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令和５年５月

神戸大学大学院経済学研究科

経済学専攻

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博　士　論　文

To achieve sustainable development goals——the role of environmental policies, ESG investments and green transformation of industries.

（持続可能な開発目標を達成するために——環境政策、ESG 投資、産業のグリーントランスフォーメーションの役割）

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Contents

Chapter 1. Introduction

With the rapid development of economic behavior among human beings, environmental issues are receiving substantial attention. Environmental pollution and climate change are widely considered key factors that affect the sustainable development of human society.

The United Nations General Assembly (UNGA) sets the Sustainable Development Goals (SDGs) in 2015 as "a shared blueprint for peace and prosperity for people and the planet, now and in the future." The 17 Sustainable Development Goals (SDGs) and their 169 specific targets have become integral parts of the development frameworks for both developing and developed countries. Environmental goals constitute a significant portion of these sustainable development objectives.

In 2022, China, the world's most populous country and the largest consumer of resources, relies on fossil fuels for energy consumption. China's air pollution is garnering widespread global attention due to its detrimental effects on human health and well-being. The majority of annual global deaths caused by air pollution are concentrated in emerging economies like China and India, which are undergoing rapid industrialization. Therefore, it is necessary to consider environmental factors in energy consumption and industrialization to achieve sustainable development goals. For over a decade, China has been the world's leading producer of crude steel. However, the steel industry in China has become the most polluting sector, serving as the primary source of pollutants such as particulate matter, sulfur dioxide, and nitrogen oxides. Reducing pollution in the steel industry is an urgent task. In 2018, the Chinese government implemented the "Three-Year Action Plan to Win the Blue Sky War," also known as the "Blue Sky Plan." This plan aims to significantly reduce the total emissions of major air pollutants, coordinate efforts to reduce greenhouse gas emissions, further decrease the concentration of fine particulate matter (PM2.5), reduce the number of heavily polluted days, improve environmental air quality, and enhance the well-being of the public under clear skies. The effectiveness of this policy remains a subject of analysis.

Previously, China implemented the new Environmental Protection Law in 2015 to effectively achieve environmental protection objectives. However, the effectiveness of the new Environmental Protection Law in achieving the goal of mitigating environmental pollution remains a subject of analysis.

In addition to regulatory measures, emerging industries are greatly anticipated to contribute to energy conservation and environmental protection. For instance, the electric vehicle (EV) industry is hailed as a promising sector. Compared to traditional internal combustion engine vehicles, EVs do not consume gasoline or diesel fuel but instead rely on electricity. However, it is important to note that over 60% of China's electricity generation comes from coal. Therefore, the question arises as to whether promoting the electric vehicle industry can genuinely alleviate air pollution and mitigate China's reliance on fossil fuel consumption.

The literature on the SDGs constitutes a significant portion of research in environmental science, green and sustainable science technologies. However, there is relatively limited research on social aspects related to the environment. The SDGs are integrated, indivisible, and intertwined in a balanced manner across the three dimensions of sustainable development: economic, social, and environmental. Hence, achieving the goals necessitates a balance among these dimensions. Building upon this foundation, this dissertation provides a comprehensive study of the three dimensions of environmental, social, and economic sustainability.

Drawing on the aforementioned background, this dissertation explores the environmental, social, and economic impacts of significant efforts made over the past decade to accomplish the Sustainable Development Goals (SDGs) from three perspectives: incorporating environmental issues into economic behavior, government actions and legislation, and the development of new industries. The dissertation primarily focuses on addressing the environmental concerns associated with specific SDGs, namely SDG 3 (Good Health and Well-being), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action).

In Chapter 2, I analyze the impact of ESG (Environmental, Social, and Governance) investments on air pollution, social well-being, and stock prices. The primary objective of the Blue Sky Plan is to reduce sulfur dioxide and nitrogen oxide emissions by more than 15% by 2020, with the steel industry playing a major role in generating these pollutants. Concurrently, China is vigorously promoting ESG investments that prioritize environmental protection, which has garnered significant attention in academia. After examining the influence of the Blue Sky Plan on ESG investments in the steel industry, I investigate the impact of ESG investments on the financial performance of steel companies. Finally, I analyze the effects of the Blue Sky Plan and ESG investments on sulfur dioxide and nitrogen oxide emissions. In this section, I employ a difference-in-differences model to analyze data from listed steel companies in China and 28 provincial-level municipalities, utilizing the latest available data up to 2020.

In Chapter 3, I examine the effects of environmental policies and legislation on air pollution, social well-being, and ESG investments. China has experienced severe levels of environmental pollution during the 2010s, posing threats to human health and significantly diminishing people's well-being. In 2015, China implements the new Environmental Protection Law, marking the first major update to environmental protection legislation since the country's establishment. The key reforms encompass three aspects: firstly, environmental non-governmental organizations gain the ability to initiate public interest lawsuits against polluting enterprises involved in illegal environmental destruction. Secondly, the law introduces greater accountability and authority for the government and officials. Additionally, it significantly increases the responsibilities of polluters. Industrial emissions of air pollutants from polluting industries are recognized as a major source of air pollution in China. ESG investments are widely acknowledged as effective means to protect the environment and ensure sustainable economic development. In this section, to investigate the impact of air pollution on people's well-being, I utilize data from the Chinese General Social Survey (CGSS), the China Family Panel Studies (CFPS), and the Chinese Social Survey (CSS) to construct a time-series dataset of provincial-level average happiness. I then explore whether ESG investments and the implementation of the new environmental law have mitigated China's environmental pollution.

In Chapter 4, I explore the impact of developments in the automotive industry on energy consumption, carbon emissions, and air pollution. In recent years, with China's economic and social development, China has become the world's largest automotive market, with automobiles emerging as the main source of air pollution in the country. Carbon emissions have always been a key research topic for sustainability, and cars emit a significant amount of carbon dioxide. Simultaneously, China's increasing demand for oil has brought forth negative issues such as energy security, carbon emissions, and air pollution. Overall, electric vehicles (EVs) are considered an industrial revolution in China's sustainable transportation due to the rapid growth in automobile numbers, leading to severe environmental, energy safety, and health problems. In this chapter, I employ data and a regression model of electric vehicle ownership to empirically analyze the impact of electric vehicle ownership on energy consumption, carbon emissions, and air pollution. Finally, Chapter 5 reviews the economic background, concludes the empirical results, and economic implications.

Chapter 2.

Policy effect of the “Blue Sky Plan” on air pollution, ESG investment, and financial performance of China’s steel industry

2.1 Introduction

In recent years, as the level of urbanization has increased, environmental pollution has become more and more serious. Environmental pollution is widely recognized as an important issue for sustainable economic growth. Environmental pollution has seriously affected people's living environment and has led to an increase in the incidence of respiratory diseases and other related illnesses. Epidemiological studies in recent years have shown a consistent relationship between particulate matter pollution and mortality. These are closely related to the Sustainable Development Goals (SDGs) set by the United Nations. This is also true for China, a country with a large population, and with the consumption of fossil energy, air pollution in China has reached a serious level, causing environmental and health problems (Chen et al., 2017), and has largely aroused residents’ dissatisfaction. Since then, the Chinese government has attached great importance to the ecological environment and has made many efforts to achieve specific emission reduction targets in the "13th Five-Year Plan" (2016–2020) to tackle environmental deterioration. These reduction targets mainly focus on the emission of nitrogen oxides and sulfur dioxide. In 2018, the Chinese government issued a “Three-Year Action Plan to Win the Blue Sky war” (hereinafter the "Blue Sky Plan"). In 2015, China's total SO2 and NOx emissions were 18.591 million tons and 18.518 million tons, respectively. The major goal of the "Blue Sky Plan" is to reduce the total emissions of sulfur dioxide and nitrogen oxides by more than 15% by 2020.

Environmental pollution can be classified into water and air pollution. In terms of water pollution, Chen et al. (2018) studied the water pollution regulation in China and found evidence that the regulation reduced pollution-intensive activities in highly regulated areas. Liu et al. (2017) estimated the impact of stricter wastewater discharge standards on all the textile printing and dyeing enterprises in Lake Tai. They found that enterprises facing new, more stringent standards decrease labor demand by approximately 7%. Most countries have begun to monitor air quality in recent years. Peng et al. (2019) examined the consistency of city- and individual-level air pollution perceptions and investigated how environmental transparency affects the actual perceived air pollution relationship. Ai et al. (2021) studied the relationship between the desulfurization price subsidy policy and SO2 emission reduction from coal-fired power plants in China. They found an obvious causal relationship between the policy and SO2 emission reduction, and the dynamic effect of the policy showed an upward trend throughout the sample period. In terms of studying policy effects, Lin et al. (2021) examined the impact of the Electricity Price Subsidy policy on NOx emissions from China's coal-fired power generation industry. They found that the EPS policy significantly reduced NOx emissions by 1.1% and increased NOx removal by 2.8%.

This study focuses on the policy effects of the “Blue Sky Plan” on the steel industry as well as the emissions of sulfur dioxide and nitrogen oxides. Although the problem of environmental pollution has been raised for decades, the Chinese government has been balancing economic growth and environmental problems until serious air pollution occurred. Air pollution became the most serious environmental problem in China since 2013, which not only significantly harmed public health but also decreased satisfactory to the government. The implementation of “Blue Sky Plan” is the first time the Chinese government decided to protect the environment at the cost of sacrificing economic growth. In 2017, the major pollutant emissions from the steel industry exceeded those of the power industry and became the largest source of pollutant emissions in the industrial sector. The steel industry in China has become a major source of air pollutants such as particulate matter, SO2, and NOx emissions. For the purpose of investigating the policy effect of the “Blue Sky Plan” on air pollution, I focus on the steel industry instead of the whole polluting industries, to avoid using irrelevant information (e.g. water pollution).

Gu et al. (2018) analyzed the sulfur dioxide emission reduction effect, energy-saving synergy effect, and carbon dioxide emission reduction of power generation, steel, and cement industries during the "11th Five-Year Plan" and "12th Five-Year Plan" periods. They showed that during the "11th Five-Year" period, the emission reduction of coal-fired power plants' desulfurization projects is critical to emission reduction. Both engineering and structural reductions can achieve low pollution emissions, but the contributions are not the same, owing to differences in related industries. Bo et al. (2021) used measurements from China’s continuous emissions monitoring system to develop estimates of emissions from the steel industry. They assessed particulate matter, sulfur dioxide, and nitrogen oxide emissions associated with China’s increasingly stringent policies from 2014 to 2018.

Recently, ESG investment has attracted substantial research attention (see Gillan et al., 2021, Zhao et al., 2018). Yuan et al. (2022) investigated the impact of ESG disclosure on the financial irregularities of Chinese listed firms. They found that ESG disclosures decrease corporate financial irregularity risks and help mitigate information asymmetry. Zhang et al. (2021) examined the heterogeneity of ESG investments in China before and after the release of the guidelines for establishing a green financial system in 2016. They show that high-ESG portfolios earn significantly higher abnormal returns than low-ESG portfolios after 2016.

Existing research rarely investigates policy effects on ESG investments in the steel industry. To the best of my knowledge, this is the first study to investigate the policy effects of the "Blue Sky Plan" on the steel industry in China. I close this gap and contribute to the literature in the following ways. First, I collect the latest available environmental, industrial, and financial data and analyze the policy effect of the “Blue Sky Plan” on ESG investment and financial performance in China’s steel industry. Second, I collect provincial economic and environmental data to investigate the policy effects on air pollution.

My results suggest that ESG investment significantly reduces the financial performance of steel companies, contrary to the findings of Zhang et al. (2021). The "Blue Sky Plan" compensates for one-third of losses from corporate ESG investments and significantly stimulates ESG investment in the steel industry. In addition, I find that the "Blue Sky Plan" reduces SO2 and NOx emissions significantly and alleviates China's air pollution problem to a large extent.

The remainder of this chapter is organized as follows. Section 2 briefly describes the study’s data. Section 3 introduces the model. The empirical results are presented in Section 4. Section 5 concludes the chapter.

2.2 Data

The sample period for my data is from 2015 to 2020. I collect the latest and most complete relevant environmental and financial data for Chinese listed steel companies. Specifically, the ESG data come from China's SynTao Green Finance, including ESG investment and environmental scores. The financial data of the steel companies are sourced from the RESSET database, including a range of financial variables such as stock return, market cap, cash holdings, short-term debt, long-term debt, profitability, and book-to-market ratio. Provincial economic and environmental data for 28 provinces are collected from the National Bureau of Statistics of China, including SO2 emissions, NOx emissions, thermal power generation, power consumption, GDP per capita, industrial added value, treatment of waste gas, treatment of wastewater, population, secondary industry share, tertiary industry share, R&D, cars, and the affected area. Table 1 briefly describes the definitions of the variables. Table 2 provides descriptive statistics of the data.

