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Poison or catalyst? How do energy saving targets matter for firm-level productivity in China

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China's Top-10000 Enterprises Energy Conservation and Low Carbon Program, enacted in 2011, sets binding energy saving targets for enterprises. However, whether energy saving target setting is a poison or a catalyst remains controversial, and no research has been conducted on how the targets affect enterprises' total factor productivity. We construct 2012–2013 panel data models by mapping the enterprises subject to the energy saving targets onto the China Industrial Enterprise Database to systematically quantify the effects of the targets on enterprises' total factor productivity. The study reveals an inverted-U-shaped curve between energy saving targets and manufacturers' total factor productivity. We also find that the targets boost an enterprise's total factor productivity by expanding the enterprise's market share and their impacts vary according to region, type of enterprise, and industry. The study shows that setting appropriate energy saving targets can improve the environment and boost enterprise productivity.

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Introduction

The greenhouse effect, climatic warming, is a significant global concern, which is caused by massive emissions of greenhouse gas, particularly CO_2 emissions. The majority of greenhouse gas is generated by fossil fuel combustion and the long-term, high-carbon business growth mode (Fyke and Matthews 2015). China, whose economy largely relies on development of energy-intensive industries, is faced with enormous pressure to handle the greenhouse effect. A 2019 report released by the International Energy Agency (IEA) reported that the world's energy-related CO_2 emissions reached roughly 33 Gt in 2018 and emissions from China stood at 10 Gt, accounting for 30.3% (Shan et al. 2020). To accomplish its incredibly heavy mission to reduce CO_2 emissions, China has set binding energy or carbon control targets for enterprises through administrative controls or institutional pressures (Fischer and Springborn 2011; Wang et al. 2016; Zhang et al. 2018; Zhang et al. 2019).

Enterprises are the primary carbon emitters nearly in every industrialized country. Small and medium-sized enterprises in the U.S. and E.U. have contributed 60% of CO_2 emissions (Martin–Tapia et al. 2008). Cutting corporate carbon emissions has become an important task. To save energy and reduce pollutant emissions, China launched the Top-1000 program to allocate energy saving targets for about 1000 top energy-consuming enterprises during the 11th Five-year Plan (FYP) period (Wu et al. 2015; Ai et al. 2021; Xiao et al. 2023). During the 12th FYP period, China also expanded the Top-1000 program to launch its Top-10000 Enterprises Energy Conservation and Low Carbon Program (hereinafter the Top-10000 program) and set energy saving targets for over 10,000 enterprises across the country (Filippini et al. 2020; Shi et al. 2023). As the Implementation Plan for China's Top-10000 program stated, nearly 17,000 enterprises contributed to more than 60% of China's 2010 energy consumption. Thus, setting energy targets for these enterprises is key to reduce carbon emissions.

Undoubtedly, mandatory energy saving targets set for listed enterprises may influence their production strategies, performance, and competitiveness. Total factor productivity (TFP) reflects productivity of all inputs and economic growth quality (Wang et al. 2013). TFP is understood as residuals of output growth after deducting factor contributions, or as the contribution to output growth due to unproductive inputs such as technological progress and institutional change (Lu and Lian 2012; Baier et al. 2006). Many factors affecting corporate TFP have been investigated, including financial development (Alfaro et al. 2009; Arizala et al. 2009), market size (Felbermayr and Jung 2018), capital accumulation (Salinas–Jimenez et al. 2006), environmental regulation (Xie et al. 2017), free trade zone (Jiang et al. 2021), and government subsidies (Bernini et al. 2017). While the literature has advanced our understanding of corporate TFP, the studies on the factors affecting overall TFP have tended to ignore the impacts of target setting. After the Chinese government set energy saving targets, this paper seeks to answer the several questions below: (1) Do the energy saving targets affect corporate TFP? (2) How do the targets affect corporate TFP overall? (3) How heterogeneous are the effects of the targets on corporate TFP?

To answer these questions, we map the enterprises that have been subjected to the Top-10000 program onto the China Industrial Enterprise Database (CIED) to construct a panel dataset and systematically quantify the effects of the targets on corporate TFP. To the best of our knowledge, only two articles published in English journals identified impacts of the enterprise-level energy saving targets on enterprises' TFP (Filippini et al. 2020; Ai et al. 2021). Compared with these studies, the contributions of this article are three-fold. First, Ai et al. (2021) only focused on 127 targeted chemical enterprises in the Top-1000 program, while Filippini et al. (2020) focused on 148 treated enterprises in the Top-1000 program. Our research covers more than 10000 enterprises in the Top-10000 program, having a significantly larger sample coverage. Second, these two studies both used a dummy variable to measure whether one enterprise participated in the Top-1000 program or not and identified the productivity impact of participation in the Top-1000 program (Filippini et al. 2020; Ai et al. 2021). However, our study constructs an indicator to measure the strength of energy saving targets, making us explore how different levels of energy saving targets influence TFP. Third, these two studies reached conflicting conclusions about the impact of the Top-1000 program on enterprises' TFP, either positive (Filippini et al. 2020) or negative (Ai et al. 2021). However, our study reveals that a non-linear curve better represents the impacts of energy saving targets on TFP, along with the mediating role of market share and the heterogeneous impacts of energy saving targets across regions, types of enterprises, and industries.

The remainder of the paper has the following structure. Part 2 systematically reviews current research on environmental target-setting, while Part 3 proposes our research hypotheses based on theoretical discussions. Part 4 discusses the research data, model settings, and variable description. Part 5 provides the baseline results, mediating mechanism analysis results, robustness tests, and heterogeneity analysis results. Part 6 offers a discussion of our findings, implications, and a conclusion.

Literature review

China has established a target-based management system to handle environmental issues. On the one hand, China has set national targets for pollutant emission reduction and energy intensity control, and decomposed them down to local governments since the 11th FYP period (Zhang 2019; Zhang and Wu 2020). Under this circumstance, local governments in China have clear responsibilities to accomplish these targets (Liang and Langbein 2015; Zhang 2021). The energy intensity targets at the local government level, focusing on energy efficiency improvement, are generally mandatory reduction rates for energy intensity. On the other hand, China has also allocated energy-related targets for enterprises. Specifically, China launched the Top-1000 program to allocate energy saving targets for about 1000 top energy-consuming enterprises during the 11th FYP period (Wu et al. 2015; Ai et al. 2021; Xiao et al. 2023), which is expanded to the Top-10000 program during the 12th FYP period (Filippini et al. 2020; Shi et al. 2023). Energy saving targets for enterprises generally regulate the amount of energy that each enterprise needed to save.

Current studies have pay attention to both types of targets for local governments and enterprises recently. The first cluster focuses on environmental targets set for local governments. Yang et al. (2020) concluded that local governments competed with each other to set high environmental goals and Hao et al. (2015) argued that decreasing CO_2 emission intensity required setting strict emission reduction targets for provinces with high emissions and less strict targets for those with low emissions. Wang et al. (2016) found that introducing energy intensity targets could reduce the carbon emissions of industries and Sun (2018) found that setting province-level emission reduction targets help improve the environment. In addition, some scholars also studied how the environmental targets could affect wind energy development (Zhang 2019), $PM_{2.5}$ concentration control (Zhang and Wu 2018), pollutant emission control (Liang and Langbein 2015; Tang et al. 2016; Zhang and Wang 2022), and economic growth goals (Zhang 2021).

