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Abstract

Recent empirical work suggests that urbanization and residential CO_2 emissions are related. This paper investigates the nonlinear impact of urbanization on residential CO_2 emissions over the period 1997–2011 in China by applying the Candelon et al. (2012) methodology. The results show that the relationship between urbanization and residential CO_2 emissions is negative over the sample which is inconsistent with the previous studies. In addition, we find the absolute difference of the estimated coefficients in two regimes of urbanization is significant. Keywords: Panel threshold model, urbanization, residential CO_2 emissions.

Keywords: Residential CO_2 emissions; Urbanization; PTR model

JEL classification: C2, R1

1 Introduction

The global climate change which is mainly caused by carbon dioxide (CO_2) emissions[1] has received increasing attention from researchers, politicians and whole society during the past two decades. The combustion of fossil fuels is the main source of CO_2. It is estimated that the world's CO_2 emissions rose from 18.04 billion ton in 1980 to 30.28 billion ton in 2010, and the residential CO_2 emissions have grown to 1.88 billion ton in 2010, which is accounting for 6.2%, 30.4% in total CO_2 emissions, Manufacturing industries and construction in 2010 (IEA, 2012), respectively. These figures tell us that residential CO_2 emissions is an important source of total CO_2 emissions, but it might have been largely ignored and the nexus between residential CO_2 emissions, economic growth and urbanization received little attention from academics. Most of these studies only investigate the relationship between urbanization and total CO2 emissions, such as Parikh and Shukla (1995);

[1] CO_2 accounted for about 76.7% of total anthropogenic greenhouse gas emissions in 2004 (IPCC, 2007).

Cole and Neumayer (2004); York (2007); York et al. (2003); Fan et al. (2006); Martínez-Zarzoso and Maruotti (2011); Zhu et al. (2012); Al-mulali et al.(2013). Poumanyvong and Kaneko (2012) is the first one as far as we know, who make an elaborated analysis on the relation between urbanization and residential CO_2 emissions, and they constructed a regression model of 88 countries over the period 1975–2005 to study the overall impact of urbanization on residential CO_2 emissions. The results indicate that there is a U-shape nexus between urbanization and residential CO_2 emissions in pooled groups and low-income group, a positive relation in middle-income group and inverted U-shape relation in high-income group. Other literatures only analyses the scale or influential factors of residential CO_2 emissions, such as Liu, Wang(2012); Fan, Liao, Liang(2013); Zhu, Peng, Wu(2012); Donglan, Dequn, Peng (2010).

In short, though the relation between urbanization and CO_2 emissions do exist in existing literatures, the relationship between of them varies across the countries, which is largely determined by their level of income and development. There is one limitation, however, to all these papers, all of them chose their threshold levels to identify the relation according to the criteria of World Bank, rather than estimating these parameters from the sample, which may lead to bias. In this paper, we explore the relationship between urbanization and residential CO_2 emissions based on panel threshold model (PTR model) which can determine the income threshold by the data itself. In addition, as far as we known, our paper is the first one studying the relation between urbanization and residential CO_2 emissions using the Chinese data in a PTR model. The contribution of this article is as follow: First, we calculate the residential CO_2 emissions which are burning from fossil fuels from 30 provinces in China over the period 1997-2011. Second, the econometric model we used can overcome the bias which caused from select threshold levels arbitrarily. Our empirical results show that the regime effect is significant, the relation between urbanization and residential CO_2 emissions, however, is not an inverted U-shape or linear relationship, and thus our findings are inconsistent with the previous study. When the level of income is under the threshold, the effect of urbanization on residential CO_2 emissions is negative, but it is not significant, and the absolute of coefficient is somewhat lower: a 10% increase in urbanization leads to only a 1% decline in residential CO_2 emissions. Once the regime is stepped over, a 10% increase in urbanization leads to a 9% decrease in residential CO_2 emissions, and more importantly, the negative impact of urbanization on residential CO_2 emissions becomes significant.

The remainder of our paper is structured as follows. The next section briefly reviews PTR model. Section 3 introduces the data and empirical results for the nexus between urbanization and residential CO_2 emissions. Finally, section 4 concludes.

2 Theoretical framework and econometric methods

In this paper, we make use of the STIRPAT model (Stochastic Impacts by Regression on Population, Affluence, and Technology, Dietz and Rosa, 1997; York et al., 2003) to analysis the impact of urbanization on residential CO_2 emissions. The model specification of STIRPAT model is as follows:

$$I_i = aP_i^b A_i^c T_i^d \varepsilon_i \tag{1}$$

Where I, P, A and T represents total environmental impact, population size, GDP per capita, and technology. a, b, c and d are to be estimated parameters and ε denote the error term. Technology (T) of the STIRPAT model varied according to the types of environment impact being studied (Poumanyvong and Kaneko, 2012). To capture the impact of urbanization on residential CO_2 emissions, we use urbanization to express T to estimate the STIRPAT model. Taking logarithmically in two sides of Eq.(1), we get the empirical model for the panel data of residential CO_2 emissions:

$$lnresico2_{it} = \mu_i + \beta_1 lnpop_{it} + \beta_2 lnpgdp + \beta_3 lnurban_{it} + \varepsilon_{it} \tag{2}$$

