Does urban-rural income inequality increase agricultural fertilizer or pesticide use? A provincial panel data analysis in China

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Abstract:

The large urban-rural income inequality and indiscriminate use of fertilizer and pesticide, as well as the related environment degradation in China during the past decades concern the society. However, little is known about the relationship between the urban-rural income inequality and agricultural fertilizer and pesticide use in China. Based on the environmental Kuznets curve hypothesis, this study aims to reveal how the urban-rural income inequality affects fertilizer and pesticide use from 1995 to 2015 in China. The results show that the relationship between per capita income of the rural households and per hectare fertilizer and pesticide use supports the environmental Kuznets curve hypothesis. Meanwhile, there exists a significant and positive relationship between the urban-rural income inequality and per hectare fertilizer and pesticide use. The share of agricultural value added in provincial gross domestic product not only directly influences fertilizer and pesticide use, but affects the relationship between the urban-rural income inequality and fertilizer and pesticide use. This study demonstrates that more efforts should be devoted to narrowing the urban-rural income inequality and deepening the reform of agricultural research and extension system to reduce agricultural fertilizer and pesticide use in China.

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Keywords:

urban-rural income inequality; pesticide; fertilizer; environmental Kuznets curve; China

1. Introduction

China has made significant achievements in agricultural and rural development during the past decades since 1978 (Huang and Rozelle, 1996; Huang et al., 2010; Lin, 1992; Wang et al., 2013). Per capita income of the rural households, measured at 2015 constant price, has increased from about 713 Chinese yuan (CNY) in 1978 to 10772 CNY in 2015, with the annual growth rate at 7.6% (National Bureau of Statistics of China, 2016a). However, there are two critical problems that greatly concern the society: the large urban-rural income inequality and serious environment degradation mainly due to the intensive use of fertilizer and pesticide (Carter, 2012; Huang et al., 2015; Zhang et al., 2015).

In general, the change in the urban-rural income ratio has experienced three stages from 1978 to 2015. During the first stage (1978-1988), the urban-rural income ratio narrowed from 3.2 to 1.9 thanks to the rural reform (National Bureau of Statistics of China, 2016a). However, it constantly rose to 3.3 in 2009 due to mixed reasons (National Bureau of Statistics of China, 2016a). Although the urban-rural income ratio again fell to 3.0 during the third stage (2010-2015), it almost equaled to the level in the late 1970s (National Bureau of Statistics of China, 2016a). In the context, the negative effects caused by the growing urban-rural income inequality attract much attention (Carter, 2012; Gao et al., 2014).

Moreover, the serious environmental degradation becomes one of the key factors that reduce social welfare in China, and the emission of agricultural pollutants is one of the main sources (Ongley et al., 2010; Rozelle et al., 1997). In particular, the intensive and indiscriminate use of fertilizer and pesticide in agricultural production has been often accused of causing serious deterioration of soil quality, water eutrophication and greenhouse gas emission (Kahrl et al., 2010;

Zhang et al., 2015; Zhu and Chen, 2002). In essence, agricultural productivity growth in China highly depends on fertilizer and pesticide use, and correspondingly, China has become the largest user of fertilizer and pesticide, consuming more than 60 million tonnes of fertilizer and 1.78 million tonnes of pesticide in 2015 (National Bureau of Statistics of China, 2016b).

In the context of the environmental Kuznets curve (EKC) hypothesis, there exists an inverted U-shaped relationship between per capita income and environment degradation (Grossman and Krueger, 1991). For a long time, however, the EKC hypothesis has been often empirically examined from the output-side perspective of environmental evolution using the emissions of pollutants including carbon dioxide (CO_2), sulfur dioxide (SO_2) and suspended particle matter (SPM) (Kaufmann et al., 1998; Lin et al., 2016; Seldon and Song, 1994). In contrast, the empirical studies of the EKC hypothesis from the input-side perspective of environmental evolution are extremely scarce except for some studies of energy consumption (Nguten-Van, 2010). Hence, little is known about the relationship of rural income and urban-rural income inequality with agricultural fertilizer and pesticide use.

This study aims to contribute to the literature by focusing on the relationship between the urban-rural income inequality and agricultural fertilizer and pesticide use, on the basis of the EKC hypothesis. In China, to narrow the urban-rural income inequality and reduce agricultural fertilizer and pesticide use are two critical tasks for sustainable economic development. This study, therefore, may have important policy implications. The analysis here is conducted on a panel dataset for 25 provinces in China during the period 1995-2015. It should be noted that in China, the province-level administrative regions are divided into three four groups: the centrally-administered municipalities, provinces, the autonomous regions, and the special administrative regions. This study focuses on the provinces within the Mainland China. To facilitate the expression, this study uniformly uses "province" to refer to the provincial administrative regions. The remainder of this study is structured as follows. Section 2 provides an overview of the main empirical literature on the EKC hypothesis and environment-inequality relationship. Section 3 introduces the sample collection, model specification and data. Section 4 shows the empirical results and develops some discussion. The final section concludes the study.

2. Literature Review

There is a growing body of empirical literature about the relationship between economic development and environment degradation based on the so-called EKC hypothesis (Dinda, 2004; Stern, 2004). Grossman and Krueger (1991) conducted the pathbreaking work, in which an econometric model was developed to investigate the environment impacts of the North American Free Trade Agreement. It was concluded that the concentrations of SO_2 and smoke increase as per capita gross domestic product (GDP) grows at low levels of national income, but then decrease with the growth of per capita GDP at higher levels of income (Grossman and Kruger, 1991). In a subsequent study, Panayotou (1993) firstly used the EKC to describe the inverted U-shaped relationship between per capita income and environment degradation.

