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Undermined Climate Policies: A Study on the Impact of Regulatory and Financial Discrimination across Heterogeneous Firms in China

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Keywords: emissions, CGE, firm heterogeneity, SME, ETS, Chinese economy

JEL classification: C67, C68, Q54, Q56, O16

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1. Introduction

China has achieved a 20% decrease in its carbon intensity of economic output during the 12th Five-Year-Plan (FYP) (2011–2015), which exceeded the target set in the FYP.[1] Statistics also show downturns in both coal consumption[2] and energy-related CO_2 emission[3] in China for 2015, indicating its remarkable progress in greenhouse-gas (GHG) mitigation. And yet, tighter mitigation targets are set for the coming years. China has officially submitted its "Intended Nationally Determined Contribution (INDC)" to the United Nations Framework Convention on Climate Change (UNFCCC) in June 2015, presenting its goal of cutting carbon intensity by 60-65% from 2005 levels by 2030. The INDC largely reinforced the commitment made in 2014 for China's CO_2 emissions to peak around 2030. Assuming that China fulfills the Copenhagen commitment and reduces its CO_2 intensity by 40-45% from 2005 levels by 2020, an average reduction in CO_2 intensity between 3.27% and 4.11% per year is required from 2010 to 2020, and between 3.97% and 4.42% from 2020 to 2030.

China has already achieved significant decarbonization of its booming economy, with rapid improvements in energy efficiency, robust uptake in renewables energy, and quick change in industrial structure. Most of this progress has been made by state-owned enterprises (SOEs) and large private firms. The *Implementation Plans for Energy Conservation Activities in One-thousand Enterprises* published in 2003 by the National Development and Reform Commission (NDRC), which was the most important governmental arm for setting emission-reduction policies, covers only the 1,000 most energy- and emission-intensive firms, mainly SOEs. The applicability of the implementation plan was expanded to the top 10,000 firms in 2011, which still covers only large emitters. Although large emitters, mainly SOEs, are the primary target of policy regulations, most of these SOEs are provided with preferential terms for financing their investment in upgrading to energy-efficient technologies and equipment, including no- or low-interest loans and easier access to public funds. The limited coverage of regulation and unbalanced financial conditions were intended to lower the monitoring and administration costs and mitigate market risks; but, in the meantime, such differences inevitably lead to market distortions that undermine the overall effectiveness of climate change policies, especially when considering the fact that small- and medium-sized enterprises (SMEs) have been expanding over the last decade with rapid growth both in terms of the number of firms and their total scale. According to the statistics in the *Yearbook of China Small and Medium Enterprises 2015*, SMEs account for 99% of total firms by number, 60% by total output value, and 75% by employment, as well as 42% by total emissions. Climate policy enforcement efforts so far in China have left the majority of smaller and private firms unaffected, thus impeding major future breakthroughs in GHG mitigation.

Generally, emitters can follow two basic strategies to meet GHG emission regulations: either adjust their input structure on the production technology frontier, or invest in energy

[1] http://www.gov.cn/xinwen/2016-02/23/content_5044990.htm

[2] http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/country-and-regional-insights/china.html

[3] http://www.iea.org/newsroomandevents/pressreleases/2016/march/decoupling-of-global-emissions-and-economic-growth-confirmed.html

technology to shift the frontier. The individual choice is determined by firms' production technologies, market conditions, profitability, financing costs, and other factors, which vary both within and between industries. For firms that are subject to emission regulation and have access to preferential financing (mainly SOEs), investing in upgrading production technologies and equipment would be preferred, while other regulated emitters (large-scale private firms) would have to rely on substituting energy input with other factors. Unregulated emitters (mainly small private firms) are, in contrast, discouraged from taking steps to reduce their emissions given lower energy prices, higher financial costs, and the absence of policy regulation. Diversified regulation leads to variance in the marginal abatement cost (MAC) for CO_2 across firms and decreases the total efficiency of emission reduction. However, unbalanced green investment also diversifies the marginal effects of making such investments, which decreases the average efficiency. Moreover, green investments are competing with other fixed capital investments for creating production capacity, which affects long-term economic growth.

Tighter mitigation targets are set for the coming decades for China. However, since low-hanging fruit for emission reductions is becoming rarer, the economy has seen decreasing effectiveness of existing policy tools and increasing costs for further GHG mitigation. The emission reduction potential of SMEs has attracted policymakers' attention, as can be seen in the Ministry of Industry and Information Technology (MIIT) report on *Guidance for Further Enforcement of Energy Conservation and Emission Reduction of SMEs* in 2010. To meet the emission targets put forward for the next decade, a package of climate policy mechanisms has been proposed and planned for China, including the establishment of a national emission trading scheme (ETS). However, SMEs are still excluded from the emission markets and the impact of partial coverage of emission regulations and unbalanced financial terms is not currently understood as a consequence of insufficient studies on that topic. In this paper, we intend to fill this gap and provide a precise model for the design of Chinese climate policies.

The paper is structured as follows: in Section 2, we review existing literature on related topics; in Section 3, we establish a stylized theoretical framework to illustrate the impact of partial coverage of emission constraints and differentiated financial conditions; and in Section 4, we briefly introduce the dynamic computable general equilibrium (CGE) model used for the numerical analysis. We discuss the simulation results in Section 5 and conclude in section 6.

2. Literature Review

The impact of partial coverage of climate policy regulations has been intensively studied in the literature on carbon leakage (Paltsev, 2001; Kuik & Gerlagh, 2003; Babiker, 2005; Barker et al., 2007; Okereke & McDaniels, 2012; Lanz et al., 2013; Chen, 2009). Paltsev used a CGE model to estimate a 10% leakage under the Kyoto Protocol. However, this area of research has mainly focused on inter-industry and cross-border leakage, while intra-industry leakage is very often overlooked, particularly for leakage among heterogeneous firms. However, as mentioned above, private firms in China are becoming more significant in terms of both economic output and GHG emission. Neglecting SMEs would not only overlook a huge source of potential GHG mitigation, but also lead to market distortion and undermine policy effectiveness.

