Network Centrality of Customers and Suppliers*

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Abstract

We construct network centrality measures for customer and supplier industries in the U.S. economy. Consistent with Ahern, et al. (2014), we find central suppliers have higher levels of systematic risk than central customers and therefore more exposed to sectoral shocks. We posit that central suppliers have incentives to channel funds to their customers via trade credit. Our empirical results are consistent with such a view. We find that the cash to cashflow sensitivity and value of cash is significantly higher for central suppliers than non-central firms, even among those financially unconstrained. In contrast, central customers have no cash to cash flow sensitivity, consistent with supplier trade credit redistribution helping to relieve customers' financial constraints. Using the 2008 financial crisis as an exogenous shock, we document that central suppliers with high pre-crisis liquidity decrease their investment, while only customers without central suppliers are sensitive to the crisis. Similarly, only customers without central suppliers are sensitive in their payable days to the crisis.

Keywords: BEA Input-Output, Network Centrality, Customer-Supplier Relationship, Value of Cash, Investment

JEL classification: G30, G32, L10, L12

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1 Introduction

The recent financial crisis highlights the need to understand how shocks propagate through the economy and market. One firm or industry can have cascading effects on the policies and performance of other firms within its network or industry. Giroud and Mueller (2010) show that exogenous shocks to corporate governance have differential impact on competitive versus non-competitive industries. Acemoglu et al. (2012) suggest that the interconnections between firms and sectors act as a propagation mechanism of idiosyncratic shocks throughout the economy. Such cascading effects were used as main arguments for the recent bailout of the major U.S. automakers (Mulally, 2008) and several large financial institutions.

In addition, there is an extensive body of research examining how customer-supplier relationships affect supplier's investment and financing policies and firm performance. Maksimovic and Titman (1991) argue that customers are reluctant to do business with suppliers facing financial distress. Kale and Shahrur (2007) show that firms lower leverage as a commitment mechanism to induce suppliers/customers to make relationship-specific investments. Hertzel et al. (2008) document that buyer bankruptcy filings significantly impact suppliers that have relationships with them. Kelly, Lustig, and Nieuwerburgh (2013) model how customer-supplier relatedness and size distribution of customers affect supplier risk. Murfin and Njoroge (2014) show that large, highly rated retailers finance themselves off the back of smaller, weaker vendors. They document that an adverse shock of bank financing to suppliers result in the cutback of investments by suppliers in order to continue trade credit financing to their customers.

In this study, we examine customer and supplier networks and the relationship between network centrality and firm financing and investment decisions. Using input-output (IO) data from the Bureau of Economic Analysis (BEA), we develop separate industry-specific degree centrality measures for supplier industries and customer industries. Degree centrality measures the number of relationships for a given node within the network. In the context of

input-output, for a node that constitutes a supplier industry, its degree centrality records the number of customer industries that order inventory and raw materials from this supplier. Following Ahern and Harford (2014), we count the number of links between significant industry pairs using a one percent threshold.[1]

First, we explore the relationship between network centrality and firm performance by constructing equal and value weighted monthly portfolios of excess returns for firms in non-central industries, central customer industries, and central supplier industries. We find that firms operating in central supplier industries have significantly more systematic risk than non-central firms using both equal-weighted and value-weighted portfolios. This finding is consistent with Ahern (2013), who finds that firms in central industries earn higher stock returns due to having greater exposure to market risk over firms in non-central industries. In contrast, firms operating in central customer industries have less systematic risk than non-central firms, significantly so using equal-weighted portfolios. In fact, a zero-cost portfolio long on central suppliers and short on central customers result in a positive and significant beta on excess market returns. This suggests that the relationship between network centrality and risks and returns differs for customers and suppliers.

Acemoglu et al. (2012) and Ahern (2013) reason that the positive relationship between network centrality and returns is due to greater exposure to sectoral shocks that are passed through central industries. This implies that central suppliers are more exposed to sectoral shocks while central customers are either not exposed to the shocks or, despite being exposed, are finding ways to mitigate these shocks. Murfin and Njoroge (2014) document that smaller vendors finance larger retailers by providing trade credit, even to the detriment of their own investments. It is possible that central suppliers are providing financing to customers (more intensely due to being central than non-central suppliers), thereby amplifying their own exposure to market risk and mitigating that of the customers. This suggests that central suppliers have stronger precautionary motives to save cash than non-central firms or central

[1] A customer-supplier pair is viewed as a significant pair if the supplier sells at least 1% of its output to this customer or if the customer orders at least 1% of its input from this supplier.

customers. To test this idea, we measure the cash to cashflow sensitivity measure proposed by Almeida, Campello, and Weisbach (2004) for non-central firms, central customers, and central suppliers. In addition, within each group, we further sort firms into those that have a S&P long-term credit rating and those that don't. This proxies for firms' access to the debt market and acts as a proxy for financial constraints.

For firms in non-central industries and central supplier industries, we find that constrained firms will have a strong (positive and significant) propensity to save cash out of cashflow, while unconstrained firms will not, consistent with the findings in Almeida, Campello, and Weisbach (2004). However, for firms in central customer industries, neither constrained nor unconstrained firms exhibit any propensity to save cash out of cashflow. In fact, when interacting centrality dummies with cashflow, we find that for suppliers, being central leads to a positive propensity to save cash out of cashflow for unconstrained firms that is larger than for constrained firms (albeit insignificant). These findings are consistent with the idea that central suppliers may be channeling funds via trade credit given to their customers by saving cash out of cashflow, which may be more prevalent when they are unconstrained.

Next, we explore the cash to cashflow sensitivity implications by studying the value of cash for firms in non-central, central customer, and central supplier industries. Faulkender and Wang (2006) find that financially constrained firms have a higher marginal value to cash holding than unconstrained firms and Denis and Sibilkov (2010) show that this is due to a stronger relationship between investment and cash holdings, allowing constrained firms to invest when they otherwise cannot. In other words, the higher value of cash comes from being able to use the cash towards value-enhancing investments rather than towards value-destroying investments or less valuable distribution of cash to shareholders (due to taxes) as firms with more than the optimal amount of cash is expected to do. To test whether the higher cash to cashflow sensitivity of central supplier firms is value-enhancing, we run the Faulkender and Wang (2006) marginal value of cash model for non-central firms, central

customers, and central suppliers.

We confirm the Faulkender and Wang (2006) result that financially constrained firms have higher marginal values of cash than unconstrained firms. We find this relationship to hold across all three sub-samples: firms in non-central, central customer, and central supplier industries. However, central supplier firms that are unconstrained have significantly higher value of cash relative to non-central firms that are unconstrained. Together with the higher propensity to save cash out of cashflow, this suggests that central suppliers consistently have a propensity to save cash out of cashflow due to having more valuable uses for their cash regardless of their financial constraint status. One possible explanation of these results is that central suppliers use their cash to maintain close and valuable relationships with their customers by providing trade credit.

To study the idea that central suppliers may be providing trade credit to their customers, we employ the financial crisis as an exogenous shock to the supply of capital. Duchin, Ozbas, and Sensoy (2010) find that firms lower investments during the financial crisis due to being financially constrained. However, having higher levels of pre-crisis liquidity, namely pre-crisis cash holdings, helps to alleviate constraints during the crisis and allow firms to invest. Following this framework, we study the change in investment during the crisis for firms in non-central, central customer, and central supplier industries. We obtain the Duchin, Ozbas, and Sensoy (2010) findings that pre-crisis liquidity leads to higher investment during crisis for non-central firms and central customers. However, for central suppliers, the crisis appears to have no impact on firm investment.

