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Impact of Urbanization on CO_2 Emissions: Regional Differences Based on Panel Estimation

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ABSTRACT

This study analysed the impact of urbanization and the level of economic development on energy-related CO_2 emissions using the STIRPAT model and provincial panel data from 1995 to 2011 for China. This study classifies the 29 provinces of China into groups according to their economic development levels and examined regional differences in the environmental impacts of urbanization. The results demonstrated that there was an inverted U-curve-shaped relationship between urbanization and CO_2 emissions in the major regions of China. However, we did not confirm the environmental Kuznets Curve relationship between income and CO_2 emissions in China, where CO_2 emissions increase monotonically with income. Among our contributions is the classification of the 29 provinces of China into three groups according to their economic development levels, which showed that the impacts of urbanization differ considerably. In two of the groups, a threshold level was identified, beyond which the emission-urbanization elasticity was negative and further increases in the urbanization rate did not contribute to higher emissions. However, for the third group only population and affluence, but not urbanization, helped to explain emissions. Therefore, the different impacts of urbanization on CO_2 emissions should be taken into consideration in future discussions of climate change policies.

INTRODUCTION

With the deteriorating global environment, global climate change caused by greenhouse gas emissions has attracted the widespread attention of scholars and policy-makers worldwide. The main greenhouse gas in terms of quantity is CO_2, which according to the IPCC (2007) accounted for about 76.7% of the global greenhouse gas emissions in 2004. Therefore, the urgent task required to mitigate global climate change is the effective reduction of CO_2 emissions. Since reform and opening up, as well as the rapid development of its economy, China's urbanization process has increased rapidly and, according to the planned development of China, China's urbanization ratio will reach 60% by 2020. The rapid development of the economy has caused the rapid growth of CO_2 emissions, and China has surpassed the United States as the largest contributor to energy consumption and global CO_2 emissions (IEA 2009). Given the great pressure to reduce CO_2 emissions from the international community, China has proposed that by 2020 the CO_2 emissions per unit of GDP will be decreased by 40-45% compared with 2005. Therefore, focusing on the relationship between the urbanization of China and CO_2 emissions, exploring the important factors that affect carbon emissions, and identifying effective measures to achieve the emissions reduction targets have very important practical significance for China's policy-makers.

In recent years, the study of the effects of urbanization on carbon emissions has attracted the widespread attention of scholars. However, the results of these studies have been mixed at best. The first strand of studies (Jones 1991, Parikh & Shukla 1995, York et al. 2003, Cole & Neumayer 2004, York et al. 2007, Lin et al. 2010) suggested that urbanization increased energy consumption and carbon emissions, whereas the second strand of studies suggested that urbanization increased the efficiency of the public infrastructure (public transportation and other facilities), which reduced energy consumption and carbon emissions (Newman & Kenworthy 1989, Dodman 2009, Fan et al. 2006, Lariviere & Lafrance 1999, Pachauri & Jiang 2008). These two conflicting conclusions indicate the complex effects of urbanization on energy use and carbon emissions, which were due to the different methods and data used in these studies. The effects of urbanization on carbon emissions are affected by the economic development levels, industrial structure, technology, and other factors, so urbanization has various effects on carbon emissions in different countries and regions.

In summary, studies of the relationship between urbanization and emissions are not conclusive, so we suggest several reasons to explain this lack of consensus. First, the relationship could be nonlinear. Second, it could vary with the level of economic development. Very few researchers have investigated the environmental impacts of urbanization under different mechanisms and development levels (Madlener & Sunak 2011, Martinez-Zarzoso & Maruotti 2011). We found that only a few empirical studies included a squared term for urbanization in the STIRPAT model to test the existence of an environmental Kuznets curve between urbanization and CO_2 emissions (Martinez-Zarzoso & Maruotti 2011, York 2003, York et al. 2007). Compared with most existing literature, this paper will introduce the squared term of urbanization in the model, analysing the environmental performance of urbanization in China.