The second cluster focuses on environmental targets set for enterprises. Some studies analyzed the target allocation, implementation, and weakness of the Top-1000 program or the Top-10000 program (Zhao et al. 2016; Ma and Liang 2018; Karplus et al. 2020). For example, Zhao et al. (2016) identified four weaknesses of enterprise-level energy saving targets in the Top-10000 program, such as limited feasibility for comparison, uncertain outcomes, difficulty in enforcement, and poorly related to national energy intensity targets. Ma and Liang (2018) confirmed that state-owned enterprises and centrally affiliated enterprises tended to be allocated higher targets than non-state-owned and locally affiliated counterparts in the Top-1000 program. Karplus et al. (2020) found evidence that enterprises deliberately overstated their performance in the Top-1000 program. Zhao et al. (2014) found that local governments can help enterprises achieve energy saving targets through skill building, funding, and price adjustment.

In addition, some other papers also evaluated influences of enterprise-level energy saving targets on enterprises' performance. For example, Xiao et al. (2023) confirmed that the Top-1000 program decreased targeted enterprises' profitability and increased their production cost. Shi et al. (2023) empirically confirmed that the Top-10000 program helped participant enterprises save energy through increasing energy efficiency and changing production scale, while some scholars also evaluated impacts of the Top-10000 program on participant enterprises' exports (Liu and Kang 2022) and employment changes (Liu and Kang 2023). In view of impacts of energy saving targets on enterprises' TFP, only two articles published in English journals are found. Specifically, Ai et al. (2021) used the difference-in-differences (DID) approach and data of chemical enterprises to confirm the negative influence of the Top-1000 program on participants' TFP change, while Filippini et al. (2020) also used the DID method to conclude that participation in the Top-1000 program increased participating iron and steel enterprises' TFP change.

Overall, current studies have deepened our understanding of China's target responsibility system, but there are some important gaps. First, current studies explore multiple effects of the region-level energy intensity targets more thoroughly than those of the enterprise-level energy saving targets. Second, current studies pay more attention to the Top-1000 program than the Top-10000 program. However, the Top-10000 program seems more important because it includes an order of magnitude more participant enterprises than the Top-1000 program. Third, though current studies have examined the impacts of both region-level energy intensity targets and enterprise-level energy saving targets, we still know little about the channels through which these targets works and whether these targets have heterogeneous or homogeneous effects on different types of participants.

Theoretical analysis and hypotheses

Target setting and corporate TFP. Many countries, including Sweden, Japan, and India, carry out environmental policies through environmental objectives. This objective system involves principles, goals, and strategies. However, environmental objectives tend to differ in clarity and operability (Edvardsson 2004), resulting in varying environmental outcomes. Targets affect actions indirectly through the development and application of task-relevant knowledge (Locke and Latham 2002; Wood and Locke 1990), which can affect individual input and performance levels (Rietbergen and Blok 2010). When enterprises are affected by government-set targets, they may exhibit opportunistic behaviors and improve their environmental behaviors by increasing legal costs or reducing illegal costs (He et al. 2019; Jin et al. 2015). Some enterprises may ignore the binding energy saving targets. Due to the competitive promotion system in China, local governments also must fulfill the energy efficiency targets imposed by the central government, who has also developed assessment indicators to further motivate local governments to promote carbon reduction policies (Sun 2018; Zhang et al. 2019; Zhang 2021). Local governments thus must strictly supervise how enterprises in their jurisdictions meet the energy saving targets.

Actually, a green corporate image is also crucial for an enterprise to survive in today's global market competition. Many consumers and investors have become more concerned about an enterprise's green image and long-term sustainability than its profitability (Wang et al. 2014). If an enterprise can attain energy saving targets, its market competitiveness can be enhanced (Esty and Geradin 1998). In view that these targets are top-down allocated by governments with mandates, listed enterprises thus have incentive to strive to accomplish them. However, the strategies that enterprises use in response to the environmental targets may depend on the costs of compliance, which also affect the extent of target realization (Vrolijk 1999). When the costs for attaining the targets are highly correlated with available resources or return on investment, enterprises are expected to make more cautious behavioral choices toward achieving the targets. Behind this relationship lies a cost-benefit comparison of production benefits and compliance costs. Then, different target intensities have different impacts on actors' decision-making and energy saving targets can possibly affect TFP in the following two ways.

First, when an enterprise's costs of achieving the target are less than the production benefits, the enterprise should be motivated to improve production technology, process or develop and commercialize new products, enabling them to get the first-mover advantage in obtaining market resources (Porter et al. 1995). Second, energy saving costs and capital input to cut down energy consumption increase with the target intensity. When an enterprise faces high compliance costs, mandatory energy saving targets may result in a crowding out effect, meaning that high compliance costs will crowd out enterprises' inputs on human resources, R&D, and technology (Zhang et al. 2014). In addition, if the targets are too difficult to achieve, enterprises may be less motivated to accomplish these targets and make little investment in energy saving (Edvardsson 2004). The two paths discussed above imply a potential inverted-U-shaped relationship between mandatory energy saving targets and enterprises' performance. Actually, some studies have identified an inverted-U-shaped association between environmental regulation and industrial TFP (Zhao et al. 2018). Thus,

Hypothesis 1: Energy saving targets and corporate productivity have an inverted-U-shaped association.

Target setting, market share, and TFP. Han et al. (2017) suggested that pollution controls promoted capital flow to highly productive enterprises and expanded their market share as an output. Aghion et al. (2015) also argued that appropriate interventions on enterprises can help them optimize their resource allocation, partly correct misallocation, and enhance their competitiveness in the industry, thus securing them a larger market share. Energy saving targets, as a typical kind of environmental regulation, are expected to guide enterprises to allocate resources rationally and encourage technological advancement, which can sharpen their competitive edge and help them gain market share. Many studies have confirmed that market share is one source of profitability, because large market share fostered scale economies and market power (Gale 1972; Buzzell et al. 1975; Rhoades 1985). In view that high profitability is positively related to productivity, expansion of market share is expected to increase corporate

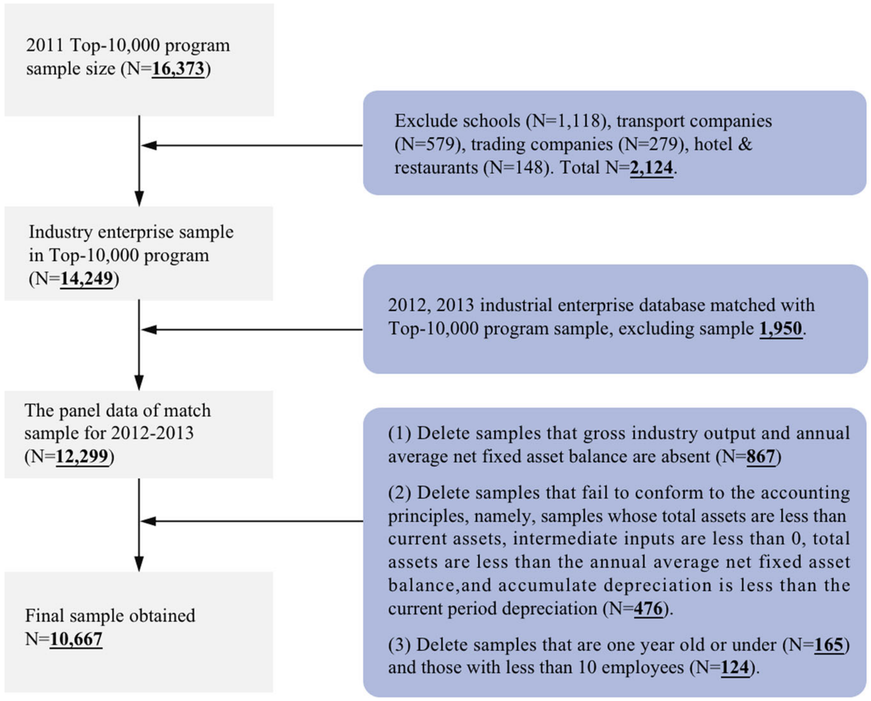

Fig. 1 Process of database matching.

productivity. Actually, Suyanto and Sugiarti (2019) demonstrated the importance of market share in increasing firm productivity in the chemical sector, in addition to R&D and competition. Thus,

Hypothesis 2: The energy saving targets can enhance an enterprise's TFP by expanding its market share.

