



On the convergence in China's provincial per capita energy consumption: New evidence from a spatial econometric analysis



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ABSTRACT

The rapid increase in per capita energy consumption is likely to be an important factor affecting the sustainable development of China's economy. In this study, the convergence of per capita energy consumption, which is an important inherent characteristic of China's energy consumption, is investigated using panel data for the period 1994–2014 for 30 Chinese provinces. To control for the potential spatial dependence in energy consumption per capita and introduce dynamics, appropriate spatial dynamic econometric models are employed. The empirical results indicate that there are both absolute and conditional β -convergences in per capita energy consumption across provinces. In addition, there is also evidence for an inverted U-shaped relationship between per capita energy consumption and per capita GDP. Therefore, per capita energy consumption would increase when economic development is relatively low. However, per capita energy consumption may decrease after a threshold level of economic development is reached. Among the factors that potential influence provincial energy consumption, the ratio of secondary industry value-added to GDP and the spatial correlation of energy consumptions in neighboring provinces are positively related to energy consumption per capita, while population density and per capita foreign direct investment do not affect energy consumption per capita significantly.

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1. Introduction

Energy serves as the material basis of human activity and a prerequisite to and guarantee of economic development. With its rapid economic development, China's energy consumption has significantly increased in recent decades: from 1.04 billion tons of standard coal in 1991 to 4.26 billion tons in 2014. At the beginning of China's reform and opening up, the level of economic development was relatively low, and the scale of energy consumption was relatively small. China's energy consumption surged with the expansion of reform and opening up and the rapid development of its economy. During the last several decades, China has achieved remarkable economic growth, and the living standard of Chinese citizens has been significantly improved. In the meanwhile, alongside robust economic growth and rapid industrialization and urbanization, China's energy consumption was soaring

while the environmental quality was deteriorating (Yuan et al., 2008; Jiang and Lin, 2012).

In 1992, China's total energy consumption exceeded its total energy production for the first time, and since then, the gap between energy consumption and production has grown. To meet the increasing energy demand, energy imports have continued to grow, and this has become a potential hurdle to China's sustainable development. In addition, because coal dominates China's energy mix, the rapid increase in energy consumption has also had a negative influence on environmental quality, which is visually reflected by the serious haze and smog pollution that have affected most areas of eastern and northern China in recent years. Since 2006, China has replaced the U.S. as the largest carbon dioxide emitter in the world. There is evidence that the current development pattern is not consistent with China's pursuit of sustainable and harmonious development.

The rapid increase in China's energy consumption has an inherent economic logic, and understanding this economic logic is important for controlling the rapid increase in energy consumption and improving the environmental quality. One important characteristic is the convergence

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in China's per capita energy consumption. Convergence is an important economic theory that was originally applied to investigate the convergence of per capita income across different regions and countries. According to neoclassical growth theory, if a country's interior regions are open to each other, under a functioning market mechanism and bound by the law of diminishing returns, the free mobility of factors will produce a self-correcting effect on any imbalance in regional economic development, with the result that the per capita income and/or output levels in different regions will tend toward equilibrium. Barro and Sala-i-Martin (1995) use a technology diffusion model to study this effect and find that the relatively low imitation cost for the technology follower and the relatively high degree of openness are two key reasons for the existence of economic convergence (i.e., the phenomenon that per capita incomes of poorer economies would tend to grow at faster rates than those of richer economies). Several types of convergence have been identified so far, including β -convergence, σ -convergence, stochastic convergence, deterministic convergence and club convergence. β -convergence refers to the fact that regions with a lower per capita output level at the beginning of a period tend to have faster economic growth. In other words, with β -convergence, there is a negative correlation between the per capita output growth rate and output level in different regions.

Because the definition of convergence was originally raised in the field of economics, so far there have been a large amount of studies on economic convergence (e.g., Baumol, 1986; Barro et al., 1991; Islam, 2003; Maasoumi et al., 2007). Since mid-1990s, partly because of China's dramatic economic growth, a growing number of literature has focus on the economic convergence across provinces and regions within China. For instance, Chen and Fleisher (1996) find evidence of the conditional convergence of per capita production across China's provinces from 1978 to 1993 by employing the framework of an augmented Solow growth model. In contrast, using provincial panel data, Weeks and Yao (2003) find empirical evidence for system-wide income divergence between regions in China during the post-reform period 1978–1997. Aroca et al. (2008) confirm that there was an increase in the spatial dependence of per capita GDP during the last two decades of the 20th century and that the spatial effect plays an important role in China's regional convergence.