2.3 Models

Difference-in-Differences (DID) method is widely applied in circumstances when certain groups are exposed to a treatment and others are not. It is a quasi-experimental design that makes use of longitudinal data from treatment and control groups to obtain an appropriate counterfactual to estimate a causal effect. This method is ideal for evaluating the impact of abrupt changes in the economic environment or changes in government policy.

Table 1. Definition of variables

Steel company variables	Definition	Sources
ESG	ESG aggregate score	SynTao
Environment	Environmental score	
Return	Annual holding period return of stock	RESSET
Market cap	Natural Logarithm of firms' total market value at the end of the year	
Cash holdings	Money funds and short-term investment divided by assets	
Short-Term Debt	Total current liabilities divided by assets	
Long-Term Debt	Total long-term liabilities divided by assets	
Profitability	Operating income divided by assets	
Book to market	Book Value at the end of the period divided by assets	
Provincial variables	**Definition**	
SO2	Sulfur dioxide emission of waste gas (10 thousand tons)	the National Bureau of Statistics of China
NOx	Nitrogen oxide emission of waste gas (10 thousand tons)	
Thermal Power generation	Thermal Power Generation by Region (10 billion kWh)	
Power consumption	Electricity Consumption by Region (100 million kWh)	
GDP Per Capita	Total output (gross domestic product, the total output of social goods and services) divided by total population (Yuan per capita)	
Industrial added value	The gross output value of industrial enterprises minus the purchase of raw materials	
Treatment of waste gas	Amount of investment completed in industrial waste gas pollution control projects	
Treatment of wastewater	Amount of investment completed in industrial wastewater pollution control projects	
Population	Total population at year end	
Secondary industry share	The share of the output value of the secondary industry in GDP	
tertiary industry share	The share of the output value of the tertiary industry in GDP	
R&D	Science and technology expenditure divided by GDP	
Cars	Civilian vehicles divided by the length of roads	
Afforestation area	In all the land that can be planted, trees and shrubs are planted by various methods, and the survival rate reaches 85% or more(hectare)	

Table 2. Descriptive statistics

Variables	Mean	Std.Dev	Min	Max	Obs
ESG	0.258	0.255	0.000	0.656	174
Environment	0.247	0.259	0.000	0.759	174
Return	0.099	0.629	−0.554	5.875	174
Market cap	23.437	0.836	21.597	25.975	174
Cash holdings	0.128	0.079	0.003	0.4721	174
Short-Term Debt	0.512	0.178	0.096	1.006	174
Long-Term Debt	0.096	0.078	$0.035*10^{-3}$	0.354	174
Profitability	0.907	0.379	0.121	1.898	174
Book to market	1.401	1.041	$0.117*10^{-3}$	4.750	174
SO2	2.850	1.173	−1.715	5.028	168
NOx	3.746	0.638	2.160	5.244	168
Thermal power generation	7.167	0.769	5.472	8.621	168
Power consumption	7.567	0.591	6.480	8.845	168
GDP Per Capita	10.956	0.409	10.164	12.013	168
Industrial added value	9.114	0.796	7.018	10.697	168
Treatment of waste gas	11.441	1.038	7.513	13.782	168
Treatment of waste water	9.610	1.305	3.951	12.013	168
Population	8.328	0.626	6.528	9.443	168
Secondary industry share	3.678	0.213	2.760	3.921	168
Tertiary industry share	3.916	0.151	3.659	4.430	168
R&D	−5.446	0.528	−6.498	−4.265	168
Cars	−5.348	0.751	−6.457	−3.374	168
Afforestation area	12.006	1.212	7.838	13.487	168

The DID estimator can be constructed as follows. Let $Y_{treat,before}$ be the sample average of Y for those in the treatment group before the experiment, and let $Y_{treat,after}$ be the sample average for the treatment group after the experiment. Let $Y_{control,before}$ and $Y_{control,after}$ be the corresponding pre-treatment and post-treatment sample averages for the control group. The DID estimator is the average change in Y for those in the treatment group minus the average change in Y for those in the control group:

$$\hat{\alpha}_1^{DID} = \left(Y_{treat,after} - Y_{treat,before}\right) - \left(Y_{control,after} - Y_{control,before}\right)$$

$$= \Delta Y_{treat} - \Delta Y_{control}$$

Where ΔY_{treat} is the average change in Y in the treatment group and $\Delta Y_{control}$ is the average change in Y in the control group. If the treatment is randomly assigned, then $\hat{\alpha}_1^{DID}$ is an unbiased and consistent estimator of the causal effect.

In the analysis of policy effect, panel regression methods are widely adopted.

$$Y_{it} = \alpha_0 + \alpha_1 DID + \boldsymbol{X\beta} + w_{it}$$

$DID = T_i \cdot P_t$

T_i is a binary variable which indicates that the observations belong to the treatment group or control group. P_t is the binary variable which indicates the observations occur before or after the treatment effect. $\mathbf{X}$ is the vector of control variables, and $\boldsymbol{\beta}$ is the vector of coefficients. DID is constructed by the product of T_i and P_t.

In this chapter, I construct a heterogeneous timing difference-in-differences (HT-DID) model to examine the policy effect of the "Blue Sky Plan" on steel companies' ESG investment decisions. The model is represented as follows:

$$ESG_{i,t} = a_0 + a_1 BSP2018 + \mathbf{X\beta} + \eta_i + \tau_t + \varepsilon_{i,t} \quad (1)$$

ESG is the aggregate ESG investment score. $BSP2018 = Treat_{i,t} \times Post_t$ represents the heterogeneous timing treatment effect of the "Blue Sky Plan." $Post_t$ equals 0 before 2018 and equals 1 otherwise. $Treat_{i,t}$ equals 1 if the company i started ESG investment before the year t, and 0 otherwise. $\mathbf{X}$ represents the vector of control variables.

Similarly, I construct the following HT-DID model to investigate the policy effect of the "Blue Sky Plan" on the relationship between ESG investment and the financial performance of steel companies.

$$ret_{i,t} = a_0 + a_1 BSP2018 + a_2 ESG_{i,t} + \mathbf{X\beta} + \eta_i + \tau_t + \varepsilon_{i,t} \quad (2)$$

where $ret_{i,t}$ denotes the annual holding period stock returns of the steel companies. According to Lins et al. (2017) and Drempetic et al. (2020), major financial variables, including market cap, cash holdings, short-term debt, long-term debt, profitability, and book-to-market ratio, are selected. η_i and τ_t represent the firm and time-fixed effects.

Finally, I study the effect of the policy on air pollution. Specifically, I collect provincial economic and environmental data and investigate whether SO2 and NOx emissions were reduced significantly after the "Blue Sky Plan." The model is introduced as follows.

$$SO2_{i,t} \text{ or } NOx_{i,t} = a_0 + a_1 PBSP2018 + a_2 ESG_{i,t} + a_3 PBSP2018 \times ESG_{i,t} + \mathbf{X\beta} + \eta_i + \tau_t + \varepsilon_{i,t} \quad (3)$$

where $SO2_{i,t}$ or $NOx_{i,t}$ denotes sulfur dioxide or nitrogen oxides emissions in a province i in year t. $PBSP2018$ equals 0 before 2018 and equals 1 otherwise, represents the policy effect of the "Blue Sky Plan" on emission of air pollutants. $\mathbf{X}$ represents the vector of control variables. Here, I reconstruct ESG data to match the provincial level panel data. Specifically, I calculate the provincial level ESG investment intensity by adding up and standardizing the ESG score of listed companies in each province. According to Ai et al. (2021), Yang et al. (2020), and Zhang et al. (2019), the control variables included thermal power generation, power consumption, GDP per capita, industrial added value, treatment of waste gas, treatment of wastewater, population, secondary industry share, tertiary industry share, R&D, cars, and the affected area. η_i and τ_t refer to provincial and time-fixed effects, respectively.

2.4 Empirical results

In this section, I first examine the policy effect of the “Blue Sky Plan” on steel companies’ ESG investment decisions. Then I study whether steel companies’ ESG investment affects their financial performance and explore the impact of the “Blue Sky Plan” on the relationship between corporate ESG investment and profitability; finally, I examine whether the “Blue Sky Plan” reduces air pollutant emissions.

First, I investigate whether the “Blue Sky Plan” stimulated ESG investments of steel companies. Table 3 presents the results of Equation (1). Case (1) shows that the larger the market cap of a company, the more ESG investments it has made, indicating that large steel companies are more willing to make ESG investments. On the one hand, large enterprises have sufficient capital to invest in fixed assets and R&D. On the other hand, large enterprises are more likely to obtain emission reduction subsidies and tax relief and are more likely to benefit from emissions trading. In case (2), I substitute environmental scores for ESG scores and obtain similar results to case (1).

Case (3) shows that the "Blue Sky Plan" significantly affects enterprises’ ESG investment. After the introduction of policy effects, the coefficient of the market cap no longer becomes significant, indicating that after the implementation of the policy, companies started to make ESG investments regardless of their size. Combining case (1), I can argue that the policy played a significant role in promoting ESG investment in small firms. Similar to Case (3), Case (4) shows that the policy has a significant effect on stimulating the environmental investment of enterprises. In general, the “Blue Sky Plan” has a significant positive impact on ESG and environmental investment, especially for relatively small-scale enterprises. One may suspect that there should be a time lag between the implementation of the policy and its impact occurred. Since the time lag of policy effect may lead to endogeneity, I delay the effect of the “Blue Sky Plan” to 2019. In case (5) and (6), the impact of the policy is supposed to be delayed. Obviously, the “Blue Sky Plan” still has significantly impact on corporate ESG investment.

Table 4 reports the empirical results of equation (2). For comparison, I also provide conventional panel regression analysis. Case (1) shows that the ESG investment of steel companies will significantly reduce their financial performance. A 1% increase in the company’s ESG investment will reduce the stock return by 0.378%, indicating that the ESG investment of steel companies will not bring immediate benefits. On the contrary, the cost of R&D investment related to emission reduction and fixed asset investment will cause significant losses to the enterprise.

Then, following Lins et al. (2017), I quartile the ESG scores before introducing them into the model. Specifically, I divide the annual ESG investment status of steel companies into four equal parts, from high to low. Case (2) shows that the top 50% of companies in the steel industry for ESG investment suffer significant losses in their financial performance.

Table 3. Policy effects of the "Blue Sky Plan" on ESG investment in China's steel industry

	Dependent variables					
	Case (1)	Case (2)	Case (3)	Case (4)	Case (5)	Case (6)
	ESG	Environment	ESG	Environment	ESG	Environment
BSP2018			0.364***	0.357***		
			(8.31)	(8.04)		
BSP2019					0.323***	0.317***
					(8.50)	(7.83)
Market cap	5.462**	5.043*	2.536	2.174	6.456***	6.022***
	(2.07)	(1.93)	(1.37)	(1.26)	(3.50)	(3.38)
Cash holdings	27.996	19.339	4.068	4.125	27.365	18.719
	(1.22)	(0.86)	(0.32)	(−0.32)	(1.40)	(0.97)
Short-Term Debt	−16.965	−16.050	−8.881	−8.122	−14.443	−13.567
	(−1.15)	(−0.98)	(−1.09)	(−0.83)	(−1.27)	(−1.03)
Long-Term Debt	−42.960	−37.329	−7.870	−2.918	−21.25	−15.966
	(−1.18)	(−1.04)	(−0.25)	(−0.10)	(−0.64)	(−0.49)
Profitability	−4.333	−5.030	−1.245	−2.003	−0.921	−1.674
	(−0.54)	(−0.58)	(−0.18)	(−0.25)	(−0.13)	(−0.22)
Book to market	−4.029	−5.398	−2.890	−4.281	−3.321	−4.701
	(−1.14)	(−1.45)	(−0.87)	(−1.17)	(−0.97)	(−1.28)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R square	0.624	0.592	0.757	0.719	0.682	0.648

Note: Values in parentheses are t-values. *, **, and *** represent for significance at 10%, 5%, and 1%, respectively. BSP2018 is the policy effect of the "Blue Sky Plan."

However, the marginal ESG investment loss for Q1 companies is 0.232%, which is much smaller than that for Q2 companies, suggesting that companies with the most ESG investments may already be reaping the benefits.

I then replace the ESG scores with environmental scores and arrive at similar conclusions. Case (3) shows that a firm's environmental investment, such as ESG investment, significantly reduces stock returns. The coefficients of the parameters are very similar to those in Case (1), which indicates that the ESG investments of these steel companies are mainly environmental investments rather than social and corporate governance investments.

Similarly, Case (4) shows that the top 50% of companies with environmental investment suffer significant financial losses. Q1 companies suffer less than Q2 companies, suggesting that the companies with the largest environmental investments may have already gained from them.

