Credit spillover effect in supply chain network: evidence from bank loan contracts

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Abstract

I show that credit spillover effect exists generally in supply chain network using a sample of 9,369 loans over the period 1986-2017. Better average customer credit quality is associated with more favorable supplier bank loan terms, including lower interest rates spread, less collateral requirement and extended loan maturity. I find that the credit spillover effect is strengthened by the following factors: customers experienced rating upgrade, more concentrated customer base, customers average size closer to supplier, less profitable customer, customer with higher accounts payable level, and supplier less central within supply chain network. I further show that the credit spillover effect identified in this paper flows in single direction from customer to supplier and weakly persists after two layers of transmission. I also show that the credit spillover effect is due to trade relationship.

JEL classification: G21, G32, L14

Key words: credit spillover, supply chain, bank loan

1. Introduction

Supply chain network consist of numerous numbers of supplier-customer relationships, which goods and services flow through. However there are certainly more than goods and services that flow through supply chain network, one of which is credit risk. Hertzel et al. (2008) found that bankruptcy risks diffuse along the supply chain in stock prices and are difficult to hedge and diversify away based on Chapter 7 bankruptcy fillings (liquidation). Kolay, Lemmon, and Tashjian (2016) confirmed the above finding under chapter 11 bankruptcy setting (reorganization) and extended the economic impact to operating performance. Agca et al. (2020) quantified the aggregated risk diffusion along the supply chain using CDS market and found increase of CDS spread in three-day windows for suppliers when customers experience adverse credit shocks.

In this paper, I empirically identify existence of credit spillover effect between supply chain partners on a very general base, contrary to the previous literature which largely focused on credit shocks such as bankruptcy or shocks in credit market. I investigate this issue by looking at how supplier's bank loan terms are affected by average customer credit quality. The reason I choose bank loan terms is as follows. Previous studies show that there is information asymmetry between supply chain members and financial markets. For instance, Baiman and Rajan (2002), Kulp et al. (2004) and Gong and Luo (2014) showed that firms learn proprietary information about their supply chain partners' financial health via repeated transactions and coordinated investments within a supply chain. It is difficult for participants in financial market to acquire this proprietary information and evaluate the credit condition of supply chain member firms. Nevertheless, banks are believed to be more informed than other groups of creditors with their more regular and deeper interactions with borrowers (Dell'Ariccia 2001; Dell'Ariccia and Marquez 2004). Thus bank loan serves as a good objective to be investigated on the credit spillover effect related to supply chain partners.

The variable of interest--average customer credit quality--is proxied by sale weighted average customer credit rating. Credit rating is publicly available information which started to be used for assessing the credit worthiness of debt issuers since the 1900s (Weinstein 1977; Hand, Holthausen and Leftwich 1992). Although the quality of the information it contains become

questionable due to perceived conflict of interest after the 2008 financial crisis, credit rating still serves as a great tool when assessing credit quality of a firm.

Previous literature explores many other aspects of the customer-supplier relationship. For example, financing policies and capital structure (Banerjee, Dasgupta and Kim 2008; Chu 2012; Cunat 2007; Garcia-Appendini and Montoriol-Garriga 2013; Kale and Shahrur 2007; Petersen and Rajan 1997; Titman and Wessels 1988; Wang 2012; Wilner 2000), mergers and acquisitions (Ahern 2012; Ahern and Harford 2014; Bhattacharyya and Nain 2011; Fee and Thomas 2004; Shahrur 2005), return predictability (Cohen and Frazzini 2008), and cost of equity (Dhaliwal et al. 2016). Therefore it is promising to start with customer-supplier relationship and later move on to other supply chain network characteristics and relationships.

Using a sample consisting of 9,369 loans of 2,074 different borrowers over the period 1986-2017 and supplier-customer relationships identified by Compustat Customer Segment database, I show that a customer base with better credit quality would help supplier reduce its bank loan charge and receive more favorable loan terms. To be more specific, one standard deviation increase in average customer rating is associated with 6.66 bps reduction in supplier loan spread. When evaluating at the median loan maturity and loan amount, the reduction in interest cost amounts to 0.29 million. Compared with suppliers with non-investment grade customers, suppliers with investment grade customers enjoys reduction in interest rate of 15.61 bps on average. Better customer credit quality is also associated with less stringent non-pricing terms of supplier loan. It reduces the probability of collateral requirement and extends the loan maturity.

In the next step, I look at how customer rating change affect supplier loan spread and the strength of the spillover effect identified above. I found that customer rating change, either upgrade or down grade, has no statistically significant effect on supplier bank loan spread. However suppliers whose customers experienced only rating upgrade would bear stronger credit spillover effect. This difference in strength of the spillover effect is consistent with further results accounting for the magnitude of the rating change and the relative importance of certain customer to the supplier. Possible explanation to this phenomenon is that suppliers whose customer underwent large deterioration in credit worthiness might fail to apply for syndicated loan and results in a survivorship bias in the loan dataset.

In addition, I analyze how this credit spillover effect differ in strength with respect to a list of supply chain network characteristics and firm attributes. The first set of variables I use is customer concentration. Dhaliwal et al. (2016) and Campello and Gao (2017) found that suppliers with higher customer concentration tend to have a higher cost of equity and cost of debt, respectively. I use four different measures of customer concentration following Campello and Gao (2017) and find that loan spread of suppliers whose customer base is more concentrated is more affected by their customers' average credit quality. Second set of variables used is relative size between customer and supplier. Customers are usually much larger than their suppliers and possess more bargaining power given the differences in size. I find that suppliers whose average customer size is relatively smaller face more credit spillover from customer credit quality to their bank loan spread. The third group of variables discussed is average customer profitability and accounts payable. Results show that suppliers whose customers on average are less profitable and hold more accounts payable endure stronger credit spillover from their customers. The fourth group of characteristics are macro level network characteristics of the supplier. Gofman and Wu (2022) showed that more upstream firms borrow more, lend more and hold more net trade credit and firms in more central chains provide more net trade credit. Gofman, Segal and Wu (2020) found that firms that are further away from consumers have higher risk premia. Thus I investigate how upstreamness and centrality of supplier firms affect the credit spillover effect from their customers. The results imply that upstreamness itself is increasing borrower loan spread but not affecting the strength of the spillover effect, while less central suppliers face stronger credit spillover from their customers.

So far the spillover is studied only from customer to supplier. To mitigate concerns regarding simultaneity bias, I construct a new sample of customer loans with average supplier ratings. Then the same test is performed on customer loan contract terms. I find no evidence that supplier credit quality is affecting customer loan contract terms, suggesting that the credit spillover effect found in this study is transmitted in single direction.

After that, I look at how far this credit spillover effect is transmitting along supply chain. I match customers of customers and construct the average rating of them. Regression result of supplier loan terms on customer of customer ratings shows that there still exists some, but not

much, credit spillover effect after two layers of transmission in the supply chain. Customer of customer ratings are associated with supplier loan spreads but not with other bank loan terms.

Finally, in order to confirm that the credit spillover happens because of the trade relationship, I match peer firms of customers that do not exist in the supply chain network and check if their average credit quality has same effect on supplier's loan contract as the customers. Results from regression analysis show little evidence that customer peer's credit quality has impact on supplier bank loan term, consolidating that the credit spillover effect identified in this paper is due to trade relationship.

The remaining of the paper is structured as follows. Section 2 introduces the research design. Section 3 shows the data and sample construction procedure. Section 4 presents the results and provides some discussion. Section 5 concludes and discussed potential future extensions.

2. Research design

2.1 Measure of customer credit quality

In this study, I use average customer credit ratings as a proxy for customer credit quality. Average customer credit ratings are calculated as following:

$$Customer\ rating_{jt} = \sum_{i}^{n_{jt}} rating_{it} \times \frac{Sale\ to\ customer_{ijt}}{Total\ sale\ to\ identified\ customer_{jt}} \quad (1)$$

where $Customer\ rating_{jt}$ stands for the sale weighted average customer rating of supplier *j* in year *t*, *i* denotes different customers of a certain supplier-year observation, n_{jt} is the total number of customers of supplier *j* in year *t,* with positive sale number reported in Compustat Customer Segment database, $rating_{it}$ is credit rating of customer *i* in year *t* from S&P ratings, $Sale\ to\ customer_{ijt}$ is the sale number reported from supplier *j* to customer *i* in year *t*, and $Total\ sale\ to\ identified\ customer_{jt}$ is the sum of all reported sale of supplier *j* in year *t*.

I transform the ratings from S&P ratings so that they can be included in the regression (AAA = 23, AA+ = 22, AA = 21, …D = 1). Under this transformation, a positive coefficient of customer credit ratings means the dependent variable is increasing with better credit ratings. The use of sale weighting instead of simple average comes from the advantage of the Compustat Customer Segment database, which includes sales number to these identified customers.

2.2 Empirical Setting

The main model used in this study is provided below in equation (2).

$$Spread_{jkt} = \alpha + \beta_1 Customer\ rating_{jt-1} + \beta_2 Borrower\ characteristics_{t-1} + \beta_3 Loan\ characteristics_{kt} + \beta_4 Macroeconomic\ factors_t + Fixed\ effects + \epsilon \quad (2)$$

where $Spread_{jkt}$ is all-in drawn spread (the amount the borrower pays in basis points over LIBOR or LIBOR equivalent for each dollar drawn down) of supplier *j*'s loan facility *k* in year *t* and *Customer rating* is the average customer rating calculated above. *Borrower Characteristics* includes borrowers', *Size* (natural log of total assets), *BM* (Book-to-market ratio), *Leverage* (total liabilities over total assets), *Tangibility* (property, plant and equipment over total assets), *Profitability* (EBITDA over total assets), *Sale growth* (annual growth rate of total sale), *Liquidity* (current assets over current liabilities) and *Cash flow volatility* (ratio of standard deviation of quarterly cash flows from operations over the four fiscal years prior to loan initiation year to total debt).

