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Comprehensive effectiveness assessment of renewable energy generation policy: A partial equilibrium analysis in China

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ABSTRACT

In order to stimulate renewable energy and control carbon dioxide emissions, the Chinese government has already introduced lots of renewable energy generation policies. Under this background, it is of great significant to figure out the economic, environmental and social effectiveness of these polices. Firstly, this paper systematically studied the framework and content of renewable energy generation policies. Secondly, this paper built a basic partial equilibrium model to calculate the equilibrium state of electricity market and carbon emissions. On this base, the effectiveness of seven renewable energy generation policies was analyzed by introducing policies into the basic model, and comparing relevant indicators in different policy scenarios with that in basic scenario. Further, an empirical analysis was made to estimate the actual benefits of these policies in China. This paper proposed an analysis method for evaluating the mechanism, effectiveness and efficiency of renewable energy generation policies. All the results and discussions in this paper can provide specific suggestions for Chinese government to shape a blueprint for implementing different kinds of policies.

1. Introduction

Developing renewable energy is an inevitable choice for environmental protection and energy structure optimization in China (Zhang et al., 2011; Zhao et al., 2013). Since 2013, the Chinese government has made a number of renewable energy generation policies, which identify renewable energy as a key component in their development plans (Peggy and Kenneth, 2014; Wang et al., 2014; Guo and Guo, 2015, 2016; Liu et al., 2014). In June 2013, *"Notice on Carrying out the Pilot Work of Carbon Emissions Trading"* was firstly implemented in Shenzhen. According to this policy, emission permits will be provided for polluters in carbon emissions trading market. Without a doubt, carbon emissions trading can limit the consumption of fossil fuels by increasing their costs. In order to further promote the development of renewable energy, *"Measures for the Assessment of Renewable Energy Generation Quotas"* was issued by the National Development and Reform Commission (NDRC), and principally approved in August 2014. Renewable energy quota system and green certificate trading set specific goals for renewable energy, and have significantly promoted the production and consumption of renewable energy. Although these policies have provided enormous development opportunities for renewable energy, it still has serious cost disadvantages. In December 2015, *"Notice on Improving the Policy of Onshore Wind Power and PV Power Grid Benchmark Price"* was introduced to increase the competitiveness of renewable energy. Meanwhile, some local governments provided investment subsidies for renewable energy generation, which can gradually reduce generation costs by improving the level of production technology. Compared to the above policies, carbon tax is believed by some scholars to be more superior, because of its advantages in environmental effectiveness and fairness (David and Linus, 2016; Brian and Nicholas, 2015). In China, carbon tax has long been regarded as an important choice for low carbon development (Liang et al., 2016; Xiao et al., 2016). However, it hasn't been officially delivered, because its tax rate is still controversial. China's carbon tax policy may be officially carried out in 2020.

This paper defines the policies which can directly support renewable energy generation, or indirectly stimulate its development by limiting fossil energy consumption and increasing the costs of fossil

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energy generation as “renewable energy generation policy”. These policies will undoubtedly raise the share of renewable energy generation, and exert great impacts on economy and environment as well. Direct subsidy policies may increase the financial pressure of government. But the effects of indirect stimulus policies, such as carbon tax, varies from country to country (Nurcan, 2016; Isabelle and Fabio, 2016). Note that, there may be some inhibitory effects between these renewable energy generation policies (Uwe et al., 2016). Thus, it will be of great significance for researching the mechanisms, effectiveness and efficiency of these policies. Whether there are repetitive incentives or opposite effects between these policies can be evaluated by comparing the evaluation results of their action mechanisms. Further, the policy assessment based on empirical analysis of China can help Chinese government judge policy effectiveness and efficiency, and provide suggestions for Chinese renewable energy policy making.

Many scholars have assessed the effectiveness of public policies, including renewable energy policies and emission reduction policies from the economic aspect (Carley, 2009; Pielke, 2011; Shrimall et al., 2015; Kilinc-Ata, 2016). Other scholars have realized that renewable energy generation policies will bring some unpredictable economic and social influences while promoting renewable energy (Mats and Thomas, 2007; Tsao et al., 2011; Zhao and Guo, 2015; Karolien et al., 2009). But no one has comprehensively assessed the effectiveness and efficiency of renewable energy generation policies from economic, social and environmental aspects. And none of the economic evaluations has taken China's all existing renewable energy policies as a case, so that they couldn’t provide much practical policy recommendations for China. Partial equilibrium theory is widely used in policy evaluation (Jung and Thorbeeke, 2003; Arndt et al., 2002; Horridge et al., 2005; Bringer et al., 2005; Ghosha and Rao, 2005), because of its advantages in emphatically analyzing the market of one certain commodity by assuming policies won’t impact on the welfare of other sectors (Sacchelli et al., 2014; Senatro et al., 2015; Gregory et al., 2013). Hence, It enables us to analyze the effect of China's renewable energy generation polices on electricity price, consumption and carbon emissions.