Cases (5)–(8) perform a heterogeneous timing difference-in-differences analysis to study the policy effect of the “Blue Sky Plan.” Case (5) suggests that a 1% increase in ESG investment will reduce the stock return by 0.556%, indicating that the coefficient of −0.378 in case (1) is underestimated. Actual losses from ESG investments are much higher. After the implementation of the “Blue Sky Plan,” companies received compensation for their ESG investments. These compensations include, but are not limited to, the government’s ESG investment subsidies: the reduction in pollutant emission taxes: and the benefits of emission allowance trading after companies’ emission reductions. Collectively, these gains do not compensate for corporate losses in ESG investment. The average compensation amount is approximately one-third of the losses caused by ESG investment.

Case (6) shows similar results. The marginal losses from ESG investments are much larger than those in Case (2). This is consistent with the results obtained in case (5). However, I also find that Q1 companies suffer fewer financial losses than Q2 companies, suggesting that the ESG investment has already yielded.

From case (7), it can be seen that each 1% increase in environmental investment reduces the stock return by 0.552%. First, this indicates that the coefficient of the variable Environment in case (3) −0.377 is underestimated. Second, through the closeness of the coefficients in cases (7) and (5), it is confirmed that the main part of the ESG investment of steel companies is environmental investment, which is consistent with the comparison results from cases (1) and (3). Case (8) shows that Q1 companies suffer significant losses from environmental investment. A 1% increase in environmental investment reduces the stock return by 0.218%, which is larger than that in case (4).

Overall, from the comparison of cases (5)–(8) and (1)–(4), I find that the "Blue Sky Plan" cannot significantly change the status quo of the decline in corporate financial performance caused by the ESG investment of steel companies. Corporate ESG investments cause significant declines in stock returns. After the implementation of the "Blue Sky Plan,” companies that invested considerably in ESG achieved certain benefits through subsidies, emission taxes, and emissions allowance trading. Therefore, I conclude that the "Blue Sky Plan" may play a role in promoting corporate ESG investment and green transformation.

Then I delay the policy effect to 2019 and report these results in case (9) – (12). Similarly, ESG investment significantly reduced the stock returns of steel companies. However, these estimates are much closer to case (1) – (4) than case (5) – (8), suggesting that the impact of the “Blue Sky Plan” has been quickly absorbed, and the steel industry rebalanced production and environmental protection in a short time.

To demonstrate the mediation effect of the “Blue Sky Plan” on financial performance of steel companies through simulating their ESG investments, I apply the Sobel test to check the joint significance and the t values are reported in table 4. Obviously, these results show that the impact of the “Blue Sky Plan” on ESG investments and the influence of ESG investments on financial performance of steel companies are joint significant in all cases. Therefore, I can conclude that the “Blue Sky Plan” significantly reduced the financial performance of steel companies by simulating their ESG investments.

Finally, I examine whether the "Blue Sky Plan" could reduce air pollutant emissions. Table 5 presents the results of Equation (3). Case (1) shows that ESG investment positively related to SO2 emission, since both of them are positively correlated with industrial level. However, the estimates of the “Blue Sky Plan” and its product with ESG investment are significantly negative, indicating that the implementation of the “Blue Sky Plan” has a significant inhibitory effect on SO2 emissions. Similarly, case (2) shows that the “Blue Sky Plan” also significantly reduced NOx emissions. I replace ESG by environmental investment in case (3) and (4), and obtain similar results. In case (5) - (8), the policy effect of the “Blue Sky Plan” is supposed to be delayed. Similarly, I still find that SO2 and NOx emissions are significantly reduced after the implementation of the “Blue Sky Plan”. Overall, the results suggest that the “Blue Sky Plan” has significantly alleviated China’s air pollution problems and gradually achieved the policy goals.

To summarize, my empirical findings imply that, in response to the serious air pollution problem in the 2010s, the Chinese government established the "Blue Sky Plan" to imitate steel firms' ESG investments. Because these ESG investments are motivated by environmental concerns, the economic benefits cannot compensate for these investments, reducing steel companies' financial performance. Fortunately, the "Blue Sky Plan" reduced SO2 and NOx emissions, which helped to alleviate air pollution.

Table 4. Policy effects of the "Blue Sky Plan" on the financial performance of China's steel industry

Dependent Variable: Annual holding period stock return												
	Case (1)	Case (2)	Case (3)	Case (4)	Case (5)	Case (6)	Case (7)	Case (8)	Case (9)	Case (10)	Case (11)	Case (12)
ESG	−0.378**				−0.556**				−0.388*			
	(−2.06)				(−2.40)				(−1.97)			
ESGQ1		−0.232**				−0.258**				−0.225**		
		(−2.36)				(−2.33)				(−2.21)		
ESGQ2		−0.330**				−0.385**				−0.317**		
		(−2.43)				(−2.36)				(−2.21)		
ESGQ3		0.077				0.028				0.091		
		(0.36)				(0.11)				(0.39)		
Environment			−0.377**				−0.522**				−0.384**	
			(−2.38)				(−2.66)				(−2.28)	
EnvironmentQ1				−0.190**				−0.218**				−0.187*
				(−2.18)				(−2.17)				(−2.01)
EnvironmentQ2				−0.226*				−0.274				−0.221
				(−1.79)				(−1.63)				(−1.47)
EnvironmentQ3				−0.030				−0.080				−0.025
				(−0.18)				(−0.42)				(−0.14)
BSP2018					0.180	0.109	0.164	0.106				
					(1.24)	(0.70)	(1.16)	(0.71)				
BSP2019									0.020	−0.052	0.017	−0.221
									(0.15)	(−0.36)	(0.12)	(−0.16)
Market cap	0.777**	0.800**	0.775**	0.795**	0.772**	0.801**	0.769**	0.793**	0.778**	0.796**	0.776**	0.793**
	(2.56)	(2.66)	(2.56)	(2.60)	(2.59)	(2.68)	(2.58)	(2.61)	(2.53)	(2.60)	(2.53)	(2.55)
Sobel test	0.0466		0.0226		0.0201		0.0117		0.0549		0.0285	
Other control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R square	0.278	0.286	0.279	0.273	0.276	0.283	0.277	0.270	0.274	0.282	0.274	0.269

Note: Values in parentheses are t-values. *, **, and *** represent for significance at 10%, 5%, and 1%, respectively. Q1, Q2, and Q3 refer to dummy variables for the first, second, and third quarters of ESG or environmental investment intensity. BSP2018 is the policy effect of the "Blue Sky Plan." The results of the Sobel test are p-values, which highlight the significance of the mediation effect that the "Bule Sky Plan" has on steel firms' financial performance by boosting their ESG investments.

Table 5. Provincial-level policy effects of the "Blue Sky Plan" on air pollutants emissions

	Dependent variables							
	(1) SO2	(2) NOx	(3) SO2	(4) NOx	(5) SO2	(6) NOx	(7) SO2	(8) NOx
ESG	0.29***	−0.11			0.22**	−0.09		
	(2.68)	(−1.61)			(2.14)	(−1.39)		
Environment			0.304***	−0.112			0.23**	−0.09
			(2.70)	(−1.64)			(2.16)	(−1.43)
PBSP2018	−2.31***	−1.41***	−2.30***	−1.41***				
	(−6.31)	(−3.54)	(-6.30)	(−3.56)				
PBSP2019					−2.42***	−1.38***	−2.41***	−1.38***
					(−5.89)	(−3.53)	(−5.87)	(−3.54)
ESG×PBSP2018	−0.17***	0.04						
	(−3.11)	(1.25)						
ESG×PBSP2019					−0.10**	0.02		
					(−2.06)	(0.49)		
Environment×PBSP2018			−0.17***	0.04				
			(−3.13)	(1.26)				
Environment×PBSP2019							−0.10**	0.02
							(−2.08)	(0.53)
Other control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Provincial fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj.R square	0.894	0.516	0.895	0.516	0.888	0.513	0.888	0.513

Note: Values in parentheses are t-values. *, **, and *** represent for significance at 10%, 5%, and 1%, respectively. PBSP2018 is the policy effect of the "Blue Sky Plan."

2.5 Conclusion

With the rapid development of China's economy, environmental pollution, especially air pollution, has seriously affected the quality of life of Chinese residents, arousing government concern. As the world's largest producer and exporter of crude steel, the pollution generated by China's steel industry has surpassed that of the power industry, ranking first among China's highly polluting industries. In this context, the Chinese government launched the "Three-Year Action Plan to Win the "Blue Sky War," which aims to solve problems such as promoting the green transformation of high-polluting industries and curbing air pollution. This study is the first to examine the policy effects of the “Blue Sky Plan” on China’s steel industry. I first analyze the impact of the “Blue Sky Plan” on steel companies’ ESG investment and financial performance. I then examine the effects of the “Blue Sky Plan” on air pollution.

From the perspective of the ESG investment of steel enterprises, the ESG-related investment of listed steel enterprises has a significant negative impact on their financial performance, especially for those companies that invested considerably in ESG. This is because these investments cost a large amount of capital in R&D and fixed assets. The “Blue Sky Plan” has compensated for the ESG investment losses of steel companies to a certain extent, with an average rate of about one-third. Additionally, I find that the “Blue Sky Plan” significantly stimulated steel companies’ ESG investments. Finally, the “Blue Sky Plan” has significantly reduced emissions of sulfur dioxide and nitrogen oxides, which has played a positive role in improving air pollution problems.

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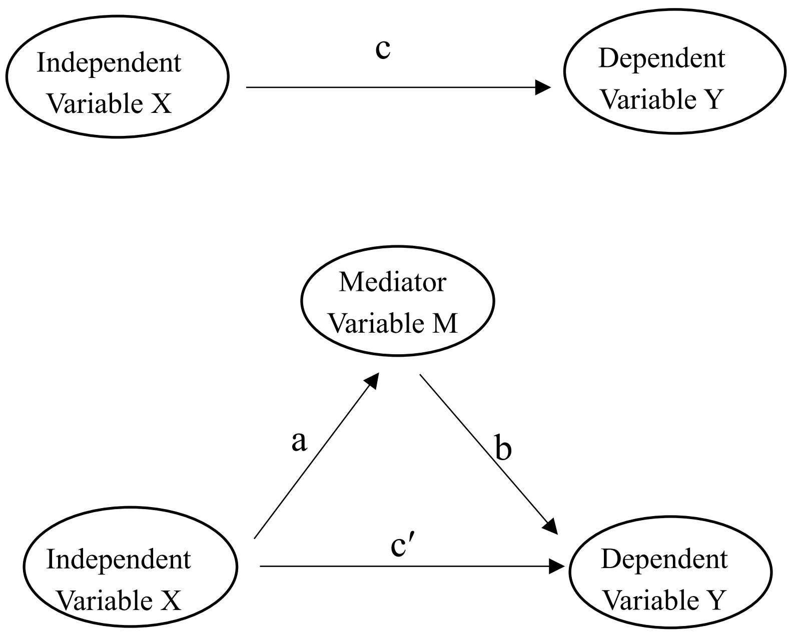
Appendix A

Mediation effect analysis.

This chapter examines the mediation effect of the “Blue Sky Plan” on financial performance of steel companies through ESG investments. The general framework of mediation effect analysis is shown in the following figure.



Here, **c** is the total effect of independent variable X on dependent variable Y. **a** is the casual effect of X on mediator variable M, and **b** is the casual effect of M on Y. **c’** is the direct effect of X on Y. Consequently, the following relationship holds.

$$c = c' + ab$$

The mediation effect holds if **a**, **b**, and **ab** are significant. Note that **c** and **c’** are not necessarily significant. To test the significance of **ab**, the Sobel test is widely applied. The test statistic is given as follows.

$$z = \frac{ab}{\sqrt{b^2 se(a)^2 + a^2 se(b)^2}} \sim N(0,1)$$

Chapter 3

Can ESG investments and new environmental law improve social happiness in China?

3.1 Introduction

With the rapid development of the economy, productivity has increased significantly, while environmental pollution has increased, resulting in a slew of environmental issues that have serious implications for public health and the sustainable development of society. Environmental protection was first introduced as a clear scientific concept in 1972 at the United Nations Conference on the Human Environment. Since then, countries all over the world have gradually improved their environmental laws. According to the Declaration on the Human Environment, "peace, development, and environmental protection are interdependent and inseparable." The primary goals of environmental management include promoting sustainable development and ensuring the happiness of citizens. These are also consistent with the UN's Sustainable Development Goals.