Data, models, and variables

Data sources and processing. This paper uses two sets of data. The first data set involves enterprise-level energy saving targets in the Top-10000 program issued by the National Development and Reform Commission (NDRC). The Top-10000 program lists energy-intensive or key energy consuming organizations. In 2011, the Top-10000 program covered 16373 organizations, which included 14,249 industrial enterprises, 1118 schools, 579 transportation companies, 279 trading companies, and 148 hotels and restaurants, each of which was subject to a specific energy saving target. This paper focuses on effects of these targets on TFP of the industrial enterprises. The remaining 2124 organizations which are not industrial enterprises were excluded from the study.

The second data set was collected from the CIED. Specifically, we mapped the enterprises in the Top-10000 program onto CIED. As the Top-10000 program was enacted in 2011, the first year of the 12$^{\text{th}}$ FYP period, this work examines impacts of the energy saving targets for 2012–2013 on corporate TFP. The database includes 311,557 samples for 2012 and 345,101 for 2013, which we matched with the 14,249 industrial enterprises in the Top-10000 program. We obtained the panel data of 12,299 matched samples.

In light of the possibility of missing or abnormal data in the CIED, we used the screening procedure proposed by Cai and Liu (2009) to further process the matched data as follows. (1) We deleted samples whose gross industrial output or annual average net fixed asset balance information were absent ($N = 867$). (2) We deleted samples that failed to conform to accounting principles ($N = 476$). (3) We deleted samples that were one year old or younger ($N = 165$) and those with less than 10 employees ($N = 124$). Finally, a total of 10,667 samples, about 74.9% of the total industrial enterprises in the Top-10000 program, were collected for the study (see Fig. 1).

Model settings and interpretation. This article investigates impacts of energy saving targets on corporate TFP and the channels through which targets can affect TFP. We constructed the panel data models in the following two steps.

Step 1. The models are set as follows for the study on the effects of the targets on TFP:

$$TFP_{i,t} = \alpha_0 + \beta_1 target_{i,t} + \lambda X_{i,t} + \sum year + \sum province + \sum industry + \varepsilon_{i,t} \tag{1}$$

$$TFP_{i,t} = \alpha_0 + \beta_1 target_{i,t} + \beta_2 target_{i,t}^2 + \lambda X_{i,t} + \sum year + \sum province + \sum industry + \varepsilon_{i,t} \tag{2}$$

$$X_{i,t} = roa_{i,t} + lev_{i,t} + fixed_{i,t} + size_{i,t} + soe_{i,t} + export_{i,t} + age_{i,t} \tag{3}$$

In Eqs. (1)–(3), $\boldsymbol{TFP_{i,t}}$ represents corporate TFP, and subscripts $\boldsymbol{i}$ and $\boldsymbol{t}$ denote the enterprise and year. For calculating TFP, please refer to the section of "Variable Measures and Description." $\boldsymbol{Target_{i,t}}$ is the target; $\boldsymbol{roa_{i,t}}$, $\boldsymbol{lev_{i,t}}$, $\boldsymbol{fixed_{i,t}}$, $\boldsymbol{size_{i,t}}$, $\boldsymbol{soe_{i,t}}$, $\boldsymbol{export_{i,t}}$, and $\boldsymbol{age_{i,t}}$ are the control variables used. To examine the non-linear relationship between energy saving targets and corporate TFP, it introduces $\boldsymbol{target^2{}_{i,t}}$. In Eq. (1), $\boldsymbol{\beta_1}$ is the parameter of $\boldsymbol{target_{i,t}}$, denoting the average effect of energy saving targets on TFP of the entire sample. If $\boldsymbol{\beta_1}$ is significantly positive, it indicates a positive impact of the targets on TFP; otherwise, the targets are not conducive to TFP growth. In Eq. (2), if $\boldsymbol{\beta_1}$ is significantly positive and $\boldsymbol{\beta_2}$ is significantly negative, it proves the inverted-U-shaped relationship. $\boldsymbol{\varepsilon_{i,t}}$ denotes a random error. This article further controls dummy variables of year, province, and industry to eliminate the interference caused by non-observable factors due to time, region, and industry differences.

Step 2. We refer to the principle of a mediation model in Baron and Kenny (1986) to study how the targets affect corporate TFP and set the models as follows: as stated in the theoretical analysis, the energy saving targets may affect an enterprise's TFP through market share expansion. To further test the mediating effect of the market share variable, we first verify whether the targets can significantly increase an enterprise's market share; second, we examine whether the market share affects TFP; last, we incorporate the targets and market share variable into the regression models together to investigate the effects of targets again.

$$marketshare_{i,t} = \alpha_0 + \theta_1 target_{i,t} + \theta_2 target^2_{i,t} + \lambda X_{i,t} + \sum year + \sum province + \sum industry + \varepsilon_{i,t} \quad (4)$$

$$TFP_{i,t} = \alpha_0 + \gamma marketshare_{i,t} + \lambda X_{i,t} + \sum year + \sum province + \sum industry + \varepsilon_{i,t} \quad (5)$$

$$TFP_{i,t} = \alpha_0 + \beta_1 target_{i,t} + \beta_2 target^2_{i,t} + \gamma marketshare_{i,t} + \lambda X_{i,t} + \sum year + \sum province + \sum industry + \varepsilon_{i,t} \quad (6)$$

As shown in Eqs. (4)–(6), $\boldsymbol{X_{i,t}}$ is still a vector composed of control variables, $\boldsymbol{marketshare_{i,t}}$ is the mediator variable of market share, and the other symbols have the same meaning as in Eq. (1).

Variable measures and description. The dependent variable is TFP. The semi-parametric methods proposed by Olley and Pakes (1996) and Levinsohn and Petrin (2003) have been widely applied to measure an enterprise's TFP. The Olley-Pakes (OP) method can consistently estimate the enterprise-level production function, but one assumption of the OP method is that investment show a monotonical relation to total output, meaning that samples with zero investment are discarded from the OP estimation (Olley and Pakes 1996). Levinsohn and Petrin (2003) developed the LP method to address this concern by using intermediate inputs instead of investment, ensuring that each sample is not omitted. Some scholars who have used LP method, GMM, fixed-effects, and OP method have found that these methods produce almost identical TFP estimates (Van Beveren 2012). With only two-year panel data, this paper uses LP instead of GMM to estimate TFP, whereas it uses fixed-effects and OP estimates for robustness tests.

