

Customer momentum research based on centrality of supply chain network

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Abstract. In recent years, the global supply chain system is being affected by huge chain reaction, thus, it is of great practical significance to study customer momentum. Based on the supply chain network data disclosed by Chinese A-share listed companies from 2011 to 2019, this paper uses edge betweenness centrality as a representative index of supplier-customer network centrality to explore the moderating effect of edge betweenness centrality on the impact of customer stock price changes on supplier stock price changes. It is found that the change of customer stock price has a significant positive correlation with the change of supplier stock price in the next month, and the higher supplier-customer edge betweenness centrality degree, the more significant the positive correlation. This conclusion is robust, and low supplier concentration will enhance the moderating effect of this indicator. Additionally, the new customer momentum factor can be further constructed by using the edge betweenness centrality. The research of this paper provides a new applicable situation for the transmission of customer momentum, helps to enrich the literature related to supply chain information management and realize the mining of Alpha in supply chain data.

Keywords: Customer stock price; Supplier's share price; Centrality of supply chain network; Edge betweenness centrality.

1. Introduction

Theory shows that the operational efficiency of a node in the supply chain will affect the cash flow and profit of that node, and thus determine its stock price (Hendricks K&Singhal V,2003). Meanwhile, due to the close economic connection between the upstream and downstream of the supply chain, when the operation of a node changes, its influence will spread to the upstream and downstream. In other words, when the stock price of a node changes, the stock price shock will be transmitted along the supply chain, making the stock price of the upstream and downstream change in coordination(Hertzel M,2008;Pandit S,2011;Chen H,2018).As one aspect of stock price transmission, customer momentum studies the impact of customer stock price changes on supplier stock price changes.

The impact of the epidemic, the tension between Russia and Ukraine, and the struggling global supply chain system are being greatly affected by the chain reaction. Study the influence of the customer share price changes to supplier price profound realistic significance.Existing literature has investigated the relationship between supply chain and stock market, showing that due to the existence of a community of interest between suppliers and customers, both the share price and financial report data of customer companies are powerful tools for predicting the share price of suppliers.Meanwhile, most literatures believe that the network centrality of the company has a significant impact on its own stock returns and financial performance indicators, and the network centrality of the client company is also closely related to the share price or performance of the supplier.Nevertheless, existing studies have not focused on the moderating effect of supplier - customer network centrality in the process of customer stock price change on supplier stock price change.

Based on the supply chain network data disclosed by listed companies in Shanghai and Shenzhen from 2011 to 2019,This paper discusses the moderating effect of the representative index of supplier-customer network centrality, namely edge betweenness centrality, on the influence of customer stock price change on supplier stock price change in the next period.It is found that the change of customer's stock price has a significant positive correlation with the change of supplier's stock price in the next

period, and the higher the supplier-customer edge betweenness centrality is, the more significant the positive correlation is. This paper has the following two innovations: Firstly, the edge betweenness centrality is used to prove that the centrality index of supplier-customer network plays a regulatory role in the transmission process of customer momentum stock price, which will provide a new applicable situation for supply chain information transmission, help to enrich the existing literature, and have enlightenment significance for the risk management of upstream and downstream enterprises. Secondly, supplier concentration is used to measure the competitive threat faced by suppliers. It is found that supplier concentration is low, namely, when suppliers face greater competitive threat in the product market, supplier stock price responds more strongly to customer stock price, and the moderating effect of edge betweenness centrality degree is greater. Thirdly, based on the robustness conclusion above, the marginal centrality of supplier to customer is taken as the weight coefficient to innovate the constituent structure of customer momentum factor and further promote the mining of Alpha information in supply chain data.

The remaining part of this paper is arranged as follows: The second part is theoretical analysis and literature review, theoretical analysis of stock price transmission in supply chain network; The third part is the research hypothesis and research design. The research hypothesis to be tested is put forward, and the sample selection, variable definition and model design are specified. The fourth part is the empirical test, which carries on the baseline regression, robustness test and heterogeneity analysis to the research hypothesis. The fifth part is further analysis. Based on the centrality of supply chain network, the edge betweenness centrality is taken as the weight coefficient of innovative customer momentum factor. Finally, the conclusion and enlightenment are given.

