EVALUATING POWER SECTOR EMISSIONS UNDER CHINA'S REGIONAL CARBON ETS PILOTS: A VIEW FROM SPACE

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Motivation

Sustaining economic growth, reducing poverty, and achieving ambitious climate change mitigation goals is arguably the main challenge of this century. This challenge is most severe for the energy sector in a fast-growing developing economy like China, which has been historically heavily reliant on burning coal to meet the ever-increasing energy demand of a rapidly expanding economy and a more affluent population. To achieve environmental goals in the power sector, China has traditionally relied on command-and-control policies. However, a significant shift was made in 2011 to experiment with regional pilot programs of carbon emission trading systems (ETS pilots).

This policy experiment in China has generated broad interest from policymakers and scholars across the world. The interest in understanding the efficacy of the ETS pilots is justified not only by their combined scale as the world's second-largest carbon market after the EU ETS but also by their unusual rate-based design, which relies on Tradable Performance Standards (TPS). TPS systems are less restrictive on output growth and are, thus, more suitable for developing countries. However, they are also less efficient than Cap and Trade (CT) systems because they can amount to implicit output subsidies for a subset of covered entities (Fischer 2001, Goulder et al. 2022). Despite the prominence of China's ETS pilots in policy and academic discussions, questions remain about their actual performance, especially when they operate alongside other command-and-control environmental regulations.

Methodology and Data

Disentangling the effect of the ETS pilots on power sector emissions from those of co-existing environmental regulations is challenging. Adding to this challenge is the problem of limited data availability and concerns over data quality in a developing country context. To overcome this two-fold challenge and to deliver a timely *ex-post* evaluation of China's ETS pilots, this study focuses on examining the changes in emissions of a co-pollutant, sulfur dioxide (SO_2), from large coal-fired power generation facilities induced by their participation in the ETS pilots. Monthly and quarterly facility-level SO_2 emissions are derived using novel NASA satellite data (Li et al., 2020).

This study causally estimates the effect of ETS pilots on coal-fired power generation facilities' emissions, using staggered and dynamic difference-in-differences (DID) frameworks. The identification strategy exploits the variations in temporal and spatial coverage of the ETS pilots compared to the overlapping environmental regulations. Analyses are carried out in three parts. First, I estimate a two-way fixed effect DID model that flexibly controls for unobserved national policies or macroeconomic shocks, unobserved time-invariant characteristics of coal-fired power generation facilities and their localities, and regional seasonality in SO_2 concentrations due to weather patterns and winter heating. Secondly, I adopt an event study or dynamic DID model to indirectly test the validity of the parallel trend assumption and estimate the lagged effects of ETS pilots over time. Lastly, I developed a stylized model adapted from Goulder et al. (2022) to provide an economic explanation of the empirical results.

Results

Contrary to the belief that ETS pilots should also reduce emissions of co-pollutants (Li et al., 2018), the results show that SO_2 emissions of treated facilities have increased by about 5% vis-a-vis untreated facilities since the ETS pilots began. Moreover, the relative increase of SO_2 emissions by the treated facilities climbs to 5.9% and 6.7%, respectively, after conditioning on the stringency of two sets of major overlapping environmental regulations.

Furthermore, the event study model reveals that the relative increase in SO_2 emissions from the treated facilities becomes statistically significant one year after the launch of the ETS pilots and grows over the post-treatment period to about 8%-9% four years after the ETS pilots began.

Lastly, the model adapted from Goulder et al. (2022) shows that the ETS pilots based on TPS could encourage facilities with relatively low initial carbon emission intensities or marginal abatement costs to increase electricity output and thus emit more SO_2 relative to a counterfactual world in which the ETS pilots had not been established. I postulate that capital-intensive investments in carbon emission abatement technologies explain the continued relative increase in SO_2 emissions over time and that overlapping command-and-control regulations could have strengthened the incentives for the treated facilities to invest in abatement technologies, based on Fowlie (2010).

Policy Implications

The observed relative increase in SO_2 emissions from the ETS-treated facilities points to a low-hanging fruit for policymakers in China. Introducing policy measures to offset the TPS system's incentives to increase output and thus SO_2 emissions could bring co-benefits in terms of public health and environmental quality (Kou et al., 2021; Almond and Zhang, 2021; Li et al., 2018; Dong et al., 2015).

Furthermore, the focus of this study on the thermal power generation sector makes its findings informative for the national ETS that covers the same sector. Thermal power generation facilities in the coastal regions in Eastern China are generally more technologically advanced (Pang and Duan, 2016) and are more likely to have relatively low carbon emission intensities or marginal abatement costs compared to facilities in central and western China. Therefore, a national ETS based on TPS could increase electricity output and emissions of co-pollutants such as SO_2 in the more densely populated eastern provinces vis-a-vis other regions. In this context, the empirical findings of this study call for measures to alleviate this potential issue. One possible policy response is designing separate emission intensity standards for different regions or power generation facilities using different combustion and cooling technologies. Another potential policy response could be to assign different weights to credits between facilities located in different regions.

Lastly, due to the lack of publicly available facility-level air pollutant and CO_2 emissions data, this study relies on SO_2 emission estimates derived from a NASA Aura/OMI satellite SO_2 data product. Although OMI satellite data products provide good alternatives to ground-based pollutant emission measures, they also have one major limitation. Accurate and credible estimates of SO_2 emissions can only be obtained for large and relatively isolated thermal power generation facilities, which means that the empirical results of this study may not extend to smaller facilities. Future empirical work can extend the analyses in this study when new and credible facility-level air pollutant emissions data becomes available. Moreover, future work that examines the ETS pilots' or the national ETS's effects on firms' performance, R&D, and adoption of cleaner technologies is also needed to shed light on the mechanisms through which carbon markets impact firm behaviours.

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