Evaluating the Greening Effect of China's National Emissions Trading Scheme

Empirical and Theoretical Discussions

by

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Abstract

Environmental sustainability stands as a paramount global challenge, necessitating concerted efforts from governments and businesses worldwide. China has implemented significant regulatory measures in recent years to address environmental concerns, notably through the establishment of the national emissions trading scheme (ETS) in 2021, the world's largest of its kind. This paper investigates the impact of the China ETS on corporate environmental performance, particularly within the context of Environmental, Social, and Governance (ESG) metrics. Additionally, it examines the mechanisms of price incentives in driving carbon emissions reduction. The empirical analysis reveals both positive and negative effects on Environmental ratings, prompting considerations for policymakers regarding policy enforcement timing and potential strategic responses from firms. Theoretical models shed light on the interplay between energy input prices, carbon fines, and clean energy investment, emphasizing the importance of understanding energy cost structures and their implications for energy consumption.

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Contents

1   Introduction

Environmental sustainability is one of the most prominent challenges in the world today, endorsed and monitored by the United Nations Sustainable Development Goals, the Conference of Parties, and multiple other international climate action frameworks. Governments and the business world are taking action to address related environmental, economic, and social challenges globally.

The Chinese government has made considerable regulatory progress in the past decade in mitigation and adaptation. Some noteworthy milestones include the 2012 *Green Credit Guidelines* , the *Environmental Protection Law* revision in 2014, the 2016 issuance of *Guiding Opinions on Building a Green Finance System*, the dual-carbon goals announced in 2020, the 2021 establishment of the national emissions trading scheme (hereinafter China ETS), etc.

Emission trading systems are a key instrument linking climate mitigation goals with business activities. By marketizing carbon allowance and allowing for exchanges and trade, it is expected to improve the allocation of emissions caps and reduce overall emissions. As of 2022, there are 25 ETSs operational across different countries and regions, covering 17% of global emissions.[1] Remarkably, the EU ETS is the world's first international emissions trading system, established in 2005 and in its 4th implementation phase now.[2] On the other hand, the China ETS, established in 2021, is the largest ETS in the world, covering over 4.5 billion tons of CO2-equivalent emissions and more than 2,000 emitters from the power generation sector.[3] It adopts an intensity-based benchmarking mechanism, in contrast to the cap-and-trade mechanism of the EU ETS and several other ETSs.

Driven by policy change and examples of sustainability practices set by global industry leaders, the Chinese business world has increasingly incorporated environmental sustainability as a performance metric, notably through Environmental, Social, and Governance

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1. International Carbon Action Partnership (ICAP), "Emissions Trading Worldwide: 2022 ICAP Status Report," ICAP, Issued: March 29, 2022. 2022, accessed April 19, 2024, https://icapcarbonaction.com/en/publications/emissions-trading-worldwide-2022-icap-status-report.

2. *EU Emissions Trading System (EU ETS)*, https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en, Accessed: May 4, 2024, European Comission.

3. *Forecasting and Prospects Research Report*, http://ceep.bit.edu.cn, Issued: January 9, 2022. Accessed: April 19, 2024. Original in Chinese, CEEP.

(ESG). By mid-2020, 1,021 Chinese A-share firms (i.e. those listed on Shanghai and Shenzhen exchanges) had released annual ESG reports (including those labeled as sustainability, CSR, and similar themes), marking a threefold increase from 2009.[4] Compliance standards for businesses in emissions control and reporting have become more stringent, especially for publicly listed and pollution-intensive firms. ESG rating agencies that cover Chinese businesses include MSCI, Bloomberg, Wind, Refinitiv, etc.

Given the pressing nature of the climate crisis, critical inquiries into the effectiveness of implemented policies underscore their importance for both social planners and businesses. Social planners require accurate policy assessments to monitor endeavors, gauge advancements, and pinpoint obstacles, enabling timely adjustments to policies as necessary. Meanwhile, as major emitters and important agents of change, businesses must be given appropriate policy incentives to strike a balance between emissions reductions and productivity.

Centered on the intersection of carbon reduction policies and corporate environmental performance, this paper aims to assess the influence of the China ETS on the sustainability practices of enterprises. Moreover, it seeks to delve into the mechanisms of price incentives within the context of reducing carbon emissions. Embarking from the analysis of the ETS, this paper provides insights into how policy interventions can effectively drive environmental sustainability while maintaining economic viability. The paper will develop as follows. First, a literature review explores previous research areas and sets the basis of the analysis in the following sections. Second, an empirical test evaluates the effect of China's national ETS on corporate environmental performance. Then, a theoretical section models the carbon reduction incentives created by carbon pricing mechanisms. Finally, the conclusion presents a summary of findings, policy insights, and areas for future research.

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4. *Is Chinese business on the cusp of a 'leapfrog moment' in ESG reporting?*, https://www.weforum.org/agenda/2021/03/chinese-business-leapfrog-moment-esg-reporting/, Issued: March 25, 2021. Accessed: May 4, 2024, World Economic Forum.

2 Literature review

The literature on sustainability policy design is well-developed, covering both *ex-ante* policy design principle guidelines and *ex-post* impuact evaluation. On the conceptual end, climate action is considered necessary for long-term economic growth but may hinder short-term development, and is a classic example of the collective action and freeriding problem. Departing from conventional collective action theory which resorts to the binding power of an external supervising authority, Ostrom (2010)[5] recommended polycentric efforts that encourage localized efforts to address climate change and emissions reduction, as opposed to solely relying on centralized global efforts. Barnett et al. (2023)[6] and Acemoglu et al. (2012)[7] highlighted the significance of investing in research and development (R& D) as catalysts for change, rather than relying excessively on gradualistic approaches to reduce emissions such as carbon taxes. Harvey et al. (2018) proposed design principles and guidelines for policymakers and advocates, customizing policies that align with the specific goals and characteristics of each sector. On the specific subject of ETS design and energy market design, Borenstein et al. (2019)[8] predicted that the Californian cap-and-trade ETS may lead to extremely low or high allowance prices, given the inelastic nature of an absolute emissions cap and the stringent carbon reduction requirements imposed by complementary policies. This effect could be even more exacerbated when compliance periods are short. Acworth et al. (2018)[9] analyzed how ETS allowance prices may be transmitted to electricity prices in the power sector. Boute (2017)[10] and Verde et al.

