Regional Carbon Emissions and Downstream and Upstream Supply Chain Decisions for Firms

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Abstract. The supply chain is essential for comprehending the financial behavior and decision-making of firms. Under the macro trend of reducing carbon emissions, there is a close connection between regional carbon emissions and corporate supply chain decisions. However, there exist few researches on the relationship between "regional carbon emissions" and "downstream and upstream supply chain concentration of firms". In view of this, this paper empirically analyses the impact of regional carbon emissions on the decision of downstream and upstream concentrations of firms, using the panel statistics of A-share listed firms in Shenzhen and Shanghai between 2008 and 2020 as the research samples. The findings show that regional carbon emissions have a significant heterogeneous impact on the downstream and upstream supply chain decisions of firms, reducing the upstream concentration of firms but strengthening the downstream concentration of firms. The mechanism analysis illustrates that regional carbon emissions decrease upstream supply chain concentration by forcing local firms to increase green innovation and weaken corporate governance and increase downstream supply chain concentration by raising the financial constraints of local firms. This paper not only enriches the field of research on influencing factors in corporate supply chain decision-making but also serves as a reference for the construction of green supply chains in the background of carbon neutrality, thus having significant practical implications as well as policy implications.

Keywords: Regional Carbon Emissions; Supply Chain Decision Making; Downstream and Upstream; Carbon Neutral.

1. Introduction

Since the Eleventh Five-Year Plan set forth energy saving and emission abatement, China has introduced a number of "carbon reduction" policies to reduce regional carbon emissions and foster low-carbon development. Three ministries, led by the Ministry of Industry and Information Technology (China), issued the "Implementation Plan for the Industrial Sector" in July 2022, with the objective of "building green and low-carbon supply chains and promoting the low-carbon and green development of supply chains." This shows that carbon emission (abbreviated as CE in the following) is tightly linked to the development decisions of corporate supply chains. As an essential component of supply chain decision-making, the "supply chain concentration" of firms includes two measurements customer concentration (upstream supply chain concentration) and supplier concentration (downstream supply chain concentration) which reflect the dispersion of downstream customers and upstream suppliers in the supply chain of firms respectively (Huan & Song, 2019). Throughout the research, the analysis of the correlation between "regional CEs" and "downstream and upstream supply chain concentration" is still relatively preliminary and there are certain research gaps.

In view of this, this paper will take the panel data of A-share listed firms in Shenzhen and Shanghai between 2008 and 2020 as the research samples, and analyze the influence of regional CEs on the decisions related to the downstream and upstream concentration of firms by establishing an empirical model based on the relevant theoretical hypotheses. And then, on the basis of this, the moderating roles of environmental regulation and firm-level political affiliation factors on the concentration of downstream and upstream supply chains of firms are investigated. After that, the paper will further analyze and verify the influence mechanism by constructing a mediating effect model and finally give corresponding policy recommendations.

The results of the study indicate that regional CEs exert a significant heterogeneous influence on downstream and upstream decisions in the supply chain. Specifically, the increment in local CEs reduces the upstream concentration of firms, but strengthens the downstream concentration, and a range of robustness tests support the robustness of the findings. In addition, the moderating effect analysis shows that higher environmental regulation further suppresses upstream concentration and increases the reinforcing effect of CEs on downstream concentration; political affiliation of firms weakens the suppressing effect of regional CEs on upstream concentration and enhances the mitigating effect of CEs on downstream concentration. The mechanism analysis in this paper demonstrates that regional CEs reduce upstream supply chain concentration by forcing local firms to increase green innovation and weaken corporate governance; regional CEs increase downstream supply chain concentration by increasing the financial constraints of local firms.

This paper enriches the related research fields and provides references for the construction of green supply chains in the context of carbon neutrality, with certain theoretical and practical significance. More specifically, it has the following possible innovations and marginal contributions: First, this paper fills the gap in the current academic research regarding the impact of regional CEs on micro-firm-level factors and the causal mechanism of downstream and upstream supply chain concentration decisions. Second, this paper clarifies the relationship between regional CEs and downstream and upstream supply chain decisions and creates an explanatory framework for analyzing the relationship by providing theoretical hypotheses and establishing a mediation model. Third, this paper proposes advice for governments to further coordinate the relationship between regional CEs and supply chain decisions in reality.

2. Literature Review and Theoretical Hypotheses

2.1. Review of Related Literature

In general, there are relatively few academic studies that use "regional carbon emissions" as a direct independent variable to examine its contribution to micro-level business decisions and supply chains. The majority of previous research has looked into the effect of environmental regulatory initiatives, such as carbon taxes, low-carbon subsidies, and carbon trading system, on "regional carbon emissions". Li and Fang (2020) analyzed the CE reduction of supply chain in the context of carbon tax, and their research results showed that carbon tax policy could increase the unit CE reduction of manufacturers, but reduce the profits of corresponding firms. And they also found that carbon taxes can be an efficient incentive for manufacturers to commit to carbon mitigation technologies or remanufacturing to lower CEs. In addition, a study by Xia and Xu (2020) compared the effects of two different environmental regulatory policies, government subsidies and carbon tax policies, on the low-carbon economic growth and identified that government subsidies can reduce the sales price and unit environmental impact of low-carbon products, increase the sales volume of low-carbon products, and improve the overall benefits of low-carbon supply chains. For carbon trading market-based environmental regulatory instruments, Calel and Dechezleprêtre (2016) pointed out that carbon trading system can stimulate firms to a certain extent to engage in low-carbon innovation by studying the impact of EU carbon trading systems on technological change. Similarly, Tian et al. (2022) analyzed the influence of Chinese CEs trading policies on domestic firms' environmental-friendly technology innovation from a micro perspective by adopting a different approach based on Porter's hypothesis; their study also showed that CEs trading policy can spur green technology innovation. On the other hand, in recent years, a few scholars have also started to directly analyze the impact of "regional carbon emissions" on micro-firms by constructing related models. For example, in their article, Ma and Hu (2022), by constructing a peak carbon pressure indicator, argued that regional peak carbon pressure dramatically incentivizes green technological innovation by nonstate firms in the jurisdiction. Specifically, under the pressure of peak carbon, regional governments are inclined to use market-oriented policy instruments, including financial subsidies and tax incentives, to facilitate innovation by firms in a sustainable manner. In summary, the existing literature is insufficient regarding the consequences of regional CE levels on firms.

