How Does The Urban-Rural Income Gap Affect Regional Environmental Pollution? ——Re-Examination Based On The Experience Of Cities At Prefecture Level And Above In China

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Research Article

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Posted Date: March 3rd, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1338786/v1

How does the urban-rural income gap affect regional environmental pollution?

——Re-examination based on the experience of cities at prefecture level and above in China

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Abstract: Based on the traditional "EKC" theory, this paper re-examines the impact of urban-rural income disparity on regional pollution and its mechanism by using panel data of Chinese cities at prefecture level and above from 2005-2015, combining demand scale and human capital perspectives. The results show that the urban-rural income gap has a significant "inverted U-shaped" trend on urban pollution. Both the scale of demand and human capital are the main mechanisms influencing the environmental pollution effect of urban-rural income gap, and the marginal pollution effects of both are "first negative and then positive" along with the widening of urban-rural income gap. The pollution effects of urban-rural income disparity have significant spatial correlation both nationally and within regions. The intensity of environmental regulations is an important factor affecting the urban-rural income gap, and has a significant "positive U-shaped" effect on regional pollution through the urban-rural income gap.

Keywords: Urban-rural income gap, regional pollution, consumption scale, human capital, spatial correlation, environmental regulation

JEL：P25, Q52, R23

1. Introduction

Over the past 40 years of reform and opening-up, China's economy has achieved sustained and rapid growth for more than 40 years. Its GDP ranks second in the world and its industrial output value has long been the world’s largest newly industrialized country. China's rapid economic growth has comprehensively improved the material living standards of residents, but it has also brought about a series of environmental degradation. As residents' awareness of environmental protection continues to increase, coordinating economic development and environmental protection has gradually become a hot issue of Chinese society. According to World Bank statistics, China's total carbon dioxide emissions in 2014 were approximately 10.29 billion tons, more than six times that of 1.46 billion tons in 1978, with an average annual growth rate of over 5.5%[1]. Especially since 2013, large-scale haze weather has swept across China, which has adversely affected the work and life of residents. The report of the 19th National Congress of the Communist Party of China pointed out: "The modernization that China wants to build is a modernization in which man and nature coexist in harmony. It is necessary to create more material wealth and spiritual wealth to meet the people's growing needs for a better life, but also to provide more high-quality ecological products to meet the people's growing needs for a beautiful ecological environment "[2]. This requires China to transform the past extensive economic model, promote supply-side adjustments, further release the reform "dividends", and strive to cultivate emerging growth points to cope with the "new economic normal" faced by the

[1] Data Sources：Word Bank Open Databas

[2] Source: “China Statistical Yearbook” over the years

country.

As a traditional economic hotspot, the issue of income disparity has emerged in China across urban and rural areas, regions, industries, and gender. Among them, as China's economic growth and industrial expansion have caused drastic changes in the urban and rural economic structure, the "dualization" of the urban and rural economy and the negative role of the urban-rural income gap in China's economic development have become increasingly prominent, and have gradually become a long-term focus of public opinion. The National Bureau of Statistics pointed out that from 2000 to 2019, the ratio of per capita disposable income of urban and rural residents in China fell from 2.78 to 2.64, while the income gap between urban and rural residents widened from 4,000 yuan to 26,000 yuan[3]. Facts show that although the relative income gap between urban and rural residents in China has been slightly converging since the 21st century, the absolute income gap between urban and rural residents has shown a clear divergence. In other words, the problem of urban and rural income inequality is still very prominent in China at this stage. Income inequality will not only cause great

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[3] Source："Outline of the 13th Five-Year Plan for the National Economic and Social Development of the People's Republic of China"

obstacles to regional growth and industrial upgrading but also derive many social problems such as public security and law, which will directly hurt residents' daily lives. The "13th Five-Year Plan" issued by the Chinese Central Government in 2016 emphasized that "industry nurturing agriculture, cities nurturing rural areas, and improving the integration of urban and rural development" are currently the key areas for China to explore new driving forces for economic growth and industrial transformation[4]. Because urban-rural income gap and environmental pollution are both key issues related to the current economic growth and industrial transformation in China, a comprehensive and systematic discussion of the interactive relationship between the urban-rural income gap and environmental pollution is of positive significance for supplementing and improving the theoretical system of the income gap and environmental pollution research, guiding and helping the formulation of regional industrial policies. Therefore, based on the existing research conclusions, this article attempts to re-discuss the actual impact of the urban-rural income gap on environmental

[4] Source："Outline of the 13th Five-Year Plan for the National Economic and Social Development of the People's Republic of China"

pollution from the perspective of traditional supply and demand theory, and further analyze the mechanism path of its impact.

Existing studies have some flaws in the discussion of the impact of the urban-rural income gap on environmental pollution. First, Grossman and Krueger (1991) and Panayotou (1993) pointed out that there is an environmental Kuznets curve (EKC) between per capita income and environmental pollution. However, because per capita income indicators cannot reflect the income differences between different income groups, this makes EKC theory is difficult to reasonably explain the actual impact of income disparity on environmental pollution. Scholars such as Coondoo and Dinda (2008) believe that it is income disparity rather than income level that affects environmental pollution; secondly, more studies have discussed the impact of regional Gini coefficient on local environmental pollution, but this is different from the urban-rural income gap; then, there are also some controversies about the actual interaction between income gap and environmental pollution. Some scholars believe that the income gap and environmental pollution are linearly related (Ghalwash, 2008; Baek and Gweisah, 2013), while other scholars believe that the two should show a non-linear correlation (Scruggs, 1998; Yang Qian and Liu Huajun, 2012); finally, the existing researches have a lot of controversies about the impact mechanism of income gap on environmental pollution. Although the research objects are involved in income levels (Vona and Patriarca, 2011), human capital (Shen Kunrong and Geng Qiang, 2001), and environmental policies (Yu Xiangyu et al., 2019), the content is often scattered and difficult to explain the current problems comprehensively and reasonably. In other words, there is still a lack of a unified understanding of "how the income gap, especially the income gap between urban and rural areas, affects environmental pollution" and "what is the mechanism for the impact of urban-rural income gap on environmental pollution". Therefore, from the two dimensions of demand and supply, the impact of the urban-rural income gap on environmental pollution and its impact mechanisms are re-organized, and the logical core of the environmental pollution impact of China's urban-rural income gap is further explored. This is not only conducive to dissolving China's urban-rural dual economic structure, but also an important guarantee for China's industrial transformation and the promotion of the "Industry" 2025 plan. Compared with the existing literature, the marginal contribution of this article lies in:

First, this article discusses the actual impact of China's urban-rural income gap on local environmental pollution and integrates the two dimensions of the demand side and the supply side to separately examine the impact path of the urban-rural income gap on environmental pollution. Urban-rural income distribution and environmental protection are both important topics in my country's economic research at this stage. Existing research mainly focuses on the inflection point of income level in the process of environmental pollution effects of the urban-rural income gap, therefore, combining the two perspectives of demand and supply to scientifically comb the relationship between the two will not only broaden the existing urban-rural income gap assessment perspective but also deepen the awareness of improving the regional environment and fostering new driving forces for industrial growth.

