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Carbon-weighted economic development performance and driving force analysis: Evidence from China

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ABSTRACT

Based on a data envelopment analysis framework, this study develops an indicator termed as carbon-weighted economic development (CWED) covering the dimensions of energy, environment, economy and resources to measure the economic development performance in a carbon-emission conscious economy. As an empirical application, the proposed approach is applied to a case study of 30 provinces in China. In addition, to identify the driving forces underlying low-carbon economic development in China, we analyze the endogenous interactions and dynamic behaviors between CWED, Foreign Direct Investment, foreign trade, industrial structure, local fiscal expenditure and energy consumption structure using a panel vector auto-regression model. The main findings show that, (1) adjusting industrial structure by vigorously developing the service industry and reducing the coal energy share in the primary energy consumption structure are the two most effective approaches to improve CWED in both the short-run and long-run; in return, CWED has positive feedback effects on both approaches in the long-run; (2) increase of the fiscal expenditure has a short-term positive effect on CWED; (3) FDI has an indirect negative effect on CWED in the long-run and foreign trade has an indirect positive effect on CWED in the short-term.

1. Introduction

The limitation of gross domestic product (GDP) as a measure of sustainable development for a country was first underlined at the United Nations Conference on Environment and Development in 1992. Since then, economic measures taking into account the effects of both GDP and other factors such as environmental protection to better reflect development quality have been discussed and proposed (Nourry, 2008). Environmental destruction brought by global warming, for instance, is one of the most challenging problems facing human race because it requires complex negotiations and collaborations among nations (Adger et al., 2013). How to curtail energy consumption and environmental pollution while maintaining growth rate of industrial productivity, in other words, promoting the development of a low-carbon economy, has become a top-priority issue to tackle for many countries. In fact, low-carbon economy is a sustainable long-term development regime encompassing many factors such as economy, society, environment, politics, law and culture (Dagoumas and Barker, 2010; Dou, 2013; Hu et al., 2011).

To design and implement suitable policies for overcoming the barriers in achieving a low-carbon economy, every country shall adopt a sound and balanced measure for economic development, which accounts for the benefits of low-carbon in place of the traditional measure that puts a dominating weight on the GDP growth factor. Development of low-carbon economy requires the fusion of multiple objectives arising from sustainable energy policy, environmental protection, economic growth, resource conservation, efficiency improvement and productivity growth. In this paper, we propose an index to measure the economic development in low-carbon system as "carbon-weighted economic development" (CWED), an indicator reflecting the cost-benefit of efforts that integrate economic growth, carbon emission and sequestration, energy consumption, and other resources needed in production.

While the importance of CWED is self evidently clear, it is surprising that there is neither well-developed definition, nor formal operational procedure on measuring the concept found in the literature. Regarding the theory and practice of CWED, several key fundamental questions need to be addressed, which are : (1) how to define CWED; (2) how to quantitatively measure it; (3) what economic factors significantly influence it. We address them through both theoretical analysis and

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empirical study of evidences from China.

To measure the development of low-carbon economy, multi-criteria decision analysis (MCDA) approaches are implemented to assess the trade-offs in a low-carbon economic system. In the realm of low-carbon or sustainable development, MCDA like goal programming (Jayaraman et al., 2015), risk management (Jackson, 2010) and portfolio decision analysis (Salo et al., 2011) are applied to evaluate different choices of strategic policies and investments balancing the rewards and risks.

Data envelopment analysis (DEA) is commonly used in calculating the relative efficiency among the assessed objectives in a low-carbon economic system from the input-output analysis perspective. Productivity has been widely recognized as a measure of economic prosperity, standard of living and the quality of an economy. There have been several studies investigating indicators related to low-carbon economic development. The Malmquist productivity (MP) indicator is one such example (Malmquist, 1953) which is usually obtained by measuring the efficiency of decision-making units (DMUs) under the framework of traditional radial DEA. Regional analysis of total factor energy efficiency in China and Japan is performed in (Chang and Hu, 2010a, 2010b; Honma and Hu, 2009; Hu and Wang, 2006).

MP represents total factor productivity (TFP) growth, reflecting changes in both technical efficiency and frontier technology of a DMU between two periods. However, in many circumstances, especially when analyzing low-carbon economy, undesirable side-product (for instance, CO_2 emissions) may be produced along with the desirable outputs. Malmquist-Luenberger productivity (MLP) index, first proposed in Chambers et al. (1996), is subsequently applied in the area of environmental and energy studies by Chung et al. (1997). MLP is based on measuring inefficiency of DMUs using directional distance function (DDF) to accommodate undesirable outputs (see Emrouznejad and Yang, 2016a, 2016b; Wang et al., 2015; Yao et al., 2015). Nonetheless, the DDF method is susceptible while there are slacks in the technological constraints, which would lead to underestimation of the inefficiency. Accounting for this issue, Fukuyama and Weber (2009) improve the DDF method to get a directional slacks-based measure of technical inefficiency (DSBI) which generalizes some of the existing slacks-based measures of inefficiency.