In addition to considering environmental regulations related to CEs as an influencing factor in corporate supply chain decisions, some authors have also studied the impact of other factors on supply chain decisions. Davarzani et al. (2015) introduced the factor of “economic-political risk” based on case data from automotive supply chains and found that the impact of economic-political risk on corporate supply chains is significant and can cause enterprise bankruptcy, strategic repositioning of the supply chain, and homogenization of procurement supply chain. Huo et al. (2015) analyzed the decision problem of a low-carbon supply chain under financial constraints and found that under financial constraints, manufacturers can achieve supply chain coordination by adjusting repurchase covenants. Jiang et al. (2022), through a comparative static analysis of the depiction and implementation of optimum decisions of the participants in the supply chain financial system, found that the optimum decisions of the participants in the supply chain financial system are influenced by the degree of loss aversion and the proportion of credit guarantees of the retailers. As for the important deciding factor of corporate supply chain concentration, related studies mainly center on the effect of supply chain concentration on other factors of the firm. For example, Zhang and Zhang (2021) revealed that customer concentration and supplier concentration have negative impacts on retail innovation behavior when other conditions are held constant, from the standpoint of supply chain concentration and retail innovation. Zhang and Ju (2022) investigated the association between concentrations of supply chain on bank credit and found an inverted U-shaped relationship between concentration of supply chain and bank credit. In the paper, How Supply Chain Concentration Affects Enterprise Investment Efficiency, Zhang and Feng (2022) took the financial statistics of A-share listed companies between 2008 and 2019 as their sample and found that supplier concentration and customer concentration reduce corporate investment efficiency and increase the over-investment of large firms and under-investment of small firms at the same time. Overall, although there is a wealth of academic research on corporate supply chain decision making, there is a dearth of research on the factors influencing the concentration of corporate supply chains.

In conclusion, although many scholars have analyzed "regional carbon emissions" and "decisions related to supply chain concentration", there are still significant shortcomings in two aspects. One is the lack of analysis of the impact of "regional carbon emissions" on micro-firm-level factors. The second is that there is still a large gap in the analysis of the causal mechanism of "downstream and upstream supply chain concentration decisions". Based on this, this paper will concentrate on the impact of regional CEs on downstream and upstream supply chain concentration decisions in the following sections in order to fill the gaps in the research area.

2.2. Theoretical Hypotheses

As mentioned above, there is a possibility that regional CE levels and related policies have an impact on the supply chain decisions of firms. In this section, the hypotheses of the impact of regional CEs on the "upstream supply chain concentration" and "downstream supply chain concentration" of firms are presented in turn with the existing studies.

2.2.1 Regional Carbon Emissions and the Upstream Supply Chain Concentration of Firms

In the context of "emissions reduction", as a city's CEs increase, the local government may increase environmental regulations by adopting more stringent negative incentives (carbon taxes) or more aggressive positive incentives (emission reduction subsidies). According to the classical "Porter hypothesis", strict environmental regulations will motivate firms to engage in more innovative activities to improve their competitiveness (Porter, 1996; Qiu, 2020). The study by Luo and Wu (2022) also suggests that air pollution can force firms to improve their green innovation level through government environmental governance and public environmental monitoring. For this reason, it is likely that an increase in regional CE levels will force local firms to undertake more green innovation activities. Resource dependency theory suggests that firms may have unequal dependencies due to the scarcity of required resources (Pfeffer & Salancik, 2003; Hillman et.al. 2022). Technologies for carbon reduction production at lower costs in such cases can be considered heterogeneous resources for a given firm. In the case of low green innovation capacity, due to the lack of technology to achieve carbon reduction at lower cost, some firms are likely to outsource some common products to a few manufacturers with low carbon reduction cost advantage; or choose to abandon the production process that generates more CEs and instead purchase intermediate manufactured products from upstream suppliers with green technology advantage at a lower price (Han & You, 2023) This strengthens companies' reliance on suppliers. However, as firms' green innovation performance improves, the resource and cost advantages of the original suppliers will gradually diminish, and the scarcity of resources for "carbon-reducing production technologies" will no longer be apparent. Accordingly, the reliance on specific suppliers will gradually decrease, and the concentration of the upstream supply chain will be diminished a step further. Based on the above analyses, this paper suggestes the following hypothesis:

H1a: The increase in regional carbon emissions (CEs) will push the concentration of the upstream supply chain to decrease by forcing firms to improve their green innovation level.

When companies apply significant resources and capital to green innovation in response to the negative impacts of CEs, their corporate governance may decline due to a lack of adequate attention and capital investment, among other things. Studies have also shown that carbon risks associated with global warming and climate change have the potential to derail firm operations and substantially degrade shareholder valuations (Tanthanongsakkun et al., 2023). For this reason, it is reasonable to infer that regional CEs are negatively related to the level of corporate governance. The higher the level of corporate governance for firms, the stronger its bargaining power, the more concentrated the upstream supply chain, and the more stable the cooperation between suppliers and the company will be. On the contrary, when a company's governance level is weakened, its bargaining power and the stability of supplier cooperation will both decrease, which will also lead to a decrease in its supply chain concentration. Based on the above analyses, this paper suggests the following hypotheses:

H1b: The increase in regional carbon emissions (CEs) will ccause a decrease in level of corporate governance for firms, which in turn will lead to a decrease in upstream supply chain concentration.

