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Do renewable electricity policies promote renewable electricity generation? Evidence from panel data

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HIGHLIGHTS

- We evaluate the effects of renewable electricity policies using the PPML technique.
- The panel dataset covers 122 countries over 1980–2010.
- The policy effects diminish as the number of policies increases.
- The effects are more pronounced before 1996 as well as in developed and emerging market countries.
- Policy effectiveness varies by the type of policy and energy source.

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ABSTRACT

Using the Poisson pseudo-maximum likelihood estimation technique, this paper evaluates the effects of renewable electricity policies on renewable electricity generation using a large panel dataset that covers 122 countries over the period of 1980–2010. The results suggest that renewable electricity policies play a crucial role in promoting renewable electricity generation, but their effectiveness is subject to diminishing returns as the number of policies increases. There is also evidence that the effects of renewable electricity policies are more pronounced before 1996 as well as in developed and emerging market countries, and the negative policy interaction effect fades with the stage of economic development. Lastly, policy effectiveness varies by the type of renewable electricity policy and energy source. Only investment incentives and feed-in tariffs are found to be effective in promoting the development of all types of renewable energy sources for electricity considered in this paper.

1. Introduction

The global economy has experienced a remarkable period of rapid growth in recent decades till the onset of the Global Financial Crisis. As a consequence, global energy demand has been increasing rapidly and is expected to be about 33% higher in the year 2035 compared to 2010 (IEA, 2011). In most countries, conventional fossil fuels, such as coal, oil and natural gas, have been the primary sources for meeting global energy demand. However, the supply constraint of fossil fuel and concerns over greenhouse gas emissions have led to a worldwide effort to diversify to renewable energy sources such as solar, wind, biomass and geothermal power.

Renewable electricity (RE) sources, can create substantial environmental and socio-economic benefits, such as minimizing greenhouse gas emissions, using local resources, increasing energy access and improving energy security (IPCC, 2011; Omer, 2009; REN, 2012). However, despite the enormous potential benefits, RE is still a relatively minor contributor to total energy supply. In 2010, the total net electricity power generated from renewable sources in the world was 4154 billion kilowatt hours (kwh), less than 21% of global final net electricity generation.[1]

The main barrier for RE development is its high fixed costs compared to non-renewable electricity (Beck and Martinot, 2004; Sawin, 2004; Verbruggen et al., 2010). Most RE projects have large initial costs, long lags in generating revenues and even longer lags in making any profits. As a result, government policies like feed-in tariffs, tax credits, tradable certificates, investment incentives, and production quotas play an important role in promoting innovation in the RE sector, and in reducing the costs and accelerating market penetration of green energy. While it is expected that these policies will assist the RE sector to develop, the extent to which

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[1] Author's calculation based on the EIA data.

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this policy assistance has led to greater production of RE power has received limited attention in the existing literature.

The majority of the literature on the effectiveness of RE policies relies on exploratory analyses and case studies (Berry and Jaccard, 2001; Bird et al., 2005; Gan et al., 2007; Zarnikau, 2011). Only a handful of studies have attempted to quantify the impacts of RE policies on the development of its target sector. In a cross-country study, Johnstone et al. (2010) find that public policies play a significant role in encouraging patent applications, but the effects on different renewable sources vary greatly by the type of policy instrument. Nicolli and Vona (2012a) and Vona et al. (2011) explore this issue further by tackling the problem of policy endogeneity. They also find evidence that renewable policies positively affect green energy innovations. In addition, there are some cross-country studies investigating the relative effectiveness of different policy mechanisms. For instance, Dong (2012) shows that feed-in tariffs increase total wind energy production capacity above the renewable portfolio standards.

There are also empirical papers analyzing the effectiveness of RE policies at the state level, using mainly U.S. data. While some state level studies reach a firm and positive conclusion (Adelaja and Hailu, 2008; Menz and Vachon, 2006; Yin and Powers, 2010), others find mixed results (Carley, 2009; Kneifel, 2008). Against this background, researchers have started to question whether the effectiveness of RE policies is conditional on natural, social and institutional environment. For instance, Delmas and Montes-Sancho (2011) argue that a large presence of non-governmental organizations, green residential customers and democratic representatives facilitate the transmission of RE policies.