The IFC commissioned ESD China Ltd. (referred to hereinafter as ESD or the Consultant) to conduct a "Study on the Potential of Sustainable Energy Financing for SMEs in China in 2012" to identify the priority industrial sectors in provinces with vibrant SME economies where there is significant potential for energy savings (IFC, 2012). The study concluded that SMEs in the top 8 energy-intensive sectors have a total energy-saving capacity of approximately 229 million tons of coal equivalent (TCE) per year, representing approximately 74% of the total potential energy-saving achievable among the 35 industrial sectors included in the 12th FYP. This amount of energy-saving capacity, if realized, would achieve a total energy cost reduction of approximately RMB 446 billion per year. However, SMEs have been overlooked by climate policy regulations during the last decade, leaving that large potential for emission reduction unexploited.

This situation has been made worse by limited access to financial resources for SMEs. Due to the relatively high risk profile that SMEs possess, commercial banks and investors are reluctant to provide financial support. This situation is exacerbated by uncertainty and information asymmetries, lack of loan guarantees and collateral, and some ambiguities in property rights and creditors' rights in the event of bankruptcy (Arora, 2009). Tsai (2015) also found that even though SMEs represent the backbone of China's economy, they lack access to bank credit. According to the National Bureau of Statistics, SMEs account for over 97% of registered industrial firms in China and generate 60% of GDP. However, larger SOEs receive over 75% of loans by amount extended by commercial banks (Zhu & Sanderson, 2009) and account for over 60% of publicly listed businesses on China's stock markets (Zhongguowang, 2012). In 2013, only 23.2% of bank loans were extended to SMEs (CBRC, 2014). Access to working capital loans is even more restricted: only 4.7% of short-term loans went to SMEs. SMEs thus rely on a wide range of alternative sources, including informal finance, online peer-to-peer (P2P) platforms, registered non-banking financial institutions (NBFIs), and underground financiers. Even with interest rates of up to 30% through unofficial credit sources, many SMEs have no other choice for funding.

Most SMEs have to rely on self-financing, including owners' capital and corporate revenue. Such self-financing often results in firms focusing on short-term profit and may make them reluctant to invest in research and development or engage in innovation activities, which tend to be long-term in nature. Limited access to financial resources is listed as the second-most severe obstacle to innovation in SMEs in China (Zhu et al., 2012). It will also affect emission reduction efforts by SMEs since investments in energy efficient technologies and equipment also take a long time to pay off.

Emission reduction behavior of firms is heterogeneous due to different regulations and financial conditions across firms, which has potentially large impacts on the effectiveness and economic implication of climate policies. Unfortunately, the impact of firm heterogeneity on climate policies has not been sufficiently studied. To make precise policy recommendations, we need to understand the following question numerically: how and to what extent does firm heterogeneity undermine the efficiency of climate policies and long-term economic growth under alternative regulation structures? Detailed data on firm heterogeneity concerning production technology, market environment, and policy regulation of different firms, as well as a structural model describing differentiated behavior of heterogeneous firms, would be helpful for understanding the question but are not readily available. In this paper, the authors intend to fill this gap by 1) identifying heterogeneous firms from a newly augmented Chinese input-output

(IO) table (Tang et al., 2014) in which information about both firm size and ownership is explicitly reported; 2) specifying the behaviors of different firms in a dynamic CGE model, and 3) estimating the emission and economic effects of alternative climate policy designs that take firm heterogeneity into consideration.

3. Theoretical Framework

In this section, we use a stylized theoretical framework to explain the heterogeneous behaviors in production- and energy-technology investment of different firms, and their implications for economic performance.

Assuming that there are $i \in \boldsymbol{I}$ firms in the economy in year t, the production technologies of each firm are addressed by using a two-level nested Cobb–Douglas function, as follows:

$$Y_{i,t} = A_i V_{i,t}^{1-\alpha_i} F_{i,t}^{\alpha_i}, \quad F_{i,t} = H_{i,t}^{\beta_i} E_{i,t}^{1-\beta_i}, \qquad \text{Eq. 1}$$

where $Y_{i,t}$ is output; $V_{i,t}$ is value-added input; and $F_{i,t}$ is the energy service input produced by energy input $E_{i,t}$ and energy-technology input $H_{i,t}$.

The price vector is denoted as $\{p_{i,t}, v_t, h_t, e_t\}$, with is elements indicating output price, value-added price, energy technology price, and energy price, respectively. Given the production technology described in Eq. 1, producers' optimal decision in a perfectly competitive market requires

$$\begin{cases} V_{i,t} = (1-\alpha_i)\dfrac{p_{i,t}Y_{i,t}}{v_t} \\ H_{i,t} = \alpha_i \beta \dfrac{p_{i,t}Y_{i,t}}{h_t} \\ E_{i,t} = \alpha_i (1-\beta)\dfrac{p_{i,t}Y_{i,t}}{e_t} \end{cases} \qquad \text{Eq. 2}$$

where $p_{i,t}=A_i' \, v_t^{1-\alpha i} h_t^{\alpha i \beta} e_t^{\alpha i(1-\beta)}$, $A_i'=A_i^{-1}\alpha_i^{\alpha i}(1-\alpha_i)^{1-\alpha i}[\beta^{\beta}(1-\beta)^{(1-\beta)}]^{\alpha i}$. The outputs of different firms are inputs to produce the final demand commodity, $W_t=\prod_i Y_{i,t}^{\gamma i}$, $(\Sigma_i \gamma_i=1)$. The corresponding demand for the individual commodity is

$$Y_{i,t} = \frac{\gamma_i}{p_{i,t}}\left(v_t \overline{V}_t + h_t \overline{H}_t + e_t \overline{E}_t\right). \qquad \text{Eq. 3}$$

Substituting Eq. 2 and the following market clearance conditions (Eq. 4) into Eq. 3, we can close the system and get the equilibrium prices of factors for each period separately.

$$\sum_i V_{i,t} = \overline{V}_t, \quad \sum_i H_{i,t} = \overline{H}_t, \quad \sum_i E_{i,t} = \overline{E}_t \qquad \text{Eq. 4}$$

In an effective market without any distortion, the equilibrium ensures that the corresponding marginal revenues of the inputs of each firm are identical to factor prices in equilibrium. That is,

$$\forall i,\ \begin{cases} \dfrac{\partial\left(p_{i,t}Y_{i,t}\right)}{\partial V_{i,t}} = v_t \\ \dfrac{\partial\left(p_{i,t}Y_{i,t}\right)}{\partial H_{i,t}} = h_t \\ \dfrac{\partial\left(p_{i,t}Y_{i,t}\right)}{\partial E_{i,t}} = e_t \end{cases}. \qquad \text{Eq. 5}$$