During the following decades, many emerging studies aimed to empirically examine the EKC hypothesis (Dinda, 2004; Stern, 2004). A group of empirical studies confirmed that there exists an inverted U-shaped relationship between environmental degradation and per capita GDP or income (Dinda, 2004; Stern, 2004). Using a cross-national panel dataset from the Global Environment Monitoring System, Seldon and Song (1994) concluded that per capita emission of SPM, SO_2, nitrogen oxide (NO_x) and carbon monoxide (CO) showed a significant inverted U-shaped relationship with per capita GDP. By taking advantage of the same data source, Grossman and Krueger (1995) examined the reduced-form relationship between per capita income and four environmental indicators: urban air pollution, the state of the oxygen regime in river basins, fecal contamination of river basis, and contamination of river basins by heavy metals, and found that environmental quality experienced an initial deterioration followed by a subsequent improvement with the growth of per capita GDP. In the case of the United States, List and Gallet (1999) used a state-level panel dataset in terms of SO_2 and NO_x emissions during the period 1929-1994, and provided evidence that the EKC hypothesis is tenable. Using a time series dataset of China from 1975 to 2005, Jalil and Mahmud (2009) observed an inverted U-shaped relationship between per capita real GDP and CO_2 emission. Similarly, Riti et al. (2017) also supported the EKC hypothesis in China by applying different estimation techniques based on the annual time series data over the period 1970-2015. In Pakistan, Nasir and Rehman (2011) confirmed the existence of the EKC hypothesis in terms of CO_2 emissions by employing the Johansen method of cointegration based on the time series data for the period 1972-2008. In addition to the inverted U-shaped relationship, Friedl and Getzner (2003) found that an N-shaped relationship between per capita GDP and CO_2 emissions fits the time series data in Austria from 1960 to 1999 to the most extent.

However, it was also concluded that the existence of the EKC hypothesis may be not true in some empirical studies, most of which were based on the international data of air pollutants (Dinda, 2004; Stern, 2004). For instance, using the data of 23 countries during the period 1974-1989, Kaufmann et al. (1998) found that the concentration of SO_2 falls as per capita GDP grows between 3000 to 12500 United States dollars (USD), and then rises as per capita GDP rises beyond 12500

USD. Based on the data of CO_2, NO_x and SO_2 emissions in Netherlands, the United Kingdom, the United States and Western Germany, de Bruyn et al. (1998) found that the emissions are positively correlated with economic growth rather than following an inverted U-shaped fashion. Dinda et al. (2000) argued that per capita real GDP shows an explicitly negative and U-shaped relationship with the concentration of SO_2 and SPM, respectively, using the city-wise annual data for 33 countries during the three periods 1979-1982, 1983-1986, and 1987-1990. Similarly, Stern and Common (2001) pointed out that there exists a monotonic relationship between per capita SO_2 emission and per capita income in a more globally sample, since the estimated turning point of per capita real GDP is much higher than the actual level. Harbaugh et al. (2002) pointed out that the pollution-income relationship was highly sensitive to the sample changes, and little evidence was obtained for an inverted U-shaped relationship between air pollutants and income. By using cointegration analysis on SO_2 emissions in 74 countries from 1960 to 1990, Perman and Stern (2003) found that the spurious regression involving the EKC hypothesis may be conducted. Recently, an empirical work conducted by Lin et al. (2016) re-examined the environment-income relationship in terms of CO_2 emission in five African countries, and denied the EKC hypothesis. In addition to the indicators other than air pollutants, Koop and Tole (1999) argued that the inverted U-shaped relationship between deforestation and per capita GDP does not exist based on the data for 76 developing countries from 1961 to 1992. Hettige et al. (2000) pointed out that the relationship between industrial water pollution and income rejected the EKC hypothesis. In the case of China, Diao et al. (2009) pointed out that the EKC hypothesis is only one of models that characterize the relationship between economic growth and environmental degradation based on analysis of six pollution indices in Jiaxing of Zhejiang.

A few studies further examined the causality between environment degradation and income (Coondoo and Dinda, 2002; Dinda and Coondoo, 2006). Coondoo and Dinda (2002) employed a Granger causality test to cross-country panel data, and concluded that the causality varies cross countries or regions. Dinda and Coondoo (2006) further argued that there may be a bi-directional causality between per capita GDP and per capita CO_2 for different groups of countries or regions, using a cross-country panel dataset covering 88 countries during the period 1960-1990.

In addition, a considerable number of studies extended the EKC hypothesis to examine the relationship between income inequality and environmental degradation (Grunewald et al., 2017; Jorgenson et al., 2017). The pioneering work was conducted by Boyce (1994). In sum, Boyce (1994) hypothesized that a growing income inequality may increase the rate of environmental time preference of both the rich and poor, which leads the two groups to take environment-damage actions. Moreover, the growing income inequality may also induce environmental degradation by encouraging the rich to transfer the environmental costs to the poor (Boyce, 1994). To examine these hypotheses, Torras and Boyce (1998) utilized the pooled ordinary least squares method to analyze the impact of inequality on air and water pollution, but obtained contrasting results. Using a cross-national dataset in terms of environmental degradation in 1985, Heerink et al. (2001) argued that higher inequality may reduce environmental degradation, which is contrary to the conclusion of Boyce (1994). Zhang and Zhao (2014) used the national and regional panel data from 1995 to 2010 in China to reveal that a more equitable income distribution is useful for controlling CO_2 emissions. Using a provincial panel dataset from 1995 to 2012 in China, Hao et al. (2016) argued that CO_2 emissions per capita increases as the income gap expands. In the case of the United States, Jorgenson et al. (2017) showed that the state-level CO_2 emissions are positively associated with the income share of the top 10 percent based on the data over the period 1997-2012. Using a panel dataset of 158 countries from 1980 to 2008, Grunewald et al. (2017) argued that for low and middle-income countries, higher income inequality is associated with lower CO_2 emissions, while in upper middle-income and high-income economies, higher income inequality increases per capita CO_2 emissions.

Note that the previous studies have shed light on the relationship between environmental degradation and economic development. However, the conclusions are far from consistent. Moreover, the relationship between the urban-rural income inequality and environmental degradation, especially the environmental issues involving agriculture, attracts little attention.

3. Methods and Materials

3.1. Sample

This study aims to investigate the relationship between the urban-rural income inequality and environmental degradation involving agriculture from the input-side perspective. Thus, we use per hectare fertilizer and pesticide use as proxies for environmental degradation related to agriculture. To meet the goal, this study employs a provincial panel dataset for 25 provinces within the Mainland China during the period 1995-2015. Beijing, Shanghai, Tianjin, Chongqing, Hainan and Tibet are not included due to the incompleteness and unavailability of data. Thus, we obtain a total sample of 525 observations.

