Research Article

Credit Risk Assessment of Supply Chain Financing with a Grey Correlation Model: An Empirical Study on China’s Home Appliance Industry

Xiaohan Huang 1, Jihong Sun 2, and Xiaoyun Zhao 3

1 School of Business, Shandong University Weihai, Weihai 264209, China
2 Center of High Education, National Institution of Education Science, Beijing 100088, China
3 College of Economics, Qufu Normal University, Rizhao 276800, China

Correspondence should be addressed to Jihong Sun; sdjhsun@126.com

Received 18 March 2021; Revised 24 May 2021; Accepted 2 June 2021; Published 14 June 2021

Abstract

Supply chain finance (SCF) plays an increasingly important role in global enterprise competition. The credit risk accompanying SCF has attracted the attention of the government, enterprises, and academia. However, with the absence of data and inaccurate information, traditional risk assessment methods are frequently failed to assess the credit risk in SCF, especially for small- and medium-sized enterprises (SMEs). In this study, a grey correlation model is introduced and applied to the SCF risk assessment process for 15 firms in the Chinese home appliance industry with 15 performance indicators that represent profitability, solvency, operational capability, and development capability. The empirical study displays the operability and effectiveness of the grey correlation model, which is superior to traditional methods in the supply chain financial risk assessment.

1. Research Background and Significance

At the beginning of the 20th century, supply chain finance (SCF) gradually developed in China and established a certain scale after nearly 20 years of development. The SCF business initiated by Shenzhen Development Bank not only provides all-round financial services for enterprises of all sizes in the supply chain but also greatly boosts the efficiency of core enterprises, accelerates their capital flow, and secures substantial profits for them. At the same time, the service has eased the funding gap of other small- and medium-sized enterprises (SMEs) in the upstream and downstream activities and contributed to their rapid growth. As of 2018, it reached a market size of 17.5 trillion and had been expected to reach 27 trillion by 2020. On January 19, 2017, the Ministry of Commerce, the National Development and Reform Commission, the Ministry of Land and Resources, the Ministry of Transport, and the State Post Bureau jointly issued the “13th Five-Year Plan for Trade and Logistics Development,” which was aimed, as stated in the planning area, at expanding financing channels and promote SCF, encouraging commercial and logistics enterprises to finance directly through equity investment, and undertaking bond financing and other mechanisms. It is aligned with assisting small- and medium-sized enterprises in obtaining funds, optimizing resource allocation in the supply chain, and improving the quality of supply chain financial services. The General Office of the State Council issued the “Guiding Opinions on Actively Promoting Supply Chain Innovation and Application” in January 2020. The “Opinions” proposes that, by the end of 2020, a batch of new technologies and new models of supply chain development suitable for my country’s national conditions will be formed, and a smart supply chain system covering my country’s key industries will basically be formed to make China an important center of innovation and application in the global supply chain. The current COVID–19 and the previous global financial crisis have caused millions of companies to go bankrupt. The
main reason is that the capital chain is broken. This has caused all sectors of society to pay attention to risk management issues, especially between banks, between enterprises, and between banks and enterprises. The credit risk between the government, banks, and many enterprises should pay attention to it. In the context of the “Internet+” economy, SCF is a relatively new research field. The relationships among commercial banks, core enterprises, and small- and medium-sized enterprises in the supply chain are becoming increasingly complex and intertwined more closely, forming a huge complex supply chain finance network.

While SCF is widely recognized and valued by the global industry, it has also encountered significant challenges and obstacles, one of which is how to control or avoid the credit risk of SCF that has resulted in many financial risks in reality, such as the Greensill incident (2021) in the USA (On March 8, 2021, Greensill, a well-known supply chain financial service provider filed for bankruptcy protection, mainly because major insurers stopped providing credit insurance for $4.1 billion of debt in its portfolio created for clients including Credit Suisse due to questions about the quality of its debt receivable assets. The incident has caused a global rethink on supply chain finance business, especially on how to control asset quality and capital security in supply chain finance); Noah Wealth stampede (2020), Minxing Pharmaceutical fraudulent loan case (2020), and the 83-ton fake gold case of Wuhan Jin-huang Jewelry (2019) in China. These incidents are forcing many financial institutions to shift to a cautious attitude towards the supply chain finance business and an increased focus on risk assessment. However, it is very difficult for companies, especially for small- and medium-sized companies, to carry out supply chain financial risk assessment since relevant information, including data, is commercial secret for individual companies and is difficult to obtain. Under this circumstance, this study introduces a grey correlation model to assess supply chain financial risk, which is exactly in line with the basic characteristics of grey systems, to overcome the difficulty of missing data to the maximum extent. For demonstrating the convenience and effectiveness of the model, 15 firms are selected as samples in the SCF of the Chinese home appliance industry for an empirical study.

The purpose of this study is to introduce a grey correlation model in supply chain financial risk assessment, firstly, which is no longer limited to the asset operation status and financial data of individual enterprises, but highlights the overall strength of the supply chain and the real transaction background between upstream and downstream enterprises, which is conducive to promoting the cooperation and coordinated development of core enterprises and upstream and downstream enterprises in the supply chain, improving the operation relationship, and realizing the value maximization and cost minimization of the supply chain. Secondly, in the SCF system, the small and medium enterprises can improve the situation of low credit rating and small capital scale with the commercial credit of core enterprises and obtain financing in a timely and effective manner, thus solving the problem of difficult and expensive financing. Finally, the study of the credit risk of enterprise SCF can reduce the financing risk of financial institutions and bring them more lucrative income.

The rest of the paper is organized as follows. Section 2 presents the previous studies. Section 3 provides the mechanism of supply chain financial credit risk. Then the model of grey relational analysis has been introduced in Section 4. Section 5 carries out the empirical study on supply chain finance credit risk. The final conclusions are drawn in Section 6.