Second, this article takes the lead in researching the urban-rural income gap and environmental pollution in cities at the prefecture level and above. Existing literature research objects are mainly concentrated on the transnational (Han Jiabin and Han Mengying, 2015) or trans-provincial (Zhan Hua, 2016) level. This article re-examines the actual impact of the urban-rural income gap on environmental pollution from the level of prefecture-level and above cities. It is not only a further investigation of the actual impact of China's urban-rural income gap on China's environmental pollution but also a scientific basis for governments at all levels to accurately formulate environmental policies.

Third, this paper uses the most detailed urban-rural permanent population and its actual income data. Since the 1980s, the cross-regional migration of China's population has accelerated. Compared with the registered population, the local permanent population can more objectively reflect the size and structure of the local population. In the context of incomplete urban-rural data at the city level in the current various data statistics, this paper manually searches, merges, and calculates the urban-rural income gap in 270 prefecture-level and above cities in China from 2005 to 2015, which reflects in more detail the regional differences in China's urban-rural income gap and will also provide more detailed data support for subsequent research.

The rest of this article is arranged as follows: The second part is literature review; the third part is model setting and data explanation; the fourth part is empirical regression and results in analysis; the fifth part is the impact mechanism test; the sixth part is the relationship between urban-rural income gap and environmental pollution introduced by spatial correlation; the seventh part is a further discussion of the urban-rural income gap and environmental pollution: the perspective of environmental regulation effects; the eighth part is the conclusion and policy enlightenment.

2. Literature review

Grossman and Krueger (1991) and Panayotou (1993) Per capita income and environmental pollution have an "inverted U-shaped" impact, and although the EKC theory has certain flaws, environmental pollution has been incorporated into the income distribution research framework earlier. This is a great enrichment to the theoretical system of the income distribution. In subsequent studies, some scholars believe that the income gap, especially the widening of the urban-rural income gap, will often aggravate environmental pollution. Boyce (1994) established a power-weighted social decision-making model (PSDM) and pointed out that the poor tend to increase the development of natural resources to maintain basic survival, while the rich prefer to transfer assets to other regions when facing environmental pollution instead of investing locally to improve environmental quality, so the widening gap between the rich and the poor will significantly worsen the local environment. From the perspective of public expenditure, Magnani (2000) pointed out that the widening income gap will restrain the government's willingness to spend on the environment and lead to increased local pollution. Xiao Rong and Li Yangyang (2013) found through empirical research that the urban-rural income gap significantly increased the carbon emissions of provinces and municipalities in central and western China. Zhong Maochu and Zhao Zhiyong (2013) conducted an empirical study on China's inter-provincial panel data from 2003 to 2010 and concluded that the widening of the urban-rural income gap significantly increased local carbon emissions, while Zhang and Zhao (2014), Hao et al. (2016) and other studies also put forward similar views. Other studies believe that the widening of the urban-rural income gap will alleviate environmental pollution under certain conditions. Heerink et al. (1995) found through cross-country empirical results that the widening of the income gap does not necessarily directly lead to environmental degradation. Some scholars have pointed out that the urban-rural income gap and environmental pollution may have a non-linear interactive relationship. Lu Li and Gao Hongying (2016) passed the empirical test of the inter-provincial panel secretary and pointed out that China's urban-rural income gap has a significant "inverted U-shaped impact" on regional carbon emissions. Liu et al. (2018) combined the income gap between urban and rural areas in China from 1996 to 2015, carbon emissions, and the per capita income gap in cities at the prefecture level and above. They empirically support the views of Lu Li and Gao Hongying and point out that per capita income level determines the local EKC inflection point. It can be found that the academic circles still have disputes over the actual impact of the urban-rural income gap on environmental pollution.

In addition, environmental pollution is affected by many factors, and there is a lack of a unified understanding of how the urban-rural income gap through the mechanism path affects environmental pollution. Given the premise of other factors, environmental pollution is mainly closely related to market demand and manufacturer's supply. Because existing research usually only has a single perspective of "market demand" or "manufacturer supply", its research conclusions have obvious blind spots in explaining the dynamic law of China's environmental pollution evolution under the background of the continuous deepening of today's market economic system. Therefore, based on the dual perspectives of "demand-side" and "supply-side", this article summarizes and summarizes the two major mechanism paths through which the urban-rural income gap affects environmental pollution from the theoretical level:

2.1 Scale of demand

In the research on the consumer side, all the conclusions are that the scale of demand has an important impact on environmental pollution, but the magnitude and direction of its impact are widely disputed. Some scholars believe that the widening income gap between urban and rural areas has aggravated environmental pollution. Through the 1986-2008 China time-series study, Pan Dan and Ying Ruiyao (2010) found that the widening income gap has significantly increased environmental pollution, and the impact has a significant lag. Han Jiabin and Han Mengying (2015) found that the widening income gap will not be conducive to the improvement of the environmental quality of the country after analyzing the experience of translational research. Zhan Hua (2018) believes that the widening of the urban-rural income gap not only reduces the low-income group's consumption preference for environmentally clean products, but may also stimulate the conspicuous consumption of high-income groups, and ultimately lead to the deterioration of the regional environment. The research of Yang Yuhan (2019) also found that the widening of the urban-rural income gap has increased regional environmental pollution by affecting the purchasing power of residents.

However, some studies believe that the appropriate expansion of the urban-rural income gap has alleviated environmental pollution. On the one hand, in the initial stage of economic development, an appropriate expansion of the income gap may be beneficial to fostering market demand for environmentally clean products, which in turn has formed the formation of frontier manufacturers to maintain production. It is beneficial to curb regional environmental pollution (Foellmi, Zweimüller, 2006; Li Pingping, 2012). Liu Donghuang and Shen Kunrong (2012) found through empirical research that the narrowing of the urban-rural income gap will increase the overall consumption scale of the market, while Zhu Qin et al. (2012) calculated by using a sequence table of comparable input-outputs and found that the expansion of the consumption scale of Chinese residents will aggravate the environment Pollution. Ma Xiaowei et al. (2019) also found through empirical tests that the widening of the urban-rural income gap in China's provinces and municipalities from 2000 to 2012 significantly suppressed consumer carbon emissions.