3.2. Model

To control for the potential influence of other factors, this study develops a multivariate model on the basis of the EKC hypothesis. The model can be describe as follows:

$$\ln Y_{it} = \beta_0 + \beta_1 \ln Income_{it} + \beta_2 \ln^2 Income_{it} + \beta_3 \ln^3 Income_{it} + \beta_4 Inequality_{it} + \beta_5 Agriculture_{it}$$

$$+ \beta_6 (Inequality_{it} \times Agriculture_{it}) + \beta_7 Cropping_{it} + \beta_8 Price_{i,t\text{-}1} + \beta_9 Trend_t + a_i + u_{it} \quad (1)$$

where the explained variable $\ln Y_{it}$ denotes per hectare agricultural fertilizer or pesticide use in the natural-logarithmic form; and the explanatory variables $\ln Income_{it}$, $\ln^2 Income_{it}$ and $\ln^2 Income_{it}$ denote the linear, quadratic and cubic terms of per capita income of the rural households in the natural-logarithmic form, respectively; $Inequality_{it}$ denotes the urban-rural income inequality; $Agriculture_{it}$ denotes the share of agricultural value added in provincial GDP; $Inequality_{it} \times Agriculture_{it}$ denotes the interaction term between $Inequality_{it}$ and $Agriculture_{it}$; $Cropping_{it}$ denotes a group of percentages of the sown area of different crops in the total sown area; $Price_{i,t\text{-}1}$ denotes the price index ratio of agricultural products to fertilizer or to pesticide for the preceding year; and $Trend_t$ is used to capture the time trend of per hectare fertilizer and pesticide use. In addition, a_i and u_{it} stand for the time-invariant effect and independent identically distributed random disturbance term, respectively. Note that per hectare fertilizer and pesticide use and per capita income of the rural households are used in their natural-logarithmic form to overcome the defect of the potential heteroscedasticity.

Equation (1) is a one-way individual-effects model. As an alternative, we replace $Trend_t$ with γ_t to construct a two-way individual-effects model, as shown in equation (2):

$$\ln Y_{it} = \beta_0 + \beta_1 \ln Income_{it} + \beta_2 \ln^2 Income_{it} + \beta_3 \ln^3 Income_{it} + \beta_4 Inequality_{it} + \beta_5 Agriculture_{it}$$

$$+ \beta_6 (Inequality_{it} \times Agriculture_{it}) + \beta_7 Cropping_{it} + \beta_8 Price_{i,t\text{-}1} + \gamma_t + a_i + u_{it} \quad (2)$$

The estimation of equations (1) and (2) may suffer the defect of the potential endogeneity due to the bidirectional causal relationship between the explained variable ($\ln Y_{it}$) and per capita income of the rural households ($\ln Income_{it}$). In the context, this study utilize the instrumental variable (IV) method to mitigate the endogeneity. Specifically, we use the first-order lagged per capita income ($lnIncome_{i,t-1}$) as the instrument of the current income ($lnIncome_{it}$). Similarly, $\ln^2 Income_{i,t-1}$, $\ln^3 Income_{i,t-1}$, $Inequality_{i,t-1}$, and $Inequality_{i,t-1} \times Agriculture_{it}$ are also used as the instruments of $\ln^2 Income_{it}$, $\ln^3 Income_{it}$, $Inequality_{it}$, and $Inequality_{it} \times Agriculture_{it}$, respectively. Moreover, the employment of the IV method can also be regarded as the robustness analysis.

3.3. Data

This study utilizes a provincial panel dataset in China during the period 1995-2015. Due to several reasons, data used in this study come from multiple sources. Please see the appendix for the details.

Per hectare fertilizer and pesticide use refers to the quantity of fertilizer and pesticide used on the total sown area for each province and each year. The National Data (http://data.stats.gov.cn/) is the main data source for fertilizer and pesticide use, and sown area. In addition, for Guangdong and Inner Mongolia, data of pesticide use in 1996 and 1997 come from China Rural Statistical Yearbook.

Data of per capita income of the rural households come from China Compendium of Statistics 1949-2008, and the National Data. In this study, per capita income ratio of the urban to rural households is used to as proxy for the urban-rural income inequality. The data source of per capita income of the urban households is the same as that the rural households. To exclude the price changes in income, per capita income of the urban and rural households is calculated at 2015 constant price based on the urban and rural consumer price indices, respectively. Most of the price indices come from the National Data. For Guizhou, the rural consumer price indices in 1994, 1995 and 1997 come from China Statistical Yearbook.

In this study, we use a dummy variable to capture the potential impact of industrial structure on per hectare fertilizer and pesticide use. For each province and each year, the dummy variable equals one if the share of agricultural value added in provincial GDP is greater than or at least equal to 15 percent, and equals zero if the share of agricultural value added in provincial GDP is less than 15 percent. In general, that the share of agricultural value added in provincial GDP is less than 15 percent is a main sign of the completion of industrialization (Ye, 2008). In this study, data of agricultural value added in 1995 and 1996 come from China Rural Statistical Yearbook, and the National Data for the period 1997-2015. Meanwhile, data of provincial GDP are collected from the National Data.

In this study, we use the percentages of the sown area of grain, vegetable and cotton, top three crops in terms of the sown area, in the total sown area to describe cropping structure. Data of the sown area of each crop and the total sown area come from the National Data.

In addition, the price index ratio of agricultural products to fertilizer or to pesticide for the preceding year is also included in the model. Since data of actual prices of agricultural products, fertilizer and pesticide are unavailable in China, we use price indices as alternatives. All data of fertilizer price indices come from the National Data. Pesticide price indices come from the statistical yearbooks of each province, China Rural Statistical Yearbook, and the National Data. Data sources of price indices of agricultural products consist of the statistical yearbooks of each province, China Statistical Yearbook of Prices and Urban Household Income and Expenditure Survey, China Yearbook of Agricultural Price Survey, and the National Data. Since the officially released price indices of agricultural products in Guangxi, Hebei, Henan, Hubei, Heilongjiang, Jiangxi, Ningxia, Shanxi, Shannxi, Sichuan, Xinjiang and Zhejiang in 2001 are not available, we use data in 2000 as alternatives.

