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Assessment of the Energy-saving Effect of Urbanization in China Based on STIRPAT Model

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ABSTRACT

Energy consumption is one of the main sources of GHG emissions in China with the development of rapid urbanization. To tackle climate change and energy conservation, China has processed a series practices that gain co-benefits towards meeting sustainable development goals along with climate change mitigation since 2007.This paper evaluates the impact factors of population, urbanization level, GDP per capita, industrialization level on the environmental energy saving impact using the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model based on China provincial panel data from 2005 to 2017. The results show that industrialization has the largest potential effect on environmental impact, followed by urbanization level, GDP per capita and population. Industrialization and GDP per capita can cause an increase in energy consumption per capita. Whereas, urbanization level and population can lead to a decrease in energy consumption per capita. An in-depth analysis on energy consumption of China's recent urbanization is carried out and policy recommendations are put forward.

Keywords: Energy consumption, STIRPAT model, Urbanization, China

1. INTRODUCTION

China's urbanization has been increasing with the average annual growth rate about 1.19% during the past 10 years, implying that at least 10 million people changed their life style from rural to urban areas annually, which has posed a great challenge to national economic and energy systems [1]. Extensive studies have been conducted to examine the role of influences of urbanization level on energy consumption, CO_2 emissions and air pollutions using both descriptive and quantitative methods.

Stochastic impact by regression on population, affluence, and technology (STIRPAT) model has been widely applied for examining such factors. Most of these studies are performed on national or provincial-data basis. Lin et al. [2], Chen et al. [3], Liu et al. [4], Wang et al. [5], and Wei et al. [6], used the STIRPAT model to make analyses of the impact factors of energy consumption and CO_2 emissions in China. Wang et al. [6] empirically studied the influences of urbanization level, industrial structure, energy structure, and foreign trade degree on CO_2 emissions in Guangdong province using an improved STIRPAT model between 1980-2010.

However, existing studies mostly focus on the population, economic level and technology level as the standard STIRPAT model. The impact factors on energy consumption including industrial structure, urbanization level, industrialized level should be further explored with national level analysis. As the impact of urbanization on energy varies at different stages of urbanization and economic development periods, it is important to build up the updated national level analysis during the recent decade, especially when China actively practiced in combatting climate change and achieving Nationally Determined Contribution (NDC) goals in recent 5 years.

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This study builds up an exclusive database by collecting panel data and information from 30 provinces in China between 2005 and 2017 [1, 7, 8]. By introducing extended variables (energy consumption, urbanization level, industrialized level, etc.), this study goes a step further to develop an extended STIRPAT model with updated data thereby improving the methodology in such studies. This study also provides political implications for appropriate energy saving and emission reduction measures for improving the urbanization quality of China in the future.

2. METHODOLOGY

2.1 STIRPAT Model

IPAT model was first introduced by Ehrlich and Holdren [9] to explore the impact on the environment of growing population. The model specified that total environmental impacts (I) are influenced by population (P), affluence (A) and technology level (T). Taking IPAT as a basis, Dietz and Rosa developed a stochastic model, the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model [10]. STIRPAT model is modified to overcome the limitations (the unit elasticity assumption, randomness for convenience of empirical analysis) by examining a variety of environmental impacts such as urbanization, industrial structure and energy structure.

To evaluate the energy saving effect of China's urbanization, this study uses the STIRPAT model as follows:

$$I_{i=}aP_i^bA_i^cT_i^de_i \quad (1)$$

It remains the multiplicative logic of the I = PAT equation, which Population (P), affluence (A) and technology (T) are regarded as the determinants of environmental impact (I). Where *a, b, c* and d are parameters to be estimated, and *e* represents the random error. Taking logarithms, the model can be expressed as