2.2 Human capital

In the research on the supply side, human capital accumulation can effectively improve local environmental pollution has become a basic consensus (Goetz and Debertin, 1998; Lan and Munro, 2013), but there is still some controversy about how the urban-rural income gap affects regional labor costs. Many opinions believe that the widening of the urban-rural income gap will inhibit the accumulation of human capital. Chao Xiaojing and Shen Kunrong (2014), from the perspective of China's inter-provincial level, found that the expansion of the urban-rural income gap in provincial administrative regions from 1995 to 2012 will strengthen rural residents' education investment financing constraints, which will not be conducive to the accumulation of human capital in the region. Lv Wei et al. (2015) also believe that the widening of the urban-rural income gap will lead to educational inequality, which is not conducive to human capital accumulation in the long run. Based on China's current national conditions, Zhang Laiming and Li Jianwei (2016) pointed out that the expansion of urban and rural income is not conducive to the equalization of labor quality, and the limited investment in the human capital of rural residents will significantly hinder the expansion of human capital in China.

However, there are opinions that the supply of high-skilled labor not only significantly increases the productivity of high-skilled labor, but also produces significant positive externalities to other residents (Liang Wenquan and Lu Ming, 2015). The possible reason is that environmentally clean products are technology-intensive products, and their R&D and production may require key breakthroughs by top talents at certain stages. The moderately widening urban-rural income gap leads to the differentiation of human capital and may have a positive effect on the cultivation of top talents (Zweimuller, 2000). In other words, in the period when the overall human capital is insufficient, the expansion of urban and rural income can promote the accumulation and agglomeration of high-skilled human capital in certain periods and is conducive to the production of technology-intensive products including environmentally clean products. Gao Fan and Wang Yanan (2016) also believe that the structural agglomeration of human capital caused by the expansion of the urban-rural income gap may promote innovation. Sun Haibo et al. (2017) found that the accumulation of human capital reaches a certain threshold before it can play a significant upgrade and innovation effect. Therefore, it can be found that in some cases, although the expansion of the urban-rural income gap has led to a slowdown in the accumulation of human capital, the innovative effect of the spatial accumulation of high human capital may help alleviate regional environmental pollution.

Based on the above-mentioned theoretical induction and logical deduction, as well as current China's actual national conditions, this article puts forward the following hypotheses:

Hypothesis 1: The urban-rural income gap significantly affects China's environmental pollution, and the impact may exhibit EKC-type nonlinear characteristics.

China has a vast territory, and many conditions such as historical development, geographical location, factor endowments, institutional policies, etc., have significant differences between regions, which also makes China's economic development also show obvious differences. Based on the consumption scale theories such as Zhan Hua (2016), Li Zihao (2017), and Liu (2018) and the human capital theories sorted out in the previous article, this article further proposes:

Hypothesis 2: The impact of the urban-rural income gap on environmental pollution has not only the threshold effect of consumption scale but also the threshold effect of human capital. This phenomenon also has a significant geographic location.

3. Model setting and variable description

3.1 Model assumptions

Given the complexity of the impact of China's urban-rural income gap on environmental pollution, this article intends to design the following empirical model based on existing research:

$$PI_{it} = \beta_0 + \beta_1 G_{it} + \beta_2 \left(G_{it}\right)^2 + \lambda D + \xi_{it} \tag{1}$$

In the formula (1), PI represents pollution intensity, I represents cities at prefecture-level and above, and t represents years; G represents the urban-rural income gap; D is the set of control variables; ξ represents the residual term. To further test the real impact of the urban-rural income gap on China's environmental pollution, this paper introduces the quadratic term of the urban-rural income gap to investigate its possible nonlinear impact on environmental pollution.

3.2 Variable selection and description

3.2.1The explained variable

Environmental pollution (PI). This article selects China's prefecture-level to use the carbon emissions of the above-mentioned cities as a measure of regional environmental pollution. The main reasons are: first of all, with the emergence of events such as "global warming and sea-level rise", "the bleak future of the "Kyoto Protocol", "the escalation of disputes in the Paris Climate Agreement" and other events in recent years, countries and regions have become more concerned about the issue of carbon emissions. Secondly, China has grown into a newly industrialized country in the world, and carbon emissions, as an important indicator of the degree of industrialization, are closely related to industrial growth and transformation and upgrading; Finally, compared to factors such as sulfur dioxide emissions, wastewater emissions, smoke and dust emissions, China's carbon emissions related data are more complete and more credible. Therefore, in the empirical stage, this article chooses carbon emissions as a measure of urban pollution.

(1)Total regional carbon emissions (CO_2).This article studies the environmental pollution of production and life in prefecture-level and above areas. Since the carbon emissions of industrial power generation mainly come from thermal power generation, and China's factor endowment has long been "rich in coal and poor in oil", which has led to a high degree of dependence on coal for domestic power production. Therefore, this article refers to the method of Han Feng and Xie Rui (2017), Selecting the carbon emissions of coal, natural gas, and liquefied petroleum gas consumption in the region to estimate the carbon emissions of the entire region. The specific estimation methods are as follows:

$$I_{i,t} = C_{coal,i,t} + C_{natural,i,t} + C_{liquid,i,t} = \sigma \times \omega \times E_{coal,i,t} + \theta \times E_{natural,i,t} + \mu \times E_{liquid,i,t} \tag{2}$$

Among them, I represent the total carbon emissions of cities at the prefecture level and above. C_{coal}, $C_{natural}$, and C_{liquid} are the carbon emissions of coal, natural gas, and LPG respectively; $E_{electricity}$, $E_{natural}$, and E_{liquid} are the regional power generation, natural gas power generation, and LPG power generation, respectively; σ is the carbon dioxide emissions coefficient of coal, the equivalent value is 1.3023 kg/kWh (Ma Zhonghai et al., 1999); ω is the proportion of coal power generation in the total power generation. Because coal power generation statistics are gradually released after 2012, and coal power generation has long been the total thermal power generation in China, this paper selects thermal power generation as a substitute variable for coal power generation for conversion; θ is the carbon dioxide emission coefficient of natural gas, and μ is the carbon dioxide emission coefficient of liquefied petroleum gas.

(2) This article uses per capita carbon emissions (total carbon emissions/GDP, PI_P, kg/person) to reflect the carbon emissions of cities at prefecture-level and above in China, and adopts carbon emission intensity (total carbon emissions/GDP, PI_G, kg/yuan))as a substitute variable for robustness discussion.

3.2.2 Explaining variables

The income gap between urban and rural areas (G). Referring to the measurement method of the Gini coefficient in Chen Gang's (2011) research, this paper intends to adopt the urban Gini index (Gini Index) to reflect the regional urban-rural income gap. The specific calculation formula is:

$$G_{it} = 1 - p_{irt} \bullet w_{irt} + p_{iut} \bullet \left(2 - w_{iut}\right) \tag{3}$$

Among them, p_r and p_u are the proportions of the urban-rural population and urban population at prefecture level and above; w_r and w_u are the proportions of rural population's total income in the total regional income, and the proportion of urban population's total income in the total regional income. The value range of the urban-rural Gini coefficient is

[0,1]. The larger the value, the larger the urban-rural income gap, and vice versa, the smaller. Since China's urban population data of prefecture-level and above cities have been published relatively and completely in various statistical yearbooks and statistical bulletins since 2005, and the relevant data has been seriously missing again after 2015, the period of this paper is 2005-2015, and the urban-rural Gini coefficient of 270 cities at prefecture-level and above in China from 2005 to 2015 was calculated based on the above method.