THEORETICAL FRAMEWORK AND MODEL SPECIFICATION

Starting from the theoretical framework of IPAT, Dietz & Rosa (1997) formulated a stochastic version of the IPAT equation using quantitative variables. These authors designated their model as STIRPAT (Stochastic Impacts by Regression on Population, Affluence and Technology). The model specification for a single year is given by the following equation:

$$I_i = \alpha P_i^{\beta} A_i^{\gamma} T_i^{\delta} e_i \quad ...(1)$$

This model preserves the multiplicative framework of the IPAT model, by decomposing environmental impacts (I_i) into the multiplication of population (P_i), affluence (A_i), and technology (T_i). In this model, α is a constant term, while β, γ and δ are the elasticities of the environmental impacts for P, A and T, respectively. e_i denotes the error term and the subscript i is the province because this is a regional analysis.

In the present study, we employ STIRPAT model and introduce urbanization, energy use efficiency, and industrialization into the theoretical framework to examine the effects of urbanization on carbon emissions at different economic development levels. By taking the logarithm form of the model, we constructed the regression model as follows:

$$\begin{aligned} \ln CO_{2it} &= \beta_0 + \beta_1 \ln P_{it} + \beta_2 \ln URB_{it} + \beta_3 (\ln URB_{it})^2 \\ &+ \beta_6 \ln T + \beta_7 \ln EI_{it} + \beta_8 \ln IND_{it} + u_{it} \\ &+ \beta_4 \ln Y_{it} + \beta_5 (\ln Y_{it})^2 \quad ...(3) \end{aligned}$$

Where, the subscripts i and t denote the region and time respectively; CO_2 represents the CO_2 emissions; P is the population size; URB denotes the urbanization level; Y is the per capita GDP, which reflects the economic development level; T denotes the technological level, which is measured based on the number of patents granted; the energy intensity, EI, is measured as the energy consumption per unit GDP and is used to reflect the energy use efficiency; and IND denotes industrialization, which is measured as the proportion of the second industry sector in the GDP and is used to reflect the industrialization development.

DATA SOURCE AND DESCRIPTION

Given the integrity and availability of panel data, we included a balanced panel dataset from 29 provinces in China for 1995-2011. The data used in this study were obtained from the China Statistical Yearbook (1996-2012), China Compendium of Statistics, China Energy Statistical Yearbook, and the Statistical Yearbook of all provinces (1996-2012). Table 1 shows the definition of all the variables.

EMPIRICAL RESULTS AND DISCUSSION

Our regression estimation was conducted in two steps. First, we estimated the whole sample without any consideration of regional differences. Second, we classified the whole sample into three subsamples according to the real GDP per capita.

The first group belonged to economically developed regions, where the per capita GDP calculated at a constant price (1990 = 100) was over 10^4 Yuan per capita, which comprised five provinces (Shanghai, Beijing, Tianjin, Jiangsu, and Zhejiang). The second group belonged to comparatively economically developed regions, where the per capita GDP calculated at a constant price (1990 = 100) was 5,000-10,000 Yuan per capita, which comprised 11 provinces (Hebei, Inner Mongolia, Liaoning, Jinlin, Heilongjiang, Fujian, Shandong, Hubei, Guangdong, Sichuan, and Xinjiang). The third group belonged to the economically less developed regions, where the per capita GDP calculated at a constant price was below 5,000 Yuan per capita, which comprised 13 provinces (Shanxi, Anhui, Jiangxi, Henan, Hunan, Guangxi, Hainan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai and Ningxia).

We estimated the impact of urbanization on the CO_2 emissions for the whole sample using four different estimation methods: fixed effects (FE), feasible generalized least squares (FGLS), linear regression with panel-corrected standard errors (PCSE), and linear regression with Driscoll-Kraay standard errors (DK). First, because of the characteristics of the panel data, we conducted an F-test and a Hausman test before selecting suitable estimation methods. Based on the test results, all of the models were estimated using an FE model. Using the Wooldridge test, the modified Wald statistic, and the cross-sectional dependence developed by Pesaran, we tested the autocorrelation within the group, groupwise heteroskedasticity, and cross-sectional dependence for the whole sample and three regions. The results suggested that there was autocorrelation within the groups, groupwise heteroskedasticity and cross-sectional dependence for the whole sample, groupwise heteroskedasticity for the economically developed regions, and groupwise heteroskedasticity and autocorrelation within the groups in the comparatively economically developed regions and economically less developed regions.

FGLS estimation was used to solve these problems. However, this method cannot be used unless the time dimension T is at least as large as the cross-sectional dimension N or the FGLS standard errors will underestimate the true variability. PCSE estimation was used to address these issues. However, the properties the PCSE estimation with a finite sample are rather poor if the cross-sectional dimension N is larger than the time dimension T. Therefore, DK estimation was used because the standard error estimates are robust to general forms of cross-sectional and temporal dependence (Hoechle 2007). Given that the cross-sectional dimension N was larger than the time dimension T for the whole sample, we focus on analysing the DK estimation results (model 4).

