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How does urbanization affect GHG emissions? A cross-country panel threshold data analysis

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HIGHLIGHTS

- Taking balanced panel data of 60 countries for 1971–2012 as a sample.
- The relationship between urbanization and GHG emissions is evaluated by the threshold model.
- The role of urbanization path including small towns, big cities and urban agglomerations is evaluated.
- The policy recommendations about GHG abatement during the process of urbanizationare provided.

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ABSTRACT

Taking the balanced panel data of 60 countries from 1971 to 2012 years as a sample, the relationship between urbanization and greenhouse gas (GHG) emissions was checked based on the threshold model. It was found that the relationship between the urbanization ratio and GHG emissions was always positive, suggesting that urbanization will inevitably lead to an increase in GHG emissions, irrespective of how high the rate of urbanization is. However, when the urbanization ratio passed 23.59% or the GHG emissions exceed 42,287 kt of CO_2 equivalent, urbanization will have more impact on GHG. Also, the urbanization paths influence the relationship between urbanization and GHG emissions. When the population in urban agglomerations of more than 1 million of total population is higher than 20.01% or the population in the largest city of urban population is above 48.27%, positive correlation between urbanization and environmental pollution will be more significant.

1. Introduction

In recent years, along with the continuous improvement of the level of global industrialization, urbanization has become an important issue. With the active promotion of governments, the level of urbanization of all countries in the world has increased rapidly. Against this special urbanization background, the speed and concentration of population and industry in cities have brought about resources' problems and environmental problems that cannot be ignored.

The question to be addressed is whether the increasing GHG emissions are caused by urbanization. With the development of the world economy, the demand for fossil energy is increasing. This is the main reason for the increasing concentration of CO_2 in the world and the generation of the earth's greenhouse. Therefore, the study of GHG emissions has a certain value for in-depth understanding of fossil energy consumption and energy economics. This is worth further study. However, there is no agreement. Some researchers consider that the relationship between emissions and urbanization is linear, but some researchers have found an inverted U-shaped relationship. Why have the existing studies failed to reach agreement? In fact, GHG emissions are divided into two types: (a) industrial and (b) urban commercial and residential. On the one hand, urbanization brings population agglomeration. The increasing demands of the urban population due to the population agglomeration and changing lifestyles are accelerating the development of that construction industry and increasing the use of motor vehicles, thereby polluting the urban air. We will call pollution the "life effect" of urbanization due to the deterioration of air quality resulting from population agglomeration in cities.

On the other hand, urbanization also brings industrial agglomeration. Because of the industrial agglomeration, cities can deal with pollution by discharging pollutants more centrally and improving the efficiency of their pollution treatment facilities, thereby effectively

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alleviating the air pollution. Moreover, compared with small cities, large cities have many tall buildings, more land and energy, more centralized and more convenient treatment of domestic waste, and reduced costs of pollution control. In addition, transportation is one of the main sources of environmental pollution. With urban development, most of the population lives in cities. Thus, the environmental pollution caused by traffic and transportation is reduced. Therefore, urbanization has realized the centralized treatment of industrial air pollution, alleviated the air pollution caused by production, and has not aggravated environmental pollution [1]. We will reduce the cost of pollution caused by industrial agglomeration in cities, thus improving air quality as the “production effect” of urbanization.

The improvement of urbanization rates has either worsened the air quality or reduced the cost of pollution control, thus, helping to improve air quality, depending on the balance between the two effects: “life effect” and “production effect”.

The existing research either directly tests the linear relationship between urbanization and pollution emission or adds the quadratic of urbanization rate in the regression model to test the nonlinear relationship between urbanization and environmental pollution. Although these studies can provide abundant empirical evidence for in-depth understanding of the relationship between urbanization and environmental pollution, this is not enough. Firstly, heterogeneity is a common problem of panel data. That is to say, each individual in a study is different, and structural relationships may vary across individuals [2]. For countries in different stages of development, with different production technologies and different environmental quality, the relationship between urbanization and environmental pollution will change with the differences of these characteristics. Therefore, to study the relationship between urbanization and environmental pollution, we must take the heterogeneity of different countries into full consideration, rather than trying to get a standardized and unique conclusion. Secondly, although adding the quadratic of urbanization rate in the regression model is a universal method to study nonlinear relations, this method cannot find the turning point in nonlinear relations accurately. In contrast, the threshold model is a good choice.

For the above reasons, taking GHG emissions as an example and based on the threshold model, the relationship between urbanization and environmental pollution is tested in this study. Furthermore, the different relationships under different urbanization levels, different levels of pollution, and different stages of development, different energy use efficiency, different population sizes, and different urbanization paths are discussed.

This paper contributes the existing research from the following two aspects. On the one hand, in the previous studies, the quadratic of urbanization rate was added to the regression equation to test the nonlinear relationship between urbanization rate and environmental pollution. In this paper, the nonlinear relationship is tested by the threshold effect model. The difference between the two methods is that, only if the relationship between urbanization and environmental pollution reverses from positive to negative or from negative to positive, the nonlinear relationship can be checked. If the relationship between urbanization and environmental pollution is always positive or negative, the previous researches failed to test the differential relationship between them, but the threshold effect model can. On the other hand, the relationship between urbanization and environmental pollution are not only related to the level of urbanization and pollution, but also depends on the economic development, population sizes, and urbanization paths. Here, the above different relationships are further discussed.

This paper is structured as follows. After reviewing the relevant literature in Section 2, we present our regression model and describe the data in Section 3. The empirical results are discussed in Section 4, and further analyses for countries with different urbanization paths are presented in Section 5. Section 6 concludes.

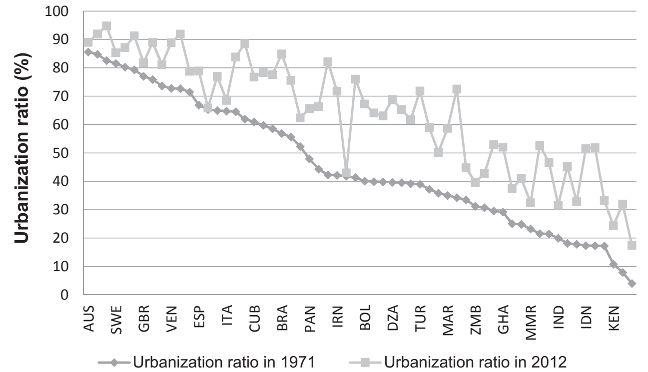


Fig. 1. The urbanization ratio of 60 countries in 1971 and 2012. Notes: The country name and code are listed in Appendix 1. Sources: World Development Index Database (WDI).

2. Trends of global urbanization and GHG emissions

Fig. 1 depicts the trend of urbanization in 60 countries from 1997 to 2012. As can be seen from Fig. 1, the urbanization rate of most countries such as Austria (85.6% in 1971, 89.0% in 2012), Australia (65.3% in 1971, 65.9% in 2012), Sweden (81.6% in 1971, 85.4% in 2012), Italy (64.8% in 1971, 68.6% in 2012), Egypt (41.8% in 1971, 43.0% in 2012), has shown an obvious growth trend, and the urbanization rate of some countries, such as Korea, Rep. (42.3% in 1971, 82.1% in 2012), Malaysia (34.3% in 1971, 72.5% in 2012), Dominican, Rep. (41.3% in 1971, 76.0% in 2012), China (17.3% in 1971, 51.9% in 2012), Turkey (38.9% in 1971, 71.8% in 2012), has doubled. These figures are enough to prove that the rapid development of the global urbanization process in recent years has been very surprising.