2. Literature Review

The theory of SCF has been continuously developed and enhanced since it was put forward to the state of being a systematic and mature system. Timme and Williams-Timme [1] first proposed the concept of SCF, exploring and explaining its meaning. It is believed that SCF is a new business model created by the cooperation among enterprises in the supply chain and financial service companies outside the supply chain to achieve the goals of the supply chain. Lamourex [2] summarized the meaning of SCF based on previous studies. He believes that SCF can systematically optimize the availability of funds and reduce costs in the enterprise ecosystem dominated by core enterprises. Gupta and Dutta [3] studied currency flows in the supply chain from the perspective of supply chain partners and established an integer programming model to solve the measurement of the dynamic level of static problems. Guided by SCF, Gelsomino et al. [4] highlighted the four key factors of accounts payable, accounts receivable, inventory, and working capital optimization for fixed asset financing and identified the most important issues to be addressed in future research. Xie and He [5] summarized and analyzed three typical models of international SCF: the leading model of logistics enterprises, the cooperation model of enterprise groups, and the service model of commercial banks and performed a comparative analysis of the three models. Finally, they posited a vision for China to develop their SCF business better. Tseng et al. [6] established a fuzzy interpretation structure model, with the help of a hierarchical model, and applied fuzzy TOTIEM to determine language preferences, benefits, and costs. The results show that sustainable supply chain financing improves the competitive advantage of enterprises through multiple attributes, which means that collaborative value innovation, strategic competitive advantage, and financial attributes are the most important aspects to improve enterprise performance.

The change in the credit risk of upstream and downstream enterprises in the supply chain has a direct impact on the business status and future development trends. According to the characteristics of SMEs, Liu and Cui [7] used the structural equation model (SEM) and the grey relation analysis models to evaluate the credit risk of SCF. With the development of the Internet, the combination of SCF and the Internet has gradually developed online, and its credit risk challenges have become more complicated. Fan et al. [8] combined the thinking and data mining direction of financial big data on the Internet to screen the financial risk
evaluation indicators of the supply chain and established a credit risk evaluation system and a three-party game model. It used qualitative and quantitative methods to analyze the principle of risk-sharing among the participants of SCF and evaluated the credit risk of SMEs. Under the innovative mode of combining online and traditional SCF, He and Shen [9] extracted the influencing factors of risks, constructed a risk evaluation system for online SCF, and evaluated these risks through the analytic hierarchy process and fuzzy comprehensive evaluation method. Li and Zhao [10] analyzed the influence factors of supply chain finance credit risk based on the systems science perspective. They built a structural equation model to explore the basic path of supply chain financial credit risk formation and established a system dynamics model to study the mechanism of system elements in the evolution of supply chain financial credit risk. Tian et al. [11] constructed a credit risk assessment model for SMEs in the supply chain financing model. The empirical results show that the model is more accurate in predicting the financing risks of SMEs in the automobile manufacturing industry and provides suggestions for commercial banks, core supply chain enterprises, and SMEs to improve the supply chain financing dilemma.

Commercial banks provide the main impetus for capital circulation in SCF and play a vital role in its development. Diercks [12] noted that commercial banks should strictly monitor and mitigate SCF business risks and introduce multiple monitoring methods. Sheng [13] explained the credit risk assessment of commercial banks in SCF and proposed suggestions and measures by taking the example of the Hunan branch of the Bank of China, supported by Lu [14] also by taking a bank as an example. Zhang [15] analyzed the risk of SCF in China from the perspective of game theory.

As the application of grey relation analysis, Deng [16] systematically expounded the grey theory in the book Grey System and proposed the grey correlation analysis model as one of the main components of the grey theory. Liu et al. [17] explained the grey relation analysis model in detail in the Grey System: Theory and Its Application including its meaning, types, formulas, and application. Wang et al. [18] improved the analytic hierarchy process and proposed an analysis method to solve the problem whereby the grey relational analysis method is not sufficiently objective to calculate the relational degree. They summed up the advantages and disadvantages of both approaches and confirmed it through empirical research. Cao et al. [19] improved the calculation method of the grey relation analysis model and overcame the limitations of specific calculation methods. He redefined the similarity of the curve and grey relational space so that the result of the calculation more reasonably reflected the essence of the grey relational degree. Tian et al. [20] carried out a classification review and evaluation of the existing grey relational degree algorithm model and found that there is no grey correlation degree algorithm that satisfies both normative and order-preserving performance and analyzed the reason. The research conclusion makes it more objective, accurate, and precise and promotes the development of the grey relation analysis model. Dagdevir and Ozceyhan [21] present an optimization of the water-based TiO₂ nanofluid preparation process for thermal conductivity and zeta potential using the Taguchi method for single-objective and grey relation analyses for multi-objective optimization. Huang et al. [22] used the grey relational analysis method to study the correlation between energy consumption and economic growth in Fujian Province. The results show that Fujian’s GDP is significantly correlated with energy consumption products. The correlation degree is greater than 0.7, indicating that the economic growth of Fujian Province is highly dependent on energy consumption.

From the existing studies of Chinese and international scholars, we have gained a profound understanding of SCF. The analysis of the SCF theory and financing mode is becoming mature. However, most of the literature studies have analyzed supply chain financial risks from the perspective of individual institutions, such as companies, banks, financial institutions, or the like. Instead, it is pertinent to understand and analyze the financial risks from the industrial perspective since the cooperation between upstream and downstream enterprises in the supply chain frequently occurs in the same industry. As for the methods, many existing studies use logistic regression or principal component analysis to study the credit risk of supply chain finance, which is difficult to carry out in reality due to the unavailability of data. This study adopts the grey correlation analysis model to overcome the uncertainty of information required in the risk assessment in the traditional methods and analyze the credit risk of the supply chain finance from a perspective of the industry.

3. Mechanism of Supply Chain Financial Credit Risk

The credit risk of SCF is evident when commercial banks and upstream and downstream enterprises carry out financing activities. Due to the negative effects of immeasurable uncertainty, their products cannot achieve the expected earnings, or the capital cannot be recovered, and there is a certain probability of economic losses. The mechanism includes the following aspects.

3.1. Principal-Agent Theory Analysis of Credit Risk in SCF

The principal-agent theory, which advocates the separation of ownership and management rights, was put forward by American economists Berles and Means in the 1930s [23]. The principal-agent relationship originates from the existence of “specialization.” The “grantor” acts as the “principal,” and the “authorized person” acts as the “agent.” Professional agents have a comparative advantage over principals. A principal-agent relationship means that one or more behavioral subjects, according to an express or implied contract, designate and hire some other behavioral subjects to serve them, while granting the latter certain decision-making rights and paying them corresponding remuneration according to the quantity and quality of the services provided by the latter.
In SCF, each enterprise in the supply chain is different from financial institutions, logistics enterprises, and other majors, and the division of labor is differentiated and clear, resulting in a principal-agent relationship.