The relationship between happiness and the environment has received increased research attention in recent years (Maddison et al., 2020; Krekel and MacKerron, 2020; Bonasia et al., 2022). Traditional economic indicators of well-being are poor predictors of happiness. Welfare policies that place a greater emphasis on happiness can help to achieve the goals of environmental and social sustainability (Gowdy, 2005). Air pollution is a major environmental issue in many countries. Menz (2011) examined data sets from 48 countries from 1990 to 2006 and discovered that people are not accustomed to particulate pollution. Even previous pollution levels can reduce current utility. Solving environmental issues and maintaining ecological balance are critical to people's happiness. Welsch (2006) investigated the relationship between air quality and happiness using panel data on self-reported happiness from ten European countries. He discovered that air pollution is a statistically significant predictor of inter-country and inter-temporal differences in subjective happiness, and that the effect of air pollution on happiness translates into a significant monetary value of improved air quality. These concerns about environmental quality and its impact on people's welfare are fundamental arguments for most countries' adoption of environmental legislation. Air quality is linked to subjective happiness in Europe, with sulfur dioxide concentrations having a significant negative impact on self-reported life satisfaction (Ferreira et al., 2013). In the United States, air pollution has a direct impact on people's happiness, as well as any measured effects through health, lost work days, and other observable outcomes (Levinson, 2012). Breslow et al. (2016) developed an integrated framework about environmental conditions and management actions in response to growing interest in assessing the impact of changing environmental conditions and management actions on happiness. They contend that happiness cannot be a secondary goal of environmental policy. The possible link between environmental policy and happiness is something that needs to be looked into further. Public support for environmental protection is a reaction to the decline in quality of life caused by the overexploitation of natural resources, and it seeks to restore happiness by improving environmental quality and ensuring a healthy ecosystem. Thus, public support serves to provide environmental protection and pollution reduction, which can be considered well-being attributes because they influence individuals' and communities' ability to achieve healthy environmental goals. Empirically, Bonasia et al. (2022) examined micro and macro data from 19 European countries from 1997 to 2019 and discover a direct link between happiness and long-term environmental protection spending in European countries. They advocated for governments to include environmental spending as a means of increasing domestic happiness, emphasizing the importance of the interaction between environmental quality and life satisfaction.

Environmental pollution in developing countries has become a global issue since the twenty-first century. Air pollution has caused serious health problems in China and India since 2010. According to the World Health Organization (2016), China and India had the highest number of air pollution-related deaths in 2012. Environmental pollution's threats to life and health severely reduced people's happiness (Huhtala and Samakovlis, 2007; Almetwally et al., 2020). Air pollution can have an impact on both physical and psychological health. Shi and Yu (2020) used the number of environmental regulations at the prefecture level to assess the welfare loss caused by air pollution. Their findings suggested a link between air pollution and individual happiness. The impact of PM2.5 emissions on happiness is more closely related to physical health than mental health. According to some studies, pollution could cause significant decreases in happiness (Chen et al., 2013; Ebenstein et al., 2017). Environmental regulations were classified into three types, according to Guo et al. (2020). (i.e., economic environmental regulation, legal environmental regulation, and supervised environmental regulation). They conducted an econometric analysis on the relationship between environmental regulations and happiness, and examined the time-lag effect of policy implementation, using micro data from the Chinese Social Census and macro data from 28 Chinese provinces and cities from 2013 to 2015. They demonstrated that long-term economic and environmental regulation can significantly improve happiness. The Chinese government has enacted environmental regulations that require cities to report their daily air quality data. This mandatory disclosure of air quality information regulation has had a significant positive impact on individual happiness, primarily by lowering air pollution (Wang et al., 2021). According to Tian et al. (2016), environmental information disclosure was effective in pollution control. In China, public information requests may be the most effective method of pollution control. According to Xu et al. (2022), all three types of environmental regulations (command-and-control, market-based, and voluntary) could reduce the negative effects of air pollution on residents' happiness, but the overall mitigation effect was nonlinear. In terms of welfare, air pollution is costly to society and individuals. Some studies examined the effects of environmental pollution on social welfare (Smyth et al. 2008; Smyth et al. 2011; Wang et al. 2020; Li and Zhou, 2020; Yang et al. 2020), whereas the effects of environmental policies on social welfare required further investigation.

In the early 2010s, China's air pollution reached crisis proportions. To protect public health, the Chinese government proposed the Action Plan for Air Pollution Prevention and Control (APAPCC) in 2013 and reformed environmental protection legislation. The new environmental protection law was approved on April 24, 2014, and went into effect in early 2015. Since the old law was passed in 1989, this was the first time the Chinese government amended the law to address the new era's environmental pollution problem. The new law emphasized “public participation” and “liability for damage” (Liu et al. 2021.). It made significant changes in the following areas. First, environmental protection and public welfare organizations could file environmental public interest litigation against polluting enterprises that commit illegal and environmentally destructive acts. Second, it increased government and official accountability and power. The new law stated unequivocally that the government is responsible for environmental quality within its administrative jurisdiction. The ecological protection red line was an important standard for assessing government officials' environmental protection responsibilities during their tenure. Local environmental agencies had the authority to halt illegal environmental activities. Furthermore, it significantly increased polluters' responsibility. High-polluting businesses must provide more specific environmental information to the public, such as the name of pollutants discharged, emission method, emission concentration and emission level, total emissions of major pollutants and excessive emissions, and details on the construction and operation of pollution prevention facilities. Furthermore, the law established a daily penalty system, which means that businesses involved in pollution cases will be fined indefinitely until they correct illegal pollutant discharge behavior.

Recently, ESG investment has been widely recognized as an effective means of protecting the environment and ensuring the economy's long-term development, attracting significant research attention. According to Li and Li (2022), an environmental protection tax implemented in China in 2018 significantly improved ESG investments by Chinese listed companies and promoted green technological innovations. They also established a link between ESG performance and green innovation. Zheng et al. (2022) discovered a long-run bidirectional comovement between ESG performance and enterprise green innovation output. According to Bada et al. (2019), high-rated government bonds outperformed low-rated bonds across all ESG dimensions. Zhou and Zhou (2021) showed that good ESG performance reduced the increase in stock price volatility caused by COVID-19, and played a role in improving "resilience" and stabilizing stock prices. Since the emission of air pollutants by polluting industries is considered the major source of air pollution in China, ESG investments strength should be closely related to air pollution.

This chapter examines how ESG investments and China's new environmental law affect social happiness. I collect the most recent environmental, macroeconomic, ESG investments, and social survey data and analyze the impact of ESG investments and new environmental legislation on social happiness. I contribute to the literatures as follows. First, while the impact of ESG investment on social welfare would be of great research interest, such issues have not been adequately studied. I fill this void by emphasizing the importance of ESG investment's social impact. Second, literature on happiness focuses primarily on the individual level. I approach my analysis in this chapter from a macro perspective. As a result, my findings are critical for policymakers.

According to my findings, China's air pollution significantly reduces social happiness. ESG investments and the new environmental law significantly reduce air pollution, restoring severely damaged social happiness in the years that follow.

The remainder of this chapter is organized as follows. Section 2 briefly describes my data. My models are introduced in Section 3. Section 4 discusses the empirical findings, and Section 5 concludes.

3.2 Data

I focus on the impact of air pollution, ESG investment, and new environmental law on social happiness in this chapter. My sample spans the years 2015 to 2019. I obtain the most recent personal happiness score from the Chinese General Social Survey (CGSS), the China Family Panel Studies (CFPS), and the Chinese Social Survey (CSS). I use all of these data to build my social happiness data because these social surveys were not conducted every year. Specifically, I use CGSS2015, 2017, and 2018, CFPS2016, and CSS2019. Then, each year, I calculate the provincial happiness score as the average of personal happiness in each province. I unify the scale of these data because the CFPS's scale of happiness score (which ranges from one to ten) differs from the CGSS's and CSS's (which range from one to five).

My ESG data, which includes environmental, social and corporate governance investment scores on China's listed companies, is provided by Syntao Green Finance in China. These scores are rated according to 14 categories and over 200 indicators. The aggregate ESG investment strength is a better indicator of local environmental protection efforts than the average ESG investment level of listed businesses, thus I calculate the ESG and environmental investment scores at the provincial level by adding up these scores in each province.

I obtain information on the air quality index (AQI), PM2.5, and PM10 from the China Air Quality Online Detection and Analysis Platform in terms of air pollution. The average of the cities within each province is used to calculate the air quality data at the provincial level.

Other control variables are gathered from the National Bureau of Statistics of China and include industrial added value, population density, afforestation area, coal consumption, government medical and educational spending, unemployment rate, GDP per capita, divorce rate, proportion of urban population, birth rate, and death rate, among others. Table 1 lists the definitions of the variables and the summary statistics.

Table 1. Definition of variables

Abbreviation	Variables	Definition	Sources	Mean	Std	Obs
HAP	Happiness	Provincial happiness level calculated by averaging personal happiness score in each province every year.	CGSS, CFPS, CSS	3.89	0.19	135
ESG	ESG score	Environmental, Social and Governance aggregate investment score	SynTao Green Finance	10.52	15.87	135
ENV	Environmental score	Environmental investment score		11.53	17.26	135
SOC	Social score	Social investment score		9.62	14.67	135
GOV	Governance score	Corporate governance investment score		10.37	15.68	135
AQI	Air Quality Index	The level of air pollution	China Air Quality Online Detection and Analysis Platform	79.42	20.10	135
PM2.5	Particulate Matter 2.5	Particulate matters that have a diameter less than 2.5 micrometers		48.51	15.37	135
PM10	Particulate Matter 10	Particulate matters that have a diameter less than 10 micrometers		85.61	29.11	135
IAV	Industrial added value	The gross output value of industrial enterprises minus the purchase of raw materials	the National Bureau of Statistics of China	12869.08	9791.1	135
PD	Population density	Density of population(person/sq.km)		2927.54	1144.94	135
AA	Afforestation area	In all the land that can be planted, trees and shrubs are planted by various methods, and the survival rate reaches 85% or more(hectare)		35.21	16.69	135
C	Coal	Coal consumption by region (10 thousand tons)		15556.12	12084.25	135
MDE	Medical expenditure	Public financial expenditure of local government-Medical treatment and public health (100 million yuan)		503.88	253.97	135
EDE	Educational expenditure	Public financial expenditure of local government-Education (100 million yuan)		1012.34	537.65	135
EC	Education construction	Completion of capital construction investment in the education sector-Total investment completed in the current year (10 thousand yuan)		1376045	1044824	135
POP	Population	Total population at year end		5008.26	2801.32	135
SO2	Sulfur dioxide	Sulfur dioxide emission of waste gas (10 thousand tons)		30.01	26.66	135
UEI	Urban environment infrastructure	Investment in urban environment infrastructure by region (100 million yuan)		202.02	140.629	135
UR	Unemployment rate	Ratio of the unemployed to the working population (%)		3.23	0.622	135
GDP	GDP per Capita	Total output divided by total population		59694.05	29139.38	135
DR	Divorce rate	Number of divorces per 1,000 people (‰)		2.95	0.98	135
PUP	Proportion of urban population	Ratio of urban population to total population (%)		61.72	11.40	135
BR	Birth rate	Rate of average number of births per 1,000 people (‰)		10.91	2.68	135
DER	Death rate	Rate of average number of deaths per 1,000 people (‰)		6.22	0.78	135

3.3 Models

First, I construct the following panel regression model to investigate the impact of air pollution on social happiness.

$$HAP_{i,t} = \alpha_0 + \alpha_1 AIR_{i,t} + \mathbf{X\beta} + \varepsilon_{i,t} \qquad (1)$$

where $HAP_{i,t}$ represents for social happiness level in province i in year t. AIR refers to air pollution, which is represented by AQI, PM2.5 and PM10. $\mathbf{X}$ represents the vector of control variables. $\varepsilon_{i,t}$ is the error term. According to Bonasia et al. (2022) and Xu et al. (2022), coal consumption, government medical expenditure, government educational expenditure, education construction, population, SO_2 emission, urban environment infrastructure, unemployment rate, divorce rate, gross domestic product, proportion of urban population, birth rate, and death rate are selected as control variables.

Then, I construct the following Difference-in-Difference models to examine the influence of ESG investment and the implementation of new environmental law on air pollution.

$$AIR_{i,t} = \alpha_0 + \alpha_1 ESG_{i,t} + \alpha_2 NEL + \mathbf{X\beta} + \varepsilon_{i,t} \qquad (2)$$

where $AIR_{i,t}$ is the air pollution level. $NEL = Treat_i \times Post_t$ represents for the influence of implementation of new environmental law on air pollution. $Treat_i$ equals 1 if the air was heavily polluted in province i in 2015 (in my sample, the annual average AQI was larger than 90), and equals 0 otherwise. $Post_t$ equals 1 after 2016 and equals 0 otherwise. I put it in this manner since these social surveys were carried out every year at the midterm. In particular, the CGSS 2015 was conducted in June 2015, just six months after the new environmental law went into effect. Since the time-lag effect of environmental policy implementation has been demonstrated by Guo et al. (2020), I postpone the treatment effect of the new environmental law to 2016. After that, I may evaluate if ESG investments and the new environmental regulation are effective at reducing severe air pollution. The vector of control variables is represented by $\mathbf{X}$. According to Borck and Schrauth (2021), Yuan et al. (2018), and Yao et al. (2020), the control variables chosen include afforestation area, urban environment infrastructure, population density, and industrial added value.