2. Research hypothesis and design

2.1 Research hypothesis and model design

Based on the effective prediction of customer network centrality on supplier stock price and the high correlation between customer network centrality and its own financial performance and stock return, this paper considers that the moderating effect of customer network activity on supplier stock price change can be measured and discussed by using network centrality method. In summary, the following hypotheses are proposed in this paper:

Hypothesis 1: The stock price change of the customer company has a significant positive correlation with the stock price change of the supplier company in the next period.

Hypothesis 2: The larger the customer-supplier edge betweenness centrality, the more significant the impact of customer stock price change on supplier stock price change in the next period.

This paper first discusses whether hypothesis 1 is true by constructing model 1. Then, the edge betweenness centrality is used to measure the importance of each pair of suppliers and customers in the supply chain network. Model 2 is constructed to explore whether hypothesis 2 is true. In order to avoid the multicollinearity problem caused by the introduction of cross-product term into the moderating effect, this paper centralizes $gysprice_{i,t}$ and $C_{i,t-1}$ during regression. Then model 3 is built on model 2. Considering that the data in this paper is panel type, bidirectional fixed effect model is finally adopted for construction after F test, LM test, modified Hausman test and LR test. Specific models 1, 2 and 3 are as follows:

Model 1:

$$gysprice_{i,t} = \alpha_0 + \alpha_1 * khprice_{i,t-1} + \alpha_2 * X1_{i,t} + \alpha_3 * X2_{i,t} + \alpha_4 * X3_{i,t} + \alpha_5 * X4_{i,t} + \alpha_6 * X5_{i,t} + \rho_i + \varphi_t + \varepsilon_{i,t} \quad (1)$$

Model 2:

$$gysprice_{i,t} = \beta_0 + \beta_1 * khprice_{i,t-1} + \beta_2 * C_{i,t-1} + \beta_3 * (khprice_{i,t-1} * C_{i,t-1}) + \beta_4 * X1_{i,t} + \beta_5 * X2_{i,t} + \beta_6 * X3_{i,t} + \beta_7 * X4_{i,t} + \beta_8 * X5_{i,t} + \rho_i + \varphi_t + \varepsilon_{i,t} \quad (2)$$

Model 3:

$$gysprice_{i,t} = \beta_0 + \beta_1 * c_khprice_{i,t-1} + \beta_2 * c_C_{i,t-1} + \beta_3 * (khprice_{i,t-1} * C_{i,t-1}) + \beta_4 * X1_{i,t} + \beta_5 * X2_{i,t} + \beta_6 * X3_{i,t} + \beta_7 * X4_{i,t} + \beta_8 * X5_{i,t} + \rho_i + \varphi_t + \varepsilon_{i,t} \quad (3)$$

The explained variable $gysprice_{i,t}$ is the stock closing price of supplier company i at time t; The explanatory variable $khprice_{i,t-1}$ is the closing price of the stock of the client company corresponding to supplier i at the t-1 moment. $c_khprice_{i,t-1}$ represents the centralized $khprice_{i,t-1}$. The moderating variable $C_{i,t-1}$ is the edge betweenness centrality at time t-1 between supplier i and its corresponding customer company. $c_C_{i,t-1}$ represents the centralized $C_{i,t-1}$. Interactive variable $khprice_{i,t-1} * C_{i,t-1}$ is the product of explanatory variable $khprice_{i,t-1}$ and moderating variable $C_{i,t-1}$. $khpriceC_c_{i,t-1}$ represents the centralized $khprice_{i,t-1} * C_{i,t-1}$. In order to avoid the interference of outliers, all continuous variables in this paper are indented at 1% and 99% levels. See the definitions and explanations of specific variables below.

2.2 Variable definition and description

2.2.1 Explained variable and Explanatory variable

Since stock prices reflect the present value of a company's expected future earnings, the price at the end of the month already reflects the company's expected earnings, unless that month exceeds expectations. Thus, this paper chose the closing price of the last trading day of each month as the explained variable and represent $gysprice_{i,t-1}$. The stock closing price of each listed customer company corresponding to each supplier on the last trading day of each month each year is used as an explanatory variable. and represent $khprice_{i,t-1}$, the unit of t is 1 month.