At the same time, great changes have also taken place in global greenhouse gas (GHG) emissions. In 1971, the top five countries for GHG emissions were the United States (US), China, Brazil, Japan, and the Democratic Republic of Congo (DR Congo), while in 2012, the top five countries for GHG emissions were China, the US, India, Brazil, and Japan. Fig. 2**.** depicts the changes of GHG emissions in several major countries, including China, the United States, Japan, India, the United Kingdom (UK) and Brazil during 1971–2012. As can be seen from Fig. 2, GHG emissions in the US and China are much higher than are those in other countries. In 1971, GHG emissions in the US were the largest in the world, and the second largest country for GHG emissions was China. In 2004, the GHG emissions in China exceeded the GHG emissions in the US. China has become the world’s largest producer of GHG emissions. During 1971–2012, GHG emissions in developing countries increased rapidly; for example, China's GHG emissions increased by 550%, India’s GHG emissions increased by 298%, and Brazil's GHG emissions increased by 208%. Compared with developing

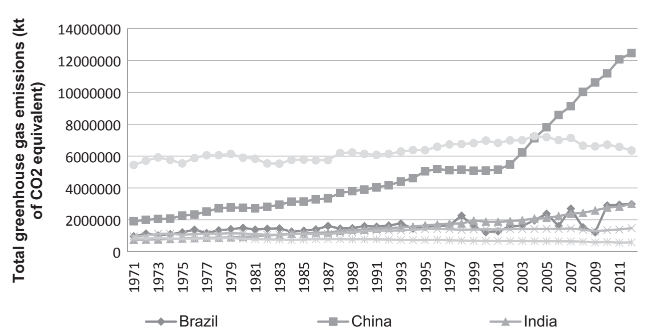


Fig. 2. The total greenhouse gas emissions in six countries during 1971–2012. Sources: World Development Index Database (WDI).

countries, GHG emissions in developed countries are relatively low. For example, GHG emissions in Japan have increased by nearly 54%, GHG emissions in the US have increased by more than 16%, and GHG emissions in the UK have declined.

3. Literature review

Research on urbanization and environmental pollution was first found in the related literature of population and environmental pollution. These studies examined the effect of population growth on pollutant emission, and they hold that the emissions of pollutants are positively related to population growth [3–7]. For example, using the data of 93 countries for 1975–1996, Shi [8] tested the relationship between population and environmental pollution and found that the positive correlation between population and environmental pollution was more obvious in low-income countries and not so obvious in high-income countries. Martnez-Zarzoso et al. [9] found that the positive correlation between population growth and environmental pollution is different in the performance of EU Member States and new members.

The results of existing studies on urbanization and environmental pollution are mainly divided into three categories. The first group considers that the relationship between urbanization and environmental pollution is linear. Urbanization brings about the increase of energy consumption and worsens the environmental quality [10–12]. For example, Parikh and Shukla [10] tested the impact of urbanization level on GHG emissions and tested energy consumption in developing countries. They found that the urban population increased by 10%, the energy consumption increased by 4.7%, and the CO_2 emissions increased by 0.3%. Cole and Neumayer [11] checked the relationship between urbanization and pollution emissions in 86 developed countries during 1975–1998. They found that the urbanization rate increased by 10%, and CO_2 emissions increased by 7%. Using data of 99 countries from 1975 to 2005, Poumanyvong and Kaneko [13] checked the relationship between urbanization and CO_2 emissions. They considered that the impact of urbanization on emissions is positive for all income groups, but it is more pronounced in the middle-income group than in other income groups. Zhang and Lin [14] found that urbanization increases CO_2 emissions in China, and the impact of urbanization on CO_2 emissions in the central region is greater than is that in the eastern region. Sadorsky [15] investigated the relationship between urbanization and CO_2 emissions in 16 emerging countries during 1971–2009. They considered that higher urbanization is associated with higher economic activity, which can increase carbon dioxide emissions. Li and Lin [16] also checked this relationship using a cross-country sample. They argued that urbanization significantly increases CO_2 emissions in the low-income, middle-/low-income and high-income groups, while it does not significantly affect CO_2 emissions for the middle-/high-income group. Liu and Bae [17] found that 1% augmentations of urbanization increase CO_2 emissions by 1% in China.

The second kind of study assumes that the relationship between urbanization and environmental pollution is linear but that urbanization can improve the use of public facilities and public transportation, create industrial agglomeration, and reduce the cost of energy consumption and pollution treatment [18–20], which helps reduce emissions of pollutants [21,22]. However, there are too few empirical studies proving this idea.

The third kind of research holds that the relationship between urbanization and environmental pollution is nonlinear. These studies draw on the empirical method of the Environmental Kuznets Curve (EKC) hypothesis to test the relationship between urbanization and pollution emission and arrive at different conclusions. The existing literature has found that the urbanization rate and environmental pollution have an inverted U-shaped relationship [23–29]. For example, based on the threshold model, Zi et al. [25] checked the relationship between urbanization and CO_2 emissions in China during 1979–2013, and they found an inverted U-shaped relationship. Further, the threshold point was 43%. Using different samples, Ouyang and Lin [26], Bekhet and Othman [28], and He et al. [29] found the same inverted U-shaped relationship. Zhang et al. [27] calculated a turn point of 73.80%.

Also, several studies have considered that the relationship between urbanization and emissions is not obvious [30]. For example, based on the data from 20 emerging countries during 1992–2008, Zhu et al. [30] found that there is little evidence in support of an inverted U-curve between urbanization and CO_2 emissions. Liu et al. made use of Chinese data from 1995 to 2012, checked the relationship between GHG emissions per capita and the urbanization ratio, and argued that the impact is small and insignificant, especially when compared to the other driving forces.

There is no agreement on the relationship between urbanization and environmental pollution, and there are great differences in the results of empirical tests. This is because the relationship between urbanization and the environment is complex, depending not only on the speed of urbanization but also on the level of industrial development, energy efficiency, environmental pollution, urbanization paths, and so on. Therefore, it is not enough to examine the relationship between urbanization and environmental pollution.

Table 1 summarizes the methods, dependent variables, and samples of the existing studies and illustrates their major conclusions. As shown in Table 1, most of the empirical models are based on STIRPAT model. However, due to the different samples, the econometrics methods adopted by these studies are different. Some samples are panel data, and POLS (Pooled Ordinary Least Squares), FE (Fixed Effect), FGLS (Feasible Generalized Least Squares) were mainly used. Some research samples are time series data, and Granger causality testes, ARDL (auto regressive distributed lag) and VECM (Vector Error Correction Model) are mainly used. In the above articles, the threshold model was first used to analyze the relationship between urbanization and CO_2 emissions in Zi et al. [25], which found the inverted U-shaped between urbanization and CO_2 emissions in China from 1979 to 2013. So far, literature using threshold effect model has been found to analyze the relationship between urbanization and GHG emissions from a global perspective. Further, the threshold effect model also provides a way to test whether there are other factors besides urbanization, which will affect the relationship between urbanization and GHG emissions. That's why we choose the threshold effect model.

4. Methodology and data

4.1. Threshold model

The threshold model, which was introduced by Hansen [34], describes the jumping character or structural break in the relationship between variables. Hansen [34] gave the least squares estimation method for threshold regression. And the threshold regression for panel data was then complemented by Wang [2]. Considering the single-threshold model, the structure equation is

$$y_{it} = \mu + X_{it} I(q_{it} < \gamma)\beta_1 + X_{it} I(q_{it} \geqslant \gamma)\beta_2 + u_i + e_{it} \quad (1)$$

where y_{it} is the dependent variable, q_{it} is the threshold variable, and $I(\cdot)$ is the indicator function. An alternative intuitive way of writing (1) is

$$y_{it} = \begin{cases} \mu + X_{it} I\beta_1 + u_i + e_{it}, & q_{it} < \gamma, \\ \mu + X_{it} I\beta_2 + u_i + e_{it}, & q_{it} \geqslant \gamma. \end{cases} \quad (2)$$

Here, the observations are divided into two regimes, with coefficients

Table 1
Literature review.

