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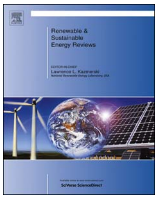

Indigenous versus foreign innovation and energy intensity in China

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ABSTRACT

This paper empirically investigates the roles of indigenous and foreign innovations in the development of technology spillovers originating from foreign direct investments, exports and imports on the energy intensity across China's 30 provinces for the period 2000–2013. The Driscoll-Kraay standard error estimator is first used to tackle the problems of heteroscedasticity and serial correlations in the models, and further discussion with a panel cointegration analysis is employed to confirm the estimates. The results indicate that indigenous innovations play a more important effect on energy intensity than foreign innovations. However, the panel threshold analysis indicates that the effects of foreign innovations on the energy intensity across China depend on the technological absorptive capacity affecting factors such as local research and development investment and human capital stock.

1. Introduction

Economic growth is a desirable goal for each country; however, it also has negative aspects, such as increasing energy demand and deteriorating environmental conditions, which are problematic for sustainable development. First, because of the large demand for energy, the world's greenhouse gas emissions are constantly increasing. Global warming has become one of the most important environmental issues and must be immediately addressed. Second, the greater demand for energy has also helped steadily drive the increase in the energy price, which worsens the energy poverty problem worldwide despite the recent temporary pictures of a cheap oil market in 2015–2016 [1]. To guarantee optimal production in a modern industrialized world and pave the way for sustainable development, a sufficient supply of energy must be available and high efficiency of energy use must be implemented.

Beginning in 1978, China has achieved exceptional economic performance. However, the growth is associated with a remarkable increase in the consumption of energy and large emissions of CO_2. In the coming decades, China's energy sector must confront major transformations of the following three areas: energy security, climate warming and energy poverty. The methodology of ensuring sustainable economic growth and development is one of the major concerns for China. To address these issues, the government has proposed a series of reforms, such as lowering the CO_2 emissions and energy consumption per unit GDP (i.e., energy intensity) by 18% and 15%, respectively, in 2020 compared with the levels in 2015 [2]. Therefore, this proposal has raised the question of the types of policies that should be adopted by the central government to reducing the energy intensity in China. This paper's objective is to offer insights on this issue.

Second, changes in energy intensity could be related to the sectorial composition or technological progress [3–15]. The composition effect could be influenced by different economic development stages and the energy potential among different countries or regions, such as shifts in the structure of an economy away from energy-intensive heavy subsectors towards high-technology subsectors [3–7]. Most of the literature has confirmed that technological progress is vital to energy intensity reductions, although few have disentangled the specific mechanisms and processes that will be required. For instance, foreign direct investment (FDI) is recognized as a potential and important source of technological progress from abroad [8–20]. When newly relocated foreign companies are more technologically advanced than their domestic counterparts, they will transfer technological know-how, managerial expertise and international marketing skills through demonstrations, labor turnover and vertical linkage effects [21]. However, the knowledge and proxy variables required to implement these technique effects to lower the energy intensity across China are controversial. To the best of our knowledges, there are at least four different proxy variables for FDI in the empirical literature. Mielnik and Goldemberg [8] select FDIs divided by total investments. HÜBLER

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Table 1
Summary of selected studies on relationship indigenous innovation, FDI, trade and energy intensity.

Studies	**Variables**			**Methods**	**Results**
	Countries	Period	Proxy variables		
Adom and Amuakwa-Mensah [6]	13 East African countries	1980–2011.	FDI/GDP; (Import+Export)/GDP	Conditional model	FDI (mix), Trade (mix)
Mielnik and Goldemberg [8]	20 developing countries	1987–1998	FDI/total investments	Regression	FDI (—)
HÜBLER and Keller [9]	60 developing countries	1975–2004	FDI/fixed capital formation, Export/GDP	FE, Two-stage least squares	FDI(mix), FDI(mix)
Adom [10]	Nigeria	1971–2011	FDI/GDP, (Import+Export)//GDP	FMOLS, CCR	FDI (—), Trade (—),
Adom [11]	South Africa	1970–2011	FDI/GDP, (Import+Export)//GDP	FMOLS,	FDI(+),Trade (—),
Adom and Kwakwa [12]	Ghana	1975–2011	FDI/GDP, (Import+Export)//GDP	FMOLS, CCR, DOLS	FDI (—), Trade (—),
Cole [13]	32 countries	1975–1995	(Import-Export)/GDP	FE	Mix
Eilliott et al. [14]	China	2005–2008	FDI/GDP	FE, Two-stage least square	FDI(—)
Zheng et al. [15]	China's 20 industrial sub-sectors	1999–2007	FDI/total fixed assets, Export/GDP, R&D	FGLS, PCSE, panel Threshold	FDI(—), Export(+),R&D (—)
Yan [16]	China	2000–2012	FDI/GDP ,export/GDP	Driscoll–Kraay	FDI(—) Export(+)
Herrerias et al. [17]	China	1985–2008	FDI/GDP, Import/GDP	Time series cross-sectional model	FDI(—) Import (—)
Herrerias et al. [18]	China	2006–2010	FDI/GDP, Import/GDP, Patinents	PCSE	FDI(—) Import (—) R&D (—)
Yu [19]	China	2003–2011	FDI/GDP	FE, Spatial panel regression	Export(+)
Jiang et al. [20]	China	1988–2007	Export/GDP	Spatial Durbin model	FDI(—)
Rafiq et al. [26]	22 Emerging Economies	1980–2010	Trade liberalization	MG, CCME, AMG	Trade (—),
Fisher-Vanden et al. [29]	China	1997–1999	R&D expenditures	Seemingly unrelated regressions	R&D (—)
Wang and Han [30]	China	2003–2012	Indigenous R&D expenditures	Driscoll–Kraay	R&D (—)