3.4 Empirical results

In this part, I first investigate whether, from a global perspective, air pollution has an impact on social happiness. The impact of ESG investments and the enforcement of new environmental protection laws on air pollution is then examined.

The empirical results of equation (1) are reported in table 2. Clearly, case (1) demonstrates that, after controlling for other factors, the impact of air pollution on social happiness is statistically and economically significant at the provincial level. One unit drop in the AQI increases social happiness by 0.674 unit, showing that an improvement in the air quality immediately and significantly increased social happiness. In cases (2) and (3), PM2.5 and

PM10, respectively, stand in for air pollution. Similar consequences to those in case (1) are visible to us. One may consider that social happiness may be affected by its previous period. Thus, I apply the dynamic panel approach, and these results are presented in case (4), (5), and (6). Similarly, the impact of air pollution on social happiness is still significant. These are in line with previous literatures (Welsch, 2006, Ferreira et al., 2013, Levinson, 2012, Breslow et al., 2016, Bonasia et al., 2022), which demonstrates the negative impact of air pollution on happiness in advanced economies.

The impact of ESG investments and the new environmental protection law on air pollution is then investigated. Table 3 displays the results of equation (2). Case (1) demonstrates that ESG investment significantly reduced air pollution after controlling for other factors. One unit increase in ESG investment would reduce 0.334 unit of air pollution and thus increase social happiness by 0.225 unit (0.334×0.674). The Sobel test statistics in table 2 suggest that This improvement is statistically significant. I obtain similar results in case (2), (3) and (4) by substituting environmental, social and corporate governance investments for ESG investments, respectively.

In case (5), I investigate the impact of the implementation of new environmental protection law on air pollution. Clearly, the new law's implementation dramatically reduced air pollution, which is consistent with Xu et al. (2022), who found that environmental regulations can mitigate the negative effect of air pollution on social happiness. I can infer that the new environmental protection law's ability to reduce air pollution is independent of the impact of ESG investments because there is little change in the estimates of ESG investments and a big increase in the adjusted R squared. Case (6), (7), and (8) achieves similar results to case (5) when environmental, social and corporate governance investments was substituted for ESG investments.

To check the robustness of my results, I substitute the PM2.5 and PM10 for AQI as dependent variable in equation (2). These results are reported in table 4 and 5, respectively. Again, ESG investments dramatically reduced PM2.5 and PM10 levels. The new environmental protection law continues to have a significant impact on reducing PM2.5 and PM10, similar to the findings from table 3, independent of the influence of ESG investments.

Overall, my findings imply that by reducing China's air pollution issues, ESG investments and the new environmental protection law considerably increased social happiness.

Table 2. Impact of air pollution on social happiness at provincial level

	Dependent variable: Happiness					
	Case (1)	Case (2)	Case (3)	Case (4)	Case (5)	Case (6)
AQI	−0.674**			−1.068**		
	(−2.66)			(−2.44)		
PM2.5		−0.686**			−1.203**	
		(−2.24)			(−2.2)	
PM10			−0.414***			−0.434
			(−2.81)			(−1.39)
Lag.HAP				9.076	12.112	5.613
				(0.5)	(0.65)	(0.31)
C	1.50E−03	1.61E−03	1.51E−03	3.3E−06	9.89E−04	6.42E−04
	(1.00)	(0.94)	(1.02)	(0.15)	(0.45)	(0.3)
MDE	0.027	0.026	0.032	0.010	−0.039	0.006
	(0.42)	(0.41)	(0.51)	(0.08)	(−0.28)	(0.05)
EDE	−0.057	−0.055	−0.045	−0.031	0.004	−0.010
	(−1.50)	(−1.46)	(−1.20)	(−0.4)	(−0.05)	(−0.12)
EC	−2.08E−06	−1.73E-06	−2.37E−06	5.71E−06	6.06E−06	5.96E−06
	(−0.55)	(−0.47)	(−0.62)	(0.99)	(1.02)	(1.01)
POP	0.073**	0.073*	0.058*	0.011	−4.09E−03	−0.015
	(2.10)	(2.04)	(1.79)	(0.16)	(−0.06)	(−0.22)
SO_2	0.086	0.118	0.099	0.135	0.313	0.220
	(0.93)	(1.16)	(1.09)	(0.29)	(0.66)	(0.47)
UEI	−0.029	−0.030	−0.025	−0.018	−0.022	−0.022
	(−1.11)	(−1.12)	(−1.01)	(−0.32)	(−0.39)	(−0.4)
UR	−2.480	−2.396	−2.412	−5.299	−6.701	−4.627
	(−0.44)	(−0.41)	(−0.42)	(−0.54)	(−0.66)	(−0.46)
GDP	−4.12E−05	−5.92E−05	−4.16E−05	−2.23E−05	−4.76E−05	2.21E−05
	(−0.42)	(−0.58)	(−0.43)	(−0.17)	(−0.35)	(0.17)
DR	−3.435*	−3.729*	−3.827*	−3.639	−3.891	−3.964
	(−1.73)	(−1.71)	(−1.95)	(−1.16)	(−1.21)	(−1.26)
PUP	1.753	1.931*	1.568	0.751	0.978	1.536
	(1.66)	(1.77)	(1.38)	(0.29)	(0.37)	(0.58)
BR	−5.738***	−5.785***	−5.266***	−1.792	−1.328	−2.404
	(−3.51)	(−3.71)	(−3.28)	(−0.55)	(−0.38)	(−0.73)
DER	−3.526	−2.184	−0.901	−10.991	−10.703	−9.785
	(−0.45)	(−0.28)	(−0.12)	(−0.95)	(−0.9)	(−0.84)
Sobel	0.00	0.00	0.00			
Adj. R square	0.314	0.300	0.295			

Values in parentheses are t-values. *, **, and *** represent for significance at 10%, 5%, and 1%, respectively. AQI, PM2.5, and PM10 refer to Air Quality Index, Particulate Matter 2.5, and Particulate Matter 10. Definitions of other control variables are provided in table 1. Sobel represents for the test statistics of Sobel test, the results of the Sobel test are p-values.

Table 3. Impact of ESG investments and the implementation of new environmental protection law on air quality index

Dependent variable: AQI								
	Case (1)	Case (2)	Case (3)	Case (4)	Case (5)	Case (6)	Case (7)	Case (8)
ESG	−0.334***				−0.328***			
	(−4.36)				(−4.38)			
ENV		−0.339***				−0.333***		
		(−4.31)				(−4.35)		
SOC			−0.308***				−0.303***	
			(−4.37)				(−4.39)	
GOV				−0.360***				−0.353***
				(−4.39)				(−4.39)
NEL					−7.974***	−8.005***	−7.963***	−7.952***
					(−3.3)	(−3.31)	(−3.29)	(−3.29)
UEI	−1.80E−03	−1.91E−03	−1.73E−03	−1.85E−03	0.017	0.017	0.017	0.017
	(−0.14)	(−0.15)	(−0.14)	(−0.15)	(1.33)	(1.32)	(1.33)	(1.32)
AA	−0.762***	−0.763***	−0.763***	−0.759***	−0.752***	−0.753***	−0.753***	−0.749***
	(−4.85)	(−4.86)	(−4.86)	(−4.82)	(−5.46)	(−5.47)	(−5.47)	(−5.43)
PD	−2.86E−04	−3.07E−04	−2.8E−04	−3.01E−04	7.63E−04	7.49E−04	7.68E−04	7.46E−04
	(−0.17)	(−0.18)	(−0.16)	(−0.17)	(0.47)	0.46	(0.48)	(0.46)
IAV	2.82E−04	2.88E−04	2.88E−04	2.80E−04	1.73E−04	1.71E−04	1.78E−04	1.69E−04
	(1.02)	(1.01)	(1.04)	(1.01)	(0.69)	0.68	(0.71)	(0.68)
Adj.R square	0.297	0.294	0.297	0.299	0.427	0.425	0.427	0.429

Values in parentheses are t-values. *, **, and *** represent for significance at 10%, 5%, and 1%, respectively. ESG, ENV, and NEL represent for ESG investment, environmental investment, and the treatment effect of new environmental protection law, respectively. Definitions of other control variables are provided in table 1.

Table 4. Impact of ESG investments and the implementation of new environmental protection law on PM2.5

	Dependent variable: PM2.5							
	Case (1)	Case (2)	Case (3)	Case (4)	Case (5)	Case (6)	Case (7)	Case (8)
ESG	−0.302***				−0.296***			
	(−4.26)				(−4.28)			
ENV		−0.305***				−0.300***		
		(−4.19)				(−4.23)		
SOC			−0.279***				−0.273***	
			(−4.27)				(−4.29)	
GOV				−0.327***				−0.319***
				(−4.30)				(−4.30)
NEL					−7.741***	−7.772***	−7.735***	−7.710***
					(−3.45)	(−3.45)	(−3.44)	(−3.43)
UEI	−4.92E−03	−5.07E−03	−4.85E−03	−4.87E−03	0.015	0.015	0.015	0.015
	(−0.42)	(−0.44)	(−0.42)	(−0.42)	(1.31)	(1.30)	(1.31)	(1.31)
AA	−0.496***	−0.497***	−0.497***	−0.493***	−0.483***	−0.484***	−0.484***	−0.481***
	(−3.76)	(−3.77)	(−3.77)	(−3.74)	(−4.33)	(−4.34)	(−4.34)	(−4.31)
PD	−1.32E−05	−3.42E−05	−7.48E−06	−2.08E−05	1.06E−03	1.05E−03	1.07E−03	1.05E−03
	(−0.01)	(−0.02)	(−0.00)	(−0.01)	(0.76)	(0.75)	(0.77)	(0.76)
IAV	2.62E−04	2.59E−04	2.68E−04	2.61E−04	1.57E−04	1.56E−04	1.62E−04	1.54E−04
	(1.10)	(1.09)	(1.13)	(1.10)	(0.76)	(0.75)	(0.78)	(0.74)
Adj.R square	0.280	0.277	0.280	0.282	0.443	0.441	0.443	0.445

Values in parentheses are t-values. *, **, and *** represent for significance at 10%, 5%, and 1%, respectively. ESG, ENV, and NEL represent for ESG investment, environmental investment, and the treatment effect of new environmental protection law, respectively. Definitions of other control variables are provided in table 1.

Table 5. Impact of ESG investments and the implementation of new environmental protection law on PM10

	Dependent variable: PM10							
	Case (1)	Case (2)	Case (3)	Case (4)	Case (5)	Case (6)	Case (7)	Case (8)
ESG	−0.392***				−0.369***			
	(−3.66)				(−3.64)			
ENV		−0.396***				−0.375***		
		(−3.61)				(−3.61)		
SOC			−0.362***				−0.341***	
			(−3.67)				(−3.65)	
GOV				−0.420***				−0.394***
				(−3.66)				(−3.63)
NEL					−13.039***	−13.071***	−13.020***	−13.030***
					(−4.04)	(−4.04)	(−4.03)	(−4.04)
UEI	−9.18E−03	−9.32E−03	−9.04E−03	−9.34E−03	0.011	0.011	0.011	0.011
	(−0.52)	(−0.52)	(−0.51)	(−0.53)	(0.64)	(0.63)	(0.64)	(0.63)
AA	−1.109***	−1.110***	−1.109***	−1.106***	−1.128***	−1.130***	−1.129***	−1.126***
	(−4.78)	(−4.8)	(−4.79)	(−4.75)	(−5.12)	(−5.14)	(−5.13)	(−5.09)
PD	−1.85E−03	−1.86E−03	−1.83E−03	−1.88E−03	−8.74E−04	−8.89E−04	−8.63E−04	−9.09E−04
	(−0.75)	(−0.76)	(−0.75)	(−0.76)	(−0.37)	(−0.38)	(−0.37)	(−0.39)
IAV	3.03E−04	2.99E−04	3.13E−04	2.98E−04	1.73E−04	1.70E−04	1.81E−04	1.67E−04
	(0.75)	(0.74)	(0.78)	(0.74)	(0.45)	(0.44)	(0.47)	(0.43)
Adj.R square	0.257	0.255	0.257	0.259	0.414	0.412	0.412	0.416

Values in parentheses are t-values. *, **, and *** represent for significance at 10%, 5%, and 1%, respectively. ESG, ENV, and NEL represent for ESG investment, environmental investment, and the treatment effect of new environmental protection law, respectively. Definitions of other control variables are provided in table 1.

3.5 Conclusion

With China's rapid economic development, air pollution has severely harmed social happiness and government satisfaction. The Chinese government enacted a new environmental law in 2015 in order to control air pollution and achieve sustainable economic growth. This chapter contributes to the literatures by investigating the impact of ESG investment strength and China's new environmental law on social happiness. Unlike previous studies, I conduct my research from a macro perspective, focusing on social happiness rather than subjective happiness at the individual level.