This result can be interpreted in two ways. First, it may be the case that central suppliers are so liquid that the crisis has no impact and central suppliers will continue to invest at high levels. This is hard to believe given the severity of the crisis and given that the general levels of investments between central suppliers and non-central firms are not statistically different. It does not appear that the liquidity results in central suppliers investing more than non-central firms (in the level). Second, it may be the case that during the crisis, central

suppliers that have more liquidity are channeling that liquidity to their central customers, thereby not using it towards their own investment. We find some evidence in support of this interpretation. We find that compared to non-central firms and compared to central customers, central suppliers that have higher cash holdings prior to crisis invest significantly less, rather than more, during the crisis. Finally, we build a sample of supplier-customer paired firms, using the customer segment database. We find that customer investments are sensitive to their own pre-crisis liquidity when customers have non-central suppliers, but are not sensitive to their own pre-crisis liquidity when they have central suppliers. Similarly, customer payable days are sensitive to their own pre-crisis liquidity when customers have non-central suppliers, but are not when they have central suppliers. Altogether, there results suggest that central suppliers mitigate risks for their customers by providing funds via trade credit.

To the best of our knowledge, our study is the first to examine separate network centrality measures for customer and supplier industries and for firms' financing and investment decisions. Network centrality measures using the BEA input-output table have gained use in recent research (e.g., Ahern, 2012; Ahern, 2013; Ahern and Hartford, 2014; Aobdia, Caskey, and Ozel, 2014; Gao, 2014). Using this data, Ahern (2012) documents that the division of vertical merger gains between target and acquirer depend on the bargaining power between the two sides. One of the important determinants of such bargaining power is the purchase relationship between target and acquirer when each party acts as suppliers and customers. Viewing an economy as a network of suppliers and customers, Ahern and Harford (2014) show that the average industry merges with a small set of local industries that are linked through customer-supplier relationships. Additionally, they find that mergers in related industries (industries that have trading relationships) strongly predicts an industry's own merger activity, suggesting that mergers propagate across the industry network.

We also contribute to the literature on supplier-customer relationship in the context of systematic risk, propensity to save cash, and the value of cash. Ahern (2013) finds a positive

relationship between returns and network centrality, suggesting that sectoral shocks pass more through central networks leading them to more exposure to systematic risk. We show that the role of the firm in the product market matters. Central suppliers experience higher systematic risk while central customers do not. Furthermore, the established relationship between financial constraints and cash to cashflow sensitivity as well as financial constraints and marginal value of cash no longer holds when considering central suppliers, suggesting that central suppliers have a stronger precautionary motive to save cash out of cashflow and higher marginal value of cash, even when unconstrained. Using a retail setting, Murfin and Njoroge (2014) show that smaller suppliers channel funds via trade credit to their large, investment-grade customers and consequently sacrifice their own growth by cutting back investments. Our research provide some evidence that central suppliers with cash reserves forgo investment and redistribute funds which alleviates customer constraints and promotes customer investment.

2 Related Literature and Hypotheses Development

In this section, we discuss related literature and use existing research to guide the development of our hypotheses.

2.1 The Product Market as a Network

Ahern (2012) examines the division of merger gains between target and acquirer from the lens of the product market relationship between them. When the target and acquirer serve as customer and supplier to each other, Ahern (2012) shows that the dependence of a customer on a supplier's input and the significance of the purchase of a customer to a supplier's total sales are important factors in the division of merger gains in a vertical merger. Ahern and Harford (2014) document that the average industry merges with a small set of local industries that are linked through customer-supplier relationships and the structure of the merger

network is very similar to the structure of the product market network. Additionally, they find that mergers in related industries (industries that have trading relationships) strongly predicts an industry's own merger activity, suggesting that mergers propagate across the industry network.

2.2 Supplier-Customer Relationship and Corporate Decisions

An extensive body of literature has explored how the relationship between supplier and customers affect their investment and financial policies. For example, Maksimovic and Titman (1991) argue that customers are reluctant to do business with suppliers facing financial distress. Kale and Shahrur (2007) show that firms lower leverage as a commitment mechanism to induce suppliers/customers to make relationship-specific investments. Hertzel et al. (2008) document that buyer bankruptcy filings significantly impact suppliers that have relationships with them. Kelly, Lustig, and Nieuwerburgh (2013) model how customer-supplier relatedness and size distribution of customers affect supplier risk. Garcia-Appendini and Montoriol-Garriga (2013) show that cash rich suppliers are able to channel liquidity to their customers when the economy was stricken by a supply shock of credit. Itzkowitz (2013) shows that suppliers that have principle customer relationships save cash for precautionary motives. Murfin and Njoroge (2014) show that large, highly rated retailers finance themselves off the back of smaller, weaker vendors. Building on extant research on customer-supplier relationships, we focus on the role of the network structure of the customer and supplier industries on firms systematic risk exposure, cash holding, value of cash, and investment decisions.

2.3 Hypotheses

Building on extant literature on economic network and the impact of interaction between supplier and customer on firms' cash holding, leverage and investment decision, we develop three main hypotheses.

First, as shown in Acemoglu et al. (2012), idiosyncratic shocks can be aggregated into economy wide fluctuations through the interconnections of the supplier and customers. As central suppliers, by definition, are linked to many important customers, a negative shock to an important customer would have significant adverse impact on a supplier's financial health. Furthermore, Murfin and Njoroge (2014) show that suppliers provide credit to customers even when customers have easy access to external capital. This suggests that when a shock occurs, central suppliers are both adversely affected by the shock due to more exposure to the network as well as having to provide financial support for customers. This suggests that central suppliers may be mitigating systematic risks for central customers. Formally, we state our first hypothesis as follows:

Hypothesis 1. *Central customer (suppliers) industries have lower (higher) systematic risks than noncentral industries.*

Next, we postulate that the network effect will be reflected in firms' cash holdings polices. Given that central suppliers need to provide financing or trade credit to customers, we expect central suppliers to have a greater tendency to save cash out of cashflows than non-central firms and central customers. Vice versa, central customers are likely to be on the benefiting end of this relationship. As such, we expected central customers to have a lower tendency to save cash out of cashflow. In the same vein, since central suppliers channel funds to their customers in order to maintain close and valuable relationships, rather than distribute funds to shareholders (that incur tax costs), we expect cash to be more valuable to central suppliers than for non-central firms and central customers. As such, our second hypothesis is as follows:

Hypothesis 2. *Central suppliers (customers) have a higher (lower) propensity to save cash out of cashflows, due to having higher (lower) marginal value of cash.*

Finally, we expect this cash policy to have a real impact on investment. We postulate that central suppliers will have lower investment during a systematic capital supply shock due to

being more impacted and having to provide support and alleviation of financial constraints for their customers, as discussed above. As such, our third hypothesis states:

Hypothesis 3. *During a systematic financial shock (such as the financial crisis of 2008), central suppliers (customers) will see lower (higher) investment due to providing (receiving) financial support.*

We test each of the three hypotheses in the sections below.

