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An analysis of technological factors and energy intensity in China

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ABSTRACT

The main purpose of this research is to explore the effects of technological factors on energy intensity, including indigenous research and development (R & D) activity, technology spillovers through openness in the form of foreign direct investment, export, and import in one united framework. By scrutinising panel data of China's 30 provinces from 2000 to 2013, this article first uses fixed effects and feasible generalised least squares to investigate the effects of these technological factors on energy intensity by taking both economic structure and energy price as control variables. The results show that indigenous R & D plays a crucial and dominant role in the declining energy intensity among the four technological factors. In addition, technology spillovers coming from the openness of foreign direct investment and import decrease energy intensity except for the export. However, further estimation with the panel threshold model confirms that the effects of technology spillovers on energy intensity depend on the levels of local inputs of R & D expenditure intensity and the full-time equivalent of R & D personnel, allowing us to formulate different policies and measures aimed at encouraging more efficient use of energy that takes into full consideration the characteristics and situations of the technology spillovers.

1. Introduction

Since China launched a nationwide economic reform and the opening up to global policy in 1978, it has experienced a 9.72% average annual growth rate in its gross domestic product (GDP) from 1978 to 2014, but the annual rate of energy demand also rose by 5.74% over the same period (National Bureau of Statistics of China, 2015). As a result, the energy intensity, calculated as the amount of energy needed to produce a unit of GDP, has dropped substantially; there were a few years when the falling trend was reversed, but then it again began to fall. However, even a dramatic reduction in energy intensity existed at the level of an aggregate economy; China still lags behind the international average energy intensity level so much.

One possible way to decrease energy intensity is through energy-saving technology. The indigenous research and development (R & D), technology spillovers embodied in foreign direct investment (FDI) and trade, transferred from developed countries are considered as essential ways to reduce China's energy intensity (Wu, 2008; Hang and Tu, 2007; Hübler and Keller, 2010; Zheng et al., 2011; Wang and Qi, 2014). During 1978–2014, China achieved a sustained expansion in its R & D, FDI inflows, and trade along with its constant decline in energy intensity. Fig. 1 shows the trends of China's R & D, FDI, trade and energy intensity between 1990 and 2014. Such a trend motivates researchers to investigate how they affect energy intensity, and it has inspired an extensive amount of literature during the past two decades.

Based on different research purposes, in empirical studies, researchers usually hypothesise that the effects of FDI and trade on energy intensity are mainly through the technology spillovers. However, the understanding and proxy variables for their spillover effects receive much less consensus (Hang and Tu, 2007; Zheng et al., 2011; Hübler and Keller, 2010; Yan, 2015). For instance, Hang and Tu (2007) adopt the amount of FDI to reflect its spillover effect on energy intensity. Both Elliott et al. (2013) and Yan (2015) choose the percentage of FDI inflows divided by GDP in their models. Inconsistent with these studies, Zheng et al. (2011) define the ratio of FDI to total fixed assets as its proxy variable. Accordingly, the different proxy variables for FDI may result in biased or mixed regression results. Furthermore, studies have also shown that both import and export have the potential to affect the energy intensity in the host countries. Few papers have noted the impacts of indigenous R & D, FDI, export and import on energy intensity in China at the same time. In order to analyse and compare different technological factors influencing energy intensity, it is necessary to analyse them in one united framework (Wang and Qi, 2014).

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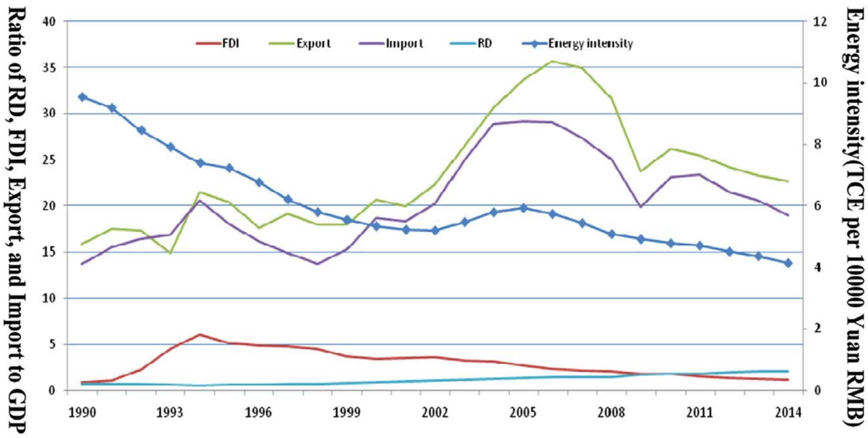