According to my findings, ESG investments improved social happiness by reducing air pollution. One unit increase in ESG investments reduced air pollution by 0.334 unit while improve social happiness by 0.225 unit. These results are consistent with Shi and Yu (2020), which showed the casual effect between air pollution and individual subjective well-being. On the other hand, the implementation of the new environmental law has a significant impact on reducing air pollution and improving social happiness. The impact of the new law is independent of ESG investments. These results are in line with Guo et al. (2020), which suggested the positive effect of environmental regulations on happiness during 2013 and 2015 in China. My findings show that the Chinese government and industries have made significant strides in environmental protection over the last decade. China's economy is rapidly progressing toward sustainable development. However, as long as the reliance on thermal power continues, sustainable development goals can hardly be achieved. The use of clean energy and its social impact could be of great importance for future research.

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Chapter 4

Does the EV industry help achieve sustainable development goals?

—— Evidence from China.

4.1 Introduction

Sustainable development goals have recently drawn a lot of attention. Reduced air pollution and slowed energy consumption growth have become China's two most pressing concerns for sustainable development. China has promoted the use of electric vehicles for this reason. In 2010, the Chinese government issued the "Decision on Accelerating the Cultivation and Development of Strategic Emerging Industries", which listed the development of electric vehicles industry as one of the strategic emerging industries. Since then, the implementation of many policies has promoted the development of electric vehicle industry. China released the "Energy-saving and New Energy Automobile Industry Development Plan (2012-2020)" in July 2012 and noted that the demand for automobiles would continue to rise for a considerable amount of time, leading to an increase in energy consumption and more severe environmental pollution issues. Accelerating the development of new energy vehicles would effectively alleviate the pressure of energy consumption and environmental pollution, stimulate the transformation and upgrading of the automotive industry, and cultivate new economic growth source and international competitive advantage of strategic initiatives. In October 2020, the Chinese government released the "New Energy Vehicle Industry Development Plan (2021-2035), striving to effectively promote the level of energy conservation and emission reduction and the efficiency of social operation, and achieve international advanced level of core technology and strong international competitiveness of quality brands of Chinese new energy vehicles. The rapid growth of China's EV industry and great efforts made by the Chinese government attract substantial research attention. (Wu et al. 2021; Zhang et al. 2017; Hao et al. 2014).

With rapid economic development and urbanization, China has become the world's largest automobile market, with an average growth rate of 17.5% since 2000 (Hao et al. 2016). Air pollution was a common challenge in the urbanization of industrialized countries (IEA, 2019), and automobiles have become a major source of air pollution in China (He & Jiang, 2021). China has introduced a series of regulations to reduce the environmental impact of air pollutants emitted by automobiles. Liu et al. (2022) used the emission factor method to analyze automobile air pollutant emissions in 31 provinces from 2006-2016, and their results showed that pollutants emission efficiency of automobiles had a significant inhibitory effect on three major air pollutants. In terms of the structure of energy consumption in automobile industry, electric vehicles, as an effective means to reduce air pollution, have long been the focus of government attention (Su et al. 2021). Xie et al. (2021) explored the environmental impact of subsidies for electric vehicles on urban air pollution. Their results indicated that a 1% increase in the size of subsidies for electric vehicles would reduce air pollution levels by 0.15%. Su et al. (2021) found that electric vehicles could not be regarded as effective measures to reduce air pollution. They suggest that EVs still do not account for a high proportion of car sales, and therefore, its effect on environmental protection is not obvious.

Carbon emission has been one of the important research topics of sustainable development. Automobiles emit large amounts of carbon compounds, causing serious environmental pollution problems, and efforts have been made worldwide to address this. Klier & Linn (2015) analyzed new vehicle registration data from European countries and found that CO_2 taxes reduced car registrations. In order to reduce automotive carbon emissions, China has also introduced several policies to develop EV industry. Zhao & Sun (2022) analyzed short- and long-term policy effects related to EV industry on carbon emissions in the local transportation sector. They found the increasing use of electric vehicles reduced carbon emission. Yu et al. (2022) found that the total life-cycle energy consumption and carbon emission of all electric vehicles are lower than those of gasoline vehicles.

China's growing oil demand brings negative issues such as energy security concerns, carbon emissions and air pollution. It was important to control the total oil consumption to ensure the security of national energy supply, and to cope with climate change and environmental pollution (Jiang et al. 2022). The transportation sector was the main source of crude oil consumption and carbon emissions in China (Wang et al., 2019). According to the forecast of Ma et al. (2012), 64% of crude oil consumption by 2030 would be consumed by the transportation sector. If the Chinese government took no action on reducing oil demand, China's oil demand would reach 808 million tons annually by 2030, with 43% of that demand coming from transportation. China's reliance on oil imports would have increased to 80% by then (Oliver et al. 2009). Automobiles have emerged as one of the major contributors to the growth in oil consumption (Zhang et al. 2017). The use of electric vehicles could largely help reduce oil consumption. According to estimates made by Wu et al. (2012), coal power would reduce well-to-wheels (WTW) CO_2 emissions by 17% compared to a low-private light passenger vehicle scenario by 2030, when it was projected to generate only 41% of the nation's electricity.

Electric vehicles have been seriously considered as an industrial revolution toward sustainable transportation in China as a result of the serious environmental, energy security, and health issues that are being caused by the rapid increase in the number of automobiles (Wu et al. 2012). Zhao & Heywood (2017) investigated how electrification could help cut energy demand, oil dependence, and carbon emissions from transportation in China. Their findings showed that electric vehicles had a great potential to do so because of its high efficiency in energy use. The performance of electric vehicles varied across different countries. Holland et al. (2016) analyzed and compared the relevant data of gasoline-powered vehicles and electric vehicles in various states in the United States, revealing that the environmental benefits of electric cars differ due to local pollution and policies. As transportation was a significant contributor to global and local air pollution (Davis & Kilian, 2011), electric vehicles had a unique appeal in transforming individual transportation. Holland et al. (2021) used a dynamic model that captured the decreasing cost of electric cars to analyze this transition in terms of reducing electricity pollution and increasing vehicle substitutability. Their analysis of the US market showed that transitioning from gasoline cars was not optimal under current substitutability, as a ban on gasoline car production would result in significant unnecessary losses. Additionally, in the UK, the pleasure of driving and the identity derived from owning and using EVs also influenced drivers' willingness to use electric cars (Schuitema et al., 2013).

Since 2009, China started to clarify the development of EVs and explicitly increased related financial support. In 2011, a comprehensive transition strategy for pure electric drive technology was proposed. The rollout took place in cities that qualified for the subsidy between 2009 and 2015. In 2016 the subsidy was expanded to the entire nation. Price subsidies decreased from 2016 to 2020. Financial support policies implied that the government believed the cost of EVs will fall as commercialization rose (Hao et al. 2014).

In the process of automobile electrification, electricity was mainly derived from thermal power generation, which was closely related to carbon emissions. Therefore, the use of coal should also be of concern. Li & Leung (2012) examined the relationship between coal consumption and real GDP in China and found that the relationship between coal consumption and GDP in eastern and central regions was bidirectional, and thus energy conservation measures may have dragged down the economies of eastern and central regions where coal-intensive industries were concentrated. Hofmann et al. (2016) applied a scenario analysis and argued that EV industry could contribute to the reduction of oil dependence, improvement of air quality, and reduction of carbon emissions only when their introduction was accompanied by aggressive electricity sector decarbonization.

Some literatures point out that the EV industry can hardly reduce air pollutants and GHG emissions (Ji et al., 2015; Mahmoud et al., 2016; Huo et al., 2010.). If electricity is still generated by fossil energy, the reduced carbon emissions and air pollution of electric vehicles in the transportation sector will be partially offset by the increase in the electricity sector. The adoption of EVs can only transfer the pollution and carbon emission between departments, which is not conducive to reduce the total carbon emissions, environmental pollution and reliance on fossil energy. As electricity in China mainly comes from thermal power generation, the relationship between the use of electric, carbon emission, air pollution and energy consumption remain unclear. Thus, I investigate whether the development of EV industry help reduce carbon emission, air pollution and energy consumption in China.

This study adds to the literatures by providing empirical evidence to show that the EV industry help reduce oil dependence in China. However, since the electricity mainly comes from thermal power, the carbon emissions and air pollutants emissions are transferred from oil consumption to coal consumption, and cannot be reduced by EV industry. I also show the regional heterogeneity of the influence of EV industry on energy consumption, carbon emission, and air pollution.

This chapter is organized as follows. Section 2 briefly describes the data. Section 3 introduces the empirical models. Section 4 discusses the results, and section 5 concludes.

4.2 Data

I focus on the impact of EVs on air pollution, carbon emissions, and energy consumption in chapter. I collected the most recent data and the sample spans the years 2015 to 2020.

My data on automobiles, which includes the amount of electric and conventional vehicles, is collected from DaaS-Auto database. In terms of air pollution, I collect data on the air quality index (AQI), PM2.5, and PM10 from the China Air Quality Online Detection and Analysis Platform. The provincial air quality data is calculated by taking the average of the cities within each province. Energy consumption data such as gasoline and coal are gathered from CSMAR database and the National Bureau of Statistics of China. Total amount of carbon emissions, carbon emissions from gasoline consumption and coal consumption are gathered from CSMAR.

Other control variables are collected from the National Bureau of Statistics of China which include GDP Per Capita, industrial added value, population density, afforestation area, proportion of urban population, treatment of waste gas, total energy consumption and employment. Table 1 lists the definitions of the variables and table 2 provides the summary statistics.

Table 1. Definition of variables

Abbreviation	Variable	Definition	Source
EV	Electric vehicle	Electric vehicle holding by citizens	DaaS-Auto
OilCar	Fuel car	Fuel car holding by citizens	
AQI	Air Quality Index	The level of air pollution	China Air Quality Online Detection and Analysis Platform
PM2.5	Particulate Matter 2.5	Particulate matters that have a diameter less than 2.5 micrometers	
PM10	Particulate Matter 10	Particulate matters that have a diameter less than 10 micrometers	
GDPPC	GDP Per Capita	Total output divided by total population	the National Bureau of Statistics of China
IAV	Industrial added value	The gross output value of industrial enterprises minus the purchase of raw materials	
PD	Population density	Density of population (person/sq.km)	
AA	Afforestation area	In all the land that can be planted, trees and shrubs are planted by various methods, and the survival rate reaches 85% or more(hectare)	
TWG	Treatment of waste gas	Amount of investment completed in industrial waste gas pollution control projects	
EMP	Employments	The number of people who engage in a certain social labor and obtain labor remuneration or operating income (10 thousands people)	
EC	Energy Consumption	Within a certain area, the various energy sources of various industries and residential families in the national economy and households will consume in a certain period of time. (10 thousand tons of standard coal)	CSMAR, the National Bureau of Statistics of China
Gaso	Gasoline	Consumption of this energy by region (10 thousand tons)	
Coal	Coal		
CO2	Total amount of carbon emissions	The sum of carbon emissions of various energy sources (10 thousand tons)	CSMAR
GCO2	Gasoline carbon emissions	Carbon emissions from gasoline consumption	
CCO2	Coal carbon emissions	Carbon emissions from coal consumption	

Table 2. Summary statistics

Variable	Obs	Mean	Std. dev.	Min	Max
EV	186	40444.78	67515.17	0	408920
OilCar	186	5123335	4090626	117249	1.98E+07
AQI	186	74.92566	21.75624	29.29235	134.6247
PM2.5	186	44.8984	16.7045	8.136612	94.59452
PM10	186	79.96283	30.57009	22.71585	164.8
EMP	186	2491.52	1674.005	181	7039
CO2	150	44117.57	32248.43	5525.828	151698.3
GCO2	150	1405.273	926.2363	54.9717	4571.759
CCO2	150	28125.07	22927.73	347.8136	97668.66
EC	180	15621.68	9260.523	1916	41826.8
Gaso	180	484.3729	317.9312	18.77	1561.02
Coal	172	15080.29	12363.17	134.98	53739.03
GDPPC	186	60892.79	28462.29	25945.98	164158
IAV	186	11595.28	10084.61	376.187	44270.51
PD	185	2897.07	1097.451	1135.53	5515
AA	186	33.39726	18.17508	4.24	66.8
TWG	184	137648	160639.7	0	966722

4.3 Models

I first construct the following models to investigate the impact of EV holdings on energy consumption such as gasoline and coal.

$$Energy_{i,t} = a_0 + a_1 EV_{i,t} + a_2 OilCar_{i,t} + \boldsymbol{X\beta} + \eta_i + \tau_t + \varepsilon_{i,t} \quad (1)$$

$$Energy_{i,t} = a_0 + a_3 EV/OilCar_{i,t} + \boldsymbol{X\beta} + \eta_i + \tau_t + \varepsilon_{i,t} \quad (2)$$

where Energy refers to gasoline or coal consumption. $EV_{i,t}$ represents for electric vehicle holdings in province i in year t. $EV/OilCar_{i,t}$ is the ratio of EV holdings to fuel car holdings. $\boldsymbol{X}$ is the vector of control variables. Here, the control variables are selected according to He et al. (2005) and Chai et al. (2012). η_i is the provincial fixed effect, and τ_t is time fixed effect.