5. Elinor Ostrom, "Polycentric systems for coping with collective action and global environmental change," *Global Environmental Change* 20, no. 4 (2010): 550–557, https://doi.org/10.1016/j.gloenvcha.2010.07.004.

6. Michael Barnett et al., "How Should Climate Change Uncertainty Impact Social Valuation and Policy?," *University of Chicago, Becker Friedman Institute for Economics Working Paper* 140 (November 2023), http://dx.doi.org/10.2139/ssrn.4621281.

7. Daron Acemoglu et al., "The Environment and Directed Technical Change," *American Economic Review* 102, no. 1 (2012): 131–166, https://doi.org/10.1257/aer.102.1.131.

8. Severin Borenstein et al., "Expecting the Unexpected: Emissions Uncertainty and Environmental Market Design," *American Economic Review* 109, no. 11 (2019): 3953–3977, https://www.aeaweb.org/articles?id=10.1257/aer.20161218.

9. W. Acworth et al., *Emissions Trading and Electricity Sector Regulation*, technical report (Berlin, Germany: ICAP, 2018).

10. Anatole Boute, "The Impossible Transplant of the EU Emissions Trading Scheme: The Challenge of Energy Market Regulation," *Transnational Environmental Law* 6, no. 1 (2017): 59–85, https://doi.org/10.1017/S2047102516000133.

(2021)[11] pointed out practical considerations in "transplanting" the EU ETS model to other countries such as China and noted particular challenges in calibrating an energy policy mix, preventing waterbed effects, balancing market-based pricing and regulatory control, etc.

On the empirical end, quantitative surveys into policy impacts and effectiveness are heavily contingent on quantifiable indicators, which are constrained by the various definitions and implications of sustainability, more so its measureability. Nevertheless, with macroeconomic and firm-level statistics, such as emissions, investment, and ESG performance, significant studies highlighted the benefits and costs of such policies. Using emissions as the indicator, Gugler et al. (2021)[12] found evidence supporting the higher efficiency of carbon pricing compared to subsidizing renewables in emissions abatement. Using investment as the indicator, Chipalkatti et al. (2021)[13] examined linkages between country-level sustainability governance and FDI inflows in 161 countries and found effects in both positive and negative directions. In China's context, aspects such as environmental quality, industrial structure, economic growth, and corporate ESG performance have been analyzed with respect to various regulations (Cao et al. 2023;[14] Dai et al. 2023;[15] Zhang et al. 2018[16]). Regarding the adoption of ESG ratings as a measure of corporate-level sustainability, there has been both endorsement and critique. Walter (2020)[17] proposed a

11. Stefano F. Verde et al., "The EU ETS and its companion policies: any insight for China's ETS?," *Environment and Development Economics* 26, no. 3 (2021): 302–320, https://doi.org/10.1017/S1355770X20000595.

12. Klaus Gugler, Adhurim Haxhimusa, and Mario Liebensteiner, "Effectiveness of climate policies: Carbon pricing vs. subsidizing renewables," *Journal of Environmental Economics and Management* 106 (2021): 102405, https://doi.org/10.1016/j.jeem.2020.102405.

13. Niranjan Chipalkatti, Quan Vu Le, and Meenakshi Rishi, "Sustainability and Society: Do Environmental, Social, and Governance Factors Matter for Foreign Direct Investment?," *Energies* 14, no. 19 (2021): 6039, https://doi.org/10.3390/en14196039.

14. Mingyao Cao, Keyi Duan, and Haslindar Ibrahim, "Green investments and their impact on ESG ratings: An evidence from China," *Economics Letters* 232 (2023): 111365, https://doi.org/10.1016/j.econlet.2023.111365.

15. Wei Dai, Mengyao Cheng, and Linhao Zheng, "The effect exerted by environment regulation on industrial structure optimization: Evidence of 286 China's cities on the prefecture level," *Heliyon* 9, no. 5 (2023): e16406, https://doi.org/10.1016/j.heliyon.2023.e16406.

16. Huaming Zhang, Zhishuang Zhu, and Yingjun Fan, "The impact of environmental regulation on the coordinated development of environment and economy in China," *Natural Hazards* 91, no. 2 (2018): 473–489, https://doi.org/10.1007/s11069-017-3137-3.

17. Ingo Walter, "Sense and Nonsense in ESG Ratings" (Forthcoming in *Journal of Law, Finance and Accounting.* Available at: https://ssrn.com/abstract=3568104 or http://dx.doi.org/10.2139/ssrn.3568104 . July 2020).

framework for sensible ESG considerations, acknowledging the dynamic tension between market performance and the social control platform with various stakeholders holding firms accountable, as well as distortions in ESG ratings.

This paper bears in mind the complexity of sustainability and refers to the empirical methodologies and specifications of past literature. It contributes to the ongoing discussion of measuring the microeconomic impacts of green policies, particularly the ESG performance impacts of the recently established China national ETS. It also attempts to establish an explanation of how carbon pricing incentivizes carbon reduction, which predicts emissions abatement outcomes in different model 'setups.

3 An evaluation of the China ETS

3.1 ETS description

In 2013 and 2014, China established 7 local pilot carbon markets in Shenzhen, Shanghai, Beijing, Guangdong, Tianjin, Hubei, and Chongqing, followed by the 2016 establishment of the Fujian carbon market.[18] Each market operates independently and covers different sectors and greenhouse gases (GHGs). Together, they paved the way for the later established national ETS. Since all local markets are still in force today, they continue to regulate emitters that are not within the scope of the national ETS. The total revenue of these 8 carbon markets has reached 2.5 billion RMB since their establishment.[19]

Given the experience and success of local carbon trading markets, in 2020, China's Ministry of Ecology and Environment announced the establishment of the national emissions trading scheme (China ETS) that would start operations in 2021.[20] Trading entities in the national ETS are called "key emitters", defined as major GHG emitters that emit 26,000 tons of carbon dioxide equivalent annually in key polluting industries. In the first year of China ETS's operations (2021-2022), power generation is the only participating

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18. *International Carbon Action Partnership*, https://icapcarbonaction.com/en, Accessed: April 19, 2024.

19. *International Carbon Action Partnership*.

