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Energy efficiency, carbon emission performance, and technology gaps: Evidence from CDM project investment

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ABSTRACT

Measuring the energy conservation and carbon emission reduction potential proves the fundamental basis for stakeholders in the cooperation over Clean Development Mechanism (CDM) projects. This research adopts the meta-frontier non-radial directional distance function based on the Data Envelopment Analysis (DEA) window analysis to measure the total factor energy efficiency and carbon emission performance of leading countries involved in CDM projects during 1990–2015. This study employs the panel quantile regression to investigate the dynamic impact of CDM projects on different energy efficiency and carbon emission performance of CDM host countries. The results indicate that, first of all, the total factor energy efficiency and carbon emission performance of CDM host countries appear much lower than those of investment countries. Second, the technology gap of energy-use and carbon emissions reduction between CDM host and investment countries is significant. Finally, with the increase of total factor energy efficiency and carbon emission performance in CDM host countries, the impact of CDM projects on their energy efficiency is always negative, and that on their carbon emission performance gradually varies from positive to negative, meaning that CDM projects are not necessarily helpful to improve the energy efficiency and carbon emission performance in host countries.

1. Introduction

The Clean Development Mechanism (CDM) is a flexible compensation mechanism proposed by the Kyoto Protocol. It allows developing countries (i.e., CDM host countries) to sell Certified Emission Reduction (CER) obtained from greenhouse gas mitigation projects to the developed countries referred to as Annex 1 parties (i.e., CDM investment countries)) to offset their emission reduction obligation (UNFCCC, 2017). According to the United Nations' Intergovernmental Panel on Climate Change (IPCC, 2014), the mitigation of climate change is a significant challenge, and CDM projects can promote economic growth and inhibit greenhouse gas emissions growth at the same time. It can enhance the sustainable development of developing countries in a cost-effective way to reduce carbon emissions.[1] Similarly, Huang and Barker (2012) argue that the development of CDM projects has significant positive impact on global carbon emissions reduction, and also helps developing countries to achieve lower-carbon development goal.

CDM projects can be used to improve the lower-carbon technology in developing countries and cut down the emission mitigation costs in developed countries. This is mainly attributed to that the total factor energy efficiency of developed countries is very high (Honma and Hu, 2014), leading to their emissions reduction cost being so high to further improve their energy efficiency and carbon emissions reduction (Apergis et al., 2015). However, the energy consumption and carbon emissions in developing countries are mainly driven by economic growth (Zhang and Da, 2015; Zhang, 2011), and their energy efficiency appears relatively lower and the carbon emissions reduction potential is tremendous. That is, higher emission reduction can be achieved at a lower cost in developing countries (Zhang et al., 2011; Chen and Groenewold, 2015). As a result, the emissions reduction cost of developed countries appears higher than that of developing countries when striving to achieve equal carbon emissions reductions (Wu and Wen, 2013; Zhang and Yan, 2015). In fact, lower-carbon technology transferred from developed countries to developing countries by CDM projects can achieve significant carbon emissions reduction

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[1] http://cdm.unfccc.int/.

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(Dechezlepretre et al., 2009). This not only can reduce the emissions reduction cost of developed countries and drive the development of CDM projects (Doukas et al., 2009), but also can improve the lower-carbon technology of developing countries (Schneider et al., 2008; Wang, 2010). It is necessary to further explore the energy conservation and emission reduction potentials of CDM host and investment countries; in particular, it is of great significance to investigate the energy efficiency and carbon emissions performance of CDM host and investment countries, and measure the technology gaps of energy utilization and carbon emission reduction between them.

In fact, whether CDM project cooperation can improve the energy efficiency and carbon emission performance of CDM host countries causes much controversy in academic circles. Some studies employ the traditional OLS regression technique to investigate the impact of CDM projects and argue that CDM projects can be helpful to improve energy efficiency and carbon emission performance (Dechezlepretre et al., 2009), because CDM projects can improve renewable power technology (Zhao et al., 2014). However, some scholars hold the opposite arguments. For example, Zhang and Wang (2011) adopt the OLS approach to evaluate the impact of CDM on the emission reductions of China at the prefecture level during 2000–2008, and argue that the CDM does not have a statistically significant effect in lowering emissions. The controversy above may be caused by different energy efficiency and carbon emission performance of varying research objects. As a result, the impact of the implementation of CDM projects on energy efficiency and carbon emission performance will vary. That is, the existing literature mainly focuses on the mean effect with the traditional regression models, and ignores the dynamic impact of CDM projects on various energy efficiency and carbon emission performance. This shortage can be covered by panel quantile regression approach, because it can reflect the relationship between independent and dependent variables at various quantiles (Binder and Coad, 2011). Hence, it is worthy to further explore how the impact of CDM projects will change on different energy efficiency and carbon emission performance of CDM host countries.