Where μ_i is the region individual effect which captures the unobserved region-specific effect. $resico2_{it}$ denotes the amount of residential CO_2 emissions of country i at year t. pop refers to the population size. $pgdp$ is per capita GDP. $urban$ represents the urbanization. As was previously mentioned, in this paper, we introduce nonlinearity in order to identify the real relation between urbanization and residential CO_2 emissions, a solution was to make use of a PTR model that proposed by Candelon et al.(2012). And this study only takes into account two regimes:

$$lnresico2_{it} = \begin{cases} \mu_i + \beta_{10} lnpop_{it} + \beta_{20} lnpgdp + \beta_{30} lnurban_{it} + \varepsilon_{it} & q_{it} \le \lambda \\ \mu_i + \beta_{11} lnpop_{it} + \beta_{21} lnpgdp + \beta_{31} lnurban_{it} + \varepsilon_{it} & q_{it} > \lambda \end{cases} \tag{3}$$

Where q_{it} refers to a threshold variable $pgdp$ and λ refers to a threshold parameter. PTR model can we rewritten as:

$$lnresico2_{it} = \mu_i + \delta_1' X_{it} I_{(q_{it} \le \lambda)} + \delta_2' X_{it} I_{(q_{it} > \lambda)} + \varepsilon_{it} \tag{4}$$

Where $\delta_j' = (\mu_j \ \beta_{1j} \ \beta_{2j} \ \beta_{3j})'$ for $j = 1,2$ and $X_{it} = (lnpop_{it} \ lnpgdp_{it} \ lnurban_{it})'$ and $I_{(\cdot)}$ is the indicator function, $\varepsilon_{it} \sim N(0, \sigma^2)$. For any given λ, the slope coefficient δ_1' and δ_2' can be estimated by OLS after the fixed-effects transformation. Conditional to a value of λ, it is possible to compute the sum of squared errors, represent as $S_1(\lambda)$:

$$S_1(\lambda) = \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\varepsilon}_{it}^2(\lambda) \tag{5}$$

The threshold parameter λ can be estimated by minimizing $S_1(\lambda)$:

$$\hat{\lambda} = argmin_{\lambda} S_1(\lambda) \tag{6}$$

Because we consider $pgdp$ as the unique therehold variable in the model, then there is only one mian problem with this threshold model. The problem is to test the threshold model, and the two regimes null hypothesis is $H_0: \delta_1 = \delta_2$. When the original hypothesis is rejected, the threshold effect is significant, implying that the relationship between urbanization and residential CO_2 is nonlinear. The detail of the PTR model can be referred to Candelon et al.(2012).

3 Data and empirical results

3.1 estimate residential CO_2 emissions

The panel data set is over the period 1997–2011 for 30 provinces of China[2]. First, we have to calculate the residential CO_2 emissions because there is no official data regarding this variable. Residential CO_2 emissions of this study come from the direct consumption of fossil fuels of city resident and rural resident which do not include indirect consumption of fuels and the biofuels used in countryside. The Formula to estimate residential CO_2 emissions which refer to IPCC is as follow:

$$resico2 = \sum_{i=1}^{n} E_i \times NCV_i \times CC_i \times COF_i \times \frac{44}{12} = \sum_{i=1}^{n} E_i \times EF_i \tag{7}$$

Where $resico2$ denotes the total residential CO_2 emissions, E_i, NCV_i, CC_i, COF_i represents the consumption, Net Calorific Values, Carbon Emission Factor and Carbon Oxidation Factor of the ith energy. EF_i refers to the CO_2 emission coefficient of fuel i. We

[2] Tibet is excluded because of data availabilities, Taiwan, Hong kong and Aomen are not considered in this paper.

compute the residential CO_2 emissions from fossil fuel burning which include raw coal, cleaned coal, washed coal, briquettes, coke, coke oven gas, other gas, crude oil, gasoline, kerosene, diesel oil, fuel oil, LPG, refinery gas, natural gas, other Petroleum product, LNG, converter gas, blast furnace gas. All the data on fossil fuels are compiled from the total final consumption item of regional energy balance tables in China Energy Statistical Yearbook. All of the emission coefficients refer to Su et al.(2010), National Coordination Committee Office on Climate Change and Energy Research Institute of the National Development and Reform Commission (NCOCCERINDRC,2007) and IPCC (2006). We substitute some fuels' emission coefficients which cannot find its emission coefficients by the similar fuel. Moreover, we adjust the Carbon Oxidation Factor according to NCOCCERINDRC(2007).

Fig.1 plots the total residential CO_2 emissions from 1995 to 2011 by region. Based on Fig.1, we find that total residential CO_2 emissions keep declining before 2000, but raise dramatically after 2000. Residential CO_2 emissions for three regions almost have no differences before 2005, while the differences become Significant between east and the others after 2005 which means that more fossil fuels are made use of in the east region than center and west. Table 1 provides a detailed description of all the variables and the data source used in this paper.