$$lnI = lna + blnP + clnA + dlnT + lne \quad (2)$$

Where ln( ) is a natural logarithm. In this form, *b, c* and *d* is the elastic coefficient, represent the percentage change happened in environmental impact caused by a 1% change in an impact factor, when controlling the other influence factors unchanged. Since York [11] stated that sociological or other control factors are able to be added into Eq. (2) with its consistence of the multiplicative specification of the model. To further evaluate the impact factors of urbanization and industrialization level of energy saving effect in China, the study reformulated the STIRPAT model by incorporating urbanization level, industrial structure into the model. The extended STIRPAT model converts into:

$$lnEnergy_{it} = a_0 + a_1lnPop_{it}+a_2lnGrowth_{it} + a_3lnUrban_{it} + a_4lnIndustry_{it} + e_{it} \quad (3)$$

Where, a_0 is a constant; a_1, a_2, a_3 are coefficients; e is stochastic error; *Energy* represents environmental impact (I), expressed as energy consumption per capita in this research of city or province *i* at year *t*.; *Pop* is population factor (P), here represented by total population; *Growth* refers to affluence (A), here represented by GDP per capita; *Urban* refers to urbanization rate, represented by ratio of none-agricultural population to total population, *Industry* is technology factor (T), represented by industrialization rate (percentage of the increased value of secondary and tertiary industry to GDP). A Variance Inflation Factor (VIF) is used to test multicollinearity in this paper[12]. If 0 < VIF < 10, the multicollinearity is acceptable; if VIF >10, there will be multicollinearity.

2.2 *Data*

This paper used panel data of 30 cities, provinces and autonomous regions in China over 2005-2017 obtained from China Energy Statistical Yearbook, China Population Statistics Yearbook and China Statistical Yearbook [1, 7, 8]. The Tibet, Taiwan, Hong Kong and Macau are excluded in the regression for the lack of data. Energy consumption ('Energy') is calculated by total energy consumption divided by total population (units of 10^4 tons standard coal) in each area in the China Population and Energy Statistical Yearbook. Data for total population ('Pop') is directly from the China Population Statistics Yearbook [7] (units of 10^4 persons). Data for urbanization rate ('Urban') is collected from the basic data of the China Population Statistics Yearbook. The data of GDP per capita ('Growth') is collected from the China Statistical Yearbook. To eliminate the influence of price index we used the data of GDP at 2000 price. Industrialization rate ('Industry') is collected from the China Statistical Yearbook.

3. RESULTS

The result shown in Table 1 of multinomial OLS regression is coded in R. Likelihood ratio test showed that for the null model was rejected at the 5% significance level. The results show that GDP per capita (GDPgrowth), industrialization level (Industry) have positive effects of energy consumption in 30 provincial level cities of China. Whereas, urbanization(urban) and population scale have negative effects. The influence of these impact factors is illustrated with their elastic coefficients in decreasing order by the absolute values as industrial level, urbanization level, population, GDP per capita respectively.

Table 1. OLS Results

Coefficients:	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-13.04199	1.16368	-11.208	< 2e-16 ***
GDPGrowth	0.49356	0.04652	10.61	< 2e-16 ***
Urban	-0.89234	0.12677	-7.039	8.92e-12***
Industry	3.30552	0.31099	10.629	< 2e-16***
Population	-0.28283	0.02002	-14.127	< 2e-16 ***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’

Industrialization level has positive impact on energy saving in China with the elastic coefficient as 3.30552, which indicates that every 1% increase in industrialization level will cause a 3.30552% increase in energy consumption. And GDP per capita has the elastic coefficient as 0.49356, which implies that every 1% increase in GDP per capita will cause a 0.49356% increase in energy consumption per capita. The industrialization level indicator consists of industrialization and service levels. From 2005 to 2017, the rapid development in industrialization and service levels of China has been fostering the growth of energy consumption. Meanwhile, the sustained growth of economy in China has kept increasing GDP per capita further driving energy consumption.

Urbanization level and population scale have negative influence on the energy consumption in China. Every 1% increase in urbanization level will cause a 0.89234% decrease in energy consumption. And every 1% rising in population scale will contribute to a 0.28283% decrease in energy consumption.