3.2.3 Control variables

(1) Industrial structure (structure). Ma and Stern (2008) believe that the upgrading of the industrial structure reduces regional carbon emissions, and Shao Shuai et al. (2019) also pointed out that the upgrading of the industrial structure will increase the level of local carbon emissions. This article refers to the research of Yuan Yuan et al. (2016) and uses the logarithm of the per capita added value of the secondary industry (10,000 yuan/person).

(2) Economic openness (FDI). Given the serious lack of urban trade data within the research span, this article intends to use the foreign direct investment to reflect the degree of regional economic openness.

Xu Helian and Deng Yuping (2012) found that technological improvements brought about by foreign direct investment have significantly improved China’s environmental pollution; however, the “pollution paradise” hypothesis argues that foreign direct investment often brings environmental pollution to the host country’s low-end industries (Markusen And Venables, 1999; Keller and Levinson, 2002). And this article selects the logarithm of the local per capita foreign direct investment (USD/person) as an indicator reflecting the degree of capital freedom.

(3) Degree of urbanization (urban). Zhang Tengfei et al. (2016) pointed out that the expansion of urbanization has increased local carbon emissions, and Liddle (2004) also believes that urbanization may help alleviate carbon emissions. Therefore, this paper selects the proportion of the urban population in the total population to reflect the degree of urbanization in the region.

(4) Infrastructure. He Wenju(2019) found that improved infrastructure will increase residents' public transportation utilization rate and reduce carbon emissions. Indicators such as highway mileage and railway mileage within the jurisdiction can reflect the level of regional infrastructure construction to a certain extent. This paper selects the

number of buses per capita (vehicles/10,000 people) in cities at and above the local level to measure the level of regional infrastructure.

(5) Finance. Lu Hongyou et al.(2015) believe that the current fiscal expansion has regulated regional pollution to a certain extent. However, Feng Haibo and Fang Yuanzi (2014) found that the negative effects of the expansion of public fiscal expenditures on China's environmental pollution control have gradually emerged. This paper selects the proportion of local annual fiscal expenditures in GDP and takes the logarithm to measure the intensity of local public fiscal expenditures.

(6) Leverage. Tamazian et al.(2009) found that financial development has a significant inhibitory effect on per capita carbon emissions, but Boutabba (2014) believes that financial expansion has increased the total regional carbon emissions. Therefore, this article selects the regional financial leverage ratio as a measure of the degree of regional financial development. The specific calculation method is: leverage ratio= the balance of various loans of financial institutions at the end of the year/GDP.

3.3 Data sources and statistical analysis of variables

The period of the sample data in this article is selected from 2005 to 2015. The selected relevant data mainly come from the "China Statistical

Yearbook", "China City Statistical Yearbook", "China Regional Statistical Yearbook", "China Electric PowerYearbook", statistical yearbooks of various provinces and cities, and annual statistical bulletins of cities at the prefecture-level and above. To avoid the heteroscedasticity problem that may appear in the empirical process, this paper has carried out logarithmic processing on some variables. In particular, this article is restricted by the statistical results of urban and rural permanent residents in various yearbooks and statistical bulletins and excludes the urban and rural Gini coefficients of all cities in Jilin Province. In addition, to obtain balanced panel data, this paper further excluded some data from prefecture-level and above cities with a serious lack of relevant data. The statistical description of the variables is shown in Table 1:

Insert Table 1

4. Empirical Results and analysis

4.1 Empirical results of the benchmark model

Models 1-3 in Table 2 show the empirical results of the impact of the urban and rural Gini coefficient on per capita carbon emissions under the basic model. Model 1 examines the relationship between the urban and rural Gini coefficient and per capita carbon emissions without the control variables. Model 2 adds control variables but does not control the regional and time effects. Model 3 further controls the regional and time effects. The results show that the primary parameter of the urban-rural Gini coefficient is significantly positive, and the quadratic parameter is significantly negative, indicating that the impact of the urban-rural income gap on urban pollution in the process of expanding is "inverted U-shaped", which is consistent with the previous hypothesis; After the effects of control variables and control areas and time, the significance of the primary and secondary terms of the urban and rural Gini coefficients in Model 3 and the parameter values did not change significantly compared with Models 1 and 2, indicating that the selection of control variables is reasonable and the model is designed. According to the primary and secondary parameter values of the urban-rural Gini coefficient, it can be found that the inflection point of the urban-rural income gap on urban pollution is at 0.2779, that is, when the urban-rural income gap is lower than 0.2779, the expansion of the urban-rural income gap increases the area per capita and when carbon emissions are higher than 0.2779, the urban-rural income gap widens and reduces per capita carbon emissions.

In addition, the parameters of industrial structure and urbanization rate in each of the control variables of Model 3 are significantly positive, indicating that an increase in the proportion of the secondary industry's added value in GDP will increase per capita carbon emissions. In other words, the current economic growth model characterized by the expansion of the secondary industry has significantly increased regional environmental pollution. The parameter of FDI is significantly negative, which shows that in China, FDI has significantly improved China's environmental pollution through the technology diffusion effect, while its "pollution paradise" effect is relatively limited in China. The parameter of the urbanization rate is significantly positive, indicating that China's rapid industrialization and urbanization have aggravated environmental pollution for a long time. Infrastructure parameters are not significant, indicating that it has no significant relationship with the environmental pollution in China. The coefficient of fiscal expenditure is significantly negative, indicating that an increase in government expenditure will increase per capita carbon emissions. The leverage ratio parameter is significantly negative, indicating that regional financial development may help to weaken production financing constraints, encourage corporate research and development, and upgrade to alleviate local pollution. In terms of the symbol and significance of comprehensive control variables, industrial structure, FDI, urbanization rate, fiscal expenditure, and leverage ratio will significantly affect local environmental pollution. Therefore, the current energy-saving and emission-reduction targets can mainly focus on optimizing industrial structure, economic opening, urbanization, government finance, and regional financial development.

Model 3 is the empirical result of the fixed effects panel model (IV-FE) under the condition that the explained variable lags one period as the instrumental variable. The result shows that the primary and secondary parameters of the urban and rural Gini coefficient are significant, and the signs are consistent with expectations. Model 4 shows the influence of the urban and rural Gini coefficient on the per capita carbon emission intensity under the PCSE model. The first term of the urban and rural Gini coefficient is significantly positive and the second term is significantly negative, which is also consistent with the original model. Therefore, in combination with the models 1-5 in Table 2, it can be found that the urban-rural income gap in prefecture-level and above cities in China from 2005 to 2015 has a significant "inverted U"-shaped impact on urban pollution.