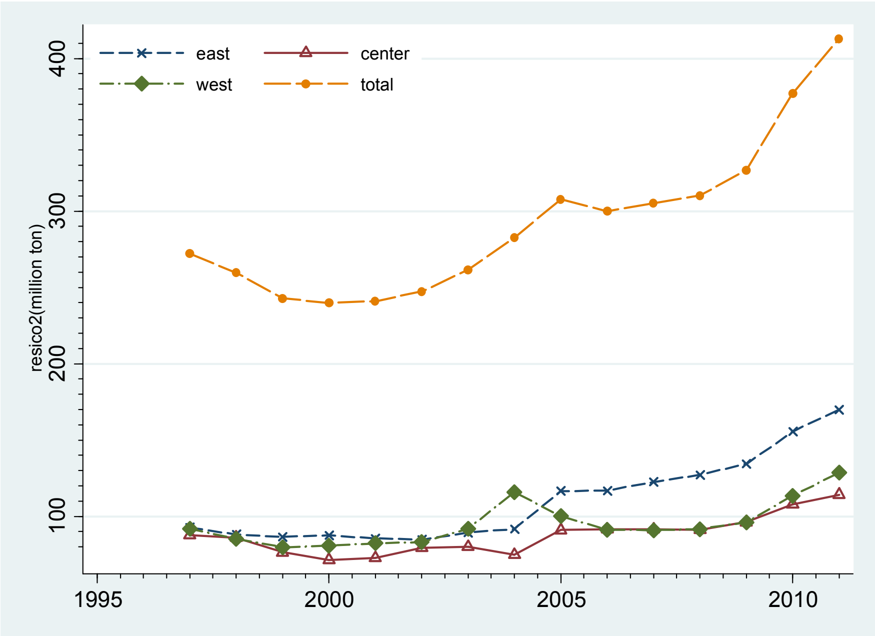

Fig 1 residential CO_2 emissions by area

Table 1 Description of the variables

Variables	Definitions	Unit	Obs	Mean	Std.dev	Min	Max
pop	population	ten thousand	450	4268.97	2578.05	496	10504.85
pgdp	GDP per capita	RMB (2000 prices)	450	15540.88	12902.26	2172.73	68639.27
urban	urbanization	percent	450	33.93	16.04	14.04	89.32
resico2	residential CO_2	ten thousand ton	450	974.96	638.81	6.00	3199.89

Notes: all the data are from China Statistical Yearbook, China Population Statistics Yearbook, China Population and Employment Statistics Yearbook, and China Energy Statistical Yearbook. Urbanization is defined as the percentage of non-agricultural population to total population.

3.2 empirical results

The empirical results are reported in Table 2. The single threshold test result (F=40.03, p = 0.00) is higher significant which suggests that there is a significant nonlinear relation between urbanization and residential CO_2 emissions. The estimated parameters of the PTR model with two regimes are listed in the Lower part of Table 2. The corresponding t-statistics are corrected for heteroskedasticity. We find that the impact of urbanization on residential CO_2 emissions is negative when per capita GDP is less than the threshold (25719.38). It is inconsistent with Poumanyvong and Kaneko(2012) while in a lower income group. The coefficient of urbanization denotes that a 10% increase in urbanization leads to a 1.2% decline in residential CO_2 emissions, however, it is not significant (t=-0.7453). The relation between urbanization and residential CO_2 emissions is not clear. When per capita GDP exceeds 25719.38 which means a middle or higher income group, the effect of urbanization on residential CO_2 emissions is negative and significant, and a 10% increase in urbanization leads to a 8.8% decline in residential CO_2 emissions. Furthermore, the relationship between population and residential CO_2 emissions is positive and more importantly, it is significant, the estimated coefficient in two different regimes is 0.3618 and 0.3971, respectively. It is almost a linear relation between them which means a 10% increase in population size leads to about 4% increase in residential CO_2 emissions. The estimated coefficient of GDP per capita is positive in two regimes which indicate the nexus between GDP per capita and residential CO_2 emissions is positive in the whole sample. When per capita GDP is over the threshold, the absolute of the estimated coefficient, however, is increasing which do not consistent with the EKC hypothesis.

Table 2 Estimation results

Test for single threshold	F	p-value
	40.03	0.00
Threshold estimates	λ	95% confidences interval
	25719.38	[20607.29, 33193.19]
coefficients estimates	Coefficient	t-statistics
Regime1: $q_{it} \leq \lambda$		
urban	-0.1246	-0.7453
pop	0.3618	1.6278
pgdp	0.2714	6.1495
Regime2: $q_{it} > \lambda$		
urban	-0.8786	-3.8233
pop	0.3971	1.6538
pgdp	0.5434	5.9656

Notes: P-value for the test of single threshold is computed from 300 simulations.

4 Conclusion

This paper examines the urbanization-residential CO_2 emissions relation by using the STIRPAT model. Under controlling the population size and per capita income, we find a nonlinear relation between urbanization and residential CO_2 emissions is different from the previous studies and this paper shed new light on urbanization-residential CO_2 emissions relation.

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