Loan Characteristics includes *Collateral* (dummy variable equals one if the loan facility is secured by collateral and zero otherwise), (natural log of) loan *Maturity*, (natural log of) loan *Amount*, *Performance pricing* (dummy variable equals one if the loan facility is performance priced and zero otherwise) and *Syndication* (dummy variable equals one if the loan is syndicated and zero otherwise). Other controls include *Term spread*, *Credit spread*, loan-purpose-, loan-type-, year- and industry-fixed effect. *Loan characteristics* (including loan-purpose-, loan-type-fixed effect) and *Macroeconomics factors* are contemporaneous while *Customer rating* and *Borrower characteristics* (including industry-fixed effect) are lagged one year to avoid use of future information. A loan deal typically packages a set of loans from the same lending banks to

the borrower and the loan contract terms are highly correlated within a loan deal. Therefore standard deviation is double clustered at firm and loan deal level.

3. Data

The main data source utilized in this paper is the Compustat Segment Customer database. The Financial Accounting Standards Board (FASB) Summary of Statement No. 14 requires firms to disclose any single customer that contributes to over 10% of the firms' sale. The Compustat Segment Customer database provides data on the name of the customer and corresponding sales figures, which can be used in identifying supplier-customer relationships and the following procedure to calculate average customer credit ratings as well as constructing other sale weighted variables used in this study. The main advantage of this dataset is the sales number that it contains. This feature of the Compustat Segment Customer database makes it desirable when calculating the average of customer characteristics. Nevertheless, the downside is that it is not as comprehensive as other production network datasets such as the FactSet Revere database.

Data on syndicated bank loans is from Thomson Reuters Loan Pricing Corporation (LPC) DealScan database. Firm information including fundamentals and ratings are from Compustat Fundamentals North America and Compustat-Capital IQ S&P Credit Ratings database respectively. A linking file provided by Chava and Roberts (2008) links the Compustat-Capital IQ database and Thomson Reuters' LPC's DealScan database.

The sample is constructed by the following process. First, customer ratings and other characteristics are merged into data from Compustat Segment Customer database to calculate sale weighted customer ratings and other variables, resulting in a dataset with unique supplier-year observations. Second, the resulting dataset and firm fundamentals are matched to the linking table provided by Chava and Roberts (2008), as well as loan characteristics from DealScan. Financial and insurance companies are excluded. The final main sample contains 9,369 loan facilities of 2,074 different borrowers over the period 1986-2017.

Table-1 provide summary statistics of the final sample. The sample average customer credit rating is slightly above 17 (A-), which is within investment grade. The average loan in the sample has spread of 228 bps, with maturity of 38.63 month and loan amount of $89.84 million. About 60% of the loans are secured with collateral, 86% are syndicated and 35% are performance priced. The average size of borrowers (suppliers) measured by total asset is about $740 million. Their customers' sale weighted average size, however, is about 50 times larger.

(Insert Table-1 here)

4. Results

4.1 Main results

4.1.1 Results on loan spread

Table-2 presents the results of regressing supplier loan spread on customer average credit rating and other controls. T-stats based on standard errors double clustered at supplier and loan deal level are provided in parentheses.

Results from column (1) is using exactly equation (2) from above. In column (1), coefficient of *Customer rating* is negative and statistically significant at 1% level after controlling for supplier characteristics, macroeconomic factors and loan characteristics, indicating that better customer credit quality is associated with lower bank charge on supplier loans. The economic effect of the reduction in loan spread is also significant. One standard deviation increase in *Customer rating* on average amounts to 6.66 bps reduction in loan spread (3.443×1.934). When evaluated at the median loan facility amount ($99.98 million) and maturity (4.33 years), one standard deviation increase in *Customer rating* is associated with total reduction in interest cost of 0.29 million on average.

In column (2) a dummy variable *Customer investment grade* is used instead of the credit rating itself. It equals 1 if the average customer credit rating is above or equal to investment

grade (BBB-, or 14) and zero otherwise. The results show that compared with suppliers whose customers on average are not within investment grade, suppliers with investment grade customers enjoy 15.61 bps reduction in their loan spread. To investigate the marginal effect of *Customer rating* around the investment grade threshold, in column (3), the sample is restricted to the interval 13<=*Customer rating*<=14 (BB+ to BBB-). In this narrow interval, coefficient of *Customer rating* is about 11 times larger than in the whole sample and significant at 10% level, suggesting that around the investment grade threshold, increase in customer credit quality is associated with much larger effect on supplier loan spread.

In column (4), suppler rating is added as additional control and sample size reduced by more than half. Coefficient of *Customer rating* is smaller than in column (1) but still significant at 5% level, suggesting that the credit spillover effect from customer credit quality to supplier's bank loan spread is robust after controlling for supplier's own credit quality.

(Insert Table-2 here)

4.1.2 Results on other bank loan terms

Table-3 shows regression results of *Customer rating* on other non-pricing terms of supplier's loan contract. In column (1), a logit regression is estimated with dependent variable being *Collateral* with same controls as in equation (2). In Column (2) to (4), same OLS regression as in equation (2) is used where the dependent variables are *Maturity*, *Amount* and *Covenant* respectively. The coefficient of *Customer rating* in column (1) is negative and significant at 10% level, suggesting that better average customer credit quality is associated with less likely requirement of collateral. In column (2), the coefficient is positive and significant at 5% level, showing that better average customer credit quality can also help extend the maturity of loan facilities. Results in column (3) and (4), however, are not significant. In general, the results in Table-3 show that better customer credit quality is associated with less stringent non-pricing loan terms of supplier.

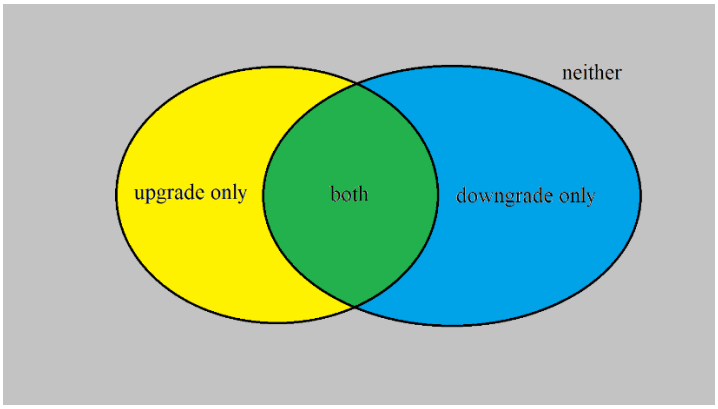
(Insert Table-3 here)

4.1.3 Results on customer rating change

A natural extension on the main model is to look at how customer rating change plays a role in the spillover process from average customer ratings to supplier bank loan term. Table-4 provides related results.

The rating change status of the customer base for each supplier-year is determined by the following: for each supplier-year, as long as one reported customer from the Segment database experience rating upgrade (or downgrade), the dummy variable *Customer upgrade* (*Customer downgrade*) for that supplier-year would be equal to one, and zero otherwise; *Customer both* equals one if both *Customer upgrade* and *Customer downgrade* equals one and zero otherwise; *Customer either* equals one if either *Customer upgrade* and *Customer downgrade* equals one and zero otherwise.

In Table-4 Panel A, the sample is split into four subsamples by the rating change status. The four groups are: upgrade only (*Customer upgrade*=1 & *Customer both*=0), downgrade only (*Customer downgrade*=1 & *Customer both*=0), both up-and downgrade (*Customer both*=1) and neither up- or downgrade (*Customer either* =0). Column (1) to (4) shows result of the main model within the four groups respectively and in column (5) the results from whole sample are reproduced for convenient comparison.



In Column (1), within the subsample that supplier experience only customer rating upgrade, the coefficient of *Customer rating* is larger in scale and remains significant at 1% level,

suggesting that among suppliers whose customer credit quality improved, the credit spillover effect to their bank loan spread is more profound. Results in column (3) also presents a larger coefficient on *Customer rating*, indicating banks are taking more attention to borrowers' customer credit quality when multiple type of rating change events happened. However, in column (2) where the subsample contains suppliers with only downgraded customers, the coefficient of interest becomes in significant. It appears that banks show less concern for borrower's customers when downgrades happen to borrower's customer base. Results in column (4) where neither upgrade or downgrade of customers happened are closer to the results from whole sample with a slightly smaller coefficient.

To further investigate the impact of customer rating change, in Table-4 Panel B, *Customer upgrade* and *Customer downgrade* are added to the main OLS model to see if they have direct effect on supplier's bank loan spread. To avoid effect of the other "treatment", when *Customer upgrade* (*Customer downgrade*) is added into the OLS, observations that falls in the downgrade (upgrade) subsample, i.e., *Customer downgrade*=1 (*Customer upgrade*=1), are excluded from the regression. In column (1), coefficient of *Customer upgrade* is positive and insignificant, suggesting that customer credit improvement does not help supplier reduce their loan charges when *Customer rating* is presented. In column (2) where *Customer rating* is removed from the regression, *Customer upgrade* still shows no significance in explaining supplier's bank loan spread. The same results are found on *Customer downgrade*. In column (3) and (4), whether or not with presence of *Customer rating*, the coefficient of *Customer downgrade* is not significant. In results not tabulated, effect of *Customer upgrade* and *Customer downgrade* within the whole sample is investigated and the results are similar.