3 Data

3.1 Network Centrality

Our network centrality measures are calculated using data from the Bureau of Economic Analysis (BEA) Benchmark Input-Output (IO) table. The Benchmark Input-Output (IO) table records trade flows between producers and purchasers in the U.S. economy. Producers include all industrial sectors and household production and purchasers include industrial sectors, households, and government entities. BEA provides updated tables every five years, with 2007 being the most recent. In this study, we use the 1997 BEA table in the main analysis. For robustness, we create a time-series for the network centrality measures by using all available BEA data (1992, 1997, 2002, and 2007).[2] Following existing literature, we exclude government, special industries, value added, and final users (IO code starting with letters S,V, or F).

Ahern and Harford (2014) view an economy as a network of suppliers and customers. The concept of network centrality is designed to capture the relative importance of a node or an edge in a graph. Graph theory is especially well-suited for studying firms in various industries by treating each industry as a node in a network and establishing the interconnection between

[2]Ahern and Harford (2014) report that customer-supplier relations remain stable over the 1982 to 2002 period. Our results are similar. However, the 2007 BEA input output data reports a significant reduction in the number of IO industries.

industries using the trade flow data from BEA. There are various network measures including degree centrality, eigenvector centrality, clustering coefficient, and closeness coefficient. Here we choose to focus on degree centrality and eigenvector centrality because they are most suited for analyzing how shocks propagate through an economic network and its impact on firm policies (Ahern and Harford, 2014).[3]

3.2 Degree Centrality

Degree centrality measures the number of links for a given node within a network. We follow Fan and Goyal (2006), Ahern (2012), and Ahern and Harford (2014) by identifying customer-supplier pairs with a substantial relationship. A relationship is defined to be substantial if either the customer industry buys at least 1% of its input from the supplier industry or if the supplier industry sells at least 1% of its output to the customer industry. For example, if supplier S1 has three customers, C1, C2, and C3, with orders of 2%, 3%, and 0.9% of its input from S1, respectively, then our measure of supplier degree centrality for S1 is 2. Higher values of degree centrality indicate that the supplier industry is connected to more substantial customers and therefore exposed to more sectorial shocks.

3.3 Eigenvector Centrality

To illustrate the construction of the eigenvector centrality measures, we use the customer industry. We first construct an adjacency matrix (A) using the ratio of the dollar purchase made by a customer from a specific supplier to its total purchases from all its suppliers. Formally, eigenvector centrality of node i is c_i defined in Equation (1) below for all other nodes $j \neq i$:

$$c_i = \frac{1}{\lambda} \sum_{j \in M(i)} c_j = \frac{1}{\lambda} \sum_{j=1}^{N} A_{ij} c_j \tag{1}$$

[3]See also Borgatti (2005) for demonstration of how these two centrality measures capture a flow process across a network that allow a shock to spread in two different directions at the same time.

where M(i) is the set of nodes that are connected to node i and is a constant. In a matrix notation,

$$Ac = \lambda c.$$

Here, c is the principal eigenvector of the adjacency matrix. High c indicates this node (industry) is well connected with its suppliers and its trading partners are themselves also well connected. Having calculated the eigenvector centrality measure for customer industries, we repeat the procedure to obtain our eigenvector centrality measure for supplier industries.

Our sample contains 481 unique I-O industries at the detailed level with unique degree and eigenvector centrality measures for our supplier and customer industries, respectively.[4] Table I reports the top ten central customer and supplier industries based on the degree centrality and Table II reports the summary statistics for our centrality measures.

3.4 Financial Statement and Market Returns Data

Next, we merge the customer and supplier eigenvector centrality measures with financial statement data by industry. We obtain corporate financial statement data from Standard & Poor's Compustat North American annual database from 1985 to 2013. All dollar amounts are deflated to 2000 dollars using CPI to adjust for inflation. We remove any firms with negative book asset value, market equity, book equity, capital stock, sales, dividends, debt, and inventory. Such firms have either unreliable Compustat data or are likely to be distressed or severely unprofitable. In addition, we delete observations in which book assets or sales growth over the quarter is greater than 1 or less than -1 and remove firms worth less than $5 million in 2000 dollars in book value or market value to remove observations that have abnormally large changes due to acquisitions or small asset bases. Next, we remove outliers defined as firm-quarter observations that are in the first and 99th percentile tails for all relevant variables used in our analysis. Following standard practice in the literature, we

[4]For robustness, we repeat our analysis using the BEA I-O industries at the summary level consisting of 124 industries and document similar results.

remove all firms in the financial and insurance, utilities, and public administration industries as they tend to be heavily regulated. In merging our network centrality measures with Compustat, we use the reported primary segment North American Industry Classification System (NAICS) code.[5] The resulting dataset consists of 116,119 firm-year observations between 1985 and 2013.

Table II presents the summary statistics for basic firm characteristics. Panel A includes all firms in industries with non-missing centrality measures. Panel B presents the summary statistics for all firms in non-central industries. These are industries that are neither a central customer nor a central supplier. Panel C report the summary statistics for all firms in industries classified as central customers (hereafter referred to as central customers for simplicity) and Panel D for all firms in industries classified as central suppliers (hereafter referred to as central suppliers for simplicity). Industries are classified as central customers if they have a customer eigenvector centrality measuring in the 10% of all customer eigenvector centralities. Similarly, industries are classified as central suppliers if they have a supplier eigenvector centrality measuring in the 10% of all supplier eigenvector centralities.

In Table III, we perform a t-test of means on the average firm characteristics and portfolio returns between non-central firms, central customers, and central suppliers. We examine the difference between central customers and non-central firms, central suppliers and non-central firms, and central suppliers and central customers. Panel A reports the firm characteristics explored in Table II. On average, both central customers and central suppliers are significantly larger, have more debt, more likely to have long-term credit rating, and hold less cash than non-central firms. In other words, firms in central industries appear to be financially stronger than firms in non-central industries. However, on average, central customers are significantly larger, have more long-term debt, are more likely to have credit ratings, and hold less cash than central suppliers.

[5]For robustness, we also constructed weighted average eigenvector centrality using NAICS from all reported Compustat business segments.

Finally, we collect monthly returns, prices, and market factors from the Center for Research in Security Prices (CRSP) database from 1985 to 2013 for all firms in our sample. Panel B of Table III runs the t-test of means on average returns. We form monthly portfolios of firms in non-central industries, firms in central customer industries, and firms in central supplier industries and calculate the equal-weighted and value-weighted portfolio returns. On average, central customers have returns statistically smaller than both the non-central firms and the central suppliers. On the other hand, the returns for the central suppliers are not statistically different on average from the non-central firms. This means that central suppliers have statistically higher returns than central customers. Overall, the t-test of means on the firm characteristics and returns suggest that central customer industries are different than central supplier industries and motivates our research question.

4 Results

4.1 Centrality and Systematic Risk

First, we study the relationship between network centrality and firm performance by examining whether central customers and central suppliers have different exposures to systematic risk. To do so, we create monthly equal-weighted and value-weighted portfolios for non-central firms, central customers, and central suppliers. We run the CAPM model on the portfolio excess returns:

$$r_{p,t} - r_{f,t} = \alpha + \beta(r_{m,t} - r_{f,t}) \tag{2}$$

where r_p is the monthly portfolio returns, r_f is the return on the riskfree asset, proxied by the 1-month Treasury, and r_m is the return on the market portfolio, proxied by the S&P500 index.

