

# Study on the Risk Contagion Effect of Energy Supply Chain Finance under the "Double Carbon" Target

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**Abstract:** The realization of the "double carbon" target will have a great impact on the contagion effect of supply chain finance risk in the energy market. The article uses social network model and GARCH model to study the contagion effect of energy supply chain finance risk from both enterprise creditworthiness and economic environment. The social network model is used to analyze the degree of differentiation of the supply chain network and the correlation between node enterprises before and after the implementation of the "double carbon" target, using the asset-liability ratio of enterprises as the default risk indicator. The GARCH model was used to empirically analyze the risk contagion effect between CSI energy and Shanghai and Shenzhen stock indices from the perspective of economic environment. The study found that there is a significant correlation and contagion effect between the financial risks of silicon energy enterprises, and the enterprises with higher creditworthiness are less affected by the implementation of the "double carbon" target plan, and the supply chain network is more obviously centralized by the "double carbon" target. The results of GARCH model show that the energy market is influenced by the external economic environment and there is risk contagion effect between markets. Based on the results of the GARCH model, we provide policy recommendations for supply chain risk prevention and control.

**Keywords:** "Double carbon" target, Supply chain finance risk, Contagion effect, Social network model, GARCH model.

## 1. Introduction

In the face of tremendous pressure to reduce emissions, China announced in December 2020 the goal of achieving peak carbon by 2030 and carbon neutrality by 2060. Achieving the "double carbon" target is not only a major component of ecological civilization construction, but also an important driving force for profound changes in corporate supply chains. The goal of "peak carbon" refers to the process in which emissions reach a historical high and continue to decline after a horizontal period; based on the achievement of peak carbon, carbon neutrality refers to the process in which the total amount of anthropogenic emissions in a certain region at a certain time is offset by the amount absorbed through afforestation, energy conservation and carbon sequestration, so as to achieve "net zero" carbon dioxide emissions. In order to smooth out the industrial chain and achieve the top-level design of the supply chain under the "double carbon" target, the government work report from 2021 has repeatedly mentioned the adoption of a series of means to prevent and resolve the supply chain financial risks of enterprises. To achieve the "double carbon" goal, the energy side is the main point, and the supply chain is an important carrier. The economic environment of each enterprise in the energy market, the creditworthiness of the enterprise and the financial management of the market have become the focus of the regulatory authorities to strictly control the market. The efficient operation of energy enterprises is the key to achieving "double carbon", and the supply chain is interconnected upstream and downstream of the energy chain to promote the development of new energy sources and the innovation of power systems, thus increasing the speed of operation of the industry and slowing down the transmission of risks (Kun et al. [1]).

With the gradual advancement of carbon peak and carbon neutral targets, scholars are paying more and more attention

to the creditworthiness level of enterprises in the supply chain and the economic environment they are in, as well as putting forward higher requirements for the management of enterprise supply chain risks (Jia, Simin, Jian, & Jianzhao [2]). Rui, Dayi, & Huilin [3] selected accounts receivable factoring business as a research object to analyze the mechanism of the role of blockchain in supply chain finance to reduce financing risk. Zhao, Jingfeng, Li, & Bo [4] show the market economy of China consists of enterprises, and the fluctuation of SMEs' finance will lead to supply chain fluctuation, while supply chain budgeting can solve the problems of SMEs' expenditure to a certain extent. Wang et al. [5] used an imbalance strategy with machine learning techniques to predict the credit risk of SMEs in China, using financial, operational, innovation, and negative information as predictors to study the credit risk contagion effects among firms in a supply chain system. Thanigai A et al. [6] used a gray decision experiment and evaluation laboratory (DEMATEL) approach, verified that different categories of risks are also contagious to each other, with the financial risk of firms being the most vulnerable to circular supply chains. In the current market turmoil and economic downturn, it is crucial to study the risk contagion effect among enterprises in supply chain finance to achieve the goal of "double carbon". With the gradual expansion of supply chain networks, scholars tend to study the interconnectedness of supply chains (Mohsen, Reza, & Kaveh [7]). Yuan et al. [8] uses social network analysis to study the social risks of high-density urban construction projects in China. Social network analysis is less applied in supply chain risk contagion effect, and this paper will enrich the application of this method by analyzing the economic environment and creditworthiness among energy companies in the supply chain through social network model.