Figure 1 shows a principal-agent relationship among commercial banks, core enterprises, and financing enterprises as well as between logistics, core, and financing enterprises. The information of the principal and agent is asymmetric. The principal aims to obtain the maximum profit from the capital, and the agent is concerned about whether his interests can be met. The two parties have different goals. From the perspective of measuring their interests, core enterprises may choose to help banks supervise financing enterprises or assist financing enterprises in cheating commercial bank loans. When core enterprises have a low position in the supply chain and rely on financing enterprises, they may choose to help finance enterprises cheat commercial banks of loans to ensure their own interests, thus increasing the credit risk of SCF.

3.2. Systematic Analysis of Financial Credit Risk in Supply Chain. System theory is one of the components of the three extant theories (system theory, information theory, and cybernetics). It is generally recognized in academic circles that system theory was founded by L.V. Bertalanffy, an Austrian American theoretical biologist. In 1932, he published the antibody system theory and put forward the idea of system theory. In 1937, the framework of general system theory was proposed, which laid the theoretical foundation for this science. It has the characteristics of interdisciplinary research and horizontally links various disciplines. It is the study of the general model, structure, and law of the system. System theory studies the common characteristics of various systems, quantitative descriptions of their functions using mathematical methods, and establishes the principles and mathematical models applicable to all systems—the logic and mathematical nature of new science.

Research and analysis of the SCF model indicate how it organically combines upstream and downstream enterprises through the supply chain to form a whole. In the SCF system, every enterprise is dynamically changing capital, goods, and information flow between them. At the same time, enterprises influence and correlate with each other, and each node may generate risks. By using system theory to study the financial credit risk of SCF, we can explore the causes of its production in detail and improve the management capabilities of enterprises in SCF.

3.3. Information Asymmetry Theory Analysis of SCF Credit Risk. In the 1970s, three economists, George Akerlof, Michael Spence, and Joseph Stiglitz, proposed the theory of information asymmetry. The theory indicates that, in market economy activities, there is information asymmetry. Each party has different amounts and content of information. Relatively speaking, the information-dominant party is in a favorable position, and the information-disadvantaged party is in a weaker position. The advantaged parties can gain benefits in the market by communicating reliable information with those having less information—the poorly performing party in the transaction will try to obtain the information they need from the other party. Market signals indicate that the problem of information asymmetry can be compensated to a certain extent. According to the theory of information economics, information asymmetry is divided into an adverse selection and a moral hazard.

In SCF, there is information asymmetry when financing companies intentionally conceal negative information from commercial banks to obtain bank loans. In the process of approving enterprises’ financing requests, commercial banks may make misjudgments that may, according to the theory of information asymmetry, lead to adverse selection. Conversely, when the financing company obtains financing, if the relevant information is concealed to the commercial bank in the production and operation process, the account is inconsistent, and the credit risk of the commercial bank is increased, which generates a moral hazard. Logistics companies may also collude with companies in the supply chain to conceal warehousing and logistics information. In the supply chain, both financing and core enterprises are likely to conceal their operating conditions, financial information, and management information, resulting in information asymmetry.

Grey system theory can partially mitigate the lack of, or fuzzy, information due to information asymmetry; thus, it is more accurate to analyze the credit risk of SCF by using the grey relation model, and the analysis results are more significant for referencing.

3.4. Supply Chain Financial Analysis of Household Appliance Industry. China’s household electrical appliance industry began in the late 1970s and early 1980s. Since its development, the industry has become one of the pillars of China’s manufacturing industry and is an important part of China’s national economy. From the perspectives of profitability, debt repayment, operation, and development capabilities, the home appliance industry is developing well in SCF.

When the 2008 financial crisis broke, China implemented the fiscal policy of “home appliances going rural to expand domestic demand” (Ministry of Finance, the Ministry of Commerce and the Ministry of Industry and Information Technology, "Notice on the National Promotion of Home Appliances to the Countryside," 2008. [http://www.gov.cn/gzdt/2008-12/05/content_1169347.htm]). Nonurban residents who bought color TV sets, refrigerators, mobile phones, and washing machines received a 13% subsidy on the product price, which quickly stimulated the
consumption of domestic electrical appliances. However, by the end of the policy, the consumption of household appliances fell sharply. In May 2012, the state council decided to implement a new policy to subsidize energy-efficient home appliances. During the 11th and 12th five-year plans, the rapid development of the world economy created much demand for China’s home appliance industry both domestically and internationally, despite China’s industry having suffered from the impact of the economic crisis. Due to the rapid development of China’s domestic economic conditions and the government’s strong policy support, such as “home appliance energy subsidies,” “home appliances to the countryside,” and “home appliances trade-in,” China’s home appliance industry developed rapidly along with its reputation in the international market. Currently, China’s home appliance industry is competitive in the international market and has established a strong market share; its scale of production ranks first worldwide. According to a report by the National Bureau of Statistics, China’s home appliance industry has been growing rapidly and stable in recent years.

In 2016, operating revenue and total profit reached 820.8 and 119.69 billion yuan and cumulative yearly increases of 13.4% and 20.4%, respectively.

With the rapid development and growth of the Internet and online shopping consumer groups in China, the number of online sales of household appliances has increased. The major home appliance companies have also established their own online sales channels. In 2010, Suning Appliance, GOME Electrical Appliances, Chunlan Group, Haier Electric, Midea Group, and other leading enterprises in the home appliance industry entered the online sales market using bespoke online sales platforms, e-commerce companies, and online shopping websites. These new sales channels ushered in a new round of sales growth in the home appliance industry with online shopping fast becoming the most promising market. The 2016 China National Grid Purchase Analysis Report jointly released by the CCID Research Institute and the China Electronics News Agency shows the following data.