Table 2 provides the estimation results based on formula (3) and the four estimation methods. We focus on the results of model 4. The results showed that nearly all of the variables were statistically significant and the signs were as we expected.

The coefficient of the variable lnURB, which represents the urbanization level, was significantly positive, while the coefficient of the squared term of lnURB was significantly negative, thereby confirming the existence of an inverted U-curve relationship between urbanization and CO_2 emissions. The results show that the CO_2 emissions increase initially before decreasing with the urbanization level, which indicates that urbanization has a reducing effect on CO_2 emissions, where urbanization decreases the CO_2 emissions after reaching a threshold level.

Based on the coefficient of the variable ln$Y$, which reflects the economic development level, the first term and the squared term were both significantly positive, and it confirmed a U-shaped environmental Kuznets curve relationship between CO_2 emissions and economic development levels, so China has passed the turning point, which is very low, and its CO_2 emissions will increase monotonically with the economic development level, i.e., the economic development level will increase China's CO_2 emissions.

The coefficient of the total population ln$P$ was 0.935 and it was significant at the 0.1% level, which confirms that population is also an important factor that promotes CO_2 emissions. The coefficient of energy intensity (lnEI), which reflects energy use efficiency, was positive and this indicates that increasing energy use efficiency will effectively restrain CO_2 emissions growth, which agreed with our expectations. Finally, the coefficient of industrialization (lnIND) was also significantly positive, which reflected the industrialization characteristics of "high energy consumption and high pollution".

Table 3 shows the corresponding test results for the three regions classified by the per capita GDP. Because of the characteristics of the panel data, we conducted an F-test and a Hausman test before selecting suitable estimation methods. According to the test results, all of the models were estimated using an FE model. The FGLS and PCSE methods are suitable for panel data with a smaller N and a larger T, but to facilitate a comparative analysis, we estimated the samples for the three regions using the DK method.

The first group comprised five provinces with an average urbanization rate of almost 60% and an average GDP per capita at a constant price of 1.466×10^4. The first group was characterized as follows: the elasticities of the population and the income with respect to carbon emissions were 0.946 and 0.979, respectively. Because the first term of urbanization was positive and not statistically significant, while the squared term is negative and not statistically significant, we did not confirm the existence of an environmental Kuznets curve between urbanization and carbon emissions, so the effects of urbanization on carbon emissions in economically developed regions were not significant. The squared term of income was positive and not statistically significant. The coefficients of energy intensity and industrialization were 0.945 and 0.166, respectively, and statistically significant at the 0.1% level, which indicates that the effects of energy intensity and industrialization were significant and positive.

The second group comprised 11 provinces with an average urbanization of 38.88% and an average GDP per capita at a constant price of 0.678×10^4. This group was characterized as follows: the average population was the highest and most of the variables were significant. With the exceptions of patents granted and industrialization, the coefficient of the first term of urbanization was positive and statistically significant at the 1% level, while that of the squared term of urbanization was negative and also statistically significant at the 1% level, which demonstrated the existence of an inverted U-shaped environmental Kuznets curve between urbanization and carbon emissions in comparatively economically developed regions. Based on the simple calculation, the CO_2 emissions increased up to a turning point, which was 29.35% urbanization for this group, while the average urbanization rate in comparatively economically developed regions was 38.88%. This shows that the comparatively economically developed regions have passed the turning point and are in a period when CO_2 emissions will decrease with the promotion of the urbanization process, so increasing the urbanization level in these regions will reduce carbon emissions. The first term and the squared term of income were both positive and statistically significant at the 0.1% level, which indicates the existence of a U-shaped environmental Kuznets curve relationship between CO_2 emissions and economic growth. Similarly, because the turning point was very low and the comparatively economically developed regions have passed it, these regions are in a period when CO_2 emissions will increase with economic growth. This group is characterized by a higher proportional elasticity of income with respect to emissions and a lower population elasticity.