	Literature	Method	Dependent variable	Period & countries/regions	Major findings
Inverted U-shaped	Zi et al. [25]	Threshold model	CO_2 emissions	1979–2013; China	Inverted U-shaped, and the threshold point is 43%.
	Ouyang and Lin [26]	Unit root, cointegration, and Granger causality tests	CO_2 emissions	1978–2011; China, Japan	Inverted U-shaped.
	Zhang et al. [27]	STIRPAT model, Two-way FE	CO_2 emissions	1961–2011; 141 countries	Inverted U-shaped, and the turn point is 73.80%.
	Bekhet and Othman [28]	VECM, and Granger causality testes	CO_2 emissions	1971–2015; Malaysia	Inverted U-shaped.
	He et al. [29]	STIRPAT model and FGLS	CO_2 emissions	1995–2013: China	Inverted U-shaped.
Linear increasing	Poumanyvong and Kaneko [13]	STIRPAT model	CO_2 emissions, CO_2 intensity	1975–2005; 99 countries	The impact of urbanization on emissions is positive for all the income groups, but it is more pronounced in the middle-income group than in the other income groups.
	Zhang and Lin [14]	STIRPAT model, FE, Two-way FE, FGLS, PCSE, and DK	CO_2 emissions	1995–2010: China	Urbanization increases CO_2 emissions in China, and the impact of urbanization on CO_2 emissions in the central region is greater than is that in the eastern region.
	Wang et al. [31]	STIRPAT model and PLS regress	CO_2 emissions	1997–2010: Beijing, China	Urbanization level has the greatest interpretative ability for CO_2 emissions.
	Al-mulali et al. [32]	Dynamic OLS, VECM, Granger causality	Total carbon dioxide emission	1980–2009: MENA (Middle East and North African) countries	Slowing down the urbanization level can help reduce the level of pollution and energy consumption.
	Sadorsky [15]	STIRPAT model, PCS, FE, and RE	CO_2 emissions	1971–2009: 16 emerging countries	Higher urbanization is associated with higher economic activity, which can increase carbon dioxide emissions.
	Li and Lin [16]	STIRPAT model, POLS, FE	CO_2 emissions	1971–2010; 73 countries	In the low-income, middle-/low-income, and high-income groups, urbanization significantly increases CO_2 emissions; for the middle-/high-income group, urbanization does not significantly affect CO_2 emissions.
	Wang et al. [33]	Panel unit root, cointegration, and causality tests	Carbon emission	1985–2014: BRICS countries	In the long-term, urbanization Granger causes carbon emission.
	Liu and Bae [17]	ARDL and VECM	CO_2 emissions per capita	1970–2015; China	1% augmentations of urbanization increase CO_2 emissions by 1%.

β_1 and β_2 depending on whether the threshold variable q_{it} is either smaller or larger than the threshold γ. The regimes are distinguished be differing regression slopes.

Given γ, the ordinary least-squares estimator of β is

$$\hat{\beta} = \{X^*(\gamma)'X^*(\gamma)\}^{-1}\{X^*(\gamma)'y^*\} \tag{3}$$

where $\hat{y}^*$ and X^* are within-group deviations. The residual sum of squares (RSS) equal to $e^{*\prime}e^*$. γ's estimator is the value that minimizes the RSS, that is,

$$\hat{\gamma} = \text{argmin}_{\gamma} S_1(\gamma) \tag{4}$$

Above is the estimated scheme search for any single threshold. The method for searching double or triple thresholds is similar.

Next, two tests are employed to determine threshold stability. The first test is to check whether $\gamma = \gamma_0$. Hansen [34] proved that the best approach is to form the confidence interval using the "no-rejection region" method with a likelihood (LR) statistic, as follows:

$$LR_1(\gamma) = \frac{\{LR_1(\gamma) - LR_1(\hat{\gamma})\}}{\sigma^2} \tag{5}$$

The second test is to check whether the coefficients are the same in each regime. The F statistic is constructed as follows:

$$F_1 = \frac{(S_0 - S_1)}{\hat{\sigma}^2} \tag{6}$$

where S_0 is the RSS of the linear model, and the S_1 is the RSS of the threshold model. Hansen [34] provided the standard test method. Here, we identify the threshold effect by a bootstrap method designed by Hansen [34].

To investigate the impact of urbanization on GHG emissions and whether there is a threshold effect, the empirical model is established based on the STIRPAT model which is widely used to investigate the relationship between urbanization and CO_2 emissions or GHG emissions (eg. [13,14,31,35,15,16,29]). The STIRPAT model is based on the Influence, Population, Affluence, and Technology (IPAT) model proposed by Ehrlich and Holdren [36]. The econometric model is established as follows:

$$\begin{aligned}\ln(GHG_{it}) = {} & \alpha_0 + \alpha_1\ln(urb_{it})(thr < \lambda_1) + \alpha_2\ln(urb_{it})(\lambda_1 \leqslant thr < \lambda_2) + \alpha_3\ln(urb_{it})(thr \geqslant \lambda_2) + \alpha_4\ln(inc_{it}) + \alpha_5\ln(pop_{it}) \\ & + \alpha_6\ln(ene_{it}) + \alpha_7\ln(ind_{it}) + \mu_{it} + \varepsilon_{it}\end{aligned} \tag{7}$$

where the dependent variable is *GHG*, which represents the total GHG emissions, which are composed of CO_2 totals, excluding short-cycle biomass burning (such as agricultural waste burning and Savannah burning) but including other biomass burning (such as forest fires, post-burn decay, peat fires, and decay of drained peat lands), all anthropogenic CH_4 sources, N_2O sources, and F-gases (HFCs, PFCs and SF6). The unit of *GHG* is kt of CO_2 equivalent.

The independent variable is *urb*, which represents the proportion of urban population, referring to people living in urban areas as defined by national statistical offices. The unit of *urb* is %.

For the controlling variables, in the empirical model given by Poumanyvong and Kaneko [13], controlling variables include *population* presented by the mid year population, *GDP per capita* presented by GDP divided by the mid year population, *energy intensity* presented by the total energy use divided by GDP, *IND* presented by the share of industry in GDP, and *SV* presented by the share of services in GDP. In the empirical model given by Zhang and Lin [14], controlling variables include *P* measured by the population size, *A* measured by the GDP per capita, *IND* measured by the share of industry sector in GDP, and *SV* measured by the share of service sector in GDP. In the empirical model given by Wang et al. [31], controlling variables include *P* denoted by population structure, *A* denoted by the economic level, *SI* denoted by the proportion of second industry, *ST* denoted by the proportion of tertiary industry, *E* denoted by energy intensity and *T* denoted by R&D

intensity. In the empirical model given by Sadorsky [15], controlling variables include *affluence* presented by the natural log of real per capita GDP, *population* presented by the natural log of total population, and *intensity* represented by the natural log of total energy use per dollar of GDP. In the empirical model given by Li and Lin [16], controlling variables include *P* denoted by the population size, *A* measured by GDP per capita, *IND* denoted by the added value of the secondary industry divided by the primary industry, *EI* denoted by the total energy use divided by GDP. In the empirical model given by He et al. [29], controlling variables include *Y* denoted by the real GDP per capita, *P* denoted by the total population, *EI* denoted by the energy use divided by GDP, *IND* denoted by the ratio of industry sector value added in GDP, and *T* denoted by the number of patents. Based on the above studies, we choose *Inc., pop, ene,* and *ind* as controlling variables.