Table IV reports the findings. Panel A present the results using equal-weighted excess

portfolio returns. Non-central firms have a beta of 1.088, while central customers have a beta of 1.008 and central suppliers have a beta of 1.319. Using a zero-cost portfolio of central customers minus non-central firms, we obtain a negative beta of -0.079. This suggests that central customers have significantly less systematic risk than non-central firms, accounting for their lower observed returns in Panel B of Table III. In contrast, a zero-cost portfolio of central suppliers minus non-central firms obtain a positive beta of 0.233 and a zero-cost portfolio of central suppliers minus central customers result in a positive beta of 0.312. In other words, central suppliers have significantly more exposure to systematic risk than both non-central firms and central suppliers. These results are corroborated in Panel B using value-weighted excess portfolio returns where central suppliers are statistically more exposed to systematic risk than non-central firms and central customers. These findings are consistent with Hypothesis 1 and suggest that centrality plays different roles for customers and suppliers. Specifically, centrality mitigates systematic risk exposure for customers but amplifies systematic risk exposure for suppliers.

4.2 Centrality and Cash to Cashflow Sensitivities

One possibility that central suppliers have more systematic risk than central customers may be that central suppliers are providing additional benefits, such as financing or trade credit, to their customers, thereby amplifying their own risks and mitigating the systematic risk of customers during bad times. To explore that possibility, we examine managerial decision to save cash out of cashflow for non-central firms, central customers, and central suppliers following the cash-to-cashflow sensitivity analysis introduced by Almeida, Campello, and Weisbach (2004):

$$\Delta Cash/TA = \beta_0 + \beta_1 CF/TA + \beta_2 MtB + \beta_3 LgTA \tag{3}$$

where Cash/TA is the ratio of cash to total assets, CF/TA is the ratio of cashflow to total assets, MtB is the ratio of market value to book value, and LgTA is the natural log of total assets.

Table V reports the cash-to-cashflow sensitivities. Almeida, Campello, and Weisbach (2004) show that financially constrained firms save more cash out of cashflow. Similar to Almeida, Campello, and Weisbach (2004), we use a dummy variable for having a S&P long-term debt credit rating to proxy for financial constraints.[6] In columns (1) and (2), we compare firms in non-central industries without a long-term debt credit rating to those with a credit rating, respectively. As expected, financially constrained firms are significantly sensitive to saving cash out of cashflow, as evidenced by the positive and significant coefficient of 0.034 in column (1). In contrast, unconstrained firms in column (2) are not sensitive to saving cash out of cashflow. However, when we turn to firms in central customer industries in columns (3) and (4), we find that regardless of having a credit rating, both constrained and unconstrained firms do not save cash out of cashflow with insignificant coefficients of 0.006 and -0.004, respectively. In other words, regardless of financial constraint status, central customers act as if they are unconstrained. This is consistent with the interpretation that their constraints are being alleviated elsewhere, potentially by their suppliers in the form of financing or trade credits. Finally, firms in central supplier industries behave consistently with saving cash out of cashflow when constrained as observed in columns (5) and (6).

In columns (7) through (12) of Table V, we compare whether the cash to cashflow sensitivities are significantly different across firms in non-central, central customer, and central supplier industries by including interactions terms between cashflow and centrality dummies. The CenCustvNC dummy is set to one if a firm is in a central customer industry and zero if it is neither central customer nor central supplier. Interacting CenCustvNC with cashflow allows us to capture the additional impact of being a central customer on the cash

[6]For robustness, we also use the Whited and Wu (2006) index as well as the Hadloack and Pierce (2010) size-age index to proxy for financial constraints.

to cashow sensitivity relative to non-central firms. The CenSuppvNC dummy is set to one if a firm is in a central supplier industry and zero if it is neither central customer nor central supplier. Interacting CenSuppvNC with Cashflow allows us to capture the additional impact of being a central supplier on the cash to cashow sensitivity relative to non-central firms. Finally, the CenSuppvCenCust dummy is set to one if a firm is in a central supplier industry and zero if it is in a central customer industry. Interacting CenSuppvCenCust with cashflow allows us to capture the differential impact of being a central supplier relative to being a central customer on the cash to cashow sensitivity.

We see that in column (7), as before, non-central firms behave consistently with constrained firms saving cash out of cashflow with a positive and significant coefficient on cashflow to assets of 0.034. In contrast, the interaction between being a central customer and cashflow (CenCust x CF / TA) is negative and significant (-0.025), confirming that being a central customer significantly reduces precautionary cash savings behavior relative to a non-central firm among constrained firms. For unconstrained firms in column (8), neither groups significantly save cash out of cashflow, as expected. We find that among constrained firms in column (9), being a central supplier does not differentially impact the tendency to save cash out of cashflow from non-central firms (CenSupp x CF / TA). Interestingly, for unconstrained firms in column (10), although insignificant, the magnitude on the interaction term is 0.023. This suggests that there may be, albeit weak or insignificant, incentives for even unconstrained central suppliers to save cash out of cashflow. In column (11), we confirm that a central supplier saves significantly more cash out of cashflow than central customers among constrained firms (CenSuppvCenCust x CF / TA). Again, in column (12), although insignificant, the magnitude of the interaction term between central suppliers versus central customers and cashflow is larger for unconstrained firms than for constrained firms in column (11) (0.027 versus 0.021), suggestive of incentives for even unconstrained central suppliers to save cash out of cashflow. This is consistent with the view that central suppliers may channel funds via trade credit to their customers.

4.3 Centrality and the Value of Cash

Faulkender and Wang (2006) find that cash holdings are more valuable for financially constrained firms and Denis and Sibilkov (2010) show that this is due to greater cash holdings being associated with higher levels of investments, with this relationship being stronger for constrained firms than unconstrained firms. To explore the possibility that central suppliers are constantly saving cash out of cashflow in order to invest, and therefore produce, we following the Faulkender and Wang (2006) procedure to examine the value of cash holdings for non-central firms, central customers, and central suppliers:

$$R_{i,t}-R_{b,t} = \beta_0+\beta_1 dC_{i,t}+\beta_2 dE_{i,t}+\beta_3 dNA_{i,t}+\beta_4 dRD_{i,t}+\beta_5 dI_{i,t}+\beta_6 dD_{i,t}+\beta_7 lC_{i,t}+\beta_8 L_{i,t}+\beta_9 NF_{i,t} \quad (4)$$

where R_i is the annualized firm returns, R_b is the annualized return on Fama-French 25 size-age benchmark portfolio, dC is the change in cash holdings, dE is the change in earnings, dNA is the change in net assets defined as total assets net of cash, dRD is the change in research and development expense, dI is the change in investment, dD is the change in dividends, lC is the one year lagged cash holdings (i.e., $C_{i,t-1}$), L is the leverage level, and NF is net financing defined as net equity issuance plus net debt issuance. Following Faulkender and Wang (2006), all right hand side variables are deflated using lagged market values.

Table VI presents the results. Columns (1), (3), and (5) show that for each dollar of additional cash holdings, firm value increase by 1.005, 0.919, and 0.931 dollars for non-central firms, central customers, and central suppliers that are financially constrained, respectively. As expected, for financially unconstrained firms, the value of cash is lower across all three groups of firms in columns (2), (4), and (6) with firm value increase of 0.824, 0.859, and 0.917 for each additional dollar of cash holding, respectively. That is, among constrained firms, non-central firms have the highest value of cash, while among unconstrained firms, central suppliers have the highest value of cash. The findings are consistent with the view that central suppliers channel funds to their customers even if their customers are larger in

size and are not financially constrained (Murfin and Njoroge, 2014). Consequently, central suppliers act more like constrained firms and holding cash is more valuable.