Before the TFP estimation, we need set the production function form. Given its wide use, we also apply the Cobb–Douglas production function (Huang 2014), which contains labor, capital, and intermediate input (see Eq. (7)):

$$Q_{i,t} = A_{i,t} L^{\alpha}_{i,t} K^{\beta}_{i,t} M^{\lambda}_{i,t} \quad (7)$$

Then, taking the logarithm of Eq. (7) yields a linear equation:

$$\mathrm{lnQ_{i,t}} = \alpha \mathrm{lnL_{i,t}} + \beta \mathrm{lnK_{i,t}} + \lambda \mathrm{lnM_{i,t}} + \mathrm{lnA_{i,t}} \Rightarrow TFP_{i,t} = \mathrm{lnA_{i,t}} = \mathrm{lnQ_{i,t}} - \alpha \mathrm{lnL_{i,t}} - \beta \mathrm{lnK_{i,t}} - \lambda \mathrm{lnM_{i,t}} \quad (8)$$

In Eqs. (7) and (8), $\boldsymbol{Q_{i,t}}$ is the output of Enterprise $\boldsymbol{i}$ for Year $\boldsymbol{t}$. Based on the methods of Li and Zhu (2005) and Guo and Jia (2005), the total output of an enterprise is used as the proxy variable of $\boldsymbol{Q_{i,t}}$. $\boldsymbol{L_{i,t}}$ denotes the enterprise's labor input and is indicated by its total employees. $\boldsymbol{K_{i,t}}$ is the capital stock of Enterprise $\boldsymbol{i}$ for Year $\boldsymbol{t}$ and indicated by net fixed assets. The intermediate input ($\boldsymbol{M_{i,t}}$) in this paper does not include the current period depreciation or payroll payable (Cai and Liu 2009; Yuan 2009). It is calculated as "intermediate input = cost of goods sold (COGS) + selling expenses + administrative expenses + financial expenses – current period depreciation – payroll payable", where the COGS consists of direct materials and manufacturing overhead. The logarithm of $\boldsymbol{A_{i,t}}$ is the so-called total factor productivity (***TFP***). Figure 2 visualizes the Kernel density distribution of TFP measured by OP and LP. The TFP results obtained by the two methods are almost identical and normally distributed.

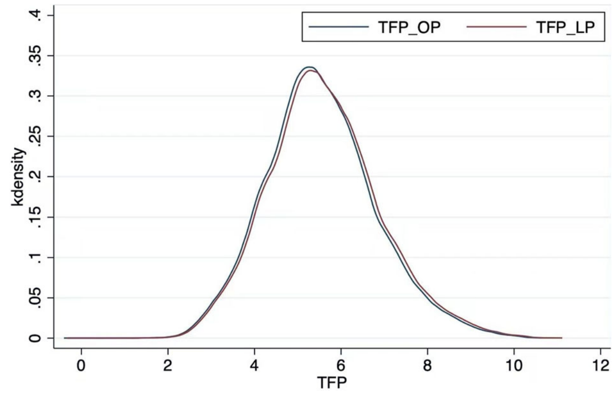

Fig. 2 Kernel density distribution of the TFP measured by OP and LP.

The independent variable is the target setting. In this paper, the proxy variable is the energy saving targets (unit: 10 ktce) that the central government sets for enterprises. The Top-10000 program issued by the NDRC on December 7, 2011 (Fa Gai Huan Zi [2011] No. 2873) lists more than 16,000 organizations and sets specific energy conservation targets (unit: tce) for each of them. The energy conservation target for every firm announced in 2011 keeps constant during the 12th FYP period. This unchanged core explanatory variable seems unreasonable given the study period of 2012 to 2013 and it may capture an inherent trend in TFP changes that does not adequately explain the causal effect of the energy saving targets. In addition, the use of absolute rather than relative values of the targets may confound the results. Therefore, we divide each target by its firm size (the natural logarithm of enterprise' total assets) to measure our independent variable (***target***).

The mediator variable is market share (***marketshare***). Referring to Han et al. (2017), we take an industry in one certain region in one certain year as a market and measures an enterprise's market share by the percentage of its added value in the industry's total added value.

This study has several control variables, as follows. (1) An enterprise's profitability (***roa***) is the ratio of net profit to fixed assets. The higher the profitability is, the more money an enterprise will invest in business expansion, new technology and equipment introduction, and research and development, thus contributing to TFP improvement. (2) Financial leverage (***lev***) is calculated as debt divided by assets. The higher the ratio is, the higher the financial risk the enterprise will face, and the less concerned it will be about productivity. Therefore, financial leverage is expected to impact productivity negatively. (3) We divide fixed assets by total assets and then use its natural logarithm to measure fixed assets (***fixed***) and (4) We calculate enterprise size (***size***) using the natural logarithm of enterprise' total assets. Through learning-by-doing (Van Biesebroeck 2005), enterprises constantly gain experience from production. The larger an enterprise is, the larger the economies of scale it can achieve, and the lower costs of procurement, production, advertising, and marketing it can realize, thus improving TFP. (5) Types of enterprises (***SOE***): Referring to the classification of enterprise in the China Industrial Statistical Yearbook, this paper distinguishes between state-owned enterprises (***SOEs***), which are assigned the value of 1, and non-state-owned enterprises

Table 1 Descriptive statistics of variables.

Variables	Full sample ($N = 21,334$)				2012 year sample ($N = 10,667$)				2013 year sample ($N = 10,667$)			
	Mean	S.D.	Min	Max	Mean	S.D.	Min	Max	Mean	S.D.	Min	Max
TFP	5.614	1.291	−0.324	11.11	5.612	1.276	−0.324	10.96	5.616	1.305	1.192	11.11
target	2.327	5.791	0.010	178.9	2.334	5.804	0.010	178.9	2.320	5.777	0.010	178.3
target^2	38.94	527.9	8.80e−05	32011	39.13	529.4	8.80e−05	32011	38.76	526.5	8.92e−05	31808
roa	0.338	1.015	−1.389	9.296	0.351	1.053	−1.389	9.296	0.325	0.976	−1.389	9.296
lev	0.608	0.299	0.013	1.787	0.607	0.291	0.013	1.787	0.609	0.306	0.013	1.787
fixed	0.427	0.229	0.020	0.952	0.429	0.227	0.020	0.952	0.425	0.231	0.020	0.952
size	6.315	1.639	2.529	11.03	6.289	1.637	2.529	11.03	6.342	1.641	2.529	11.03
SOE	0.070	0.256	0	1	0.070	0.256	0	1	0.0704	0.256	0	1
export	0.234	0.423	0	1	0.235	0.424	0	1	0.233	0.423	0	1
age	14.19	11.77	2	74	13.69	11.77	2	74	14.69	11.74	3	74
marketshare	0.927	2.575	0.010	24.75	0.910	2.538	0.010	24.75	0.943	2.612	0.010	24.75

Table 2 Correlation test of variables.

Variables	VIF	TFP	Target	Target^2	Roa	Lev	Fixed	Size	SOE	Export	Age
target	3.42	0.299***	1								
target^2	2.83	0.149***	0.783***	1							
toa	1.16	0.197***	−0.054***	−0.018***	1						
lev	1.15	−0.106***	0.047***	0.007	−0.191***	1					
fixed	1.29	−0.128***	0.129***	0.024***	−0.225***	−0.066***	1				
size	1.77	0.760***	0.332***	0.150***	−0.064***	0.007	−0.029***	1			
SOE	1.20	0.054***	0.087***	0.038***	−0.061***	0.070***	0.076***	0.184***	1		
export	1.37	0.275***	−0.002	0.041***	−0.023***	−0.085***	−0.184***	0.293***	−0.032***	1	
age	1.17	0.142***	0.118***	0.079***	−0.050***	−0.003	−0.090***	0.223***	0.275***	0.153***	1
marketshare	1.64	0.618***	0.449***	0.310***	0.039***	−0.012*	−0.023***	0.535***	0.101***	0.175***	0.154***

TFP Total Factor Productivity, *target* Target/The Natural Logarithm of Enterprise' Total Assets, *target^2* Square of Target, *roa* Return on Assets, *lev* Enterprise Financial Leverage, *fixed* Fixed Assets, *size* Enterprise Scale, *SOE* Enterprise Ownership, *export* Whether The Enterprise Is An Exporter, *age* Enterprise Age, *marketshare* Enterprise Market Share.
*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

(***NonSOEs***) which are assigned the value of 0. (6) Export dummy variable (***export***): Export is considered a major driver of demand, and the export delivery value in the database is used to identify the export enterprises. If an enterprise's export delivery value is greater than 0, then it is an export enterprise, and its ***export*** is assigned the value 1; if its export delivery value is 0 or empty, then it is a non-export enterprise, and its ***export*** is assigned the value 0. (7) We calculate enterprise age (***age***) as "current year – year of business commencement + 1," as the CIED only provides the year of business commencement.

