

How Does Industry Interconnection Affect Corporate Social Responsibility?— Empirical Evidence from the Perspective of Production Networks

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Abstract: *With the deepening division of labor in the global industrial chain, the impact of industry characteristics on corporate social responsibility (CSR) practices has become increasingly prominent. Based on the industry level, this study explores the correlation characteristics of different industries in the production network and their intrinsic connection with CSR performance. First, the study constructs a production network based on the input-output tables of 2015 and 2020, analyzes the characteristics of the production network, and finds that the production network can maintain stability and become more concentrated over time. Second, it uses the data of Chinese listed companies from 2010 to 2021 to analyze the impact of the production network on the fulfillment of corporate social responsibility, and finds that the production network has a significant negative effect on CSR performance. Finally, the study discusses the heterogeneous characteristics of this impact, and reveals that the inhibitory effect of industry correlation on CSR is more prominent in industries located in less developed regions and state-controlled enterprises. This study provides a new theoretical perspective for understanding the influencing factors of industry-level CSR, and also offers empirical evidence for formulating differentiated strategies to improve CSR performance.*

Keywords: *Production Network; Corporate Social Responsibility (CSR); Industry Correlation; Industrial Characteristics*

1. Introduction

In recent years, global consumers have been paying growing attention to the environmental and social impacts of their consumption choices. Consequently, enterprises across different industries are confronted with mounting pressure to ensure that certain minimum standards are respected not only by themselves but also by their stakeholders. Meanwhile, a growing number of studies have begun to focus on enterprises' fulfillment of corporate social responsibility (CSR) and their role in networks. Philipp Herkenhoff (2024) ^[25] found that CSR performance tends to improve progressively as it cascades from upstream suppliers with low CSR levels to downstream suppliers with high CSR performance. Si Lijuan et al. (2022) ^[32] examined the impact of green credit policies on enterprises' environmental social responsibility from the dual perspectives of external constraints and internal attention. Gu Leilei et al. (2022) ^[29] systematically discussed the implications of CSR in the financial sector. Bellamy, M.A. et al. (2020) ^[4] explored the interrelationships between administrative environmental innovation, supply network structure, and environmental disclosure. However, we observe that most existing CSR studies are conducted at the firm level; analyses of CSR at the industry level are often confined to individual industries, and there is a paucity of research examining CSR fulfillment across different industry dimensions.

A growing body of literature has demonstrated that corporate social responsibility (CSR) activities serve as crucial avenues for enhancing corporate reputation (BARNETT, 2010) ^[3] and shaping consumer perceptions (ELTANTAWY, 2009) ^[12]. Against the backdrop of the in-depth advancement of global economic integration and continuous technological innovation, firms are no longer constrained to a single market but proactively pursue broader market opportunities, thereby fostering increasingly close inter-industry linkages. Nevertheless, a subset of large corporations lacks a sense of social and environmental accountability; their pursuit of short-term economic profit maximization at the expense of sustainability has exerted uncontrollable negative impacts (Veldman and Willmott, 2017) ^[27].

Industry characteristics directly determine the priorities and directions for enterprises in fulfilling corporate social responsibility (CSR). Different industries bear distinct CSR obligations due to their inherent attributes. The core innovation of this study lies in elevating CSR research from the traditional firm-level analysis to the industry-level within the production network framework. At the theoretical level, this study breaks through the limitations of conventional CSR research, which mostly focuses on internal factors (e.g., firm size, governance structure) and external pressures (e.g., regulations and public opinion) (Dorobantu et al., 2024; Hersel et al., 2023) ^{[10][16]}. By expanding the analytical scope to the production network, it facilitates a more comprehensive understanding of enterprises' roles and responsibilities in the global economy. At the practical level, examining industry linkages can promote cross-industry collaboration and the coordination of CSR practices. By clarifying their positions in the industry network (e.g., centrality), enterprises can fulfill CSR more effectively. This not only helps reduce operational risks and costs (Li, S.P. et al., 2023; DesJardine et al., 2021) ^{[22][9]} but also drives social progress by leading the development of industry standards and implementing public welfare initiatives (Dwertmann et al., 2023; Gibson, 2022) ^{[11][14]}. In addition, focusing on industry centrality can drive the overall upgrading and technological innovation of the industrial chain. Core enterprises usually invest substantial R&D resources to boost industrial chain development. For instance, Palit et al. (2022) ^[24] explored technological knowledge in global supplier networks but did not conduct an in-depth analysis of the role of central industries, a research gap that this study aims to address.