As before, in columns (7) through (12), we include dummy and interaction terms to capture the effect of centrality on the value of cash. In columns (7) and (8), the results show that while being a central customer increases future abnormal returns (0.021, significant at the 10% level in column (7), and 0.031, significant at the 5% level in column (8)), the value of cash is not statistically different than firms in non-central industries. However, in columns (9) and (10), the value of cash for central suppliers is not statistically significant from non-central firms for constrained firms, but significantly higher (at the 10% level) with an interaction term of 0.134 for unconstrained central suppliers relative to unconstrained non-central firms.[7] This suggests that even with unconstrained access to financing, central suppliers are finding productive and valuable uses for cash, rather than less valuable uses such as being distributed back to shareholders.[8] This suggests that central suppliers have seemingly inexhaustible opportunities for valuable use of cash. While it is difficult to imagine a firm with unlimited valuable investment opportunities, it is more reasonable to consider that central suppliers are channeling funds to their customers, allowing valuable investment and relationships to continue. Given this, our results are consistent with the findings in Murfin and Njoroge (2014).

5 Centrality During Crisis

To explore the idea that central suppliers mitigate risks for customers by providing funds and trade credit, we employ the recent financial crisis as an exogenous financial shock. Employing the framework in Duchin, Ozbas, and Sensoy (2010), we study the change in investment during the crisis for firms in non-central, central customer, and central supplier

[7]We find significant higher cash holdings for central supplier firms than non central firms when both are financially constrained, suggesting that holding cash is more valuable.

[8]Faulkender and Wang (2006) argue that when a firm more cash than optimal, it will exhaust valuable investment opportunities and start to channel funds back to investors which incur tax costs that reduce the value of cash.

industries.

5.1 Centrality and Investment

Duchin, Ozbas, and Sensoy (2010) find that while the crisis decreased investment, having higher liquidity in the form of cash holdings prior to the crisis of 2008 allows a firm to overcome the financial constraints during the crisis and continue to invest. We follow their setup by defining the financial crisis to cover the periods starting the 3rd quarter of 2007 through the 2nd quarter of 2008 (isCrisis). We define prior cash holdings as the cash holdings of the firm one year prior to the crisis at the 2nd quarter of 2006 (using the quarter before that if it is missing). Following Duchin, Ozbas, and Sensoy, we restrict our estimation sample starting the 3rd quarter of 2006 through 2nd quarter of 2008, maintaining one year prior to crisis and one year during the crisis, i.e., maintaining a balanced number of years prior to and during the crisis.

Table VII uses a firm fixed-effects model to estimate the effect of the crisis and pre-crisis liquidity on the change in investment for firms in non-central, central customer, and central suppliers industries, respectively, in columns (1) through (3). For non-central firms, we obtain the Duchin, Ozbas, and Sensoy (2010) results, namely that higher prior cash holdings increase investment during the crisis period. Similarly, for central customers, while the crisis significantly reduced investment, having more prior liquidity allow for increased investment during the crisis. In contrast, for central suppliers, the crisis appears to have no effect on the investment behavior.

There are two interpretations for the central supplier results in column (3) of Table VII. First, given the previous finding that central suppliers appear to be saving more cash out of cashflow than other firms, it may be the situation that estimating on a sample of central suppliers is equivalent to estimating over a sample of liquid firms. In other words, central suppliers are never constrained to the point that the crisis mattered for them. While this is plausible, the constant in column (3) does not appear to be significantly higher than the non-

central firms, as that interpretation would suggest. Second, also given the previous finding of central suppliers saving more cash out of cashflow, we argued that it is possible that central suppliers are channeling funds to their customers. That is, during the crisis, it is possible that any additional liquidity of the central suppliers are being channeling towards alleviating constraints for their customers rather than into investment, leaving their investment behavior unchanged during the crisis.

In order to distinguish these two interpretations, we compare the effect of centrality on the impact of liquidity on investment during the crisis by including dummies and interaction terms in columns (4) through (6) of Table VII. In column (4), we compare central customers to non-central firms and find that central customers invest significantly less (at the 1% level) during crisis than the non-central firms. This finding is consistent with the possibility that these central customers receive less trade credit from their suppliers during the crisis, consequently leading to cutting back of investments. In column (5), we compare central suppliers to non-central firms and find no significant differences in investment during the crisis between central suppliers and non-central firms. However, for central suppliers, having higher cash holdings prior to crisis leads to significantly less, rather than more, investment during crisis. This is consistent with the interpretation that central suppliers with more liquidity are channeling their funds to their customers rather than investment. Finally, in column (6), we compare central suppliers to central customers. We find that central suppliers invest more than central customers during the crisis. However, central suppliers that have more liquidity invest significantly less than central customers, consistent with the results in column (5). This suggests that when central suppliers have larger cash holdings prior to crisis, they invest less than firms in both central customer and non-central industries, despite saving more cash out of cashflow. This is more consistent with the second interpretation that the funds are being used, or channeled, elsewhere.

5.2 Supplier-Customer Paired Sample

While the previous evidence is consistent with the interpretation that central suppliers are mitigating the constraints of customers by offering financing or trade credit, one major limitation is that our sample does not allow us to directly test whether central suppliers are channeling funds via trade credit to *their* customers. To explore these ideas more directly, we construct a paired sample of suppliers and customers in the U.S. from 2006 to 2009, covering the 2007-2008 financial crisis. Information on the firms' principal customers are collected from the Compustat Customer Segment database. In compliance with statement of financial accounting standards No. 14 and 131, U.S. public firms are required to disclose the identify of the amount of sales to customers whose purchases represent more than 10% of the firms' total annual sales. To address the endogeneity concerns, we adopt a difference in difference approach in which we compared customer capital expenditure before and after the onset of the financial crisis as a function of customer centrality, crisis dummy, and pre crisis liquidity. While this sample of customer-supplier pairs allow us to directly test the customer-supplier relationship, it also limits our number of observations.

In Table VIII, we repeat the analysis in Table VII by testing the effect of supplier centrality on customer investment during the crisis using this smaller sample of supplier-customer pairs. In column (1), we estimate the baseline specification with customer investment as the dependent variable among the sample of customers with non-central suppliers. Among customers with non-central suppliers, we find that they are significantly sensitive (at the 10%) to their own pre-crisis liquidity during the crisis. That is, they invest less during the crisis; however, larger pre-crisis cash holdings help cushion the negative impact of the crisis on investment. In column (2), we estimate customer investment among the sample of customers with central suppliers. In contrast to column (1), we find that for these customers with central suppliers, crisis does not appear to have impacted investment and these firms are not sensitive to their own pre-crisis liquidity. This is consistent with the interpretation that their central suppliers are mitigating the adverse effects of the crisis for

these customers and provides stronger evidence of our story.

In columns (3) and (4) of Table VIII, we include the supplier's pre-crisis liquidity as an additional control. One would not expect the pre-crisis liquidity of the supplier to impact customer investment unless the customers were benefiting from this liquidity. Column (3) examines the impact for customers with non-central suppliers and column (4) for customers with central suppliers. While supplier pre-crisis liquidity is not significant in either sub-sample, it is worthwhile to note that the sign and magnitudes of the coefficients are consistent with our story. That is, column (3) reports that non-central suppliers' pre crisis liquidity has a negative impact (although insignificant) on customers' investment during crisis. In contrast, column (4) shows that central suppliers' pre crisis liquidity has a positive impact (again insignificant) on customers' investment during crisis.