About the empirical aspects of the contagion effect of supply chain finance risk. In order to describe the contagion effect of supply chain finance risk more precisely, more and

more econometric models are used, not only logistic models, Copula functions, and contagion models, but also covering VAR-GARCH models. Jia L et al. [9] combined the risk management theory in economics and the distributed hydrological model in hydrology to conclude that the risk of any node in the supply chain system is likely to spread to the whole chain and even lead to the collapse of the whole system. In order to achieve the goal of "double carbon", some unexpected events will affect the stability of the supply chain system and have an impact on the contagion effect of risk among the nodal enterprises in the chain, Pan, Zhao, & Miu [10] used the ternary VAR-GARCH(1,1)-BEKK model to investigate the risk contagion effect among enterprises in three industries. risk contagion effects are studied. The global supply chain is disturbed by the epidemic. Fahad, Yue xiang, & Ahmet [11] use mathematical models to study the impact of different industries in precious metals on the Dow Jones index. supply chain finance is a new model that closely unites the business of each enterprise, and the fluctuation of the enterprise will affect related enterprises in the same industry or other industries. The existence of supply chain bullwhip effect, superimposed on the risk of upstream and downstream enterprises through the supply chain propagation, in order to more accurate prediction judgment of supply chain risk, Liang [12] used GARCH model to get better results.

At the present stage, the control of enterprise supply chain financial risks under the "double carbon" target has received the attention of many scholars at home and abroad, along with the development and utilization of new energy, system transformation and technological innovation, enterprise supply chain financial risks and their contagion effects have become increasingly complicated, but few scholars have explored the risk contagion effects among enterprises in the "double carbon" target. However, few scholars have explored the risk contagion effect among enterprises in the energy market under the "double carbon" objective. It is particularly important to analyze the risk contagion effect among energy enterprises, prevent and control supply chain risks, and achieve enterprise quality and efficiency improvement. Therefore, the article is based on the creditworthiness of enterprises and the economic environment of the energy market to study the contagion effect of supply chain financial risks under the "double carbon" target, in order to better promote the financial management of enterprise supply chain risks under the "double carbon" target.

The content of this paper is as follows. The second part briefly introduces the definition and concept of social network model and VAR-GARCH model. The third part analyzes the supply chain network structure using social networks. The fourth part uses the GARCH model to analyze the inter-chain risk contagion effect. The fifth part makes targeted policy recommendations.

## 2. Study Design

In order to effectively reveal the contagion effect among the market risks in the supply chain system, the article firstly selects the social network model to analyze the credit risk contagion effect among the silicon energy enterprises from the level of enterprise creditworthiness; and then uses the VAR-GARCH model to empirically analyze the contagion effect between the energy market and other markets from the level of economic environment.

## 2.1. Sample Selection and Data Processing

The realization of the "double carbon" target will not only have a certain impact on the normal operation of the industry chain, but also on the energy market. The article selects the listed companies in the silicon energy concept sector as the nodes through the Flush APP, excluding ST and ST\* enterprises, and finally selects 22 energy enterprises as the research samples. The social network model is constructed by selecting the balance sheet ratio of enterprises in 2020 and 2021 as indicators of default risk and creditworthiness, and analyzing the risk contagion effect among silicon energy enterprises before and after the "double carbon" target is proposed; for enterprises, the impact of economic environment is most directly manifested in daily stock returns, and the fluctuation of each enterprise in the supply chain system will affect the whole chain and the supply chain. Therefore, the article selects the period from January 3, 2017 to December 31, 2021 as the research interval, and chooses the daily returns of CSMAR Energy Stock Index and Shanghai and Shenzhen Stock Index to measure the risk contagion effect between the energy market and the economic market to explore the supply chain risk contagion effect (Qun, Ying, Rui, & Qun [13]). Data are obtained from the CSMAR Guotaian Financial Research Database.