The inter-temporal linkage is determined by energy technology investment in this model, which is a part of the final demand and can be written as

$$CNS_t + \hat{H}_t = W_t;\ \ \overline{H}_t = \delta\overline{H}_{t-1} + \hat{H}_t. \qquad \text{Eq. 6}$$

Equation 6 indicates that the optimal investment matches the following condition:

$$h_t + \rho\delta W_{t+1} = W_t \xrightarrow{\forall t, w_t = 1} h_t = 1 - \rho\delta. \qquad \text{Eq. 7}$$

Now we can differentiate the market and regulatory conditions of firms to analyze firms' heterogeneous behavior. We assume that only a subset of firms are regulated by emission constraints, the cost of regulated energy input is denominated as $e_t'=\theta e_t$ (θ>1), and regulated firms are subsidized for their green investments. The target of the subsidy is reducing the input cost of energy services ($F_{i,t}$) to the no-regulation level so as to restore firm competitiveness. The subsidy rate is set as ($0<1-\varphi<1$), and so the input cost for $F_{i,t}$ is $f_{i,t}=B_i'(\varphi h_t)^{\beta}(\theta e_t)^{1-\beta}$ ($B_i'=\beta^{-\beta}(1-\beta)^{1-\beta}$). To return the cost to the no-regulation level, $B_i'h_t^{\beta}e_t^{1-\beta}$, the subsidy rate is set as $\varphi=\theta^{(\beta-1)/\beta}$.

With regulation, the optimal input decision in Eq. 2 is now changed to

$$\begin{cases} V_{i,t} = \left(1-\alpha_i\right)\dfrac{p'_{i,t}Y_{i,t}}{v_t} \\ H_{i,t} = \alpha_i\beta\dfrac{p'_{i,t}Y_{i,t}}{\varphi h_t} \\ E_{i,t} = \alpha_i\left(1-\beta\right)\dfrac{p'_{i,t}Y_{i,t}}{\theta e_t} \end{cases}, \qquad \text{Eq. 8}$$

where $p'_{i,t}=\ \varphi^{\alpha i\beta}\theta^{\alpha i(1-\beta)}p_{i,t}$. For unregulated firms (indicated by $j\in\boldsymbol{I}$), $\theta=\varphi=1$; for regulated nonsubsidized firms ($k\in\boldsymbol{I}$), θ>1 and φ=1; for regulated subsidized firms ($m\in\boldsymbol{I}$), θ>1 and $\varphi=\theta^{(\beta-1)/\beta}$. Thus, the market clearance conditions are:

$$\begin{cases} \overline{V}_t = \sum_i \left(1-\alpha_i\right)\dfrac{p_{i,t}Y_{i,t}}{v_t} + \sum_k \left[\theta^{\alpha_k(1-\beta)} - 1\right]\left(1-\alpha_k\right)\dfrac{p_{k,t}Y_{k,t}}{v_t} \\ \overline{H}_t = \sum_i \alpha_i\beta\dfrac{p_{i,t}Y_{i,t}}{h_t} + \sum_k \left[\theta^{\alpha_k(1-\beta)} - 1\right]\alpha_k\beta\dfrac{p_{k,t}Y_{k,t}}{h_t} + \sum_m \left(\dfrac{1}{\phi} - 1\right)\alpha_m\beta\dfrac{p_{m,t}Y_{m,t}}{h_t} \\ \overline{E}_t = \sum_i \alpha_i\left(1-\beta\right)\dfrac{p_{i,t}Y_{i,t}}{e_t} - \sum_k \left[1-\theta^{\alpha_k(1-\beta)-1}\right]\alpha_k\left(1-\beta\right)\dfrac{p_{k,t}Y_{k,t}}{e_t} - \sum_m \left(1-\dfrac{1}{\theta}\right)\alpha_m\left(1-\beta\right)\dfrac{p_{m,t}Y_{m,t}}{e_t} \end{cases}.$$

Eq. 9

The first terms on the right-hand side of the three equations in Eq. 9 are identical to the market clearance condition in the no-regulation scenario (Eq. 4), and the additional terms show the impact of the heterogeneous response of different firms to unbalanced regulation. Compared with the no-regulation scenario, demand is higher for V and H and lower for E, which leads to higher v and h but lower e. Table 1 shows the heterogeneous responses of different firms to unbalanced regulation. Unregulated firms tend to use more energy since it is cheaper, relative to the no-regulation scenario, to substitute V and H. This leads to carbon leakage. The marginal abatement cost for energy input, $(\theta-1)e$, is identical for regulated firms, but the approaches may be differentiated. Subsidized firms tend to rely solely on investing in energy technology to substitute for energy. The effect of the subsidy is so strong that energy-technology investment also squeezes out the input of V. Unsubsidized firms must input more V to meet their energy constraints, although V becomes more expensive. Thus, energy input would be more concentrated in unregulated j firms; energy-technology investments would be more concentrated in subsidized m firms. The unbalanced regulations lead to unequal marginal revenues of energy technology and energy input, which shifts the economy from its optimal equilibrium. Aside from that, green investments and the enforcement of the green-investment subsidy also must compete with fixed assets investment for financial resources, which affects the long-term economic growth path. Analyzing the exact impact of the dual distortion on economic output requires a systematic numerical model, which is introduced in the next section.

Table 1. Heterogeneous Response of Firms to Unbalanced Regulation

Firm	θ	φ	MR(V)[1]	MR(H)	MR(E)	V	H	E
j	1	1	v	h	e	↓[2]	↓	↑[3]
k	>1	1	v	h	θe	↑	↑	↓
m	>1	$\theta^{(\beta-1)/\beta}$	v	φh	θe	↓	↑	↓

Note: 1. MR(·) stands for Marginal Revenue of factor input;
2. ↓ indicates a decrease in factor input compared with the no-regulation scenario;
3. ↑ indicates an increase in factor input compared with the no-regulation scenario.