2.2.2 Moderating variable -- edge betweenness centrality

The centrality of customer-supplier network can be used as a moderating variable in the process of customer stock price change affecting supplier stock price change. Edge betweenness centrality is a measure of medality. It is defined as: Among all shortest paths between nodes in the network, the proportion of the shortest paths passed by this edge. The higher the edge centrality is, the higher the medality is. The formula is as follows:

$$C_B(e) = \sum_{s,t \in V} \frac{\sigma(s,t|e)}{\sigma(s,t)} \quad (4)$$

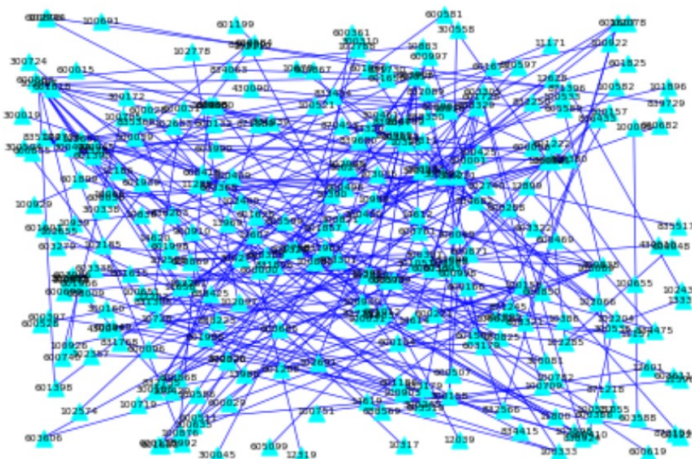


Figure 1. structure of supply chain network in 2019 (Note: Derived from Python Network)

In empirical analysis, Seiler (2016) and Douglass (2017) pointed out that edge betweenness centrality is highly correlated with sales ratio. High edge betweenness centrality means that the customer company covers a larger proportion of the sales volume of the supplier. Thus, this paper uses the function “edge Betweenness centrality” in Python Networkx to obtain the edge betweenness centrality C between suppliers and their corresponding customers, and takes it as a reasonable adjusting variable to study the impact of customer stock price changes on supplier stock price changes., measuring all supplier-customer relationships in the supply chain network. Figure 1 shows the structure of the supply chain network in 2019 with the supplier-customer edge betweenness

centrality as the weight of the edge, where the node is the listed company disclosing the data of the supply chain network.

2.2.3 Control variables

Referring to the studies of Fu Neng Pu (2013), Wang Dawei, Wang Xuebiao (2008), Su Baotong (2004) and other scholars, the growth rate of net asset per share, net profit, operating income, net asset per share and net income per share in corporate financial indicators are taken as the control variables of the model. The specific definitions of all variables are shown in Table 1:

Table 1. Variable definitions

Variable types	Control variable name	Variable code	definition
Control-variables	Growth rate of net assets per share	X1	Net asset per share for the current period/net asset per share for the same period last year-1
	Net profit growth rate	X2	(Current year net profit - last year net profit)/last year net profit
	Growth rate of operating income	X3	(Current year's operating income - last year's operating income)/last year's operating income
	Earnings per share	X4	Net profit/Total shares
	Net asset per share	X5	Total shareholders' equity/number of common shares

2.3 Samples and data sources

The sample of this paper is the annual supply chain network data published by A-shares of Shanghai and Shenzhen stock exchanges from 2011 to 2019, including the business relationship and stock code of primary supply chain and the business relationship and stock code of secondary supply chain; the annual monthly share price of each listed company as a supplier and the annual monthly share price of its corresponding customer; Supplier concentration, customer concentration, quarterly net asset growth rate, net profit growth rate, operating income growth rate, earnings per share and net asset per share data for each company.

According to existing research practices, the sample data are processed in this paper according to the following steps: (1) Eliminating unlisted suppliers and customers on the basis of the published supply chain network, non-A-share suppliers that did not disclose X1, X2, X3, X4, X5; (2) Calculating the edge betweenness centrality of each pair of supplier-customer in supply chain network data for each year; (3) Organizing supplier and customer company data for each pair of supplier - customer each year and month. The final sample included 1633 company-monthly observations from the CSMAR database.