Insert Table 2

4.2Robustness and endogeneity test

(1) Robustness test. Model 1-2 performed bilateral tailing of 1% and bilateral tailing of 1% on the explained variables respectively. Among them, the primary parameter of the urban and rural Gini coefficient was significantly positive, and the quadratic parameter was significantly negative, which was consistent with the regression results of the basic model; The inflection points of Model 1-2 are 0.2727 and 0.2953, which are still close to the results of the basic model. Model 3 uses carbon emission intensity to replace the original indicator as to the explained variance of the model. The primary term of the urban and rural Gini coefficient is significantly positive, and the second term is significantly negative. The inflection point is about 0.3070, which is also basically consistent with the original model. Model 4 replaces the original control variables with the one-period lagging term of the control variables to conduct an empirical test on the original model. The urban-rural Gini coefficient is still significantly positive for the primary term and significantly negative for the quadratic term, and the inflection point is at about 0.2546 which is still consistent with the original model.

(2) Endogenous testing. Given the serious endogeneity between the variables may have a significant impact on the empirical regression results, this article must fully consider the potential endogeneity of the model. On the one hand, the setting of the empirical model in this paper cannot include all the factors that affect environmental pollution, such as environmental protection expenditures and R&D personnel in cities at and above the level; on the other hand, there is a two-way cause and effect between the explained variables and explanatory variables of the empirical model in this paper. The relationship is that the urban-rural income gap affects environmental pollution, and environmental pollution, in turn, affects the urban-rural income gap. Therefore, this article refers to the research of Gao Fan and Wang Yanan (2016) and selects the explanatory variable to lag one period as an instrumental variable to test the model's endogeneity. The results are shown in Model 5, the Hansen test value is within a reasonable interval, indicating that the selection of the instrumental variables in this paper is reasonable and effective; after the system GMM model is used to deal with the endogenous problem, the primary parameter of the urban and rural Gini coefficient is significantly positive, and the quadratic parameter is significant It is negative, which is consistent with the empirical results of the basic model; in Model 5, the

inflection point of the urban-rural income gap on China's environmental pollution is located at about 0.2615, which is not much different from the inflection point of the basic model.

Therefore, combining the two-sided shrinking test, the two-sided censoring test, the explanatory variable/explanatory variable index replacement method, and the systematic GMM method can be considered that the empirical results of the basic model are robust.

Insert Table 3

4.3 Heterogeneity analysis

Given China's vast territory, factors such as geographic location, factor endowments, and historical conditions have significant heterogeneity among regions, and the above heterogeneity may lead to differences in the impact of the urban-rural income gap on urban environmental pollution. Therefore, it is very important to discuss the heterogeneity of urban environmental pollution caused by the urban-rural income gap. This article refers to existing research and uses three classification standards to discuss consistency: First, according to the practice of most traditional documents, the sample cities are divided into eastern, central, and western regions according to their geographic location; the second is to draw on the research of Li Jingrui (2017), divide the median of the sample capital-labor ratio in 2013 as the dividing line, and divide the cities into high and low according to the capital-labor ratio of each city in 2013; the third is to refer to the method of city size division by Sun Weizeng et al. (2018) and classify cities with an urban population of more than 3 million in 2013 as large cities, and classify them as small and medium-sized cities with an urban population of less than 3 million. The results of heterogeneity analysis are shown in Table 4:

Models 1-3 respectively give the empirical results of the impact of the urban-rural income gap on urban pollution in the eastern, central, and western regions of China. Among them, the "inverted U-shaped" impact of the urban and rural Gini coefficient on per capita carbon emissions is more significant in the eastern, central, and western regions of China. From the perspective of the inflection point of environmental pollution, the inflection points in the eastern, central, and western regions are 0.2276, 0.2574, and 0.2860 respectively, which are all within the value range of [0,1], indicating that the income gap between urban and rural areas in China from 2005 to 2015 has a significant "inverted U-shaped" impact on environmental pollution in the eastern, central, and western regions. In addition, the inflection point of China's environmental pollution has been increasing from the east, middle, and west, indicating that from the east to the west, the pollution incentive range of the widening urban-rural income gap in China has shown a continuous expansion. Among the control variables, industrial structure, urbanization, and fiscal intensity have significantly expanded environmental pollution in the eastern region, while FDI and infrastructure have significantly suppressed environmental pollution, and the environmental pollution effect of the leverage ratio is not significant; for the central region, the urbanization rate, fiscal intensity, and increased environmental pollution have no significant impacts on other factors; for the western region, the industrial structure and urbanization rate are the main factors affecting local environmental pollution, and the effects of other factors are less obvious.

Model 4-5 gives the empirical results of capital-labor endowment heterogeneity. The first-order parameter of the urban-rural Gini coefficient in areas with a high capital-labor ratio and the low-capital-labor ratio is significantly positive, and the quadratic parameter is significantly negative. Moreover, the environmental inflection point of areas with a high capital-labor ratio is located at 0.2797, while the environmental inflection point of areas with a low capital-labor ratio is located at 0.2784.

The inflection points of the two types of areas are similar. Therefore, the income gap between urban and rural areas in China is either in areas with high capital-labor ratios or areas with high capital-labor ratios. Areas with low capital-labor ratios all have a significant "increase" and then "decrease" influence on environmental pollution, and there is no significant difference in the locations of the environmental pollution peak points of the urban-rural income gap between the two types of areas. Among the control variables, the industrial structure of cities with high capital-labor ratio, urbanization rate, and fiscal strength are the main factors that increase environmental pollution, while FDI plays a major role in reducing pollution; for cities with low capital-labor ratios, the industrial structure and urbanization rate are the main factors that exacerbate urban pollution, while FDI and leverage have significantly suppressed local pollution.

In addition, this article draws on the research of Sun Weizeng et al. (2018), classifies cities at prefecture level and above with urban populations of more than 3 million in 2015 as large cities, and classifies the remaining samples as small and medium-sized cities, trying to discuss the heterogeneous impact of urban-rural income gap on environmental pollution from the perspective of city scale, and the results are shown in

Model 6-7. The results show that the urban-rural Gini coefficient of large cities and per capita carbon emissions show a “rising first and then suppressing”, with an inflection point at 0.2039; while the urban-rural Gini coefficient of small and medium-sized cities also shows a trend of “rising first and then suppressing” per capita carbon emissions, its inflection point is at 0.2903, which is much larger than that of large cities. Therefore, the urban-rural income gap between the two cities has the same impact on environmental pollution. The scope of pollution incentives for the income gap between urban and rural areas is much higher than that in large cities. Among the control variables, the industrial structure, urbanization rate, and fiscal intensity in large cities have increased environmental pollution, while FDI and infrastructure have played a good environmental cleaning effect; for small and medium-sized cities, the industrial structure and urbanization rate have increased environmental pollution. The main factors of pollution and FDI and leverage ratio have a significant positive effect on reducing local pollution.