2. Literature Review and Research Hypotheses

2.1. Characteristics of Production Networks

The concept of the input-output production network originated from the research of Sonis and Hewings (1998) ^[26]. It integrates social network analysis with input-output matrices to form the input-output production network, hereinafter referred to as the production network. As identified in the study of Cheung et al. (2020) ^[7], the stronger the connection between two network members, the more similar their performance within the social network; social networks enhance information accessibility and sharing among network members. Production networks exhibit analogous characteristics.

At the macro level, Acemoglu et al. (2014) ^[1] incorporated inter-sectoral game processes, macroeconomic risk models, and financial interaction models to construct a consistent framework for production networks, expounding on the role of production networks in the process of macroeconomic fluctuations. At the micro level, enterprises demonstrate more complex attributes within the network. For instance, Li, L.J. and Shou, Y.Y. (2024) ^[21] distinguished between production networks and distribution networks, revealing that the central position of a project in the production network can improve product quality, whereas its central position in the distribution network can boost product sales.

Meanwhile, Janet Gao et al. (2021) ^[18] found that production networks possess stability. On the one hand, industrial chains can prevent the stagnation of key nodes and core links, ensuring the basic operation of production networks—a property defined as the resistance resilience of industrial chains (Chen Xiaodong et al., 2022) ^[28]. On the other hand, industrial chains have the ability to readjust resource allocation, restore production functions, and gradually return to normalcy following external negative shocks—a property termed the recovery resilience of industrial chains (Grossman G.M. et al., 2023) ^[15]. Ma Xiaoyu et al. (2023) ^[31] discussed the influencing factors of such resilience.

Furthermore, Kim et al. (2015) ^[20] found that hub enterprises located at the core of an industry can transmit shocks or recovery effects to related industries through input-output linkages. Industries at the center of production networks typically establish intensive input-output connections with more upstream and downstream industries. Thus, when confronted with external shocks, they can acquire required resources more rapidly, adjust supply-demand structures, and achieve hedging and self-repair. In contrast, peripheral industries with low centrality in the network rely on single transaction paths, resulting in weak flexibility. They struggle to achieve rapid responses through network collaboration, thereby exhibiting lower resilience levels (Lai Guoshu et al., 2024) ^[30]. Therefore, this paper proposes Hypothesis 1:

Hypothesis 1: Production networks tend to maintain stability and become increasingly concentrated over time.

2.2. Production Networks and Corporate Social Responsibility

Since Bowen (1953) ^[5] first defined corporate social responsibility (CSR), research on this field has

been evolving continuously. Corporate interests are not merely the sum of shareholder interests or the interests of investors recorded in corporate registrations, but rather the aggregation of the interests of all stakeholders. Enterprises need to establish close collaborative relationships with stakeholders in related industries to jointly promote industrial development and progress. Hsueh and Chang (2008)^[17] pointed out that the CSR cooperation model among manufacturers is of great significance for the assessment of corporate social responsibility risks. McDonnell and Cobb (2020)^[23] explored how social movements centered on corporate social responsibility influence board turnover. In recent years, scholars both at home and abroad have engaged in increasing discussions on social responsibility issues in supply chains.

Some scholars have begun to explore corporate social responsibility (CSR) issues from the perspective of the entire supply chain. Jose M. (2013)^[19] proceeded from the global supply chain and examined the intrinsic link between CSR activities and corporate supply chains on the basis of constructing a global supply chain network model. Others have chosen to study specific segments of the supply chain. Danuta et al. (2013)^[8] explored the impact of supply chains on the achievement of CSR goals in depth, starting from logistics risks in supply chain management.

Domestic research has also been refined in recent years. Xu Jian (2014)^[36] discussed methods for evaluating CSR risks in supply chains. Xi Shuangna et al. (2018)^[35] constructed a Bayesian network topology model for supply chain CSR risks, and analyzed the main sources of CSR risks in supply chains of manufacturing enterprises. Zhang Jiping et al. (2024)^[37] examined the impact of supply chain network position on corporate ESG performance.