One might concern that the above result could be due to the construction process of the two dummy variables since as long as one customer experienced credit rating upgrade or downgrade, the relative dummy would equal one. The dummy ignored the relative importance the upgraded (or downgraded) customers are to the supplier and the severity of the rating change. To mitigate such concerns, a measure of customer rating change taking care of both issues is constructed to capture, for each supplier-year observation, the average customer rating change. The corresponding variable *Customer rating change* is constructed as below:

$$Customer\ rating\ change_{jt} = \sum_{i}^{n} rating\ change_{it} \times \frac{Sale\ to\ customer_{ijt}}{Total\ sale\ to\ identified\ customer_{jt}}$$

where $rating\ change_{it}$ is number of levels of rating change of customer *i* in year *t*. For instance, rating change from BBB-to BBB is 1 (14 to15) and from AAA to AA is -2 (23 to 21). This part helps capture the severity of the rating change. The second part, the sale weights, which already used in construction of the main variable of interest, helps capture the relative importance the upgraded (or downgraded) customers are to the supplier.

In Table-4 Panel C first two columns, *Customer rating change* is added into the main model. In both columns, whether *Customer rating* presents or not, the coefficient of *Customer rating change* is not significant, implying that customer rating changes is not associated with supplier's bank loan spread. Nevertheless, when looking at the subsamples where average customer ratings change is positive and negative in column (3) and (4) respectively, similar results as in Panel A and B shows up. For suppliers whose customer credit quality increased, the spillover from customer credit quality to their bank loan spread is more significant, while suppliers with deteriorated customer credit quality are less affected by spillover from their customers. A possible explanation is that suppliers whose customer credit condition deteriorates a lot would be less likely to have bank loan approved, which creates a survivorship bias in the loan dataset. This survivorship bias may result in loss of supplier-loan observations in which loan spreads increase dramatically after large deterioration of customer credit quality and then lead to insignificance of coefficients of *Customer rating change*.

(Insert Table-4 here)

4.2 Effects of supply chain network attributes and other characteristics

In the following section, I discuss how some supply chain network attributes and other characteristics affect the credit spillover from customer credit quality to supplier bank loan spread.

4.2.1 Customer concentration

The first supply chain network attribute to be discussed is customer concentration. Campello and Gao (2017) showed that suppliers whose customer base is more concentrated is charged more interest rate spread by their banks. It would certainly be interesting to look at how the credit spillover from customer credit quality to supplier bank loan spreads varies between subsamples of suppliers with different customer concentration level.

Following Campello and Gao (2017), I construct four measures for customer concentration: *Concentration_sale*, *Concentration_size*, *Concentration_HHI*, and *Concentration_max*. *Concentration_sale* is the sum of the percentage sale to the customers that are identified as major customer in Compustat Segment database. *Concentration_size* is *Concentration_sale* weighted by customer size. *Concentration_HHI* is Herfindahl index of sale to large customers. *Concentration_max* is simply the percentage of sale the supplier assigns to its largest customer. The exact definitions of these measures are presented as below:

$$Concentration\_sale_{jt} = \sum_{i}^{n_{jt}} \frac{Sale\ to\ customer_{ijt}}{Total\ sale_{jt}}$$

$$Concentration\_size_{jt} = \sum_{i}^{n_{jt}} \frac{Sale\ to\ customer_{ijt}}{Total\ sale_{jt}} \times Size_{it}$$

$$Concentration\_HHI_{jt} = \sum_{i}^{n_{jt}} \left(\frac{Sale\ to\ customer_{ijt}}{Total\ sale_{jt}}\right)^2$$

$$Concentration\_max_{jt} = \max_{i=1,\dots n_{jt}} \frac{Sale\ to\ customer_{ijt}}{Total\ sale_{jt}}$$

where $Total\ sale_{jt}$ is total sale of supplier *j* in year *t*, $Size_{it}$ is size of customer *i* in year *t*. Other variables are defined in the same way as in equation (1)

Results across four different measures of customer concentration are very consistent. In column (1) and (2) of the four panels in Table-5, customer concentration measures are added to the main model. The coefficients of all four customer concentration measures are positive and three out of four are significant whether or not *Customer rating* is in the regression, implying

that borrowers with higher customer concentration do face higher interest rate in their bank loans.

In column (3) and (4), the sample is split into two subsamples, where in column (3) is the subsample with concentration measure smaller than or equal to the median of the concentration measure, and in column (4) is the subsample with concentration measure higher than median. Coefficients on *Customer rating* is larger in absolute value in column (4) than in column (3) and more significant across all four panels. In the last column of each panel, t-test result of the difference between coefficients in column (3) and (4) of *Customer rating* is provided. In all four panels the difference is significant. These results suggest that higher customer concentration is associated with stronger credit spillover effect from customer credit quality to supplier's bank loan spread.

(Insert Table-5 here)

4.2.2 Relative size of customer and supplier

The next supply chain characteristics to be looked at is the relative size of customers and suppliers. Generally speaking, customers on average is much larger than their suppliers. The median of the ratio of average customer total assets over supplier total assets is above 40 in the sample. Larger customers tend to have more bargaining power and a relatively larger supplier might be more resistant against spillover from their customers. The measures of relative size of customers and suppliers are: *Relative size* and *Relative size original*. The first measure calculated sale weighted average size of the customers where size is natural log of total assets. The second measure use the original level of total assets as the size of firms. A smaller *Relative size* means a smaller average customer size relative to their suppliers. The exact definitions are as below:

$$Relative\ size_{jt} = \frac{1}{Size_{jt}} \sum_{i}^{n_{jt}} Size_{it} \times \frac{Sale\ to\ customer_{ijt}}{Total\ sale\ to\ identified\ customer_{jt}}$$

$$Relative\ size\ original_{jt} = \frac{1}{\exp\left(Size_{jt}\right)} \sum_{i}^{n_{jt}} \exp\left(Size_{it}\right) \times \frac{Sale\ to\ customer_{ijt}}{Total\ sale\ to\ identified\ customer_{jt}}$$

where $Size_{jt}$ is natural logged assets of supplier *j* in year *t*.

In first two columns of Table-6 Panel A, *Relative size* is added to the main model and the coefficients are insignificant, implying that the relative size of customers and suppliers is not associated with supplier bank loan spread. In column (3) and (4) the sample is split into two subsamples based on median of *Relative size*. Results of the low *Relative size* subsample is presented in column (3) and the high group is in column (4). The coefficient on *Customer rating* in column (3) is larger in scale and more significant than that in column (4), suggesting that the credit spillover effect is stronger within the subsample where customer size is closer to suppliers. The difference between the coefficients, however, is not significant, as presented in the last column of Table-6 Panel A. Results in Panel B using the original total assets level is similar. In general, there is evidence that credit spillover effect from customer credit quality to supplier bank loan spread is stronger when customers are relatively closer in size as their customers, but the difference between high and low groups is not statistically significant.

(Insert Table-6 here)

4.2.3 Other customer characteristics

In this section, effects of two more customer characteristics on the strength of credit spillover from customer to supplier are investigated. The first is average customer profitability and the second is average customer accounts payable. Kim, Song and Zhang (2015) showed that borrowers whose customers on average are more profitable is receiving lower bank loan interest rate spread and less stringent loan terms. More profitable customers shall have better ability to pay to their customers and debtors, thus shall have better credit quality. The effect of customer profitability on the credit spillover effect from customer to supplier is therefore of interest.

Measure of average customer profitability is constructed following Kim, Song and Zhang (2015) who used sale weighted average of customer return on assets (ROA).

$$Customer\ profitability_{jt} = \sum_{i}^{n_{jt}} ROA_{it} \times \frac{Sale\ to\ customer_{ijt}}{Total\ sale\ to\ identified\ customer_{jt}}$$

where ROA_{it} is ROA of customer *i* in year *t*.

In Table-7 Panel A, first two columns, *Customer profitability* is added into the main model. In column (1), the coefficient on *Customer profitability* is negative and significant at 10% level, suggesting that customer profitability is associated with reduction in supplier bank loan spread. However, coefficient of *Customer profitability* becomes insignificant once *Customer rating* is added back into the regression in column (2). In column (3) and (4), the sample is split into two subsamples by median of *Customer profitability* where in column (3) is the subsample with low customer profitability and in column (4) the subsample of high customer profitability. Interestingly, the coefficient of *Customer rating* in column (3) is more significant than in column (4), implying that credit spillover from customer to supplier loan spread is stronger within the subsample of less profitable customers than the more profitable ones. Nevertheless, the difference between coefficients in two subsample is not statistically significant.

Another customer characteristic naturally comes into interest is the level of accounts payable. Trade credit is an important channel through which customers are tied to suppliers and it is reasonable to assume that the credit spillover effect is stronger within suppliers whose customers have higher average level of accounts payable. Average customer accounts payable level is calculated as below:

$$Customer\ AP_{jt} = \sum_{i}^{n_{jt}} AP_{it} \times \frac{Sale\ to\ customer_{ijt}}{Total\ sale\ to\ identified\ customer_{jt}}$$

Where AP_{it} is accounts payable of customer *i* in year *t* over its total cost of good sold.