In recent years, as the problems of energy shortage and environmental degradation have become acute for many countries, a growing number of studies have investigated the convergence in energy consumption and environmental quality. For instance, Herrerias (2012) uses a weighted distribution dynamics approach to reexamine and verify the convergence in world energy intensity, although the characteristics of convergence differ in developing and developed countries. Markandya et al. (2006) verify the existence of convergence in energy intensity among 12 transition countries in Eastern Europe and 15 countries in the European Union (EU), and the energy consumption intensity in transition countries significantly converges to the average of EU countries. Similarly, using a dataset of IEA countries, Liddle (2009) finds evidence for the convergence in commercial and industrial electricity intensities. More recently, the unit root test techniques were frequently used in the studies on the convergence in energy consumption. Meng et al. (2013) examine and verify the conditional convergence in energy consumption per capita in Organization for Economic Cooperation and Development (OECD) countries over the period 1960–2010 by applying Lagrange multiplier (LM) tests and the LM tests based on the residual augmented least squares regression (RALS-LM). Using similar unit root tests for panel data, Mishra and Smyth (2014) find supportive evidence for stochastic conditional convergence of per capita energy consumption in the Association of Southeast Asian Nations (ASEAN) countries. However, not all of extant studies support the existence of convergence in energy consumption. Mohammadi and Ram (2017) explore convergence in per capita energy consumption across the US States by employing parametric and non-parametric methods, while they fail to find solid evidence for the existence of convergence in per capita energy consumption in the

U.S. In recent years, as environmental problems attracted worldwide attention, the issue of convergence in environmental quality has also been investigated by some researchers. In a pioneering study of this field, List (1999) utilizes the time series method to verify the convergence in emissions of sulfur dioxide and nitrogen oxide among different states in the United States. Strazicich and List (2003) verify the β -convergence of CO₂ emissions among 21 industrialized countries from 1960 to 1997 by employing cross-sectional and time series techniques. Panopoulou and Pantelidis (2009) apply the convergence test method proposed by Phillips and Sul (2007) and find that carbon dioxide emissions in 128 countries present a form of club convergence. Recently, Hao and Wei (2015) and Hao et al. (2015) used China's provincial data to test and verify the existence of convergence in CO₂ and SO₂ emissions across Chinese provinces, respectively.

The investigation on the convergence in per capita energy consumption across different provinces has important policy implications for China that is currently pursuing sustainable economic growth. If the convergence in per capita energy consumption indeed exists, it is possible that the total energy consumption could be held under control (Jobert et al., 2010). Given that the combustion of fossil energy especially coal is the main source of air pollutions in China (Chen et al., 2006; Bloch et al., 2012), to curb total energy consumption is vital for the improvement in environmental quality. As a result, if the convergence in per capita energy consumption could be verified, Chinese government could formulate differentiated and targeted policies for different provinces to control energy consumption and improve the environmental quality. For instance, for the provinces with relatively high energy consumption per capita, because the energy consumption has a tendency to grow slower or decrease faster, strict regulations on energy consumption and environment could be conducted. In contrast, for the provinces that have relatively low energy consumption per capita, convergence implies the potential of further cutting energy consumption is limited. Therefore, to improve environmental quality, the policy makers in these provinces should pay more attention to the other influential factors of energy consumption and the environmental conditions such as industrial structure and trade openness.

The purpose of this study is thus to fill the gap in the literature by exploring the existence of convergence in per capita energy consumption across Chinese provinces. Specifically, the main contribution of this paper is twofold. First, through the quantitative analysis on the convergence in energy consumption across China's provinces, the important relationship between the convergence of energy consumption and environmental quality is highlighted. Especially, some influential factors of environmental equality are also incorporated to evaluate their effects on energy consumption and the environment. Second, appropriate spatial econometric methods are employed to examine the convergence in per capita energy consumption across Chinese provinces so that the potential endogeneity caused by spatial dependency could be well addressed. By fully accounting for the spatial dependency of energy consumption, the estimation results are more reasonable and reliable.

The rest of this paper is organized as follows: the second section briefly introduces the theoretical framework for the empirical study, suggesting that there may be convergence in per capita energy consumption; the third section interprets the spatial econometric tools utilized in this study; the fourth section explains the source of the data and the variables used in the estimations; the fifth section provides the estimation results and the corresponding analysis; and the final section concludes the research and provides corresponding political recommendations.

2. Theoretical framework

According to neoclassical growth theory (e.g., Solow, 1956; Mankiw et al., 1992), the per capita income of different economies may converge to the same steady state level. In other words, the farther an economy is

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