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Clean-energy policies and electricity sector carbon emissions in the U.S. states

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ABSTRACT

State governments in the United States have enacted various clean-energy policies to decarbonize electric utilities, diversify energy supplies, and stimulate economic development. With a panel data set for 48 continental states from 1990 to 2008, fixed-effect panel regressions are estimated to test the impacts of clean-energy policies on total carbon emissions, electricity consumption, and carbon intensity. The results indicate that supply-side policy tools, such as RPS and EERS, are negatively correlated with carbon intensity in the electricity sector. More aggressive policies are needed to reduce total carbon emissions.

1. Introduction

In response to the urgent need for immediate climate mitigation actions to address the threats posed by global climate change and the lack of policy action from the federal government, state governments act as pioneers in climate and clean-energy policies in the United States (Rabe, 2004, 2008), with multiple interrelated policy goals, including energy diversification, decarbonization, and economic development. Characterized by some as the "golden" age of state energy policies, the past two decades have seen states' proactive competition in state policy innovation across a series of instruments and tools (Busch et al., 2011; Byrne et al., 2007; Carley, 2011).

A very important motivation for these energy policies is to reduce carbon emissions in different sectors of the economy, especially in the electric-power sector. In 2008, electric utilities accounted for 40.6% of total carbon emissions in the United States, the largest among all the economic sectors. Compared with the tremendous difficulties in measuring and reducing carbon emissions in the residential, commercial and transportation sectors, which are diffused downstream sources, the electricity sector presents unique opportunities for the government to apply effective and efficient upstream policies to inventory, monitor, and reduce carbon emissions. Since the late 1990s, the electricity sector became the focus of energy policy as the boundaries between climate and energy policies became increasingly blurred (Ellerman, 2012). State-level "clean" or "green" electricity mandates have filled the policy void resulting from the inaction of the U.S. federal government in climate mitigation.

The coupling of climate and energy policies brings both benefits and costs. On the positive side, it may make climate policies politically acceptable when policy-makers attach multiple goals to instruments and build a broader alliance for advocacy. On the down side, evaluating the effectiveness of these policy tools is likely to be obscured. In current academic and political discussions, much attention has been paid to the energy diversity effects of clean energy and climate policies (Carley, 2009; Kneifel, 2008; Yin and Powers, 2010; Yi and Feiock, 2014), while less attention is paid to the impact of these policy tools on carbon emissions. While a diversified energy supply may lead to increased energy security, energy diversification does not necessarily lead to decarbonization in the electricity sector, and increased reliance on renewable energy supplies does not automatically lead to effective climate mitigation. Similarly, efforts to increase energy efficiency have resulted in significant economic savings, but whether and to what extent efficiency measures have led to reduced carbon emissions remain unexamined.

Therefore, it is of both policy and academic importance to evaluate the effectiveness of state clean-energy policies in reducing carbon emissions in the electricity sector. A number of pertinent research questions arise. Have state clean-energy policies

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effectively reduced carbon emissions? Do particular policy tools, such as renewable portfolio standards (RPS), energy efficiency resource standards (EERS) and public benefit funds (PBF), reduce carbon emissions in different ways? Are supply-side and demand-side energy policy tools equally effective?

This paper addresses these research questions by empirically examining the determinants of carbon emissions in the electricity sector in the U.S. states. By decomposing carbon emissions into electricity consumption and carbon intensity, and by evaluating the impacts of demand-side and supply-side energy policy tools separately, this paper examines their relative impacts on carbon emissions.

In the next section, a brief overview of extant literature on state clean-energy policies is presented. Section three will discuss different measures of carbon reduction in the electricity sector, followed by hypotheses for the impacts of state energy policies on electricity sector carbon emissions. Econometric model and results are presented next. The analysis concludes with a discussion of policy implications.

2. Background: state clean-energy policies and carbon emissions

Several lines of research inform this analysis. The first stream of studies focuses on the adoption of state-level climate and clean-energy policy instruments in the United States. These studies seek answers to why sub-national entities, such as state and local governments, take on the challenge of climate change response, despite relatively little progress made at the federal level. Rabe (2004, 2008) explained state actions to address climate change focusing on three dimensions: politics, economics, and mechanics. Policy entrepreneurs are very important in forming policy alliances to advocate policy changes for clean energy and climate change response. States ostensibly adopt policies that impose least economic costs and build maximum political consensus. For example, RPS, although theoretically not as effective as carbon pricing in climate change mitigation, have been widely adopted due to relatively broad political constituencies.