5.3 Centrality and Trade Credit

Finally, we examine whether centrality plays a role in the customer's availability of trade credit. Using the supplier-customer paired sample described above, we track the change in log of customer payable days around the financial crisis. Table IX presents the results. In column (1) of the table, we use the entire sample of supplier-customer pairs. The results indicate that customer payable days decrease significantly during the crisis, consistent with suppliers pulling back on offering trade credit during this period of economic difficulty. However, customers with high pre-crisis liquidity are able to increase payable days, significant at 5%, indicating that suppliers extend trade credit to customers that can repay. Likewise, central customers are also able to increase payable days, significant at 10%, consistent with central customers having more bargaining power than non-central customers.

In column (2) of Table IX, we examine the log of customer payable days for only the sub-sample of customers with non-central suppliers. We find results largely consistent with column (1). Specifically, only customers with high pre-crisis liquidity and central customers are able to increase their trade credit during the crisis. Column (3) provides the results for

the sub-sample of customers with central suppliers. In contrast to previous results, customers with central suppliers appears not to be sensitive in their payable days to the crisis. These results are consistent with central customers having more trade credit than non-central customers as well as central suppliers providing trade credit to mitigate systematic risks for customers.

6 Conclusion

This paper examines customer and supplier networks and the relationship between network centrality and firm performance. Using input-output data from the Bureau of Economic Analysis, we develop separate industry-specific degree centrality measures for supplier industries and customer industries and classify firms based on their industries' customer and supplier degree centrality measures as being non-central, central customers, or central suppliers.

First, we explore the relationship between network centrality and firm performance and find that firms operating as central suppliers have more systematic risk than non-central firms, consistent with Ahern (2013), while firms operating as central customers have significantly less systematic risk than non-central firms and central suppliers. This suggests that the relationship between network centrality and risks and returns differs for customers and suppliers. Furthermore, we hypothesize that central customers are more likely to receive trade credit from their suppliers, hence, they are less financially constrained. We find empirical support for this view. Specifically, using framework in Almeida, Campello, and Weisbach (2004), we find that for firms in central customer industries, neither constrained nor unconstrained firms have significant propensity to save cash out of cash flow, consistent with the view that suppliers channel funds to central customers, thereby relieving the financial constraints of their customers. In contrast, we find firms in central supplier industries have significant cash to cashflow sensitivity for both financially constrained as well as

unconstrained firms. This suggests that central supplier firms have a consistent need for cash savings regardless of their ability to obtain external financing.

Next, we examine the value of cash for non-central, central customers, and central suppliers, respectively. We find evidence in support of the view that supplier channel funds to their central customers which in turn lower the value of cash to central customers. Moreover, we document that cash is more value to central supplier than central customer, suggesting that central suppliers have either more valuable investment opportunities or use cash for valuable trade credit redistribution in order to maintain close and valuable business relationships with their clients.

Lastly, to mitigate the concern over endogeneity, we take advantage of the recent financial crisis as an exogenous shock on the supply side of credit provision to examine the change in capital investment for non-central, central customers, and central suppliers respectively. We also conduct a difference in difference test using the paired customer supplier data to test the differential impact of supplier centrality on customers' investment. Our results show that central suppliers with high cash holding pre crisis cut back on their investment during crisis, suggesting that these suppliers may sacrifice their own investment in order to redistribute cash to their customers. Finally, using this same framework, we find that only customers without central suppliers are sensitive in their payable days to the crisis.

Taken altogether, our research documents that centrality in the supplier-customer network has strong implications for performance and financial policies. We join the emerging research that explore the role of industry centrality in corporate finance (Aobdia, Caskey,and Ozel, 2014; Ahern, 2012; Ahern, 2013; Ahern and Hartford, 2014). To the best of our knowledge, our study is the rst to examine separate network centrality measures for customer and supplier industries in the context of cash holdings and trade credit.

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Table I: List of top ten customer and supplier industries by degree centrality. Panel A lists the ten most central customer industries and panel B lists the ten most central supplier industries. Industries are sorted based on their degree centrality.

Panel A: Central Customer Industries

Industry	Centrality Measure
Offices Of Physicians, Dentists, And Other Health Practitioners	72
Telecommunications	85
Food Services And Drinking Places	102
Motor Vehicle Parts Manufacturing	104
Commercial And Institutional Buildings	113
New Residential 1-Unit Structures, Nonfarm	113
Real Estate	118
Hospitals	128
Wholesale Trade	204
Retail Trade	223

Panel B: Central Supplier Industries

Industry	Centrality Measure
Iron And Steel Mills	162
Plastics Plumbing Fixtures And All Other Plastics Products	167
Semiconductors And Related Device Manufacturing	176
Advertising And Related Services	177
All Other Miscellaneous Professional And Technical Services	210
Real Estate	226
Wholesale Trade	247
Power Generation And Supply	287
Monetary Authorities And Depository Credit Intermediation	375
Management Of Companies And Enterprises	423

Table II: Sample statistics of centrality measures and common firm characteristics. Industries are considered central if their centrality measure fall within the top 10%. Panel A reports the summary statistics for all firms in industries with non-missing centrality measures. Panel B reports the statistics for all firms in non-central industries. Panels C and D report the statistics for all firms in central customer industries and central supplier industries, respectively.

Panel A: All firms

	No. Obs	Mean	Std Dev	1%	25%	50%	75%	99%
Customer Degree Centrality	128533	43.114	66.447	2.3	8	13	32	223
Supplier Degree Centrality	128533	34.308	59.792	0	4	10	28.8	247
Customer Eigen Centrality	128533	0.041	0.091	0.002	0.008	0.012	0.023	0.629
Supplier Eigen Centrality	128533	0.048	0.030	0.017	0.029	0.035	0.049	0.125
Ln(Total Assets)	128533	5.284	2.197	1.250	3.644	5.131	6.767	10.616
Book-to-Market Ratio	118269	0.731	0.628	0.077	0.330	0.557	0.913	3.355
Total Debt / TA	128158	0.219	0.191	0.000	0.039	0.194	0.345	0.735
Long-term Debt / TA	128248	0.165	0.172	0.000	0.005	0.120	0.269	0.677
Short-term Debt / TA	128433	0.055	0.092	0.000	0.001	0.017	0.065	0.443
Has LT Debt Rating	128533	0.207	0.405	0.000	0.000	0.000	0.000	1.000
Has ST Debt Rating	128533	0.068	0.252	0.000	0.000	0.000	0.000	1.000
Cash Ratio	128522	0.158	0.193	0.000	0.021	0.080	0.225	0.836
CapX / Sales	124061	0.101	0.192	0.002	0.020	0.040	0.088	1.085
RD / Sales	126584	0.054	0.163	0.000	0.000	0.000	0.040	0.853
Receivables Days	119666	57.7	35.3	2.2	35.8	53.9	73.5	182.8
Payable Days	125093	61.5	71.8	6.6	26.6	42.0	66.6	422.5
Inventory Days	105494	52.8	41.3	1.8	22.5	46.0	71.9	197.7