However, the global CDM host and investment countries just mainly concentrate in a few states. According to the UNFCCC (2017), by 31 May 2017, the proportions of global registered CDM projects in China, India, Mexico, Thailand, Chile, Philippines, Colombia and Peru are more than 70%, and, especially, the proportion of China is 48.43%. Accordingly, the UK, Switzerland, Netherlands, Japan, Sweden, USA, Spain and Italy are the most active investment countries in the CDM projects, and have participated in more than 80% of global CDM projects. Therefore, this research focuses on the sixteen countries above participating in CDM project cooperation and calculates the dynamic impact of CDM projects when the energy efficiency and carbon emission performance of CDM host countries stay at different levels, so as to provide an appropriate reference for international climate change negotiations, and the investment decisions of CDM project.

The contribution of this research mainly includes two aspects. For one thing, in order to avoid the efficiency measurement bias caused by ignoring the technology gap, we adopt the meta-frontier non-radial directional distance function based on the DEA window analysis to measure the total factor energy efficiency and total factor carbon emission performance under group-frontier and meta-frontier technologies of CDM host and investment countries, and evaluate the technology gap of energy conservation and carbon emissions reduction between the two kinds of countries. For another, this paper adopts panel quantile regression model to explore whether the CDM projects can always have positive impact on various levels of energy efficiency and carbon emission performance in CDM host countries.

The remainder of this paper is organized as follows. Section 2 reviews related literature. Section 3 introduces research methods and data definitions. Section 4 presents empirical results and discussions. Finally, Section 5 concludes the paper and puts forward some policy suggestions.

2. Related literature review

Up to now, a body of literature has investigated the impact of CDM project on developing countries from various perspectives. This paper reviews the relevant literature from three aspects: the impact of energy conservation and emission reduction potential on CDM project investment, the impact of CDM projects on carbon emission reduction in developing countries, the definitions and the research methods for total factor energy efficiency and total factor carbon emission performance.

First of all, existing studies have investigated the impact of energy conservation and emission reduction potential on CDM project investment. Some research discovers that higher potentials of energy conservation and carbon emission reduction can attract more CDM project investment (Koo, 2017a, 2017b). For example, more than 83% of the projects in CDM portfolio are located in Asia, and more than 69% of the projects are in China and India alone. This is because China has comparative advantage of lower opportunity cost in energy efficiency projects, while India appears to have comparative advantage in hydro power projects (Rahman and Kirkman, 2015). However, some research holds that the number of CDM projects is very limited in some other developing countries, such as Philippines and Thailand, though their energy efficiency is very low (Zhang et al., 2011). Obviously, it is still a controversial issue whether the CDM project investment is consistent with the energy conservation and emission reduction potential. Thus, this paper further measures the potential of energy conservation and emission reduction in some leading developing countries involved in CDM projects.

Second, a lot of studies have explored the impact of CDM projects on carbon emissions reduction in developing countries, but their viewpoints have not reached a consensus. Some scholars argue that the implementation of CDM projects can effectively mitigate carbon emissions (Zhao et al., 2014; Erickson et al., 2014; Benites-Lazaro and Mello-Thery, 2017). For example, Lim and Lam (2014) claim that the number of registered CDM projects in energy sector is in rising trend and helps in large amount of emission reduction in Malaysia. However, there are also some scholars insisting that the CDM projects should not be helpful to reduce carbon emissions (Zavodov, 2012). For instance, Murata et al. (2016) claim that the co-benefits of CDM projects of reducing air pollutant emissions per avoided carbon emission is shown to be much lower than the values reported in previous studies, and the positive effect of the co-benefits of CDMs is rather limited. Thus, it is still in dispute whether CDM projects are helpful to carbon emissions reduction in developing countries. This may be attributed to the fact that the existing studies just evaluate the average impact or its changing trend of CDM projects on carbon emission reduction. However, they are unable to reflect the dynamic impact of CDM projects on carbon emission reduction of host countries when their low-carbon technologies and emission reduction potentials are different. That is to say, it is worthy to further investigate whether CDM project can always promote the energy efficiency and carbon emission performance in developing countries when they arrive at different levels. In fact, the panel quantile regression employed by this paper can well solve this problem.

Third, total factor energy efficiency and total factor carbon emission performance are the key indices influencing efficiency measurement deviation, and have always been calculated by the non-radial directional distance function in much literature (Chiu et al., 2012; Toloo et al., 2018). Specifically, total factor energy efficiency considers the impact of the interaction of various input factors (Hu and Wang, 2006; Li and Lin, 2017), and its measurement result is confirmed to be more accurate to a certain extent (Jia and Liu, 2012; Wang et al., 2012). Then total factor carbon emission performance is often measured by the ratio of the potential target carbon intensity to the actual target carbon intensity. It considers all input factors in the production process and thus can reduce carbon emission performance measurement deviations (Zhang and Wei, 2015; Hu et al., 2017; Zhou et al., 2010). Besides, as for their measurement approach, the non-radial directional distance