2.2.2 Regional Carbon Emissions and the Downstream Supply Chain Concentration of the Firms

Apart from lower corporate governance, increased regional CEs may lead to higher raw material and product prices, lower corporate profitability and productivity, and higher environmental risks, which increase the uncertainty of sustained profitability of firms in the region (Rassier & Earnhart, 2010; Shi, Y. et al., 2022); in turn, investors are exposed to higher direct risks (damage to firm assets due to environmental pollution penalties), default risks (difficulties in recovering investors' capital due to operational difficulties caused by environmental regulations), and reputational risks (lawsuits due to environmental issues) (Shen & Ma, 2014; Shi, et al., 2022). This can largely undermine investors' confidence in investing in firms in the region concerned, leading to financing difficulties for these firms and exacerbating their financial constraints. When firms face high financial constraints, they are likely to rely more on selling their products to relatively fixed downstream customers who have more capital to obtain a more stable source of funds. Accordingly, the downstream supply chain concentration of the firm will also increase. Based on the above analyses, this paper suggests the following hypothesis:

H2: The increase in regional carbon emissions (CEs) will strengthen the financial constraints of firms, which in turn will result in greater concentration in their downstream supply chains

3. Sample Descriptive Statistics and Empirical Model Setting

3.1. Samples Selection and Data Source

In order to verify the theoretical hypothesis proposed in the previous section, considering the availability of enterprise indicators and the representativeness of the sample, this paper uses all A-share listed firms in Shenzhen and Shanghai between 2008 and 2020 as the original sample, and obtains the sample statistics of the original listed companies from the Guotaian CSMAR database and merges them. The further screening process of the sample is as follows. First, due to the financial statements of the financial industry are different from other firms, this paper screens through CSMAR industry codes to exclude the financial industry samples; second, the samples of ST firms in the study period are excluded, and third, the samples with gearing ratios of more than 1 are excluded; finally, to remove the impact of the extreme samples on the empirical analysis, all consecutive variables are winsorized by 1% up and down in this paper.

3.2. Supply Chain Concentration Indicators

Referring to the standard practice of related literature, the downstream and upstream of the supply chains of firms are considered in detail in this paper. The sum of the squared ratios of the top five suppliers to total purchases disclosed by listed firms is used as the measure of supplier concentrations in the upstream supply chains, Con_p. The sum of the squared ratios of the top five customers to total sales disclosed by listed firms is used as the measure of customer concentrations in the downstream supply chains, Con_c. The larger the value of Con_p and Con_c, the higher the concentrations of the supply chains of the firms.

3.3. Regional Carbon Emission Index

At present, the relevant statistical agencies in China do not provide direct monitoring data on carbon dioxide (CO2) emissions. Most domestic scholars estimate China's CO2 emissions based on the CO2 emission estimation methods introduced in the IPCC guidelines for national GHG inventories designated by the UNFCCC. On the basis of the energy classification in the energy balance sheet, 8 energy sources, including coal, coke, gasoline, crude oil, kerosene, fuel oil, diesel, and natural gas, are chosen to calculate the CO2 emissions of each type of energy consumption and sum up to yield the total CO2 emissions. In this paper, the CE data of Chinese prefecture-level cities from 2008-2017 are adopted from the CEADs China Carbon Accounting Database based on the apparent accounting of provincial CE inventories. The CEADs China Carbon Accounting Database is a multiscale carbon accounting inventory and socio-economic and trade database covering China and other developing countries, jointly compiled by nearly 1,000 scholars from China and other countries with the co-support of the National Natural Science Foundation of China, the International Cooperation Program and Key Research and Development Program of the Ministry of Science and Technology, and the Research Council of the United Kingdom, through data crowdfunding collection and calibration. Hence, this database is authoritative and can be chosen for conducting further analysis. Considering that CEs have a certain skewness problem, the panel data of CEs of different cities (lnco2) are finally constructed by drawing on the current available literature literature for logarithmic processing in the empirical evidence.

3.4. Empirical model setting

To test the hypotheses formulated above, this paper will use the panel data of listed firms to bbuild a two-way fixed effect model for empirical analyses, as shown in formulas (1) and (2) :

$$Con\_p_{ict} = \alpha_0 + \alpha_1 lnco2_{ct} + \alpha_2 X_{it} + Year_{FE} + Industry_{FE} + \varepsilon_{ict}{}^1 \tag{1}$$

$$Con\_c_{ict} = \beta_0 + \beta_1 lnco2_{ct} + \beta_2 X_{it} + Year\_FE + Industry\_FE + \varepsilon_{ict}{}^2 \tag{2}$$

Among them, the subscripts i, c, and t represent the listed firms, the city where the listed firms are registered, and the chosen fiscal year, respectively. The core explanatory variables, $Con_p_{ict}$and Con_c_{ict}respectively represent the downstream and upstream concentration of the supply chain of the Listed company i in year t, and are used to measure the downstream and upstream supply chain decisions of firms. $lnco2_{ct}$Is the core explanatory variable of this paper, that is, the CEs of city c in year t. For the specific construction method, refer to the discussion in the previous part. Therefore,

α_1, β_1 it is the key parameter to be evaluated in this paper. In addition, X_{it} a series of control variables are used to control various firm-level financial and governance characteristics. The variables of $Year\_FE$ and $Industry\_FE$ are the year and field fixed effects, seperatively. $\varepsilon_{ict}{}^{1}, \varepsilon_{ict}{}^{2}$ Is the disturbance term of this model? In addition, to avoid the heteroskedasticity problem from compromising the reliability of the empirical evidences, all statistical inferences in this paper are discussed basing on heteroskedasticity robust standard errors. To sum up, this paper will use a two-way fixed effect model to conduct a rigorous empirical analysis of the theoretical assumptions proposed above.