Much attention has also been paid to the use of specific clean energy and climate policy tools, such as RPS (Matisoff, 2008; Chandler, 2009; Huang et al., 2007; Lyon and Yin, 2010; Yi and Feiock, 2012), net metering (Stoutenborough and Beverlin, 2008), tax incentives (Ciocirlan, 2008), EERS (Nadel, 2006), and climate action plans (Wheeler, 2008). These studies systematically analyzed the political, social, economic and natural determinants of clean-energy policy choices. The influence of technological potential, citizen ideology, policy actions of neighboring states and prior commitment to green policies are found to be important predictors for state adoption of these policy tools.

Although understanding why governments make commitments to climate change response and clean energy is important, a more crucial task is to evaluate whether these policies have achieved their claimed effectiveness. Studies have evaluated the effects of these policy tools on clean-energy development (Carley, 2009; Yin and Powers, 2010; Kneifel, 2008; Yi, 2013, 2014). What was missing in this literature is that these policy tools were adopted not only to stimulate growth of the clean energy industries, but more importantly to reduce carbon emissions. The extant literature has paid little attention to the effect of these tools on carbon emissions.

Several studies have examined carbon emission reductions in the U.S. states. Jiusto (2006) compared different accounting methods for electricity sector carbon emissions in the states for 1999, and found that taking interstate electricity flows into account could significantly affect emission levels. An indicator framework was put forward to assess carbon emissions reduction efforts in the transportation sector, the electricity sector, heating services, and the whole economy (Jiusto, 2008). Several indicators for carbon emissions were assessed, including total carbon emissions, per-capita carbon emissions, and carbon intensity. Based on this indicator framework, Drummond (2010) examined the influence of climate-action plans on per-capita carbon emissions for residential, commercial, transportation, and total nonindustrial sectors from 1990 to 2007. The analysis indicated that climate action plans were associated with a modest reduction in state per-capita carbon emissions. However, missing in this study was the electricity sector, which accounts for a considerable share of carbon emissions and for which substantive decarbonization efforts are being undertaken. Many important carbon-reduction policies are targeted at the electric utilities, for example, incentives to increase the deployment of renewables and enhance energy efficiency in the generation, transmission, and distribution of electricity as well as funding for carbon sequestration and storage research. An empirical examination of the actual effect of these policies on carbon emissions from the electricity sector is needed.

In the energy economics literature, a series of studies were conducted to examine the relationships among carbon intensity, energy intensity, and carbon factor. Various versions of decomposition methods have been used to investigate what accounts for decreasing carbon intensity in OECD countries (Greening et al., 1998; Sun and Malaska, 1998), developing countries (Ang et al., 1998; Han and Chatterjee, 1997), and transition economies (Viguier, 1999). For example, Ang (1999) suggested that carbon intensity was affected by GDP, fuel-carbon emission factor, fuel mix, sectoral energy intensity, and product mix. However, the decomposition method could not fully replace an econometric analysis in evaluating what factors were at work, especially when the purpose was to assess the possible causal effect of policy intervention, because policy design may have unintended or unsatisfactory consequences due to disturbances posed by other socio-economic processes. The results from previous decomposition studies, however, still inform this study by providing relevant explanatory variables to be included in the empirical analysis.

3. Measuring emissions reduction in electric utilities

Several key questions should be answered in evaluating carbon emissions in electrical power generation. The issues involve two aspects: choosing a suitable indicator for assessing the effects of carbon-reduction efforts by electric utilities, and matching appropriate policies with their intended effects in empirical models.

Three useful indicators for evaluating carbon-emissions reduction in the electricity sector are total carbon emissions, per-capita carbon emissions, and carbon intensity. Total carbon emissions is a direct measure and easily understandable. However, this measure assumes that states with different levels of population and gross state product (GSP) are subject to the same energy constraints, a highly unrealistic assumption. Using total carbon emissions as the only indicator disadvantages large states (such as California, Texas, and New York) in the analysis.

Per-capita emissions is a better measure in that it normalizes carbon emissions between small states and large states (Drummond, 2010). Using per-capita emissions could better capture the underlying emissions associated with energy consumption and individual behavior, and is thus suited for examining residential, commercial, transportation, and total nonindustrial emissions. But applying per-capita emissions in the electricity sector fails to take into account the composition of electricity demand and, in particular, the effects of substantial industrial demand.

Jiusto (2008) argued that carbon intensity, defined as carbon emissions per unit of energy consumed, captures the net effect of