Enterprises' production, operation and social activities are not only related to their supply chains, but also closely linked to the macro environment in which they operate (Charpin et al., 2020)^[6]. Falcone, E.C. (2024)^[13] revealed an inverted U-shaped relationship between corporate network prominence and CSR consistency, indicating that enterprises with moderate network prominence exhibit higher CSR consistency. In addition, leading companies can prioritize industry CSR norms only when their supply chain partners share compatible CSR standards. This suggests that the large-scale production networks formed by interwoven corporate supply chains also play an irreplaceable role in corporate social responsibility. Meanwhile, Song Yan et al. (2023)^[33] found that the impact of CSR on enterprises is heterogeneous. Drawing on Tian Hong and Liu Yutian (2025)^[34], this paper adopts the CSR reports of listed companies from Hexun.com, constructs an input-output production network, integrates the macro environment of enterprises with their supply chains, analyzes industry correlation and corporate CSR behaviors, and proposes Hypothesis 2:

Hypothesis 2: The higher the degree of industry correlation, the lower the level of CSR fulfillment.

3. Data and Methods

3.1. Data

This study selects Chinese listed companies from 2010 to 2021 as research samples, yielding a final dataset of 40,022 annual observations. The independent variable—industry correlation (centrality)—is calculated based on the 2015 inter-industry input-output table (mid-period data of the sample), with the data sourced from the official website of the National Bureau of Statistics of China. The dependent variable and mediating variables are derived from the CSR measurement results of listed companies published on Hexun.com. Control variables are obtained from the CSMAR database, covering the relevant data on firm characteristics and industry characteristics.

The explanatory variable, centrality, which proxies for the degree of industry correlation, is measured by the industry centrality calculated from the 2015 input-output table released by the National Bureau of Statistics of China, with reference to the methodology of Janet Gao (2021)^[18]. The specific calculation steps are as follows: First, we construct an inter-sectoral production network by establishing an input-output (IO) matrix based on the input-output table issued by the National Bureau of Statistics. Second, drawing on Ahern (2015)^[2], we calculate the value of trade flows between all pairs of industries within the production network and then measure the industry centrality, which includes four core dimensions: Degree Centrality, Betweenness Centrality, Closeness Centrality, and Eigenvector Centrality. Finally, we match the industry codes of listed companies with the national economic industry classification standards to assign the corresponding centrality characteristics of the target industries to individual firms.

The explained variable is corporate social responsibility (CSR), with the CSR data sourced from the

CSR reports of listed companies on Hexun.com. Specifically, the composite CSR score of Chinese listed companies from the Hexun Database is adopted as the proxy for corporate social responsibility performance. Based on the information disclosed in the CSR reports and financial statements of Chinese listed companies, this score systematically evaluates firms' CSR fulfillment from five dimensions: shareholder responsibility, employee responsibility, responsibility towards suppliers, customers and consumer rights and interests, environmental responsibility, and public responsibility.

The control variables are the basic firm-level information extracted from the CSMAR database. In the regression analysis, to control for the impacts of firm-specific characteristics and external environments, we incorporate a set of firm-level control variables, including total assets, market-to-book ratio, and stock profitability. Additionally, we include an industry-level control variable—the average salary of employees in the industry—in the regression model.

3.2. Analytical Strategy

We estimate the following panel regression model to examine the relationship between corporate social responsibility (CSR) and industry correlation:

$$Total_{it} = \alpha_0 + \alpha_1 centrality_i + \alpha_2 X_{i,t} + \varepsilon_{i,t} \tag{1}$$

Here, Total denotes the composite CSR score of Chinese listed companies released by Hexun.com, which serves as a proxy for corporate social responsibility (CSR). Centrality refers to the centrality of the national economic industry classification to which the company belongs, including Degree Centrality, Betweenness Centrality, Closeness Centrality, and Eigenvector Centrality. X represents the control variables, and ε denotes the error term. i stands for individual firms, while t indicates time. Hypothesis 2 (H2) focuses on the coefficient α_1 of the core explanatory variable. If the disclosure of CSR information exerts an inhibitory effect on the high-quality development of enterprises, α_1 should be significantly negative, which would verify Hypothesis 2.

4. Construction and Evolution of Production Networks

4.1. Measurement of Production Networks

This study employs the competitive input-output table provided by the National Bureau of Statistics of China, which accounts for both the sources and destinations of all products in the Chinese economy. To measure the degree of interaction between a given industry and other sectors in the supply chain, the following steps are implemented: First, this paper constructs an adjacency matrix A using the data from the first quadrant of the input-output matrix. Second, based on the varying proportions of inputs from different industrial sectors relative to the total inputs of a specific industry, the input share of each industry in another industry is calculated as the trade flow. The calculation of trade flows between specific industries is specified as follows: using the input-output table, this paper develops a percentage-based production matrix B, where each entry $b(i,j)$ represents the percentage of inputs supplied by industry i to industry j . Finally, we map the production network based on matrix B and calculate four centrality metrics for each industry within the network, namely Degree Centrality, Betweenness Centrality, Closeness Centrality, and Eigenvector Centrality. See Table 1 for specific definitions.