Then, I construct the following models to investigate how EV holdings affect carbon emissions.

$$CO2_{i,t} = a_0 + a_1 EV_{i,t} + a_2 OilCar_{i,t} + \boldsymbol{X\beta} + \eta_i + \tau_t + \varepsilon_{i,t} \quad (3)$$

$$CO2_{i,t} = a_0 + a_3 EV/OilCar_{i,t} + \boldsymbol{X\beta} + \eta_i + \tau_t + \varepsilon_{i,t} \quad (4)$$

where CO2 refers to total carbon dioxide emission, carbon dioxide emission from gasoline consumption or carbon dioxide emission from coal consumption. $\boldsymbol{X}$ is the vector of control variables. Here, the control variables are selected according to Wang et al. (2013) and Lin & Du (2015). Again η_i and τ_t represent for the provincial and time fixed effect, respectively.

Last, I investigate the influence of EV holdings on air pollution by applying the following models.

$$AirPollution_{i,t} = a_0 + a_1EV_{i,t} + a_2OilCar_{i,t} + \boldsymbol{X\beta} + \eta_i + \tau_t + \varepsilon_{i,t} \quad (5)$$

$$AirPollution_{i,t} = a_0 + a_3EV/OilCar_{i,t} + \boldsymbol{X\beta} + \eta_i + \tau_t + \varepsilon_{i,t} \quad (6)$$

where air pollution is represented by air quality index (AQI), PM2.5 or PM10. X is the vector of control variables selected according to Xie et al. (2021) and He & Jiang (2021).

4.4 Empirical Results

4.4.1 Impact of electric vehicle holdings on energy consumption, carbon emission and air pollution

First, I examine the influence of EV holdings on energy consumption. Table 3 reports the results of equation (1) and (2). Clearly, I can observe that EV holdings have significant negative impact on gasoline consumption and positive impact on coal consumption, suggesting that the use of electric vehicles can significantly reduce gasoline consumption. However, since electricity mainly comes from thermal power generation, the use of electric vehicles significantly increased the consumption of coal. On the other hand, the fuel car holdings have no significant impact on gasoline consumption. That is because the Chinese government made great efforts to restrict the use of fuel cars. For example, license issuance for fuel car has been strictly restricted in Beijing and Shanghai, however, for electric vehicles, license issuance is unlimited with no license fee.

Then I replace the number of electronic and fuel cars by their ratios. I can observe that the EV/OilCar ratio has significant negative impact on gasoline consumption and positive impact on coal consumption. Totally, these results suggest that the use of EVs reduce the gasoline consumption, and thus reduce the reliance on oil import. However, EV cannot reduce the reliance on fossil energy.

Then, I examine the influence of EVs on carbon emissions. Table 4 represents these results from equation (3) and (4). Obviously, the increase of EVs significantly reduced carbon emissions from gasoline consumption and increased carbon emissions from coal consumption. These results are in line with table 3. In addition, the positive impact of EVs on carbon emissions from coal consumption is much larger than the negative impact on carbon emissions from gasoline consumption. As a consequence, I can observe that EV holdings significantly increased total carbon emission. That is because the production of EVs increased dramatically in recent years. In 2021, China sold over 3.5 million EVs, about 52% of the whole sales in the world. Although the increased carbon emissions from coal consumption by the use of EVs can be offset by the decrease of the use of fuel cars, the carbon emission in the production process of EVs still increased substantially. After replacing the number of EV and fuel car holdings by their ratio, similar results can be obtained. Totally, I can conclude that under the current stage, the development of EV industries does not help reducing carbon emissions.

Table 3. Impact of EV holdings on gasoline and coal consumption.

	Gasoline		Coal	
EV	−5.17e-4***		6.51e-3**	
	(0.00)		(0.04)	
OilCar	4.42e-6		−9.62e-4***	
	(0.50)		(0.00)	
EV/OilCar		−1347.40**		58023.94***
		(0.04)		(0.00)
EMP	−0.07**	−0.09***	−0.52	−0.33
	(0.02)	(0.00)	(0.49)	(0.67)
GDP	0.01***	4.9e-3**	−0.28***	−0.52***
	(0.00)	(0.02)	(0.00)	(0.00)
IAV	−0.01*	1.06e-5	0.52***	0.82***
	(0.06)	(0.99)	(0.00)	(0.00)
Individual fixed effect	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES
Adj.R2	0.59	0.55	0.75	0.71

Values in parentheses are p-values. *, **, and *** represent for significance at 10%, 5%, and 1%, respectively.

Table 4. Impact of EV holdings on carbon emissions.

	CO2		Gasoline CO2		Coal CO2	
EV	0.02***		−0.002***		0.01*	
	(0.01)		(0.00)		(0.08)	
OilCar	−0.0003		0.00002		−0.002***	
	(0.36)		(0.44)		(0.00)	
EV/OilCar		66119.26*		−4882.858*		68230.08*
		(0.06)		(0.07)		(0.06)
EMP	−8.63***	−7.79***	−0.01	−0.09	−3.42	0.05
	(0.00)	(0.01)	(0.97)	(0.68)	(0.20)	(0.98)
GDP	−0.63***	−0.52***	0.04***	0.02***	−0.43***	−0.79***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
IAV	0.92***	0.71***	−0.05**	−0.02	0.67**	1.00***
	(0.00)	(0.00)	(0.03)	(0.19)	(0.02)	(0.00)
EC	4.56***	4.58***	0.006	0.007	3.88***	3.79***
	(0.00)	(0.00)	(0.70)	(0.71)	(0.00)	(0.00)
Individual fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
Adj.R2	0.85	0.84	0.59	0.57	0.80	0.76

Values in parentheses are p-values. *, **, and *** represent for significance at 10%, 5%, and 1%, respectively.

Finally, I examine the influence of EV holdings on air pollution. These results are presented in Table 5. Clearly, EVs has no significant impact on air quality index, PM2.5 and PM10. Given the fact that EV holdings would increase the consumption of coals, the air pollutants emission was transferred from the oil consumption to coal consumption. Thus, at the current stage, developing the EV industry cannot help mitigating air pollution.

Table 5. Impact of EV holdings on air pollution.

	AQI		PM2.5		PM10	
EV	−1.3e-5		−2.6e-5		1e-5	
	(0.68)		(0.35)		(0.82)	
OilCar	−5.5e-7		−7.3e-7		−1.6e-6	
	(0.66)		(0.54)		(0.39)	
EV/OilCar		−58.37		−50.98		193.59
		(0.69)		(0.72)		(0.44)
GDPPC	−9.4e-5	−2.1e-4	−3.7e-7	−1.1e-4	1.4e-4	1.6e-6
	(0.66)	(0.36)	(0.99)	(0.62)	(0.64)	(0.99)
IAV/GDP	0.91**	1.09**	0.69**	0.93**	0.91*	1.16*
	(0.02)	(0.02)	(0.04)	(0.04)	(0.09)	(0.07)
PD	−1.1e-3	−1.3e-3	−9.5e-4	−9.9e-4	−4.5e-3	−4.9e-3*
	(0.50)	(0.42)	(0.52)	(0.49)	(0.11)	(0.07)
AA	0.18	0.07	0.02	−0.02	0.74	0.58
	(0.76)	(0.91)	(0.98)	(0.97)	(0.45)	(0.56)
TWG	5.1e-6	6.7e-6	2.3e-6	4.5e-6	1.6e-5	−1.7e-5
	(0.37)	(0.27)	(0.61)	(0.40)	(0.0.12)	(0.12)
EC	1.3e-3**	1.2e-3**	1.4e-3***	9.8e-4	2.5e-3*	2.4e-3**
	(0.04)	(0.04)	(0.01)	(0.11)	(0.08)	(0.04)
Individual fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
Adj.R2	0.75	0.75	0.71	0.69	0.72	0.73

Values in parentheses are p-values. *, **, and *** represent for significance at 10%, 5%, and 1%, respectively.

In sum, I can conclude that the significant increase in electric vehicles help reducing the consumption of gasoline, and thus reduce the reliance on oil import. However, since the electricity is mainly generated by coal, the carbon emissions and air pollutants emissions are transferred from oil consumption to coal consumption. Therefore, the development of EV industry cannot help reducing carbon emissions and air pollution. My empirical results are partially consistent with the scenario analysis of Hofmann et al. (2016), who suggest that unless the electricity industry decarbonized, the introduction of EVs would not contribute to the reduction of oil dependence, air quality improvement and carbon emission reduction. In my empirical analysis, EV industry can contribute to the reduction of oil dependence.

4.4.2 Heterogeneity analysis: thermal power reliance

As concluded above, the primary reason that the development of the EV industry has not reduced carbon emissions and air pollutants emissions is the heavy reliance on thermal power generation. As a result, I investigate the regional heterogeneity of the influence of EV industry development based on thermal power reliance. Figure 1 shows the percentage of thermal power generation to total power generation in each province in 2021. I divide my sample into two groups --- above and below the average level of thermal power reliance in China.

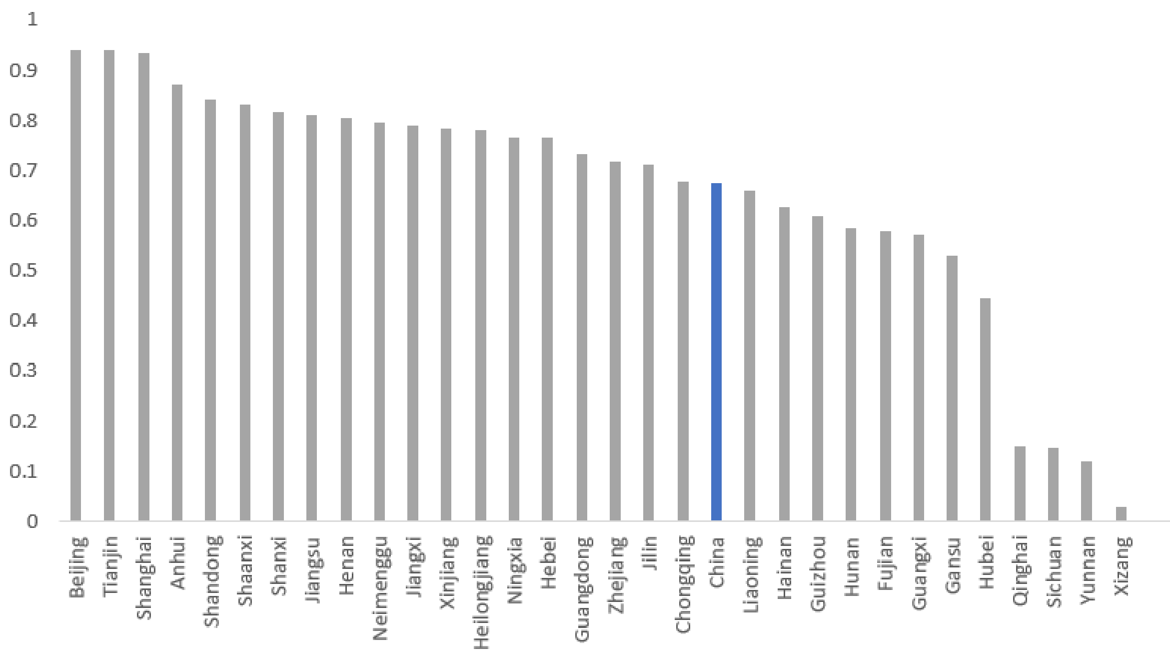

Figure 1. Thermal power reliance in 2021.

The findings of the heterogeneity study based on thermal power reliance are shown in Table 6. The EVs significantly cut gasoline consumption in Group A, which is heavily reliant on thermal power generation. However, coal consumption did not grow considerably. As a result, carbon emissions from gasoline use were greatly reduced, while overall carbon emissions and carbon emissions from coal consumption were not significantly raised. As a consequence, EVs has no discernible influence on air pollution.

On the other hand, EVs significantly reduced gasoline consumption and boosted coal consumption in group B, which relies less on thermal power generation. As a result, carbon emissions from gasoline consumption were greatly lowered, whereas overall carbon emissions and carbon emissions from coal consumption were significantly raised.

In addition, the influence of the substantial increase in EVs on air pollutants emissions is limited.