In 2016, China’s B2C grid purchase market, including mobile terminals, reached 384.6 billion yuan, a year-on-year increase of 27.9%. Regardless of mobile terminal products, the online market size of pure household electrical and electronic products was 179.6 billion yuan, an increase of 35.3%. In 2016, the penetration rate of online shopping in the home appliance market reached 19.95%. The three giants, Jingdong, Tmall, and Suning Tesco, have occupied most of the market, and the channel pattern of the online shopping market of home appliances is stable (CCID Research Institute, China Electronics News 2016; China National Grid Purchase Analysis Report 2016).

As of the end of 2017, there were 67 listed companies in China’s home appliance industry, of which 20 were listed on the Shanghai Stock Exchange and 47 on the Shenzhen Stock Exchange. Of those listed on the Shenzhen Stock Exchange, the small- and medium-sized sectors accounted for 28 listings. According to relevant statistics, in 2017, China’s household appliance industry grew rapidly, and its output value reached 1.70 billion yuan, an increase of 9.8% over the same period of the previous year (data from Zhongyikang Data). With the advancement of supply-side structural reform, the innovation capability of China’s home appliance industry has increased, and production technology has clearly shown an upward trend. Research and development progress appear endless.

4. Establishment of the Grey Relational Analysis Model

The basic idea of the Grey correlation analysis is to determine whether the relationship between two factors is close based on the similarity of the geometry of the sequence curve; a more similar curve indicates a greater correlation. There is no specific requirement for the sample size. The sample is irregular, and there is no situation whereby the quantitative result does not match the qualitative analysis result. This method compensates for deficiencies arising from systematic analysis using mathematical-statistical methods [24].

4.1. Calculation of the Grey Absolute Degree of Incidence.

4.1.1. Calculation of Initial Point Annihilation Image.

Assuming \( X_0 = (x_0(1), x_0(2), \ldots, x_0(n)) \) as a sequence of system characteristic behaviors, we define

\[ X_i = (x_i(1), x_i(2), \ldots, x_i(n)), \quad i = 1, 2, \ldots, m, \quad (1) \]

as a related factor sequence.

4.1.2. Calculation of \( |s_0|, |s|, \) and \( |s_i - s_0| \).

\[ |s_0| = \sum_{k=2}^{n-1} x_0^0(k) + \frac{1}{2} x_0^0(n), \]

\[ |s| = \sum_{k=2}^{n-1} x_i^0(k) + \frac{1}{2} x_i^0(n), \quad (4) \]

\[ |s_i - s_0| = \sum_{k=2}^{n-1} (x_i^0(k) - x_0^0(k)) + \frac{1}{2} (x_i^0(n) - x_0^0(n)). \]

4.1.3. Calculation of the Grey Absolute Degree of Incidence: \( \xi_0 \).


\[ \varepsilon_{ui} = \frac{1 + |s_i| + |s|}{1 + |s_i| + |s| + |s_i - s|} \] (5)

4.2. Calculation of the Grey Relative Degree of Incidence

(1) To calculate the initial point annihilation image of \( X_i \), we define

\[ X_i^D = (x_i(1)d, x_i(2)d, \ldots, x_i(n)d) \] (6)

Substituting \( x_i(k)d = x_i(k) - x_i(1) \) \((k = 1, 2, \ldots, n)\), \( X_i^D \) is the initial point annihilation image of \( X_i \), obtaining

\[ X_i^D = X_i^u = \left( x_i^u(1), x_i^u(2), \ldots, x_i^u(n) \right) \] (7)

(2) Calculate \(|s_i|\), \(|s|\), and \(|s_i - s|\):

\[ |s_i| = \sum_{k=2}^{n-1} x_i^u(k) + \frac{1}{2} x_i^u(n), \]

\[ |s| = \sum_{k=2}^{n-1} x_i^u(k) + \frac{1}{2} x_i^u(n), \]

\[ |s_i - s| = \sum_{k=2}^{n-1} \left( x_i^u(k) - x_i^u(1) \right) + \frac{1}{2} \left( x_i^u(n) - x_i^u(1) \right) \] (8)

(3) Calculate the grey relative degree of incidence: \( \gamma_{ui} \)

\[ \gamma_{ui} = \frac{1 + |s_i| + |s|}{1 + |s_i| + |s| + |s_i - s|}, \]

\[ \rho_{ui} = \theta \epsilon_{ui} + (1 - \theta) \gamma_{ui}, \quad \theta \in [0, 1]. \] (10)

Generally, \( \theta = 0.5 \). \( \rho_{ui} \) not only shows the similarity between the fold lines \( X_0 \) and \( X_i \), but also reflects the closeness of the rate of change of \( X_0 \) and \( X_i \) relative to the starting point. It is a quantitative index to show in a more comprehensive way whether the links between sequences are similar (Liu Sifeng, Yang Yingjie, Wu Lifeng. Grey System Theory and Its Application. Beijing: Science Press:85, 2014).

4.3. Calculation of the Grey Synthetic Degree of Incidence

5. Empirical Analysis of SCF Credit Risk

The credit risk evaluation index system was constructed; the degree of correlation between 2012 and 2016 was calculated using the grey correlation model; and the ranking and changes of each enterprise were obtained.

5.1. Data Sources. Sixty-seven home appliance companies—listed on the Shanghai Stock Exchange and the Shenzhen Stock Exchange—are selected as research samples, with ten upstream appliance parts companies and five downstream distribution and service enterprises, of which eleven came from the Shanghai and Shenzhen sectors, and four from the small- and medium-sized sectors. The sample companies are listed in Table 1.

In this study, 15 listed companies in the home appliance industry with business connections were selected. The supply relationships and products are shown in Figure 2. The five companies on the left side of the picture are downstream in the supply chain, offering distribution and enterprises, with most products being sold directly to consumers. The ten companies on the right are upstream in the supply chain and provide various home appliance parts to the five companies on the left. Zhejiang Sanhua Intelligent Controls, Zhejiang Kangsheng, Suzhou China Create Special Material, and Guangzhou Echom Sci. & Tech. are classified as mediumsized. As a relatively mature SCF industry, the home appliance industry has a complicated supply relationship, which is not limited to Figure 2.

According to the analysis of corporate financial capability, this study selected 15 indicators grouped by profitability, solvency, operational capability, and development capability to form a risk indicator system. The data are obtained from the company’s annual financial reports. The specific indicators are shown in Table 2.