3.5. Selection of Control Variables

Considering that other factors of firms possibly also have an influence on the level of green technology innovation of firms, to preclude the endogeneity problem caused by omitted variables, this paper first selects a series of firm characteristic indicators as control variables. Drawing on the practice of existing literature, the control variables at the firm level in this paper include: firm size (Size, measured by the natural logarithm of the total assets of listed firms at the end of the year), corporate asset-liability ratio (Leverage, measured by the total liabilities of listed firms at the end of the year as a percentage of total assets Proportion measurement), firm age (Age, measured by the firms' listing years), corporate operating performance (ROA, measured by the return on assets of the listed firms in the current year), fixed asset scale (Fix, measured by the ratio of fixed assets of the listed firms in the current year), cash Ratio (Cash, measured by the ratio of cash held by listed firms in the year), board independence (Indratio , measured by the percentage of independent directors of listed firms in the year), board size (Boardsize, measured by the percentage of board of directors in listed firms in the year), management Layer shareholding ratio (Mshare, measured by the shareholding ratio of the management of the listed firms in the year), ownership concentration (Top1, measured by the shareholding ratio of the biggest shareholder of the listed firms in the year), firm ownership (SOE, measured by whether the listed firms are state-owned or not). Table 1 is the variable types, names, and detailed definitions used in this paper. Table 2 is the descriptive statistics of each variable.

Table 1. Detailed definitions of variables.

Variable type	Variable name and letter representation	Variable definition description
Explained variable	Supply chain upstream concentration (Con_p)	The concentration of upstream suppliers in the supply chain of listed firms in the current year
	Supply chain downstream concentration (Con_c)	The concentration of downstream customers in the supply chain of listed firms in the current year
Core explanatory variable	Urban carbon emission (ln co2)	log (total apparent carbon dioxide emissions of the city [million tons])
Firm Control Variables	Firm scale (Size)	ln (the total assets of the firms at the end of the current year)
	Corporate asset-liability ratio (Leverage)	The ratio of the firms' total liabilities to total assets for the year
	Business Age (Age)	The firms' listing years
	Business performance (ROA)	Return on assets of the listed firms for the year
	Fixed assets scale (Fix)	The ratio of fixed assets to total assets of the firms in the current year
	Cash Ratio (Cash)	The company's cash holding ratio for the year
	Board Independence (Indratio)	The percentage of independent directors of the firms in the current year
	Board size (Boardsize)	The percentage of shares held by the board of directors of the firms
	Management shareholding ratio (Mshare)	The shareholding ratio of the management of the firms
	Top 1 concentration of corporate equity (Top 1)	The shareholding ratio of the biggest shareholder of the firms in the year
	Firm Ownership (SOE)	Dummy variable: If the firm is state-owned , it will be set to a value of 1, otherwise it will be set to a value of 0

Table 2. Descriptive statistics of variables.

	N	Mean	SD	Min	Median	Max
Con p	14323	0.351	0.204	0	0.307	1
Con c	20470	0.313	0.229	0	0.25	1
lnco2	21848	3.895	0.758	0.818	3.978	5.441
Size	21848	21.979	1.271	19.35	21.797	26.105
Leverage	21848	0.425	0.211	0.027	0.417	0.908
Age	21848	9.005	6.728	0	8	25
ROA	21848	0.628	0.441	0.044	0.524	3.037
Fix	21848	00.223	0.166	0.002	0.188	0.769
Cash	21848	1.287	2.394	0.036	0.563	30.123
Indratio	21848	40.227	8.474	0	37.5	66.667
Boardsize	21848	11.981	19.301	0	0.044	68.606
Mshare	21848	12.753	20.269	0	0.085	70.869
Top1	21848	0.356	0.151	0.082	0.338	0.758
SOE	21848	0.393	0.488	0	0	1

Prior to the empirical regression analysis, the correlation results between the main study variables also need to be analyzed, and the correlation coefficient matrices of the core explanatory and control variables are presented in Table 3. The correlation coefficient matrix in Table 3 illutrates that the correlation coefficients between the control variables are not large, and the highest correlation coefficient between the core explanatory variables lnco2 and the control variables is only 0.14. Therefore, there is no systematic bias in the statistical inference due to the highly co-linear problem of this paper. In summary, the empirical model is established correctly and there will be no unidentifiable problem.

Table 3. Matrix of correlation coefficients between core explanatory and control variables.

	lnco2	Size	Leverage	Age	ROA	Fix	Cash	Indratio	Boardsize	Mshare	Top1	SOE
lnco2	1.00											
Size	0.07***	1.00										
Leverage	0.01	0.51***	1.00									
Age	0.03***	0.35***	0.40***	1.00								
ROA	0.00	0.04***	0.16***	0.05***	1.00							
Fix	-0.14***	0.11***	0.12***	0.08***	0.04***	1.00						
Cash	0.01*	-0.26***	-0.52***	-0.28***	-0.15***	-0.19***	1.00					
Indratio	0.00	-0.04***	-0.05***	-0.06***	-0.03***	-0.05***	0.06***	1.00				
Boardsize	0.04***	-0.33***	-0.37***	-0.55***	-0.09***	-0.19***	0.27***	0.10***	1.00			
Mshare	0.04***	-0.33***	-0.38***	-0.56***	-0.09***	-0.19***	0.28***	0.10***	0.99***	1.00		
Top1	0.06***	0.22***	0.07***	-0.08***	0.09***	0.07***	-0.01	0.04***	-0.09***	-0.11***	1.00	
SOE	0.03***	0.35***	0.33***	0.42***	0.10***	0.23***	-0.17***	-0.09***	-0.48***	-0.49***	0.22***	1.00

4. Empirical Results

4.1. Analysis of the Benchmark Regression Results

The results of the benchmark stepwise regression of the previous empirical model equation (1) are revealed in Table 4. The explanatory variables are all listed companies' upstream supply chain supplier concentration in the current year, and the core explanatory variable is the scale of CEs in the city where the company is located lnco2. Among them, column (1) does not control for any fixed effects and control variables, column (2) adds firm-level control variables, and column (3) further adds industry and year two-way fixed effects. It can be seen that the estimated coefficients of all model core explanatory variables lnco2 are significantly negative, regardless of the controls. This empirical result, therefore, suggests that the higher the CEs from the location of listed companies, the lower the concentration of upstream supply chains of firms

Table 4. Carbon emissions and upstream concentration of corporate supply chains.