Table 1 summarizes the mean value and standard deviation of the main variables in three years: 1995, 2005 and 2015, given a panel dataset used in this study.

4. Results and Discussion

This study firstly implements estimation and statistical inference with the ordinary least squares (OLS) technique for equation (1) and (2). On this basis, the panel-IV technique is then utilized to overcome the defects of the potential endogeneity. Since the sample in this study consists of most of the provinces in China, it could not be treated as a random sample from a large population. As set forth by Wooldridge (2013), in the context, the fixed-effects (FE) regression is always more reasonable and convincing than random-effects (RE) regression. For the purpose of comparison, the results of both FE and RE regressions are reported in Tables 2 and 3. The within R-squared of these models ranges from 0.88 to 0.96, which illustrates that the model in this study perform well.

We firstly analyze the relationship between per capita income of the rural households and per hectare fertilizer use. As shown in Table 2, the estimated coefficients of the linear term of per capita income of the rural households are significant and positive, while the estimated coefficients of the quadratic term are significant but negative. Meanwhile, none of the coefficients of the cubic terms of per capita income of the rural households is significant. It demonstrates that there exists an inverted U-shaped relationship between per hectare fertilizer use and per capita income of the rural households, which is consistent with the EKC hypothesis. That is to say, per hectare fertilizer use firstly rises as per capita income of the rural households grows, but then falls with the growing per capita income of the rural households beyond the turning point. Since both per hectare fertilizer use and per capita income of the rural households in this study are used in their natural-logarithmic forms, per capita income of the rural households at the turning point can be calculated using the equation $Income^* = \exp\left(-\frac{\beta_1}{2\beta_2}\right)$. As shown in Table 2, in terms of the income-fertilizer relationship, per capita income of the rural households at the turning point ranges from 10.8 to 12.74 thousand CNY. Given that the average per capita income of the rural households for the 25 provinces was around 11 thousand CNY in 2015, it implies that the current per hectare fertilizer use is very close to the peak point in China. This is identical with the slowing growth of per hectare fertilizer use and the fact that per hectare fertilizer in 2015 is less than that in 2014 in China (National Bureau of Statistics of China, 2016b). It should be noted, however, the disparity among different provinces remains. Per capita income of the rural households in the eastern provinces, such as Zhejiang and Jiangsu, is beyond the turning point, while that in most central and western provinces, such as Gansu, Guizhou and Qinghai, remains far lower than the turning point.

Table 3 summarizes the estimation results of the relationship between per capita income of the rural households and per hectare pesticide use. In all models, the linear terms of per capita income of the rural households are significant and positive, and the quadratic terms are significant and negative. In addition, in contrast to the results in Table 2, the cubic terms of per capita income of the rural households are significant and positive. Thus, these results seem to show that the relationship between per hectare pesticide use and per capita income of the rural households follows an N-shaped rather than a "Kuznetsian" inverted U-shaped pattern. In other words, the results in Table 3 seem to demonstrate that per hectare pesticide use will firstly rises, then falls, and finally again rises as per capita income of the rural households grows. Hence, is it true? By using the equation

$Income^* = \exp\left(-\frac{\beta_2 \pm \sqrt{\beta_2^2 - 3\beta_1\beta_3}}{3\beta_3}\right)$, we are able to calculate the peak and trough turning points of the so-called N-shaped curve. As shown in Table 3, in general, per capita income of the rural households at the peak turning point ranges from 3.74 to 8.69 thousand CNY, while that at the trough turning point ranges from 25.78 to 117.61 thousand CNY. Given that average per capita income of the rural households is only 11.05 thousand CNY in 2015, it is far less than the trough turning point in whatever cases. In the context, the results illustrate that relationship between per hectare pesticide use and per capita income of the rural households effectively support the EKC hypothesis. In this study, the average per capita income of the rural households in all the 25 provinces is beyond the peak turning point of the so-called N-shaped curve. In fact, per hectare pesticide use has experienced a constantly decrease from 11.05 kg in 2012 to 10.72 in 2015 (National Bureau of Statistics of China, 2016b).

The relationship between the urban-rural income inequality and per hectare fertilizer and pesticide use is the issue of interest in this study. As shown in Tables 2 and 3, the coefficients of the urban-rural income ratio in all models are significant and positive, implying that per hectare fertilizer and pesticide use increase as the urban-rural income ratio expands. Meanwhile, the impact of the urban-rural income ratio on per hectare pesticide use is much greater. It is also found that the impact of the urban-rural income ratio on per hectare fertilizer and pesticide use is influenced by the share of agricultural value added in provincial GDP. Taking the first column of Table 2 as an example, each unit increase in the urban-rural income ratio may induce a 14-percent ($0.09 \times 100\% + 0.05 \times 100\% = 14\%$) increase in per hectare fertilizer use if agricultural value added is greater than or equal to 15 percent of provincial GDP, but only a 9-percent increase in per hectare fertilizer use otherwise, with other factors held constant. Similarly, in the case of the first column of Table 3, each unit increase in the urban-rural income ratio is associated with a 38-percent (0.13 × 100% + 0.25 × 100% = 38%) increase in per hectare pesticide use if agricultural value added is greater than or equal to 15 percent of provincial GDP, but only a 13-percent increase in per hectare pesticide use otherwise, with other factors held constant. It should be noted, however, Table 1shows that at least since 2005, the share of agricultural value added in provincial GDP of all the sampled provinces has become less than 15 percent. It demonstrates that the current relationship between per capita income of the rural households and per hectare fertilizer and pesticide use may not be influenced by whether agricultural value added is greater than or equal to 15 percent of provincial GDP.

Most studies agree that there exists a positive relationship between income inequality and environmental degradation (Hao et al., 2016; Zhang and Zhao, 2014). In the context, the results in this study are consistent with the previous studies. A convincing explanation may be that the expansion of the urban-rural income inequality may probably induce the knowledgeable and young rural labors to migrant to the urban areas for off-farm employment so that they can earn higher off-farm wages (Fan et al., 2013). The rural labor out-migration further causes a shortage of labors allocated into agricultural production and the corresponding rise in agricultural labor cost (Ebenstein et al., 2011; Li and Zhao, 2010). As an alternative to agricultural labor inputs, the intensive use of fertilizer and pesticide is the key measure to stabilize and increase agricultural productivity (Luan, 2017). As argued by Ebenstein et al. (2011), rural labor out-migration and per hectare fertilizer use are positively correlated using panel data on villages in China during the period 1987-2002.