Panel B: Firms in Non-central Industries

	No. Obs	Mean	Std Dev	1%	25%	50%	75%	99%
Customer Degree Centrality	81284	11.206	6.213	1.9	6.5	9.2	13	25
Supplier Degree Centrality	81284	9.965	8.294	0	4.5	7	13	37
Customer Eigen Centrality	81284	0.015	0.022	0.002	0.007	0.010	0.014	0.129
Supplier Eigen Centrality	81284	0.033	0.011	0.013	0.027	0.031	0.035	0.085
Ln(Total Assets)	81284	5.176	2.212	1.222	3.515	4.963	6.662	10.616
Book-to-Market Ratio	75656	0.703	0.608	0.074	0.314	0.535	0.880	3.250
Total Debt / TA	81026	0.199	0.183	0.000	0.023	0.167	0.320	0.703
Long-term Debt / TA	81092	0.147	0.163	0.000	0.002	0.095	0.243	0.650
Short-term Debt / TA	81208	0.052	0.087	0.000	0.001	0.016	0.063	0.416
Has LT Debt Rating	81284	0.195	0.396	0.000	0.000	0.000	0.000	1.000
Has ST Debt Rating	81284	0.072	0.258	0.000	0.000	0.000	0.000	1.000
Cash Ratio	81278	0.181	0.207	0.000	0.026	0.098	0.266	0.865
CapX / Sales	78803	0.078	0.140	0.002	0.020	0.038	0.076	0.750
RD / Sales	79513	0.074	0.189	0.000	0.000	0.009	0.074	1.094
Receivables Days	77245	62.1	34.0	4.3	40.4	57.6	77.5	181.6
Payable Days	79728	57.3	58.5	7.1	27.7	42.4	65.4	323.8
Inventory Days	68168	57.7	41.7	2.1	28.9	50.4	76.2	206.3

Panel C: Firms in Central Customer Industries Only

	No. Obs	Mean	Std Dev	1%	25%	50%	75%	99%
Customer Degree Centrality	21263	112.989	90.561	32	32	43	223	223
Supplier Degree Centrality	21263	9.358	9.186	0	4	4	16	37
Customer Eigen Centrality	21263	0.077	0.066	0.012	0.012	0.049	0.156	0.156
Supplier Eigen Centrality	21263	0.055	0.028	0.022	0.033	0.044	0.098	0.098
Ln(Total Assets)	21263	5.668	2.179	1.306	4.176	5.588	7.132	10.929
Book-to-Market Ratio	19487	0.785	0.668	0.088	0.360	0.591	0.968	3.612
Total Debt / TA	21216	0.269	0.205	0.000	0.094	0.253	0.406	0.788
Long-term Debt / TA	21226	0.215	0.191	0.000	0.033	0.189	0.340	0.741
Short-term Debt / TA	21253	0.054	0.097	0.000	0.000	0.014	0.059	0.472
Has LT Debt Rating	21263	0.255	0.436	0.000	0.000	0.000	1.000	1.000
Has ST Debt Rating	21263	0.059	0.236	0.000	0.000	0.000	0.000	1.000
Cash Ratio	21259	0.108	0.143	0.000	0.015	0.053	0.145	0.678
CapX / Sales	20171	0.206	0.327	0.002	0.025	0.055	0.217	1.491
RD / Sales	21256	0.003	0.040	0.000	0.000	0.000	0.000	0.061
Receivables Days	18220	44.3	40.9	1.6	10.3	37.2	63.5	196.7
Payable Days	20117	85.5	116.9	5.8	23.8	40.8	82.2	576.5
Inventory Days	15109	41.7	39.4	1.5	9.4	31.0	62.1	170.9

Panel D: Firms in Central Supplier Industries Only

	No. Obs	Mean	Std Dev	1%	25%	50%	75%	99%
Customer Degree Centrality	11110	15.535	7.316	0	9.6	20.7	20.7	23.5
Supplier Degree Centrality	11110	89.500	32.733	42	49.1	102.0	109.7	177
Customer Eigen Centrality	11110	0.013	0.007	0.008	0.008	0.008	0.015	0.033
Supplier Eigen Centrality	11110	0.077	0.033	0.037	0.050	0.074	0.074	0.162
Ln(Total Assets)	11110	5.299	2.104	1.270	3.750	5.190	6.767	10.052
Book-to-Market Ratio	10295	0.775	0.633	0.083	0.361	0.606	0.968	3.343
Total Debt / TA	11067	0.220	0.203	0.000	0.029	0.186	0.345	0.765
Long-term Debt / TA	11076	0.164	0.180	0.000	0.003	0.111	0.263	0.699
Short-term Debt / TA	11101	0.057	0.092	0.000	0.001	0.019	0.068	0.435
Has LT Debt Rating	11110	0.197	0.397	0.000	0.000	0.000	0.000	1.000
Has ST Debt Rating	11110	0.051	0.220	0.000	0.000	0.000	0.000	1.000
Cash Ratio	11110	0.175	0.190	0.000	0.027	0.105	0.262	0.768
CapX / Sales	10754	0.094	0.168	0.002	0.020	0.042	0.088	0.929
RD / Sales	11047	0.064	0.149	0.000	0.000	0.005	0.065	0.659
Receivables Days	10674	57.8	29.1	9.1	42.1	53.3	66.4	194.7
Payable Days	10706	60.0	64.2	6.3	28.4	44.2	66.6	364.8
Inventory Days	9170	55.1	36.9	2.5	32.0	49.2	70.5	191.6

Table III: T-test of means by centrality. Non-central firms denote firms that are in industries with centrality below the top 10% in both customer and supplier. Central customers denote firms in industries with customer centrality measures in the top 10% and supplier centrality measures below the top 10%. Central suppliers denote firms in industries with supplier centrality measures in the 10% and customer centrality measures below the top 10%. Panel A compares the means of common firm characteristics between central and non-central firms. Panel B compares the means of market returns between central and non-central firms. Significance at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Panel A: Firm characteristics

	Non-central Firms (1)	Central Customers (2)	Central Suppliers (3)	Central Cust. - Non-central (4)		Central Supp. - Non-central (5)		Central Supp. - Central Cust. (6)	
Ln(Total Assets)	5.176	5.668	5.299	0.492	***	0.124	***	-0.369	***
Book-to-Market Ratio	0.703	0.785	0.775	0.082	***	0.073	***	-0.009	
Total Debt / TA	0.199	0.269	0.220	0.071	***	0.022	***	-0.049	***
Long-term Debt / TA	0.147	0.215	0.164	0.069	***	0.017	***	-0.052	***
Short-term Debt / TA	0.052	0.054	0.057	0.002	**	0.005	***	0.003	**
Has LT Debt Rating	0.195	0.255	0.197	0.061	***	0.002		-0.059	***
Has ST Debt Rating	0.072	0.059	0.051	-0.012	***	-0.020	***	-0.008	***
Cash Ratio	0.181	0.108	0.175	-0.073	***	-0.006	***	0.067	***
CapX / Sales	0.078	0.206	0.094	0.128	***	0.016	***	-0.112	***
RD / Sales	0.074	0.003	0.064	-0.070	***	-0.009	***	0.061	***
Receivables Days	62.1	44.3	57.8	-17.8	***	-4.3	***	13.5	***
Payable Days	57.3	85.5	60.0	28.1	***	2.7	***	-25.4	***
Inventory Days	57.7	41.7	55.1	-16.0	***	-2.6	***	13.4	***