The daily closing prices of 1217 groups of stocks from the three markets collected were logarithmically processed to obtain return data.

$$u_t = \ln\left(\frac{P_t}{P_{t-1}} + 1\right) * 100 \quad (1)$$

Where  $P_t$  and  $P_{t-1}$  are the closing prices of stocks on day  $t$  and day  $t-1$ , respectively, and  $u_t$  is the return on day  $t$ .

## 2.2. Social Network Model

The social network analysis method is good for visualizing the correlation between nodes, therefore, this paper chooses this method to study the contagion effect of default risk among silicon energy companies. Social network analysis is a method used to analyze the relationship between actors, evaluating relational data rather than attribute data, i.e., analyzing data between variables regarding correlation, group association, etc., and applying it to the supply chain system can well portray the degree of association between nodes. The article selects the gearing ratio of silicon energy enterprises in 2020 and 2021 to analyze the change of correlation between nodes before and after the implementation of the "double carbon" target, i.e. the risk contagion effect between enterprise nodes in the chain.

The spatial correlation matrix of silicon energy enterprises' risks was constructed. The correlation between the listed enterprises' gearing ratios is analyzed using equation (2), and 0 is chosen as the threshold value. The correlation coefficient of two variables greater than 0 corresponds to the value "1" in the binary matrix, which indicates the existence of risk contagion between two node enterprises, and vice versa, which corresponds to "0," i.e., they are not relevant.

$$cov(x, y) = \frac{1}{n-1} \sum_{i=1}^{n-1} (x_i - \bar{x})(y_i - \bar{y}) \quad (2)$$

Where  $x_i$  and  $y_i$  denote the  $i$ -th node enterprise, respectively.

Intermediate centrality of default risk correlation network

among silicon energy enterprises. Intermediate centrality refers to the fact that a node in the chain is at the shortest distance from other multiple pairs of nodes is that this node enterprise has a high intermediate centrality, which measures the degree of control of the node enterprise over the risk contagion of the whole chain. Let the number of shortcuts between node j and node k be  $g_{jk}$ , the number of shortcuts through the third point x be expressed by  $g_{jk}(x)$ , and the ability of city x to control the association between city j and city k be expressed by  $b_{jk}(x)$ , and the sum of the intermediate degree of all pairs of points passing through city x can be compared with the maximum number of shortcuts through city x to obtain the intermediate centrality. The relative number expression, calculated as :

$$C_{bet}(x) = \frac{2 \sum_j \sum_k b_{jk}(x)}{N(N-1)} \quad (3)$$

$$b_{jk}(x) = \frac{g_{jk}(x)}{g_{jk}} \quad (4)$$

### 2.3. VAR-GARCH Model

Burroughs Levin extends the ARCH model to a GARCH model-generalized autoregressive conditional heteroskedasticity model. The financial time series in which the true variance deviates from the model fit and the variance of the disturbance term  $u_t$  depends on the prior conditional variance  $u_{t-i}$ , i.e., the ARCH model. The unbiased estimation expression is Equation (5).

$$\sigma_t^2 = \frac{1}{m-1} \sum_{i=1}^m (u_{t-i} - \bar{u})^2 \quad (5)$$

Where  $\sigma_t^2$  is the variance of stock volatility on day t and  $u_i$  is the logarithmic return.

The ARCH model expression is Equation (6) and Equation (7).

$$y_t = \sqrt{\sigma_t^2} \varepsilon_t \quad (6)$$

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^m \alpha_i u_{t-i}^2 \quad (7)$$

Where  $y_t$  is the return at day t,  $\sigma_t^2$  is the variance at day t, and  $\varepsilon_t$  is the dispersion of the true value.

Based on the extension and optimization of the ARCH

model, the GARCH model can better analyze and predict the time series volatility. the GARCH (p,q) model expression is Equation (8) and Equation (9).

$$\alpha_i = \sigma_t \varepsilon_t \quad (8)$$

$$\sigma_t^2 = \omega + \sum_{i=1}^p \alpha_i \varepsilon_{t-i} + \sum_{j=1}^q \beta_j \sigma_{t-j}^2 \quad (9)$$

Where  $\omega > 0$ ,  $\alpha_i > 0$ , p,q are the lagged orders of historical returns and prior series variance, respectively, and  $\alpha_i$  is the conditional variance.