In summary, the "inverted U-shaped" impact of the urban-rural income gap on environmental pollution is significant in the eastern and central regions, but not in the western region. In addition, the environmental inflection point of the urban-rural Gini coefficient in the central region, high-capital-labor regions, and small and medium-sized cities is far away. Therefore, the urban-rural income gap has only an increased effect on regional environmental pollution in reality; while the environmental inflection points of the eastern region, low-capital labor regions, and urban-rural Gini coefficients of large cities are located at a lower position. Therefore, the urban-rural income gap in the above-mentioned regions has a significant "inverted U-shaped" impact on environmental pollution.

Insert Table 4

5. Mechanism test

The previous article empirically tested the actual impact of China's urban-rural income gap on environmental pollution and discussed its robustness and heterogeneity. As mentioned above, the urban-rural income gap has an impact on the regional environment from both the demand and supply sides. Therefore, from the demand side, this article uses the logarithm of the regional per capita consumption (yuan/person) as an intermediary index to test the changes in the urban-rural income gap. The actual impact of changes in the scale of demand, which in turn leads to changes in regional environmental pollution, is specifically measured as follows:

$$consumption_{it} = consumption_{iut} \bullet p_{iut} + consumption_{irt} \bullet p_{irt}$$

Among them, $consumption_{it}$ represents the actual per capita actual consumption expenditure of cities at the I prefecture level and above in year t (thousand yuan/person), $consumption_{iut}$ and $consumption_{irt}$ are the actual urban per capita consumption expenditures and rural per capita actual consumption expenditures, respectively. Among them, $consumption_{iut}$ and $consumption_{irt}$ are the per capita nominal consumption expenditure of urban residents and the per capita nominal consumption expenditure of rural residents, respectively, obtained by deflation according to the urban consumer price index of the province (city) where the city is located and above, and the consumer price index of rural residents in China (base period: 2005).In addition, this article uses the human capital index as an intermediary indicator to test from the perspective of the supply side that the urban-rural income gap causes changes in human capital, and then affects the actual impact of environmental pollution. The calculation method of the human capital index is as follows:

$$h_{it} = \frac{edu_{ipt} \bullet 6 + edu_{ijt} \bullet 12 + edu_{ict} \bullet 16}{du_{ipt} + edu_{ijt} + edu_{ict}}$$

(4)

Among them, h is the human capital index, edu is the number of students in school, and p, j, and c are an elementary school, junior high school, and university, respectively.

In addition, to effectively test the mediation effect, this paper sets the empirical model as:

$$consumption_{it} = \alpha_{10} + \alpha_{11} G_{it} + \lambda D + \varepsilon_{it} \tag{5}$$

$$HC_{it} = \alpha_{20} + \alpha_{21} G_{it} + \lambda D + \varepsilon_{it} \tag{6}$$

$$PI_{it} = \alpha_{30} + \alpha_{31} G_{it} + \alpha_{32} consumption_{it} + \alpha_{33} G_{it} \bullet consumption_{it} + \lambda D + \varepsilon_{it} \tag{7}$$

$$PI_{it} = \alpha_{40} + \alpha_{41} G_{it} + \alpha_{43} HC_{it} + \alpha_{44} G_{it} \bullet HC_{it} + \lambda D + \varepsilon_{it} \tag{8}$$

$$PI_{it} = \alpha_{50} + \alpha_{51} G_{\mathrm{it}} + \alpha_{52} consumption_{it} + \alpha_{53} HC_{it} + \alpha_{54} G_{it} \bullet consumption_{it} + \alpha_{55} G_{it} \bullet HC_{it} + \lambda D + \varepsilon_{it} \tag{9}$$

Among them, consumption and HC represent the regional per capita consumption and human capital index, respectively. Equations 1-2 test the mediating effect of per capita consumption and human capital index on the urban-rural income gap. Equations 3-4 test the mediating effects of per capita consumption and human capital in the process of urban-rural income gap affecting environmental pollution. Equation 5 adds the interaction terms of the urban-rural income gap and per capita consumption, and human capital index to the original model, and comprehensively examines the changes in market demand and human capital caused by changes in urban-rural income gap, and thus the actual impact on urban pollution. The test results are shown in Table 5 below:

Insert Table 5

The results of Model 1-2 show that the expansion of the urban-rural income gap in cities at the prefecture-level and above in China from 2005 to 2015 has generally restrained regional consumption and human capital. And through the test results of Model 3, it can be found that the expansion of the consumption scale can not only increase the consumption of environmentally friendly products and reduce pollution, but also may increase environmental pollution due to the restriction of the urban-rural income gap. The results of Model 4 show that although the accumulation of human capital helps directly reduce urban environmental pollution, the urban-rural income gap can also increase environmental pollution through the indirect effects of human capital.

From the results of Model 5, it can be seen that after incorporating per capita consumption， human capital, and their respective interactions with urban and rural Gini coefficients into the model, at the end of the demand scale, the parameter of per capita consumption is significantly negative, and the parameter of the interaction term with the urban-rural income gap is significantly positive, which means that the expansion of demand directly reduces urban pollution on the one hand. This may be caused by the upgrade of demand caused by consumption expansion and then promote the consumption of environmentally friendly products; on the other hand, the urban-rural income gap may indirectly and significantly restrain the overall consumption scale of environmentally friendly products through the income distribution effect while the scale of demand is expending. On the human capital side, the human capital index parameter is significantly negative, and the interaction term with the urban-rural income gap is positive. This shows that the expansion of human capital also directly reduces urban pollution. This is obviously because the expansion of human capital has expanded the accumulation of skilled labor. "Pool" actively promotes the production of environmentally friendly products by enterprises; however, the urban-rural income gap induces the formation of a small amount of high-end human capital through the income distribution effect, and indirectly hinders the improvement of the regional environment by inhibiting the accumulation of local human capital. The test results of Model 5 are further obtained after the first derivative of the demand scale and human capital are obtained:

$$\frac{\partial PI}{\partial consumption} = 1.6854G - 0.2203, \frac{\partial PI}{\partial HC} = 6.9450G - 2.1161 \quad (10)$$

When $\partial PI / \partial consumption = 0$ it can be found that the environmental pollution inflection point of the urban and rural Gini coefficient to per capita consumption is at 0.1307, that is, when the urban and rural Gini coefficient is less than 0.1307, the expansion of per capita consumption alleviates environmental pollution; when the urban and rural Gini coefficient is greater than 0.1307, the expansion of per capita consumption aggravates environmental pollution. And when $\partial PI / \partial HC = 0$ it was found that the environmental pollution inflection point of the urban-rural Gini coefficient on the human capital index was at 0.3047, that is, when the urban-rural Gini coefficient was less than 0.3047, the human capital index had a depressing effect on per capita carbon emissions; when the urban-rural Gini coefficient was greater than 0.3047, the human capital index promotes per capita carbon emissions.