Table 1 Measurement of Production Networks.

Degree Centrality	The higher the degree of a node, the greater its degree centrality, indicating that the node is more important within the network. The degree centrality of an industry measures the extent of its connections with other industries; specifically, a higher degree centrality value denotes a larger number of distinct industries linked to the target industry. The specific measurement formula is as follows: $degree\ centrality = N_{degree}/n-1$
Between Centrality	It characterizes the node importance index by the number of shortest paths passing through a given node. The betweenness centrality of an industry measures the number of other industries that are connected through this industry; specifically, a higher betweenness centrality value indicates that more other industries are linked via the target industry. The specific measurement formula is as follows: $BC = \sum \frac{d_{st}()}{d_{st}}$.

	Where d_{st} denotes the number of shortest paths from node s to node t , and $d_{st}(n)$ denotes the number of shortest paths from node s to node t that pass through node n .
Closeness Centrality	<p>It reflects the proximity between a given node and other nodes within the network. The closeness centrality of an industry is derived from the sum of the shortest paths from this industry to all other industries in the production network, followed by a normalization process, which is equivalent to calculating the average shortest distance from this industry to all other industries. The smaller the average shortest distance of an industry, the greater its closeness centrality. If there is no accessible path between node i and node j, d_{ij} is defined as infinity, and its reciprocal is 0. In other words, a higher closeness centrality value indicates that the industry has closer connections with other industries. The specific measurement formula</p> $d_i = \frac{1}{n} \sum_{j \neq i} d_{ij}$ <p>is as follows:</p> $CC_i = \frac{1}{d_i} = \frac{n-1}{\sum_{j \neq i} d_{ij}}$
Eigenvector Centrality	<p>The importance of an industry depends not only on the number of its neighboring industries (i.e., the degree of the industry) but also on the importance of those neighboring industries. The more important the connected neighboring industries are, the more important the node itself is. We calculate the eigenvector centrality of each industry as the entry in the principal eigenvector e of the adjacency matrix A. The vector e is the solution to the following equation: $Ae = \lambda e$.</p> <p>where λ is the largest eigenvalue of matrix A. In other words, a higher eigenvector centrality of an industry indicates that the industries associated with it are more important.</p>

4.2. Evolution of Production Networks

Figure 1 below presents the inter-sectoral production network based on the trade flows reported in the 2015 input-output table. Nodes represent industries classified under the national economic industry census, and edges between nodes denote the trade flows between corresponding pairs of industries. This figure depicts a connected and directed network. We constructed two network graphs by comparing the industry centrality metrics calculated from the 2015 input-output (IO) matrix, and analyzed the two graphs. The results show that all industries are interconnected, yet they exhibit substantial differences in the degree of connectivity.

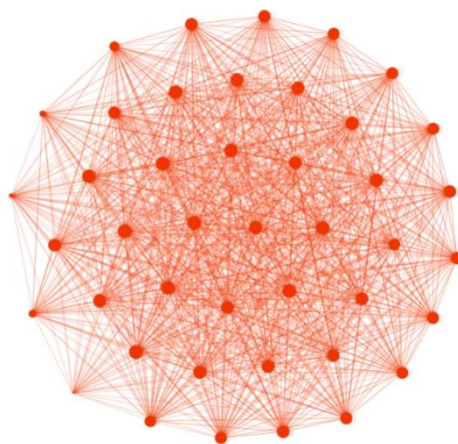


Figure 1: Production Network Diagram, 2015.

Table 2 lists the most central and most peripheral industries calculated based on the industry eigenvector centrality in 2015. The most core industries include mineral products, equipment, and other sectors related to natural resource exploitation. The most peripheral industries are mainly various service sectors, such as finance and education.

Table 2: Industry Selection, 2015.

Most Central Industries	Most Peripheral Industries
Non-metallic Mineral Products	Finance
Metal Ore Mining and Processing Products	Information Transmission, Software and Information Technology Services
General Equipment	Education
Metal Products	Public Administration, Social Security and Social Organizations
Chemical Products	Leasing and Business Services

Table 3 presents the most central and most peripheral industries calculated based on the eigenvector centrality in 2020. The most core industries include not only mineral mining and equipment sectors, but also scientific research-related industries. In addition to public administration service sectors, the most peripheral industries have also begun to include specialized equipment sectors such as mining equipment manufacturing. Through comparison, we can conclude that the structure of China’s production networks remains stable over time and is therefore unlikely to be altered by the subjective characteristics or behaviors of individual enterprises.