## 3. Social Network Analysis

### 3.1. Overall Silicon Energy Supply Chain Network Structure

In order to effectively portray the degree of change in the spatial correlation network structure of supply chain financial risks before and after the implementation of the "double carbon" target, UCINET is used to draw the correlation network diagrams of default risks between nodes in 2020 and 2021.

The comparison of Figure 1 and Figure 2 shows that after the implementation of the "double carbon" target, the network diagram of default risks of silicon energy enterprises is less differentiated and shows a trend of centralized pairs. The risks close to the center play an important role in the network, with many nodes close to the center, indicating that the risks embedded in the core and upstream and downstream enterprises in the silicon energy supply chain have a significant impact on the stability of the whole chain. Figure 1 shows that in 2020, YJGD, SJSK, and TBDG are located in the center of the network diagram, while QBJT, GBKJ, HBXC, and SLJN are in the more central position of the network due to their diversified business types and good profitability. Figure 2 shows that in 2021, the "double carbon" strategic plan will gradually unfold, with QBJT at the core of the network diagram, followed by YJGD and LJLN. Other node companies are scattered in the network diagram with similar distance. It can be seen that the realization of the "double carbon" goal has a huge impact on the enterprises in the silicon energy chain, and there is a "small world phenomenon" in the supply chain financial risk related network.

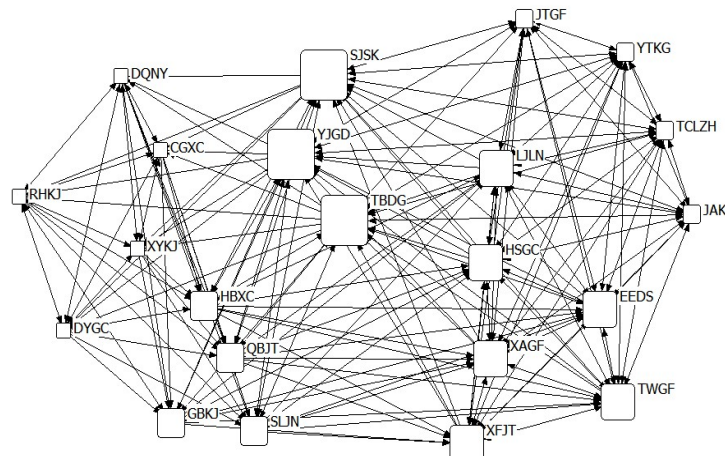


Figure 1. 2020

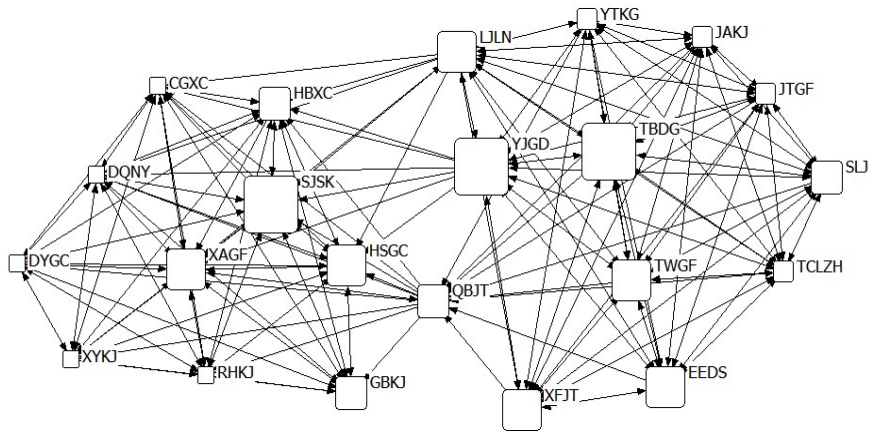


Figure 2. 2021

### 3.2. Intermediate Centrality Analysis

The intermediate centrality indicates the intermediacy of the entire network. Table 1 shows the dynamic evolution of default risk among silicon energy node enterprises in 2020 and 2021. 2020, YJDK, SJSK, and TBDG as vertically integrated industry chain, which has contributed to the competitive advantage of enterprises. However, in 2021, with