5.2. The Empirical Analysis. The home appliance industry is one of the traditional advantageous industries in supply chain finance. Among them, Qingdao Haier (600690) achieved a global turnover of 241.9 billion yuan in 2017. On December 21 of the same year, Qingdao Haier ranked 50th in the 2017 “Top 500 Global Brands” (14th), ranking compiled by the World Brand Lab in the United States, compared with 76th in the previous year. It has risen 26 places and since then Haier has entered the world’s top 50 brands. At the same time, Haier Group seized the opportunity of the “Internet+” era to create business models such as “Internet + industry,” “Internet + commerce,” “Internet + finance,” “Internet + residence,” and “Internet + culture.” It owns Haier Industrial Finance Company, which provides supply chain financial services, and is involved in food and agriculture, medical and health, green finance, intelligent manufacturing, and shared consumption industries. At the same time, it also has its own e-commerce platforms, including Haimao Yunshang cross-border e-commerce, Jushanghui, Goodaymart, and Haier Mall. It has been transformed and upgraded from traditional commercial distribution channels to a bilateral platform for value interaction and constructed an open platform led by user experience in the Internet era with the Internet of Things and logistics services as the core. Because Qingdao Haier has a mature supply chain financial system, Qingdao Haier is selected as the characteristic behavior sequence.

Through the index set determined above, the original sequence set determines the characteristic behavior sequence, namely, Qingdao Haier, and the related factor sequence, namely, the other 14 companies. In this paper, the sample data of 15 listed companies in the household
appliances industry from 2012 to 2016 were imported into the grey correlation analysis model for empirical research, and the results were analyzed and discussed.

5.2.1. Determine Characteristic Behavior Sequence and Related Factor Sequence. In this study, Qingdao Haier (600690) is used as the characteristic behavior sequence. The other 14 companies are Gree Electric (000651.SZ), the Midea Group (000333.SZ), Hisense Electric (600600.SS), Sichuan Changhong (600839.SS), Zhejiang Sanhua Intelligent Control (000205.SZ), Zhejiang Sanhua Intelligent Controls (300475.SZ), Anhui Julong Transmission Technology (002290.SZ), Zhenjiang Goldensea Environment Technology (300217.SZ), Guangzhou Echom Sci. & Tech. (600347.SZ), Zhejiang Kangsheng (002418.SZ), and Zhejiang Sanhua Intelligent Controls (002420.SZ). We establish a behavior indicator sequence for 15 companies and the previously determined indicator set. First, 2016 is taken as an example to calculate the grey degree of incidence of each enterprise.

5.2.2. Calculation of Grey Absolute Degree of Incidence. The behavior indicator matrix has to be substituted into Formula (3) to obtain the initial point annihilation image of the sequence, denoted as $x_i^0$.

$$x_i^0 = (0.0000, 15.1000, 11.8100, -2.2400, -10.8600, -11.0300, 47.3600, 256.3400, -3.3400, 1.1400, -4.1800, -11.1400, 2.6700, 12.0300, 5.6300)$$

$$x_i^1 = (0.0000, 7.0800, 3.8400, -3.8800, -7.2300, -7.6500, 30.5200, 959.0700, -1.3800, 4.9100, 14.8500, -8.0400, -4.0600, 1.4400, 6.3100)$$

$$x_i^2 = (0.0000, 17.0600, 3.4000, 0.0200, -10.5600, -11.0300, 23.3900, 246.4600, -8.7300, -6.6800, -9.5500, -11.8900, -2.8300, 1.7100, 27.1600)$$

$$x_i^3 = (0.0000, 15.0200, 3.4300, 1.9700, -4.8900, -4.9700, 63.9900, 229.1100, 1.4900, -2.6100, -3.0000, -5.3700, 22.9100, 2.1400, 140.2700)$$

$$x_i^4 = (0.0000, 21.6700, 0.2700, 2.6700, 0.6700, 0.0700, 23.6100, 358.6300, -0.0400, 0.2200, -0.3800, -1.9000, -3.6000, -1.9900, -38.6900)$$

$$x_i^5 = (0.0000, 6.7300, 0.7200, -1.4200, -6.2200, -6.8600, 14.2300, 852.3700, -3.4800, 0.5300, -8.7800, -0.1600, -4.8600, 3.6400)$$

$$x_i^6 = (0.0000, 6.6700, 5.0400, -6.3600, -12.9300, -13.3600, 204.8600, 35.3300, -9.5200, -10.0900, -8.8400, -13.0100, -25.5700, 4.6900, -3.7300)$$

$$x_i^7 = (0.0000, 23.9800, 0.3500, 4.0600, -6.4800, -7.0800, 8.1000, -6.7500, -6.4400, -6.9500, -9.8000, 6.2000, 1.1400, 23.8400, 469.9000)$$

$$x_i^8 = (0.0000, 13.9600, -0.2800, 0.0600, -0.5200, -0.9500, 35.7200, 379.1100, 0.2400, 0.0300, 1.6600, -1.9600, -5.5600, 41.5300, -2.7800)$$

$$x_i^9 = (0.0000, 26.7700, 0.7500, 12.3000, -3.0500, -3.2000, 13.4700, 1803.0200, -0.3300, -2.4100, 1.0000, -7.3900, 17.4300, -0.6500, -15.1400)$$

$$x_i^{10} = (0.0000, 9.8600, 2.9700, -1.1800, -16.0400, -16.4700, 7.4800, 285.7300, -12.7400, -15.4700, -14.9300, -17.6900, -3.9000, 20.8700, 6.8000)$$

$$x_i^{11} = (0.0000, 6.6800, 0.0400, -0.8600, 0.0900, -0.2500, 58.4600, 176.9400, 5.0900, 4.0300, 5.2100, 0.2800, 53.7300, -0.1600, -81.3400)$$

The Grey absolute degree of incidence of 14 enterprises was calculated and sorted into Table 3.

5.2.3. Grey Relative Degree of Incidence. When calculating the grey relative degree of incidence, first, the behavior index matrix should be initialized and introduced into Formula (7) to obtain the initial image of the sequence, denoted as $x_i'$.
Dongfang Electric Heating Technology is mainly engaged in various types of high-performance electric heaters, heating systems, and control cabinets.

Liba Enterprise Joint-Stock is mainly engaged in laminating board series products and coated board series products, which have wide application in various fields.