Table 3: Industry Selection, 2020.

Most Central Industries	Most Peripheral Industries
Research and Experimental Development	Insurance
Pharmaceutical Products	Pumps, Valves, Compressors and Similar Machinery
Metal Products	Glass and Glass Products
Other Specialized Equipment	Specialized Equipment for Mining, Metallurgy and Construction
Residential Building Construction	Catering Services
Plastic Products	Urban Public Transport and Highway Passenger Transport
Railway Transport and Urban Rail Transit Equipment	Livestock Products
Coal Mining and Washing Products	Ships and Related Equipment
Medical Instruments and Devices	Road Freight Transport and Transport Supporting Activities

Figure 2 below presents the inter-sectoral production network based on the trade flows reported in the 2020 input-output table. It can be observed that the production network has maintained a similar structure over time: each network comprises several major industry clusters that are closely interconnected with one another. It also includes a number of industries on the periphery of the network, which are directly linked to only a few other industries. In addition, we find that compared with the 2015 production network diagram, the 2020 production network is more concentrated, which verifies Hypothesis 1.

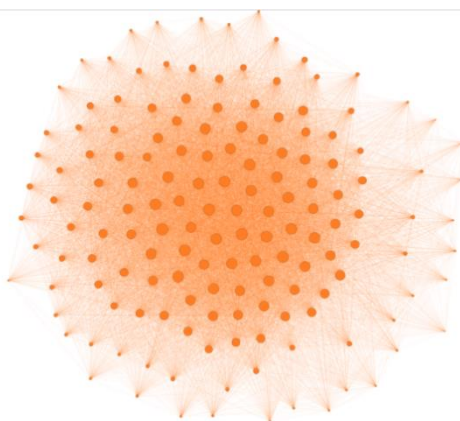


Figure 2: Production Network, 2020.

5. Results

5.1. Descriptive Statistics

Table 4 presents the results of the descriptive statistics conducted on the main variables. The mean

values of the explanatory variables in this paper's sample—namely Degree Centrality, Betweenness Centrality, Closeness Centrality, and Eigenvector Centrality—are 0.002, 1.943, 0.936, and 0.153 respectively. It can be observed that the degree centrality of industries is at the lowest level, while the betweenness centrality is at the highest level. The corresponding standard deviations are 0.001, 0.148, 0.137, and 0.023, indicating that the centrality of most industries in China is relatively concentrated. In our sample, the mean value of the corporate social responsibility (CSR) score of enterprises is 22.978, which suggests that the overall level of corporate social responsibility in China is relatively low. The standard deviation of the CSR score is 14.509, implying a high degree of dispersion in the CSR performance of Chinese enterprises. The remaining detailed results of the descriptive statistics are presented in the table below.

Table 4: Descriptive statistics.

Variable	N	Mean	p50	SD	Min	Max
degree	40,022	0.002	0.002	0.001	0.000	0.004
between	40,022	1.943	1.976	0.148	1.000	2.024
close	40,022	0.936	0.955	0.137	0.000	1.000
eigenvector	40,022	0.153	0.156	0.023	0.000	0.164
Total	40,058	22.978	21.190	14.509	-18.450	90.870
Total-asset	32,802	6.2344e+07	3380260.865	8.0190e+08	0.000	3.3350e+10
return	32,803	0.108	0.000	0.556	-0.924	15.211
Be/me	32,802	1.961	0.991	9.319	0.000	586.237
AE-Salary	32,802	122,737.100	115,323.860	60,637.613	24,814.36	970,251.61

5.2. Basic Analysis

This study employs the model specified in Formula (1) to examine the relationship between the central position of an industry and its corporate social responsibility (CSR). Table 5 presents the regression results without the inclusion of control variables. It can be observed that: The regression coefficient of Degree Centrality on CSR is -911.767, which is statistically significant at the 1% level, indicating that the more types of industries a given sector is associated with, the lower its CSR performance. The regression coefficient of Betweenness Centrality on CSR is -4.155, significant at the 1% level, implying that the more industries connected through a specific sector, the lower its CSR level. The regression coefficient of Closeness Centrality on CSR is -3.834, significant at the 1% level, suggesting that the closer the connections between a given industry and other sectors, the lower its CSR performance. The regression coefficient of Eigenvector Centrality on CSR is -25.611, significant at the 1% level, demonstrating that the more important the industries associated with a specific sector are, the lower its CSR level.