20. *Administrative Measures for Carbon Emission Trading (Trial)*, https://www.mee.gov.cn/xxgk2018/xxgk/xxgk03/202012/W020201230736907121045.pdf, Accessed: April 19, 2024.

industry, consisting of over 2000 key emitters and over 4.5 billion tons of CO2-equivalent emissions.[21] Power generation is categorized under the utilities sector. In the following years from 2023 to 2025, participating industries are expected to expand to cover petrochemicals, chemicals, building materials, iron and steel, non-ferrous metals, paper, aviation, and other key-emitting industries belonging to the upper sectoral category of manufacturing and transport.[22]

(a) China ETS Volume, Price, and Value   (b) Comparison of ETS allowance prices
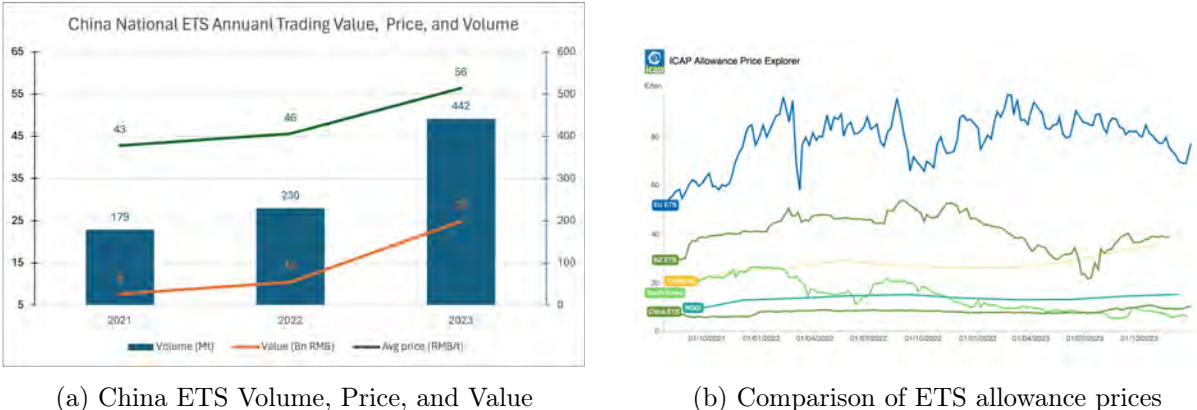
Figure 1: Comparison of ETS volumes and allowance prices

China ETS, unlike the cap-and-trade mechanism of EU ETS or California ETS, adopts an *ex-post* intensity-based benchmarking mechanism. In the primary market, regulated emitters receive a free pre-allocation of emission allowances based on their output level and a carbon emissions intensity benchmark based on their means of production For example, the 2019-2020 benchmark of general coal-fired power sets above 300 MW was 0.877 tCO2/MWh for electricity or 0.126 tCO2/GJ for heat.[23] Producers with a lower emissions intensity than the benchmark may have an advantage in emitting less carbon than allocated for the same level of output. In the secondary market, China Emissions Allowances (CEAs) are exchanged through the Shanghai Environment and Energy Exchange (SEEE). CEAs for different years, namely 2019-2020, 2021, and 2022 are categorized as three different products but have similar prices. The compliance period is every two calendar years. Trading entities were asked to submit emission allowances in 2021 corresponding to emis-

21. *Forecasting and Prospects Research Report*.

22. *China ETS Industry Sector Inclusion Timeline*, Source: Refinitiv, Accessed: April 12, 2024.

23. *Implementation Program for the Setting and Allocation of Total National Carbon Emission Trading Allowances for 2019-2020 (Power Generation Sector)*, https://www.mee.gov.cn/xxgk2018/xxgk/xxgk03/202012/W020201230736907121045.pdf, Issued: December 29, 2020. Original in Chinese, Ministry of Ecology and Environment.

sions from 2019 and 2020, and submit allowances in 2023 for emissions generated in 2021 and 2022.[24]

The following empirical analysis aims to quantify the effect of China's national ETS on the level of environmental performance of key companies in the affected industries. It makes a sectoral comparison between ETS-covered and non-covered industries, making a claim on the sectoral effect of the ETS.

Table 1: ETS-participating Sectors and Year of Participation

ETS-participating Sectors	Upper Industry Categories (GB/T 4754-2017)	Year of ETS Participation
Power generation	Utilities	2021
Papermaking Refinery Chemicals Building materials Steel Non-ferrous metal	Manufacturing	2023-2025
Civil aviation	Transport	2025

3.2 Hypotheses

The establishment of China's ETS sends a strong signal to the power generation industry that their excessive emissions will generate additional costs, incenting more efforts to cut emissions. To cut emissions, common practices include sourcing more clean energy input, reducing fossil fuel input, optimizing production technologies, improving energy efficiency, managing operational usage, etc., which may increase their environmental pillar scores. Particularly, because of the intensity-based benchmarking mechanism, firms may choose to adopt technologies that generate less emissions per MWh of electricity, such that their output levels remain the same. These efforts may organically spill over to other sub-categories of the utility industry due to upstream and downstream supply chain interactions and technology transfers, while also inorganically raising the average environmental performance of the entire utility industry, leading to a general increase in

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24. *International Carbon Action Partnership*.

the Environmental ratings in the utility industry.

Hypothesis 1: The establishment of China's national ETS causes an increase in the Environmental ratings of utility companies.

A similar incenting effect also applies to other emission-intensive industries that have been named by the policy in question, including papermaking, refinery, chemicals, etc., all of which belong to the upper industry categories of manufacturing and transportation. Similar organic spillover and inorganic average increasing effects also apply. However, since they are not directly nor immediately included in the first batch of ETS-applicable industries, they may take a more progressional approach to reducing emissions, hence leading to a less significant increase in the Environmental pillar scores.

Hypothesis 2: The establishment of China's national ETS causes an increase in the Environmental ratings of companies in the manufacturing and transportation industries.

Hypothesis 3: The establishment of China's national ETS improved the Environmental ratings of utility companies more significantly than manufacturing and transportation companies.

The three hypotheses will be tested using the same regression model but with different samples.