2.4 Descriptive statistics

The descriptive statistical results show that: (1) a large number of samples indicates strong reliability of the results; (2) Through the centralized processing of the customer company's previous stock closing price $khprice$, the supplier - customer edge betweenness centrality degree C and their interaction terms, it helps to alleviate the multicollinearity problem.

3. Empirical test

3.1 The benchmark return

Hypothesis 1 is tested first, and the first column of Table 2 shows the regression results for model 1. The results show that the regression coefficient of the stock price of the last client company $khprice1$ is about 0.19, and it is significant at the test level of 1%. This shows that the stock price change of the

customer company in the previous period has a significant positive correlation with the stock price change of the supplier in the current period.

Columns 2 to 5 of Table 2 show the model regression results of random effect, individual fixed effect, time fixed effect and bidirectional fixed effect for hypothesis 2. By means of F test, LM test, modified Hausman statistic test and LR test, the bidirectional fixed effect model was finally selected. Thus, this paper only makes a detailed interpretation of column 5, the bidirectional fixed effect model/Model 3. The results show that: (1) the regression coefficient of the stock price $c_khprice1$ of the last client company after centralization is about 6.416, and it is significant at the test level of 1%. (2) After centralization, the regression coefficient of the cross product term $khpriceC_c1$ between the stock price $c_khprice1$ of the last customer company and the edge betweenness centrality degree c_C1 of the last supplier-customer is about 41.08, and is significant at the test level of 1%. This shows that when considering the influence of “X1, X2, X3, X4, X5”, the higher the edge betweenness centrality of the pair of suppliers and customers, the more significant the positive impact of the stock price change of the customer company on the stock price change of the supplier company. Hypothesis 2 is verified.

Table 2. Analysis of empirical results of baseline regression

VARIABLES	(1) gysprice	(2) gysprice	(3) gysprice	(4) gysprice	(5) gysprice
khprice1	0.190*** (0.0507)				
c_khprice1		4.564*** (1.685)	3.809* (2.007)	3.143** (1.426)	6.416*** (1.940)
khpriceC_c1		28.29*** (10.83)	23.30* (12.85)	19.71** (9.261)	41.08*** (12.43)
c_C1		-231.8*** (50.57)	-306.5*** (56.88)	-15.55 (45.89)	-75.47 (96.99)
X1	6.142*** (0.600)	4.781*** (0.660)	4.383*** (0.766)	6.811*** (0.792)	2.189*** (0.757)
X2	-0.0191 (0.0230)	-0.0173 (0.0224)	-0.0184 (0.0217)	0.00907 (0.0473)	-0.0249 (0.0196)
X3	0.693*** (0.195)	0.686*** (0.190)	0.666*** (0.183)	2.254*** (0.487)	0.333* (0.177)
X4	-4.974*** (0.541)	-4.886*** (0.530)	-5.252*** (0.523)	10.64*** (1.213)	-1.962*** (0.745)
X5	1.891*** (0.177)	2.008*** (0.179)	1.970*** (0.260)	0.785*** (0.135)	2.510*** (0.256)
Constant	3.484*** (1.003)	-31.70*** (7.850)	-42.45*** (8.940)	2.083 (7.018)	-5.028 (15.12)
Observations	569	569	569	569	569
R-squared			0.518	0.585	0.647

Note: Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

3.2 Robustness test

3.2.1 Gradually increase control variables

Based on the studies of Fan Longzhen and Wang Haitao (2003), Xuanjuan Chen et al.(2010) and Lei Guangyong et al.(2012), this paper introduced corporate governance structure variables and market environment variables to conduct robustness tests on the basis of Model 3. The definitions of newly added control variables are shown in Table 3:

Table 3. Added control variable definitions

The name of a control variable is added	Variable code	definition
Financial leverage	X6	Change in earnings per common share/change in EBIT
Operating leverage	X7	Change rate of eBIT/change rate of production and sales volume
Comprehensive lever	X8	Change rate of net profit/change rate of main business income
Monthly total market value of individual stocks	X9	Monthly share price * Total share capital
Monthly transaction amount of individual stocks	X10	Monthly transaction amount + monthly transaction fee