Descriptive statistics of variables are in Table 1. Standard deviations of ***target*** and ***TFP*** differ greatly, meaning that the cross-sectional variation of the two variables is elastic. Table 2 presents correlations between variables. TFP is positively correlated with the targets, as the correlation coefficient is 0.299. To further exclude the effects of multicollinearity, this article calculates the variance inflation factor (VIF) for every variable. The maximum VIF is 3.42, which is well below the minimum value (10) required under the rule of thumb, indicating there is no severe multicollinearity.

Empirical results and analysis

Benchmarking the effects of the targets on TFP. Table 3 lists the basic results of impacts of the Top-10000 program targets on corporate TFP. Model 1 shows results of the linear relationship between the targets and TFP, which incorporates all fixed effects. Overall, the targets significantly improve corporate TFP. The coefficient of ***target*** is 0.0677 ($p < 0.01$). If the target intensity increases one unit, then the corporate TFP increases by 0.0677. Its economic implication is that the output growth which is not explained by the growth of factors inputs can increase by 0.0677 for one unit increase of target intensity.

Do the targets simply have a positive impact on TFP? Or will they start to negatively impact TFP when they exceed a threshold? According to the theoretical models, we assume an inverted-U-shaped relation between the targets and TFP. Models 2, 3, 4, and 5 in Table 3 list the non-linear estimation results, which present the regression results without all fixed effects and without the dummy variables of year, industry, and province, respectively. The linear regression coefficients of ***target*** are 0.00855 ($p < 0.01$), 0.01464 ($p < 0.01$), 0.00595 ($p < 0.01$), and 0.01642 ($p < 0.01$). When the quadratic term of the variable target (***target^2***) is included in the models, its regression coefficients are significantly negative, indicating non-linear inverted-U-shaped impacts of the targets on TFP.

In Table 3, Model 6 presents the results with all variables included. The coefficient of ***target*** is 0.01429 ($p < 0.01$), and the coefficient of ***target^2*** is -0.00019 ($p < 0.01$). Therefore, higher targets do not always help; they may hinder an enterprise's development. Along with the increase of energy saving target intensity, an enterprise's TFP first grows and then drops. In other words, the output growth which is not explained by the growth of factors inputs first increases and then decreases. Specifically, it starts to drop after the target intensity reaches the turning point (37.2). According to the descriptive statistics, the average target for industrial enterprises in the Top-10000 program is 2.327, which suggests that the targets set for most enterprises do not reach the turning point. For most enterprises, appropriate increases in energy saving targets can help improve their TFP in the short run. However, the maximum value of target is 178.9

Table 3 Basic regression results.

Variables	TFP_LP					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
target	0.0677*** (0.0020)	0.00855*** (0.0021)	0.01464*** (0.0020)	0.00595*** (0.0020)	0.01642*** (0.0020)	0.01429*** (0.0020)
$target^2$		−0.00015*** (0.0000)	−0.00019*** (0.0000)	−0.00013*** (0.0000)	−0.00021*** (0.0000)	−0.00019*** (0.0000)
roa		0.1279*** (0.0037)	0.1291*** (0.0036)	0.1234*** (0.0037)	0.1329*** (0.0037)	0.1287*** (0.0036)
lev		−0.2262*** (0.0169)	−0.1573*** (0.0167)	−0.1932*** (0.0170)	−0.1859*** (0.0166)	−0.1564*** (0.0167)
fixed		−0.2473*** (0.0205)	−0.1539*** (0.0204)	−0.2607*** (0.0204)	−0.1401*** (0.0205)	−0.1553*** (0.0204)
size		0.4299*** (0.0048)	0.4444*** (0.0047)	0.4349*** (0.0048)	0.4458*** (0.0046)	0.4456*** (0.0047)
SOE		−0.3068*** (0.0279)	−0.1012*** (0.0272)	−0.2693*** (0.0276)	−0.1385*** (0.0275)	−0.1086*** (0.0272)
export		0.1033*** (0.0129)	0.0318** (0.0130)	0.0853*** (0.0130)	0.0471*** (0.0128)	0.0293** (0.0130)
age		−0.0026*** (0.0006)	−0.0034*** (0.0006)	−0.0024*** (0.0006)	−0.0025*** (0.0006)	−0.0028*** (0.0006)
marketshare		0.1714*** (0.0030)	0.1610*** (0.0029)	0.1691*** (0.0029)	0.1628*** (0.0029)	0.1610*** (0.0029)
Constant	5.9146*** (0.0865)	2.9607*** (0.0332)	2.8508*** (0.0616)	2.9661*** (0.0564)	2.7723*** (0.0428)	2.8468*** (0.0616)
year	YES	NO	NO	YES	YES	YES
industry	YES	NO	YES	NO	YES	YES
province	YES	NO	YES	YES	NO	YES
N	21134	21134	21134	21134	21134	21134
R-sq	0.1877	0.6925	0.7288	0.7067	0.7175	0.7289
Turning point	——	28.3	37.8	22.6	39.2	37.2

Notes: Standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Turning points are calculated with exact values of coefficients.

which is larger than the turning point of 37.2. Thus, we should also lower energy saving targets for those enterprises with targets larger than the turning point to promote their TFP.

The control variables of enterprise size, operating profit, and export status all significantly positively influence TFP. Profits and exports can alleviate an enterprise's financing constraints, enhancing its R&D efficiency and productivity. The variables of fixed assets, SOE, financial leverage, and enterprises' age are negatively correlated with TFP. After the inclusion of the quadratic term of ***target***, the goodness-of-fit is good ($R^2 = 0.7289$). In this study, a non-linear curve can better fit the relationship between the targets and TPF. Therefore, the following part analyses the average impact of the targets on TFP based on the non-linear relationship model.

Mediation of Market Share. The empirical analysis above indicates an inverted-U-shaped correlation between targets and TFP. Appropriate energy saving targets can improve corporate TFP, but how the targets impact overall TFP is still unclear. Table 4 shows test results of how targets affect TFP of the entire sample. Models 7, 9, and 11 present the test results with no control variables included. After the inclusion of all control variables, Models 8, 10, and 12 demonstrate almost identical regression results. For the industrial enterprise samples in this paper, the non-linear relationship between targets and market share is supported. Model 8 indicates that the coefficient of ***target*** is positive ($\beta = 0.1690$, $p < 0.01$), while that of $\boldsymbol{target^2}$ is -0.0002 ($p < 0.01$). When the government sets reasonable energy saving targets, enterprises can obtain a higher market share. Model 10 presents the regression results about impacts of market share on TFP. The regression coefficient of ***marketshare*** is significantly positive ($\beta = 0.1612$, $p < 0.01$), indicating that market share is the key factor of the TFP increase. Model 12 includes ***target***, $\boldsymbol{target^2}$, and ***marketshare***, whose regression coefficients are significantly positive ($\beta = 0.0143$, $p < 0.01$), significantly negative ($\beta =$ -0.0002, $p < 0.01$), and significantly positive ($\beta = 0.1610$, $p < 0.01$), respectively. The R^2 of the model reaches 72.89%, suggesting a strong explanatory power. The Sobel test p-value for this model is smaller than 0.001 and Bootstrap test (1000) shows that the 95% confidence interval for the indirect effect mediated by market share does not contain zero (Coef = 0.0195, Z = 17.94, p = 0.000, CI = [0.017375 −0.0216]). Thus, the targets can affect enterprises' TFP through market share expansion.