Based on the above results, it can be concluded that the scale of demand and human capital have significantly affected environmental pollution and the impact has a "positive U-shaped" trend, and the urban-rural income gap has played a key control role in the above-mentioned impact process.

6. The relationship between urban-rural income gap and environmental pollution introduced by spatial correlation

With the strengthening of China's regional integration trend, the correlation between production and consumption in various regions continues to deepen. Given the possible spatial correlation of environmental pollution, the concept of "spatial correlation" needs to be introduced when examining the environmental pollution effects of the urban-rural income gap. In other words, the environmental pollution among cities above the prefecture-level in China may be geographically related. To characterize the spatial correlation of environmental pollution between regions, it is required to select an appropriate spatial weight matrix to modify the original model. This article uses Moran's I index to reflect the relevance of regional environmental pollution, and its basic expression is as follows:

$$Moran's\_I=\frac{\sum_{i=1}^{n}\sum_{j=1}^{n}d_{ij}\left(PI_i-\overline{PI}\right)\left(PI_j-\overline{PI}\right)}{S^2\sum_{i=1}^{n}\sum_{j=1}^{n}d_{ij}} \tag{11}$$

In the above formula, $\overline{PI}=\frac{1}{n}\sum_{i=1}^{n}PI_i$ $S^2=\sum_{i=1}^{n}\left(PI_i-\overline{PI}\right)^2$ n is the number of cities at the prefecture-level and above (the value is 270 in this paper), and d_{ij} is the spatial weight matrix. Considering that the spatial correlation of environmental pollution is mainly manifested in the degree of geographical distance, this paper selects the geographical distance matrix as the space weight matrix, and the geographical distance matrix is defined as $d_{ij}=\begin{Bmatrix}1/d^2, i\neq j\\ 0, i=j\end{Bmatrix}$ d is the distance between the urban areas of two prefecture-level and above cities.

Concerning existing research, this paper sets the environmental pollution model of the urban-rural income gap including spatial correlation as:

$$PI_{it}=\alpha_{60}+\alpha_{61}G_{it}+\alpha_{62}+\left(G_{it}\right)^2\lambda D+\rho+\varepsilon_{it} \tag{12}$$

The test results of the relationship between the urban-rural income gap and environmental pollution with the introduction of spatial correlation are shown in Table 6. The results of Model1 show that, after considering the spatial correlation, the primary parameters of the urban and rural Gini coefficients in the full sample and the eastern, central, and western samples are still significantly positive, and the quadratic parameters are significantly negative, and the size and sign of the parameter are similar to the regression results of the basic model, indicating that from 2005 to 2015, the impact of urban-rural income gaps on environmental pollution in all prefecture-level and above cities in China or eastern, central, and western cities showed a steady "inverted U-shaped" trend. The environmental inflection points of the country, the east, the central, and the west are located at 0.2510, 0.2205, 0.2505, and 0.2672 respectively, which have not changed much from the basic model. In addition, the sign, size, and significance of the control variables are not much different from the regression results of the basic model. Therefore, it can be considered that it is reasonable to incorporate spatial correlation into the basic model. In addition, after incorporating spatial correlation into the basic model, the ρ parameter is positive across the country and in the eastern, central, and western regions, and both have passed the 1% significance test, indicating that whether it is in the country or the eastern, central, and western regions internally, there is a significant positive spatial correlation between environmental pollution in cities at prefecture level and above. In other words, the increase in the environmental pollution in a specific area will significantly drive environmental pollution in surrounding areas.

Insert Table 6

7. Further discussion on the urban-rural income gap and environmental pollution: the perspective of environmental regulation effects

From the foregoing, it can be seen that the urban-rural income gap has a significant "inverted U-shaped" impact on urban pollution, and this impact is realized through its nonlinear impact on the scale of demand and human capital. So in the context of China's increasingly strict environmental system in recent years, what is the actual impact of the urban-rural income gap on urban pollution? Based on the above perspective, examining the actual impact of urban-rural income disparity on urban pollution may help to better understand the inherent relationship between China's urban-rural income disparity and regional environmental pollution. Zhanhua (2018) pointed out that the intensity of environmental regulations and the urban-rural income gap has had a significant impact on the regional environment. Therefore, this paper re-examines the urban-rural income gap and environmental pollution in cities at the prefecture level and above in China from the perspective of the intensity of environmental regulations.

Environmental regulation intensity (regulation). Existing studies have adopted three main types of environmental regulation indicators: one is the proportion of pollution investment and pollution charges in each region in the added value of the secondary industry; the other is the laws, regulations, policies, rules, and regulations related to the environment formulated and promulgated for the region organizing documents, using the number of results to reflect the intensity of regional environmental regulations; third, constructing the intensity of local pollution emissions and the intensity of environmental regulations with the help of regional industrial smoke, industrial wastewater, and sulfur dioxide emissions as a proportion of the added value of the secondary industry. As this article selects China's prefecture-level and above cities from 2005 to 2015 as the research object, this article refers to the research of Song Deyong and Yang Qiuyue (2019) and uses industrial smoke, industrial wastewater, and sulfur dioxide emissions to account for the proportion of the secondary industry's added value in 2005-2015 China's prefecture-level and above cities' environmental regulation intensity index, the specific calculation method is as follows:

$$pd_{ijt} = p_{ijt}/GDP_{\sec,\, ijt} \tag{13}$$

In the above formula, p_{ijt} represents the emissions of the jth pollutant from prefecture-level and above cities in year t, GDP_{sec} represents the added value of the secondary industry, and pd represents the pollution emission intensity per unit of the added value of the secondary industry. On this basis, the above calculation results are further standardized:

$$pd^{s}_{ijt} = \frac{pd_{ijt} - \min pd_j}{\max pd_j - \min pd_j} \tag{14}$$

In the above formula, pd^{s}_{ijt} is the normalized value of p_{ijt}. Based on the above results, the intensity of environmental regulations can be calculated:

$$regulation_{it} = \frac{n}{\sum_{j=1}^{n} pd^{s}_{ijt}} \tag{15}$$

To investigate how the urban-rural income gap affects urban pollution from the perspective of environmental regulation, this paper introduces environmental policies based on the original model, to explore the actual effect of environmental regulation in the impact of the urban-rural income gap on environmental pollution, the model is as follows :

$$G_{it} = \beta_{10} + \beta_{11} \ln reg_{it} + \lambda D + \varepsilon_{it} \tag{16}$$

$$PI_{it} = \beta_{20} + \beta_{21} G_{it} + \beta_{22} \ln reg_{it} + \lambda D + \varepsilon_{it} \tag{17}$$

$$PI_{it} = \beta_{30} + \beta_{31} G_{it} + \beta_{32} \ln reg_{it} + \beta_{33} \ln reg_{it} + \lambda D + \varepsilon_{it} \tag{18}$$

$$PI_{it} = \beta_{40} + \beta_{41} G_{it} + \beta_{42} \left(G_{it}\right)^2 + \beta_{43} \ln reg_{it} + \beta_{44} \ln reg_{it} \cdot G_{it} + \lambda D + \varepsilon_{it} \tag{19}$$