In Table-7 Panel B, results regarding customer accounts payable are presented. As in previous sections, the first two columns show results of adding *Customer AP* into the main model and in column (3) and (4) subsample results are presented, where in column (3) is the low *Customer AP* part of the sample and in column (4) the higher part. The coefficients of *Customer*

AP in both column (1) and (2) are negative and significant at 10% level, showing some evidence that average customer accounts payable is associated with supplier bank loan spread. Coefficient of *Customer rating* is larger and more significant in column (4) than in column (3), suggesting that the credit spillover from customer to supplier is more profound when customers on average have a higher level of accounts payable.

(Insert Table-7 here)

4.2.4 Network level characteristics

In this section I investigate how some production network characteristics of the supplier is affecting the strength of the credit spillover effect from their customers. These include *Upstreamness* following Gofman and Wu (2022) and four centrality measures: *Degree centrality*, *Closeness centrality*, *Betweenness centrality*, and *Eigenvector centrality*. *Upstreamness* is constructed to measure the shortest distance a firm's product need to travel to reach general consumers. The larger upstreamness a firm has, the further away it is from consumers and higher it sits within the supply chain network. Four centrality measures use different ways to calculate how central a firm is within the supply chain network. The data used in this section is provided by Gofman and Wu (2022) and the sample period is reduced to 2003-2017.

Results on *Upstreamness* are presented in Table-8 Panel A. In column (1) and (2), *Upstreamness* is added to the main model and coefficients on *Upstreamness* are both positive and significant. These suggests that firms that are upper-stream in the production network faces larger bank loan spread. The results coincide with Gofman, Segal and Wu (2020) where they found firms with higher upstreamness have higher expected return on their stocks. In column (3) and (4), the sample is split into two subsamples based on median of *Upstreamness* as usual. Although the coefficient of *Customer rating* is significant in column (3) but not in column (4), the difference is small in scale and not statistically significant. The subsample results thus show little evidence that vertical position in supply chain network corresponds to strength of credit spillover effect from customer to supplier.

Results on centrality are presented in Table-8 Panel B, C, D and E. From results in column (1) and (2) of the four panels, three out of four coefficients of the centrality measure are positive, indicating that in general more central firms face higher bank loan spread. In column (3) and (4) of the four panels, again the sample is split based on median of the centrality measures. In the first three panels, the coefficient of *Customer rating* is larger and more significant in the lower centrality subsample, suggesting that credit spillover from customer to supplier loan spread is more significant when suppliers are less central in the supply chain network. Possible explanation for this result is that since more central firms are, both directly and indirectly, related to larger number of and more diversified supply chain partners than the less central ones, the spillover from direct customers are likely to be attenuated due to spillover transmitted from other parts of the supply chain network. In addition, it could be more efficient for banks to assess the creditworthiness of customers of less central borrowers since they sit on the edge of supply chain network and works closely with fewer number of and more crucial supply chain partners

(Insert Table-8 here)

4.3 Can supplier average credit quality affect customer bank loan spread?

One might concern that the results so far could be driven by simultaneity bias, in other words, credit spillover is happening both from customer to supplier and from supplier to customer. In this section, I construct a new sample based on Compustat Customer Segment database that, instead of focusing on supplier-year related average customer credit ratings, generates average supplier ratings for the customer-year level observations. The variable of interest is calculated as:

$$Supplier\ rating\_average_{it} = \sum_{i}^{n_{jt}} rating_{jt} \times \frac{Sale\ from\ supplier_{ijt}}{Total\ sale\ from\ identified\ supplier_{jt}}$$

where $Supplier\ rating\_average_{it}$ is sale weighted average supplier credit rating for customer *i* in year *t*, $rating_{jt}$ is credit rating of supplier *j* in year *t*, $Sale\ from\ supplier_{ijt}$ is

identified sale in the Customer Segment database from supplier *j* to customer *i* in year *t* and $Total\ sale\ from\ identified\ supplier_{jt}$ is the sum of all sale to customer *i* in year *t*.

The same OLS model as in equation (2) is used and regression results of regressing customer bank loan terms on supplier rating and other controls are shown in Table-9. *Supplier invgrade_average* is dummy variable equals one if average supplier credit rating is within investment grade and zero otherwise. From Table-9, coefficients of *Supplier rating_average* and *Supplier invgrade_average* are not significant on any of the customer bank loan terms, implying that supplier credit quality is not associated with customer loan terms and the credit spillover effect studied in this paper flows in single direction from downstream to upstream of the supply chain.

(Insert Table-9 here)

4.4 Effects of customer's customer on supplier bank loan spread

Given that the credit spillover effect is single direction from customer to supplier, it is essential to look at how far this spillover can live on within supply chain. Thus I matched customer of customers using the supplier-customer relationship provided by Compustat Customer Segment database and calculated the average customer of customer credit rating to investigate whether the credit spillover effect is still significant after another level of transmission along supply chain.

Results regressing supplier bank loan terms on customer of customer credit ratings are provided in Table-10. *Customer of customer rating* is the calculated average rating using equation (1) twice and *Customer of customer investment grade* is dummy variable equals one if corresponding *Customer of customer rating* is in investment grade and zero otherwise. In column (1), coefficient of *Customer of customer rating* is negative and significant at 5% level. Nevertheless, in all other columns, the coefficients of interest are not significant. These results together provide some evidence that the credit spillover effect to supplier bank loan terms still

exists from customer of customer, but the strength is much weaker than spillover from direct customers.

(Insert Table-10 here)

4.5 Peer of customers

To further consolidate that the credit spillover effect discussed in this paper happens because of trade relationship between suppliers and customers, I look at if peer firms of customers that do not belong to the supply chain network would have significant impact on supplier's loan term. I match all firms that works in same industry and same state as the identified customer *i* and does not belong to supplier *j*'s customer base in year *t*, then calculate the average rating of the matched peers of customer *i*. Then this average peer rating is used in place of customer *i*'s rating in equation (1) to calculate the sale weighted average peer rating, *Customer peer rating.*

Table-11 presents OLS regression results using *Customer peer rating* instead of *Customer rating* using model in equation (2). *Customer peer investment grade* is the dummy variable that equals one if *Customer peer rating* is in investment grade and zero otherwise. From column (2), coefficient of *Customer peer investment grade* is weakly significant at 10% level and coefficient of *Customer peer rating* is significant but negative in column (5). All other coefficients of interest are insignificant. Although peer rating seems to be associated with supplier bank loan amount, but the negative coefficient indicates that better peer rating reduces supplier loan amount, which is in opposite direction of what normally expected. In a nutshell, better customer peer firms' credit quality does not significantly improve supplier's bank loan term. The credit spillover effect identified in this paper is result of trade relationship.

(Insert Table-11 here)

4 Conclusion

In this paper, I studied credit spillover effect in supply chain network utilizing the impact average customer credit quality has on supplier bank loan terms. I find that better customer credit quality is associated with more favorable supplier bank loan terms, including smaller interest rate spread, less collateral requirements and longer loan maturity. Effect of various variables on the strength of credit spillover effect is investigated and results show that most of the variables would create heterogeneity in the spillover effect. Additionally, I show that the credit spillover effect is single directional from customer to supplier, and it still weakly exists after two layers of transmission within the supply chain network. Finally I show that the credit spillover effect is due to trade relationship. Effect of other micro- and macro-level production network characteristics on credit spillover in supply chain network requires further investigation.

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Tables and Appendix

Table-1 Summary statistics

This table presents summary statistics for the variables used in this study. It covers 9,369 loan facilities over the period 1986-2017. Variable definitions are provided in Appendix.

VARIABLES	Mean	Q25	Median	Q75	SD	N
Loan characteristics						
Spread	228.3	125	200	300	153.4	8,416
Collateral	0.600	0	1	1	0.490	9,369
Maturity	3.654	3.332	3.951	4.094	0.723	9,369
Amount	4.498	3.219	4.605	5.858	1.854	9,369
Syndication	0.862	1	1	1	0.345	9,369
Performance pricing	0.352	0	0	1	0.477	9,369
Covenant	4.408	0	3	8	4.705	9,369
Borrower characteristics						
Size	6.607	5.149	6.659	8.037	2.003	9,369
BM	0.542	0.263	0.450	0.739	0.563	9,369
Tangibility	0.327	0.127	0.251	0.483	0.250	9,369
Profitability	0.112	0.0804	0.122	0.172	0.151	9,369
Sale growth	0.615	-0.0131	0.0915	0.265	14.73	9,369
Liquidity	2.107	1.170	1.691	2.502	1.720	9,369
Leverage	0.601	0.427	0.580	0.736	0.296	9,369
Cash flow volatility	0.105	0.0390	0.0676	0.120	0.159	9,369
Macroeconomic factors						
Term spread	1.617	0.580	1.820	2.700	1.265	9,369
Credit spread	0.927	0.700	0.870	1.040	0.336	9,369
Ratings						
Customer rating	17.22	15	17.54	20	3.443	9,369
Customer investment grade	0.861	1	1	1	0.345	9,369
Customer upgrade	0.166	0	0	0	0.372	9,369
Customer downgrade	0.208	0	0	0	0.406	9,369
Customer both	0.0307	0	0	0	0.173	9,369
Customer either	0.343	0	0	1	0.475	9,369
Customer rating change	-0.0969	0	0	0	0.991	9,369
Supplier rating	12.67	10	12	15	3.619	4,498
Customer of customer rating	17.17	15.11	17	20	3.033	1,705
Customer of customer investment grade	0.896	1	1	1	0.305	1,705
Customer peer rating	14.77	12.38	15.13	17	3.418	4,639
Customer peer investment grade	0.634	0	1	1	0.482	4,639
Supply chain network characteristics						
Concentration_sale	0.297	0.130	0.230	0.410	0.226	9,369