Control variables were gradually added on the basis of Model 3 to conduct robustness test. The final column constructs the model as follows:

Model 4:

$$\text{gysprice}_{i,t} = \beta_0 + \beta_1 * c_khprice_{i,t-1} + \beta_2 * c_C_{i,t-1} + \beta_3 * (khpriceC_c_{i,t-1}) + \beta_4 * X1_{i,t} + \beta_5 * X2_{i,t} + \beta_6 * X3_{i,t} + \beta_7 * X4_{i,t} + \beta_8 * X5_{i,t} + \beta_9 * X6_{i,t} + \beta_{10} * X7_{i,t} + \beta_{11} * X8_{i,t} + \beta_{12} * X9_{i,t} + \beta_{13} * X10_{i,t} + \rho_i + \varphi_t + \varepsilon_{i,t} \quad (5)$$

The results show that :(1) after the centralization of new control variables gradually added on the basis of bidirectional fixed effect model 3, the $c_khprice1$ coefficient of customer company's stock price changed little and was still significant at the test level of 1% .(2) After centralization, the coefficient of $c_khprice1$ and the $khpriceC_c1$ cross term of c_C1 has a small change, and is still significant at the test level of 1%. This suggests that, after considering the influence of X1, X2, X3, X4, X5, X6, X7, X8, X9 and X10, the change of customer's stock price in the previous period is still significantly positively correlated with the change of supplier's stock price in the current period. The higher the edge betweenness centrality degree of supplier to customer is, the more significant the positive correlation effect of customer's stock price change in the previous period on the change of supplier's stock price in the current period is, indicating that the result is robust. Hypothesis 1 and 2 are verified.

3.2.2 Endogeneity test

In order to test the robustness of the results and eliminate the possible endogeneity problems, this paper adopts the method of delaying all control variables for one period to conduct endogeneity test, and constructs the bidirectional fixed effect model 5 as follows:

Model 5:

$$\text{gysprice}_{i,t} = \beta_0 + \beta_1 * c_khprice_{i,t-1} + \beta_2 * c_C_{i,t-1} + \beta_3 * (khpriceC_c_{i,t-1}) + \beta_4 * X1_{i,t-1} + \beta_5 * X2_{i,t-1} + \beta_6 * X3_{i,t-1} + \beta_7 * X4_{i,t-1} + \beta_8 * X5_{i,t-1} + \beta_9 * X6_{i,t-1} + \beta_{10} * X7_{i,t-1} + \beta_{11} * X8_{i,t-1} + \beta_{12} * X9_{i,t-1} + \beta_{13} * X10_{i,t-1} + \rho_i + \varphi_t + \varepsilon_{i,t} \quad (6)$$

After the lag of all control variables, the empirical results show that :(1) the regression coefficient of customer stock price in the previous period after centralization is 6.444, which is still significant at the test level of 1% (see appendix for detailed regression results). (2) After centralization, the regression coefficient of the cross product $khpriceC_c1$ between the stock price $c_khprice1$ of the last customer company and the marginal center degree c_C1 of the last supplier-customer is about 41.35, which is still significant at the test level of 1% (see appendix for detailed regression results). This indicates that the endogeneity problem of model 3 is small, the results are robust, and hypotheses 1 and 2 can still be verified.

3.3 Heterogeneity analysis

Referring to existing literature, this paper uses supplier concentration degree to measure the competitive threat faced by suppliers, ranks the supplier concentration degree of the company, and

divides the supplier concentration degree into high and low groups for regression respectively. The results show that: (1) the $c_khprice1$ regression coefficient of customer stock price in the last period after the centralization of column 1 is about 180.5, much higher than the $c_khprice1$ regression coefficient of column 2, 6.618, and both are significant at the test level of 5%. (2) After the centralization of column 1, the regression coefficient of $khpriceC_c1$, the intersecting term of $c_khprice1$ in the stock price of the last customer and c_C1 in the edge betweenness centrality degree of the last supplier -customer, is about 1147, much higher than 42.32 of $khpriceC_c1$ in the second column, and both are significant at the test level of 5%. This indicates that suppliers face greater competitive threat when supplier concentration is low, that is, the change of supplier stock price in the current period has a stronger positive correlation with the change of customer stock price in the previous period, and is more affected by the positive moderating effect of supplier-customer edge betweenness centrality.