4. Model and Data

We use a CGE model to analyze the impact of regulation on emissions and economic performance, taking firm heterogeneity into consideration. In this section, we provide a brief overview of the model and database.[4] The model is a multi-sector one-region recursive dynamic CGE model that accounts for multiple firm types, differentiated policy regulation, and endogenous energy-technology investment. The model is calibrated to 2010 as the base year. Future periods (indicated by t) are simulated on the basis of the results for the preceding period. The model assumes neo-classical macro closure, that is, it assumes full use and employment of capital and labor.

4.1 Data

The analysis in this paper takes advantage of a unique database developed by Tang et al. (2014). This database, the augmented 2010 Chinese national IO table, includes data on 42 sectors

[4] The introduction in this section would be focused on the part related to firm heterogeneity and green investment. For other technical detail, please refer to Appendix I or contact the authors.

(indexed by *i)* and information on firm heterogeneity. Firms in each industry are distinguished by two dimensions (indicated by *f*): ownership (state-owned, foreign-invested, or domestic private) and size (large or small), as shown in Table 2. Tang and colleagues developed a constrained optimization method to construct the table by using the official Chinese 2010 IO table (the *Annual Surveys of Industrial Production*, which contains firm-level information on balance sheets, production, ownership, etc., from the National Bureau of Statistics of China) and firm-level export and import data for 2010 (from China's General Administration of Customs). The layout of this augmented IO table is shown in Table 3. To estimate CO_2 emissions by sector and firm type based on this augmented Chinese IO table, the following steps are taken. We first follow the conventional method (Peters et al., 2006) to estimate China's CO_2 emissions from fuel combustion in physical terms, using the 2008 Chinese energy-balance table and the Intergovernmental Panel on Climate Change emission factors. Combining this information with the energy input data (in monetary terms) for four energy sectors (coal mining, washing, and processing; oil and gas extraction; petroleum processing and coking, and nuclear fuel processing; and gas production and supply) from the conventional Chinese national IO table, the CO_2 emissions per CNY of energy use by energy type can be estimated. Since the energy input data in monetary terms by sector and firm type is available in the augmented Chinese IO table, assuming that there is no difference in energy price across firms (all firms face the same market price for a specific type of energy – a strong but necessary assumption lacking more detailed and reliable energy price data), CO_2 emissions by sector and firm type can be estimated.

Table 2. List of Firm Types

SIZE	OWNERSHIP		
	STATE	FOREIGN	PRIVATE
LARGE	*LSOE*	*LFIE*	*LGE*
SMALL	*SSOE*	*SFIE*	*SME*

Table 3. Structure of the IO Table with Multiple Firm Types

<table>
<tr><td></td><td>I</td><td colspan="3">1</td><td colspan="3">2</td><td>…</td><td colspan="3">i</td><td>Cns.</td><td>Save</td><td>Exp.</td></tr>
<tr><td></td><td>F</td><td>1</td><td>…</td><td>f</td><td>1</td><td>…</td><td>f</td><td>…</td><td>1</td><td>…</td><td>f</td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">1</td><td>1</td><td colspan="10" rowspan="10">Domestic Intermediate Input</td><td colspan="2" rowspan="10">Domestic Commodity Consumption</td><td rowspan="10">Export</td></tr>
<tr><td>⋮</td></tr>
<tr><td>f</td></tr>
<tr><td rowspan="3">2</td><td>1</td></tr>
<tr><td>⋮</td></tr>
<tr><td>f</td></tr>
<tr><td>⋮</td><td>⋮</td></tr>
<tr><td rowspan="3">i</td><td>1</td></tr>
<tr><td>⋮</td></tr>
<tr><td>f</td></tr>
<tr><td>1</td><td></td><td colspan="10" rowspan="3">Intermediate Import</td><td colspan="2" rowspan="3">Import for Final Consumption</td></tr>
<tr><td>⋮</td><td></td></tr>
<tr><td>i</td><td></td></tr>
<tr><td>Wage</td><td></td><td colspan="10" rowspan="4">Value Added</td></tr>
<tr><td>Tax</td><td></td></tr>
<tr><td>Dep.</td><td></td></tr>
<tr><td>Rev.</td><td></td></tr>
</table>

4.2 Production Technology

The production technology of each producer is addressed by a nested constant elasticity-of-substitution (CES) function. The nesting structure follows the KLEM structure: industry- and firm-specified capital ($K_{i,f}$) and labor (L) compose the value-added level (VA), which is then nested with energy composition (ENG), consisting of different energy products. The value-added and energy composition (*VAE*) is then nested with the composition of intermediaries (*M*) to produce the final product (*Y*). The nesting structure is shown in Figure 1. The parameters in the nested-CES functions of each firm type in each industry are calibrated by the IO table, which contains firm heterogeneity data as shown in Table 3.

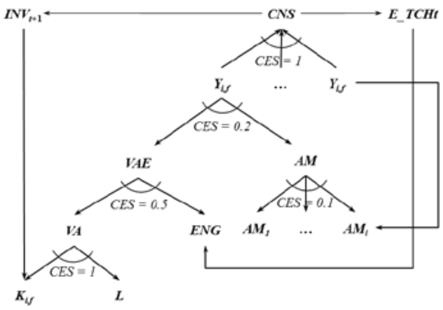

Figure 1. Nesting Structure of CES Production Function

The product can be used for consumption (*CNS*), investment in capital for use in future periods (*INV*), and investment in energy technologies that can increase energy efficiency in both the current and future periods (*E_TCH*).

4.3 Energy Supply and Emission Accounting

Six energy industries are included in the model: coal mining, oil extraction, petrochemical, thermal power generation, renewable power generation, and natural gas supply. These industries produce raw and washed coal (*Coal*), crude oil (*Crude*), petroleum (*Ptr*), electricity (*ELE*; thermal and renewable) and natural gas (*NG*), respectively. The energy supply is also addressed in a nested-CES form, as shown in Figure 2. Energy technology (*E_TCH*) is also an input for energy supply as an extra factor that is substitutable to physical energy input. From this, higher energy prices or constraints on energy input would lead to higher demand for energy technology. Energy-technology investment is a decision made at the firm level and leakage is not considered in the model. *E_TCH* accumulates in a similar manner as capital.

