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Revisiting cross-province energy intensity convergence in China: A spatial panel analysis

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ABSTRACT

Understanding the convergence of energy intensity helps in assessing whether policies targeted at reducing energy intensity are effective and should thus be continued or reinforced. This paper analyzes the convergence of cross-province energy intensity in China based on panel data of 29 provinces for the period 2003–2015 by means of sigma convergence, kernel density analysis, and unconditional and conditional beta convergence. The empirical results show that the omission of spatial spillovers underestimates conditional beta convergence. We thus argue that the implementation of effective policy for reducing energy intensity depends not only on the driving forces in the own province but also on the spatial spillover effects in neighboring provinces, particularly technology transfer, knowledge spillovers, and the input-output relationship. From the analysis, it follows that adopting low-energy capital, attracting more FDI inflows and developing indigenous innovation capabilities are major policy handles.

1. Introduction

As the largest energy consumer and largest carbon dioxide emitter in the world, China's energy consumption has risen five-fold since the country's economic reform and opening up in 1978. In 2012, for the first time, China accounted for more than half of global coal consumption (BP, 2013). Due to its demand for energy, China is currently facing two major challenges: energy scarcity and environmental degradation (Jiang and Lin, 2012; Yao and Chang, 2014).

Energy efficiency improvement has been widely regarded as a cost-effective way to address both energy scarcity and environmental degradation (Andrews-Speed, 2009). Previous studies have been devoted to developing different indicators and models for tracking the economy-wide energy efficiency performance in China and elsewhere (Zhou and Ang, 2008; Zhou et al., 2012; Filippini and Zhang, 2016). Of the alternative energy efficiency indicators, the energy-GDP ratio has been widely used for analyzing and supporting policy analysis due to its ability to directly measure the link between energy consumption and economic activity, as well as its ease of interpretation (Metcalf, 2008; Le Pen and Sévi, 2010; Stern and Jotzo, 2010; Liddle, 2010).

The Chinese central government has been aware of the need to reduce energy intensity for more than a decade (Herrerias et al., 2013). In its 11th Five-Year Plan (2006–2010), it set an imperative target of reducing the overall energy intensity by 20% relative to the benchmark of 2005. Since there exist clear regional differences in energy resource endowments, economic growth patterns, and levels of technological development, the regional targets for reducing energy intensity vary across different provinces. As a result, in the 11th Five-Year Plan, more stringent targets were set for the eastern provinces than for the western provinces, with the central provinces taking an intermediate position. By the end of 2010, China had successfully reduced its aggregate energy intensity by 19.1%. In the 12th Five-Year Plan (2011–2015), the country-level energy intensity target was set at a reduction of 16% with reference to the year 2010. At the province level, as shown in Fig. 1, different energy intensity reduction targets have been assigned. Despite the efforts made by different provinces to reduce energy intensity, there still exist substantial gaps among them.

Understanding the provincial energy intensity gaps can help policy makers in designing and implementing effective policies to respond to the ever-growing environmental degradation in China. In this respect, two possible policy handles arise. One option is to focus on provinces that have already substantially reduced their energy intensity. However, this strategy is relatively expensive because it becomes increasingly difficult to further reduce their energy intensity because the

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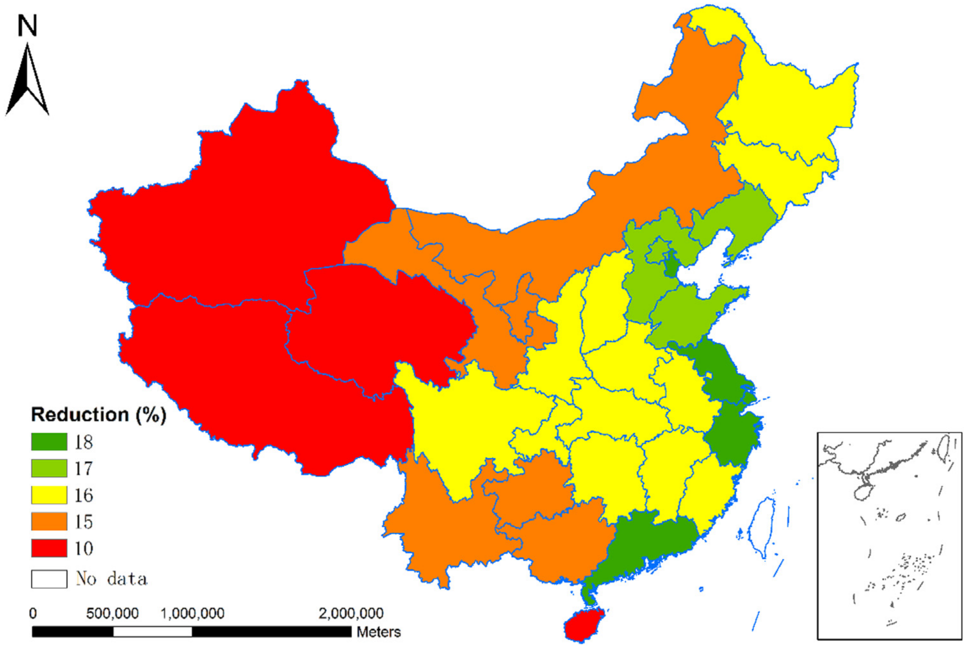