Sichuan Changhong is an influential information appliance content and service provider. The company’s main business covers the research and development, manufacturing, sales, and service of TV, refrigerator, air conditioner, IT, refrigerator compressor, and other product lines.

Figure 2: Supply relationship of sample companies.

\[ x_1 = (1.0000, 2.2367, 1.9672, 0.8165, 0.1106, 0.0966, 4.8788, 21.9943, 0.7265, 1.0934, 0.6577, 0.0876, 1.2187, 1.9853, 1.4611) \]

\[ x_2 = (1.0000, 1.7453, 1.4042, 0.5916, 0.2389, 0.1947, 4.2126, 101.9547, 0.8547, 1.5168, 2.5632, 0.1537, 0.5726, 1.1516, 1.6642) \]
Table 2: SCF credit risk index system.

| Indicator       | Metric                          | Calculation                                                                 |
|-----------------|---------------------------------|-------------------------------------------------------------------------------|
| Profitability   | Return on assets (U1)           | Net profit/average asset total • 100%                                        |
|                 | Sales gross margin (U2)         | (Net operating income – operating costs)/net operating income • 100%          |
|                 | Return on equity (U3)           | Net profit/average shareholder equity • 100%                                 |
|                 | Net sales margin (U4)           | Net profit/net operating income • 100%                                       |
| Solvency        | Flow ratio (U5)                 | Current assets/current liabilities                                            |
|                 | Quick ratio (U6)                | Quick-moving assets/current liabilities                                       |
|                 | Asset-liability ratio (U7)      | Total liabilities/total assets • 100%                                        |
|                 | Long-term asset suitability rate (U8) | (Total shareholders’ equity + total long-term liabilities)/(total fixed assets/long-term investment) • 100% |
| Operating       | Inventory turnover rate (U9)    | Cost of sales/average inventory balance                                       |
| capacity        | Accounts receivable turnover rate (U10) | Net sales revenue/average balance of accounts receivable                     |
|                 | Fixed asset turnover rate (U11) | Sales revenue/average net value of fixed assets                               |
|                 | Total asset turnover rate (U12) | Sales revenue/average asset total                                             |
| Development     | Yearly growth rate of operating income (U13) | The increase in operating income this year/the total operating income in the previous year • 100% |
| ability         | Capital accumulation rate (U14) | The increase in shareholders’ equity this year/sharholders’ equity at the beginning of the year • 100% |
|                 | Profit growth rate (U15)        | Total profit growth this year/total profit of the previous year • 100%        |

Table 3: Grey absolute degree of incidence.

| Company code | Grey absolute degree of incidence | Calculation |
|--------------|-----------------------------------|-------------|
| 000651.SZ    | ε_01 = 0.8794                     | 0.8794      |
| 600839.SS    | ε_02 = 0.8326                     | 0.8326      |
| 000333.SS    | ε_03 = 0.9785                     | 0.9785      |
| 600060.SS    | ε_04 = 0.6479                     | 0.6479      |
| 002050.SZ    | ε_05 = 0.9168                     | 0.9168      |
| 002418.SS    | ε_06 = 0.8768                     | 0.8768      |
| 300217.SS    | ε_07 = 0.8854                     | 0.8854      |
| 603519.SS    | ε_08 = 0.6750                     | 0.6750      |
| 603677.SS    | ε_09 = 0.7648                     | 0.7648      |
| 603311.SS    | ε_10 = 0.9419                     | 0.9419      |
| 002290.SZ    | ε_11 = 0.8178                     | 0.8178      |
| 300475.SS    | ε_12 = 0.5794                     | 0.5794      |
| 603578.SS    | ε_13 = 0.8245                     | 0.8245      |
| 002420.SZ    | ε_14 = 0.9581                     | 0.9581      |

5.2.4. Calculation of Grey Synthetic Degree of Incidence.

The grey absolute ε_{0i} and grey relative degree of incidence γ_{0i} are substituted into Formula (10):

$$\rho_{0i} = \theta \epsilon_{0i} + (1 - \theta) \gamma_{0i}, \quad \theta \in [0, 1].$$  (11)

Generally, θ = 0.5. We calculate the grey synthetic degree of incidence and rank in Table 5 for 2016.

5.3. Evaluation Result. The grey degree of incidence of 14 listed companies in the household appliance industry from 2012 to 2016 is calculated and ranked (Table 5).

The higher the degree of association and the stronger the correlation between the evaluated listed and ideal companies, the lower the credit risk degree of the listed company. The higher the risk ranking, the higher the correlation...
between the evaluated listed company and the ideal company. Companies with more stable operations carry a lower credit risk.

From the empirical results, the listed companies ranking high in the household appliance industry include Gree Electric, Midea Group, and Sanhua Intelligent Controls, and their credit risks are relatively small. Gree Electric has steadily improved its ranking from 7th place in 2012 to first place in 2016. In 2016, Gree Electric achieved a total operating income of 110.113 billion yuan, an net profit of 15.421 billion yuan, and tax payments of 13.075 billion yuan. Gree Electric has holdings in 59 companies that constitute its own supply chain. There are 48 industrial manufacturing companies and 5 sales companies, as well as companies responsible for technology research and development, information technology, and financial services. Zhuhai Gree Group Finance Co., Ltd. plays the role of the supply chain’s financial funder. Since the launch of financial services for enterprises in the industrial chain until the end of 2014, it has provided more than 25 billion yuan of financial support to enterprises in the industrial chain, including more than 8 billion yuan of financial support for small- and medium-sized enterprises (30% of total financing). The Midea Group was ranked relatively high over the past 5 years. Although fluctuating slightly, it advanced from sixth place in 2012 to second in 2016. It has consolidated its leading position in the SCF of the home appliance industry and enjoys strong development. Sanhua Intelligent Controls is a global leader in refrigeration control components and is located downstream of the home appliance industry chain. It was listed in the Shenzhen SME sector in 2005. From 2012 to 2016, its ranking has remained in the top five, indicating that the company has strong credit.