The controlling variables include *Inc., pop, ene*, and *ind*. *Inc* refers to GDP per capita, which is GDP divided by midyear population. GDP is the sum of the gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions either for the depreciation of fabricated assets or for the depletion and degradation of natural resources. Data are in constant 2010 U.S. dollars. *pop* refers to total population, which is based on the de facto definition of population, which counts all residents, regardless of legal status or citizenship. The values shown are midyear estimates. Energy use is closely related to the GHG emissions in the process of urbanization [37,38], so we add energy intensity as a controlling variable. *ene* refers to energy use per capita. Energy use refers to the use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport. The unit of *ene* is kg of oil equivalent per capita. *ind* refers to the proportion of industry value added of GDP. Industry corresponds to the International Standard Industrial Classification (ISIC) divisions 10–45 and includes manufacturing (ISIC divisions 15–37). It comprises value added in mining, manufacturing (also reported as a separate subgroup), construction, electricity, water, and gas. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for either the depreciation of fabricated assets or the depletion and degradation of natural resources. The origin of value added is determined by ISIC, revision 3. And i = 1, …, n identifies the country, t refers to each yearly observation, and ε is the error term.

4.2. Sample selection

Our objective is to identify the relationship between urbanization and GHG emissions. We selected a cross-country panel data set. The data for all variables were obtained from the World Bank's World Development Indicators (WDI) (World Bank, 2017). The sample list, which includes 60 countries, is shown in Table 2. As shown in Table 2, the sample contains 4 low-income economies, 20 low-middle-income economies, 17 upper-middle-income economies, and 19 high-income economies.

4.3. Summary statistics

The summary statistics of the key variables are given in Table 3. As shown in Table 3, the mean of variable *urb* is 55.417, which indicates that the average proportion of urban population is 55.417%. Overall, more than half of the population has moved into cities, but the urbanization level is still lower in several countries. For example, the proportion of urban population in Nepal in 1971 was only 4.005%, and the proportion of urban population in Uruguay in 2012 was 94.803%.

Table 2
Sample list.

Income group	Countries			
Low-income economies	DR Congo	Nepal	Senegal	Zimbabwe
Low-middle-income economies	Bangladesh	Bolivia	Cameroon	Congo, Rep.
	Egypt, Arab Rep.	El Salvador	Ghana	Guatemala
	Honduras	India	Indonesia	Kenya
	Morocco	Myanmar	Nigeria	Pakistan
	Philippines	Sudan	Tunisia	Zambia
Upper-middle-income economies	Algeria	Argentina	Brazil	China
	Colombia	Cuba	Dominican, Rep.	Ecuador
	Iran, Islamic Rep.	Malaysia	Mexico	Panama
	Paraguay	Peru	Thailand	Turkey
	Venezuela, RB			
High-income economies	Australia	Austria	Chile	Denmark
	Finland	France	Greece	Ireland
	Israel	Italy	Japan	Korea, Rep.
	Netherlands	Portugal	Spain	Sweden
	United Kingdom	United States	Uruguay	

Notes: low-income economies refer to economies with $1005 or less GDP per capita, low-middle-income economies refer to economies with $1006 to $3955 GDP per capita, upper-middle-income economies refer to economies with $3956 to $12,235 GDP per capita, and high-income economies refer to economies with $12,236 or more GDP per capita.

5. Results

The threshold effects with *urb*, *GHG*, *Inc.*, *pop*, and *ene* are significant, while the threshold effect of *ind* is not obvious. The LR test result was shown in Fig. 3, and The threshold regression results are shown in Table 4. As shown in Table 4, *urb* has a positive and significant coefficient during the entire period, suggesting that the bigger the proportion of urban population, the larger the GHG emissions. The population agglomeration in cities causes more GHG emissions and more environmental problems. This is because the processes of population urbanization and industrial urbanization are inseparable. The precondition for population agglomeration in a city is the agglomeration of industry in the city; when the population and industry gather at the same time, complex environmental problems will be caused. However, there was a threshold effect with urbanization, and the first and second thresholds are 23.59% and 28.61%. When the urbanization ratio was lower than 23.59%, the influence of urbanization on GHG emissions was lower. When the urbanization ratio exceeded 23.59% and was lower than 28.61%, the effect of urbanization on GHG emissions increased. When the urbanization ratio was bigger than 28.61%, the influence of urbanization decreased. Thus, more attention should be paid to the relationship between urbanization and GHG emissions if the urbanization ratio is between 23.59% and 28.61%.

In addition, the results of the controlling variables also have some valuable results.*inc.* has a negative and significant coefficient, suggesting that more GDP per capita is associated with more GHG emissions.*pop* has a positive and significant coefficient, suggesting that a large population will cause more GHG emissions. *ene* also has a positive and significant coefficient, which means that a higher level of energy consumption is associated with more GHG emissions. *ind* has a positive and significant coefficient, suggesting that an economy with a higher proportion of secondary industry is more likely to cause more GHG emissions.

Table 3
Summary statistics of the key variables.

Variable	Obs	Mean	Std. Dev.	Min	Median	Max
GHG	2520	447733.8	1,117,790	4965.814	111710.1	12,500,000
urb	2520	55.417	21.729	4.005	56.666	94.803
Inc.	2520	10913.180	14040.190	166.817	3686.513	61174.550
pop	2520	71,300,000	187,000,000	1,406,643	18,800,000	1,350,000,000
ene	2520	1560.929	1645.040	85.599	785.560	8438.403
ind	2520	30.946	9.252	4.077	30.269	77.414

The threshold effect of *GHG* proved that there are two threshold points: one is 42,287 kt of CO_2 equivalent, and the other is 670,993 kt of CO_2 equivalent. When the GHG emissions are below 42,287 kt of CO_2 equivalent in an economy, the relationship between urbanization and GHG emission is not significant, suggesting that the rapidly increase of the urban population will not definitely cause more GHG emissions. For example, the GHG emissions in Congo, Rep., the Dominican Republic, El Salvador, Guatemala, Honduras, Nepal, Panama, Tunisia, and Uruguay in 2012 were not more than 42,287kt of CO_2 equivalent. Only when the GHG emissions are above 42,287 kt of CO_2 equivalent, the increasing urban ratio will cause more GHG emissions. For economies with more than 670,993 kt of CO_2 equivalent, in particular, rapid increase of the urban population has a greater impact on GHG emissions. In 2012, 8 of the countries in our samples had GHG emissions of more than 670,993 kt of CO_2 equivalent; these are China, US, India, Brazil, Japan, DR Congo, Indonesia, and Australia. So, in several countries