The results also show that per hectare fertilizer and pesticide use is also directly affected by the share of agricultural value added in provincial GDP. As shown in Tables 2 and 3, the dummy variable indicating that the share of agricultural value added in provincial GDP is greater than or equal to 15 percent ($Agriculture_{it}$) shows a significant and negative association with per hectare fertilizer and pesticide use. In the case of that the share of agricultural value added in provincial GDP is greater than or equal to 15 percent, per hectare fertilizer and pesticide use may be 16- to 18-percent and 57- to 69-percent lower than when the share of agricultural value added in provincial GDP is less than 15 percent, with other factors held constant. Note that the shrink of agriculture in an economy is often inevitably associated with urbanization and industrialization (Jiang et al., 2013; Shi et al., 2016). Correspondingly, the rapid urbanization and industrialization would then increase the demand for agricultural products. Due to the limitations of natural resources, including arable land and water, the growth of agricultural productivity highly depends on the intensive use of fertilizer and pesticide.

The cropping structure is also related to per hectare fertilizer and pesticide use. Table 2 shows that there are significant and positive relationships between the percentages of vegetable and cotton sown area in the total sown area and per hectare fertilizer use. Similarly, the results in Table 3 also show that each point increase in the percentages of vegetable and cotton sown area is associated with a 2- to 3-percent increase in per hectare pesticide use, with other factors held constant. In addition, Table 3 also shows a positive relationship between the percentage of grain sown area and per hectare pesticide use.

5. Conclusion

In China, the large urban-rural income inequality and indiscriminate use of fertilizer and pesticide, as well as the related environment degradation in China during the past decades concern the society. However, little is known about the relationship between urban-rural income inequality and agricultural fertilizer and pesticide use. Based on the EKC hypothesis, this study utilizes the provincial panel data during the period 1995-2015 to reveal how the urban-rural income inequality affects fertilizer and pesticide use in China. The main conclusion is that the urban-rural income inequality shows a significant and positive relationship with both per hectare fertilizer and pesticide use, and such a relationship may be affected by the share of agriculture in the economy. In addition, per capita income of the rural households has an inverted U- and N-shaped relationship with per hectare fertilizer and pesticide use, respectively. Given China's current income level of the rural households, these results support the EKC hypothesis. Furthermore, cropping structure exhibits a significant impact on per hectare fertilizer and pesticide use. The results in this study are robust to different estimation strategies and techniques.

The findings in this study has important implications. Given the negative relationship between the urban-rural income inequality and agricultural fertilizer and pesticide use, this study suggests that to narrow the urban-rural income inequality and reduce agricultural fertilizer and pesticide use are two harmonious requirements of China's sustainable economic development. Therefore, China's government should concentrate on progressively raising the income level of the rural households. For this purpose, some effective measures, such as boosting the rural infrastructure, deepening the reform of the circulatory system of agricultural products, accelerating the urbanization, and improving rural education, should be implemented (Guo, 2005; Lin, 2003). In addition, more efforts should be devoted to improving agricultural technology research and extension to help reduce fertilizer and pesticide use in agriculture (Zhang et al., 2015).

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References

Boyce, J.K., 1994. Inequality as a cause of environmental degradation. Ecol. Econ. 11(3), 169-178.

Carter, C.A., 2012. The urban-rural income gap in China: implications for global food markets. Amer. J. Agr. Econ. 79(5), 1410-1418.

Coondoo, D., Dinda, S., 2002. Causality between income and emission: a country group-specific econometric analysis. Ecol. Econ. 40(3), 351-367.

de Bruyn, S.M., van den Bergh, J.C.J.M., Opschoor, J.B., 1998. Economic growth and emissions: reconsidering the empirical basis of environmental Kuznets curves. Ecol. Econ. 25(2), 161-175.

Diao, X.D., Zeng, S.X., Tam, C.M., Tam, V.W.Y., 2009. EKC analysis for studying economic growth and environmental quality: a case study in China. J. Clean. Prod. 17(5), 541-548.

Dinda, S., 2004. Environmental Kuznets curve hypothesis: a survey. Ecol. Econ. 49(4), 431-455.

Dinda, S., Coondoo, D., 2006. Income and emission: a panel data-based cointegration analysis. Ecol. Econ. 57(2), 167-181.

Dinda, S., Coondoo, D., Pal, M., 2000. Air quality and economic growth: an empirical study. Ecol. Econ. 34(3), 409-423.

Ebenstein, A., Zhang, J., McMillan, M.S., Chen, K., 2011. Chemical Fertilizer and Migration in China. NBER Working Papers Series 17425, National Bureau of Economic Research, Cambridge, Massachusetts.

Fan, X., Wang, Q., Gao, T., 2013. Expected rural-urban income gap and the impact on Chinese rural labor force immigration. J. Quant. Tech. Econ. (7), 20-35. (in Chinese)

Friedl, B., Getzner, M., 2003. Determinants of CO_2 emissions in a small open economy. Ecol. Econ. 45(1), 133-148.

Gao, Y., Zheng, J., Bu, M., 2014. Rural-urban income gap and agricultural growth in China: an empirical study on the provincial panel data, 1978-2010. Chin. Agr. Econ. Rev. 6(1), 92-107.

Grossman, G.M., Krueger, A.B., 1991. Environmental Impacts of a North American Free Trade Agreement. NBER Working Papers Series 3914, National Bureau of Economic Research, Cambridge, Massachusetts.

Grossman, G.M., Krueger, A.B., 1995. Economic growth and the environment. Q. J. Econ. 110(2), 353-377.

Grunewald, N., Klasen, S., Martínez-Zarzoso, I., Muris, C., 2017. The trade-off between income inequality and carbon dioxide emissions. Ecol. Econ. 142, 249-256.

Guo, J., 2005. Human capital, the birth rate and the narrowing of the urban-rural income gap. Soc. Sci. Chin. (3), 27-37. (in Chinese)

Hao, Y., Chen, H., Zhang, Q., 2016. Will income inequality affect environmental quality? Analysis based on China's provincial panel data. Ecol. Indic. 67, 533-542.