3.3   Methodology

We use a difference-in-difference (DID) model which is commonly in evaluating the impacts of policies. P is the time variable denoting the scenario before and after the policy announcement in 2021; T is the group variable of treatment and control based on whether the industry to which the enterprise belongs is within the scope of the ETS.

$$\text{E}_{igt} = \beta_0 + \beta_1 \cdot T_g + \beta_2 \cdot P_t + \beta_3 \cdot D_{igt} + \gamma_{igt} + \varepsilon_{igt}$$

γ is a set of control variables that may affect the dependent variable that is other than the policy in question, typically concerning financial performance metrics as suggested by Lei, N., Miao, Q. & Yao, X. (2023),[25] and Lu, S., and Cheng, B. (2023).[26] Detailed

25. Ni Lei, Qin Miao, and Xin Yao, "Does the implementation of green credit policy improve the ESG performance of enterprises? Evidence from a quasi-natural experiment in China," *Economic Modelling* 127 (2023): 106478, https://doi.org/10.1016/j.econmod.2023.106478.

26. Shiyu Lu and Bo Cheng, "Does environmental regulation affect firms' ESG performance? Evidence

variable definitions and summary statistics are listed in Table 2 below.

Table 2: Variable Labels and Definitions

| Labels	Variables	Definitions
EScore	Dependent variable	Corporate environmental performance obtained from Wind's ESG rating
T	Group variable	A dummy variable which equals 1 for treated industries, and 0 otherwise
P	Time variable	Equals 1 for 2021 and beyond
D	Interaction term of T and P	$D = T \times P$
SScore	(Control) The social performance of enterprise	Obtained from Wind's ESG rating
GScore	(Control) The governance performance of enterprise	Obtained from Wind's ESG rating
Size	(Control) Firm size	The natural logarithm of total annual assets
Lev	(Control) Debt level	The ratio of total liabilities to total assets at the end of the year
ROA	(Control) Return on assets	The ratio of net profit to total asset
SOE	(Control) Ownership nature	A dummy variable that equals 1 when the firm is state-owned
Indep	(Control) Independent director ratio	The number of independent directors divided by the total number of directors
ROE	(Control) Return on equity	Net income / average shareholder equity
ATO	(Control) Asset turnover Ratio	Total sales / average assets
Cashflow	(Control) Business performance	Cashflow / total asset
Inv	(Control) Inventory turnover ratio	Cost of goods sold / total asset
Fixed	(Control) Fixed Asset Ratio	Fixed asset / total asset
Growth	(Control) Revenue growth rate	Revenue this year / revenue last year -1
Board	(Control) Board members	Natural log of the number of board members
TobinQ	(Control) Tobin's Q	Market value / book value of equity net of liabilities

from China," *Managerial and Decision Economics* 44, no. 4 (2023): 2004–2009, https://doi.org/10.1002/mde.3796.

3.4 Data

Data from 12,829 firms in 17 industries are collected from Wind Financial Terminal, a financial database specializing in Chinese companies. Variables include ESG rating data, particularly the environmental pillar scores, of public companies from Wind along with their social and governance pillar scores and financial data for every year between 2018 and 2022. The sample excluded 4 categories from all of China's industries for the lack of data: repairs, finance, public sector, and international organizations.

Table 3: Summary Statistics

Variable	Obs	Mean	Std. dev.	Min	Max
E	12,202	2.461152	1.989815	.02	10
S	12,203	4.305459	1.824986	0	10
G	12,203	6.553438	.9531579	.63	10
Size	12,819	22.51152	1.368947	19.80989	26.45228
Lev	12,819	.4179561	.1974172	.052086	.9244456
ROA	12,819	.0434514	.071104	-.382078	.255226
ROE	12,810	.0650677	.1412514	-.961592	.415105
ATO	12,818	.6427709	.4051832	.061936	2.891314
Cashflow	12,818	.0554087	.0661469	-.1614397	.2656142
Inv	12,766	.1280019	.1064561	.0003123	.654397
Fixed	12,819	.2134217	.1487258	.0015913	.6893799
Growth	12,815	.1433798	.3275176	-.653478	2.032411
Board	12,818	2.111099	.1914768	1.609438	2.639057
Indep	12,818	.3779418	.0537592	.2857143	.5714286
TobinQ	12,818	1.847474	1.194315	.802414	9.817297
SOE	12,819	.3128169	.4636586	0	1
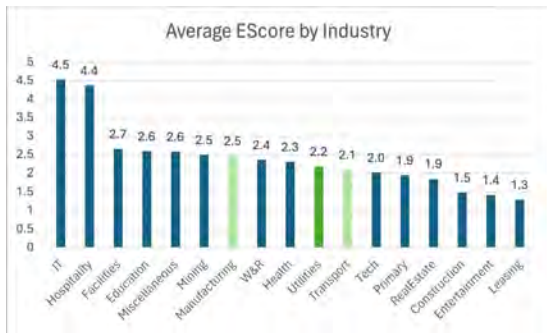
(a) Average Environmental Pillar Score by Industry
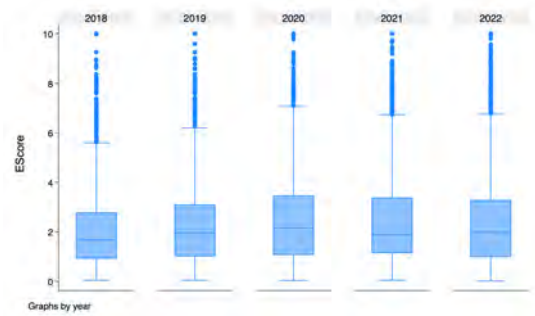
(b) Environmental Pillar Score Box Plot by Year

Figure 2: Summary of Environmental Pillar Scores

Due to data availability challenges, the specific emissions amount of key emitters from 2018 to 2022 cannot be identified to be included in this dataset. However, we can still derive valuable insights into how the ETS affects major players in the selected industries and their environmental commitments.

3.5 Results

This experiment is run 3 times for different groupings of treatment and control. First, the treatment group is the industry currently included in China's ETS – that is, utilities; Second, the treatment group includes industries announced to be included in China's ETS in the near future – that is, manufacturing and transport; Third, on all three industries above. The first grouping (named "Current") evaluates the direct effect of the ETS on the included utility companies; The second grouping (named "Future") evaluates the spillover effect of the announcement of ETS on related industries and reflects how the expectation of ETS participation affects firm environmental performance; The third grouping (named "All") reflects an overall effect on the three environmentally impactful industries. For each grouping, the first specification ("Complete") included all control variables, while the second specification ("Partial") dropped some control variables, keeping only those included in the specification in the aforementioned referenced articles. Reports are reported in Table 4.