Finally, the third group belonged to economically less developed regions where the average urbanization rate was 28.29% and the average GDP per capita was 0.429×10^4 Yuan at a constant price. The explanatory variables considered in this group had effects on carbon emissions, especially income, population, energy intensity, patents granted, and urbanization levels. Similarly, we found an inverted U-shaped relationship between urbanization and CO_2 emissions in these regions. The CO_2 emissions increased up to a turning point, which for this region was 19.24% urbanization. The average level of urbanization in this region was 28.29% and we concluded that these regions have also passed the turning point and are in a period when CO_2 emissions will decrease as urbanization levels increase. The elasticity of income with respect to carbon emissions was 1.035 and the coefficient of the squared term of income was positive, but not statistically significant. In summary, we confirmed the applicability of the ecological modernization theory to comparatively economically developed regions and economically less developed regions, but we did not confirm the ecological modernization theory for economically developed regions. For the environmental Kuznets curve between income and carbon emissions, we include the squared term of income as an explanatory variable in the regression, the sign of which was positive and not statistically significant for economically developed regions and economically less developed regions. The results showed that there was not an inverted U-shaped environmental Kuznets curve between income and carbon emissions in China, which is now in a period when CO_2 emissions will increase with income.

Thus, the effects of population, urbanization, affluence, and the technological level on CO_2 emissions appear to be heterogeneous among different regions with variable economic development levels, and this heterogeneity was not in complete agreement with the different income categories. It is clear that other factors, such as the industrial structure and technology, are responsible for the difference in the CO_2 emissions in regions with different economic development levels, which should be a focus of future research.

We can find the following phenomenon from our empirical results. The first interesting phenomenon is that, there was an inverted U-shaped environmental Kuznets curve between urbanization and carbon emissions for the whole sample, which suggests that China has already passed the turning point and is in a period when CO_2 emissions will decrease as urbanization increases, which agrees with ecological modernization theory. We can explain this phenomenon from the difference in energy consumption between rural residents and urban residents. First of all, at present China's energy consumption structure is in the direction of low carbon development, and energy consumption structure of urban residents transforms from the predominance of coal into clean energy dominant and coal in subordinate position. However, at present, the proportion of coal in rural energy consumption structure is gradually decreasing; there is no substantial change in the basic pattern of rural energy consumption dominated by coal. Therefore, the migration of migrant workers from rural areas to urban areas can reduce carbon emissions to a certain extent. Secondly, at the present stage of our country, the marginal consumption demand elasticity with respect to energy of rural residents is greater than that of urban residents, therefore, the increasing urbanization will instead reduce marginal consumption demand elasticity with respect to energy.

The second finding is that the coefficients of the first term of per capita income are positive and statistically significant in the three regions, and the coefficients of the squared term of per capita income are also positive and not statistically significant in most developed regions and less developed regions. This shows that there exists U-shaped Kuznets curve between per capita income and CO_2 emissions

Table 1: Definition of the variables used in the study for the period 1995-2011.

Variable	Definition	Unit of measurement
CO_2 emissions (CO_2)	Energy-related CO_2 emission	104 ton
GDP per capita (Y)	GDP divided by the population at the end of the year	104 Yuan per capita (1990 prices)
Population (P)	Total population at the end of the year	104
Urbanization (URB)	Percentage of urban population in the total population	Percent
Energy intensity (EI)	Total energy use divided by GDP	Tce per 104 Yuan
Industrialization (IND)	The ratio of industry sector value added in GDP	Percent
Patents (T)	The number of patents at the end of the year	Piece

Notes: Data for Tibet, Hongkong, Macao and Taiwan were excluded. The data for Chongqing was included in Sichuan.

Table 2: Estimation results: CO_2 emissions model for the whole sample during 1995-2011.

Variables	FE (M1)	FGLS (M2)	PCSE (M3)	DK (M4)
ln*URB*	0.225***(0.059)	0.0499(0.028)	0.065(0.108)	0.225**(0.061)
(ln*URB*)^2	-0.033***(0.009)	-0.008*(0.004)	-0.01(0.016)	-0.033**(0.009)
ln*Y*	1.014***(0.007)	1.023***(0.002)	1.024***(0.0095)	1.014***(0.01)
(ln*Y*)^2	0.015***(0.002)	0.007***(0.0008)	0.007*(0.004)	0.015***(0.002)
lnP	0.935***(0.021)	0.986***(0.008)	0.989***(0.024)	0.935***(0.013)
ln*T*	-0.0003(0.002)	-0.004***(0.0006)	-0.004(0.003)	-0.0003(0.001)
ln*EI*	1.005***(0.006)	1.035***(0.002)	1.038***(0.01)	1.005***(0.015)
ln*IND*	0.052***(0.014)	0.004(0.005)	-0.001(0.024)	0.052*(0.023)
Constant	0.952***(0.207)	0.937***(0.083)	0.877**(0.273)	0.952***(0.138)
R^2	0.998		0.9996	0.998
Autocorrelation test	$F(1,28)=22.764^{***}$			
Cross-sectional dependence test	CD=3.171**			
Heteroskedasticity test	$\chi^2(29)=18489.51^{***}$			
Observations	4437	4437	4437	4437