Harbaugh, W.T., Levinson, A., Wilson, D.M., 2002. Reexamining the empirical evidence for an environmental Kuznets curve. Rev. Econ. Stat. 84(3), 541-551.

Heerink, N., Mulatu, A., Bulte, E., 2001. Income inequality and the environment: aggregation bias in environmental Kuznets curves. Ecol. Econ. 38(3), 359-367.

Hettige, H., Mani, M., Wheeler, D., 2000. Industrial pollution in economic development: the environmental Kuznets curve revisited. J. Dev. Econ. 62(2), 445-476.

Huang, J., Huang, Z., Jia, X., Hu, R., Xiang, C., 2015. Long-term reduction of nitrogen fertilizer use through knowledge training in rice production in China. Agr. Syst. 135, 105-111.

Huang, J., Rozelle, S., 1996. Technological change: rediscovering the engine of productivity growth in China's rural economy. J. Dev. Econ. 49(2), 337-369.

Huang, J., Yang, J., Rozelle, S., 2010. China's agriculture: drivers of change and implications for China and the rest of world. Agr. Econ. 41(S1), 47-55.

Jalil, A., Mahmud, S.F., 2009. Environment Kuznets curve for CO_2 emissions: a cointegration analysis for China. Energy Policy 37(12), 5167-5172.

Jiang, L., Deng, X., Seto, K.C., 2013. The impact of urban expansion on agricultural land use intensity in China. Land Use Policy. 35(14), 33-39.

Jorgensen, A., Schor, J., Huang, X., 2017. Income inequality and carbon emissions in the United States: A state-level analysis. 1997-2012. Ecol. Econ. 134, 40-48.

Kahrl, F., Li, Y., Su, Y., Tennigkeit, T., Wilkes, A., Xu, J., 2010. Greenhouse gas emissions from nitrogen fertilizer use in China. Environ. Sci. Technol. 13(8), 688-694.

Kaufmann, R.K., Davidsdottir, B., Garnham, S., Pauly, P., 1998. The determinants of atmospheric SO_2 concentrations: reconsidering the environmental Kuznets curve. Ecol. Econ. 25(2), 209-220.

Koop, G., Tole, L., 1999. Is there an environmental Kuznets curve for deforestation? J. Dev. Econ. 58(1), 231-244.

Li, M., Zhao, L., 2010. Impact of rural labor migration on the formation of the ageing of agricultural labors—An analysis based on Liaoning province. Chin. Rural Econ. (9), 68-75. (in Chinese)

Lin, Q., Omoju, O.E., Nwakeze, N.M., Okonkwo, J.U., Megbowon, E.T., 2016. Is the environmental Kuznets curve hypothesis a sound basis for environmental policy in Africa? J. Clean. Prod. 133, 712-724.

Lin, J.Y., 1992. Rural reforms and agricultural growth in China. Amer. Econ. Rev. 82(1), 34-51.

Lin, Y., 2003. Issues concerning agriculture, countryside and farmers, and Chinese rural development in the future. Issues Agr. Econ. (1), 19-24. (in Chinese)

List, J.A., Gallet, C.A., 1999. The environmental Kuznets curve: does on size fit all? Ecol. Econ. 31(3), 409-423.

Luan, J., 2017. Does agricultural labor migration have substitution relation with fertilizer use? Experience and evidence from China's main provinces and municipalities planting crops. West Forum 27(4), 12-21. (in Chinese)

Nasir, M., Rehman, F.U., 2011. Environmental Kuznets curve for carbon emissions in Pakistan: an empirical investigation. Energy Policy 39(3), 1857-1864.

National Bureau of Statistics of China, 2016a. China Statistical Yearbook. China Statistical Press, Beijing. (in Chinese)

National Bureau of Statistics of China, 2016b. China Rural Statistical Yearbook. China Statistical Press, Beijing. (in Chinese)

Nguyen-Van, P., 2010. Energy consumption and income: a semiparametric panel data analysis. Energy Econ. 32(3), 557-563.

Ongley, E.D., Zhang, X., Yu, T., 2010. Current status of agricultural and rural non-point source pollution assessment in China. Environ. Pollut. 158(5), 1159-1168.

Panayotou, T., 1993. Empirical tests and policy analysis of environmental degradation at different stages of economic development. World Employment Programme Research Working Paper 238, International Labour Office, Geneva.

Perman, R., Stern, D.I., 2003. Evidence from panel unit root and cointegraion tests that the environmental Kuznets curve does not exist. Aust. J. Agr. Resour. Econ. 47(3), 325-347.

Riti, J.S., Song, D., Shu, Y., Kamah, M., 2017. Decoupling CO_2 emission and economic growth in China: is there consistency in estimation results in analyzing environmental Kuznets curve? J. Clean. Prod. 166, 1448-1461.

Rozelle, S., Huang, J., Zhang, L., 1997. Poverty, population and environmental degradation in China. Food Policy 22(3), 229-251.

Seldon, T.M., Song, D., 1994. Environmental quality and development: is there a Kuznets curve for air pollution emissions. J. Environ. Econ. Manag. 27(2), 147-162.

Shi, K., Chen, Y., Yu, B., Xu, T., Li, L., Huang, C., Liu, R., Chen, Z., Wu, J., 2016. Urban expansion and agricultural land loss in China: a multiscale perspective. Sustainability 8(8), 790.

Stern, D.I., 2004. The rise and fall of the environmental Kuznets curve. World Dev. 32(8), 1419-1439.

Stern, D.I., Common, M.S., 2001. Is there an environmental Kuznets curve for sulfur? J. Environ. Econ. Manag. 41(2), 162-178.

Torras, M., Boyce, J.K., 1998. Income, inequality, and pollution: a reassessment of the environmental Kuznets curve. Ecol. Econ. 25(2), 147-160.

Wang, S.L., Tuan, F., Gale, F., Somwaru, A., Hansen, J., 2013. China's regional agricultural productivity growth in 1985-2007: a multilateral comparison. Agr. Econ. 44(2), 241-251.

Wooldridge, J.M., 2013. Introductory Econometrics: A Modern Approach, 5th edition. South-Western, Mason.