Furthermore, an alternative panel difference-in-difference test is run year-by-year following the first grouping where utilities are the treated industry group. Since data is missing for some entities for specific years, a balanced sub-sample is taken from the original sample so that all entities have complete data each year, ensuring that they receive the treatment at the same time. While a significant positive impact is identified on the interaction term (coefficient = .6651547, robust standard error = .0049782, significant at the 0.01 level) and passes the Granger causality test, it cannot pass the parallel trends test, as shown in Figure 3.
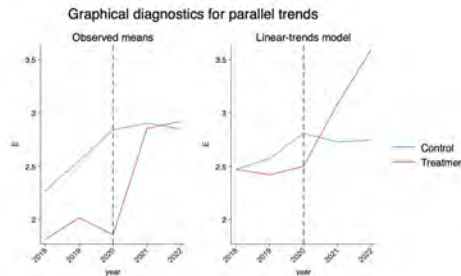

Figure 3: Year-by-year DID Trend Plot

Table 4: Regression Results

	(1)Current		(2)Future		(3)All	
	Complete	Partial	Complete	Partial	Complete	Partial
EScore	0.098***	0.092***	0.178***	0.174***	0.183***	0.177***
	(0.024)	(0.024)	(0.052)	(0.051)	(0.052)	(0.051)
T	-1.025***	-0.985***	-0.118	-0.092	-0.171**	-0.145*
	(0.167)	(0.164)	(0.076)	(0.075)	(0.076)	(0.075)
D	0.750***	0.689***	-0.102*	-0.105*	-0.069	-0.071
	(0.119)	(0.118)	(0.057)	(0.057)	(0.057)	(0.057)
SScore	0.349***	0.348***	0.356***	0.355***	0.352***	0.350***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
GScore	0.100***	0.107***	0.102***	0.109***	0.099***	0.107***
	(0.015)	(0.015)	(0.016)	(0.016)	(0.015)	(0.015)
Size	0.417***	0.404***	0.414***	0.402***	0.407***	0.394***
	(0.023)	(0.022)	(0.023)	(0.023)	(0.023)	(0.022)
Lev	-0.692***	-0.765***	-0.732***	-0.786***	-0.777***	-0.812***
	(0.138)	(0.132)	(0.141)	(0.135)	(0.138)	(0.133)
ROA	-2.543***	-1.175***	-2.506***	-1.175***	-2.450***	-1.157***
	(0.525)	(0.228)	(0.537)	(0.230)	(0.527)	(0.229)
SOE	0.005	0.019	0.008	0.022	-0.032	-0.018
	(0.056)	(0.056)	(0.057)	(0.057)	(0.056)	(0.056)
Indep	-0.405	-0.340	-0.393	-0.322	-0.379	-0.319
	(0.333)	(0.333)	(0.338)	(0.338)	(0.333)	(0.333)
ROE	0.629***		0.589**		0.559**	
	(0.231)		(0.238)		(0.232)	
ATO	0.113*		0.115**		0.147**	
	(0.058)		(0.058)		(0.058)	
Cashflow	0.946***		0.943***		0.927***	
	(0.235)		(0.237)		(0.235)	
Inv	-0.300		-0.255		-0.162	
	(0.211)		(0.213)		(0.210)	
Growth	-0.205***		-0.191***		-0.201***	
	(0.041)		(0.041)		(0.041)	
TobinQ	0.067***		0.070***		0.068***	
	(0.015)		(0.015)		(0.015)	
_cons	-8.859***	-8.466***	-8.750***	-8.384***	-8.553***	-8.137***
	(0.496)	(0.481)	(0.518)	(0.504)	(0.508)	(0.493)
R^2	0.1828	0.1748	0.1839	0.1756	0.1796	0.1711
N	12,145	12,202	11,730	11,780	12,145	12,202

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

3.6 Discussion

The result on the average treatment effect of the first grouping, *Current*, shows that China's ETS has a significant positive impact on the environmental performance of utility companies, aligning with *Hypothesis 1*. This could be because the establishment of the ETS nudged utility companies to reduce carbon emissions to cut related costs, hence improving their environmental ratings.

The result on the average treatment effect of the second grouping, *Future*, shows that

China's ETS has a somewhat significant negative impact on the environmental performance of manufacturing and transport companies, conflicting with *Hypothesis 2* while aligning with *Hypothesis 3*. This negative effect can be attributed to several reasons, one of which could be that the ETS incentivized environment-negligent profit-maximizing practices for short-term gains before these industries are integrated into the Scheme since the price of carbon emissions is expected to rise in the future. Another explanation could be a focus on efficiency and profits as part of post-COVID recovery goals, and sustainability is given less priority.

3.7 Limitations

The empirical test is significantly constrained by data availability. The first and foremost constraint is the lack of data on strictly defined "key emitters" and "non-key emitters". Emissions data are not widely and publicly available. The ideal dataset for the purpose of this empirical design would include plant-level emissions, matched with company-level performance indicators. However, this dataset is not available to the author as of now. In the absence of emissions data, using ESG ratings as a proxy for company environmental performance may obscure the direct effect on emissions amount since ESG ratings are compounded metrics with other criteria than emissions. Additionally, a higher ESG rating does not necessarily mean a greener business.

Another restriction is that this dataset was only able to identify the primary sectoral classification of enterprises (i.e. utilities, manufacturing, and transport), while the ETS regulates enterprises based on secondary classifications (e.g. power generation, papermaking, refinery, etc.). The grainy classification of the sample creates spillovers and cannot accurately identify the differential effects on the secondary level.

The timeline of China ETS could account for the failure of the parallel trends test. Due to the trial of local carbon markets preceding the national market, companies in power generation and other included industries may have already adjusted their emissions behavior prior to 2021, violating the parallel trends with other industries. To address this concern, a regression discontinuity design near the national ETS inclusion threshold of

26,000 t emissions can be done for only the power generation sector, revealing whether the inclusion of the national ETS incentivized significant changes in performance compared to those emitting slightly below the threshold.