We contribute to the literature by proposing a CWED index that better measures the low-carbon economic development. We establish a quantitative approach to measure CWED under the framework of MLP index through measuring inefficiency by a modified DSBI including non-conventional inputs and undesirable outputs. Through defining and measuring CWED index, we provide a tool for policy makers to evaluate the low-carbon economic development. We extend theories and empirical methods of previous researches on analyzing the driving forces behind low-carbon economic development through endogenous growth models using panel vector auto-regression (PVAR). We are also able to formulate five testable hypotheses regarding the relationships between the CWED driving factors and the low-carbon economic growth and then test them with empirical data. Practical insights and policy implications for policy makers are drawn from the empirical study using the data of China from 1998 to 2014.

With CWED defined, the driving forces behind low-carbon economy development need to be explored to find effective ways to improve CWED. Existing research using the index dividing methods (Chang and Hu, 2010a, 2010b; Emrouznejad and Yang, 2016a, 2016b) or the econometric tools (Fisher-Vanden et al., 2006) to identify the driving factors either neglect some relevant economic variables that are not directly used in the index measuring process or overlook the endogeneity between these economic variables. Moreover, the feedback effect of low-carbon economic development on the driving forces is ignored.

Many economic factors may drive the low carbon economic development in short or long-run. First of all, the four main driving factors in traditional economic growth literature are considered: FDI (Borensztein et al., 1998; Chang, 2010; Mehic et al., 2013), foreign trade (Badinger, 2005; Dollar, 1992; Edwards, 1998), industrial structure (Lande, 1994; Shaffer, 2009) and local fiscal expenditure (Futagami et al., 1993; Greiner, 2005). Furthermore, energy consumption structure is investigated as the fifth driving factor in low-carbon economic development for its determinant role in setting the baselines of energy consumption and environmental pollution (Andrews-Speed, 2009; Bian et al., 2013a, 2013b).

Five testable research hypotheses regarding the relationships between each of the five factors and the low-carbon economic growth are proposed. Firstly, the “Pollution Haven Hypothesis” holds in China as China's relatively lax environmental regulation attracts the inflow of foreign investment in polluting sectors, which in turn increases the proportion of polluting sectors in industrial composition. Given the high correlation between the FDI location choice and foreign trade specialization, we hypothesize that foreign trades are carried out without accounting for the environmental cost impacts of policy regulation. Consequently, foreign trade can hinder the growth of low-carbon economic development. Environmental protections are public goods offered mostly by the public sectors rather than the private sectors, therefore we develop the hypothesis that increase of environment-related government expenditures contributes to a more sustainable development. As energy consumption and environmental pollution of the secondary sectors have much larger scales than the tertiary sectors do, we hypothesize that industrial structure upgrading leads to a more sustainable economic growth. Lastly, we hypothesize that adjustment of energy supply structure from the traditional fossil fuel dominated one to a clean energy supply composition with lower levels of carbon emission promotes the growth of low-carbon economy. Empirical analysis based on data from China positively supports all the afore-mentioned hypotheses except the one on foreign trade. Details of the empirical study using the data from 1998 to 2014 are given in Section 4.

Besides theoretical analysis, we also provide practical insights and policy implications for policy makers through the empirical study. Being a leading developing country, China currently undergoes a structural transition of industrialization and urbanization which makes it an ideal candidate for our case study. Hong and Sun (2011) argue that the rapid economic growth of China is mainly attributed to the accumulation of productive factors while technological progress plays no significant role. As the country with the largest energy consumption and greenhouse gas emissions, China strives to achieve a strategic balance among economic development, energy consumption and environmental protection (Bi et al., 2014). Policy makers in China have recognized the non-sustainability of its current mode of economic growth, and the necessity in explicitly accounting for the hidden costs associated with the lack of efficiency and quality. They are in search of solutions to a multi-objective problem of boosting the economy at a satisfactory rate, saving energy and protecting environment simultaneously. To achieve this goal and obtain a low-carbon economic development, Chinese government has initiated and implemented various policies, effectively shaping economic activities through regulatory policy guidance. In 2014, China lowered its CO_2 emissions per unit of GDP by 27% compared to the 2005 level and the share of non-fossil fuels in total primary energy supply reached 12.6% (IEA, 2016a).[2] Such dynamic changes in the economic development path and the policy-setting in China generate a rich dataset for conducting empirical analysis. It is important to note that the proposed framework for measuring and analyzing CWED is not specific to China. Our approach and discussion can be extended to analyze a much broader range of low-carbon economic issues in an international context.

The paper is organized as follows. In Section 2, we review the theoretical and empirical literatures which analyze indicators and measures relevant to economic development in a low-carbon system.

[2] http://www.iea.org/statistics/statisticssearch/report/?country=CHINA&product=renewablesandwaste&year=2014.