Ye, X., 2008. Major choices must be made by modern agriculture building in the medium-term industrialization. Issues Agr. Econ. (1), 12-17,47. (in Chinese)

Zhang, C., Hu, R., Shi, G., Jin, Y., Robson, M.G., Huang, X., 2015. Overuse or underuse? An observation of pesticide use in China. Sci. Total Environ. 538, 1-6.

Zhang, C., Zhao, W., 2014. Panel estimation for income inequality and CO_2 emissions: a regional analysis in China. Appl. Energy 136(C), 382-392.

Zhu, Z.L., Chen, D.L., 2002. Nitrogen fertilizer use in China-contributions to food production, impacts on the environment and best management strategies. Nutr. Cycl. Agroecosyst. 63(2-3), 117-127.

Table 1

Descriptive statistics of main variables.

Variable	Unit	1995		2005		2015	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Per hectare fertilizer use	kg	229.78	78.54	297.90	94.79	359.51	106.35
Per hectare pesticide use	kg	6.63	4.94	9.27	6.27	11.13	6.71
Urban per capita income	10^3 CNY	6.31	1.43	12.75	2.59	28.32	4.73
Rural per capita income	10^3 CNY	2.45	0.73	4.36	1.39	11.05	2.98
Urban-rural income ratio	/	2.68	0.59	3.06	0.63	2.63	0.37
Share of agriculture value added in provincial GDP ≥ 15 percent	yes = 1; no = 0	0.64	0.49	0.00	0.00	0.00	0.00
Percentage of grain sown area	%	73.26	8.84	66.10	11.17	65.90	13.34
Percentage of vegetable sown area	%	6.09	3.44	11.14	3.38	13.78	7.57
Percentage of cotton sown area	%	3.19	5.26	3.02	6.33	2.20	6.57
Crop-fertilizer price index ratio	/	1.13	0.08	1.03	0.05	1.08	0.03
Crop-pesticide price index ratio	/	1.31	0.08	1.12	0.08	0.99	0.02

Note: The number of observations is 525.

Table 2

Estimation results for the relationship between urban-rural income inequality and fertilizer use, 1995-2015.

Explanatory variables	ln$Fertilizer_{it}$: Panel-OLS				ln$Fertilizer_{it}$: Panel-IV			
	One-way		Two-way		One-way		Two-way	
	FE	RE	FE	RE	FE	RE	FE	RE
ln$Income_{it}$	1.01***	1.05***	1.01***	1.04***	0.99***	1.03***	1.07***	1.08***
	(5.31)	(5.53)	(5.10)	(5.27)	(4.64)	(4.89)	(4.78)	(4.97)
ln$^2Income_{it}$	-0.21**	-0.21**	-0.21*	-0.21*	-0.20*	-0.20*	-0.22*	-0.22*
	(-2.02)	(-2.01)	(-1.91)	(-1.87)	(-1.84)	(-1.84)	(-1.94)	(-1.88)
ln$^3Income_{it}$	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02
	(0.84)	(0.80)	(1.11)	(1.04)	(0.76)	(0.73)	(1.20)	(1.12)
$Inequality_{it}$	0.09***	0.09***	0.05**	0.05**	0.09***	0.10***	0.05*	0.05**
	(4.69)	(4.98)	(2.22)	(2.47)	(4.21)	(4.50)	(1.73)	(1.98)
$Agriculture_{it}$	-0.16***	-0.17***	-0.16***	-0.18***	-0.16***	-0.17***	-0.17***	-0.18***
	(-2.73)	(-2.95)	(-2.78)	(-2.96)	(-2.62)	(-2.85)	(-2.75)	(-2.93)
$Inequality_{it} \times Agriculture_{it}$	0.05**	0.06***	0.05**	0.06**	0.06**	0.06***	0.05**	0.06**
	(2.50)	(2.67)	(2.32)	(2.49)	(2.41)	(2.59)	(2.30)	(2.47)
$Cropping_{it}$								
Grain	0.00	0.00	-0.00	-0.00	0.00	0.00	-0.00	-0.00
	(0.46)	(1.10)	(-0.75)	(-0.12)	(0.46)	(1.10)	(-0.75)	(-0.15)
Vegetable	0.01**	0.01***	0.00	0.01**	0.01**	0.01***	0.00	0.01**
	(2.52)	(3.54)	(1.33)	(2.24)	(2.49)	(3.53)	(1.26)	(2.13)
Cotton	0.01***	0.01***	0.005	0.01**	0.01***	0.01***	0.00	0.01**
	(2.96)	(3.67)	(1.29)	(2.05)	(2.94)	(3.67)	(1.28)	(2.03)
$Price_{i,t-1}$	-0.02	-0.02	0.01	0.01	-0.02	-0.02	0.01	0.01
	(-0.44)	(-0.41)	(0.14)	(0.14)	(-0.46)	(-0.43)	(0.17)	(0.16)
$Trend_t$	-0.01***	-0.02***			-0.01**	-0.02***		
	(-2.62)	(-3.31)			(-2.18)	(-2.82)		
γ_t			Yes	Yes			Yes	Yes
Constant	4.33***	4.20***	4.58***	4.44***	4.34***	4.21***	4.55***	4.42***
	(22.11)	(21.40)	(20.83)	(20.26)	(20.52)	(20.08)	(19.17)	(18.95)
R-squared (within)	0.80	0.80	0.81	0.81	0.80	0.80	0.81	0.81
F statistics	183.25		68.92					
Wald χ-squared		2006.91		2050.98	2.71×10^6	1980.60	2.75×10^6	2032.35
Rho	0.92	0.89	0.92	0.89	0.92	0.89	0.92	0.89
Turning point (10^3 CNY)	11.23	12.15	11.18	12.42	11.68	12.74	10.80	11.88
Number of observations	525	525	525	525	525	525	525	525

Note: Figures in parentheses are *t* statistics in the first and third columns, but *z* statistics in the other columns. *, **, and *** denote the significance under 10, 5, and 1 percent, respectively.

Table 3

Estimation results for the relationship between urban-rural income inequality and pesticide use, 1995-2015.