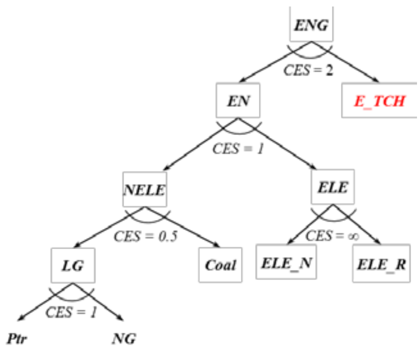

Figure 2. Energy Nesting Structure

CO_2 emissions from direct combustion of fossil fuel are accounted for according to policy regulations. In other words, electricity usage and fossil fuel input for feed-in-stock in industries are not included in CO_2 accounting.

4.4 Investment Decision and Capital Accumulation

Investment decision is at the firm level: each firm determines its investment demand according to profit rate and financial cost, calculated as follows:

$$g_{i,f} = \frac{\beta \exp\left[a\left(ror_{i,f} - \overline{ror}_{i,f}\right)\right]}{1+\beta \exp\left[a\left(ror_{i,f} - \overline{ror}_{i,f}\right)\right]}\left(g^{\max} - g^{\min}\right) + g^{\min}, \qquad \text{Eq. 10}$$

where $g_{i,f}$ is the desired growth rate of capital accumulation of f firms in sector i; g^{max} and g^{min} are the upper- and lower-bound of capital growth rate, set exogenously in a logit curve to prevent irrationally extreme capital growth. $ror_{i,f}$ is the capital rate-of-return of firm f in industry i. $ror_{i,f}$ is calculated as follows:

$$ror_{i,f} = \frac{1-\delta + pk_{i,f}}{1+r_f}, \qquad \text{Eq. 11}$$

where δ is the depreciation rate of capital, $pk_{i,f}$ is the rental price of firm-specified capital (i.e., the profit), and r_f is the financial cost, which is differentiated with respect to firm type. a and β are parameters estimated from statistical data.

4.5 Scenarios

The benchmark for cross-scenario comparison is the business-as-usual (BAU) scenario in which mandatory intensity targets are enforced for certain types of firms to fulfill an exogenously determined total intensity target that meets China's commitment in the INDC. In the BAU scenario, the climate regulations cover only SOEs and large private firms and only SOEs have access to preferential financial terms. The unbalanced regulatory structure is shown in Table 4. In addition to the BAU scenario, the NULL scenario, featuring no policy regulations, is also introduced.

Table 4. Unbalanced Regulation Structure in the BAU Scenario

SCALE	OWNERSHIP		
	STATE	FOREIGN	PRIVATE
LARGE	*LSOE*	*LFIE*	*LGE*
SMALL	*SSOE*	*SFIE*	*SME*

Note: Regulated firm types are shaded, with the darker shading indicating access to preferential financial conditions.

The purpose of preferential financial terms and conditions is to encourage green investment and increase market competitiveness. In order to replicate that purpose, in the model we nullify policy regulation for each period to determine a set of energy input costs for firms "free of regulation" and then restore the regulations with an endogenous subsidy to SOEs for green investment to match their energy input cost to the "free of regulation" costs. Figure 3 shows the process.

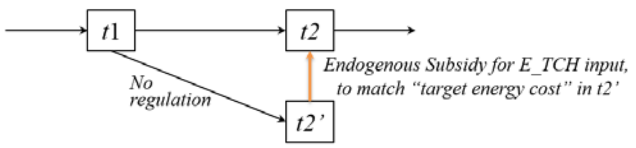

Figure 3. Simulation Process for Preferential Financial Conditions

The total intensity target is set to decrease China's CO_2 emission per unit of GDP by 3.62% per year beginning in 2011. This target assures that China will meet the commitment made in its INDC to decrease the carbon intensity by 60% from 2005 levels before 2030 (Figure 4).

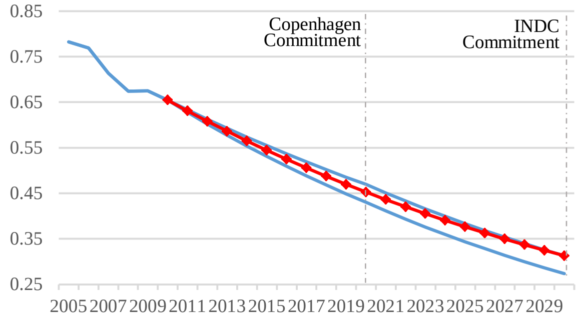

Figure 4. China's Emission Commitments and Intensity Target Setting

Aside from NULL and BAU scenarios, a third set of scenarios in which emission trading is introduced and alternative settings for regulatory coverage and financial equalization are also taken into consideration (Table 5).

Table 5. Scenarios with Emission Trading

FINANCIAL CONDITION	**REGULATION COVERAGE**	
	partial	full
differentiated	*ETS_P_D*	*ETS_F_D*
equalized	*ETS_P_E*	*ETS_F_E*

In the partial-coverage scenarios, only SOEs and large private firms are regulated by emission constraints and can participate in emission trading; in the full-coverage scenarios, all firms are equally regulated and are able to trade their emission in an integrated carbon market. In the various financial condition scenarios, the endogenous subsidy for green investment is provided for SOEs as in the BAU scenario, while in the equalized scenarios, the subsidy is eliminated.

5. Simulation Results

In this section, we compare alternative scenarios for their impact on CO_2 emissions and long-term economic growth in China. We refer to differentiated green investment behavior and the efficiency of heterogeneous firms to explain the differences in emissions and economic performance.

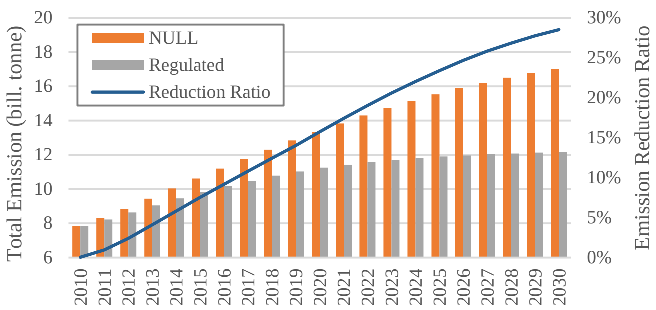

Figure 5. Emission Reduction Effect of Climate Policies

Note: The emission trajectories are set identically for all scenarios, other than NULL, to assure their comparability

5.1 Overview of Emission and Economic Effects

The model simulation shows that if China can fulfill its commitment to reduce carbon intensity by 60% or more from 2005 levels by 2030, a peak in total emissions can be expected around 2030, as shown in Figure 5. The peak level in 2030 is around 12.1 billion t, which is 28.5% lower that the potential emissions compared with the NULL scenario.