	(1)	(2)	(3)
Explained variables:	Con_p	Con_p	Con_p
lnco2	-0.010***	-0.004*	-0.008***
	(0.002)	(0.002)	(0.002)
Size		-0.041***	-0.047***
		(0.002)	(0.002)
Leverage		0.025**	0.013
		(0.012)	(0.012)
Age		0.003***	0.002***
		(0.000)	(0.000)
ROA		-0.023***	0.004
		(0.005)	(0.006)
Fix		0.105***	0.062***
		(0.012)	(0.013)
Cash		0.011***	0.011***
		(0.001)	(0.001)
Indratio		-0.000*	-0.000
		(0.000)	(0.000)
Boardsize		0.002***	0.003***
		(0.001)	(0.001)
Mshare		-0.002***	-0.003***
		(0.001)	(0.001)
Top1		0.040***	0.017
		(0.012)	(0.012)
SOE		-0.010**	-0.011**
		(0.004)	(0.004)
Year FE	No	No	Yes
Industry FE	No	No	Yes
Observations	14,323	14,323	14,323
R-squared	0.001	0.074	0.133

Note: ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels, respectively. Values in parentheses are heteroskedasticity robust standard errors. "Yes" means the fixed effect is controlled, and "No" means the fixed effect is not controlled.

The results of the baseline stepwise regression of the previous empirical model equation (2) are shown in Table 5. The explanatory variables are all listed companies' downstream supply chain customer concentration Con_c in the current year, and the core explanatory variable is the size of CEs in the city where the firm is located lnco2. Again, column (1) does not control for any fixed effects and control variables, column (2) adds firm-level control variables, and column (3) further adds industry and year two-way fixed effects. It can be seen that the estimated coefficients of all the core explanatory variables of the model, lnco2, are significantly positive at the 1% statistical level, regardless of the controls. Thus this empirical result indicates that the higher the CEs of the location of listed firms, the higher the concentration of the downstream supply chains of firms.

Combining the basic empirical results in Tables 4 and 5, it is clear that regional CEs have a significant heterogeneous effect on the downstream and upstream supply chain decisions of firms, which reduces the upstream concentration of firms but strengthens the downstream concentration of firms.

Table 5. Carbon emissions and downstream concentration of corporate supply chains.

	(1)	(2)	(3)
Explained variables:	Con_c	Con_c	Con_c
lnco2	0.010***	0.015***	0.017***
	(0.002)	(0.002)	(0.002)
Size		-0.035***	-0.041***
		(0.002)	(0.002)
Leverage		0.042***	0.048***
		(0.011)	(0.011)
Age		-0.000	0.000
		(0.000)	(0.000)
ROA		-0.080***	-0.060***
		(0.004)	(0.004)
Fix		0.082***	-0.054***
		(0.012)	(0.011)
Cash		0.003***	0.002***
		(0.001)	(0.001)
Indratio		-0.001***	-0.000*
		(0.000)	(0.000)
Boardsize		0.001	0.001
		(0.001)	(0.001)
Mshare		-0.001	-0.001**
		(0.001)	(0.001)
Top1		0.076***	0.063***
		(0.012)	(0.011)
SOE		0.022***	0.010**
		(0.004)	(0.004)
Year FE	No	No	Yes
Industry FE	No	No	Yes
Observations	20,470	20,470	20,470
R-squared	0.001	0.056	0.144

Note: See the Note to Table 4.

4.2. Robustness Tests

The robustness tests are carried out in this section. First, although this paper has controlled for time-fixed effects and industry-fixed effects in the benchmark models (1) and (2), the internal system structure of the industry, the internal management structure of the firm, and the external survival environment change all the time as time passes. This can lead to significant differences in the development of different industries over time series. And these differences may affect the governance patterns, strategic decisions, etc. of the firms. Therefore, this paper needs to further control for the above potential factors. By adding the fixed effect of industry multiplied by year to the baseline model equations (1) and (2), this paper can control for the differences in changes in different industries over time to reduce the impact of this factor on the conclusions of this paper.

Robustness tests considering industry trends are shown in Table 6, and likewise, all columns control for firm-related factors as well as two-way fixed effects. Specifically, column (1) studies the impact of regional CEs on the upstream supply chain of the firm, and column (2) studies the impact of regional CEs on the downstream supply chain of the firm. From the results, it can be observed that the estimated co-efficients of lnco2 are -0.008 as well as 0.017, both of which also pass the 1% significance test and are fully consistent with the previous findings. Therefore, data shows that the basic conclusions of this paper still exist and are robust.

Table 6. Consideration of industry trends over time.

	(1)	(2)
Explained variables:	Con_p	Con_c
lnco2	-0.008***	0.017***
	(0.002)	(0.002)
Size	-0.047***	-0.041***
	(0.002)	(0.002)
Leverage	0.011	0.050***
	(0.012)	(0.011)
Age	0.002***	0.000
	(0.000)	(0.000)
ROA	0.005	-0.059***
	(0.006)	(0.004)
Fix	0.065***	-0.055***
	(0.013)	(0.011)
Cash	0.011***	0.002***
	(0.001)	(0.001)
Indratio	-0.000	-0.000*
	(0.000)	(0.000)
Boardsize	0.003***	0.001
	(0.001)	(0.001)
Mshare	-0.003***	-0.001*
	(0.001)	(0.001)
Top1	0.016	0.065***
	(0.012)	(0.011)
SOE	-0.011**	0.010**
	(0.004)	(0.004)
Year FE	Yes	Yes
Industry FE	Yes	Yes
Year FE* Industry FE	Yes	Yes
Observations	14,315	20,466
R-squared	0.142	0.151

Note: See the Note to Table 4.

The second robustness test performed in this paper is to replace the estimated model. Since the distribution of the core explanatory variables, Con_p and Con_c, cannot be taken as negative in this paper, i.e., there is truncation. Therefore, this paper further conducts a robustness test based on the use of the restricted dependent variable model, panel Tobit.