Robustness Tests. First, we conduct a robustness test through winsorizing the independent variable. There may be some bias resulting from outliers, which affects the reliability of the research conclusions. For mitigating potential impact of outliers, we winsorize the explanatory variable at 0.5% and 99.5%, and then run regression models again. The regression results of Models 13–15 in Table 5 support an inverted-U-shaped correlation between targets and TFP, and market share mediates the impacts of energy saving targets. Thus, the conclusions remain robust.

Second, we also conduct a robustness test using alternative measurements of TFP (see Table 6). Specifically, we measure corporate TFP with the FE method in Models 17 and 18, while we use the OP method in Models 19 and 20. The coefficients of *target* are all positive and significant in Models 16, 18, and 20. In addition, the coefficients of $target^2$ are all significantly negative. The conclusion of this study is further verified.

Third, we conduct a robustness test by excluding potential impacts of other policies (see Table 7). Some contemporaneous policies may also confuse our results. In order to address this concern, we control for the low-carbon city pilot (LCCP) and the carbon emission trading system pilot (CETSP) policies. For cities that had implemented these policies in 2012 and 2013, we assigned the corresponding policy variable the value of 1, and otherwise, 0. After controlling for the two policies, the results still support that our conclusions are strongly robust.

Table 4 Mediating effects of market share.

Variables	marketshare		TFP_LP		TFP_LP	
	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
target	0.2358***	0.1690***			0.0467***	0.0143***
	(0.0062)	(0.0058)			(0.0027)	(0.0020)
target^2	−0.0006***	−0.0002***			−0.0005***	−0.0002***
	(0.0001)	(0.0001)			(0.0000)	(0.0000)
marketshare			0.2898***	0.1612***	0.2760***	0.1610***
			(0.0032)	(0.0027)	(0.0035)	(0.0029)
roa		0.0265***		0.1288***		0.1287***
		(0.0059)		(0.0037)		(0.0036)
lev		0.0103		−0.1515***		−0.1564***
		(0.0315)		(0.0167)		(0.0167)
fixed		0.1197***		−0.1421***		−0.1553***
		(0.0355)		(0.0203)		(0.0204)
size		0.5136***		0.4527***		0.4456***
		(0.0109)		(0.0046)		(0.0047)
SOE		0.1561*		−0.1121***		−0.1086***
		(0.0836)		(0.0273)		(0.0272)
export		0.1537***		0.0223*		0.0293**
		(0.0244)		(0.0129)		(0.0130)
age		0.0072***		−0.0028***		−0.0028***
		(0.0018)		(0.0006)		(0.0006)
Constant	0.4931***	−3.2470***	5.8207***	2.8269***	5.6980***	2.8468***
	(0.1659)	(0.1701)	(0.0717)	(0.0617)	(0.0712)	(0.0616)
year	YES	YES	YES	YES	YES	YES
industry	YES	YES	YES	YES	YES	YES
province	YES	YES	YES	YES	YES	YES
N	21134	21334	21134	21134	21334	21134
R-sq	0.2309	0.3788	0.4407	0.7275	0.4567	0.7289

Notes: Standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 5 Robustness tests through winsorizing targets.

Variables	marketshare	TFP_LP	TFP_LP
	Model 13	Model 14	Model 15
target	0.1690***		0.0157***
	(0.0058)		(0.0020)
target^2	−0.0002***		−0.0002***
	(0.0001)		(0.0000)
marketshare		0.1538***	0.1536***
		(0.0027)	(0.0028)
Control	YES	YES	YES
Constant	−3.2470***	2.8352***	2.8558***
	(0.1701)	(0.0615)	(0.0614)
year	YES	YES	YES
industry	YES	YES	YES
province	YES	YES	YES
N	21334	21334	21334
R-sq	0.3788	0.7243	0.7259

Notes: Standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Fourth, we also conduct a robustness test after deleted samples in four province-level cities. The four municipalities as provinces, including Beijing, Shanghai, Tianjin, and Chongqing, have higher administrative rankings and resource advantages than other cities. Thus, we drop the firms from these four municipalities to rerun regression models (see Table 8). Models 26–28 support the results that energy saving targets nonlinearly influence TFP through market share.

Fifth, we also conduct robustness tests by controlling other confounding factors. Provincial and industry regulations that change over time may also be confounders. To address this concern, we rerun the regression models by controlling for year-industry, year-province, and industry-province fixed effects, respectively (see Table 9). The results of models in Table 9 are also consistent with our findings.

Finally, we also conduct a robustness test using the Causal Mediation Analysis (CMA). Traditional method can't identify the causal links between energy saving targets, market share, and TFP. For example, an increase of corporate TFP may also enables a more effective market supply. Thus, we attempt to address this issue using the CMA model developed by Imai et al. (2010). This approach uses the counterfactual inference principle to identify causal mediating effect, which can overcome selection bias in previous statistical analyses. Table 10 presents a comprehensive picture of the causal mediating effect of market share. The CMA analysis results show that market share mediates about 72.38% of the effect of target setting on TFP.

Heterogeneity Tests. The above results demonstrate a non-linear relationship between the targets and TFP. A reasonable target will improve TFP. Are there differences in impacts of targets on TFP across different regions, types of enterprises, and industries? This section analyzes the heterogeneous effects of targets on TFP in term of these three aspects (Table 11).

First, region-specific heterogeneity is considered. To verify whether there are differences in effects of targets on TFP of enterprises in different regions, the industrial enterprise samples are divided based on their registration places into eastern and non-eastern groups using the Health Statistics Yearbook of China's classification method. There are noticeable distinctions in the industrial structure and natural resources of the eastern and non-eastern regions, as well as certain distinctions in market competition, thus enterprises in eastern and non-eastern regions

Table 6 Robustness tests using alternative measurements of TFP.

Variables	marketshare	TFP_FE	TFP_FE	TFP_OP	TFP_OP
	Model 16	Model 17	Model 18	Model 19	Model 20
target	0.1690***		0.0022**		0.0143***
	(0.0058)		(0.0009)		(0.0020)
target^2	−0.0002***		−0.0000***		−0.0002***
	(0.0001)		(0.0000)		(0.0000)
marketshare		0.0440***	0.0452***	0.1608***	0.1607***
		(0.0013)	(0.0013)	(0.0027)	(0.0029)
Control	YES	YES	YES	YES	YES
Constant	−3.2470***	−0.8791***	−0.8738***	2.8556***	2.8756***
	(0.1701)	(0.0281)	(0.0281)	(0.0617)	(0.0616)
year	YES	YES	YES	YES	YES
industry	YES	YES	YES	YES	YES
province	YES	YES	YES	YES	YES
N	21334	21334	21334	21334	21334
R-sq	0.3788	0.5866	0.5876	0.7204	0.7218

Notes: Standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 7 Robustness tests by excluding potential impacts of other policies.