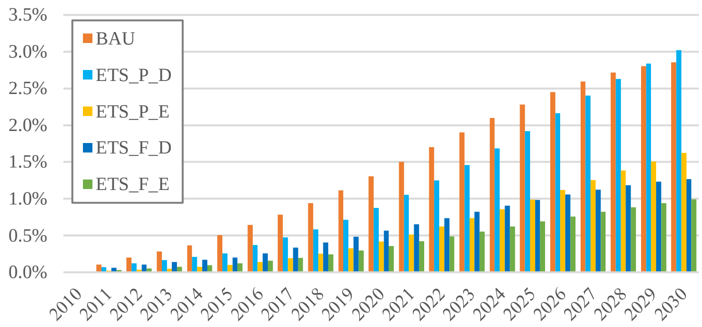

Figure 6. GDP Loss Compared to NULL Scenario

Although total emissions are set identically, the economic output in the alternative scenarios differs. The average yearly GDP growth under BAU is 6.26%, which is 0.15% lower than under NULL, which leads to a 2.9% GDP loss in 2030. Introducing ETS with the original regulation structure (ETS_P_D) lowers GDP loss in the early stages, but the loss begins to increase faster and surpass that of BAU after 2028. The average yearly GDP growth under ETS_P_D is 6.25%. Expanding the coverage of regulation (ETS_F_D) or eliminating unbalanced subsidy for green investments (ETS_P_E) leads to better economic effects. The average GDP growth rate is 6.34% under the ETS_F_D scenario and 6.32% under the ETS_P_E scenario. The GDP losses are also lower compared with the BAU and ETS_P_D scenarios. Of course, with a fully balanced regulation structure (ETS_F_E), the ETS generates the best economic output with 6.36% annual GDP growth. Figure 6 shows the cross-scenario comparison of the GDP losses[5] against the NULL scenario.

Comparing the economic effect of the ETS_P_E and ETS_F_D scenarios in Figure 6, we can conclude that elimination of the unbalanced green investment subsidy leads to a better economic performance in short-run, but in the long-run, balancing the regulation by expanding its coverage to all types of firms has the first-order effect.

5.2 Carbon Leakage and Emission Transfer

In the partial-coverage scenarios, the unbalanced regulation leads to variation in the MAC for CO_2 across firms. Variation in MAC, on one hand, directly lowers the short-term efficiency of emission reduction efforts, according to classical economics. And on the other hand, it leads to diversified incentives for green investments, and thus, affects the long-term efficiency of green investment. The difference in carbon leakage between regulated and unregulated firms in the partial-coverage scenarios shows the extent of regulation-induced distortion, as shown in Figure 7.

[5] GDP loss, rather than GDP, is used since the GDP differences across scenarios are very small compared to the absolute level of GDP. Using GDP loss makes the differences more visible in the figure.

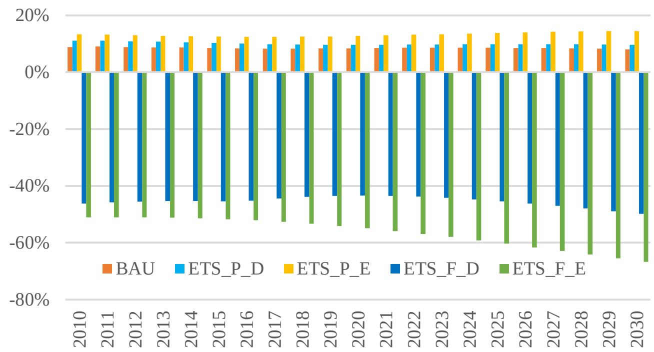

Figure 7. Carbon Leakage and Emission Transfer Rate

We can conclude from the figure that the carbon leakage in ETS_P_D is higher than the BAU scenario. Considering the fact that the emission target is enforced by using an intensity target in the BAU scenario, it implies a hidden output subsidy for emitters who can expand their output to acquire more emission permits. Without the subsidy for regulated firms in the EST_P_D scenarios, the regulated firms are worse off in their competition with unregulated firms, which leads to higher levels of leakage. The negative effect of the higher distortion level in ETS_P_D, especially over the long run, overwhelmed the positive effect of ETS, and led to higher economic losses compared to the BAU scenario. Elimination of the preferential subsidy for green investments by SOEs in the ETS_P_E scenario further worsened the competitive conditions for regulated firms, and thus intensified the distortion. Although the positive effect of elimination of the unbalanced financial subsidy led to higher economic output in the short run, we find a higher growth rate in the GDP loss, as shown in Figure 6.

Another interesting conclusion we can make from Figure 7 is that the effects of eliminating the unbalanced subsidy for green investment in the partial-coverage and full-coverage scenarios are actually opposite to one another. Two effects are involved. First, elimination of the subsidy worsens the competitive conditions of SOEs, and thus tends to be substituted by non-state owned firms to a greater extent, which leads to higher leakage. Second, elimination of the unbalanced subsidy directs more financial resources to small firms, which encourages emission reduction efforts by these firms. The first effect dominates in the partial-coverage scenarios, while the latter dominates in the full-coverage scenarios, which causes the opposite net effect.

5.3 Green Investment Allocation and Efficiency

The unbalanced financial conditions for different firms cause another type of distortion. The partial regulation increases the incentives for green investments in regulated firms, and furthermore, the preferential financial conditions further distort green investments toward SOEs. As introduced in the theoretical model, the concentration of green investments in regulated firms, especially subsidized SOEs, leads to unequal marginal revenues across firms and decreases the average efficiency of green investments. Aside from that, the higher demand for green investments is competing with other fixed capital investments, which will further affect the long-term economic growth.