Multicollinearity test has been done with all the variables. We use Variance Inflation Factor (VIF) to quantify the severity of multicollinearity among the set of variables in Table 2. Using average VIF under 10 as criteria, we consider the regression results acceptable with very limited collinearity.

Table 2. Collinearity Diagnostics

Variable	VIF
GDPGrowth	4.384936
Urban	5.13368
Industry	2.118514
Population	1.115138

4. DISCUSSION

According to Environmental Kuznets Curve (EKC) [13], which implies that environmental degradation or emissions are an inverted U-shaped function of per capita income. As economic growth initially increases environmental degradation and energy consumption, but beyond some level, the trend reverses, economic growth eventually can lead to environmental upgrading and a reduction in per capita emissions. From 2000 to 2018, China is still under the rapid economic sustained growth period, with the increasing energy consumption as the byproduct. So far, most of the provinces are still in the left-hand part of the U-shaped curve.

Whereas, the industry proportions of first-tier level cities as Beijing, Shanghai are turning down to decrease and their tertiary industry proportion are increasing as the main industry to aggregated populations and services products with less energy consumptions relatively. In addition, technology innovations in big cities or provinces further improve the energy efficiency and keep decreasing the marginal cost of energy saving.

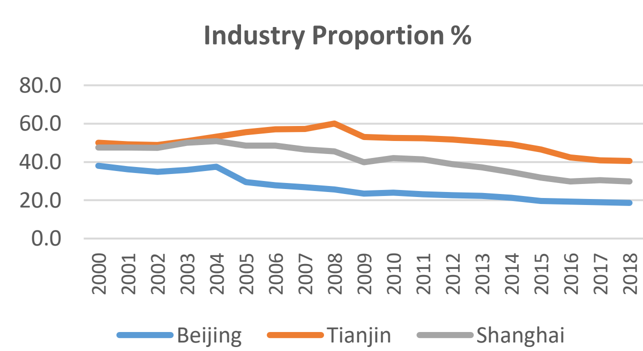

Figure 1. Industry proportion of Beijing, Tianjing, Shanghai (2000-2018)

Furthermore, through targeted measures and steady top-down actions such as replacing coal with natural gas projects [14] and Blue Sky Protection Campaign [15], 2+26 cities were cooperating to tackle the environmental challenges with anti-pollution actions. Beijing has shut down 5,000 small polluting or below standard enterprises in two years [16]. In the meantime, those shut-down enterprises and unemployed people may "move or transfer" pollution to rural sites, where environmental regulations are loose, as for the case of the heavy polluting Capital Steel factory moving from Beijing to Tangshan, Hebei province in 2008. In 2019, 11 years later, 13 iron and steel groups with factories in the main districts of Tangshan city were demanded to move to rural counties in Hebei, which involved 51.35 million Mt/year steel capacity [17]. Without national unified standards, the pollution will be squeezed out from restricted areas to other areas, but the overall pollution still exists. In this case, with the increase of the urbanization and population, cities and provinces may squeeze out the heavily polluted industry and substitute with energy saving technology innovations, which bring out the negative influence on energy consumption as the outcome.

5. CONCLUSION

Based on China's 30 cities and provincial panel data from 2005 to 2017, this paper evaluates the energy-consumption effect of China's urbanization using STIRPAT model. The findings of this study are summarized as follows. Firstly, industrialization in China increased energy consumption per capita from 2005 to 2017. A 1% increase in industrialization can cause 3.3% increase in energy consumption per capita. A 1% increase in GDP growth per capita is associated with 0.49% increase in energy consumption per capita. While 1% increase in urbanization or population can decrease 0.89% or 0.28% respectively. The improvement in technology and tertiary industry has mitigated the increasing in energy consumption caused by rapid development during last 2 decades. In the future, more efforts should be made in energy efficiency improvement and clean energy with China's urbanization.

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