4   Carbon reduction incentives: a theoretical framework

4.1   Uniform carbon pricing

4.1.1   Static model

Drawing from the previous section, we now shift to consider why and how carbon pricing motivates carbon reduction, and how this price incentive interacts with substitute price, time scope, resource scarcity, and other factors.

We start with a baseline static model where there is a uniform price for carbon-intensive energy sources. Think from the perspective of a small power generation company in a competitive market that purchases two types of energy sources as inputs: carbon-intensive energy sources such as coal (denoted as C) and clean energy sources such as hydrogen (denoted as R). With a combination of this resource input, the company produces one energy output such as electricity to sell to consumers at one price. The goal of the firm is to choose an optimal production set, i.e. a cost-minimizing amount of C and R, to produce a fixed amount of electricity output. Below are detailed assumptions.

Assumption 1: (Input-output) The firm only uses two inputs (C and R) and produces only one output (Y)

Assumption 2 (Technology constraints): $Y = \alpha \cdot C + \beta \cdot R$, where α and β are both positive and represent the factor productivity, i.e. energy efficiency of C and R, respectively

Assumption 3 (Price constraints): Factor prices are at p_C and p_R per unit respectively, $0 < p_C < p_R$. The total cost function is hence $TC = C \cdot p_C + R \cdot p_R$

Assumption 4 (Rational cost minimizer with a fixed output objective): The firm generates a fixed amount of output $\bar{Y}$. As a rational agent, the firm chooses an optimal bundle (C^*, R^*) that reaches this output at the minimal TC

Evidently, given some fixed α, β, p_C, and p_R, the optimal solution will depend on

factor prices and factor productivity. Depending on whether the marginal rate of technical substitution (MRTS, here representing energy efficiency) α/β is smaller than, equal to, or greater than the price ratio p_C/p_R, the firm chooses a corner solution with all fossil fuel, an arbitrary interior solution, or a corner solution with all clean energy. In other words, the firm will rely on whichever energy source that is more cost-efficient, i.e. the source that generates more electricity output for every dollar spent on buying this energy source. The graph below illustrates the solution.
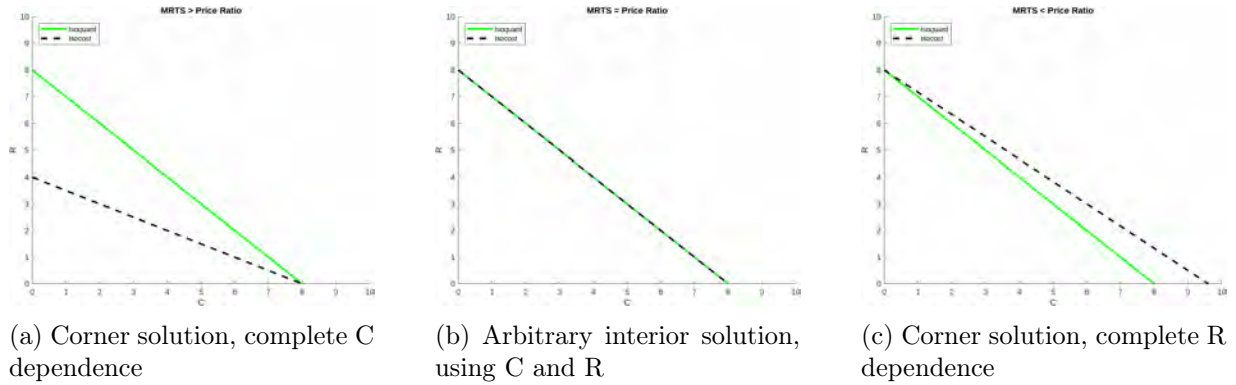

(a) Corner solution, complete C dependence

(b) Arbitrary interior solution, using C and R

(c) Corner solution, complete R dependence

Figure 4: Solutions of Static Uniform Pricing Model

4.1.2 Dynamic model

Let us now consider a dynamic scenario where there is a progressive increase in the relative price of carbon emissions, for reasons such as increasingly stringent carbon taxes. In a time scope t (20 years, 50 years, 100 years, etc., to infinity), the price of fossil fuel will exogenously increase at a fixed rate $r > 0$ each year. Foreseeing this price increase, the power generation firm has an incentive to shift away from fossil fuels to clean energy, particularly when the tipping point described in the above static setup is reached. However, this transition must be a progressive process rather than an immediate one, where the firm must choose to reduce its fossil fuel usage at a fixed rate $d > 0$ each year. The goal of the firm, generating the same amount of total energy $\bar{Y}$ at each time period, is to choose the optimal carbon reduction rate d such that the total cost of energy for all periods aggregated is minimized.

Additionally, for simplicity, we can assume that in the first period $t = 1$, the firm starts with a total dependence on fossil fuel and zero clean energy usage. It is hence implied that

$p_C/p_R < \alpha/\beta$, based on the previous static model. Assume no future discounting. Below is a detailed description of the model.

Table 5: Consumption of C and R in Each Period

t	C	p_C	R	p_C
1	C	p	0	kp
2	$(1-d)C$	$(1+r)p$	dC	kp
3	$(1-d)^2 C$	$(1+r)^2 p$	$[1-(1-d)^2]C$	kp
...	...	...	...	...
n	$(1-d)^n C$	$(1+r)^n p$	$[1-(1-d)^n]C$	kp

$$
\begin{aligned}
\sum_{t=1}^{n} TC_t &= \sum_{t=1}^{n} TC_t^C + \sum_{t=1}^{n} TC_t^R \\
&= \sum_{t=1}^{n} (1-d)^{t-1} \cdot C \cdot (1+r)^{t-1} \cdot p + \sum_{t=1}^{n} [1-(1-d)^{t-1}] \cdot C \cdot k \cdot p \\
&= C \cdot p \cdot \sum_{t=1}^{n} \left[(1+r)^{t-1} \cdot (1-d)^{t-1} + k \cdot \left(1-(1-d)^{t-1}\right) \right]
\end{aligned}
$$

The optimal choice of d depends on how rapidly the price ratio catches up with the marginal rate of technical substitution (MRTS). The faster the price ratio increases and the smaller the initial price gap between C and R, the sooner C will be less cost-efficient than R, leading to a larger d chosen by the firm. Given a sufficiently large time horizon for this catch-up to occur, d will converge to some value, such that for every period after this convergence, the firm only inputs R and does not use C. This implies that for the policy maker, assuming an exogenous initial energy input price, raising carbon prices faster, and announcing the long-term nature of this price rise can incentivize a faster energy transition, which matches our intuition. Below are some illustrative examples of different choices of d given some n, k, and r.