Variables	marketshare	TFP_LP	TFP_LP	TFP_LP	TFP_LP
	Model 21	Model 22	Model 23	Model 24	Model 25
target	0.1690***		0.0139***		0.0143***
	(0.0058)		(0.0020)		(0.0020)
target^2	−0.0002***		−0.0002***		−0.0002***
	(0.0001)		(0.0000)		(0.0000)
marketshare		0.1613***	0.1613***	0.1612***	0.1610***
		(0.0027)	(0.0029)	(0.0027)	(0.0029)
LCCP		−0.0767***	−0.0703***		
		(0.0194)	(0.0194)		
CETSP				0.209	0.212
				(0.2519)	(0.2511)
Control	YES	YES	YES	YES	YES
Constant	−3.2470***	2.8216***	2.8415***	2.8276***	2.8475***
	(0.1701)	(0.0617)	(0.0616)	(0.0617)	(0.0616)
year	YES	YES	YES	YES	YES
industry	YES	YES	YES	YES	YES
province	YES	YES	YES	YES	YES
N	21334	21334	21334	21334	21334
R-sq	0.3788	0.7279	0.7292	0.7275	0.7289

Notes: LCCP = Whether an enterprise's location city is a low-carbon pilot city; CETSP = Whether an enterprise's location city is a carbon emission trading system pilot city; Standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

may respond to the targets in different ways. Models 40 and 41 in Table 11 show that both eastern and non-eastern samples indicate an inverted-U-shaped correlation between targets and TFP. However, their turning points differ greatly, at 19.6 (eastern region) and 49.2 (non-eastern region), respectively. The turning point appears earlier for eastern samples, largely because they face greater competition pressure and has pioneered to adopt more advanced and efficient production models to expand their market share, giving them a cumulative TFP advantage. In the face of the targets set by governments, they have less potential and less room for TFP increase.

Second, enterprise type-specific heterogeneity is considered. Compared with non-SOEs, SOEs face higher external pressures, such as higher constraints on executive power, agency conflicts, quality of internal control, and external supervision. Therefore, registered SOEs, state-owned joint ventures, joint state-collective enterprises, and wholly SOEs are all classified as SOEs, while others are classified as non-SOEs. Regressions are run separately for SOEs and non-SOEs (see Models 42 and 43). The coefficients of *target* are significantly positive, while those of *target*^{2} are significantly negative in both models. Regardless of whether the sampled enterprises are classified as state-owned, the targets and TFP have an inverted-U-shaped relationship. Model 42 shows that setting lower targets for non-SOEs (*turning point* = 30.8) can better boost TFP. Without much governmental support, non-SOEs are more motivated to improve technology, increase productivity, and develop new markets to make up for the cost of reaching the targets. The turning point (69) appears later for SOEs because governments control their critical business resources, including political and tax preferences, bank loans, and policy-related subsidies (Ma and Liang 2018). SOEs also have closer relationships with governments than non-SOEs, and governments can also subsidize the losses of SOEs. Thus, there is a need to set higher target intensities to force SOEs to improve technology and increase productivity.

Third, industry-specific heterogeneity is considered. The differences in the effects of policy interventions across industries have attracted many scholars' attention (Conrad and Wastl 1995). According to Models 44, 45 and 46, for manufacturing enterprises and those in industries of the power, gas, and water production and supply, the regression coefficients of *target* are significantly positive ($p < 0.01$), and those of ***target²*** are significantly negative ($p < 0.01$), meaning targets and TFP have a significant inverted-U-shaped correlation in these industries. Moreover, turning points vary greatly on the inverted-U-shaped curves between targets and TFP across different industries. Manufacturing enterprises are more resilient to energy conservation targets as they are major polluters. Despite China's industrial restructuring by expanding low-energy-use industries and restricting or phasing out energy-intensive industries in recent years, the manufacturing industry still has staggeringly high pollution intensities and energy consumption. When the manufacturing industry faces high targets, there is more room to save energy, cut emissions and improve productivity.

Table 8 Robustness tests by deleting samples in four municipalities.

Variables	marketshare	TFP_LP	TFP_LP
	Model 26	Model 27	Model 28
target	0.1653***		0.0162***
	(0.0060)		(0.0022)
target^2	−0.0002***		−0.0002***
	(0.0001)		(0.0000)
marketshare		0.1687***	0.1682***
		(0.0029)	(0.0031)
Control	YES	YES	YES
Constant	−3.1336***	2.8464***	2.8669***
	(0.1635)	(0.0623)	(0.0621)
year	YES	YES	YES
industry	YES	YES	YES
province	YES	YES	YES
N	20156	20156	20156
R-sq	0.3812	0.7247	0.7261

Notes: Standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Discussion and conclusion

Summary. In this paper, we collected energy saving targets for more than 10,000 industrial enterprises from China's Top-10000 program, which was issued in 2011. We mapped the data onto CIED and used the matched data to construct 2012–2013 panel data models to systematically study impacts of energy saving targets on corporate TFP. Compared with previous studies (Filippini et al. 2020; Ai et al. 2021) which general covered about 100 targeted enterprises in the previous Top-1000 program, our dataset includes much more participant enterprises in the Top-10000 program, making our sample more representative. In addition, instead of using a dummy variable to measure whether an enterprise participated in the Top-1000 program or not (Filippini et al. 2020; Ai et al. 2021), our study constructs an indicator to measure the strength of energy saving targets. This can uncover the impacts of target difficulty.

Table 10 Robustness tests with the Causal Mediation Analysis.

Variables	marketshare	TFP_LP
	Model 38	Model 39
target	0.2483***	0.0124***
	(0.0044)	(0.0017)
target^2	−0.0007***	−0.0002***
	(0.0000)	(0.0000)
marketshare		0.1302***
		(0.0036)
Control	YES	YES
Constant	−0.1733	2.1964***
	(0.1133)	(0.0463)
year	YES	YES
industry	YES	YES
province	YES	YES
N	21334	21334
R-sq	0.2653	0.7388
ACME	0.0325 [0.0292-0.0358]	
Direct Effect	0.0123 [0.0090-0.0157]	
Total Effect	0.0447 [0.0404-0.0491]	
% of Tot Eff mediated	0.7238 [0.6609-0.8028]	

Notes: Standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 9 Robustness tests by controlling other confounding factors.

Variables	marketshare	TFP_LP	TFP_LP	marketshare	TFP_LP	TFP_LP	marketshare	TFP_LP	TFP_LP
	Model 29	Model 30	Model 31	Model 32	Model 33	Model 34	Model 35	Model 36	Model 37
target	0.1458***		0.0124***	0.1458***		0.0124***	0.1499***		0.0130***
	(0.0043)		(0.0014)	(0.0043)		(0.0014)	(0.0043)		(0.0015)
target^2	−0.0001		−0.0002***	−0.0001		−0.0002***	−0.0001*		−0.0002***
	(0.0000)		(0.0000)	(0.0000)		(0.0000)	(0.0000)		(0.0000)
marketshare		0.1308***	0.1302***		0.1307***	0.1302***		0.1307***	0.1298***
		(0.0021)	(0.0022)		(0.0021)	(0.0023)		(0.0021)	(0.0023)
Control	YES	YES	YES	YES	YES	YES	YES	YES	YES
Constant	−3.9759***	2.3622***	2.3926***	−4.2771***	2.3147***	2.3556***	−3.7844***	2.3660***	2.4049***
	(0.1240)	(0.0416)	(0.0417)	(0.1026)	(0.0348)	(0.0350)	(0.0821)	(0.0280)	(0.0283)
year	YES	YES	YES	YES	YES	YES	YES	YES	YES
industry	YES	YES	YES	YES	YES	YES	YES	YES	YES
province	YES	YES	YES	YES	YES	YES	YES	YES	YES
year-industry	YES	YES	YES	NO	NO	NO	NO	NO	NO
year-province	NO	NO	NO	YES	YES	YES	NO	NO	NO
industry-province	NO	NO	NO	NO	NO	NO	YES	YES	YES
N	21334	21334	21334	21334	21334	21334	21334	21334	21334
R-sq	0.3911	0.7374	0.7388	0.3911	0.7376	0.7390	0.3964	0.7395	0.7409

Notes: Standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 11 Heterogeneity tests.