Companies with more stable rankings are Goldensea Environment Technology, Dongfang Electric Heating Technology, and Echom Sci. & Tech. Goldensea Environment Technology is a professional manufacturer of well-known environmental protection filtration materials in China. It set up factories in Zhejiang, Zhuhai, Tianjin, Suzhou, and other places. At the same time, sales networks have been established in Sichuan, Shandong, and Jiangsu. It has established long-term cooperative relationships with Gree, LG, Midea, Samsung, Mitsubishi Heavy Industries, Haier, Hisense, Changhong, Chunlan, and other

| Company code | 2016 | Rank | 2015 | Rank | 2014 | Rank | 2013 | Rank | 2012 | Rank |
|--------------|------|------|------|------|------|------|------|------|------|------|
| 000651.SZ    | 0.9191 | 1    | 0.8533 | 3    | 0.8925 | 3    | 0.8605 | 4    | 0.8003 | 7    |
| 600839.SS    | 0.7204 | 9    | 0.8154 | 5    | 0.7364 | 11   | 0.7371 | 9    | 0.7408 | 10   |
| 000333.SZ    | 0.9189 | 2    | 0.9185 | 2    | 0.8570 | 4    | 0.9493 | 2    | 0.8332 | 6    |
| 600060.SS    | 0.6588 | 13   | 0.6229 | 13   | 0.7071 | 13   | 0.7328 | 11   | 0.8516 | 4    |
| 002050.SZ    | 0.8468 | 3    | 0.9590 | 1    | 0.8399 | 5    | 0.9183 | 3    | 0.9133 | 1    |
| 002418.SZ    | 0.8215 | 5    | 0.6464 | 12   | 0.7691 | 8    | 0.8103 | 6    | 0.8712 | 2    |
| 300217.SZ    | 0.7457 | 7    | 0.6691 | 10   | 0.8176 | 7    | 0.7717 | 8    | 0.7118 | 12   |
| 603519.SS    | 0.6912 | 12   | 0.6574 | 11   | 0.9312 | 1    | 0.9630 | 1    | 0.8664 | 3    |
| 603677.SS    | 0.7123 | 10   | 0.7884 | 4    | 0.6970 | 14   | 0.7988 | 7    | 0.7677 | 8    |
| 603311.SS    | 0.8418 | 4    | 0.7269 | 8    | 0.8234 | 6    | 0.8261 | 5    | 0.8478 | 5    |
| 002290.SZ    | 0.7089 | 11   | 0.7067 | 9    | 0.9022 | 2    | 0.6793 | 13   | 0.6632 | 13   |
| 300475.SZ    | 0.5769 | 14   | 0.5538 | 14   | 0.7421 | 10   | 0.7330 | 10   | 0.7267 | 11   |
| 603578.SS    | 0.7374 | 8    | 0.8387 | 4    | 0.7134 | 12   | 0.6645 | 14   | 0.6589 | 14   |
| 002420.SZ    | 0.7661 | 6    | 0.7568 | 7    | 0.7525 | 9    | 0.6998 | 12   | 0.7655 | 9    |

Table 4: Grey relative degree of incidence of 14 enterprises.

| Company code | Grey relative degree of incidence | Grey relative degree of incidence |
|--------------|----------------------------------|----------------------------------|
| 000651.SZ    | 0.9589                           |                                  |
| 600839.SS    | 0.6083                           |                                  |
| 000333.SZ    | 0.8594                           |                                  |
| 600060.SS    | 0.6696                           |                                  |
| 002050.SZ    | 0.7769                           |                                  |
| 002418.SZ    | 0.7661                           |                                  |
| 300217.SZ    | 0.6059                           |                                  |
| 603519.SS    | 0.7705                           |                                  |
| 603677.SS    | 0.6597                           |                                  |
| 603311.SS    | 0.8574                           |                                  |
| 002290.SZ    | 0.6000                           |                                  |
| 300475.SZ    | 0.5744                           |                                  |
| 603578.SS    | 0.6504                           |                                  |
| 002420.SZ    | 0.5741                           |                                  |

Table 5: Grey degree of incidence and ranking from 2012 to 2016.
domestic, commercial, and automotive air-conditioning manufacturing enterprises. It ranks between 4th and 8th and is relatively stable while carrying relatively low credit risk. The ranking of Dongfang Electric Heating Technology in the past five years has been in the middle position, and its overall situation is relatively stable, with minimal fluctuations and low credit risk. Echom Sci. & Tech. ranked lower in 2013 than in 2012, but after 2013, its ranking has steadily improved, rising to sixth place in 2016, which indicates that Echom Sci. & Tech. has developed rapidly in recent years, and its credit risk has been steadily reduced.

The rankings of enterprises such as Qijing Machinery, Three Stars New Materials, Kangsheng, and Sichuan Changhong have changed greatly, indicating that the operating conditions of these enterprises are highly volatile, and more attention should be paid to their credit risks.

The lower-ranked enterprises are Julong Transmission Technology, Hisense Electric, Liba Enterprise Joint-Stock, and China Create Special Material. Julong Transmission Technology is mainly engaged in the research and development, production, and sales of new and high-efficiency energy-saving washing machine deceleration clutches. Several products are nonbidding procurement products of leading enterprises in the washing machine industry, such as Haier and Midea. The ranking in the past five years is outside the top 10, indicating an overall weakness and high credit risk. Hisense Electric ranked 4th in 2012, 11th in 2013, and 13th in the following years. Most of its subsidiaries are manufacturing companies, which indicates that its SCF suffers from poor development high credit risk. Liba Enterprise Joint Stock was ranked third in 2012, and first from 2013 to 2014; in 2015, however, its rank quickly fell to 11th place, before falling further in 2016. The reason is that although the absolute financial value of the enterprise still shows an upward trend, its operating income growth rate, gross profit margin of sales, return on investment, and cash income ratio have all decreased to varying degrees since 2014. This shows that the development momentum of the enterprise is insufficient, and thus, its credit risk gradually increases. Although China Create Special Material rose to second place in 2014, it ranked relatively low in other years and ultimately ranked 11th in 2016. This shows that the credit status of the company is not satisfactory, although it does indicate great development prospects.

