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Interfaces with Other Disciplines

Analysis on China's eco-innovations: Regulation context, intertemporal change and regional differences

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ABSTRACT

Eco-innovation is recognized as a determinant of success or failure of environmental protection efforts in the long run. This paper attempts to examine China's eco-innovation gains in response to the energy saving and emissions reduction (ESER) policy enforced during 2006–2010. We first construct an integrated analysis framework to evaluate the changes of energy and environmental performance used as the proxy of eco-innovation, and then the intertemporal change of China's eco-innovation gains as well as the regional differences is investigated. The results indicate that China had accelerated its process of eco-innovations during 2006–2010 when a series of ESER policies were enforced. The developments and wide adoptions of advanced energy saving and environmentally friendly technologies serve as the primary driving forces, while upgrading management skills and organizational designs contribute relatively little. Furthermore, the realizing paths of cross-region eco-innovations in China are obviously discrepant.

1. Introduction

To relieve the constraints of energy shortage and environmental deterioration to China's sustainable economic growth, great efforts have been taken by the central government to enforce energy saving and emissions reduction (ESER) during the 11th five-year plan (FYP). By the end of 2010, China had decreased its energy intensity by nearly 20 percentage points compared with 2005 levels, and the total amount of sulphur dioxide (SO_2) and chemical oxygen demand (COD) emissions in this developing country have respectively been reduced by 14.29 percent and 12.45 percent during the same period. However, as the low hanging fruits have been picked over, the marginal costs for further energy saving and emissions reduction efforts are increasing rapidly. The prospect of China's energy and environmental situations in the following several decades are still unknown and an effective long-term mechanism for promoting ESER practices is urgently required.

Eco-innovation, which plays a crucial role in decoupling China's rapid economic growth from its resource consumptions and environmental pollutions, is considered as one of the most important determinants of success or failure of energy saving and environmental protection practices in the long run (Jaffe, Newell, & Stavins, 2002). In general, eco-innovation is defined as the process of developing or implementing new products, processes or organizational arrangements which significantly decrease environmental impact but provide increased competitiveness of the users (Fussler & James, 1996; Kemp & Pearson, 2008; OECD, 2009). Yet due to the existence of dual externalities including environmental externalities and knowledge spillovers, firms lack the incentives to invest voluntarily in eco-innovation activities (Jaffe, Newell, & Stavins, 2003). In this context, some normative analysis suggest that public policies on energy saving and environmental protection, when appropriately designed, can stimulate the innovation and adoption of environmental-friendly technologies (López-Gamero, Claver-Cortés, & Molina-Azorín, 2009; Perino & Requate, 2012).

Up to now, numerous studies focus on the actual effects of environmental policies on eco-innovation (see Kemp & Pontoglio, 2011 and Popp, 2010a for a review). The dominant view insists that policy instruments designed to improve environmental quality can encourage environmentally-friendly technological change. On the one hand, policy instruments internalizing environmental externalities change the direction of technological change towards environmental innovations. Based on induced innovation hypothesis proposed by Hicks (1932), early studies found that some emissions reduction policies such as carbon/energy tax drive up the prices of fossil fuels relative to other inputs, and then induce the development of

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energy-efficient technologies. For example, Newell, Jaffe, and Stavins (1999) demonstrate that there exist a positive relationship between energy price and the improvement of energy efficiency in home appliances such as air conditioners and gas water heaters. Popp (2002) finds a long-term positive elasticity of energy patenting regarding energy price, i.e., patents on energy-efficiency technologies increase when the price of energy goes up. Kumar and Managi (2009) also verified that substantial oil price-induced technological progress at the world level has emerged when long-term oil prices are rising. More recently, Lukas and Welling (2014) point out that the European Union emissions trading scheme creates financial incentives for companies to invest in climate-friendly innovations in order to reconcile economic efficiency with ecological efficiency.

On the other hand, wide adoption of existing leading environmentally friendly technologies is another important pathway for firms' eco-innovation gains, and well-designed environmental policies that are linked to market conditions and to firms' technological capabilities can effectively accelerate this process. Jaffe, Newell, and Stavins (2005) indicate that energy conservation tax credits or technology subsidies speed the adoption of new environmental technologies by decreasing uncertain returns on investment for firms. Taylor, Rubin, and Hounshell (2005) find that stricter SO_2 emissions standards force the wide utilization of desulfurization facilities. Recently, Popp (2010b) points out that firms tend to adopt newer post-combustion control techniques to save costs in response to increasing regulatory stringency.