Variables	Regional Characteristics		Types of Enterprises		Industry Characteristics		
	Eastern	Non-Eastern	SOE	Non-SOE	Mining	Manufacturing	Power, Gas, and Water Production and Supply
	Model 40	Model 41	Model 42	Model 43	Model 44	Model 45	Model 46
target	0.00550**	0.02439***	0.01546***	0.01380***	0.02219*	0.01979***	0.11068***
	(0.0026)	(0.0031)	(0.0047)	(0.0022)	(0.0117)	(0.0026)	(0.0065)
target^2	−0.00014***	−0.00025***	−0.00011***	−0.00022***	−0.00027	−0.00024***	−0.00208***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0002)	(0.0000)	(0.0002)
roa	0.1233***	0.1307***	0.1364***	0.1276***	0.0136***	0.0019***	0.0058***
	(0.0051)	(0.0052)	(0.0196)	(0.0037)	(0.0033)	(0.0003)	(0.0010)
lev	−0.1850***	−0.1463***	−0.1107*	−0.1590***	−0.2971***	−0.1597***	−0.0455
	(0.0236)	(0.0237)	(0.0626)	(0.0174)	(0.0771)	(0.0183)	(0.0311)
fixed	−0.1439***	−0.1465***	−0.1282*	−0.1611***	−0.1718**	−0.3456***	−0.00950
	(0.0292)	(0.0287)	(0.0687)	(0.0213)	(0.0792)	(0.0232)	(0.0435)
size	0.4782***	0.4150***	0.5132***	0.4381***	0.4410***	0.4670***	0.3771***
	(0.0067)	(0.0066)	(0.0181)	(0.0049)	(0.0190)	(0.0055)	(0.0135)
SOE	−0.1197***	−0.0931**	——	——	0.0721	−0.1635***	−0.0148
	(0.0410)	(0.0366)	——	——	(0.0914)	(0.0414)	(0.0441)
export	0.0193	0.0209	0.0241	0.0291**	0.0429	0.0367**	−0.0232
	(0.0145)	(0.0245)	(0.0530)	(0.0134)	(0.1122)	(0.0143)	(0.1089)
age	−0.0031***	−0.0026***	−0.00180	−0.0030***	−0.0050***	−0.0032***	0.00220
	(0.0008)	(0.0008)	(0.0012)	(0.0007)	(0.0019)	(0.0007)	(0.0013)
marketshare	0.1569***	0.1693***	0.1077***	0.1747***	0.0875***	0.0856***	0.0996***
	(0.0034)	(0.0049)	(0.0065)	(0.0032)	(0.0118)	(0.0022)	(0.0061)
Constant	2.6456***	3.0326***	2.2589***	2.8759***	3.2935***	2.9771***	2.1034***
	(0.1637)	(0.0724)	(0.2039)	(0.0655)	(0.2876)	(0.0654)	(0.1371)
year	YES	YES	YES	YES	YES	YES	YES
industry	YES	YES	YES	YES	YES	YES	YES
province	YES	YES	YES	YES	YES	YES	YES
N	10688	10446	1460	19674	1173	17547	2414
R-sq	0.7539	0.6870	0.8152	0.7210	0.7126	0.6646	0.7817
Turning point	19.6	49.2	69	30.8	41.2	40.6	26.6

Notes: Standard errors are in parentheses. Turning points are calculated with exact values of coefficients.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

The empirical results reveal an inverted-U-shaped correlation between energy saving targets and corporate TFP. An enterprise's TFP first grows and then drops along with the increase of energy saving target intensity. On average, there is a turning point on the curve where it peaks. Apart from the effects of the targets on the micro-mechanism of the factor mobility of enterprises, we also find that the targets boost an enterprise's TFP by expanding its market share. Moreover, targets' impacts vary across regions, types of enterprises, and industries. Previous studies are inconclusive as to whether energy efficiency target setting is a poison or a catalyst, because their findings about the impact of the Top-1000 program on enterprises' TFP are conflicting, either positive (Filippini et al. 2020) or negative (Ai et al. 2021). However, our study reveals a non-linear relationship between the energy saving targets and TFP, clarifying previous debates on when energy saving targets are beneficial.

Policy implications. Our findings provide valuable policy implications. First, we should set appropriate levels of energy saving targets to enhance corporate efficiency and improve the environment, avoiding too high targets or too low targets. The targets do not always have a positive or negative influence on corporate TFP and their effects vary with the increase of the target pressure. The average energy saving target intensity for samples is 2.327, but the turning point is about 37.2. The targets set for most enterprises are well below the turning point and are not strong enough to motivate enterprises. In the short term, appropriately raising the energy saving targets for most industrial enterprises is a feasible way to improve TFP. However, for those enterprises whose target intensities are higher than 37.2, it is better to lower these targets.

Second, it is important to set higher energy saving targets for non-eastern enterprises, SOEs, and manufacturing enterprises than their counterparts. This study finds the effects of targets are heterogeneous across ownership patterns, regions, and industries. Specifically, the potential of energy saving targets to promote TFP of the eastern samples, non-SOEs, and non-manufacturing enterprises is less than that for their counterparts. It is necessary to increase the targets for non-eastern enterprises, SOEs, and manufacturing enterprises correspondingly. To develop flexible and feasible environmental protection policies and enforcement plans, target setters should consider not only enterprises' energy consumption or pollutant emission intensity but also their energy saving or emission reduction potential according to their ownership patterns, regions, and industries, to make the targets a stronger TFP growth driver.

Third, we should use market share as a beacon to set and adjust energy saving targets for enterprises. The empirical study in this paper reveals the transmission mechanism behind how the targets affect TFP. The targets' direct impact on TFP are implicit, whereas changes in market share are explicit. Enterprises should respond positively to mandatory targets allocated by governments, promptly adjust their long-term development strategies, and seek technological improvement and innovation to enhance their market competitiveness. Market share can serve as a beacon for governments seeking to set energy saving targets for enterprises. In other words, governments can track and evaluate energy saving targets based on enterprises' market share. If a target can boost the market share of an enterprise, the target is reasonable and scientific. Otherwise, it needs to be revamped.

Limitations and future directions. This paper also has two limitations. First, due to their availability and relevance, we collected data for 2012 and 2013 only. Specifically, China National Bureau of Statistics adjusted some indicators in CIED in 2014. For example, the total number of indicators in the database in 2013 to 2015 are 88, 66, and 84, respectively. Some important indicators were missing in 2014, including net profit and selling expenses. This limitation, resulting from data unavailability, restricted us from looking into long-term effects of energy targets on TFP. In practice, it may take time for enterprises to fulfill these targets and the effects of target setting may also take a few years to manifest. Second, limited by data availability, we mainly analyzed how energy saving targets affect TFP from the perspective of resource allocation. We did not explore how technological innovation or improvement affects the relationship between the targets and TFP. Future studies can use data with more phases to test these two issues above.

Data availability

The datasets generated during and/or analyzed during the current study are available on websites of relevant authorities (including: The China Industrial Enterprise Database, which can be accessed through the following link: http://microdata.sozdata.com/index.html#/Single/Basic?year=2014; Notably, this database is not free, but readers can register and buy it. The National Development and Reform Commission: https://www.ndrc.gov.cn/xxgk/zcfb/gg/201205/t20120521_961013.html).

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Competing interests

The authors declare no competing interests.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

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