A limitation of this model is that it assumes clean energy to be readily available, opposite to the reality where extensive research and development are needed to facilitate the use of clean energy sources. There should be a significant fixed cost invested to develop such technologies and grow clean energy stock, in addition to a variable cost. Section 4.2.2 will attempt to address this limitation.
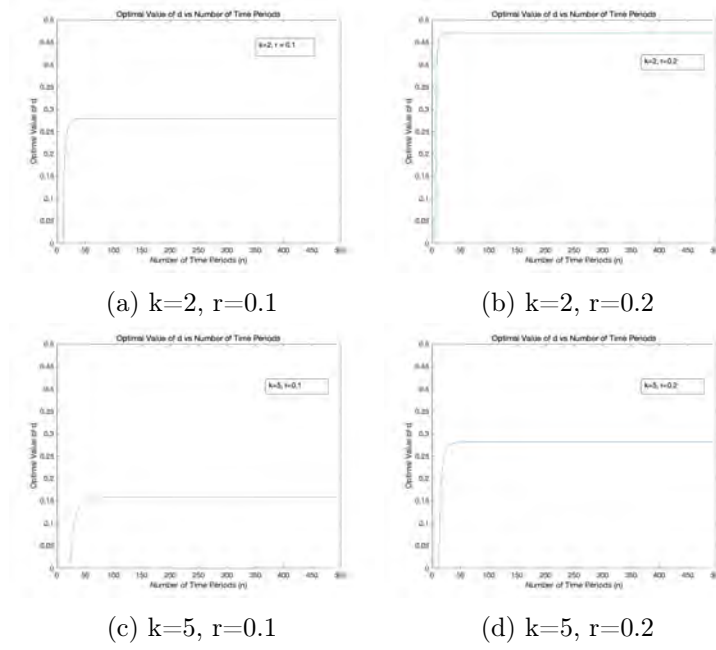
(a) k=2, r=0.1   (b) k=2, r=0.2

(c) k=5, r=0.1   (d) k=5, r=0.2

Figure 5: Solutions Given Different Parameters

4.2 Two-part carbon pricing

4.2.1 Static model

Based on the previous uniform carbon pricing model, we construct a two-part pricing scheme that captures a carbon fine. If the firm inputs equal to or below the threshold fossil fuel quantity of C_f, the per unit factor price of fossil fuels is still the regular price p_C. If the firm consumes a quantity of fossil fuel above the threshold, it will pay a carbon fine that is a markup rate λ above the regular price. That is, for every unit of excessive fossil fuel consumption, the unit cost of fossil fuel is $(1 + \lambda) \cdot p_C$.

This new pricing plan changes the firm's budget line from a straight line to a two-part polyline with different slopes (corresponding to two price ratios) and the pivotal point is at $C = C_f$. For $C < C_f$, the slope is p_C/p_R, the same as before in the static uniform pricing model. For $C > C_f$, the slope is $(1 + \lambda) \cdot p_C/p_R$, which is steeper, representing an increase in the relative price of fossil fuel. Despite this difference, the firm's optimal bundle still depends on how the MRTS compares to the two price ratios. Figure 6 illustrates the optimal bundle given different cost efficiencies.
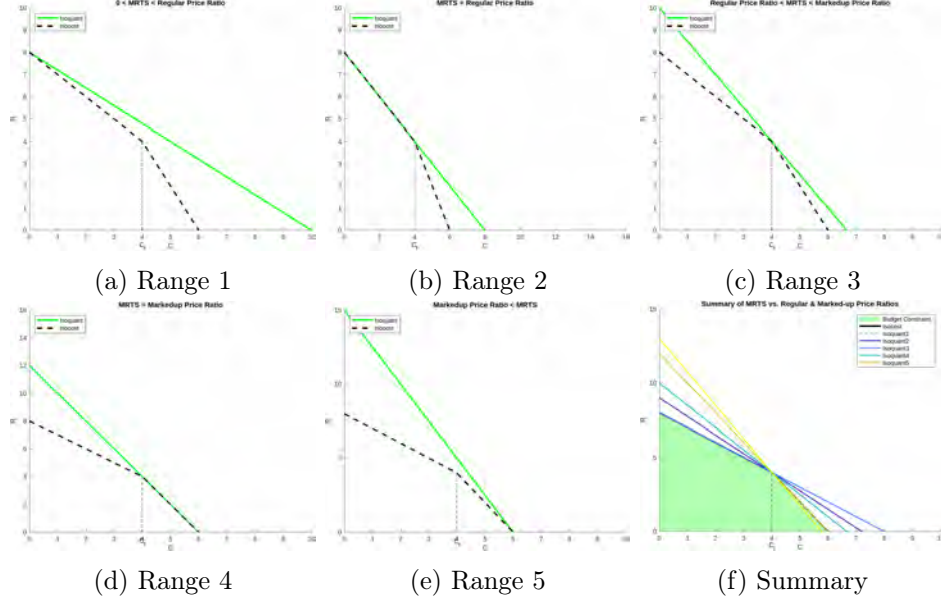
(a) Range 1 (b) Range 2 (c) Range 3

(d) Range 4 (e) Range 5 (f) Summary

Figure 6: Solutions of Static Two-Part Pricing Model

4.2.2 Dynamic model

We now make this model dynamic but in a different way than the previous dynamic model. Previously, the increase in the relative price of carbon is considered exogenous, and resource scarcity is not considered. We scrutinize these underlying assumptions by assuming that endowments of fossil fuel and clean energy are both scarce. However, clean energy supply can grow with investment, which will in turn affect the price of clean energy. This resembles the macroeconomic Solow model where the capital stock grows with investment. This model is inherently dynamic with multiple periods.

For simplicity, we assume that $\alpha = \beta = 1$, hence $Y = C + R$, removing the need to consider MRTS.

On the resource demand side, for each time period, the firm still chooses a cost-minimizing input bundle of fossil fuel and clean energy (C^*, R^*) for a fixed goal of total electricity output $(\overline{Y})$.