Concentration_size	3.054	1.333	2.324	4.117	2.415	9,321
Concentration_HHI	0.0800	0.0156	0.0361	0.0873	0.175	9,369
Concentration_max	0.208	0.120	0.169	0.250	0.152	9,369
Relative size	1.735	1.313	1.570	1.951	0.710	9,321
Relative size original	404.7	13.29	50.91	203.2	2,973	9,321
Customer profitability	0.134	0.0919	0.136	0.169	0.0867	9,269
Customer AP	0.475	0.102	0.127	0.167	4.697	9,268
Eigenvector centrality	0.0474	0.00601	0.0199	0.0556	0.0742	3,607
Degree centrality	0.0569	0.0123	0.0347	0.0734	0.0715	3,607
Closeness centrality	0.727	0.679	0.730	0.778	0.0792	3,607
Betweenness centrality	0.0163	1.51e-06	0.00232	0.0130	0.0538	3,607
Upstreamness	1.384	1	1	2	0.987	3,629

Table-2 Supplier bank loan spread and customer credit quality

This table presents regression results of supplier bank loan spread on average customer credit quality and other controls as in equation (2). In column (1) the regression is exactly as in equation (2). In column (2) the dummy variable *Customer investment grade* is used instead of *Customer rating*. In column (3) the regression is performed on subsample that contains only supplier-year observations with average customer credit rating ranging from BB+ to BBB-. In column (4) supplier rating is added into the regression as additional control. Variable definitions are provided in Appendix. T-values are presented in parentheses and are based on robust standard errors clustered at both firm and loan deal level. *, **, and *** denote significance at 10%, 5% and 1% level respectively.

	(1)	(2)	(3)	(4)
Dependent Variable	*Spread*	*Spread*	*Spread*	*Spread*
Customer rating	-1.934***		-24.71*	-1.654**
	(-4.31)		(-1.96)	(-2.53)
Customer investment grade		-15.61***		
		(-3.44)		
Supplier rating				-9.179***
				(-9.13)
Size	-10.66***	-10.82***	-16.14***	3.637
	(-6.57)	(-6.68)	(-3.21)	(1.33)
BM	22.74***	22.64***	29.27*	24.35***
	(5.65)	(5.61)	(1.86)	(3.87)
Tangibility	-2.292	-0.872	127.6***	-8.768
	(-0.20)	(-0.08)	(3.41)	(-0.49)
Profitability	-85.62***	-86.01***	-175.9***	-95.22***
	(-4.70)	(-4.68)	(-3.62)	(-3.01)
Sale growth	0.155***	0.150***	-4.851**	-0.646
	(5.97)	(5.80)	(-2.26)	(-0.19)
Liquidity	-1.382	-1.354	-2.622	-3.771
	(-1.20)	(-1.16)	(-0.76)	(-1.54)
Leverage	96.44***	96.56***	146.7***	77.65***
	(7.49)	(7.51)	(3.93)	(5.33)
Cash flow volatility	-9.662	-9.519	20.99	35.70
	(-1.04)	(-1.01)	(0.34)	(0.88)
Term spread	7.022**	6.798**	13.52	4.838
	(2.17)	(2.10)	(1.53)	(1.27)
Credit spread	24.77**	25.04**	22.99	27.72**
	(2.05)	(2.07)	(0.95)	(2.10)
Collateral	63.23***	63.10***	44.34***	51.63***
	(17.38)	(17.30)	(3.66)	(10.23)
Maturity	0.498	0.296	6.258	8.543
	(0.14)	(0.08)	(0.43)	(1.49)
Amount	-19.02***	-18.96***	-10.60*	-25.39***
	(-11.85)	(-11.87)	(-1.92)	(-11.18)
Syndication	-1.466	-1.462	-24.64	-2.696
	(-0.26)	(-0.26)	(-1.06)	(-0.17)
Performance pricing	-46.29***	-46.21***	-22.61*	-41.76***
	(-14.33)	(-14.29)	(-1.92)	(-10.50)

Loan type FE	Yes	Yes	Yes	Yes
Loan purpose FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
N	8416	8416	661	4068
adj. R-sq	0.488	0.488	0.524	0.582

Table-3 Supplier non-pricing bank loan terms and customer credit quality

This table presents regression results of supplier non-pricing bank loan terms on average customer credit quality and other controls as in equation (2). In column (1), a logit model on *Collateral* is used instead of OLS and pseudo R-square is provided. Column (2), (3) and (4) show regression results using equation (2) with dependent variable being *Maturity*, *Amount* and *Covenant* respectively. The dependent variable is removed from the regression as controls. Variable definitions are provided in Appendix. T-values are presented in parentheses and are based on robust standard errors clustered at both firm and loan deal level. *, **, and *** denote significance at 10%, 5% and 1% level respectively.

	(1)	(2)	(3)	(4)
Dependent Variable	*Collateral*	*Maturity*	*Amount*	*Covenant*
Customer rating	-0.0176*	0.00398**	-0.00616	-0.00502
	(-1.71)	(2.06)	(-1.57)	(-0.32)
Size	-0.495***	-0.000215	0.607***	-0.213***
	(-13.53)	(-0.04)	(51.10)	(-5.06)
BM	0.503***	-0.0156	-0.0773***	0.270**
	(5.98)	(-1.14)	(-3.15)	(2.31)
Tangibility	-0.523**	0.102**	0.185**	0.562*
	(-2.16)	(2.58)	(2.32)	(1.66)
Profitability	-2.080***	0.185***	0.337***	2.014***
	(-3.83)	(3.58)	(3.34)	(6.33)
Sale growth	0.105	-0.000807*	-0.00153**	-0.00156
	(1.63)	(-1.96)	(-2.17)	(-1.01)
Liquidity	0.0790***	0.0106**	-0.0164*	0.0702*
	(2.98)	(2.40)	(-1.93)	(1.89)
Leverage	2.237***	-0.000108	0.197***	0.976***
	(10.20)	(-0.00)	(3.15)	(4.08)
Cash flow volatility	-0.298	-0.113**	0.484***	-0.392
	(-1.18)	(-2.35)	(4.79)	(-1.35)
Term spread	0.0142	-0.00591	-0.0266	0.00322
	(0.20)	(-0.49)	(-1.00)	(0.03)
Credit spread	0.00832	-0.128***	-0.0192	-0.00797
	(0.05)	(-4.11)	(-0.33)	(-0.03)
Collateral		0.0365**	-0.0675**	2.691***
		(2.54)	(-2.11)	(25.73)
Maturity	0.188***		0.260***	0.117
	(2.84)		(9.68)	(1.30)
Amount	-0.0659*	0.0599***		0.226***
	(-1.86)	(9.79)		(5.47)
Syndication	-0.246**	0.138***	0.592***	1.783***
	(-1.97)	(5.60)	(14.04)	(12.66)
Performance pricing	0.552***	0.0741***	0.341***	3.345***
	(7.85)	(6.30)	(12.84)	(29.27)
Loan type FE	Yes	Yes	Yes	Yes
Loan purpose FE	Yes	Yes	Yes	Yes

Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
N	9318	9369	9369	9369
adj. R-sq		0.580	0.722	0.508
pseudo R-sq	0.262			

Table-4 Impact of customer rating change on supplier loan spread and credit spillover effect

This table presents regression results of supplier bank loan spread on customer credit rating change and subsample analysis based on different status of such rating change. In Panel A, the sample is separated into four subsamples based on customer rating change status. Regression using model in equation (2) is performed. Column (1) to (4) show results of subsamples containing supplier whose customers experienced upgrade only, downgrade only, both upgrade and downgrade and neither downgrade. The results from the whole sample is reproduced in column (5) for comparison. In Panel B two dummy variables *Customer upgrade* and *Customer downgrade* are added into the regression in column (1) and (3) respectively. In column (2) and (4) *Customer rating* is removed from the regression compared with column (1) and (3). In column (1) and (2) only suppliers' whose customer experienced no downgrade is used. In column (3) and (4) only suppliers' whose customer experienced no upgrade is used. In Panel C column (1), *Customer rating change* is included in the regression model from equation (2). In column (2) *Customer rating* is removed from the regression compared with column (1). In column (3) and (4), the sample is split into two subsamples based on *Customer rating change*. The subsample in column (3) contains subsample with *Customer rating change*>0 and in column (4) contains subsample with *Customer rating change*<0. T-test on difference of coefficients of *Customer rating* in column (3) and (4) is presented in the last column. Controls include borrower characteristics, loan characteristics and macroeconomic factors. Variable definitions are provided in Appendix. T-values are presented in parentheses and are based on robust standard errors clustered at both firm and loan deal level. *, **, and *** denote significance at 10%, 5% and 1% level respectively.