Table 6 reports the regression results with control variables incorporated, which are consistent with those in Table 5. In both sets of regressions, the four centrality metrics we measure all show negative coefficients that are statistically significant at the 1% level. This finding indicates that a higher degree of industry correlation is associated with lower CSR performance, thus supporting our Hypothesis H2.

Table 5: Baseline Regression Results.

VARIABLES	(1) Y	(2) y	(3) y	(4) y
degree	-911.767*** (-18.34)			
between		-4.155*** (-8.48)		
close			-3.834*** (-7.25)	
eigenvector				-25.611*** (-8.08)
Constant	24.775*** (203.19)	31.048*** (32.51)	26.564*** (53.06)	26.881*** (54.98)
Observations	40,022	40,022	40,022	40,022
R-squared	0.008	0.002	0.001	0.002

t-statistics in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 6: Baseline Regression Results with Control Variables Included.

VARIABLES	(1) Y	(2) y	(3) y	(4) y
degree	-970.293*** (-16.08)			
between		-3.424*** (-6.27)		
close			-3.032*** (-5.19)	
eigenvector				-20.681*** (-5.88)
Total-asset	0.000*** (10.17)	0.000*** (10.76)	0.000*** (10.82)	0.000*** (10.78)
return	0.406*** (2.61)	0.409*** (2.62)	0.403*** (2.58)	0.402*** (2.57)
Be/me	0.069*** (6.46)	0.070*** (6.54)	0.069*** (6.52)	0.069*** (6.52)
AE-Salary	-0.000*** (-4.81)	-0.000*** (-2.83)	-0.000*** (-2.79)	-0.000*** (-2.90)
Constant	26.146*** (106.59)	30.515*** (28.06)	26.700*** (45.14)	27.036*** (46.32)
Observations	32,791	32,791	32,791	32,791
R-squared	0.017	0.010	0.010	0.010

t-statistics in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

5.3. Robustness Test

To ensure the robustness of the empirical results in this paper, the following three methods are adopted for robustness tests:

First, the corporate social responsibility (CSR) score is converted into a dummy variable based on ratings. For enterprises with an overall CSR score greater than 40, the dummy variable T is assigned a value of 1; for those with an overall CSR score less than or equal to 40, the dummy variable T is assigned a value of 0. A logistic regression is conducted, and the results are presented in Table 7. It can be observed from Table 6 that after replacing the explained variable (CSR score) with a dummy variable, the regression coefficients of industry centrality metrics on the dummy variable remain significantly negative at the 1% level. These regression results are consistent with those obtained using the CSR score as the explained variable above, which supports our original hypothesis and demonstrates that our conclusions are relatively robust.

Table 7: Results with Dummy Variables Introduced.

VARIABLES	(1) T	(2) T	(3) T	(4) T
degree	-15.270*** (-9.16)			
between		-0.116*** (-7.32)		
close			-0.085*** (-4.96)	
eigenvector				-0.544*** (-5.30)
Control	YES	YES	YES	YES
Constant	YES	YES	YES	YES
Observations	32,791	32,791	32,791	32,791
Number of code	4,181	4,181	4,181	4,181

z-statistics in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Second, two industry-level control variables, ICN (number of enterprises in the industry) and ICAS (average salary of the industry), are incorporated into the model. The regression is conducted again, and the results are presented below. As shown in Table 8, after adding the new industry-level control variables (number of enterprises in the industry and average salary of the industry), the regression coefficients of industry centrality metrics on the dummy variable remain significantly negative at the 1% level. These

regression results are consistent with those obtained using the CSR score as the explained variable above, which supports our original hypothesis and demonstrates that our conclusions are relatively robust.

Table 8: Regression Results with Industry-level Control Variables Added.