Table 3: Estimation results: CO_2 emissions model for three subsamples during 1995-2011.

Variables	Developed regions	Comparatively developed regions	Less developed regions
ln*URB*	0.152(0.12)	0.196**(0.052)	0.207**(0.066)
(ln*URB*)^2	-0.016(0.017)	-0.029**(0.008)	-0.035**(0.011)
ln*Y*	0.979***(0.028)	1.022***(0.007)	1.035***(0.011)
(ln*Y*)^2	0.009(0.006)	0.018***(0.003)	0.002(0.002)
ln*P*	0.946***(0.029)	0.97***(0.046)	0.858***(0.038)
ln*T*	-0.008(0.004)	0.002(0.003)	-0.005**(0.001)
ln*EI*	0.945***(0.028)	1.006***(0.006)	1.017***(0.016)
ln*IND*	0.166***(0.026)	-0.002(0.022)	-0.067(0.033)
Constant	0.462(0.305)	1.012**(0.319)	1.838***(0.289)
R^2	0.9998	0.9994	0.998
Autocorrelation test	$F(1, 4)=4.441$	$F(1, 10)=171.166^{***}$	$F(1,12)=18.78^{**}$
Cross-sectional dependence test	CD=0.408	CD=1.024	CD=0.047
Heteroskedasticity test	$\chi^2(5)=25.21^{***}$	$\chi^2(11)=324.41^{***}$	$\chi^2(13)=13174.5^{***}$

Notes: The fixed effects model was preferred to the pooled-OLS model and the test is not reported. Standard errors are shown in parentheses.*p < 0.05; **p < 0.01; ***p < 0.001

only in comparatively developed region. As the turning point is very low, this region has been in the period that CO_2 emissions increase as per capita income increases. It does not confirm the existence of U-shape Kuznets curve in most developed and less developed regions as the effects of the squared term of per capita income are not significant. In summary, from Table 3, the impacts of per capita income on CO_2 emissions in most developed region are least among the three regions, which means that the effects of per capita income on CO_2 emissions are instead weakened in economically most developed regions.

The third finding is that the coefficients of energy intensity with respect to carbon dioxide emissions are 1.017, 1.006 and 0.945 respectively in the less developed, comparatively developed and most developed regions. It indicates that energy intensity is one of the critical and significant factors that influence CO_2 emissions and the impacts of energy intensity also declines continuously from the less developed region to comparatively developed and most developed regions, which confirms that energy use efficiency in the economically most developed regions is the highest, followed by comparatively developed regions and the lowest energy use efficiency is in less developed regions.

CONCLUSIONS AND POLICY IMPLICATION

In this study, we conducted a multivariate analysis of the factors that affected CO_2 emissions in 29 provinces during 1995-2011. We used the STIRPAT model, the environmental Kuznets curve hypothesis, and the ecological modernization theory as our theoretical framework. To study the nonlinear relationship among urbanization, income and carbon emissions, we introduce the squared terms of urbanization and the per capita GDP into the STIRPAT model. We tried to expand the model to facilitate a comprehensive interpretation of the complex relationships among urbanization, income, technological levels and carbon emissions. For the four panel datasets that comprised the whole sample and the three sub-samples, which were classified according to the economic development levels, we use several estimation methods to obtain more precise estimates of coefficient for all the explanatory variables.

The results indicate that there was an inverted U-shaped environmental Kuznets curve between urbanization and carbon emissions for the whole sample, which agrees with ecological modernization theory and are in accordance with the findings of Ehrharht-Martinez et al.(2002) and York et al. (2003). Based on these results, some policy implications for our urban planners and policy makers can be provided.