Panel A: Subsample analysis

Subsample	Upgrade only (1)	Downgrade only (2)	Both (3)	Neither (4)	Whole sample (5)
Customer rating	-4.564***	-0.0344	-6.983**	-1.560***	-1.934***
	(-2.94)	(-0.03)	(-2.04)	(-2.78)	(-4.31)
Controls	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
N	1154	1470	254	5538	8416
adj. R-sq	0.502	0.527	0.512	0.506	0.488

Panel B: Effect of customer upgrade and downgrade

	(1)	(2)	(3)	(4)
Customer upgrade	0.915	3.818		
	(0.20)	(0.84)		
Customer downgrade			-0.657	2.506
			(-0.15)	(0.59)
Customer rating	-2.006***		-1.506***	
	(-3.82)		(-3.09)	
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
N	6692	6692	7008	7008
adj. R-sq	0.495	0.496	0.495	0.496

Panel C: Effect of average customer rating change

Subsample	Whole sample	Whole sample	*Customer rating change*>0	*Customer rating change*<0	
	(1)	(2)	(3)	(4)	Diff. (3)-(4)
Customer rating change	1.048	-0.421			
	(0.71)	(-0.29)			
Customer rating	-2.001***		-5.200***	-1.068	-4.132**
	(-4.33)		(-3.38)	(-1.11)	(-2.51)
Controls	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Industry FE	Yes	Yes	Yes	Yes	
N	8416	8416	1200	1495	
adj. R-sq	0.488	0.487	0.497	0.522	

Table-5 Effect of customer concentration on credit spillover from customer to supplier bank loan spread

This table presents results regarding effect of customer concentration on credit spillover from customer to supplier bank loan spread. The customer concentration variables used are *Concentration_sale*, *Concentration_size*, *Concentration_HHI* and *Concentration_max* in Panel A, B, C and D respectively. In all panels, column (1) includes the customer concentration variable in the regression model from equation (2). In column (2) *Customer rating* is removed from the regression compared with column (1). In column (3) and (4), the sample is split into two subsamples based on median of the customer concentration variable. The subsample in column (3) contains subsample with customer concentration below median and in column (4) contains subsample with customer concentration above median. T-test on difference of coefficients of *Customer rating* in column (3) and (4) is presented in the last column. Controls include borrower characteristics, loan characteristics and macroeconomic factors. Variable definitions are provided in Appendix. T-values are presented in parentheses and are based on robust standard errors clustered at both firm and loan deal level. *, **, and *** denote significance at 10%, 5% and 1% level respectively.

Panel A: *Concentration_sale* as concentration measure

Subsample	Whole sample (1)	Whole sample (2)	Low (3)	High (4)	Diff. (3)-(4)
Concentration_sale	17.02**	14.93**			
	(2.26)	(2.00)			
Customer rating		-1.863***	-0.565	-3.040***	2.475***
		(-4.16)	(-0.98)	(-4.38)	(2.79)
Controls	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Industry FE	Yes	Yes	Yes	Yes	
N	8416	8416	4210	4206	
adj. R-sq	0.487	0.489	0.517	0.478	

Panel B: *Concentration_size* as concentration measure

Subsample	Whole sample (1)	Whole sample (2)	Low (3)	High (4)	Diff. (3)-(4)
Concentration_size	1.321*	1.310*			
	(1.84)	(1.83)			
Customer rating		-2.056***	-0.715	-3.293***	2.578***
		(-4.49)	(-1.35)	(-4.35)	(2.86)
Controls	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Industry FE	Yes	Yes	Yes	Yes	
N	8371	8371	4186	4230	
adj. R-sq	0.488	0.490	0.524	0.474	

Panel C: *Concentration_HHI* as concentration measure

Subsample	Whole sample (1)	Whole sample (2)	Low (3)	High (4)	Diff. (3)-(4)

Concentration_HHI	14.33**	13.08*			
	(2.03)	(1.88)			
Customer rating		-1.909***	-0.342	-3.126***	2.784***
		(-4.26)	(-0.58)	(-4.71)	(3.22)
Controls	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Industry FE	Yes	Yes	Yes	Yes	
N	8416	8416	3906	4510	
adj. R-sq	0.487	0.488	0.516	0.475	

Panel D: *Concentration_max* as concentration measure

Subsample	Whole sample	Whole sample	Low	High	
	(1)	(2)	(3)	(4)	Diff. (3)-(4)
Concentration_max	13.91	13.44			
	(1.31)	(1.28)			
Customer rating		-1.927***	-0.201	-3.583***	3.382***
		(-4.30)	(-0.36)	(-5.20)	(3.90)
Controls	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Industry FE	Yes	Yes	Yes	Yes	
N	8416	8416	4208	4208	
adj. R-sq	0.487	0.488	0.523	0.466	

Table-6 Effect of relative size on credit spillover from customer to supplier bank loan spread

This table presents results regarding effect of relative size of customer and supplier on credit spillover from customer to supplier bank loan spread. The relative size variables used are *Relative size* and *Relative size original* in Panel A and B respectively. In both panels, column (1) includes the relative size variable in the regression model from equation (2). In column (2) *Customer rating* is removed from the regression compared with column (1). In column (3) and (4), the sample is split into two subsamples based on median of the relative size variable. The subsample in column (3) contains subsample with relative size below median and in column (4) contains subsample with relative size above median. T-test on difference of coefficients of *Customer rating* in column (3) and (4) is presented in the last column. Controls include borrower characteristics, loan characteristics and macroeconomic factors. Variable definitions are provided in Appendix. T-values are presented in parentheses and are based on robust standard errors clustered at both firm and loan deal level. *, **, and *** denote significance at 10%, 5% and 1% level respectively.

Panel A: Relative size using logged assets level

Subsample	Whole sample (1)	Whole sample (2)	Low (3)	High (4)	Diff. (3)-(4)
Relative size	-3.681	2.734			
	(-0.98)	(0.69)			
Customer rating		-2.173***	-2.416***	-1.334*	-1.082
		(-4.47)	(-3.90)	(-1.94)	(-1.18)
Controls	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Industry FE	Yes	Yes	Yes	Yes	
N	8371	8371	4130	4286	
adj. R-sq	0.487	0.489	0.565	0.398	

Panel B: Relative size using original assets level

Subsample	Whole sample (1)	Whole sample (2)	Low (3)	High (4)	Diff. (3)-(4)
Relative size original	-0.000147	0.000159			
	(-0.16)	(0.19)			
Customer rating		-2.068***	-2.133***	-1.634**	-0.499
		(-4.49)	(-3.39)	(-2.28)	(-0.53)
Controls	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Industry FE	Yes	Yes	Yes	Yes	
N	8371	8371	4119	4297	
adj. R-sq	0.487	0.489	0.548	0.416	

Table-7 Effect of customer profitability and accounts payable on credit spillover from customer to supplier bank loan spread

This table presents results regarding effect of customer profitability and accounts payable on credit spillover from customer to supplier bank loan spread. The variables used are *Customer profitability* and *Customer AP* in Panel A and B respectively. In both panels, column (1) includes the average customer characteristics in the regression model from equation (2). In column (2) *Customer rating* is removed from the regression compared with column (1). In column (3) and (4), the sample is split into two subsamples based on median of the average customer characteristics. The subsample in column (3) contains subsample with average customer characteristics below median and in column (4) contains subsample with average customer characteristics above median. T-test on difference of coefficients of *Customer rating* in column (3) and (4) is presented in the last column. Controls include borrower characteristics, loan characteristics and macroeconomic factors. Variable definitions are provided in Appendix. T-values are presented in parentheses and are based on robust standard errors clustered at both firm and loan deal level. *, **, and *** denote significance at 10%, 5% and 1% level respectively.

Panel A: Customer average profitability

Subsample	Whole sample	Whole sample	Low	High	
	(1)	(2)	(3)	(4)	Diff. (3)-(4)
Customer profitability	-45.06*	-24.34			
	(-1.85)	(-1.24)			
Customer rating		-1.855***	-1.665***	-0.665	-1.000
		(-3.85)	(-2.63)	(-0.97)	(-1.09)
Controls	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Industry FE	Yes	Yes	Yes	Yes	
N	8324	8324	4163	4253	
adj. R-sq	0.488	0.489	0.513	0.484	

Panel B: Customer average accounts payable

Subsample	Whole sample	Whole sample	Low	High	
	(1)	(2)	(3)	(4)	Diff. (3)-(4)
Customer AP	-0.371*	-0.355*			
	(-1.96)	(-1.83)			
Customer rating		-2.023***	-1.183*	-2.164***	0.981
		(-4.38)	(-1.87)	(-3.22)	(1.08)
Controls	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Industry FE	Yes	Yes	Yes	Yes	
N	8325	8325	4162	4254	
adj. R-sq	0.487	0.489	0.509	0.484	

Table-8 Effect of network level characteristics on credit spillover from customer to supplier bank loan spread

This table presents results regarding effect of network level characteristics of suppliers on credit spillover from customer to supplier bank loan spread. The network level characteristics used are *Upstreamness*, *Degree centrality*, *Closeness centrality*, *Betweenness centrality* and *Eigenvector centrality* in Panel A, B, C, D and E respectively and kindly provided by Gofman and Wu (2022). The sample period is reduced to 2003-2017. In all panels, column (1) includes the network level characteristics in the regression model from equation (2). In column (2) *Customer rating* is removed from the regression compared with column (1). In column (3) and (4), the sample is split into two subsamples based on median of the network level characteristics. The subsample in column (3) contains subsample with network level characteristics below median and in column (4) contains subsample with network level characteristics above median. T-test on difference of coefficients of *Customer rating* in column (3) and (4) is presented in the last column. Controls include borrower characteristics, loan characteristics and macroeconomic factors. Variable definitions are provided in Appendix. T-values are presented in parentheses and are based on robust standard errors clustered at both firm and loan deal level. *, **, and *** denote significance at 10%, 5% and 1% level respectively.