Fig. 1. The trends of China's R & D, FDI, trade and energy intensity during 1990–2014 (in constant 1978 price). *Source:* Calculations based on National Bureau of Statistics of China, 1991–2015

In addition, the effects of the technology spillovers through FDI, export and import on energy intensity could be heavily affected by the host country's specific characteristics, such as the human capital stocks, the financial development, the technological gaps and the indigenous innovation efforts (Lai et al., 2006; Zheng et al., 2011; Adom, 2015). For instance, Zheng et al. (2011) report that when the input in technological innovation increases, China's energy intensity will rise with export expansion. They show that if investment in technological innovation as a percentage of the revenue from principle business is more than 1.4% but less than 1.6%, export growth will decrease energy intensity. Adom (2015) finds that when absorptive capacity in Nigeria reaches different stages, the impact of FDI on energy intensity will also show different effects. However, the conventional linear regression method has an important limitation in that it cannot solve the problem of a structural break in the impact of independent variables on the dependent variable. It shows an average effect of the whole panel data on estimators, which is not an objective depiction of reality.

In response to these problems, this study employs the CH-LP framework (Cole and Helpman, 1995; Lichtenberg and van Pottelsberghe de la Potterie, 1998) and the panel threshold model (Hansen, 1999, 2000) to analyse the effects of these technological factors on energy intensity under a united analysis framework. The major contributions are threefold. First, we consider different technological factors in one united framework, which allows us to understand and assess their relative strengths in influencing energy intensity. Second, by employing the panel threshold model, this research is able to account for regional heterogeneity and better understand how the technology spillovers influence China's provincial energy intensity. Third, diversified policies and measures aimed at encouraging more efficient use of energy that takes into full consideration the characteristics and situations of various technology spillovers are presented.

The rest of the paper is organised as follows. Section 2 reviews the related literature. The empirical model, data, and estimation methods are all presented in Section 3. Section 4 investigates the effects of technological factors on energy intensity with both linear and nonlinear regression methods. The final section concludes the findings and policy implications.

2. Literature review

There are a large number of papers exploring the nexus between FDI, energy price, trade, economic structure, R & D activities, urbanisation and energy intensity. To motivate our paper, we briefly mention a few of them, but particularly emphasise the technological factors.

2.1. Energy price and energy intensity

The price of energy is usually identified as an important external factor that affects the energy intensity in the regression literature. It influences energy demand through both substitution and income effects. A significant impact of rising China's energy price on the declining of energy intensity was observed by Hang and Tu (2007), Wu (2012), Yan (2015), Huang et al. (2017). Hang and Tu (2007) use the time series over the period 1985–2005 and suggest that raising energy prices via economic instruments can be used as the main option for decreasing the energy intensity in China. Later, Wu (2012), Yan (2015), Huang et al. (2017) find evidence that the energy price has a decreasing effect on the energy intensity based on China's provincial panel data. However, Mulder et al. (2014) use a dataset of 23 service sectors in 18 OECD countries over the period 1980–2005 but find a limited role for energy price in explaining variation in energy intensity, casting doubt on the effectiveness of the price instruments on the effectiveness to decrease energy intensity.

2.2. Urbanisation and energy intensity

Urbanisation is one of China's key stages at present. It affects energy intensity with complicated relationships. First, the movements of population into cities involve changes in economic structure (occupations change) and constructions of urban public infrastructures, spurring the expansion of energy-intensive industries, such as the steel and cement industries, etc. Meanwhile, urbanisation concentrates economic activities in the city, which brings about economies of scale and opportunity for decreasing energy intensity. Second, urbanisation, accompanied by increasing incomes, leads to a change in consumer behaviour, increasing dependence on more modern means of transport in the cities and replacements of non-commercial energy by commercial energy in households. Accordingly, the empirical evidence provided by current literature is both controversial and obscure. With a balanced panel dataset of China's provinces covering the period from 1995 to 2009, Song and Zheng (2012) conclude that urbanisation significantly increases energy intensity. A similar result can be found in Yan (2015). Liu and Xie (2013) reveal there is existence of a nonlinear causal relationship between urbanisation and energy intensity for China. Both Sadorsky (2013) and Ma (2015) find that the impact of urbanisation on aggregate energy intensity is mixed.

2.3. Structural change and energy intensity

Structural change involving both economic structure and energy consumption structure is also presented as an important factor (Garbaccio et al., 1999; Wei et al., 2006; Zheng et al., 2011; Li and