4. Further analysis: customer momentum factor based on supply chain network centrality

It can be seen from the above analysis that the marginal centrality between customer and supplier is a reasonable moderating variable of the influence process of customer stock price change on supplier stock price change. The higher the customer-supplier edge betweenness centrality, the more significant the positive correlation between customer stock price and supplier stock price in the next month. Thus, edge betweenness centrality can be used as the weight of customer momentum to build a more effective customer momentum factor, so as to enhance the profitability of customer momentum strategy and mine more Alpha information in supply chain data. The standard customer momentum weighted using the sales ratio (customer relationship as a percentage of the supplier's total sales) is first described below, followed by customer momentum weighted using network centrality. Suppose i is a supplier, j is its corresponding customer, N_i is the number of customers of company i , c_{ij} is the rate of return of customer j in the past month, w_{ij}^{sales} is the sales ratio of customer j to company i , and $cmom_i^{1M}$ is the customer momentum of company i .

$$cmom_i^{1M} = \sum_{j=1}^{N_i} w_{ij}^{sales} mom_j^{1M}, i = 1, 2, \dots, N \quad (7)$$

Based on the problem that sales ratio "has many missing values and is difficult to be counted", this paper uses the edge betweenness centrality in network centrality as the weight factor of customer momentum, assumes that it is the edge betweenness centrality between supplier i and customer j , and rewrites Equation (7) into Equation (8), as shown below:

$$cmom_i^{1M} = \sum_{j=1}^{N_i} w_{ij}^{centrality} mom_j^{1M}, i = 1, 2, \dots, N \quad (8)$$

$$w_{ij}^{centrality} = c_{ij} / \sum_{j=1}^{N_i} c_{ij}, i = 1, 2, \dots, N \quad (9)$$

A large number of studies have shown that the medium-term momentum strategy is effective in all stock markets. If the medium-term momentum strategy is fully effective in customer companies, the influence will be spread to supplier companies. Thus, the customer momentum factor of T months can be defined as follows, where c_{ij} is the return rate of customer j in the past T months:

$$cmom_i^{TM} = \sum_{j=1}^{N_i} w_{ij}^{centrality} mom_j^{TM}, i = 1, 2, \dots, N \quad (10)$$

$$w_{ij}^{centrality} = c_{ij} / \sum_{j=1}^{N_i} c_{ij}, i = 1, 2, \dots, N \quad (11)$$

Based on the above customer momentum factors, the standard customer momentum strategy can be improved, which is conducive to the mining of Alpha information in the stock market.

5. Research conclusions and implications

Most existing literatures consider only the influence of customer stock price change on supplier stock price change, but ignore the moderating effect of supplier - customer network centrality in this process.

Firstly, a period (month) on customer share price changes in the current supplier price moves a significant positive correlation, and edge betweenness centrality degree as the representative indicators of supplier-client network interactive activity, is more effective than customer concentration control variables. The higher the supplier-customer marginal centrality is, the more significant the positive correlation is. Meanwhile, the above conclusion still holds under the robustness test and endogeneity test. Secondly, when supplier concentration is low, suppliers face greater competitive threat. The more strongly the supplier's stock price change responds to the customer's stock price change in the previous period, and the stronger the moderating effect of supplier - customer edge betweenness centrality degree is. Thirdly, based on the above research, edge betweenness centrality can be used as a reasonable weighted variable of customer momentum factor, so as to creatively construct a new customer momentum factor and promote the improvement of standard customer momentum strategy.

Meanwhile, there are some deficiencies in this paper, which need to be further studied and improved. First of all, due to the inability to obtain the relevant data of unlisted suppliers and customers, the supply chain network based on the edge betweenness centrality of suppliers and customers is biased, and there may be the problem of self-selection of samples, which will be further studied after the enterprise supply chain information disclosure is more perfect. Additionally, the influence of the stock price of the client company in the previous period on the stock price of the supplier company in the current period may be related to the general industry trend in economic activity, in which case there may be a case of miscapturing the industry trend as a whole, rather than the influence of a specific relationship.

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