Panel A: Upstreamness

Subsample	Whole sample (1)	Whole sample (2)	Low (3)	High (4)	Diff. (3)-(4)
Upstreamness	6.031**	5.293*			
	(2.08)	(1.83)			
Customer rating		-1.668**	-1.537*	-1.286	-0.251
		(-2.57)	(-1.66)	(-1.33)	(-0.19)
Controls	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Industry FE	Yes	Yes	Yes	Yes	
N	3256	3256	1702	1554	
adj. R-sq	0.513	0.514	0.530	0.522	

Panel B: Degree centrality

Subsample	Whole sample (1)	Whole sample (2)	Low (3)	High (4)	Diff. (3)-(4)
Degree centrality	48.87	39.70			
	(1.31)	(1.05)			
Customer rating		-1.768***	-2.354**	-0.396	-1.958
		(-2.70)	(-2.50)	(-0.44)	(-1.53)
Controls	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Industry FE	Yes	Yes	Yes	Yes	
N	3236	3236	1626	1610	
adj. R-sq	0.511	0.512	0.510	0.543	

Panel C: Closeness centrality

Subsample	Whole sample (1)	Whole sample (2)	Low (3)	High (4)	Diff. (3)-(4)
Closeness centrality	49.64	57.08*			
	(1.63)	(1.87)			
Customer rating		-1.901***	-1.910**	-1.121	-0.789
		(-2.91)	(-2.00)	(-1.22)	(-0.61)
Controls	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Industry FE	Yes	Yes	Yes	Yes	
N	3236	3236	1631	1605	
adj. R-sq	0.511	0.513	0.502	0.537	

Panel D: Betweenness centrality

Subsample	Whole sample (1)	Whole sample (2)	Low (3)	High (4)	Diff. (3)-(4)
Betweenness centrality	-116.4***	-117.6***			
	(-5.07)	(-5.16)			
Customer rating		-1.840***	-2.365**	-1.717*	-0.648
		(-2.83)	(-2.40)	(-1.75)	(-0.48)
Controls	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Industry FE	Yes	Yes	Yes	Yes	
N	3236	3236	1619	1617	
adj. R-sq	0.512	0.514	0.508	0.529	

Panel E: Eigenvector centrality

Subsample	Whole sample (1)	Whole sample (2)	Low (3)	High (4)	Diff. (3)-(4)
Eigenvector centrality	82.10**	76.79**			
	(2.33)	(2.17)			
Customer rating		-1.737***	-1.307	-1.610*	0.303
		(-2.66)	(-1.37)	(-1.69)	(0.23)
Controls	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Industry FE	Yes	Yes	Yes	Yes	
N	3236	3236	1618	1618	
adj. R-sq	0.512	0.513	0.503	0.540	

Table-9 Customer bank loan terms and supplier credit quality

This table presents regression results of customer bank loan terms on average supplier credit quality and other controls as in equation (2). In column (1) the regression is exactly as in equation (2) except that here customer loan spread is regressed on *Supplier rating_average*. In column (2) the dummy variable *Supplier invgrade_average* is used instead of *Supplier rating_average*. In column (3), a logit model on *Collateral* is used instead of OLS and pseudo R-square is provided. Column (4), (5) and (6) show regression results using equation (2) with dependent variable being *Maturity*, *Amount* and *Covenant* respectively. The dependent variable is removed from the regression as controls. Variable definitions are provided in Appendix. T-values are presented in parentheses and are based on robust standard errors clustered at both firm and loan deal level. *, **, and *** denote significance at 10%, 5% and 1% level respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	*Spread*	*Spread*	*Collateral*	*Maturity*	*Amount*	*Covenant*
Supplier rating_average	-0.524		0.0199	0.00346	0.00295	-0.00181
	(-0.85)		(0.99)	(1.31)	(0.43)	(-0.10)
Supplier invgrade_average		0.489				
		(0.13)				
Size	-6.712***	-6.944***	-0.665***	0.00789	0.437***	-0.403***
	(-3.05)	(-3.17)	(-11.35)	(0.90)	(20.98)	(-6.46)
BM	34.22***	34.21***	0.593***	-0.0125	-0.138*	0.525**
	(4.68)	(4.67)	(2.67)	(-0.45)	(-1.85)	(2.44)
Tangibility	3.353	4.500	0.511	0.0258	-0.128	-0.326
	(0.23)	(0.31)	(1.20)	(0.47)	(-0.77)	(-0.83)
Profitability	-178.1***	-178.4***	-4.805***	0.319***	0.0745	-0.829
	(-4.15)	(-4.17)	(-3.27)	(3.02)	(0.31)	(-1.12)
Sale growth	-8.260	-8.298	0.316*	0.0230	0.127***	0.0258
	(-1.55)	(-1.57)	(1.72)	(1.29)	(2.94)	(0.16)
Liquidity	4.888*	4.970*	0.224***	0.0463***	0.0316	0.161*
	(1.73)	(1.75)	(2.85)	(3.91)	(1.06)	(1.90)
Leverage	135.4***	135.2***	3.234***	-0.00631	0.386**	1.031**
	(7.99)	(8.00)	(6.30)	(-0.10)	(2.57)	(2.26)
Cash flow volatility	157.1**	155.3**	2.177	-0.549**	-0.179	-2.223
	(2.13)	(2.11)	(1.25)	(-2.40)	(-0.32)	(-1.47)
Term spread	4.033	4.074	0.00387	-0.0138	-0.00963	0.00254
	(1.14)	(1.15)	(0.03)	(-0.79)	(-0.23)	(0.02)
Credit spread	35.20**	34.96**	-0.199	-0.0777	0.0577	0.178
	(2.21)	(2.20)	(-0.68)	(-1.63)	(0.64)	(0.88)

Collateral	73.37***	73.24***		0.0649***	-0.228***	2.453***
	(11.41)	(11.36)		(2.84)	(-3.16)	(13.20)
Maturity	-4.119	-4.298	0.411***		0.0249	-0.147
	(-0.64)	(-0.66)	(3.05)		(0.48)	(-1.20)
Amount	-23.09***	-23.12***	-0.163***	0.00349		0.181***
	(-11.88)	(-11.89)	(-2.96)	(0.48)		(4.75)
Syndication	16.85	16.86	0.406	0.0607	0.462***	0.295
	(1.33)	(1.33)	(1.27)	(0.95)	(3.76)	(1.53)
Performance pricing	-17.21***	-17.21***	0.254*	0.0706***	0.511***	3.049***
	(-4.65)	(-4.65)	(1.90)	(4.48)	(11.32)	(22.84)
Loan type FE	Yes	Yes	Yes	Yes	Yes	Yes
Loan purpose FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
N	3760	3760	4568	4712	4712	4712
adj. R-sq	0.619	0.619		0.703	0.409	0.512
pseudo R-sq			0.447			

Table-10 Supplier bank loan terms and customer of customer credit quality

This table presents regression results of supplier bank loan terms on average customer of customer credit quality and other controls as in equation (2). In column (1) the regression is exactly as in equation (2) except that here suppleir loan spread is regressed on *Customer of customer rating*. In column (2) the dummy variable *Customer of customer investment grade* is used instead of *Customer of customer rating*. In column (3), a logit model on *Collateral* is used instead of OLS and pseudo R-square is provided. Column (4), (5) and (6) show regression results using equation (2) with dependent variable being *Maturity*, *Amount* and *Covenant* respectively. The dependent variable is removed from the regression as controls. Variable definitions are provided in Appendix. T-values are presented in parentheses and are based on robust standard errors clustered at both firm and loan deal level. *, **, and *** denote significance at 10%, 5% and 1% level respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	*Spread*	*Spread*	*Collateral*	*Maturity*	*Amount*	*Covenant*
Customer of customer rating	-2.954**		-0.0360	0.00728	-0.0112	-0.0497
	(-2.22)		(-1.12)	(1.58)	(-1.25)	(-1.06)
Customer of customer investment grade		8.079				
		(0.61)				
Size	-15.64***	-15.53***	-0.506***	0.0178	0.639***	-0.107
	(-4.51)	(-4.47)	(-6.25)	(1.50)	(31.83)	(-1.14)
BM	9.951	7.644	0.520***	0.0305	-0.0861	0.161
	(1.12)	(0.86)	(2.59)	(1.14)	(-1.50)	(0.54)
Tangibility	21.34	13.46	-0.574	0.143	0.320*	1.217
	(0.80)	(0.51)	(-1.03)	(1.62)	(1.90)	(1.56)
Profitability	-98.42***	-96.56***	-0.0846	0.169	0.527***	2.172***
	(-3.63)	(-3.69)	(-0.07)	(1.43)	(3.02)	(3.14)
Sale growth	-3.007***	-2.814***	0.214	0.00618	-0.0315***	0.00919
	(-3.09)	(-2.95)	(0.92)	(1.36)	(-3.15)	(0.12)
Liquidity	-1.282	-1.632	0.0790*	-0.00310	-0.0155	0.157**
	(-0.61)	(-0.79)	(1.74)	(-0.33)	(-1.08)	(2.19)
Leverage	110.4***	112.5***	2.880***	-0.0143	0.265*	1.538**
	(5.34)	(5.41)	(5.45)	(-0.18)	(1.85)	(2.35)
Cash flow volatility	21.69	30.75	-0.734	0.0310	1.013***	-0.847
	(0.43)	(0.62)	(-0.86)	(0.21)	(4.13)	(-0.71)
Term spread	-3.420	-3.736	-0.109	-0.0414	0.0981	-0.452*
	(-0.46)	(-0.49)	(-0.68)	(-1.53)	(1.56)	(-1.80)