6. Conclusion

Supply chain financial risks are increasingly attracting attention, especially in the period of the COVID-19. The disclosure of financial risk level in the supply chain enhances the transparency of supply chain finance information and helps reduce the risk level of supply chain finance in this industry. In addition, a clear risk level of supply chain finance of major listed companies contributes to strengthening the cooperation between upstream and downstream enterprises and financial institutions in this supply chain, which has important practical significance for the development of the whole industry. However, with the absence of data and inaccurate information, traditional risk assessment methods are difficult to implement for enterprises. In this study, a grey correlation model is introduced and applied to the supply chain financial risk assessment process for 14 firms in the Chinese home appliance industry. The empirical study measures the financial risk level of each firm, which is highly consistent with reality. The operability and effectiveness of the model reflect the superiority of the grey correlation model in the supply chain financial risk assessment. It is highly recommended that the model can be used as an effective risk assessment tool in corporate supply chain financial services in the future.

The sample companies selected in the empirical analysis are representative, but the size of the sample is small, which may have a certain impact on the accuracy of the model results. In addition, in the grey correlation model, the selection of risk indicators also indirectly affects the system behavior, which affects the accuracy of the empirical analysis results. Therefore, the size of the sample and the selection of risk indicators make the empirical analysis of this study subject to certain errors. Accordingly, in the future, the sample size and risk indicators can be expanded to characterize the system behavior more comprehensively and improve the accuracy of the grey model in the process of assessing the risk level of supply chain finance.

Data Availability

The data used to support the findings of this study are included in the annual financial report of the company and is available in the database of the Shanghai Stock Exchange (http://www.sse.com.cn/disclosure/listedinfo/regular/) and Shenzhen Stock Exchange (http://www.szse.cn/disclosure/listed/fixed/index.html).

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

This research was funded and supported by the Annual Basic Research Foundation Program of the National Institute of Education Science, “Research on the Evaluation of Scientific Research Performance of “Double First Clas” Universities in China” (Grant no. GYD2018008). The authors are grateful to all those who participated in data collection and entry.

References

[1] S. G. Timme and C. Williams-Timme, “The financial-SCM connection,” Supply Chain Management Review, vol. 4, no. 2, pp. 33–40, 2000.
[2] M. Lamoureux, “A supply chain finance prime,” SCF, vol. 4, no. 5, pp. 34–48, 2007.
[3] S. Gupta and K. Dutta, “Modeling of financial supply chain,” European Journal of Operational Research, vol. 211, no. 1, pp. 47–56, 2011.
[4] L. M. Gelsomino, R. Mangiarcina, A. Perego, and S. C. F. Tumino, “A literature review,” International Journal of
Physical Distribution and Logistics Management, vol. 46, no. 4, pp. 348–366, 2016.

[5] S. Xie and B. He, “Analysis of three typical models of international SCF,” Economic Theory and Business Management, vol. 4, pp. 80–86, 2013.

[6] M.-L. Tseng, M. K. Lim, K.-J. Wu, and K.-J. Wu, “Improving the benefits and costs on sustainable supply chain finance under uncertainty,” International Journal of Production Economics, vol. 218, no. 218, pp. 308–321, 2019.

[7] Y. Liu and Y. Cui, “Credit risk assessment of SMEs under SCF—based on SEM and grey correlation model,” Technoeconomics and Management Research, vol. 12, pp. 14–19, 2016.

[8] F. Fan, G. Su, and X. Wang, “Research on credit risk assessment and risk management of SMEs under SCF mode,” Journal of Central University of Finance and Economics, vol. 12, pp. 34–43, 2017.

[9] S. He and S. Shen, “Online supply chain financial risk assessment based on third-party B2B platform,” Southeast Academic Research, vol. 3, pp. 139–147, 2016.

[10] G. Li and S. Zhao, “Research on the evolution mechanism and management of supply chain financial credit risk under the background of resumption of work and production—based on the SEM-SD model,” Commercial Research, vol. 5, pp. 112–122, 2020.

[11] K. Tian, X. Zhuang, and W. Zhao, “Credit risk assessment of small and medium-sized enterprises under the supply chain finance model—based on data analysis of automobile manufacturing,” Journal of Industrial Technological Economics, vol. 40, no. 5, pp. 15–20, 2021.

[12] L. A. Diercks, “Identifying and managing troubled borrowers in asset-based lending scenarios,” Commercial Lending Review, vol. 19, no. 5, pp. 38–55, 2004.

[13] F. Sheng, Research on Supply Chain Financial Risk Control of Bank of China Hunan Branch, Hunan University, Changsha, China, 2009.

[14] H. Lu, Research on Risk Management of a Bank’s SCF, Zhengzhou University, Zhengzhou, China, 2017.

[15] Y. Zhang, “Financial risk management and exploration of China’s bank supply chain—based on game,” Technoeconomics and Management Research, vol. 1, pp. 72–76, 2018.

[16] J. Deng, Grey System (Social and Economic), National Defense Industry Press, Beijing, China, 1985.

[17] S. Liu, Y. Dang, and Z. Fang, Grey System Theory and Its Application, Science Press, Beijing, China, 8th edition, 2010.

[18] J. Wang, J. Guo, and X. Lian, “A comparative study of two improved grey correlation analysis methods,” Journal of North China Electric Power University, vol. 6, pp. 72–75, 2005.

[19] M. Cao, Y. Dang, R. Zhang, and J. Lu, “Improvement of the calculation method of grey correlation degree,” Statistics and Decision, vol. 7, pp. 29–30, 2007.

[20] M. Tian, S. Liu, and Z. Bu, “A review of research on grey correlation algorithm,” Statistics and Decision, vol. 1, pp. 24–27, 2008.

[21] T. Dagdevir and V. Ozceyhan, “Optimization of process parameters in terms of stabilization and thermal conductivity on water based TiO2 nanofluid preparation by using Taguchi method and Grey relation analysis,” International Communications in Heat and Mass Transfer, vol. 120, pp. 1–10, 2021.

[22] Y. Huang, Y. Huang, and J. Qiu, “Analysis of the grey correlation between energy consumption and economic growth in Fujian Province,” IOP Conference Series: Earth and Environmental Science, vol. 657, no. 1, 2021.

[23] A. A. Berle and G. C. Means, The Modern Corporation and Private Property, Macmillan, New York, NY, USA, 1932.

[24] S. Liu, Y. Yang, and L. Wu, Grey System Theory and its Application, Science Press, Beijing, China, 7th Edition, 2014.