The findings of the panel Tobit estimation are presented in Table 7, where all columns are controlled for firm dimension control variables as well as industry and year fixed effects. As shown by the results in Table 7, after replacing the model, the findings of this paper remain robust: it reduces the upstream concentration of firms but strengthens the downstream concentration of firms.

Table 7. Panel Tobit estimation results.

	(1)	(2)
Explained variables:	Con_p	Con_c
lnco2	-0.013***	0.017***
	(0.004)	(0.004)
Size	-0.044***	-0.040***
	(0.002)	(0.002)
Leverage	0.025**	0.010
	(0.011)	(0.010)
Age	0.002***	0.000
	(0.000)	(0.001)
ROA	0.001	-0.030***
	(0.005)	(0.004)
Fix	-0.040***	-0.040***
	(0.013)	(0.012)
Cash	0.005***	0.001**
	(0.001)	(0.001)
Indratio	-0.000	-0.000
	(0.000)	(0.000)
Boardsize	0.000	-0.001*
	(0.001)	(0.001)
Mshare	-0.000	0.001
	(0.001)	(0.001)
Top1	0.001	0.062***
	(0.015)	(0.014)
SOE	-0.000	-0.004
	(0.006)	(0.006)
Year FE	Yes	Yes
Industry FE	Yes	Yes
Observations	14,323	20,470
Number of code	3,270	3,282

Note: See the Note to Table 4.

4.3. Analysis of Moderating Effects

The previous benchmark regressions and robustness tests have verified that regional CEs have substantial effects on the downstream and upstream of firms. This section will further consider the latent moderating effects. First, the moderating effect of environmental regulation is considered. This paper uses the natural log lnhb of the amount of environmental investment in environmental projects completed by the region in the current year to characterize environmental regulations. Table 8 shows the results of the analysis of the moderating effects of environmental regulations. Again, all columns control for firm-related factors as well as two-way fixed effects. Specifically, column (1) examines the impact of regional CEs on firms' upstream supply chains, and column (2) examines the impact of regional CEs on firms' downstream supply chains. The estimated coefficients of the two columns are 0.005 and 0.007, respectively, and both are significantly positive, as indicated by the interaction term lnco2*lnhb, the core explanatory variable for the moderating effect. This finding suggests that higher environmental regulation intensity further suppresses the upstream concentrations in the corporate supply chains, while reducing the mitigating effect of CEs on the downstream concentration in the corporate supply chains.

Table 8. Analysis of regulatory effects of environmental regulations.

	(1)	(2)
Explained variables:	Con_p	Con_c
lnco2	-0.030***	-0.010
	(0.010)	(0.009)
lnhb	-0.026***	-0.032***
	(0.009)	(0.008)
lnco2*lnhb	0.005**	0.007***
	(0.002)	(0.002)
Size	-0.047***	-0.041***
	(0.002)	(0.002)
Leverage	0.012	0.048***
	(0.012)	(0.011)
Age	0.002***	-0.000
	(0.000)	(0.000)
ROA	0.005	-0.059***
	(0.006)	(0.004)
Fix	0.064***	-0.052***
	(0.013)	(0.011)
Cash	0.011***	0.002***
	(0.001)	(0.001)
Indratio	-0.000	-0.000*
	(0.000)	(0.000)
Boardsize	0.003***	0.001
	(0.001)	(0.001)
Mshare	-0.003***	-0.001**
	(0.001)	(0.001)
Top1	0.017	0.063***
	(0.012)	(0.011)
SOE	-0.012***	0.009**
	(0.004)	(0.004)
Year FE	Yes	Yes
Industry FE	Yes	Yes
Observations	14,323	20,470
R-squared	0.134	0.145

Note: See the Note to Table 4.

Second, the moderating effect of corporate political affiliation is considered. Referring to the standard practice of existing literature, this paper constructs corporate political affiliation indicators for this part of the analysis. Based on the subdivision of political connectedness of corporate executives, the corporate political connectedness level indicator (PCLevel) is constructed: 1 if the general manager or chairman in this firm was or is currently a section-level cadre, 2 if a division-level cadre, 3 if a department-level cadre, 4 if a ministry-level cadre, and 0 if no political connectedness.

Table 9 shows the moderating effect analysis results of political relevance. Likewise, all columns control for firm-related factors and two-way fixed effects. Specifically, column (1) studies the effect of regional CEs on the upstream supply chain of the firm, and column (2) studies the effect of regional CEs on the downstream supply chain of the firm. The interaction term lnco2*PCLevel, the core explanatory variable for the moderating effect, yields an estimated coefficient of -0.003 for both columns, which is significantly negative. Thus, this finding is just the opposite of the effect brought by environmental regulation, namely, the presence of politically connected firms further weakens the suppression of regional CEs on the concentration of firms' upstream supply chains and enhances the mitigating effect of CEs on the concentration of downstream supply chains.

Table 9. Analysis of the moderating effect of political connections.

	(1)	(2)
Explained variable:	Con_p	Con_c
lnco2	-0.004	0.019***
	(0.003)	(0.003)
PCLevel	0.010*	0.002
	(0.005)	(0.005)
lnco2*PCLevel	-0.003**	-0.003**
	(0.001)	(0.001)
size	-0.047***	-0.039***
	(0.002)	(0.002)
Leverage	0.011	0.044***
	(0.012)	(0.011)
Age	0.002***	-0.000
	(0.000)	(0.000)
ROA	0.005	-0.059***
	(0.006)	(0.004)
Fix	0.063***	-0.052***
	(0.013)	(0.011)
Cash	0.011***	0.002**
	(0.001)	(0.001)
Indratio	-0.000	-0.000*
	(0.000)	(0.000)
Boardsize	0.003***	0.001
	(0.001)	(0.001)
Mshare	-0.003***	-0.001**
	(0.001)	(0.001)
Top1	0.016	0.063***
	(0.012)	(0.011)
SOE	-0.012***	0.006
	(0.004)	(0.004)
Year FE	Yes	Yes
Industry FE	Yes	Yes
Observations	14,323	20,470
R-squared	0.134	0.149

Note: See the Note to Table 4.