Appropriate smoothing of the original data is very important for model checking. In this system of equations, this paper takes the logarithm of the environmental regulation intensity index, abbreviated as lnreg. The results are shown in Table 7. The results of Model 1 show that the lnreg parameter is significantly negative, indicating that environmental regulations have significantly suppressed the urban-rural income gap. From the results of Model 2, it can be found that the primary parameter of environmental regulation is significantly negative, and the second parameter is significantly positive. This indicates that theoretically, the impact of environmental regulation on environmental pollution is "inhibiting" and then "promoting" positive. The possible reason for the "U-shaped" trend is that: appropriate environmental regulations can help eliminate high-polluting enterprises and effectively regulate residents' consumption behavior. Industrial transformation and consumption upgrades can effectively reduce environmental pollution; however, as the intensity of regulation continues to increase, the excessive environmental threshold may not only inhibit the daily needs of ordinary residents but also force companies to "steal discharge" of pollutants, which will increase environmental pollution. According to Model 3, it can be seen that the urban and rural Gini coefficient parameter is significantly positive, that is, the expansion of the urban and rural Gini coefficient in China at this stage has increased the local per capita carbon emissions as a whole. Model 4 adds the urban-rural Gini coefficient based on Model 2. As a result, the primary term of environmental regulation is significantly negative, the second term is significantly positive, and the parameter of the urban-rural income gap is significantly negative. Therefore, it can be considered that the urban-rural Gini coefficient has played a significant intermediary role in the process of environmental regulation in the process of "suppressing" and then "promoting" carbon emissions per capita. That is, appropriate environmental regulations can help improve the urban-rural income gap, and thus reduce environmental pollution, in turn, excessively stringent environmental regulations may increase the income gap between urban and rural areas and worsen the regional environment.

Insert Table 7

8. Conclusions and policy implications

Environmental protection and the income gap between urban and rural areas are hot issues of concern to the Chinese economy and society at this stage. This article explores the impact and mechanism of the urban-rural income gap in China's prefecture-level and above cities on environmental pollution from 2005 to 2015. Different from the existing research which mainly starts from the perspective of income level, this article first points out from the theoretical and logical level: the urban-rural income gap mainly affects environmental pollution through the scale of demand and human capital, and the above-mentioned mechanism constitutes the impact of the urban-rural income gap an important reason for the "inverted U-shaped" trend effect in which environmental pollution first increases and then decreases. Based on the above logical deduction, this paper uses panel data from 270 prefecture-level and above cities in China from 2005 to 2015 for empirical testing. The results show that the income gap between China's urban and rural areas has indeed led to an "inverted U-shaped" trend in local environmental pollution, and the inflection point of environmental pollution appears at 0.2779. The "inverted U-shaped" trend of environmental pollution of the urban-rural income gap is notable in the eastern, central, and western regions, regions with high capital-labor ratio, low capital-labor ratio, or large and small cities. The urban-rural income gap significantly affects environmental pollution through two channels: demand scale and human capital. The inflection point of urban-rural income environmental pollution between demand scale and human capital is located at 0.1307 and 0.3047. This is also the main cause of the "inverted U-shaped" trend of environmental pollution caused by the urban-rural income gap. Given the potential spatial correlation of environmental pollution, the empirical results of the spatial correlation model in this article show that after the introduction of spatial correlation, the "inverted U-shaped" trend of China's urban-rural income gap on environmental pollution is still significant, with the inflection point at 0.2501 and geographical proximity and the impact of the correlation on environmental pollution is also significant. Environmental regulations have a "positive U-shaped" impact on environmental pollution through the income gap between urban and rural areas, in other words, reasonable environmental regulations can help improve the environment. However, excessive environmental regulations will not help energy conservation and emission reduction but may increase environmental pollution.

Therefore, this article has the following policy enlightenments to deal with China's environmental pollution at this stage:

First, each region should choose the macro-control measures for the urban-rural income gap that is appropriate to the region's characteristics and that can maximize the local potential to ensure stable economic growth and steady improvement of residents' lives while maximizing energy conservation and emission reduction. The eastern region, regions with high capital-labor ratios, and large cities' urban-rural income gaps are already at a low overall position, but proactively adopting urban-rural economic integration and promoting urban-rural integration can still effectively alleviate environmental pollution; for the central and western regions, low-capital-labor regions as for small and medium-sized cities, the integration of urban and rural income may increase local pollution in the short term, and it is particularly important to establish a governance system that coordinates industrial growth and environmental protection.

Second, relying on urban and rural income governance policies and scientifically combining market mechanisms to manage the local environment. In areas with low urban-rural income gaps, market consumption and basic education should be actively expanded, especially support and tilt for inclusive people's livelihood expenditures; in areas with high urban-rural income gaps, local industry status, resource endowments, etc. should be combined objective reality and reasonable promotion of consumption upgrades and human capital accumulation, to avoid excessive consumption and waste of resources.

Third, build and improve a comprehensive environmental protection management system. In the process of urban-rural dualization and environmental pollution control, it is particularly critical to construct and improve the pollution control system from the perspective of regional characteristics. Therefore, effectively explore the pollution control effects of industry, urbanization, and environmental regulations, increase market-oriented construction, actively participate in and integrate the global production system, comprehensively promote infrastructure construction, encourage and guide financial development, technological innovation, and other means that will pollute the region Governance is of great significance.

Fourth, focus on the coordination of local governance and regional cooperation. The spatial relevance of environmental pollution requires that regions need to gradually get rid of the previous single local governance model and transform it into regional cooperative governance. Therefore, it is necessary to encourage the transition from regional competition to regional cooperation, eliminate regional administrative barriers and local protectionism, and promote regional Inter-industry collaboration and integration, and integration of regional factor markets to improve resource efficiency.

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Acknowledgements:

None declared to all authors. The responsibility for any errors rests solely with the authors.

Funding:

The authors are grateful for financial support from the major project of the National Social Science Foundation of China (Grant No. 17ZD099).

Availability of data and materials:

The data on the quality of export products in the article comes from the China Customs Database, and the data on the control variables at the enterprise level comes from the Database of Chinese Industrial Enterprises.

Competing interests:

The authors declare that they have no competing interests.

Consent to publish:

This manuscript does not contain data from any individual person.

Ethics approval and consent to participate：

There is no human participants, human data or human tissue involved in the manuscript.

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Conceptualization: Wei-wei He,

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