This paper aims to contribute to this literature using a large panel dataset. Our analysis extends previous research in three ways. First, empirical analysis on the effectiveness of RE policies remains scarce; the few cross-country studies like Johnstone et al. (2010) mainly focus on renewable patent counts rather than RE generation. In this paper we use a more direct proxy for RE sector development, namely the share of electricity generation from non-hydro renewable energy sources (Brunnschweiler, 2010; Carley, 2009). Second, although many previous studies (Azuela and Barroso, 2011; Blyth et al., 2009; Fischer and Preonas, 2010) mention that interaction of RE policies would affect the effectiveness of RE policies, the assertion remains untested. In this paper, we empirically investigate whether there are policy interaction effects in RE generation. Third, most previous studies lump different countries together in their analyses regardless of their state of development, and do the same to different periods, different policy instruments and different energy sources. In this paper, we allow for heterogeneity amongst countries, periods, policy instruments, and energy sources, respectively.

The remainder of the paper is structured as follows. Section 2 describes the data and methodology used to examine the effects of RE policies on RE generation. Section 3 presents and discusses the empirical findings. Section 4 concludes.

2. Data and the methodology

Our dataset covers 122 countries for 31 years from 1980 to 2010 and is unbalanced. The dataset is compiled using data from three different sources: the Energy Information Administration (EIA) of the United States, the World Development Indicators of the World Bank, and the International Energy Agency (IEA). Data descriptions and summary statistics are provided in Appendix A.

To assess the effects of RE policies on RE generation, we specify our estimation regression as follows.

$$Y_{it} = a + \mathbf{X}_{it}\delta + \beta Policy_{it} + u_i + v_t + \omega_{it} \quad (1)$$

where Y_{it} is a measure of electricity generation from non-hydro renewable sources as a share of total electricity generation in country i at year t, $Policy_{it}$ is the RE policy variable, $\mathbf{X}_{it}$ denotes the vector of control variables, a is the constant, δ is the vector of coefficients of control variables, β is the coefficient of policy variable, u_i is country fixed effects used to capture time-invariant country heterogeneity, v_t is time fixed effects used to capture time-variant global shocks, and ω_{it} is the random error, representing the net effect of all other unobservable factors that might influence Y_{it}. δ and β measure the influence (i.e. marginal effect) of their associated explanatory variable on the dependent variable, keeping other explanatory variables constant.

It should be pointed out that, this modeling framework allows for the possibilities that some control variables (e.g. income) may affect RE policies. At the same time, RE policies may also be affected by factors not included in the control variables set (e.g. policymakers' preference). However, as our interest is the total effect of RE policies on RE generation, not what is driving RE policies, the current modeling framework is appropriate.

Our measurement of RE generation, Y_{it}, excludes a key player in the sector – hydropower. This is because large hydropower projects often bring about serious negative environmental and social externalities and therefore regarded by many as a non-viable renewable source (Brunnschweiler, 2010).[2] In addition to the aggregate measure, we also consider different types of renewable sources for electricity, including (i) biomass and waste; (ii) solar, tide and wave; and (iii) wind energy. The share of these three sources in overall non-hydro RE generation was 91% in the year 2010.[3] All electricity generation data is obtained from the EIA.

The RE policy variable, $Policy_{it}$, is our key explanatory variable. A database on public policies for RE compiled by the IEA is used to construct alternative RE policy indicators. In this paper, we consider the following six policy instruments: (1) investment incentives such as risk guarantees and capital grants that aim at reducing the capital cost of RE production; (2) tax incentives used to encourage RE production; (3) feed-in tariffs, which are a form of price regulation designed to guarantee producers of RE power a cost-based price; (4) voluntary programs, in which members agree to undertake socially beneficial actions, such as buying RE; (5) production quotas, which place a requirement on the minimum amount of electricity supply that comes from renewable sources; and (6) tradable certificates, which provide a tool for trading and meeting RE obligations among consumers and producers, and a mechanism for tracking and verifying RE sources.

Following Carley (2009) and Johnstone et al. (2010), dummy variables are first created to record the implementation of different policy instruments. For each of the six policy instruments, a dummy variable takes a value of 0 prior to implementation of the policy and 1 thereafter.[4] Three separate measures of aggregate RE policy are then constructed from the six policy dummy variables to provide a representation of the overall policy support of RE generation for a given country. The first aggregate RE policy variable, *poldum*, is also a dummy variable. For a given year and a given country, the variable takes a value of 1 if the country adopts any of the six policies described above, and 0 otherwise. The second variable, *polavg*, is a simple average of all the six policy dummies and normalized to lie within the range of 0 to 1. The last aggregate policy variable, *polpca*, is constructed using the principal components method in order to reduce the dimensionality of the set of individual policy variables. As the first principal component

[2] Some examples are the giant Three Gorges Dam in China and Illisu Dam project in Turkey.

[3] Author's calculation based on the EIA data.

[4] Any policy that becomes effective after October in a given year is coded as effective the following year.