Figure 8 shows the trajectory of total green investment (left panel) and its efficiency (right panel) to illustrate the argument mentioned above. In the BAU and ETS_P_D scenarios, green investment increases quickly as the emission targets tighten. The total amount of accumulated green investment through 2030 accounts for about 8% of GDP. However, the efficiency of green investment, defined as the change of CO_2 intensity from the NULL scenario divided by the amount of green investment per unit of energy input, decreases dramatically, especially after 2025. Both expanding the coverage of regulation (ETS_F_D) and elimination of the subsidy for SOE green investment (ETS_P_E) lower the total demand for green investments, while at the same time, its efficiency is significantly increased. In the ETS_P_E scenario, the accumulated green investment accounts for 4.4% of GDP in 2030 and 5.5% in the ETS_F_D scenario; while their efficiency rates in 2030 are 69% and 39% higher than that of BAU. With the fully balanced regulation structure (ETS_F_E), total green investment accounts for 4% of GDP in 2030, which is the lowest among the various scenarios. At the same time, green investment efficiency under ETS_F_E is the highest among the scenarios considered, which 84% higher efficiency compared with the BAU level.

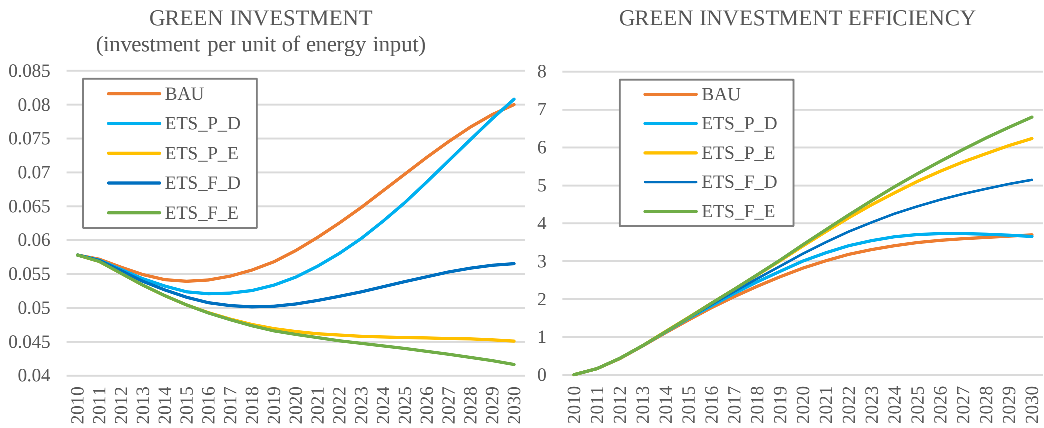

Figure 8. Total Green Investment and Efficiency

Note: Green investment efficiency is defined as the change of CO_2 intensity from the NULL scenario divided by the amount of green investment per unit of energy input.

Figure 9 shows the distribution of green investments in 2030. It indicates that with fully balanced regulation (ETS_F_E), the total amount of green investment accounts for about 4% of GDP in 2030, the largest share (about one-third) of which is made in small private firms (i.e., in SMEs). However, when small firms are exempted from emission constraints, they lose their incentives to make further investments in energy technology. Meanwhile, the higher demand from regulated firms for energy technology leads to higher costs for green investments, which further discourages green investments in small firms. From Figure 9 we can see that in the ETS_P_E scenario, the share of green investment in regulated firms increases, while the share in unregulated small firms decreases. The preferential subsidy for SOEs has a stronger effect in distorting the total demand and allocation of green investment. In the ETS_E_D scenario, the share of green investment decreases in all non-SOE firms, while the share for SOEs increases significantly, which overwhelms the decrease in other firms. And in the BAU and ETS_P_D scenarios, the joint effect of this dual distortion further distorts the allocation of green investment. The total amount of green investment with dual distortion (BAU and ETS_PD) accounts for about 8% of GDP in 2030, of which more than 65% is invested by SOEs.

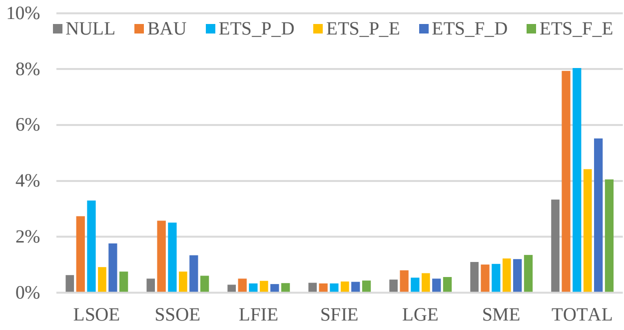

Figure 9. Total Green Investment (Share of GDP, 2030)

5.4 Economic Cost to Implement Green Investment Preference

The preferential subsidy not only distorts the allocation of green investment, but also requires remarkable public financing resources to implement it. As introduced in the theoretical model, the subsidy rate is determined by the gap between the energy input costs of SOEs in the regulated and unregulated scenarios. Figure 10 shows expenditures on the subsidy in the various scenarios. The expenditures grow along with the tightening of the emission targets. In the BAU scenario, subsidy expenditures account for 3.2% of GDP in 2030 and 3.6% in the ETS_P_D scenario. The expenditures in the ETS_F_D scenario are significantly lower, at 1.4% of GDP in 2030, since small firms share a large burden of the emission reduction when there is full-coverage regulation, which lowers the input cost of energy for SOEs.

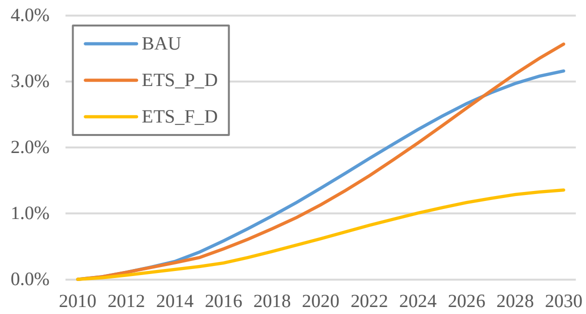

Figure 10. Green Investment Subsidy (Share of GDP)

5.5 Implication to the Fulfilment of Emission Targets

As shown in Figure 6, with partial regulation coverage and a preferential green investment subsidy, the distortion in the allocation of emission reduction burden and green investment across firms leads to greater economic losses. The level of distortion is partly determined by the share of emissions by regulated firms – as the share of emissions from regulated firms decreases, emission targets must be set more tightly. Meanwhile, the differences between regulated and unregulated firms in energy input costs will harm the competitive condition of regulated firms and lower their market share. Thus, the emission targets of regulated firms need to be further tightened to fulfill the same total emission target, which widens the variance in the marketplace. The preferential green investment subsidy can, to some extent, compensate for the loss of competitiveness in SOEs, but at the same time, it decreases demand for energy, which would decrease energy prices and lead to a decrease in the share of regulated firms' emission. A negative loop is triggered and intensified by the tighter emission target, which accelerates the growth of economic losses from emission reductions.