On the resource supply side, in the first period, the factor endowments are $(\overline{C}, \overline{R})$. For future periods, the same $\overline{C}$ is endowed every period, while the clean energy supply can grow with investment, causing the total amount of available energy resources to increase.

Supply and demand are connected by the same carbon fine mechanism outlined in the static scenario, where the price of fossil fuel will be marked up at $(1 + \lambda) \cdot p_C$ if the

threshold C_f is exceeded. Assume $\overline{C} > C_f$ such that there will be a positive amount of carbon fine generated in the first period to start the dynamics. The carbon fine paid by the firm each period will be 100% reinvested by the policymaker to stimulate the growth of renewable energy supply, following the equation of $R_{t+1} = R_t + i \cdot I_t$, where R_t denotes the amount of clean energy supply available for input at time t, I_t denotes investment, and i represents the efficiency of investment. Further, the price of clean energy is subject to the supply quantity, following the equation of $p_{R_t} = a - b \cdot R_t$, where $a, b > 0$ are given constants.

Recall that a fixed amount of $\overline{Y}$ must be generated each time period. Assume $\overline{Y} = \overline{C} + \overline{R}$, such that the firm consumes all resource endowments in the first period. This implies that as more renewable energy becomes available, there will be some amount of resource surplus that is not consumed by the firm. We assume that this surplus cannot be carried over to the next period and does not affect prices.

A further assumption is that the initial prices $p_R > (1 + \lambda) \cdot p_C > p_C$, such that the firm would initially rather pay the carbon fine than use clean energy.

Intuitively, we can reason that the fine generated in the first period leads to an increase in the supply of R and a decrease in the price of R. However, this will not immediately change the consumption bundle of the firm if $p_R > (1 + \lambda) \cdot p_C$ is still true. The "fine $\rightarrow$ investment $\rightarrow$ increase in supply and decrease in clean energy price" dynamics continue until the marginal cost of one additional unit of clean energy decreases to reach the same level of fossil fuel (i.e. $(1 + \lambda) \cdot p_C$), where the firm will be prompted to shift their energy consumption to rely more on clean energy. In the next period, the firm will start using less C and a positive amount of R.

While less dependence on fossil fuels matches our goal, this shift also means that less carbon fine will be generated, hence the investment in renewable energy will be lowered. Depending on the parameters, this may lead to a stagnant equilibrium where the firm uses some $C \in (0, C_f)$ and some $R > 0$, at the same unit price. There is no further momentum from this dynamic system internally to generate carbon fines, invest in renewable energy, decrease the price of R, and increase the usage of R. The shift away from fossil fuels is
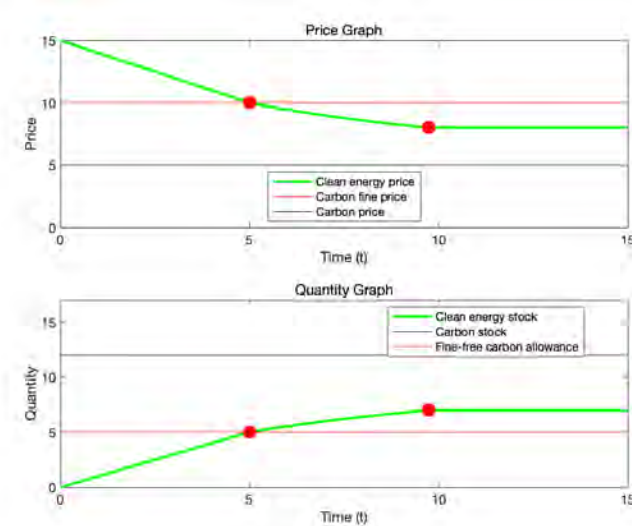
Figure 7: An Incomplete Transition Away from Carbon

not complete, and some external incentive is needed to further reduce carbon emissions. Figure 7 illustrates a numerical example of such a scenario.

5   Conclusion

This paper explored the effect of the 2021-established China ETS on firm ESG performance in regulated industries and unpacked some underlying decarbonization incentives in response to the price signal of emissions. The empirical test, albeit limited, revealed both positive and negative effects in emissions reduction caused by the ETS establishment. It implies that the policymaker should consider the potential adverse effect caused by the time gap between policy announcement and enforcement. A regression discontinuity design is suggested to examine whether the emissions amount cutoff will incentivize opportunistic behaviors of firms, such as strategically emitting slightly below the threshold. The theoretical model introduced some basic interactions of energy input prices, carbon fines, and carbon reduction. It highlights the importance of considering the "fixed cost + variable cost" structure of clean energy and the R&D needed and the implications of such a cost structure on growing the supply and demand of clean energy. Relating to R&D, further dynamics in the change of MRTS and price signals can be considered.

Furthermore, studies of the interactions between ETSs can be an important subject.

For example, although EU ETS and China ETS work independently, they may have overlapping impacts on cross-border entities such as multinational enterprises (MNEs). In relation to recent developments, the EU's new Carbon Border Adjustment Mechanism (CBAM), which applies to EU imports from certain industries, effectively matches the price signals of EU ETS and other ETSs. Given the context that EU ETS has one of the highest allowance prices in the world,[27] CBAM may have significant impacts on EU's trade partners, and the ETSs they operate. This effect will be even stronger as ETSs expand to cover more industries, particularly pollution-intensive industries where MNEs are concentrated, such as chemicals, automobiles and automotive components, steel, etc. Therefore, sectoral analysis and predictions can be helpful in understanding how ETSs may interact and the implications for their participants. Another area worthy of further research in is how well companies react to environmental policies, in terms of financial resiliency, operational efficiency, etc., while complying with regulations. This question exemplifies significance especially as considerable number of new regulations being are made, and updates and changes happen frequently. To this end, Gladwin and Walter (1976)[28] proposed a useful framework for analyzing how an MNE subsidiary behaves differently from its parent in response to social issues such as pollution control, based on the heterogeneity, dynamism, and stability of the external environment.

27. *International Carbon Action Partnership*.

28. Thomas N. Gladwin and Ingo Walter, "Multinational Enterprise, Social Responsiveness, and Pollution Control," *Journal of International Business Studies* 7, no. 2 (1976): 57–74, ISSN: 0047-2506, 1478-6990, accessed May 11, 2024, http://www.jstor.org/stable/154546.

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