the gradual implementation of the "double carbon" plan, the production costs of enterprises have been strengthened, and the ability to influence the same industry slightly reduced. The superior geographical location of QBJT (Ningbo) makes it less affected in the new environment, and the epidemic has less impact on the production, export and operation of the company. It can be seen that the higher the level of corporate creditworthiness, the less the degree of impact by the outbreak.

Table 1. Characteristics of the financial risk network structure of the silicon energy chain

Enterprise	2020	Layer	2021	Layer
YJGD	6.266	1	8.57	2
SJSK	6.266	1	0.698	3
TBDG	6.266	1	0.698	3
QBJT	2.116	2	25.714	1
GBKJ	2.116	2	0	4
HBXC	2.116	2	0.698	3
SLJN	2.116	2	0.698	3
TWGF	1.126	3	0.698	3
XAGF	1.126	3	0.698	3
HSGY	1.126	3	0.698	3
EEDS	1.126	3	0.698	3
LJLN	1.126	3	8.571	2
XFJT	1.126	3	0.698	3
XYKJ	0.279	4	0	4
RHCL	0.279	4	0	4
DYGC	0.279	4	0	4
DQNY	0.279	4	0.698	3
CGXC	0.279	4	0.698	3
JAKJ	0.075	5	0.698	3
JTGf	0.075	5	0.698	3
YTKG	0.075	5	0.698	3
TCLZH	0.075	5	0.698	3

## 4. Empirical Studies

Manolis N. Syllignakis[14] selects two markets in Central and Eastern Europe and uses GARCH model for dynamic analysis of financial contagion. The article selects the SSE and SZSE indices as well as CSI energy daily returns from January 2017 date to 2021 as the study sample and the data

processing analysis is done using Eviews software.

### 4.1. Descriptive Statistical Analysis

After logarithmic treatment of the historical data of the market indexes, the three stock index returns are smooth and the statistical indicators of the variables are shown in Table 2.

Table 2. Descriptive statistics

Index	Mean	Median	SD	Min	Max	Skewness	Kurtosis
SSE	0.013	0.045	1.064	-8.034	5.553	-0.629	9.025
SZSE	0.031	0.050	1.393	-8.828	5.439	-0.602	6.472
CSI Energy	0.003	0.030	1.484	-8.056	6.072	-0.199	6101

The JB values of the three returns are 1920.801, 684.950, and 495.547, respectively, indicating that none of the series obeys the positive-terrestrial distribution.

### 4.2. GARCH Model

The stock price reflects the risk premium of the firm. The

sample data are all time series, and in order to avoid the phenomenon of pseudo-regression, therefore, the article first

performs a smoothness test on the series before conducting the empirical analysis. The results are shown in Table 3.

Table 3. ADF test results

Index	ADF	P	Conclusion
SSE	-34.758 ***	0	Stable
SZSE	-34.578 ***	0	Stable
CSI Energy	-35.864 ***	0	Stable

Note: \*\*\* indicates that the original hypothesis is rejected at 1% significant level, indicating that the series is smooth.

The results of the ADF test in Table 1 show that all three stock index return data with drift terms are smooth with p-values of zero, i.e., the original hypothesis of the existence of unit root in the time series is not accepted, and the time series obeys the zero-order single integer i.e., I(0) process. Then, the autocorrelation test and heteroskedasticity test are in line with the modeling requirements.

Finally, we determine whether there is an ARCH effect. The ARCH-LM test results show that the original hypothesis is rejected, i.e., there is an ARCH effect in the three return series, so the modeling can be performed.