5. Mechanism Analysis

Why does regional CE have a significant heterogeneous effect on the downstream and upstream supply chain decisions of firms, which reduces the upstream concentration of firms but strengthens the downstream concentration of firms? To verify the mediating effect of both, the following mediating effect model is established in this section.

$$Z_{it} = \gamma_0 + \gamma_1 lnco2_{ct} + \gamma_2 X_{it} + +Year_{FE} + Industry_{FE} + \mathrm{Sec}_{FE} + \varepsilon^1_{ict} \tag{3}$$

$$y_{ict} = \delta_0 + \delta_1 lnco2_{ct} + \rho Z_{it} + \delta_2 X_{it} + +Year_{FE} + Industry_{FE} + \mathrm{Sec}_{FE} + \varepsilon^2_{ict} \tag{4}$$

Among them, $Z_{it}$is the intermediary variable? If the model satisfies both the significance in formula (3) and the neutral $\gamma_1$and significant ρin formula (4)δ_1, it indicates that Z_{it}there is a mediating effect. y_{ict}And Con_c_{ict}respectivelyCon_p_{ict}.

5.1. Mechanism of the Upstream Supply Chain

The mechanism of regional CEs on the upstream of the supply chains is examined at first. On the one hand, regional pollution forces firms to boost their commitment in green innovation and other aspects, which will reduce the productivity of firms in their main business, and then may affect their supply chain decisions.

This paper adopts the quantity of green patent applications of listed firms, which is the sum of the quantity of green patent applications of listed firms and their subsidiaries to evaluate the green technology innovation, and the selection of this index mainly takes the following two points into consideration: First, the green patent data has a clear technology classification compared with the R&D investment data, which can further classify the green patent data according to the innovation value of different technologies while intuitively reflecting the level of green innovation of enterprises; Second, the patent application cycle is long, and it usually takes about two years from patent application to final authorization, which leads to a large lag in patent authorization data. Considering that it is likely that patented technologies have an influence on firm performance during the application period, this paper uses green patent application data to identify the green innovation performance of industries and firms.

The data source for the number of green patent applications of listed firms is the Green Patent Research Database (GPRD) of the China Research Data Service Platform (CNRDS). The database is a specialized database that combines Chinese patent data and green patent category number standards published by the World Intellectual Property Office and is matched for development. With reference to the current available literature on the modeling method of the green patent application index, this paper uses the number of all green invention patents ("+ 1" and takes the natural logarithm form) lnGP applied by firms in the year as the measure.

Table 10 examines the mediating effect of green innovation activities of firms. In which, both columns of the model control for all control variables as well as two-way fixed effects. Firstly, as seen in column (1), the estimated coefficient of lnco2 is significantly positive at the 1% statistical level, i.e., CEs force firms to increase green innovation. Further observing the estimated results in column (2), the estimated coefficient of green innovation lnGP is -0.018, which is significantly negative at the 1% level, indicating that more green innovation by firms reduces the concentration of suppliers upstream of the firms' supply chains. Therefore, this mediating path is validated.

Table 10. Mechanism I: Green innovation.

	(1)	(2)
Explained variables:	lnGP	Con_p
lnGP		-0.018***
		(0.003)
lnco2	0.016***	-0.008***
	(0.003)	(0.002)
Size	0.091***	-0.046***
	(0.005)	(0.002)
Leverage	0.003	0.014
	(0.018)	(0.012)
Age	-0.005***	0.002***
	(0.001)	(0.000)
ROA	0.026***	0.005
	(0.008)	(0.006)
Fix	-0.119***	0.059***
	(0.020)	(0.013)
Cash	-0.001	0.011***
	(0.001)	(0.001)
Indratio	0.000	-0.000
	(0.000)	(0.000)
Boardsize	-0.003**	0.003***
	(0.001)	(0.001)

Mshare	0.003**	-0.003***
	(0.001)	(0.001)
Top1	-0.051**	0.015
	(0.022)	(0.012)
SOE	0.010	-0.010**
	(0.007)	(0.004)
Year FE	Yes	Yes
Industry FE	Yes	Yes
Observations	21,848	14,323
R-squared	0.095	0.135

Note: See the Note to Table 4.

On the other hand, regional CEs may also affect the level of governance of firms themselves, which in turn affects strategic supply chain decisions. Regarding the portrayal of the governance level of listed companies, drawing on the relevant literature such as Gu and Zhou (2017) and Zhou et al. (2020), comprehensive indicators are constructed to consider four dimensions such as incentives, supervision, and decision-making, and the level of governance is measured by descending the dimension using principal component analysis, and the first principal component obtained is taken as a comprehensive indicator reflecting the level of corporate governance, and the indicators are specifically selected as shown in Table 11. A higher indicator score means a better level of internal corporate governance.

Table 11. Detailed Structure of Corporate Governance Indicators.

Dimension	Index	Indicator description
Incentives	Executive compensation	Total annual remuneration of directors, supervisors and executives
	Executive shareholding ratio	Volume of shares held by management / paid-in capital
The supervisory role of the board of directors	The percentage of independent directors	Number of Independent Directors / Number of Directors
	board size	Number of Directors
Supervisory role of ownership structure	Institutional shareholding ratio	Total institutional shareholding ratio /100
	Equity checks and balances	The total of the percentage of shares held by the second to fifth largest shareholders / percentage of shares held by controlling shareholders
General manager's decision-making power	Part-time job of chairman and general manager	1 if the two positions are combined , otherwise 0

Table 12 examines the mediating effects of the level of corporate governance of firms. In this case, both columns of the model control for all control variables as well as for two-way fixed effects. Firstly, as seen in column (1), the estimated coefficient of lnco2 is significantly negative at the 1% statistical level, i.e., CEs do reduce the level of corporate internal governance. Further observing the estimated results in column (2), the estimated coefficient of the level of corporate governance is 0.023, which is significantly positive at the 1% level, a finding that indicates that the higher the degree of corporate governance, the more concentrated the downstream supply chain is. Therefore, the mechanism path that regional CEs reduce the level of corporate own governance and thus the concentration of the upstream supply chains is verified.

