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The drivers of energy intensity in China: A spatial panel data approach☆

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ABSTRACT

We use a panel of 29 Chinese provinces for the period 2003–2011 to estimate the drivers of energy intensity by means of a spatial Durbin error model. We find an inverted U-shaped relationship between energy intensity and income (energy intensity Kuznets curve). Ten provinces, notably the developed east coast provinces, have already passed the turning point of 29,673 RMB. The number of years for the other 19 provinces to reach the turning point ranges between 8.3 (Jilin) and 21.8 (Yunnan). The share of the secondary sector in the own province and in neighboring provinces causes an increase in energy intensity, the capital-labor ratio a decrease. Foreign direct investment (FDI) has a significant negative spatial spillover impact on energy intensity. To improve the sustainability of its energy resources and its environmental conditions, China needs to continue reducing its energy intensity by further developing modern industrial systems to counterbalance the negative effects of its economic growth and energy consumption. An adequate policy handle is investment in research and development and stimulation of their introduction into production processes. For that purpose, market mechanisms can be readily applied, particularly energy prices that adequately reflect energy scarcity and external effects. FDI is also an effective tool to transfer advanced technology to China.

1. Introduction

The world has been witnessing the rapid growth of the Chinese economy since 1978 when the country started its nationwide economic reform and opening up to the global economy. The spectacular growth has, however, been accompanied by an equally unprecedented consumption of energy. China became the world's largest coal consumer in 1986, the second largest electricity consumer in 1995, and the second largest oil consumer in 2002 (BP, 2009). Finally, in 2010, China took over the top position in energy consumption from the US (Herrerias, Cuadros, & Orts, 2013) with a record of 22.52 billion toe (tons of oil equivalent), thus slightly surpassing the amount of 21.70 billion toe consumed by the US (Pao, Fu, & Tseng, 2012).

Energy consumption is the source of many serious environmental problems (Suri & Chapman, 1998). Behind the above figures is an array of energy-related environmental issues, notably emissions of particle matter, carbon dioxides, nitrogen oxides, and sulfur dioxides. There are two main reasons for environmental degradation in China. One is that China heavily depends on pollution intensive fossil fuels, notably coal. The second is the inefficient use of energy that has not only resulted in a huge waste of energy, but also a

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deteriorating environment. Particularly, China's energy intensity (the ratio of energy consumption to GDP) is very high, as compared to developed countries (Hang & Tu, 2007).

For a good living environment and sustainable economic growth, the Chinese government has specified several national goals of environmental protection with improving energy efficiency as one of its top priorities. Energy intensity reduction has thus become a critical and strategic issue for China's long-term development (Zhao, Ma, & Hong, 2010). In its 11th Five-Year Plan (2005–2010), China implemented for the first time a strict target, aiming to achieve 20% reduction in energy intensity by 2010 (Wang, 2011). In the 12th Five-Year Plan (2010–2015), the goal was further accentuated by an additional 16% reduction target.

We examine in this paper the development of energy intensity over space and time, as well as its drivers. We pay inter alia attention to the impact of per capita gross provincial product on energy intensity, particularly whether there exists a Kuznets curve. The notion of an Environmental Kuznets Curve (EKC) dates back to Grossman and Krueger (1991). They were the first to analyze the environmental degradation–income linkage. Subsequently, many studies have surged focusing on the relationship between per capita income and certain types of pollutants (De Bruyn, 1997), such as suspended particle matter (Cole, Rayner, & Bates, 1997; Orubu & Omotor, 2011), sulfur dioxide emissions (Stern & Common, 2001; Leitão, 2010; Stern, 2010), nitrogen oxides emissions (List & Gallet, 1999; Millimet, List, & Stengos, 2003; Maddison, 2006), carbon dioxide emissions (Saboori, Sulaiman, & Mohd, 2012; Esteve & Tamarit, 2012) and water pollution (Selden & Song, 1994; Paudel, Zapata, & Susanto, 2005; Lee, Chiu, & Sun, 2010).

Several studies have addressed a possible energy intensity Kuznets Curve (EIKC), i.e. whether energy intensity increases as income rises from low levels, and then falls as income rises beyond a critical value (Galli, 1998). In studies of an EIKC, the effects of economic activity are generally decomposed into a scale, composition and technique effect (Grossman & Krueger, 1991). In the present study, the scale effect is captured by Gross Provincial Product (*GPP*). Basically, when *GPP* goes up, more energy is consumed. The composition effect refers to sector structure (Elliott, Sun, & Chen, 2013).[1] Typically, a developing country experiences a shift from agriculture to industry and finally to services. According to Antweiler, Copeland, and Taylor (2001) and Herrerias et al. (2013), the industrial sector is known to be energy intensive while the energy intensity of the service sector is relatively low. The composition effect tends to lead to a rise in energy intensity followed by a decline when income grows and the economy shifts towards the service sector (Stern, 2004; Elliott et al., 2013. This development is strengthened by the technique effect in that richer countries can afford a technology shift toward more energy efficient techniques. The composition and technique effect may be so strong that they outperform the scale effect.

Despite its importance for scientific research and for energy policy-making, the relationship between energy intensity and per capita GDP or per capita *GPP* has received little attention in China. One of the few exceptions is Song and Zheng (2012), who use provincial panel data from 1995 to 2009 and find a quadratic relationship between energy intensity and income. However, the asserted EIKC may be spurious because of methodological flaws. First, the authors ignore time specific effects, notably trends in energy intensity and per capita *GPP*. The estimated relationship may thus reflect the correlation between the trending factors that affect energy intensity and per capita *GPP* rather than the impact of the latter on energy intensity per se. Besides, the study ignores spillover effects among the provinces, thus violating Maddison (2006) who suggests controlling for potential spillover effects when exploring the EKC hypothesis. Spillover effects are likely to exist among Chinese provinces. For example, an energy-rich province can export energy at a low price to its neighbors which may thus have little incentive to reduce energy intensity because of access to cheap energy.

The objective of this paper is to empirically analyze the relationship between energy intensity and per capita *GPP* in China. The structure of the paper is as follows. Section 2 introduces the main variables that have been analyzed in the literature as drivers of energy intensity while Section 3 presents the econometric model. Section 4 discusses the empirical results and Section 5 concludes.

2. The energy intensity drivers

The dependent variable is energy intensity (*EI*). It is defined as the amount of energy consumed to generate a unit of provincial output. Formally:

$$EI = \frac{Energy\ \ consumption}{GPP} \tag{1}$$

Average EI development over time is presented in Fig. 1. The figure shows a clear downward trend with an interruption in 2002 and 2003, as a consequence of the spurt of economic growth (Andrews-Speed, 2009). After 2003 the downward trend continued at approximately the same speed as before 2002.

By geo-visualizing the average annual energy intensity (Fig. 2), we find that the high energy intensity provinces are clustered in northwest China. In contrast, the low energy intensity provinces are concentrated in the middle and southeast provinces. There is a range of intermediate provinces in between.

We next consider the following drivers.

[1] Sinton and Levine (1994) use a decomposition method to analyze energy intensity in China's industrial sector between 1980 and 1990. They find that intra- industry sector change is an important factor causing energy intensity to decrease. Similar conclusions have been reached by Zhang (2003), Ma and Stern (2008) and Fisher-Vanden et al. (2004).