Unintended Consequences of Energy Intensity Standards: Evidence from Energy Conservation Programs in China

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Overview

Energy intensity standards (or output-based regulations), as a policy instrument for correcting negative externalities and the underinvestment of energy technology on the production side, enforce regional, industrial or individual targets on energy use or emissions per unit of output to encourage the adoption of cleaner energy technology and investment in energy efficiency and are increasingly common around the world.

This paper argues that the mandatory standard for energy intensity (energy use per output) may influence local administrators to overregulate energy consumption for energy intensive firms, thereby leading to unintended consequences of energy efficiency degradation. Suppose that in a developing region where manufacturing sectors account for most regional outputs, firms with higher outputs presumably account for most energy use, and thus, the energy intensity of these firms affects the overall efficiency of the entire region. After the implementation of intensity targets, local administrators may enforce tighter regulations for firms with higher energy use to meet conservation targets, but doing so may also limit the output of productive firms.

A key research question is whether the intensity targets unintentionally lead to disproportionately tighter regulations in firms with higher energy consumption and production output, thus unintendedly lowering the firms' energy efficiency. Energy efficiency degradation occurs when the economic costs for upgrading energy efficiency are relatively high while the firm operates at increasing returns to scale, which may result in a greater than proportional loss of output, thereby lowering energy use per output.

Methods

This study investigates the impact of energy intensity standard on firms' energy efficiency by utilizing a national energy intensity reduction target during the eleventh Five-Year Plan in China as a quasi-natural experiment. The policy sets the national intensity reduction target, reducing the country's energy use per unit of GDP by 20% from 2006--2011, and further allocates specific targets for each province on the basis of a set of factors of each province, including economic development, sectoral distribution, and historical energy use. This provides both before-and-after and cross-province variations for identification. The empirical analysis proceeds in five steps:

First, our empirical analyses combine two data sources, including the Annual Survey of Industrial Firms (ASIF) and the Environmental Survey and Reporting (ESR), to construct a detailed firm-level panel dataset including firms' address, ownership, sector, main product, outputs, sales, employment, total assets, energy use, and other related detailed information.

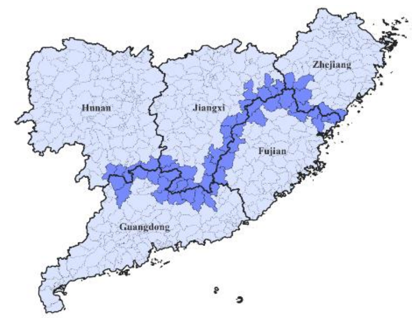
Second, one concern about the difference-in-differences (DiD) strategy is that the provincial targets are assigned on the basis of the provincial historical energy use, and thus the reduction targets may be correlated with the dependent and independent variables at the same time. To mitigate this concern, we use the firms located in the counties along the provincial borders (see Panels A and B in Figure 1) with different targets as our sample to compare the firms' energy consumption and operation response before and after the policy by assuming that, in the absence of the intensity target, firms located at the provincial border should be ex ante identical or similar, and the outcome variables and covariates of these firms, such as energy consumption and intensity, are highly comparable before the implementation of intensity targets. Our summary statistics and balance checks for firm-level characteristics related to our sample, including both time-invariant and pre-2003 covariates, are well balanced next to the provincial borders.

Third, this study employs a difference-in-difference (DiD) strategy to identify the impact by combining two types of variations: the provincial variation in intensity reduction targets (high, medium and low reduction targets) and the time variation before and after the start of the intensity standard. The dependent variable denotes the energy intensity for firm industry i in province p in year t, which is calculated as the firm's total energy consumption divided by output. The key explanatory variable is the interaction between a dummy indicator of regulatory status and a dummy variable of the policy indicator, capturing the effect of the intensity standard on a firm's energy efficiency in the higher standard region relative to the lower standard region.

Fourth, to address another identification concern that some unobservable time-varying provincial characteristics may be correlated with our dependent and independent variables, we conduct a difference-in-differences-in-differences (DDD) strategy by including firm-level energy intensity before the shock in the triple term and adding industry-province-year fixed effects (η_{ipt}) in the model to control for the unobserved regional industry-level specific shocks that coexist with firms' energy consumption and production in those regions.

Fifth, we conduct a series of robustness tests to examine our results, including alternative measurements for key explanatory variables, confounding policies, and flexible estimations. In addition**,** to better understand the possible channels through which the intensity standard works, we examine firms' operating response to the intensity standard in terms of three aspects: scale effects, composition effects, and technique effects.

Panel A.