Table 12. Mechanism II: Corporate Governance Level.

Explained variable:	(1) Corporate Governance Level	(2) Con_p
Corporate Governance Level		0.023***
		(0.003)
lnco2	-0.012**	-0.008***
	(0.005)	(0.002)
size	-0.192***	-0.042***
	(0.004)	(0.002)
Leverage	0.178***	0.003
	(0.027)	(0.012)
Age	-0.007***	0.002***
	(0.001)	(0.000)
ROA	-0.098***	0.005
	(0.010)	(0.006)
Fix	-0.126***	0.066***
	(0.028)	(0.013)
Cash	0.006***	0.011***
	(0.002)	(0.001)
Indratio	0.034***	-0.001***
	(0.001)	(0.000)
Boardsize	0.011***	0.002***
	(0.002)	(0.001)
Mshare	0.016***	-0.003***
	(0.002)	(0.001)
Top1	-0.744***	0.030**
	(0.030)	(0.012)
SOE	-0.205***	-0.005
	(0.010)	(0.004)
Constant	2.955***	1.297***
	(0.093)	(0.040)
Year FE	Yes	Yes
Industry FE	Yes	Yes
Observations	21,054	13,972
R-squared	0.694	0.135

Note: See the Note to Table 4.

5.2. Mechanism of the Downstream Supply Chain

By further considering the downstream supply chain mechanism of the firm, this paper argues that the external shock of CEs affects the firm's financial constraints and thus affects the downstream decision of the supply chain. Table 13 examines the mediating effect of corporate financial constraints. Among them, the SA index is utilized to evaluate the financial constraints of the firms, and the larger the index is, the stronger the financial constraints faced by the firm. In which, both columns of the model control for all control variables as well as two-way fixed effects.

Firstly, it can be seen from column (1) that the estimated coefficient of lnco2 is significantly positive at the 1% statistical level, i.e., regional CEs raise the financial constraints of firms. Further observing the estimation result of column (2), the estimated coefficient of SA is 0.162, which is significantly positive at the 1% level, this finding indicates that the higher the financial constraints of the firm, the higher the concentration of the firm's downstream supply chain. Therefore, the mechanism path that regional CEs increase the firm's own finacial constraint, which in turn increases the concentration of downstream supply chains, is confirmed.

Table 13. Mechanism III: Corporate Financial Constraints.

	(1)	(2)
Explained variable:	SA	Con_c
SA		0.162***
		(0.017)
lnco2	0.004***	0.016***
	(0.001)	(0.002)
size	1.183***	-0.233***
	(0.001)	(0.021)
Leverage	0.029***	0.044***
	(0.006)	(0.011)
Age	-0.039***	0.006***
	(0.000)	(0.001)
ROA	-0.005***	-0.059***
	(0.002)	(0.004)
Fix	0.035***	-0.060***
	(0.005)	(0.011)
Cash	0.005***	0.001*
	(0.000)	(0.001)
Indratio	0.000***	-0.000**
	(0.000)	(0.000)
Boardsize	-0.001***	0.001*
	(0.000)	(0.001)
Mshare	0.001***	-0.002**
	(0.000)	(0.001)
Top1	0.025***	0.060***
	(0.005)	(0.011)
SOE	-0.005***	0.011***
	(0.002)	(0.004)
Year FE	Yes	Yes
Industry FE	Yes	Yes
Observations	21,848	20,470
R-squared	0.996	0.148

Note: See the Note to Table 4.

6. Conclusions and Policy Advice

This paper takes a panel of all A-share listed firms in Shenzhen and Shanghai between 2008 and 2020 as the samples of the study, and on the basis of the relevant theoretical hypotheses, dissects the influence of regional CEs on the decisions related to the downstream and upstream concentration of firms by establishing empirical models. The empirical analysis finds the following findings: First, regional CEs have a significant heterogeneous impact on the downstream and upstream supply chain decisions of firms, and the increase of regional CEs reduces the upstream concentration of firms but strengthens the downstream concentration, and a series of robustness tests support the robustness of the results. Second, the analysis of moderating effects shows that higher environmental regulations further suppress the concentration of upstream supply chains and increase the strengthening effect of CEs on the concentration of downstream supply chains; political affiliation of firms weakens the suppression effect of regional CEs on the concentration of upstream supply chains and enhances the mitigation impact of CEs on the concentration of downstream supply chains. Third, the mechanism analysis shows that regional CEs reduce upstream supply chain concentration by forcing local firms to increase green innovation and weaken corporate governance; regional CEs increase downstream supply chain concentration by raising the financial constraints of local firms.

On the basis of the above findings, relevant policy advice given in this study is as follows:

First, the regional environment (carbon emissions) can significantly affect the concentration of downstream and upstream supply chains of firms in the whole industry, and there are significant variations in CEs and enterprise supply chain construction in different regions. Therefore, local governments should constantly adhere to the principle of adapting to local conditions when setting macro-level CE targets, which should be based on the development of regional enterprises, the downstream and upstream conditions of their supply chains, and the various effects generated by CEs from a macro perspective.

Second, when the government carries out environmental regulation and pollution control and sets environmental protection policies, it should fully think about the impact of the relevant policies on the downstream and upstream supply chains at the micro-firm level. Specifically, the formulation and modification of the policies, such as local carbon tax and carbon reduction subsidies should be within the reach of firms, in accordance with the objective law of their development, not too fast or too radical, and as far as possible to avoid excessive impact on the supply chain structure of local firms.

Third, this paper illustrates that the rise in regional CEs reduces the upstream concentration of firms, but strengthens the downstream concentration of firms. For this reason, in the process of implementing policies, local governments also need to make dynamic adjustments and dynamic optimization according to the location of the region's dominant firms and the majority of firms in the overall industrial value chain, as well as the downstream and upstream supply chains affected by the implementation of policies, so as to achieve an optimal balance between economic growth and environmental governance and reduce efficiency losses.

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