of China's economy–An empirical study based on a spatial durbin model a nd threshold model. Econ. Res-Ekon. Istraz. 1–20. https://doi. org/10.1080/1331677X.2022.20352 43.

8. Porter, M.E., 1991. Towards a dynamic theory of strategy. Strateg. Manag. J. 12, 95–117.

9. Yang, C.H., Tseng, Y.H., Chen, C.P., 2012. Environmental regulations, induced R&D, and prod uctivity: evidence from Taiwan's manufacturing industries. Resour. Energy Econ. 34 (4), 514–532. https://doi.org/10.1016/j.reseneeco.2012.05.001.

10. Qiu, L.D., Zhou, M., Wei, X., 2018. Regulation, innovation, and firm selection: the porter hyp othesis under monopolistic competition. J. Environ. Econ. Manag.92, 638–658.

11. Du, K., Cheng, Y., Yao, Xin., 2021. Environmental regulation, green technology innovation, an d industrial structure upgrading: The road to the green transformation of Chinese cities. Energy Ec onomics. 98. 105247. https://doi.org/10.1016/j.eneco.2021.105247

12. Xia, Q., Quan, M., Li, H., Hao, X., 2022. Is environmental regulation works on improving ind ustrial resilience of China? Learning from a provincial perspective. Energy Reports. 8. 4695-4705. https://doi.org/10.1016/j.egyr.2022.03.168.

13. Ouyang, X.L., Li, Q., Du, K.R., 2020. How does environmental regulation promote technologi cal innovations in the industrial sector? Evidence from Chinese provincial panel data. Energy Poli cy 139, 111310.

14. Hu, W., Tian, J., Chen, L., 2021. An industrial structure adjustment model to facilitate high-qu ality development of an eco-industrial park. Sci. Total Environ. 766, 142502 https://doi.org/10.101 6/j.scitotenv.2020.142502.

15. Langpap, C., Shimshack, J., 2010. Private citizen suits and public enforcement:Substitutes or c omplements. Environ. Econ. Manage. 59, 235–249.

16. Shi, L., 2020a. Industrial structure changes, spatial spillover and economic growth in the Yangt

ze River Delta. J. Coastal Res. 107 (SI), 377–382. https://doi.org/10.2112/ JCR-SI107-086.1.
17. Zhao, X., Mahendru, M., Ma, X., Rao, A., Shang, Y., 2022. Impacts of environmental regulatio ns on green economic growth in China: new guidelines regarding renewable energy and energy eff iciency. Renew. Energy 187, 728–742. https://doi.org/10.1016/j.renene.2022.01.076.
18. Lv, J., Zhang, l., 2021. Research on environmental regulation and business performance from t he perspective of technological innovation. Econ. Manage.35, 40–46.
19. Shi, L., 2020b. Changes of industrial structure and economic growth in coastal regions of Chin a: a threshold panel model based study. J. Coastal Res. 107 (SI), 278–282. https://doi.org/10.2112/ JCR-SI107-068.1.
20. World Bank. World Development Report 1992: Development and Environment; China Financi al and Economic Press: Beijing, China, 1992.
21. Shuai, S., Fan, Z. Modeling the role of environmental regulations in regional green economy e fficiency of China: Empirical evidence from super efficiency. J. Environ. Manag. 2020, 261, 1102 27.
22. Zhang, G.X., Zhang, P.D., Zhang, Z.G., Li, J.X., 2019. Impact of environmental regulations on industrial structure upgrading: an empirical study on Beijing-Tianjin-Hebei region in China. J. Cle an. Prod. 238, 117848.
23. Zhu, X.H., Zeng, A.Q., Zhong, M.R., Huang, J.B., Qu, H.P., 2019. Multiple impacts of environ mental regulation on the steel industry in China: a recursive dynamic steel industry chain CGE ana lysis. J. Clean. Prod. 210, 490–504.
24. Ge, T.; Li, J.; Sha, R.; Hao, X. Environmental regulations, financial constraints and export gree -nsophistication:Evidence from China's enterprises. J. Clean. Product. 2020, 251, 119671.
25. George, G.; McGahan, A.M.; Prabhu, J. Innovation for inclusive growth: Towards a theoretical framework and a research agenda. J. Manag. Stud. 2012, 49, 661–683.
26. Rajapaksa, D.; Islam, M.; Managi, S. Natural capital depletion: The impact of natural disasters on inclusive growth. Econ. Disasters Clim. Chang. 2017, 1, 233–244.
27. Eiadat, Y.; Kelly, A.; Roche, F.; Eyadat, H. Green and competitive? An empirical test of the me diating role of environmental innovation strategy. J. World Bus. 2008, 43, 131–145.
28. Gray, W.B.; Shadbegian, R.J. Plant vintage, technology, and environmental regulation. J. Envir on. Econ. Manag. 2013, 46, 384–402.
29. Grossman, G.M.; Kreuger, A.B. Economic growth and the environment. Q. J. Econ. 1995, 110, 353–377.
30. Xie, R.; Yuan, Y.; Huang, J. Different types of environmental regulations and heterogeneous in fluence on "green" productivity: Evidence from China. Ecol. Econ. 2017, 132, 104–112.
31. Hahn, R.W. The political economy of environmental regulation: Towards a unifying framewor k. Public Choice 1990, 65, 21–47.
32. Tietenberg, T.H.; Lewis, L. Environmental and Natural Resource Economics; Routledge: Lond on, UK; New York, NY, USA, 2018.
33. Hahn, R.W. Market power and transferable property rights. Q. J. Econ. 1984, 99, 753–765.
34. Pigou, A.C. The Economics of Welfare; MacMillan: London, UK, 1920.
35. OECD. Guidelines for the Application of Environmental Economic Instruments; China Enviro nmental Science Press: Beijing, China, 1994; pp. 12–13.
36. Gan, C., Zheng, R., Yu, D., Influence of indusrial stucture's change on economic growth and fl uctuation. Economic Research Journal. 2011, 46(05), 14. (in Chinese)

37. Wang, Y., Sun, X., Gao, X., 2019. Environmental regulation and green productivity growth: E mpirical evidence on the Porter Hypothesis from OECD industrial sectors. Energy Policy 132, 611 –619. https://doi.org/10.1016/j.enpol.2019.06.016.
38. Song, M., Tao, W., Shen, Z., 2022. Improving high-quality development with environmental re gulation and industrial structure in China. Journal of Cleaner Production. 132997. https://doi.org/1 0.1016/j.jclepro.2022.132997.
39. Song, Y., Wei, Y., Zhu, J., Liu, J., Zhang, M., 2021. Environmental regulation and economic gr owth: a new perspective based on technical level and healthy human capital. J. Clean. Prod. 318, 1 28520 https://doi.org/10.1016/j. jclepro.2021.128520.
40. Jin, H., Li, Y., 2021. The Influence of Population aging on Chinese residents' consu mption level and the regional difference. Economy & Management. 35, 23-32.