Firstly, as we have been in the period that carbon dioxide emissions decrease as more rural residents migrate to urban areas, Chinese government should take effective measures to provide security for the migration of rural population to urban areas, especially, we should provide a series of security for the new generation of migrant workers in their work, life and study to make them feel at ease in city work and make contribution to the city development.

Secondly, in the process of urbanization, we should reflect Chinese characteristic and follow the path of low carbon development of new-style urbanization. In the two and three tier cities of China, we should reform and perfect the city natural gas and other clean energy infrastructure and encourage residents to use more renewable energy to replace traditional energy, thereby reducing the city's carbon emissions. In terms of transportation, we should limit private transport with high CO_2 emissions, such as set higher purchase tax and maintenance fee for private cars with high emissions and increase gasoline prices; at the same time, we should construct and perfect large-scale public traffic mode. Or, in the small cities without the condition for subway construction, we should advocate the residents to use city public bicycles.

Thirdly, Chinese urbanization process is characterized by attaching great importance to the development of small towns and the construction of new countryside. Therefore, we should take effective measures to vigorously develop the role of small towns in connecting urban areas and rural areas and invest funds to construct the infrastructure for natural gas and other clean energy that completely covers Chinese small towns and rural areas. Moreover, we should continuously reduce the proportion of coal in the rural household energy consumption and continuously improve the proportion of clean energy.

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REFERENCES

Cole, M.A. and Neumayer, E. 2004. Examining the impact of demographic factors on air pollution. Population and Development Review, 2(1): 5-21.

Dietz, T. and Rosa, E.A. 1994. Rethinking the environmental impact of population, affluence and technology. Human Ecology Review, 1: 277-300.

Dietz, T. and Rosa, E.A. 1997. Effects of population and affluence on CO_2 emissions. Proceedings of the National Academy of Sciences, USA 94(1): 175-179.

Dodman, D. 2009. Blaming cities for climate change? An analysis of urban greenhouse gas emissions inventories. Environment and Urbanization, 21: 185-201.

Ehrhardt-Martinez, K., Crenshaw, E.M. and Craig Jenkins, J. 2002. Deforestation and the environmental Kuznets Curve: A cross-national investigation of intervening mechanisms. Social Science Quarterly, 83(1): 226-243.

Fan, Y., Lui, L.C., Wu, G. and Wei, Y.M. 2006. Analyzing impact of factors of CO_2 emissions using the STIRPAT model. Environmental Impact Assessment Review, 26(4): 377-395.

Hoechle, D. 2007. Robust standard errors for panel regressions with cross-sectional dependence. Stata Journal, 7: 281-312.

IEA 2009. World Energy Outlook 2008. OECD.

IPCC (Intergovernmental Panel on Climate Change) 2007. Climate change 2007. Synthesis report. A contribution of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

Jones, D.W. 1991. How urbanization affects energy-use in developing countries. Energy Policy, 19(7): 621-630.

Lariviere, I. and Lafrance, G. 1999. Modelling the electricity consumption of cities: Effect of urban density. Energy Economics, 21: 53-66.

Lin, B.Q. and Liu, X.Y. 2010, China's carbon dioxide emissions under the urbanization process: Influence factors and abatement policies. Economic Research Journal, 8: 66-78.

Madlener, R. and Sunak, Y. 2011. Impacts of urbanization on urban structures and energy demand: What can we learn for urban energy planning and urbanization management? Sustainable Cities and Society 1: 45-53.

Martinez-Zarzoso I. and Maruotti, A. 2011. The impact of urbanization on CO_2 emissions: Evidence from developing countries. Ecological Economics, 7: 1344-1353.

Newman, P. W. G. and Kenworthy, J.R. 1989. Cities and Automobile Dependence: An International Sourcebook. Gower Technical, Aldershot.

Pachauri, S. and Jiang, L. 2008. The household energy transition in India and China. Energy Policy, 36: 4022-4035.

Parikh, J. and Shukla, V. 1995. Urbanization, energy use and greenhouse effects in economic development: Results from a cross-national study of developing countries. Global Environmental Change, 5(2): 87-103.

York, R., Rosa, E.A. and Dietz. T. 2003. STIRPAT, IPAT and ImPACT: Analytic tools for unpacking the driving forces of environmental impacts. Ecological Economics, 46(3): 351-365.

York, R. 2007. Demographics trends and energy consumption in European Union Nations, 1960-2025. Social Science Research, 36: 855-872.