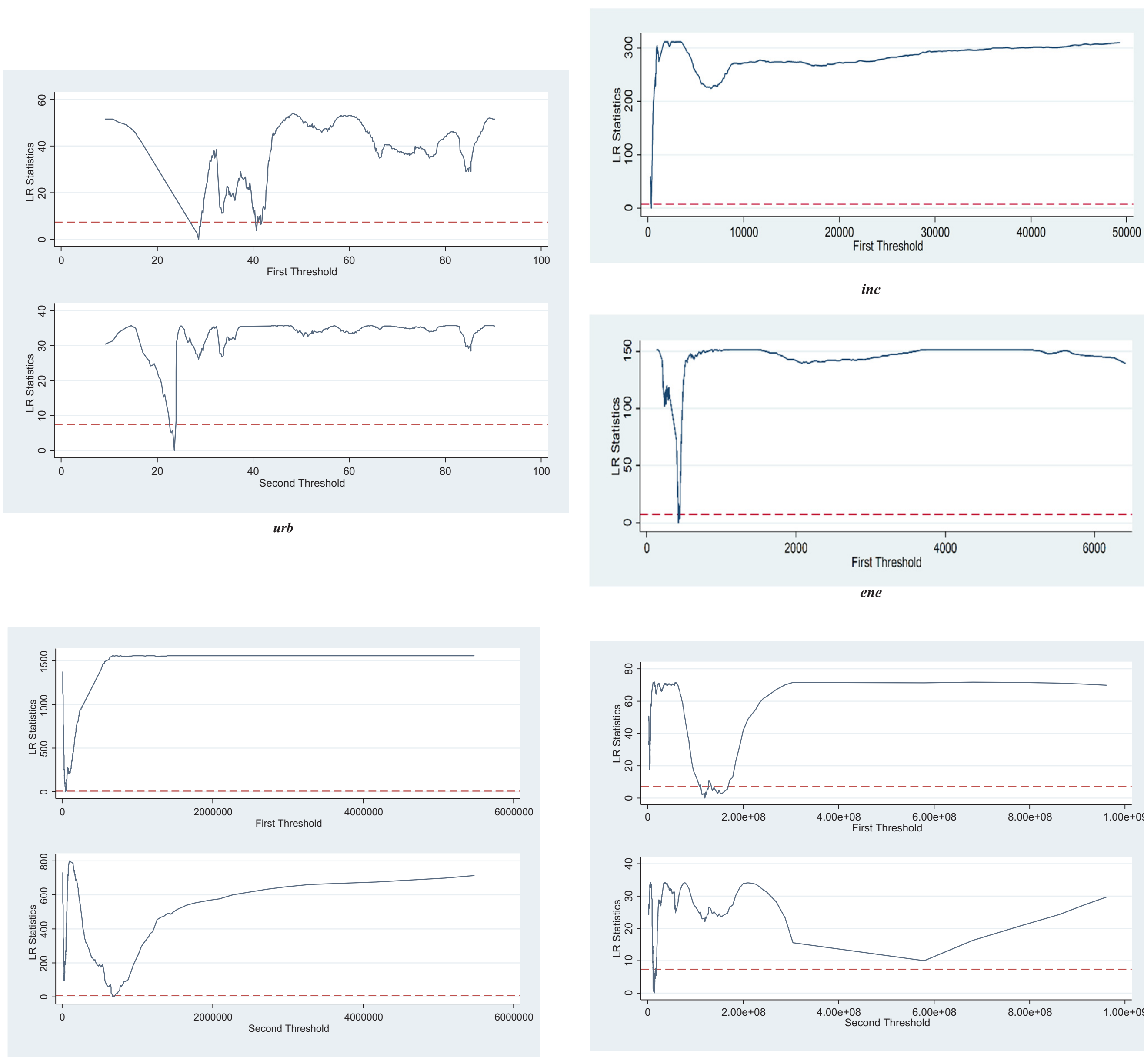


Fig. 3. LR test results for entire sample.

Table 4
Threshold regression results for entire samples.

Threshold variable	Urbanization ratio (*urb*)	GHG emissions (*GHG*)	GDP per capita (*Inc.*)	Population (*pop*)	Energy per capita (*ene*)	Line regression
Threshold point	23.59, 28.61	42287, 670,993	347.98	1.37e + 07, 1.19e + 08	425.16	
lnurb ($thr \le \gamma_1$)	0.179**	0.066	0.835***	0.373***	0.661***	0.447***
	(2.16)	(1.64)	(14.17)	(6.80)	(12.55)	(8.09)
lnurb ($\gamma_1 < thr \le \gamma_2$)	0.458***	0.371***	0.376***	0.482***	0.421***	
	(6.27)	(9.42)	(7.08)	(8.88)	(8.17)	
lnurb ($thr > \gamma_2$)	0.290***	0.706***		0.628***		
	(4.45)	(17.84)		(10.90)		
lninc	−0.226***	−0.216***	−0.123***	−0.315***	−0.302***	−0.283***
	(−6.87)	(−9.20)	(−3.70)	(−9.68)	(−9.80)	(0.03)
lnpop	0.875***	0.524***	0.880***	0.680***	0.875***	0.889***
	(75.08)	(47.07)	(79.25)	(29.03)	(80.96)	(0.01)
lnene	0.743***	0.466***	0.610***	0.800***	1.001***	0.767***
	(18.38)	(15.66)	(15.00)	(9.78)	(24.96)	(0.0411)
lnind	0.159***	0.126***	0.308***	0.086*	0.292***	0.097**
	(3.26)	(3.63)	(6.29)	(1.78)	(6.25)	(0.05)
F statistics	1238.36	2688.09	1528.55	1235.85	1639.46	
Observation	2520	2520	2520	2520	2520	2520
Within R^2	0.778	0.884	0.788	0.778	0.799	0.7684
LR test	[22.79, 23.90]***	[41739, 43092]***	[323.18, 355.79]***	[1.24e+07, 1.39e+07]***	[418.40, 427.25]***	
	[22.32, 28.86]***	[661572, 679365]***		[1.14e+08, 1.21e+08]***		
Method	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect	Fixed effect

Note: T statistics are in parentheses.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

with either a large population or a large amount of GDP, urbanization is more closely related to GHG emissions, which is something that should receive more attention.

The threshold effect of *inc* proved that the single threshold point was 347.98 U.S. dollars. Although *urb* has a positive and significant coefficient for the entire period, when the GDP per capita is less than 346.98 U.S. dollars, the increasing urbanization ratio will cause more GHG emissions. In addition, according to the EKC hypothesis, the relationship between GDP per capita and pollutant emissions is the inverted U type, suggesting that, when the GDP per capita is lower, pollutant emissions will increase, following the increasing of GDP per capita until the turning point, and then decrease following the increasing of GDP per capita. So, poor countries with less GDP per capita need to face two problems at the same time. One is the increasing pollution due to the low level of economic development, and the other is the greater seriousness of the worsening effect of urbanization on environmental pollution when the economic level is low.

The threshold effect of *pop* proved that the double threshold points were 1.37e + 07 and 1.19e + 08. Although the coefficients of *urb* were always positive and significant, the impact of urbanization on GHG emissions increased gradually as the population increased, especially when the population exceed 1.19e + 08; examples of this include China, India, Brazil, Indonesia, and the US.

The threshold effect of *ene* proved that the single threshold point was 425.16 kg of oil equivalent per capita. During the entire period, the coefficient of *urb* was positive and significant; however, when the energy per capita was lower than 425.16 kg of oil equivalent, the impact of urbanization on GHG emissions was greater. Thus, in economies with lower energy efficiency, a rapid increase of urban ratio will obviously harm the environment.

6. Further analyses for countries with different urbanization paths

According to international experience, urbanization generally goes through three stages: the development stage of small towns, the development stage of urban agglomeration in small cities and cities, and the reverse urbanization stage of the migration from large cities to small towns. From the perspective of urbanization, we can not only develop small towns, but also develop large and medium-sized cities and urban agglomerations to achieve urbanization. For example, the urbanization of the developed countries has been in the third stage. The urbanization of Russia has just experienced the first stage of the development of small towns, and it has entered the second stage of the development of urban agglomeration, while South Korea has been developing mainly with urban agglomeration. Table 5 describes the urbanization path of sample countries in 2014.