Explanatory variables	ln*Pesticide*$_{it}$: Panel-OLS				ln*Pesticide*$_{it}$: Panel-IV			
	One-way		Two-way		One-way		Two-way	
	FE	RE	FE	RE	FE	RE	FE	RE
ln*Income*$_{it}$	2.06***	2.36***	1.91***	2.30***	1.98***	2.30***	1.62***	2.09***
	(5.27)	(5.89)	(4.71)	(5.51)	(4.51)	(5.18)	(3.53)	(4.52)
ln^2*Income*$_{it}$	-0.83***	-0.86***	-0.87***	-0.89***	-0.76***	-0.80***	-0.78***	-0.81***
	(-3.86)	(-3.86)	(-3.87)	(-3.79)	(-3.33)	(-3.39)	(-3.30)	(-3.27)
ln^3*Income*$_{it}$	0.11**	0.11**	0.10**	0.11**	0.09**	0.10**	0.09*	0.09*
	(2.55)	(2.51)	(2.41)	(2.37)	(2.16)	(2.18)	(1.88)	(1.91)
Inequality$_{it}$	0.13***	0.16***	0.18***	0.20***	0.16***	0.20***	0.22***	0.24***
	(3.18)	(4.03)	(3.91)	(4.33)	(3.46)	(4.18)	(4.00)	(4.39)
Agriculture$_{it}$	-0.57***	-0.61***	-0.62***	-0.64***	-0.57***	-0.62***	-0.66***	-0.69***
	(-4.89)	(-5.13)	(-5.10)	(-5.13)	(-4.63)	(-4.92)	(-5.16)	(-5.17)
Inequality$_{it}$ × *Agriculture*$_{it}$	0.25***	0.26***	0.26***	0.27***	0.25***	0.26***	0.28***	0.28***
	(5.61)	(5.68)	(5.79)	(5.68)	(5.28)	(5.40)	(5.79)	(5.66)
Cropping$_{it}$								
Grain	0.02***	0.02***	0.02***	0.02***	0.02***	0.02***	0.02***	0.02***
	(5.33)	(5.52)	(4.91)	(5.16)	(5.26)	(5.45)	(4.92)	(5.20)
Vegetable	0.02***	0.02***	0.02***	0.03***	0.02***	0.02***	0.02***	0.03***
	(2.65)	(3.93)	(3.22)	(4.27)	(2.67)	(3.96)	(3.46)	(4.50)
Cotton	0.02***	0.02***	0.02***	0.02***	0.02***	0.02***	0.03***	0.03***
	(3.19)	(3.51)	(3.36)	(3.57)	(3.23)	(3.57)	(3.51)	(3.75)
Price$_{i,t-1}$	-0.03	-0.03	-0.01	-0.01	-0.06	-0.05	-0.01	-0.01
	(-0.43)	(-0.36)	(-0.08)	(-0.07)	(-0.78)	(-0.67)	(-0.09)	(-0.06)
Trend$_t$	0.01	-0.01			0.01	-0.01		
	(1.27)	(-0.52)			(0.79)	(-0.81)		
γ_t			Yes	Yes			Yes	Yes
Constant	-1.37***	-1.77***	-1.37***	-1.85***	-1.39***	-1.80***	-1.31***	-1.87***
	(-3.49)	(-4.39)	(-2.98)	(-3.93)	(-3.28)	(-4.20)	(-2.63)	(-3.72)
R-squared (within)	0.67	0.67	0.68	0.67	0.67	0.67	0.68	0.68
F statistics	91.39		33.64					
Wald χ-squared		948.44		932.19	81219.29	937.31	79990.12	919.82
Rho	0.95	0.88	0.96	0.88	0.95	0.89	0.96	0.88
Peak turning Point (10^3 CNY)	7.43	Null	4.48	7.65	8.69	Null	3.74	6.59
Trough turning Point (10^3 CNY)	26.18	Null	59.34	34.83	25.78	Null	117.61	60.33
Number of observations	525	525	525	525	525	525	525	525

Note: Figures in parentheses are *t* statistics in the first and third columns, but *z* statistics in the other columns. *, **, and *** denote the significance under 10, 5, and 1 percent, respectively.

Appendix Table A.1

List of sources of data used in this study.

Variables	Data source
Total fertilizer use	Data come from the National Data (http://data.stats.gov.cn/).
Total pesticide use	Data of Guangdong and Inner Mongolia in 1996 and 1997 come from China Rural Statistical Yearbook, and the other data come from the National Data.
Total sown area	Data come from the National Data.
Per capita income of the rural households	Data in 1994-2001 come from China Compendium of Statistics 1949-2008, and those in 2002-2015 come from the National Data.
Per capita income of the urban households	Data in 1994-2001 come from China Compendium of Statistics 1949-2008, and those in 2002-2015 come from the National Data.
Urban consumer price indices	Data come from the National Data.
Rural consumer price indices	Data of Guizhou in 1994, 1995 and 1997 come from China Statistical Yearbook, and the others come from the National Data.
Agricultural value added	Data in 1995 and 1996 come from China Rural Statistical Yearbook, and those in 1997-2015 come from the National Data.
Gross domestic product	Data come from the National Data.
Grain sown area	Data come from the National Data.
Vegetable sown area	Data come from the National Data.
Cotton sown area	Data come from the National Data.
Fertilizer price indices	Data come from the National Data.
Pesticide price indices	Data in 1994 come from the statistical yearbooks of each province, those in 1995, 1996 and 1999 come from China Rural Statistical Yearbook, and the others come from the National Data.
Price indices of agricultural products	All data in 1994 and data of Fujian, Gansu, Guangdong, Guizhou, Hunan, Jilin, Jiangsu, Liaoning, Inner Mongolia, Qinghai, Shandong and Yunnan in 2001 come from the statistical yearbooks of each province, those in 1995-2000 come from China Statistical Yearbook of Prices and Urban Household Income and Expenditure Survey, those in 2002 come from China Yearbook of Agricultural Price Survey, and those in 2003-2015 come from the National Data. Data of Guangxi, Hebei, Henan, Hubei, Heilongjiang, Jiangxi, Ningxia, Shanxi, Shannxi, Sichuan, Xinjiang and Zhejiang in 2001 are unavailable, we use data in 2000 as alternatives.

Note: All data are at the province level.