Competition and Regulation as a Means of Reducing CO_2 Emissions: Experience from U.S. Fossil Fuel Power Plants

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Overview

During the last decade, the electricity sector in the U.S. has undergone considerable change. On the supply side, the plummeting of gas prices induced by the so-called shale gas revolution has created incentives for power producers to increase gas usage and even to switch investment decisions in new capacity from coal to gas. As natural gas emits less than 50% of the CO_2 per kwh that coal does, emissions might have dropped as a result of fuel competition. Policy-wise, greenhouse gas emissions from the generating fleet have become a nationwide concern: in 2013, U.S. electricity generation accounted for more than 2,000 million tons of carbon dioxide (CO_2) emissions, or about 38% of the total U.S. energy-related emissions. About 70% of the electricity generated in 2013 was produced from fossil fuels (U.S. Energy Information Administration (EIA), 2016b).

In 2015, the Obama administration announced CO_2 reduction strategies to cut CO_2 emissions by 26-28% by 2025 compared to 2005 levels.[1] One important measure for achieving this aim is the so-called Clean Power Plan. As part of this, the U.S. Environmental Protection Agency (EPA) has suggested federal regulations to require existing power plants to reduce power sector emissions by 32% from their 2005 levels by 2030 (U.S. Environmental Protection Agency (EPA), 2015). While the Clean Power Plan is widely expected to be eliminated under the current presidency, a number of state-specific rules that permit fewer carbon emissions from electricity generation are in force for many years. Beginning in the early 2000s, states have introduced different means of regulation, from CO_2 performance standards (e.g. in Washington) to regional cap-and-trade programs (e.g. the Regional Greenhouse Gas Initiative (RGGI)). Both trends, inter-fuel competition and regulation, seem to have significantly decreased electricity-related CO_2 emissions. From their peak in 2007, CO_2 emissions from electricity generation in the U.S. dropped by about 16% between 2007 and 2013 (U.S. Energy Information Administration (EIA), 2016b). However, whether the main reason for CO_2 reduction was competition or regulation remains an empirical question.

In this article, we analyze the success of the U.S. states in reducing CO_2 emissions from fossil fuel power plants. We identify CO_2 emission performance at the state level over time, and drivers that may have contributed to changing CO_2 developments. Faced with these developments, we argue that an overall fuel switching from high emitters like coal-fired power plants to cleaner technologies like natural gas combustion has occurred.

Methods

To examine whether or not state-specific fuel price developments and/or CO_2 regulations drove down emissions, we follow a two-step approach. First, we employ nonparametric data envelopment analysis techniques that allow us to measure the relative CO_2 emission performance across states considering the multiple-input and multiple-output production structure of electricity generation. As inputs, we use fuel consumption and nameplate capacity, and, as outputs, the electricity produced and CO_2 emissions. In doing so, we are able to provide a more comprehensive picture of each state's fossil fuel electricity generation process and its relative CO_2 emission performance, compared to a simple output-oriented CO_2 intensity measure, such as CO_2 emissions per unit of electricity produced. Comprehensive reviews of data envelopment analysis applications in energy and environmental studies can be found in Zhou et al. (2008) and Zhang and Choi (2014). Furthermore, a number of studies have addressed the measurement of the environmental efficiency of U.S. power plants (see, e.g., Färe et al., 2013; Hampf and Rødseth, 2015; Sueyoshi et al., 2010; Sueyoshi and Goto, 2013; Welch and Barnum, 2009).

In a second stage, we regress the performance indicators we have obtained on the state-specific natural gas prices, the states' CO_2 regulatory policies and a number of other state-specific factors in order to identify the main drivers of the development. This approach allows us not only to answer the question of whether fuel price competition and/or

[1] Press statement released by the Office of the Press Secretary, The White House, accessible at www.whitehouse.gov/the-press-office/2015/03/31/fact-sheet-us-reports-its-2025-emissions-target-unfccc.

emissions regulation have proven to be successful in comprehensively reducing greenhouse gases but also to evaluate the impact of regulatory reforms at the state level.

Results

We find that the CO_2 emission performance across all states improved, on average, by 15% from 2000 to 2013. Decomposing the performance index into its elements, efficiency change and technological change, revealed that this development was mainly due to technological progress. However, the observed efficiency decline in 24 of the 48 states shows that half of the states were not fully able to implement the technological improvements introduced in some innovative states. Furthermore, our second-stage results support the argument of increased inter-fuel competition induced by the shale gas revolution and the positive impact of this on electricity-related CO_2 emissions. That is, lower natural gas prices come with a higher state-specific CO_2 emission performance over time. Furthermore, considering state-level regulatory policies, the results suggest a positive impact of regional cap-and-trade programs on the state-specific CO_2 emission performance over time.

Conclusions

Altogether, we conclude that lower gas prices and stringent CO_2 regulations are suitable means to reduce electricity-related CO_2 emissions. However, although the effect of lower natural gas prices is statistically significant, it should be carefully interpreted. Taken literally, a $5 drop in the natural gas price, as observed on the national level between 2008 and 2013, is estimated to increase a state's CO_2 emission performance by about 5 percentage points. Whether or not this effect is small or large in environmental terms cannot be clearly answered within our framework. A more comprehensive evaluation should include all the economic and environmental costs (and benefits): in the case of natural gas, this also incorporates the environmental costs resulting from shale gas exploitation. A similar argument applies to our estimated effect of cap-and-trade regulation. While regional cap-and-trade programs seem to be very effective in reducing CO_2 emissions, policy makers should carefully weigh the costs and benefits of such programs before considering a regional and sectoral expansion.

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