VARIABLES	(1) Y	(2) y	(3) y	(4) y
degree	-773.200*** (-12.77)			
between		-1.786*** (-3.27)		
close			-2.402*** (-4.14)	
eigenvector				-17.239*** (-4.94)
Control	YES	YES	YES	YES
Constant	YES	YES	YES	YES
Observations	32,791	32,791	32,791	32,791
R-squared	0.032	0.027	0.027	0.027

t-statistics in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Third, special samples are excluded: the comprehensive industry (S90), monetary and financial industry (J69), and other financial industry (J66) are removed from the sample to avoid interference of special industries with the empirical results. The regression is conducted again, and the results are presented in Table 9. As shown in Table 9, after excluding the special samples, the regression coefficients of industry centrality metrics on the dummy variable remain significantly negative at the 1% level. These regression results are consistent with those obtained using the CSR score as the explained variable above, which supports our original hypothesis and demonstrates that our conclusions are relatively robust.

Table 9: Regression Results with Special Samples Excluded.

VARIABLES	(1) Y	(2) y	(3) y	(4) y
degree	-970.293*** (-16.08)			
between		-3.424*** (-6.27)		
close			-3.032*** (-5.19)	
eigenvector				-20.681*** (-5.88)
Control	YES	YES	YES	YES
Constant	YES	YES	YES	YES
Observations	32,791	32,791	32,791	32,791
R-squared	0.017	0.010	0.010	0.010

Robust *t*-statistics in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

5.4. Heterogeneity Analysis

5.4.1. Regional Prosperity

The impact of production networks on corporate social responsibility (CSR) varies with the location and nature of enterprises. Therefore, it is more valuable to study the impact of heterogeneous enterprise characteristics on CSR. Different industries have distinct regional distributions due to their unique industrial attributes, and governments in different regions impose different policy requirements related to corporate social responsibility. Regional governments' emphasis on local people's livelihood and employment environment will prompt enterprises to adjust their behaviors and pay more attention to their social responsibilities. In addition, different regions have different customs and cultural backgrounds, which will also make the social responsibilities of local enterprises present regional characteristics. Therefore, this paper further divides enterprises into two categories according to their regional locations: prosperous regions and non-prosperous regions. The prosperous regions include four cities: Beijing, Shanghai, Guangzhou and Shenzhen, while other regions are classified as non-prosperous regions. An empirical test is conducted based on this grouping. Table 10 presents the impact of enterprise centrality on CSR in prosperous regions, and Table 11 shows the impact of enterprise centrality on CSR

in non-prosperous regions.

Table 10: Regression Results of Prosperous Regions.

VARIABLES	(1) y	(2) y	(3) y	(4) y
degree	-698.583*** (-5.38)			
between		-2.426** (-2.34)		
close			-1.456 (-1.34)	
eigenvector				-10.411 (-1.58)
Control	YES	YES	YES	YES
Constant	YES	YES	YES	YES
Observations	8,815	8,815	8,815	8,815
R-squared	0.023	0.020	0.020	0.020

t-statistics in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

According to Table 10, in prosperous regions, only Degree Centrality and Betweenness Centrality exert a negative impact on corporate social responsibility (CSR). Moreover, compared with the full sample, the impact of Betweenness Centrality on CSR of enterprises in prosperous regions has diminished. In contrast, Closeness Centrality and Eigenvector Centrality have no statistically significant impact on CSR of enterprises in prosperous regions. Overall, in prosperous regions, the higher the industry centrality, the lower the level of corporate social responsibility.

Table 11: Regression Results of Non-prosperous Regions.

VARIABLES	(1) y	(2) y	(3) y	(4) y
degree	-855.371*** (-12.23)			
between		-2.939*** (-4.57)		
close			-2.612*** (-3.76)	
eigenvector				-17.613*** (-4.21)
Control	YES	YES	YES	YES
Constant	YES	YES	YES	YES
Observations	23,976	23,976	23,976	23,976
R-squared	0.012	0.007	0.006	0.006

t-statistics in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

According to Table 11, in non-prosperous regions, Degree Centrality, Betweenness Centrality, Closeness Centrality, and Eigenvector Centrality all exert a negative impact on corporate social responsibility (CSR). Overall, in non-prosperous regions, the higher the industry centrality, the lower the level of corporate social responsibility.

By analyzing Table 10 and Table 11, we can find that compared with prosperous regions, the negative correlation between enterprise centrality and CSR is more significant in non-prosperous regions. In other words, the higher the industry correlation in non-prosperous regions, the lower the CSR performance will be compared with that in prosperous regions.

5.4.2. Heterogeneity in Ownership Nature

Different industries have different national positioning and ownership natures due to their distinct characteristics and levels of importance. Therefore, this paper classifies enterprises into three categories based on their ownership nature: state-owned enterprises (SOEs), central state-owned enterprises, and others (foreign-funded enterprises and other types). Regression analysis is conducted separately for the three categories of enterprises. Table 12 presents the regression results of enterprise centrality on corporate social responsibility for state-owned enterprises. Table 13 shows the regression results of enterprise centrality on corporate social responsibility for private enterprises. Table 14 reports the regression results of enterprise centrality on corporate social responsibility for enterprises in the *others* category.

