Exploring the relation between urbanization and residential CO2 emissions in China: a PTR approach

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November 2013

Online at http://mpra.ub.uni-muenchen.de/55379/
MPRA Paper No. 55379, posted 17. April 2014 05:48 UTC
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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).
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:

$$I_t = aP_t^b A_t^c T_t^d \varepsilon_t$$  (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 $\varepsilon$ 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:

$$\ln resico2_{it} = \mu_i + \beta_1 \ln pop_{it} + \beta_2 \ln pgdp + \beta_3 \ln urban_{it} + \varepsilon_{it}$$  (2)

Where $\mu_i$ 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:

$$\ln resico2_{it} = \begin{cases} 
\mu_i + \beta_{10} \ln pop_{it} + \beta_{20} \ln pgdp + \beta_3 \ln urban_{it} + \varepsilon_{it} & q_{it} \leq \lambda \\
\mu_i + \beta_{11} \ln pop_{it} + \beta_{21} \ln pgdp + \beta_3 \ln urban_{it} + \varepsilon_{it} & q_{it} > \lambda 
\end{cases}$$  (3)

Where $q_{it}$ refers to a threshold variable $pgdp$ and $\lambda$ refers to a threshold parameter. PTR model can we rewritten as:
\[ ln(resico2_{it}) = \mu_i + \delta'_1 X_{it} I(q_{it} \leq \lambda) + \delta'_2 X_{it} I(q_{it} > \lambda) + \varepsilon_{it} \]  \hspace{1cm} (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 \( \lambda \), the slope coefficient \( \delta'_1 \) and \( \delta'_2 \) can be estimated by OLS after the fixed-effects transformation. Conditional to a value of \( \lambda \), it is possible to compute the sum of squared errors, represent as \( S_1(\lambda) \):

\[ S_1(\lambda) = \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\varepsilon}_{it}^2(\lambda) \]  \hspace{1cm} (5)

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

\[ \hat{\lambda} = \text{argmin}_\lambda S_1(\lambda) \]  \hspace{1cm} (6)

Because we consider \( pgdp \) as the unique threshold variable in the model, then there is only one main 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:

\[ resico2 = \sum_{i=1}^{n} E_i \times NCV_i \times CC_i \times COFi \times \frac{4.4}{12} = \sum_{i=1}^{n} E_i \times EF_i \]  \hspace{1cm} (7)

Where \( resico2 \) denotes the total residential \( CO_2 \) emissions, \( E_i, NCV_i, CC_i, COFi \) represents the consumption, Net Calorific Values, Carbon Emission Factor and Carbon Oxidation Factor of the \( i \)th 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 CO₂ 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 CO₂ emissions from 1995 to 2011 by region. Based on Fig.1, we find that total residential CO₂ emissions keep declining before 2000, but raise dramatically after 2000. Residential CO₂ 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.
Table 1 Description of the variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definitions</th>
<th>Unit</th>
<th>Obs</th>
<th>Mean</th>
<th>Std.dev</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>pop</td>
<td>population</td>
<td>ten thousand</td>
<td>450</td>
<td>4268.97</td>
<td>2578.05</td>
<td>496</td>
<td>10504.85</td>
</tr>
<tr>
<td>pgdp</td>
<td>GDP per capita</td>
<td>RMB (2000 prices)</td>
<td>450</td>
<td>15540.88</td>
<td>12902.26</td>
<td>2172.73</td>
<td>68639.27</td>
</tr>
<tr>
<td>urban</td>
<td>urbanization</td>
<td>percent</td>
<td>450</td>
<td>33.93</td>
<td>16.04</td>
<td>14.04</td>
<td>89.32</td>
</tr>
<tr>
<td>resico2</td>
<td>residential CO₂</td>
<td>ten thousand ton</td>
<td>450</td>
<td>974.96</td>
<td>638.81</td>
<td>6.00</td>
<td>3199.89</td>
</tr>
</tbody>
</table>

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 CO₂ 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 CO₂ 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 CO₂ emissions, however, it is not significant \((t=-0.7453)\). The relation between urbanization and residential CO₂ 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 CO₂ emissions is negative and significant, and a 10% increase in urbanization leads to a 8.8% decline in residential CO₂ emissions. Furthermore, the relationship between population and residential CO₂ 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 CO₂ emissions. The estimated coefficient of GDP per capita is positive in two regimes which indicate the nexus between GDP per capita and residential CO₂ 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

<table>
<thead>
<tr>
<th>Test for single threshold</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40.03</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Threshold estimates

| λ                        | 25719.38 | [20607.29, 33193.19] |

coefficients estimates

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>t-statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regime1: ( q_{it} \leq \lambda )</td>
<td></td>
</tr>
<tr>
<td>urban</td>
<td>-0.1246</td>
</tr>
<tr>
<td>pop</td>
<td>0.3618</td>
</tr>
<tr>
<td>pgdp</td>
<td>0.2714</td>
</tr>
</tbody>
</table>

| 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.

Acknowledgements

We think Professor Dr. Christophe Hurlin for providing the program code. This research is supported by the National Social Science Foundation of China (12AJL007).

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