### 4.3. Parameter Estimation of GARCH Model

The results of the GARCH model fit are as follows.

$$\begin{aligned} \text{SSE: } u_{sz,t} &= -0.0445u_{sz,t-6} + \varepsilon_{1,t} \\ \sigma_{sz,t}^2 &= 0.021 + 0.113\varepsilon_{sz,t-1}^2 + \\ &0.879\sigma_{sz,t-1}^2 \\ \text{SZSE: } u_{sz,t} &= -0.047u_{sz,t-4} + \varepsilon_{1,t} \\ \sigma_{sz,t}^2 &= 0.056 + 0.099\varepsilon_{sz,t-1}^2 + \\ &0.877\sigma_{sz,t-1}^2 \\ \text{CSI Energy: } u_{sz,t} &= -0.030u_{sz,t-8} + \varepsilon_{1,t} \end{aligned}$$

$$\sigma_{sz,t}^2 = 0.108 + 0.118\varepsilon_{sz,t-1}^2 + 0.836\sigma_{sz,t-1}^2$$

In the ARCH models for the daily returns of SSE, SZSE and CSI, the coefficients of the ARCH and GARCH terms are equal to 1, which means that the return series have strong volatility persistence. The residuals obey the t-distribution with significant degrees of freedom, indicating that the distribution of the return series is "spiky and thick-tailed", which is consistent with the actual situation caused by new policies in the financial market. The estimated models are tested for residual autocorrelation and heteroskedasticity, and the results show that the constructed GARCH model eliminates autocorrelation and does not contain ARCH effects. Therefore, the GARCH models fitted for the three stock index returns are valid.

Several iterations of the time series of the three markets were performed to finally obtain the convergence point GARCH model. The results in Table 4 show. In the matrix expressions, the parameter Z values of all three returns are significant, indicating that there is a significant contagion effect between the SSE, SZSE, and CSI stock index returns.

Table 4. Parameters estimation of GARCH model

Matrix	Parameters			
	C	SSE	SZSE	CSI Energy
SSE	0.0147	0.7227	0.5906	0.0191
	[4.5608]	[17.9320]	[86.8459]	[27.0440]
SZSE	0.0473	1.3832	0.6478	-0.1601
	[4.9973]	[91.8121]	[13.2144]	[-13.2007]
CSI Energy	0.0171	1.4903	-0.4575	0.8741
	[3.7883]	[30.2667]	[-11.8454]	[48.8007]

## 5. Conclusion

Based on the internal factors of enterprise credit chain, the article uses social network model to analyze the correlation among enterprises in the silicon energy market in 2020 and 2021. With the advancement of the "dual carbon" strategy, the core companies in the supply chain are shifting and the upstream and downstream companies are changing their interconnectedness. It can be seen that the "double carbon" target has a significant impact on the silicon energy market. Based on the external factors of the economic environment chain, the article uses the VAR-GARCH model to empirically analyze the risk contagion effect among SSE index, SZSI index and CSI energy from January 3, 2017 to December 31, 2021.

Based on the above analysis, the following conclusions are drawn: Firstly, the development of China's financial market is still immature, and the realization of the "double carbon" target has a certain impact on the relatedness of the node

enterprises in the supply chain, which has led to the reduction of the differentiation of the network structure and the more obvious centralization. The higher the level of creditworthiness of enterprises, the stronger the ability to prevent and control risks. Secondly, the empirical analysis found that the three stock index log return series have spikes and thick tails, and the GARCH model can better predict the market return volatility. Thirdly, the results of the GARCH model show that the economic environment will have some impact on the energy market and there is a risk contagion effect among supply chains under unexpected events.

In order to identify and mitigate different risks, maintain the stability of the supply chain system, and help the implementation of the "double carbon" target strategy, the following recommendations are proposed: Firstly, enterprises should improve their own operational capabilities, strengthen risk prevention and control tools, and improve their own creditworthiness. Secondly, policy makers or market monitors should be forward-looking and try to curb risks at the source,

so as to maintain the overall stability of supply chain finance. Thirdly, the system related to supply chain finance in China is not comprehensive, and a proper mechanism at this time is conducive to the sustainability of supply chain finance, and also more conducive to the prevention of supply chain finance risks.

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