Induced Innovation from Environmental Regulation: Evidence from China

Understanding the impact of environmental regulation on productivity is central to the long-standing political debate around the economic effects of environmental policy. Regulations aiming to reduce air pollution have been shown to have large health benefits, but they are also costly and reallocate production away from regulated. This is particularly salient in the developing world, where emerging economies seek growth and prosperity yet face serious pollution problems that threaten human health and productivity. The discourse is often framed around an "industry versus environment" or "jobs versus environment" tradeoff, as economic models indicate that the costs associated with environmental regulation could impede competitiveness and economic growth. Yet more stringent environmental standards also could stimulate investments and induce innovation that enhances efficiency and productivity (i.e., the "Porter hypothesis").

In this paper, we estimate the effect of the most comprehensive environmental regulation in the developing world to date on firm-level total factor productivity (TFP) in China. We study the Two Control Zone (TCZ) policy, which was implemented in 1998 and stipulated specific objectives towards reducing SO_2 emissions in 175 selected prefectures across China. We use firm-level data and employ a heterogeneous difference-in-difference approach to study both "dirty" firms that are directly regulated (i.e., those in high-polluting sectors located in regulated regions) as well as "clean" firms that are also regulated but face lower compliance costs. Estimating the impact on both types of firms allows us to capture the *net* effects of the regulation on all firms located in regulated regions as opposed to strictly the effects on the dirtiest of regulated firms. This is critical for fully understanding the implications of an environmental regulation on firms. Although the regulation explicitly targets high-polluting sectors, firms in low-polluting sectors also may be indirectly affected through substitution or enhanced competitiveness due to lower compliance costs.

Our results indicate that the TCZ regulation increased firm TFP by 8.6% for clean firms and 1.7% for dirty firms. While the effects on dirty regulated firms are dampened significantly relative to clean firms, the effects on dirty firms relative to firms in unregulated regions are still positive. Furthermore, the *net* effects of the regulation are clearly positive. The conclusions would have been starkly different had we focused strictly on estimating the effects on dirty regulated firms with the triple-difference approach, as this would have only provided us with the *negative* 6.8% estimate for dirty firms relative to clean firms in regulated regions, not only missing the positive effect on clean firms but also representing a biased estimate due to using clean firms as a (poor) control group.

We explore the mechanisms underlying these results and conclude that the most plausible explanation is that the regulation induced innovation by way of more efficient use of various inputs, and especially through capital productivity improvements. The "Porter hypothesis" (Porter and Van der Linde, 1995) argues that environmental policy could trigger the adoption of new innovations—including technologies, but also new processes and practices—that, in turn, improve efficiency. We find that capital-labor substitution can

explain some of our results, especially for the small improvements made by dirty firms, but more efficient use of capital, labor, and intermediate inputs are the biggest drivers.

We also find firms respond heterogeneously by firm ownership type, size, and age. We find evidence that large, old, state-owned dirty firms are heavily favored. Their productivity increases by just as much as their clean counterparts, suggesting that significant costs were not imposed upon them. On the other hand, non-state-owned dirty firms, and especially those that are small, are hurt the most. Small, clean firms appear to be the most responsive, achieving a 13.3% increase in TFP.

This paper makes three primary contributions. First, our findings contribute to the literature examining the impact of environmental regulations on firms (e.g., Jaffe et al., 1995; Greenstone, 2002; Walker, 2011; Greenstone, List, and Syverson, 2012; Ryan, 2012; Kahn and Mansur, 2013; Walker, 2013; Hafstead and Williams, 2018). Although there has been a long-standing debate about the economic costs of environmental regulations, most studies to date examine developed countries. Emerging economies are increasingly important in this context given their growing roles in the global economy as well as their increasing contributions to environmental pollution. China is a particularly important empirical setting as the world's largest developing country. Only a few studies so far have examined this question in a developing country context (Liu et al., 2017; Hering and Poncet, 2014; He et al., 2018).

Second, we provide evidence consistent with the strong version of the "Porter hypothesis". We find that environmental regulations actually can have *positive* effects on firm productivity, and our preliminary findings suggest that this can be explained by an induced innovation effect (i.e., more efficient use of inputs). Most of the literature in this area concludes that environmental regulations have negative effects on firms and their competitiveness, with a focus on how regulation affects directly regulated dirty firms relative to clean firms in regulated regions. Our results suggest that when firms are relatively clean but still regulated, there may be more opportunities for input efficiency improvements in order to comply with the costs. On the other hand, the dirtiest of firms that may require large capital investments in order to comply are likely forced to retire.

Lastly, our findings highlight how environmental regulations also may indirectly affect clean firms located in regulated regions, and accounting for this is important. By estimating the effects of the regulation on both clean and dirty firms, we are able to study the *net* effects while also addressing the bias associated with spillovers to clean firms when they are otherwise used as a control group. Doing so leads to starkly different conclusions relative to what we would have concluded if we only captured effects on dirty firms.