This paper first systematically studied the framework and content of renewable energy generation policies. On this base, a basic partial equilibrium model was built, which can be used for predicting sector profits, consumer surplus and carbon emissions in the equilibrium state. Further, the mechanisms of renewable energy generation policies were analyzed by introducing policies into the basic partial equilibrium model. The differences between partial equilibrium states indicate the environmental benefits, government fiscal revenues and social welfares brought by each policy. Additionally, this paper integrated partial equilibrium theory and empirical analysis of China, and provided specific suggestions for making policy choice and determining policy intensity.

The rest of the paper is organized as follows: Section 2 presents the framework and content of renewable energy generation policy. Section 3 shows the method and methodology, which mainly contains partial equilibrium theory, model assumption and partial equilibrium model. Section 4 discusses the different policy scenarios. Section 5 provides the empirical results and analysis. At last, Section 6 discusses the conclusions.

2. Renewable energy generation policy

2.1. Framework of renewable energy generation policy

The “renewable energy generation policy” mentioned in this paper is not a single policy but a framework containing several policies, which can directly or indirectly promote the development of renewable energy generation (see Fig. 1). Direct renewable energy generation policies are a series of policy measures, which can directly enhance the profits and competitiveness of renewable energy generation. Indirect renewable energy generation policies are other policy measures, which can increase the demand for renewable energy by cutting coal use and carbon emissions.

2.2. Analysis of renewable energy generation policy contents

2.2.1. Renewable portfolio standard & green certificate trading

Renewable portfolio standard (RPS) is a mandatory provision for the proportion of renewable energy generation in total electricity generation. It was firstly proposed by the U.S. Environmental Protection Agency (EPA) in the 1990s (Galen et al., 2015). Green electricity certificate is a policy instrument used to implement renewable portfolio standard. Fossil fuel power generation enterprises can meet the RPS by buying green certificates from renewable power generation enterprises, or paying high fines. Renewable power generation enterprises can gain extra profit from selling green certificates.

2.2.2. Electricity price subsidy for renewable energy

Electricity price subsidy for renewable energy is an enabling policy to reduce its huge cost disadvantage and maintain the normal operation of renewable energy enterprises. At present, renewable energy generation cost is about three times as much as thermal power generation cost in China, while the benchmark price of renewable energy generation is less than twice of that of thermal power generation. Hence, the government has to subsidize the price gap between the benchmark prices of renewable energy generation and thermal power generation.

2.2.3. Technology R&D subsidies for renewable energy

Accumulated knowledge and experience, which can help reduce the generation costs of renewable energy, mainly relay on research and development (R&D) investment. The Chinese national and local governments give a certain proportion of R&D investment subsidy to renewable energy generation enterprises to alleviate their financial pressure when developing new technologies.

2.2.4. Carbon Tax

Carbon tax, as a part of the environmental tax, mainly relies on the government functions to control negative externality. Finland first implemented the carbon tax policy in 1990s (Zhang et al., 2016). Carbon tax is a strong policy, which can exert great impact on market mechanism and significantly promote renewable energy generation, but also impacts greatly on every field of national economy. The carbon tax scheme has been submitted to the State Council on December 2013, and *“The environmental protection tax law (Exposure draft)”* has been finished on July 2015, which emphasized the “tax-for-fees” reform. Needless to say, carbon tax reform has been gradually put on the agenda.

2.2.5. Eliminate backward production capacity

Eliminating backward small thermal power units is an important measure to speed up the transformation of power industry, promote energy conservation and emission reduction, and optimize the power structure. This policy measure will bring extra costs to thermal power generation enterprises, thus restricting its generation eventually.

2.2.6. Optimize industrial structures

Electricity intensity of the second industry is quite higher than that of the third industry. Thus, promoting industrial restructuring will reduce electricity demand. Under this background, optimizing industrial structure will not only reduce the generation of thermal power, and increase the share of renewable energy as well.

2.2.7. Pollutant discharge permit system

Pollutant discharge permit system regulates that all pollutant emission departments can only legally discharge under the premise of pollutant discharge permits. Thermal power generation enterprises, as pollutant emission units, have to pay extra costs to get pollutant discharge permits from government or other pollutant emission units.