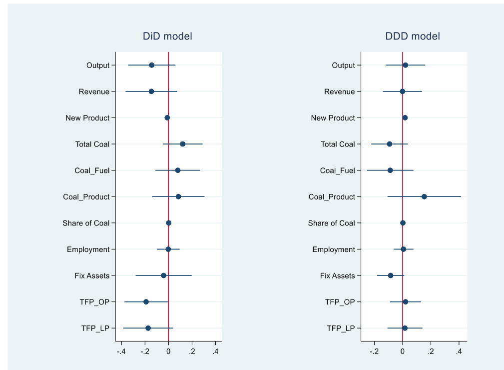


Panel B.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Panel A. Baseline (Dependent Var. = ln(*Energy/Output*))							
$Target_P \times Post_t$	0.289**	0.282**	0.246**	0.246*				
	(0.125)	(0.111)	(0.110)	(0.122)				
$Target_P \times Post_t \times \ln(\text{int}_{f,02-04})$					-0.191***	-0.198***	-0.108*	-0.108*
					(0.051)	(0.047)	(0.055)	(0.055)
$Post_t \times \ln(\text{int}_{f,02-04})$			-0.096**	-0.096**			-0.090***	-0.090***
			(0.036)	(0.036)			(0.027)	(0.016)
N	4869	4869	3236	3236	2579	2579	2579	2579
R^2	0.922	0.924	0.923	0.923	0.947	0.947	0.948	0.948
	Panel B. Intensity Level (Dependent Var. = ln(*Energy/Output*))							
$Stringent_p \times Post_t$	1.225**	1.170**	0.988**	0.988*				
	(0.481)	(0.433)	(0.441)	(0.473)				
$Stringent_p \times Post_t \times \ln(\text{int}_{f,02-04})$					-0.132***	-0.137***	-0.466***	-0.466**
					(0.030)	(0.028)	(0.121)	(0.146)
$Post_t \times \ln(\text{int}_{f,02-04})$			-0.092**	-0.092**			0.375**	0.375**
			(0.037)	(0.037)			(0.142)	(0.154)
N	4869	4869	3236	3236	2579	2579	2579	2579
R^2	0.923	0.924	0.923	0.923	0.947	0.948	0.948	0.948
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Characteristics	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Industry-year FE	Yes	Yes	Yes	Yes	No	No	No	No
Province-industry-year FE	No	No	No	No	Yes	Yes	Yes	Yes
Cluster	City	City	City	Province	City	City	City	Province

Note: Robust standard errors clustered at different levels are reported in parentheses. 3. ***, **, and * denote significant at 1%, 5%, and 10%, respectively.

Panel C.



Panel D.

Figure 1. Preliminary Results

Results

The table in Panel C displays our estimation results, and the figure in Panel D provides a mechanism analysis. Our preliminary results have four key findings. First, the estimated coefficients, $target_p \times post_t$, across all four columns are statistically significant and positive, suggesting that a more stringent target for energy intensity may lead to a lower energy efficiency gain relative to the region with a less stringent conservation target. The estimated coefficients, $target_p \times post_t \times ln(int_{f02-04})$, are negative and statistically significant, implying that energy use intensity in high-energy firms decreases relative to that in low-energy firms and relative to that in other high-energy industries in lower-target regions, whereas all firms experienced a significant decline in energy use per output after the intensity standard was implemented. Third, our estimation results are robust across different model specifications and choices of cluster standard errors; our conclusions are also consistent when we use alternative identification strategies, such as PSM-DiD, and isolate the confounding policies of SO2 emission controls, the "Top 1000" energy saving program, and the financial crisis. Fourth, our mechanism analysis investigates three potential channels that may explain our main results: scale effects, composite effects, and technology effects. Our results reveal that energy intensity targets have negative and statistically significant effects on firms' production and productivity, whereas firms' energy use is relatively greater in regions with stringent intensity targets after controlling for the average trend of energy use in our sample.

Conclusions

Overall, this paper concludes that firms with high energy use before the implementation of intensity standards have experienced a significant decline in energy use per output in higher target regions after the target is enforced compared with firms with high energy use located in lower target regions, suggesting that stringent reduction targets for energy use can effectively improve energy use efficiency for energy-intensive firms. However, we also find that, on average, a firm's energy intensity in higher reduction target regions has experienced an increase in energy use per output relative to that in regions with lower reduction targets, and this increase is due mainly to output loss caused by the stringent regulation for energy use. This paper contributes to the literature in two ways. First, we build on the literature on intensity standard policies by showing the unintended consequences of energy efficiency degradation led by the overregulation of energy use when the intensity reduction target is relatively high. Second, a growing body of literature focuses on the energy efficiency gap and has analyzed insufficient investment or technology adoption for energy efficiency. This paper contributes to the efficiency gap on the production side by documenting the unintended consequences of intensity targets for lowering energy efficiency and production because of the overregulation of energy use led by stringent targets. Our findings also challenge a popular policy strategy, output-based regulations, that is used to improve the economic efficiency of energy use, and the efficiency loss can be amplified in a developing region where energy-intensive sectors account for most of the outputs and production is increasing in return to scale.