As we summarize from the existing literature that a majority of previous empirical studies focus on the effects of a single environmental policy instrument on a specific type of eco-innovations in a given technological field. But in practice, a portfolio of policy instruments including command-and-control measures (such as technology-based standards) and market-based policy instruments (such as environmental tax and energy-saving subsidies) is employed synchronously to address all kinds of environmental problems in different circumstances (Bennear & Stavins, 2007). These environmental instruments create incentives or constraints for the development and adoption of different eco-innovation types through different channels (Kesidou & Demirel, 2012; Triguero, Moreno-Mondéjar, & Davia, 2013). In many cases, there often exists very complicated interaction effects among these policy instruments (Zhang, Zhang, Liu, & Bi, 2013), thus it is generally difficult to distinguish the eco-innovation effect of one environmental policy instrument from another. In this context, a more comprehensive analysis framework is indispensable to investigate the actual eco-innovation effects of the combination of various environmental instruments from a macro perspective.

In this paper, we attempt to examine the integrated eco-innovation effects of China's energy saving and emissions reduction policy enforced during the 11th FYP. Unlike previous studies that used environmental R&D investment or environmental patents as the proxy of eco-innovation, this paper constructs a productivity index specified at energy saving and emissions reduction for eco-innovation measurement as suggested by Arundel and Kemp (2009). The advantages of employing this index include two aspects. On the one hand, it can capture the comprehensive effects of all kinds of eco-innovation practices including technological and non-technological types. On the other hand, the productivity index is easy to be further decomposed into several components so that we can identify the channels through which production units conduct their eco-innovations. The rest of this paper is organized as follows: Section 2 describes the definition of eco-innovations and selects a proper indicator for its measurement, Section 3 elaborates the methodology used in this study, Section 4 reports the actual eco-innovation effects of China's ESER policy along with the pathway diversities among 30 administrative provinces, Section 5 concludes the paper and puts forward some useful policy implications.

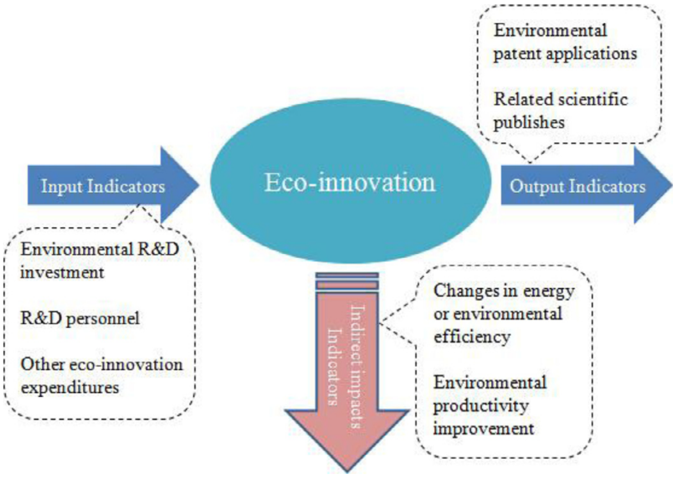

Fig. 1. Alternative measurement indicators for eco-innovation.

2. Definition of eco-innovation and its measurement

2.1. Definition of eco-innovation

In recent years, eco-innovation firstly proposed by Fussler and James (1996) has acquired increasing attention from policy makers and scholars worldwide. Due to the involvement of interdisciplinarity in sociology, economics and ecology, different definitions for eco-innovation have emerged without a standardized statement (Kemp & Pearson, 2008; OECD, 2009; Rennings, 2000; EIO, 2013). This paper applies the conception illustrated by OECD (2009) as follows:

"*The creation or implementation of new or significantly improved products (goods and services), process, marketing methods, organizational structure and institutional arrangements which – with or without intent – lead to environmental improvements compared to relevant alternatives*".

Three distinguishing characteristics can be drawn from the above definition of eco-innovation: (1) *Universality*: there are many types of eco-innovation practices ranging from technological dimensions to social and institutional ones, such as eco-products, eco-processes or eco-organizations (Triguero et al., 2013). Moreover, it is not just limited to the traditional innovation introduced by Schumpeter (1934), but encompasses the diffusion of already available environmentally-friendly products, processes, or organizations. (2) *Effectiveness*: it underlines the real environmental effects of all types of innovation activities, regardless of whether they were intended to be "ecological" or not. Eco-innovation gains can thus result from firms' other economic activities such as increasing market share or reducing production costs, although these practices are not predominantly motivated by environmental concerns (Horbach, Rammer, & Rennings, 2012). (3) *Relativity*: compared to the previous technology (or organization), the new one improves the environmental performance of adopters.

2.2. Measurement for eco-innovation

Eco-innovation is difficult to be fully and directly assessed due to its intrinsic "eco" element. Hence several alternative indicators are usually employed by existing empirical studies. Arundel and Kemp (2009) offer a review on available measurement indicators for eco-innovation and group them into three categories as shown in Fig. 1.

As the main sources of technological eco-innovations, input measures such as environmental R&D expenditures or personnel have been given a priority to the measurement of eco-innovation (Demirel & Kesidou, 2011; Popp & Newell, 2012). However, this type of indicators may be biased when there are inefficient R&D investments (Kumar & Managi, 2009). As an alternative, some output indicators