However, the emission reduction commitments made by China are all in terms of carbon intensity. Since it is calculated as emission per unit of economic output, a decrease in economic output would require a corresponding decrease in total emissions to keep up with the intensity target. Considering the effect of the feedback loop of uneven regulation and emission leakage, the unbalanced regulation scenarios significantly limit the potential for China's emission reduction efforts. According to the simulation results, in the BAU scenario the upper bound of China's emission commitment (65% decrease in carbon intensity from 2005 level by 2030) is unreachable, as shown in Figure 11. Further tightening the intensity target for regulated firms in BAU scenario between 1% and 10% leads to both decreases in total emission and GDP. However, the decrease in GDP accelerates as the emission target gets tighter, and surpasses the rate of total emission reduction, which leads to an upward curve in total carbon intensity before reaching the target. In the full coverage scenarios, such a situation is not observed.

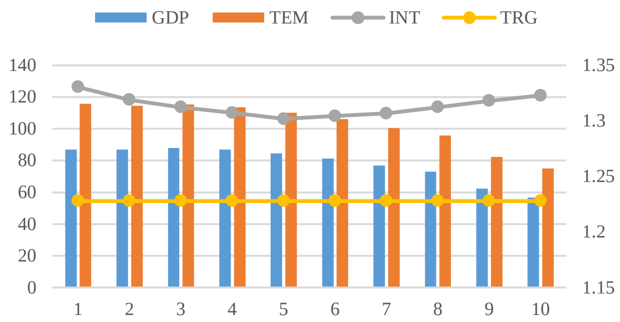

Figure 11. Implication of Tighter Emission Targets (BAU, 2022)

Concluding Remarks

Firm heterogeneity in production technologies and market conditions leads to variation in the responses of firms to policy regulations, which has significant implications for the effectiveness and economic efficiency of climate change policies. In this paper, we distinguished different types of firms with respect to their ownership type and size by using firm-level survey data, and separated them in the form of an IO table. A multi-sector, multi-period CGE model was applied to analyze the behavior of firms under unbalanced regulation and differentiated market conditions. Small private firms are mainly exempt from the emission constraints in the current regulatory structure for climate policy, while state-owned firms and large firms must follow the regulations and meet mandatory CO_2 intensity targets. In addition, a portion of regulated firms, mainly SOEs, are provided with preferential financial terms and conditions, including low- and no-interest loans and access to public funds, which is done to boost their market competitiveness. The numerical model simulation indicates that the exemption of small private firms from policy regulation leads to carbon leakage from regulated to unregulated firms, which intensifies the variance among firms in sharing the emission reduction burden and the incentives for green investment. SOEs have the highest incentives and make the majority of green investments for lowering their CO_2 intensity, while other regulated large private firms mainly rely on substituting fossil fuel energy with other input factors to fulfill their emission targets. Unregulated firms are discouraged from taking emission reduction efforts and making green investments given their lower energy prices and higher green investment costs, which leads to carbon leakage from regulated to unregulated firms. The leakage further intensifies the variation in emission reduction burden and green investment allocation since it decreases the market share of regulated firms and lowers the average efficiency of emission reduction efforts and green investment. At the same time, higher demand for green investment and subsidy expenditures for implementing the preferential financial conditions for SOEs leads to competition with other capital investment for financial resources, which affects economic growth in the long run. According to the scenario simulation results, the mandatory intensity target in the BAU scenario can decrease the total CO_2 emission by 30% at the cost of a 3% GDP loss in 2030.

Introducing emission trading does not necessarily lead to higher economic efficiency for emission reductions since the trading mechanism can increase leakage from regulated to unregulated firms, which intensifies the differences in emission reduction efforts and lowers average efficiency, especially in the long run. Elimination of the preferential subsidy for green investment or expanding regulation coverage can significantly increase the economic efficiency of emission reduction. Elimination of the preferential subsidy for SOEs equalizes the financial costs for green investment across firms and mitigates the distortion in the allocation of green investment. In the ETS_P_E scenario, green investment in SOEs is significantly decreased, which is mainly shifted to large private firms. While total green investment is 64% lower than in the BAU scenario, its average efficiency for improving energy efficiency is 71% higher. Even with a lower level of green investment, the higher efficiency of green investment combined with the reduction in subsidy expenditures leads to a higher economic growth rate (6.32%). Comparatively, expanding the regulatory coverage of emission constraint leads to higher economic efficiency. This scenario not only lowers the distortion in the emission reduction burden shared by different types of firms by equalizing the MACs, but also mitigates the misallocation of green investment by narrowing the gap between energy input costs of different firms. In the ETS_F_D scenario, total green investment is higher than that in the ETS_P_E scenario and its efficiency is lower. However, small private firms, who are exempted from regulation in the ETS_P_E scenario, contributed about 1/3 of the total emission reduction. Thus, the average yearly GDP growth is higher (6.34%). Further, in a perfectly balanced regulatory structure with full coverage of emission constraints and equivalent financial conditions for green investment, the economic efficiency of emission reduction is the highest (annual GDP growth at 6.36%) and the total efficiency of green investment is also the highest.

Summarizing the abovementioned results, we can conclude that under the unbalanced regulatory structure, the varying emission reduction strategies of different type of firms are significantly affecting the effectiveness and economic efficiency of climate policies in China. Expanding the coverage of regulation has a first-order effect in improving the economic efficiency of emission reduction efforts. On the other hand, overinvestment in energy technologies by a small portion of firms may decrease the total efficiency of investments and dampen long-term economic growth by competing with other fixed-capital investments for financial resources. A market-oriented arrangement for determining how firms share emission reduction burdens and mechanism for allocating green investment is crucial for China to achieve a more ambitious emission target in the long run.

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