These findings imply that coal consumption, carbon emissions, and air pollution emissions by industries are extremely high in regions that rely heavily on thermal power generation. Despite rapid growth in the EV sector in recent years, the quantity of coal consumed, carbon emissions, and air pollutants generated by the EV industry is fairly minor when compared to traditional heavy polluting industries. However, in regions where thermal power generation is less prevalent, basic coal consumption, carbon emissions, and air pollution emissions are comparatively low. As a result, the rapid development in EVs boosted coal consumption and carbon emissions in these locations. Because regions that rely less on thermal power do not suffer from severe pollution, the widespread use of electric vehicles could not considerably reduce air pollution.

Table 6. Heterogeneity analysis based on thermal power reliance

	Gasoline	Coal	CO2	Gasoline CO2	Coal CO2	AQI	PM2.5	PM10
Group A: Above the average level of thermal power reliance								
EV	−4.4e-4*	−0.01	8.2e-3	−1.6e-3*	−1.7e-4	−1.2e-5	−2.1e-5	2.2e-5
	(0.08)	(0.46)	(0.55)	(0.08)	(0.99)	(0.7)	(0.43)	(0.64)
OilCar	4.8e-6	−6.7e-4*	−5.8e-4	5.5e-5*	−1.6e-3***	−3.7e-7	−6.1e-7	−1.6e-6
	(0.57)	(0.09)	(0.20)	(0.08)	(0)	(0.78)	(0.62)	(0.37)
Adj.R2	0.54	0.34	0.86	0.60	0.87	0.78	0.74	0.78
Group B: Below the average level of thermal power reliance								
EV	−1.2e-3***	0.03***	0.04**	−5.6e-3***	0.06***	7.8e-5*	2.3e-5	1.3e-4
	(0)	(0.01)	(0.02)	(0)	(0)	(0.05)	(0.17)	(0.12)
OilCar	2.4e-5	−5e-5	−1.3e-3	1.5e-4	−1.9e-3**	−8.4e-6**	−6.3e-6**	−1.5e-5***
	(0.58)	(0.95)	(0.36)	(0.38)	(0.03)	(0.02)	(0.01)	(0)
Adj.R2	0.78	0.33	0.87	0.84	0.66	0.83	0.81	0.80
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Values in parentheses are p-values. *, **, and *** represent for significance at 10%, 5%, and 1%, respectively.

4.4.3 Heterogeneity analysis: net electricity imports and exports

In China, the disparities in economic growth and energy distribution among regions dictate the many linkages between electrical power generation and consumption. Electricity gaps (defined as electricity generation minus electricity consumption) are common in developed regions, although economically impoverished regions in the central and western regions usually generate extra electricity. As a result, the impact of promoting electric vehicles in certain regions will be determined by local power sources. If a region's power supply is mostly provided by other provinces, an increase in electricity consumption caused by the promotion of electric vehicles in that region would have less of an impact on local carbon and air pollutants emissions, resulting in an increase in carbon and air pollutants emissions in electricity exporting provinces. Thus, based on net electricity import and export, I analyze the regional heterogeneity of the effect of EV sector growth. Figure 2 displays the difference between electricity generation and consumption in 2021. My samples are divided into two categories: net electricity import regions and net electricity export regions.

The findings of the heterogeneity study based on net electricity import and export are presented in Table 7. Clearly, the growth of the EV sector has had no discernible influence on coal consumption or carbon emissions in net electricity import regions. However, the growth of the EV industry significantly increased overall carbon emissions and carbon emissions from coal consumption in net electricity export regions. These results indicate that China's unequal distribution of electricity has a regional transfer effect on the impact of EV promotion on carbon emissions. The increased demand for electricity generated by the growth of EVs has also been transferred to electricity exporting areas. As a result, electricity exporting areas are forced to use thermal power to close the electricity imbalance in a short amount of time, increasing carbon emissions in exporting areas.

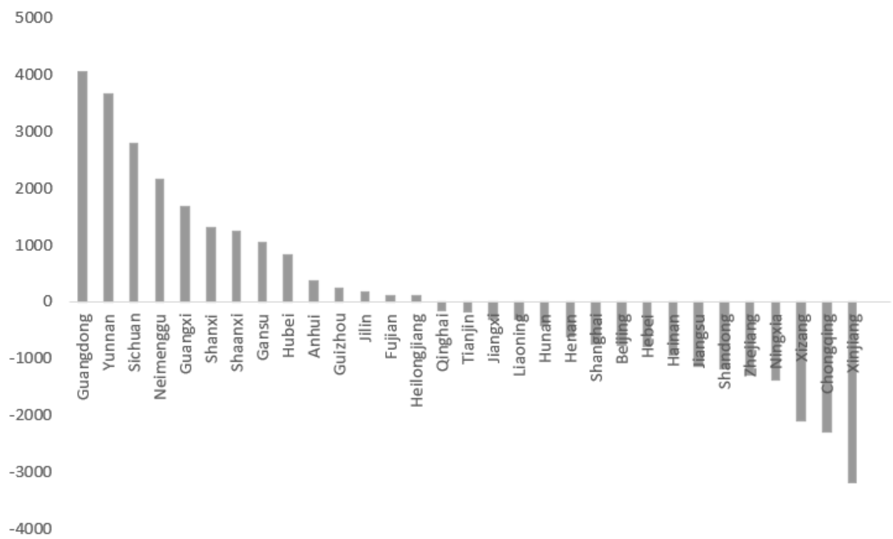

Figure 2. Difference between electricity generation and consumption in 2021 (10^8 kWh)

Table 7. Heterogeneity analysis based on net electricity import and export

	Gasoline	Coal	CO2	Gasoline CO2	Coal CO2	AQI	PM2.5	PM10
Group A: Net electricity import								
EV	−6.4e-4*	−5.2e-3	4.1e-3	−2.1e-3	−4.6e-3	−1.9e-5	−2.4e-5	−1.1e-6
	(0.09)	(0.25)	(0.79)	(0.11)	(0.48)	(0.53)	(0.42)	(0.98)
OilCar	−2.9e-6	−3.9e-4	−2.9e-4	−3.1e-5	−1.1e-3**	−1.3e-6	−1.4e-6	−3.6e-6*
	(0.82)	(0.13)	(0.53)	(0.54)	(0.04)	(0.37)	(0.33)	(0.07)
Adj.R2	0.54	0.40	0.73	0.58	0.70	0.84	0.81	0.82
Group B: Net electricity export								
EV	−7.7e-4*	0.05*	0.11***	1.6e-4	0.1**	9.9e-5	2.6e-5	2.1e-4
	(0.09)	(0.07)	(0.01)	(0.93)	(0.02)	(0.29)	(0.76)	(0.11)
OilCar	4.6e-5**	−1.2e-3	−1.6e-3	1.4e-4*	−1.6e-3	−5.9e-6**	−4.7e-6*	−8.3e-6**
	(0.04)	(0.39)	(0.21)	(0.06)	(0.19)	(0.04)	(0.06)	(0.04)
Adj.R2	0.78	0.38	0.92	0.81	0.90	0.77	0.70	0.78
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Values in parentheses are p-values. *, **, and *** represent for significance at 10%, 5%, and 1%, respectively.

4.5 Conclusion

In the past decade, China is committed to the development of electric vehicle industry for multiple purpose. In addition to developing the automobile industry, carbon emission reduction, environmental protection, and oil dependence reduction have been raised for sustainable development goals.

Existing literatures on the environmental impact of electric vehicles mainly focuses on the technology, lacking a comprehensive assessment of the impact of electric vehicles from sustainable development perspective. Therefore, this chapter investigates the impact of electric vehicle holdings on energy consumption, carbon emission, and air pollution. Unlike Hofmann et al. (2016), who employed an environmental input-output model and conducted a scenario analysis on this issue, this study provides substantial empirical evidence in the years that the market share of EVs increased dramatically.

My empirical evidence shows that the increase in electric vehicles could help cut oil consumption and thereby reduce dependency on oil import. Unfortunately, because

China's electricity industry mostly relies on thermal power generation, carbon emissions and air pollutants have shifted from oil use to coal consumption with the significant growth of EV industry. Furthermore, I investigate regional heterogeneity in terms of thermal power reliance and net electricity import and export. According to empirical findings, the rapid expansion of EVs increased coal consumption and carbon emissions in regions with low reliance on thermal power generation, but had little effect in places with strong reliance on thermal power production. Finally, I highlight the presence of a regional transfer effect of the impacts of EV development. That is, the higher carbon emissions from EVs were transferred from net electricity import regions to net electricity export regions.

My results suggest that, since the development of the EV industry has far exceeded the speed of transition to clean energy, the expansion of the EV industry will not contribute to the achievement of the environmental and climate change issues. To accomplish sustainable development goals, comprehensive policies to balance the development of clean industries must be implemented.

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Chapter 5

Conclusions

Environmental policies, ESG (Environmental, Social, and Governance) investments, and the green transformation of industries play crucial roles in achieving sustainable development goals (SDGs). These initiatives address the pressing environmental challenges, promote responsible business practices, and foster the transition to a sustainable and inclusive global economy.

Environmental policies comprise regulations and guidelines established by governments to protect and preserve the environment. They aim to mitigate pollution, conserve natural resources, reduce greenhouse gas emissions, and promote sustainable practices. These policies provide a framework for businesses and industries to operate within environmentally responsible boundaries, encouraging them to adopt cleaner technologies, improve resource efficiency, and minimize their ecological footprint.

ESG investments, on the other hand, represent financial investments that take into account environmental, social, and governance factors alongside traditional financial metrics. Investors increasingly acknowledge that a company's performance in these areas can influence its long-term sustainability and financial performance. ESG investing integrates environmental criteria (such as carbon emissions and resource usage), social criteria (such as labor practices and community engagement), and governance criteria (such as board composition and executive compensation) into investment decisions. By directing capital towards companies with strong ESG practices, investors incentivize responsible business conduct and foster sustainable development.

The green transformation of industries refers to the shift from resource-intensive and environmentally harmful practices to sustainable and low-carbon alternatives. This transformation involves adopting clean and efficient technologies, transitioning to renewable energy sources, improving resource management, and embracing principles of the circular economy. By greening industries, pollution can be reduced, climate change can be mitigated, resources can be conserved, and sustainable economic growth can be promoted.

This dissertation, therefore, investigates the role of these three elements in achieving sustainable development goals, and their effects are found to be multifaceted. I focus on the economic, social, and environmental aspects of the sustainable development goals and examine the impact of various factors on air pollution, carbon emissions, and social well-being.

Chapter 2 examines the influence of the "Blue Sky Plan" on ESG investment and financial performance in China's steel industry, as well as its impact on air pollution. The study reveals that ESG investments made by steel enterprises significantly impact the financial performance of listed steel companies, particularly those engaging in large-scale ESG investments. This is primarily due to the substantial R&D and fixed asset funding required for such investments. However, the "Blue Sky Plan" partially offsets the financial losses associated with ESG investments in the steel industry. Moreover, the plan promotes ESG investments in steel companies and substantially reduces emissions of SO2 and nitrogen oxides, thereby ameliorating air pollution. The research concludes that the "Blue Sky Plan" and ESG investments in the steel industry play a critical role in alleviating environmental burdens and fostering sustainable economic growth.

Chapter 3 examines the impact of environmental policies and new environmental laws on air pollution, social well-being, and ESG investments. The study reveals four main conclusions: 1. Air pollution (measured by AQI/PM2.5/PM10) has a significant negative impact on social well-being. 2. ESG investments significantly reduce air pollution, even when controlling for other factors. 3. The implementation of new environmental laws leads to a significant decrease in air pollution. 4. ESG investments and the New Environmental Protection Law have a positive effect on social welfare. These findings suggest that environmental policy reforms and the enforcement of legislation in China effectively address air pollution issues, while ESG investments contribute to environmental protection and sustainable development.

Chapter 4 examines the impact of the electric car industry on energy consumption, carbon emissions, and air pollution. The study concludes that the growth of electric vehicles contributes to a reduction in oil consumption and dependence on oil imports. However, the rapid expansion of China's electric car industry has resulted in a shift in carbon dioxide emissions and air pollution from oil consumption to increased coal usage. Geographical analysis indicates that the proliferation of electric vehicles has led to higher carbon emissions from coal consumption in regions with low coal dependency, while regions heavily reliant on coal have experienced a lesser impact. Moreover, the development of electric vehicles has altered energy consumption patterns, with carbon emissions from electric cars transitioning from electricity imports to electricity exports. Overall, the study suggests that the electric car industry's expansion is outpacing the transition to clean energy, underscoring the necessity for comprehensive policies that balance the growth of clean industries to attain environmental and climate objectives aligned with the Sustainable Development Goals.

In summary, the dissertation emphasizes the significance of environmental policies, ESG investments, and sustainable industries in addressing air pollution, reducing carbon emissions, and improving social well-being. It underscores the importance of the "Blue Sky Plan" and highlights the challenges and implications associated with the development of the electric car industry in the pursuit of sustainable development goals.

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