Credit spread	40.21**	41.09**	0.0568	-0.152***	-0.121	1.149*
	(2.21)	(2.11)	(0.15)	(-2.59)	(-1.08)	(1.89)
Collateral	49.87***	50.80***		0.0917***		2.443***
	(6.25)	(6.32)		(3.15)		(9.98)
Maturity	8.782	7.049	0.544***		0.217***	0.432*
	(1.10)	(0.88)	(3.23)		(3.59)	(1.91)
Amount	-19.84***	-19.64***	-0.0827	0.0454***		0.0278
	(-5.37)	(-5.33)	(-1.06)	(3.77)		(0.27)
Syndication	17.22	17.22	-0.548*	0.123**	0.546***	1.423***
	(1.20)	(1.21)	(-1.92)	(2.49)	(5.34)	(4.25)
Performance pricing	-48.29***	-50.37***	0.462***	0.0570**	0.390***	3.317***
	(-5.84)	(-5.99)	(2.73)	(2.11)	(6.26)	(12.41)
Loan type FE	Yes	Yes	Yes	Yes	Yes	Yes
Loan purpose FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
N	1541	1541	1611	1705	1705	1705
adj. R-sq	0.479	0.477		0.613	0.766	0.498
pseudo R-sq			0.266			

Table-11 Supplier bank loan terms and peer of customer credit quality

This table presents regression results of supplier bank loan terms on customer's peer credit quality and other controls as in equation (2). In column (1) the regression is exactly as in equation (2) except that here suppleir loan spread is regressed *Customer peer rating*. In column (2) the dummy variable *Customer peer investment grade* is used instead of *Customer peer rating*. In column (3), a logit model on *Collateral* is used instead of OLS and pseudo R-square is provided. Column (4), (5) and (6) show regression results using equation (2) with dependent variable being *Maturity*, *Amount* and *Covenant* respectively. The dependent variable is removed from the regression as controls. Variable definitions are provided in Appendix. T-values are presented in parentheses and are based on robust standard errors clustered at both firm and loan deal level. *, **, and *** denote significance at 10%, 5% and 1% level respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	*Spread*	*Spread*	*Collateral*	*Maturity*	*Amount*	*Covenant*
Customer peer rating	-0.433		-0.0147	0.00255	-0.0137***	0.000528
	(-0.65)		(-0.98)	(0.82)	(-2.66)	(0.02)
Customer peer investment grade		-8.123*				
		(-1.76)				
Size	-12.99***	-12.88***	-0.451***	0.00469	0.606***	-0.0983
	(-5.72)	(-5.67)	(-9.60)	(0.56)	(39.69)	(-1.63)
BM	16.38***	16.73***	0.448***	-0.0138	-0.112***	0.105
	(2.80)	(2.85)	(3.84)	(-0.72)	(-3.23)	(0.65)
Tangibility	12.56	12.55	-0.361	0.0672	0.321***	0.431
	(0.80)	(0.81)	(-1.12)	(1.28)	(2.99)	(0.89)
Profitability	-114.7***	-114.5***	-2.134***	0.161**	0.366***	2.085***
	(-5.31)	(-5.34)	(-3.16)	(2.23)	(2.93)	(4.77)
Sale growth	0.725	0.713	0.104	0.00665	-0.0162*	0.0666
	(0.43)	(0.43)	(1.42)	(1.36)	(-1.67)	(1.10)
Liquidity	-1.871	-1.893	0.0418	0.00523	-0.0172	0.0348
	(-1.21)	(-1.22)	(1.38)	(0.83)	(-1.61)	(0.78)
Leverage	73.04***	73.70***	1.987***	-0.0684	0.125	0.814**
	(3.78)	(3.81)	(5.97)	(-1.21)	(1.59)	(2.39)
Cash flow volatility	-58.51***	-58.71***	-0.163	-0.130	0.266*	-0.250
	(-2.78)	(-2.79)	(-0.33)	(-1.13)	(1.70)	(-0.46)
Term spread	12.20***	12.31***	0.0487	-0.00273	-0.0291	-0.0895
	(2.60)	(2.62)	(0.50)	(-0.16)	(-0.77)	(-0.58)
Credit spread	39.66**	40.00**	-0.0567	-0.0820*	-0.129*	-0.0863

	(2.09)	(2.11)	(-0.20)	(-1.72)	(-1.75)	(-0.24)
Collateral	63.47***	63.35***		0.0274		2.587***
	(12.25)	(12.24)		(1.40)		(16.94)
Maturity	-3.093	-2.990	0.125		0.268***	0.0781
	(-0.59)	(-0.57)	(1.37)		(7.62)	(0.61)
Amount	-17.07***	-17.19***	-0.123***	0.0648***		0.0901
	(-7.25)	(-7.29)	(-2.58)	(7.82)		(1.45)
Syndication	8.102	8.109	-0.350*	0.139***	0.569***	1.835***
	(1.01)	(1.01)	(-1.94)	(4.28)	(9.61)	(9.36)
Performance pricing	-46.07***	-46.03***	0.733***	0.0680***	0.281***	3.454***
	(-9.62)	(-9.62)	(7.21)	(3.92)	(7.72)	(20.40)
Loan type FE	Yes	Yes	Yes	Yes	Yes	Yes
Loan purpose FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
N	4108	4108	4534	4639	4639	4639
adj. R-sq	0.480	0.481		0.585	0.728	0.523
pseudo R-sq			0.285			

Appendix: variable definition

VARIABLES	**Definition**
Loan characteristics	
Spread	the amount the borrower pays in basis points over LIBOR or LIBOR equivalent for each dollar drawn down
Collateral	dummy variable equals one if the loan facility is secured by collateral and zero otherwise
Maturity	natural log of loan maturity in number of month
Amount	natural log of loan amount in millions of dollar
Syndication	dummy variable equals one if the loan is syndicated and zero otherwise
Performance pricing	dummy variable equals one if the loan facility is performance priced and zero otherwise
Covenant	total number of financial and general covenant
Borrower characteristics	
Size	natural log of total assets
BM	Book-to-market ratio
Tangibility	property, plant and equipment over total assets
Profitability	EBITDA over total assets
Sale growth	annual growth rate of total sale
Liquidity	current assets over current liabilities
Leverage	total liabilities over total assets
Cash flow volatility	ratio of standard deviation of quarterly cash flows from operations over the four fiscal years prior to loan initiation year to total debt
Macroeconomic factors	
Term spread	interest rate spread between 11-yr treasury bond and fed funds
Credit spread	interest rate spread between moody BAA and AAA corporate bond
Ratings	
Customer rating	sale weighted average customer credit rating, as defined in equation (1)
Customer investment grade	dummy variable equals 1 if the average customer credit rating is above or equal to investment grade (BBB-, or 14) and zero otherwise
Customer upgrade	dummy variable equals one if for certain supplier-year observation, one or more reported customer from experienced rating upgrade, and zero otherwise
Customer downgrade	dummy variable equals one if for certain supplier-year observation, one or more reported customer from experienced rating downgrade, and zero otherwise

Customer both	dummy variable equals one if both Customer upgrade and Customer downgrade equals one and zero otherwise
Customer either	dummy variable equals one if either Customer upgrade and Customer downgrade equals one and zero otherwise
Customer rating change	sale weighted average customer credit rating change
Supplier rating	supplier (borrower) credit rating
Customer of customer rating	sale weighted average customer of customer credit rating, as defined in equation (1)
Customer of customer investment grade	dummy variable equals 1 if the average customer of customer credit rating is above or equal to investment grade (BBB-, or 14) and zero otherwise
Customer peer rating	sale weighted average customer peer credit rating, as defined in equation (1)
Customer peer investment grade	dummy variable equals 1 if the average customer peer credit rating is above or equal to investment grade (BBB-, or 14) and zero otherwise
Supply chain network characteristics	
Concentration_sale	the sum of the percentage sale to the customers that are identified as major customer
Concentration_size	*Concentration_sale* weighted by customer size
Concentration_HHI	Herfindahl index of sale to large customers
Concentration_max	the percentage of sale the supplier assigns to its largest customer
Relative size	sale weighted average size of the customers over size of supplier where size is natural log of total assets
Relative size original	sale weighted average size of the customers over size of supplier where size is original level of total assets
Customer profitablity	sale weighted average of customer return on assets
Customer AP	sale weighted average of customer total accounts payable over total cost of good sold
Eigenvector centrality	the eigenvector corresponding to the largest eigenvalue of the graph adjacency matrix
Degree centrality	number of edges connecting to each node in supply chain network
Closeness centrality	the inverse sum of the distance from a node to all other nodes in the graph
Betweenness centrality	the number of shortest paths between all nodes that pass through certain node over total number of shortest paths between all nodes
Upstreamness	the shortest distance a firm's product need to travel to reach general consumers, definition following Gofman and Wu (2022)