As shown in Table 5, the urbanization rate of four countries—Uruguay, Japan, Israel, and Argentina—is more than 90%, However, the urbanization paths are very different in these four countries. According to the largest ratio and the metro ratio, all the sample countries can be divided into two groups: the first group comprises countries whose largest ratio is bigger than the metro ratio, the second group comprises countries whose largest ratio is smaller than the metro ratio. There are 35 countries in the first group and 25 countries in the second group.

For the first group, taking Uruguay as an example, the population in the largest city of urban population is 52.18%, which is larger than that in urban agglomerations of more than 1 million, indicating that most of the urban population lives in the several largest cities, and the other cities in urban agglomerations have not developed. The situation is similar in Chile, Denmark, Sweden, Finland, Peru, Dominican Republic, Greece, and other countries. In addition, the urbanization path in The Netherlands is very different; in 2014, the urban ratio was 89.91%, but the largest ratio was only 7.15%, neither the metro ratio is only 6.42%. So, the urbanization path in The Netherlands is small towns, and most of the urban populations live in small towns. The situation is similar in Algeria.

For the second group, the population in the largest city is smaller than are those in the urban agglomerations of more than 1 million, suggesting that the development of urban agglomerations in these countries is more mature, and the cities in the urban agglomerations can form a good interactive support and relatively develop balance. For example, the largest ratio in the US is 7.17%, which is also lower than

Table 5
The urbanization path in different countries in 2014.

Country	Urban ratio (%)	Largest ratio (%)	Metro ratio (%)	Country	Urban ratio (%)	Largest ratio (%)	Metro ratio (%)
Uruguay	95.15	52.18	49.65	Panama	66.29	63.29	41.95
Japan	93.02	31.96	65.18	El Salvador	66.26	26.35	17.46
Israel	92.08	47.05	56.59	Austria	65.92	30.96	20.41
Argentina	91.60	38.16	43.96	Congo, Rep.	64.96	57.74	37.50
Netherlands	89.91	7.15	6.42	Ecuador	63.52	26.37	27.44
Chile	89.36	41.12	36.74	Ireland	62.95	39.73	25.01
Australia	89.29	21.36	59.11	Portugal	62.91	43.85	40.04
Venezuela, RB	88.94	10.65	29.17	Morocco	59.70	17.04	22.35
Denmark	87.50	25.41	22.23	Paraguay	59.42	59.26	35.21
Sweden	85.67	17.62	15.10	China	54.41	3.10	23.98
Brazil	85.43	11.94	39.77	Honduras	54.14	23.08	12.49
Finland	84.09	25.47	21.42	Cameroon	53.82	24.48	25.94
Korea, Rep.	82.36	23.39	47.56	Ghana	53.39	17.24	17.52
United Kingdom	82.35	19.15	28.49	Indonesia	53.00	7.53	10.46
United States	81.45	7.17	45.26	Guatemala	51.12	34.98	17.88
Spain	79.36	16.63	24.40	Thailand	49.17	27.04	15.71
France	79.29	20.47	22.59	Nigeria	46.94	15.23	15.46
Mexico	78.97	21.25	37.79	Philippines	44.49	28.66	14.35
Peru	78.29	40.10	31.39	Senegal	43.39	53.75	23.32
Dominican, Rep	78.06	35.37	27.61	Egypt, Arab Rep.	43.07	46.58	25.17
Greece	77.68	36.16	28.09	DR Congo	41.98	35.92	23.18
Cuba	76.97	24.37	18.76	Zambia	40.47	32.88	13.31
Colombia	76.16	26.26	42.39	Pakistan	38.30	22.69	21.68
Malaysia	74.01	29.63	21.93	Sudan	33.62	39.40	13.25
Turkey	72.89	24.85	37.55	Myanmar	33.55	27.01	13.21
Iran, Islamic Rep.	72.86	14.62	26.02	Bangladesh	33.52	31.79	14.09
Algeria	70.13	9.33	6.54	Zimbabwe	32.50	29.84	9.70
Italy	68.82	8.84	17.70	India	32.37	5.96	14.48
Bolivia	68.11	28.24	47.72	Kenya	25.20	32.49	10.51
Tunisia	66.65	26.63	17.75	Nepal	18.24	22.10	4.03

Notes: The largest ratio refers to the population in the largest city of urban population of urban population; the metro ratio refers to the population in urban agglomerations of more than 1 million% of total population.

other countries. However, the metro ratio in the US is 45.26%, which shows that most of the urban population in the US lives in urban agglomerations and that the scale of these cities is balanced and the proportion of the population living in the megacities is not very high. Also, in China, the largest ratio is only 3.10%, but the metro ratio is close to 24%, which has contributed to the development strategy of urban agglomeration in China in the past ten years. Besides the US and China, the second group includes Brazil, India, Japan, the UK, France, and other countries with either higher GDP per capita or larger population.

The urbanization mode includes two kinds of small towns and urban agglomerations. The two models have different effects on environmental pollution and pollution reduction. In small towns, although the urbanization has played an important role in promoting the developing of industrialization. However, due to the improper layout of small towns, it has also put great pressure on the environment of small towns. Therefore, environmental planning for small towns is very necessary. Compared to small towns, large cities and urban communities are more likely to control and reduce pollution because of economies of scale for countries that have already entered middle- and late-industrialization. However, in spite of the scale of economic advantages of urban agglomeration in the area of pollution control, the urban agglomeration environment problems have emerged due to the high concentration of population and industry, including the agglomeration and superposition effect of urban agglomeration water pollution, the heat island group effect of urban agglomeration, and the solid waste of urban agglomeration.

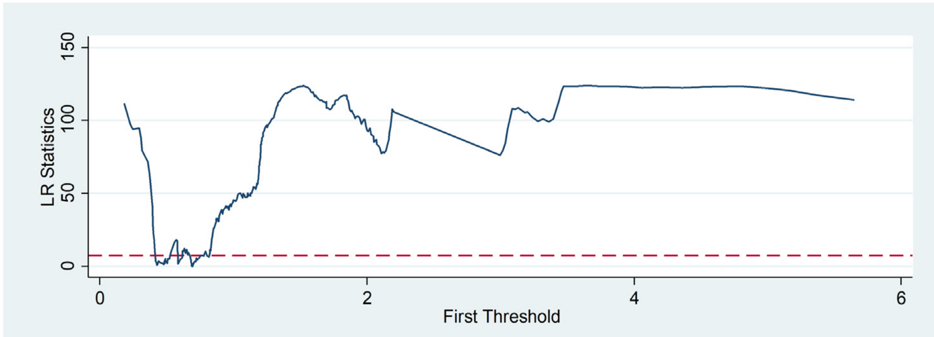
At the beginning of industrialization and urbanization, the development of small towns quickly and effectively concentrated the population and industry into cities and towns. On the one hand, the

Table 6
Threshold regression results with different urbanization paths.