Note: FMOLS, CCR and DOLS denote the fully OLS, Canoncial cointergration regression, and dynamic OLS, respectively.
FE, PCSE and FGLS denote fixed effects model, Panel-Corrected Standard Errors, and Feasible Generalized Least Squares, respectively.
MG, CCEMG, AMG denote mean group estimator, common correlated effects mean group estimator, and augmented mean group estimator, respectively.
"+" and "—" stand for FDI, trade or R&D increase energy intensity and descrease energy intensity, respectively. Mix represents that the results are mixed.

and Keller [9] adopt the ratio of FDIs to fixed capital formation in their models. Adom [10,11] and Adom and Kwakwa [12] use the percentage of FDI divided by GDP as the proxy variable to capture the technique effect upon the energy intensity in China. In Zheng et al. [15], FDI is defined as the ratio of total fixed assets. As provided by these studies, the effect of FDI on energy intensity is controversial and biased [8–20].

In addition, both imports and exports have the potential to affect the energy intensity in the host countries [9–13,15–20]. When competing on the world market, firms have the impetus to increase the inputs into indigenous innovations. In order to enhance the competitiveness of their exported products or services and contend with green trade barriers, firms can import technically advanced equipment and introduce energy-saving technologies, and these barriers have become increasingly strict as evidenced by the increasing prevalence of technical standards in international trade [22]. However, the greater export of energy-intensive products and primary products may increase the industrial energy intensity. Few papers have noted the impacts of FDIs, exports and imports on the energy intensity in China at the same time. In this paper, we focus on the technique effect and distinguish two key factors: indigenous and foreign innovations. The FDI together with exports and imports are considered as the three important channels of technology spillovers and indigenous research and development investment (R&D) required to capture indigenous innovation. Researchers may promote technological progress and contribute to advancements in energy efficiency. Such a distinction is crucial for separately understanding and assessing the roles of indigenous and foreign innovations on energy intensity.

Third, the effects of the technology spillovers through FDIs, exports and imports 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. For China, Elliott et al. [14] argue that the unbalanced nature of development across China means that the absorptive capacity of firms is likely to differ by region, and it is linked to a region's level of development. Zheng et al. [15] report that the effect of exports on energy intensity is connected to the indigenous R&D. Seyoum et al. [23] suggest that domestic firms with a higher absorptive capacity experience a positive technology spillover effect, while those with a low absorptive capacity witness a negative effect. Because China's regions are heterogeneous in terms of the development stage and the mitigation potential, conventional linear regression methods ignore the moderating role of the subsidy intensity on the relationship between technology spillovers and energy intensity behavioral intentions. Consequently, the subsidy behaviors on energy intensity will not be sufficiently clear.

Therefore, in this paper, the main objective is to investigate the effects of indigenous innovation and foreign innovation through FDIs and trade on energy intensity. to substitute this deleted sentence. To meet the objectives of the study, We first use Coe and Helpman [24] and Van Pottelsberghe de la Potterie and Lichtenberg [25] to construct a united framework for China's provincial technology spillovers in 2000–2013. Second, the Driscoll-Kraay standard error estimator is employed to explore the effects of indigenous and foreign innovations on energy intensity. A panel cointegration analysis is applied to confirm the estimates. Then, further research based on the panel threshold analysis can explain the regional heterogeneity and help understand how foreign innovations influence China's energy intensity. Finally, diversified policies and measures that promote a more efficient use of energy that fully considers the characteristics and effects of foreign and indigenous innovations are presented Finally, in order to easily extend this methodology outside of China to other developing countries, the study is performed using USD rather than RMB.

The structure of the rest of this paper is as follows. Section 2 reviews the related economic literature. Section 3 develops the theoretical framework for building China's provincial technology spillovers and describes the empirical model as well as the data. Section 4 reports the methodology and discusses the results. The final section provides the conclusions.