Table 12: Regression Results of State-owned Enterprises.

VARIABLES	(1) y	(2) y	(3) y	(4) y
degree	-1,610.460*** (-13.29)			
between		-4.697*** (-4.86)		
close			-4.037*** (-3.86)	
eigenvector				-28.006*** (-4.42)
Control	YES	YES	YES	YES
Constant	YES	YES	YES	YES
Observations	11,614	11,614	11,614	11,614
R-squared	0.027	0.015	0.014	0.014

t-statistics in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 13: Regression Results of Private Enterprises.

VARIABLES	(1) Y	(2) y	(3) y	(4) y
degree	-333.906*** (-5.01)			
between		0.770 (1.16)		
close			0.074 (0.10)	
eigenvector				-1.192 (-0.28)
Control	YES	YES	YES	YES
Constant	YES	YES	YES	YES
Observations	18,223	18,223	18,223	18,223
R-squared	0.032	0.031	0.031	0.031

t-statistics in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 14: Regression Results of Foreign-funded and Other Enterprises.

VARIABLES	(1) Y	(2) y	(3) y	(4) y
degree	-1,288.380*** (-6.20)			
between		-5.345*** (-2.88)		
close			-5.821*** (-3.03)	
eigenvector				-38.753*** (-3.35)
Control	YES	YES	YES	YES
Constant	YES	YES	YES	YES
Observations	2,954	2,954	2,954	2,954
R-squared	0.034	0.024	0.025	0.025

t-statistics in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

By analyzing the regression results of the three groups presented in Table 12, Table 13, and Table 14, we can see that the results for state-owned enterprises in Table 12 and for enterprises in the *others* category in Table 14 are consistent with the baseline regression, where all four variables exert a negative impact on corporate social responsibility (CSR). However, in the regression results for private enterprises in Table 13, only Degree Centrality shows a negative impact on CSR, indicating that the more types of industries a given sector is associated with, the lower its CSR performance.

In summary, we find that compared with private enterprises, the negative correlation between

enterprise centrality and CSR is more significant for state-owned enterprises and enterprises in the *others* category. In other words, the higher the industry correlation of state-owned enterprises and enterprises in the *others* category, the lower their CSR performance will be compared with that of private enterprises.

6. Conclusion and Recommendations

First, this study adopts the input-output production network approach to assess industry centrality. By constructing production network diagrams for 2015 and 2020, we find that compared with the 2015 production network, the 2020 version remains stable and becomes more concentrated. Second, through an extensive review of existing research on corporate social responsibility (CSR) in supply chains, we observe that the fulfillment of CSR within the broader industry-level production network system has received scant attention. Therefore, we utilize the 2015 production network and data of Chinese listed companies from 2010 to 2021 to analyze its impact on CSR performance, and find that production networks exert a significant effect on enterprises' CSR fulfillment. Finally, this paper conducts a heterogeneity analysis of the impact of production networks on CSR. The results show that the negative correlation between enterprise centrality and CSR is more pronounced in non-prosperous regions than in prosperous ones; similarly, this negative correlation is more significant for state-owned enterprises and other types of enterprises compared with private enterprises. The research on the impact of production networks on CSR holds important theoretical and practical significance. It not only helps deepen our understanding of the influencing factors of CSR and expand the research perspective of CSR, but also facilitates cross-industry cooperation and coordination, and reduces enterprise operational risks.

This study provides the following three recommendations for China's high-quality economic development and the construction of a modern industrial system: First, enterprises should formulate clear CSR strategies and clarify their responsibilities and obligations across all associated industries. Meanwhile, they should enhance corporate transparency, disclose their CSR practices and impacts on a regular basis, help the public and stakeholders gain a better understanding of their CSR performance, and promote continuous improvement of CSR work. Second, industry organizations and associations can promote industry self-regulation, establish industry standards and best practices, urge enterprises to fulfill CSR in all associated industries, and build a cross-industry CSR network. Third, government regulatory authorities should establish a scientific CSR evaluation mechanism based on the characteristics of different industries, conduct regular assessments of enterprises' CSR performance in various associated industries, and urge enterprises to make improvements based on the evaluation results.

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