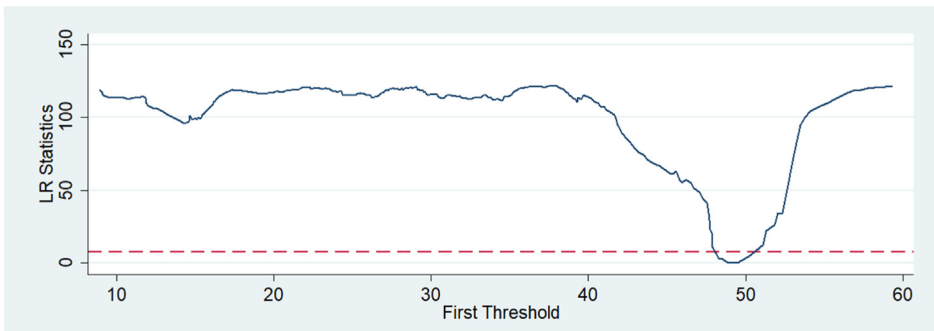
Threshold variable	Metro ratio (*met*)	Largest ratio (*largest*)
Threshold point	20.01	48.27
lnurb ($thr \le \gamma_1$)	0.247***	0.445***
	(4.25)	(8.16)
lnurb ($thr > \gamma_1$)	0.332***	0.556***
	(5.98)	(9.87)
lninc	−0.351***	−0.316***
	(−10.58)	(−9.62)
lnpop	0.877***	0.924***
	(76.75)	(75.48)
lnene	0.855***	0.832***
	(20.69)	(20.12)
lnind	0.128***	0.059
	(2.65)	(1.21)
F statistics	1435.32	1413.10
Observation	2520	2520
Within R^2	0.777	0.768
LR test	[19.86, 20.03]***	[47.89, 48.53]***

Note: Standard errors are in parentheses.
**$p < 0.05$.
*$p < 0.1$.
*** $p < 0.01$.

development of urbanization was promoted. On the other hand, the centralized treatment of pollution was realized by the construction of environmental infrastructure. The defects of small towns in dealing with environmental pollution are as follows: because of the small scale of their economy and their relatively small population, it is impossible to realize scale economy of pollution control. In the middle and late period of industrialization and urbanization, the population of small



Metro ratio



Largest ratio

Fig. 4. LR test results for further regression.

towns gradually migrated to large cities, and the urban agglomeration of big cities formed gradually. The urban agglomeration effectively solved the problem of the high cost of pollution control in small towns and realized the scale economy of pollution control. However, urban agglomeration also brings particular environmental problems, that is, urban agglomeration diseases. Therefore, the environmental problems caused by the two modes of small towns and urban agglomeration are different, and the performance of pollution control has both advantages and disadvantages.

To check the impact of the urbanization path on the relationship between urbanization and GHG emissions, we take two variables as threshold variables; these are metro ratio (*met*), and largest ratio (*largest*), and we repeat the threshold regression in Table 4. The results are shown in Table 6.

As shown in Table 6, there was a threshold effect with metro ratio (*met*), the threshold was 20.01%, and the LR test result was shown in Fig. 4. When the metro ratio was lower than 20.01%, the influence of urbanization on GHG emissions was lower. When the metro ratio passed 20.01%, the effect of urbanization on GHG emissions increased. Hence, regardless of the large proportion of the population in the urban agglomeration, urbanization will increase GHG emissions; however, when the urban population is higher than 20.01%, the increase of GHG emissions will become more obvious. In 2014, the ratio of urban agglomerations in 38 countries, including China, Japan, the US, and Brazil was higher than 20.01%, and the ratio of urban agglomerations in 22 countries, including Thailand, India, Italy, and Sweden, was lower than 20.01%.

There was a threshold effect with largest ratio (*Largest*), and the threshold was 48.27%. When the largest ratio is higher than 48.27%, the impact of urbanization on GHG emission will be bigger, suggesting that more attention should be paid to environmental protection when there are more people living in the largest cities. In 2014, there were 6 countries—Panama, Paraguay, Congo, Rep., Senegal, and Uruguay—with a largest ratio higher than 48.27%.

7. Conclusions

In recent years, urbanization and greenhouse gas (GHG) emissions have become two global issues. Whether to reduce GHG emissions in the process of global urbanization is a seeming dilemma that has attracted wide attention from the academic community. However, the existing research on urbanization and environmental pollution has not reached consensus. Some studies suggest that there is a positive linear relationship between the urbanization rate and environmental pollution, that is, the increase of the urbanization rate will increase GHG emissions. Other studies show that the urbanization rate and environmental pollution have an inverted U shape relationship, that is, following the increasing of urbanization ratio, the environmental pollution will increase until the turning point and then decrease.

In fact, the relationship between urbanization and environmental pollution is not simple. The relationship between the two depends not only on the urbanization rate and environmental pollution but also on other factors. For example, when the level of economic development is low, the construction of environmental protection facilities cannot keep up with the speed of urbanization, which will lead to increasingly serious environmental pollution caused by urbanization. When the level of economic development is high, the environmental protection facilities are sound, the investment of environmental governance is large, and the rate of urbanization is faster; however, this is not good, as the increasing urbanization will increase environmental pollution. Moreover, urbanization has two development paths: big cities and small towns. Different development paths will also affect the relationship between urbanization and environmental pollution.

Taking balanced panel data of 60 countries for 1971–2012 as a sample, we examined the relationship between urbanization and GHG emissions based on the threshold model. We found that the relationship between the urbanization ratio and GHG emissions was always positive, suggesting that urbanization will lead inevitably to an increase in GHG emissions, irrespective of how high the urbanization rate is. Nevertheless, the relationship between the urbanization rate and GHG emissions is different in the economies with different urbanization rate, GHG emission, economic development level, population scale, and energy efficiency. The empirical findings from threshold regression are as follows:

(1). There was a threshold effect with urbanization, and the first and second thresholds were 23.59% and 28.61%. When the urbanization ratio was lower than 23.59%, the influence of urbanization on GHG emissions was lower. When the urbanization ratio passed 23.59%, and was lower than 28.61%, the effect of urbanization on GHG emissions increased. When the urbanization ratio passed 28.61%, the effect of urbanization on GHG emissions dropped. In 2012, only Nepal and Kenya had a lower urbanization rate of 28.61%. It has been shown that most countries have already passed the second threshold of urbanization rate. With the improvement of urbanization rate, GHG emissions will inevitably increase. This conclusion is different from the previous inverted U-shaped relationship. However, we find this conclusion is relatively robust through the threshold effect model of other variables, which also proves the conclusion.

(2). The first and second thresholds of GHG are 42,287 kt of CO_2 equivalent and 670,993 kt of CO_2 equivalent. When the GHG emissions is below 42,287 kt of CO_2 equivalent in one economy, the relationship between urbanization and GHG emissions is not significant. Only when the GHG emissions are above 42,287 kt of CO_2 equivalent, the increasing urban ratio will cause more GHG emissions. In 2012, there are nine sample countries which GHG emissions are lower than 42,287 kt of CO_2 equivalent. The nine countries are El Salvador, Panama, Honduras, Guatemala, Dominican, Rep., Uruguay, Congo, Rep., Tunisia, and Nepal. It has been shown that, the increasing growth of urbanization in these nine countries does not necessarily lead to the increase of GHG emissions. In addition, there are eight sample countries which GHG emissions are higher than 42,287 kt of CO_2 equivalent, and lower than 670,993 kt of CO_2 equivalent. The eight countries are Paraguay, Cuba, Ecuador, Denmark, Senegal, Kenya, Ireland, and Sweden. This proofs that the increasing of urbanization ratio in these countries will slightly cause GHG emissions. For other 43 countries, the process of urbanization will cause more GHG emissions, which should be paid more attention.

(3). The only threshold of *inc.* represented by GDP per capita is 347.98 U.S. dollars. When the GDP per capita is less than 346.98 U.S. dollars, the increasing urbanization ratio will cause more GHG emissions. In 2012, only the GDP per capita in Congo, Dem. Rep. was lower than 347.98 U.S. dollars, and the GDP per capita in other countries were more. So whether the country is a low-income country or a high-income country, the GHG emissions caused by urbanization are almost the same.