Fig. 1. Regional energy intensity reduction targets (%) in the 12th Five-Year Plan. (Data source: http://www.gov.cn/gongbao/content/2011/content_1947196.htm)

low-hanging fruit has already been harvested. The other option is to focus on the "laggards" in an attempt to accelerate their energy intensity reduction, possibly by making use of the experiences of the "pioneers". Either way, for sustainable economic development, China's policy makers should better understand how provincial energy intensity changes over time (Burnett, 2016).

Convergence is a concept that stems from the economic growth literature, particularly the income growth literature (Barro, 1991). In energy intensity studies, the convergence concept has also been used, mostly at the country level. For instance, Mulder and De Groot (2007) showed that technological progress, knowledge spillover, technology diffusion, and sectoral shifts are important sources of energy intensity convergence. Miketa and Mulder (2005) analyzed energy productivity convergence (the reciprocal of energy intensity) in ten manufacturing sectors across 56 developed and developing countries for the period 1971–1995. Markandya et al. (2006) showed the convergence of energy intensity in a sample of European countries towards the European Union average. Mulder and De Groot (2007) investigated the convergence of cross-country energy productivity at the sectoral level using panel data of 14 OECD countries for the period 1970–1997. Herrerias (2012) investigated the convergence of energy intensity for 83 countries over the period 1971–2008 by means of the distribution dynamics approach. Kiran (2013) used a fractional cointegration model to investigate the energy intensity convergence of 21 OECD countries.

Similar to international convergence studies, there are several studies of energy intensity convergences at the regional level. A recent example is Burnett and Madariaga (2016), who found evidence of convergence in state-level energy intensity in the US. To the best of our knowledge, there are only few studies dealing with this issue in China. An example is Yu (2012), who applied spatial econometric models to test provincial energy intensity convergence. He found absolute beta convergence of provincial energy intensity and conditional beta convergence when taking into account spatial effects. Herrerias and Liu (2013), who found evidence of electricity intensity convergence across Chinese provinces based on monthly data for the period 2003–2009 by means of unit root tests. Pan et al. (2015) applied data envelopment analysis (DEA) and spatial Markov chain analysis to test the club convergence of regional energy efficiency. More recently, Zhang and Broadstock (2016) showed club convergence in cross-province energy intensity. The study by Zhang et al. (2017) investigated the convergence of provincial energy efficiency by using DEA, considering spatial effects.

A crucial aspect of convergence analysis based on a sample of spatial units, as in the case of the present study, is spatial spillover, i.e., that the sample elements are not independent but interact with and influence each other. Although Yu (2012) took into account spatial effects, one shortcoming of his study in examining energy intensity convergence is that he ignored potential exogenous spatial effects. Technically speaking, a major vehicle of energy intensity convergence is technology diffusion across provinces. Explicit inclusion of the technology spillover vehicles in a convergence model is necessary not only from a substantive point of view but also from an econometric point of view. The omission of potential spatial spillovers may lead to omitted variable bias, i.e., to under- or overestimation of the determinants of convergence. Thus, it is necessary to include spillover effects in a convergence model to reduce potential model specification errors (Folmer and Oud, 2008). Otherwise, it may lead to biased conclusion, and even undermine scientific results.

The purpose of this paper is to model the convergence of energy intensity in China by considering both the own determinants of convergence and their spatial spillovers. In addition to spillovers in the systematic model components, we also test and control for spatially correlated disturbances (see Section 2.1). The remainder of this paper is organized as follows. Section 2 introduces the convergence models as well as the data used in this paper. Section 3 presents the modeling results. Section 4 concludes; it also includes some policy recommendations.

2. Methods and data

There are different convergence concepts and models in the literature, as summarized by Petterson et al. (2014). In this paper, we use the following three common concepts: σ convergence, kernel density analysis and β convergence.[1] σ convergence is defined as the decline in

[1] Because of the small sample size, we do not analyze stochastic convergence, which requires panel unit root tests (Le Pen and Sévi, 2010).