(4). The first and second thresholds of *pop* represented by total population are 1.37e + 07 and 1.19e + 08, respectively. When the population exceeds 1.19e + 08, the impact of urbanization on GHG emissions increases gradually as the population increases. In 2012, the population of 18 countries including Uruguay, Panama, Ireland, Congo, Rep., Finland, Denmark, El Salvador, Paraguay, Israel, Austria, Honduras, Sweden, Dominican, Rep., Bolivia, Portugal, Tunisia, Greece, and Cuba was less than 1.37e + 07. And the population of 10 countries including Mexico, Japan, Bangladesh, Nigeria, Pakistan, Brazil, Indonesia, United States, India, and China was more than 1.19e + 08. It has been shown that, we should pay more attention to the urbanization in countries with large population, since the increasing of GHG emissions caused by urbanization in these countries are more compared to others.

(5). The only threshold of *ene* represented by energy use per capita is 425.16 kg of oil equivalent per capita. When the energy per capita is lower than 425.16 kg of oil equivalent, the impact of urbanization on GHG emissions will be greater. In 2012, there are eight sample countries which energy intensity was lower than 425.16 kg of oil equivalent per capita. The eight countries are Bangladesh, Senegal, Myanmar, Cameroon, Ghana, Nepal, Congo, Dem. Rep., and Sudan. It has been shown that, the increasing growth of urbanization in these eight countries will cause more GHG emissions, and the influences of urbanization in other 52 countries are less.

(6). The only threshold of *met* represented by the proportion of population in urban agglomerations with more than 1 million population of total population is 20.01%. When the metro ratio is higher than 20.01%, the influence of urbanization on GHG emission is higher, such as Japan, Australia, United States, and Brazil. And the only threshold of *Largest* represented by the population in the largest city of urban population is 48.27%. When the largest ratio is higher than 48.27%, the impact of urbanization on GHG emissions will be bigger, such as Panama, Paraguay, Congo, Rep., Senegal, and Uruguay.

To sum up, we proposed the following policy recommendations. Firstly, in the process of the rapid development of global urbanization, we should pay close attention to the GHG emissions caused by urbanization. Because, urbanization will inevitably lead more GHG emissions, no matter the urbanization ratio is high or low. Secondly, in the countries with large population, such as Mexico, Japan, Bangladesh, Nigeria, Pakistan, Brazil, Indonesia, United States, India, and China, we should pay special attention to the development of urbanization. Since in these countries, the GHG emissions caused by urbanization are more than those in other countries. Thirdly, besides urbanization, we should also pay attention to the path of urbanization. When the metro ratio is higher than 20.01%, or the largest ratio is higher than 48.27%, the impact of urbanization on GHG emissions will be bigger.

Despite our valuable conclusions, this paper has several limitations. For example, because of the limitations of the data, we cannot obtain more data before 1971, which makes it impossible for us to analyze the dynamic relationship between the urbanization development and GHG emissions in some developed countries. Additionally, as mentioned earlier, the environmental pollution caused by urbanization; however, at present, we have not deeply analyzed the relationship between the two different sources of pollution and urbanization, which is also necessary for understanding the mechanism between urbanization and GHG emissions.

Acknowledgements

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Appendix A

See Appendices 1 and 2.

Appendix 1
Country list.

Country Name	Country Code	Country Name	Country Code	Country Name	Country Code
Algeria	DZA	France	FRA	Nigeria	NGA
Argentina	ARG	Ghana	GHA	Pakistan	PAK
Australia	AUS	Greece	GRC	Panama	PAN
Austria	AUT	Guatemala	GTM	Paraguay	PRY
Bangladesh	BGD	Honduras	HND	Peru	PER
Bolivia	BOL	India	IND	Philippines	PHL
Brazil	BRA	Indonesia	IDN	Portugal	PRT
Cameroon	CMR	Iran, Islamic Rep.	IRN	Senegal	SEN
Chile	CHL	Ireland	IRL	Spain	ESP
China	CHN	Israel	ISR	Sudan	SDN
Colombia	COL	Italy	ITA	Sweden	SWE
DR Congo	COD	Japan	JPN	Thailand	THA
Congo, Rep.	COG	Kenya	KEN	Tunisia	TUN
Cuba	CUB	Korea, Rep.	KOR	Turkey	TUR
Denmark	DNK	Malaysia	MYS	United Kingdom	GBR
Dominican Republic	DOM	Mexico	MEX	United States	USA
Ecuador	ECU	Morocco	MAR	Uruguay	URY
Egypt, Arab Rep.	EGY	Myanmar	MMR	Venezuela, RB	VEN
El Salvador	SLV	Nepal	NPL	Zambia	ZMB
Finland	FIN	Netherlands	NLD	Zimbabwe	ZWE

Appendix 2
The urbanization rate of 60 sample countries in 1971 and 2012.

Country Code	Urbanization ratio in 1971	Urbanization ratio in 2012	Change of urbanization ratio
AUS	85.60%	89.02%	3.42%
ISR	84.79%	91.95%	7.16%
URY	82.57%	94.80%	12.23%
SWE	81.56%	85.36%	3.80%
DNK	80.24%	87.14%	6.90%
ARG	79.32%	91.30%	11.97%
GBR	77.03%	81.83%	4.80%
CHL	75.88%	88.99%	13.10%
USA	73.61%	81.11%	7.50%
VEN	72.76%	88.85%	16.09%
JPN	72.67%	91.90%	19.24%
FRA	71.46%	78.82%	7.36%
ESP	66.85%	78.90%	12.05%
AUT	65.30%	65.86%	0.56%
GRC	64.95%	77.00%	12.05%
ITA	64.75%	68.56%	3.81%
FIN	64.52%	83.82%	19.30%
NLD	61.91%	88.58%	26.66%
CUB	60.98%	76.78%	15.81%
MEX	59.78%	78.41%	18.63%
PER	58.50%	77.62%	19.12%
BRA	56.89%	84.90%	28.01%
COL	55.57%	75.60%	20.03%
IRL	52.27%	62.39%	10.12%
PAN	47.92%	65.70%	17.78%
TUN	44.31%	66.27%	21.97%
KOR	42.26%	82.14%	39.88%
IRN	42.11%	71.77%	29.66%
EGY	41.84%	43.00%	1.16%
DOM	41.29%	76.04%	34.75%
BOL	40.08%	67.28%	27.20%
COG	39.92%	64.10%	24.18%
ECU	39.81%	63.09%	23.28%
DZA	39.67%	68.87%	29.21%
SLV	39.50%	65.29%	25.78%
PRT	39.20%	61.76%	22.56%
TUR	38.95%	71.83%	32.89%
PRY	37.23%	58.94%	21.71%
GTM	35.86%	50.21%	14.35%
MAR	35.01%	58.70%	23.69%

(*continued on next page*)

Appendix 2 (*continued*)

Country Code	Urbanization ratio in 1971	Urbanization ratio in 2012	Change of urbanization ratio
MYS	34.27%	72.53%	38.26%
PHL	33.49%	44.81%	11.32%
ZMB	31.24%	39.59%	8.35%
SEN	30.72%	42.78%	12.06%
HND	29.57%	52.93%	23.36%
GHA	29.17%	52.07%	22.90%
PAK	25.08%	37.43%	12.34%
COD	24.85%	40.95%	16.10%
MMR	23.22%	32.47%	9.25%
CMR	21.58%	52.68%	31.09%
THA	21.44%	46.68%	25.24%
IND	19.99%	31.63%	11.64%
NGA	18.15%	45.23%	27.08%
ZWE	17.86%	32.83%	14.98%
IDN	17.34%	51.49%	34.15%
CHN	17.29%	51.89%	34.60%
SDN	17.22%	33.32%	16.10%
KEN	10.78%	24.37%	13.59%
BGD	7.90%	31.99%	24.09%
NPL	4.01%	17.52%	13.51%

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