Panel B: Market returns

	Non-central Firms (1)	Central Customers (2)	Central Suppliers (3)	Central Cust. - Non-central (4)		Central Supp. - Non-central (5)		Central Supp. - Central Cust. (6)	
Equal weighted returns	1.447%	1.325%	1.520%	-0.122%	***	0.073%	***	0.195%	***
Value weighted returns	1.605%	1.614%	1.852%	0.009%		0.248%	***	0.238%	***

Table IV: CAPM regressions by centrality. Monthly equal-weighted and value-weighted portfolios are created based on firms in non-central industries, firms in central customer industries, and firms in central supplier industries. Non-central firms denote firms that are in industries with centrality below the top 10% in both customer and supplier. Central customers only denote firms in industries with customer centrality measures in the top 10% and supplier centrality measures below the top 10%. Central suppliers only denote firms in industries with supplier centrality measures in the 10% and customer centrality measures below the top 10%. Panel A runs the CAPM using equal-weighted portfolio excess returns and Panel B uses value-weighted excess portfolio returns. Significance at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

Panel A: Equal-weighted Portfolios

	Non-central Firms (1)	Central Customers (2)	Central Suppliers (3)	Central Cust. - Non-central (4)	Central Supp. - Non-central (5)	Central Supp. - Central Cust. (6)
Rm-Rf	1.088 ***	1.008 ***	1.319 ***	-0.079 ***	0.233 ***	0.312 ***
	(0.032)	(0.048)	(0.040)	(0.029)	(0.030)	(0.046)
Constant	0.007 ***	0.006 ***	0.006 ***	-0.001	-0.001	0.000
	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)
No. Obs	355	355	354	355	354	354
Adj R^2	0.8144	0.7259	0.7649	0.0274	0.2256	0.1735

Panel B: Value-weighted Portfolios

	Non-central Firms (1)	Central Customers (2)	Central Suppliers (3)	Central Cust. - Non-central (4)	Central Supp. - Non-central (5)	Central Supp. - Central Cust. (6)
Rm-Rf	0.954 ***	0.983 ***	1.447 ***	0.029	0.492 ***	0.466 ***
	(0.015)	(0.037)	(0.057)	(0.035)	(0.058)	(0.075)
Constant	0.009 ***	0.009 ***	0.008 ***	0.000	-0.001	-0.001
	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)	(0.003)
No. Obs	355	355	354	355	354	354
Adj R^2	0.9454	0.7799	0.6923	0.0026	0.2175	0.1407

Table V: Cash to cashflow sensitivity by centrality. We follow the Almeida, Campello, and Weisbach (2004) procedure to calculate cash-to-cashflow sensitivity for firms in non-central industries, firms in central customer industries, and firms in central supplier industries. Non-central firms denote firms that are in industries with centrality below the top 10%. Central customers denote firms in industries with customer centrality measures in the top 10%. Central suppliers denote firms in industries with supplier centrality measures in the 10%. Significance at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

	Non-central Firms		Central Customers		Central Suppliers	
	No LTCR	Has LTCR	No LTCR	Has LTCR	No LTCR	Has LTCR
	(1)	(2)	(3)	(4)	(5)	(6)
CF / TA	0.034 ***	0.004	0.006	-0.004	0.028 ***	0.008
	(0.003)	(0.009)	(0.006)	(0.015)	(0.008)	(0.024)
MtB	0.001	0.001 *	0.002 ***	0.002	0.002 **	0.006
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.004)
LgTa	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
Constant	-0.004 *	0.000	-0.007 **	-0.004	-0.006 **	-0.009
	(0.002)	(0.003)	(0.003)	(0.004)	(0.003)	(0.008)
No. Obs	47548	12519	11413	4306	6776	1645
Adj. R^2	0.0052	0.0002	0.0011	0.0001	0.0035	0.0054

	Central Customers v. Non-central Firms		Central Suppliers v. Non-central Firms		Central Suppliers v. Central Customers	
	No LTCR	Has LTCR	No LTCR	Has LTCR	No LTCR	Has LTCR
	(7)	(8)	(9)	(10)	(11)	(12)
CF / TA	0.034 ***	0.003	0.034 ***	0.002	0.007	-0.008
	(0.003)	(0.010)	(0.003)	(0.009)	(0.006)	(0.015)
MtB	0.001	0.001 **	0.001	0.002 **	0.002 ***	0.003 **
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.002)
LgTa	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
CenCustvNC	0.000	-0.001				
	(0.001)	(0.002)				
CenCustvNC x CF / TA	-0.025 ***	-0.005				
	(0.008)	(0.013)				
CenSuppvNC			0.001	-0.001		
			(0.001)	(0.002)		
CenSuppvNC x CF / TA			-0.005	0.023		
			(0.008)	(0.023)		
CenSuppvCenCust					0.001	-0.001
					(0.001)	(0.002)
CenSuppvCenCust x CF / TA					0.021 **	0.027
					(0.011)	(0.025)
Constant	-0.004 **	0.000	-0.004 **	0.000	-0.007 ***	-0.005
	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)	(0.004)
No. Obs	58961	16825	54324	14164	18189	5951
Adj. R^2	0.0045	0.0003	0.005	0.0006	0.0024	0.0016

Table VI: The value of cash by centrality. We follow the Faulkender and Wang (2006) procedure to calculate the value of cash for firms in non-central industries, firms in central customer industries, and firms in central supplier industries. Non-central firms denote firms that are in industries with centrality below the top 10%. Central customers denote firms in industries with customer centrality measures in the top 10%. Central suppliers denote firms in industries with supplier centrality measures in the 10%. Significance at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

	Non-central Firms		Central Customers		Central Suppliers	
	No LTCR	Has LTCR	No LTCR	Has LTCR	No LTCR	Has LTCR
	(1)	(2)	(3)	(4)	(5)	(6)
dC	1.005 ***	0.824 ***	0.919 ***	0.859 ***	0.931 ***	0.917 ***
	(0.061)	(0.082)	(0.076)	(0.146)	(0.119)	(0.119)
dE	0.576 ***	0.420 ***	0.502 ***	0.342 ***	0.573 ***	0.564 ***
	(0.037)	(0.060)	(0.055)	(0.102)	(0.064)	(0.137)
dNA	0.421 ***	0.224 ***	0.351 ***	0.231 ***	0.371 ***	0.195 ***
	(0.031)	(0.035)	(0.029)	(0.035)	(0.046)	(0.073)
dRD	0.900 ***	-0.491	0.012	-3.709 **	0.659	0.205
	(0.214)	(0.404)	(1.190)	(1.603)	(0.623)	(1.053)
dI	-2.192 ***	-1.624 ***	-1.598 ***	-1.707 **	-2.346 ***	-0.135
	(0.437)	(0.460)	(0.499)	(0.835)	(0.537)	(0.918)
dD	3.916 ***	1.319 **	2.153 **	1.578	0.903	1.194
	(0.465)	(0.668)	(0.890)	(1.143)	(0.925)	(2.292)
lC	0.145 ***	0.409 ***	0.219 ***	0.407 ***	0.181 ***	0.341 ***
	(0.040)	(0.065)	(0.045)	(0.075)	(0.051)	(0.116)
L	-0.438 ***	-0.537 ***	-0.489 ***	-0.619 ***	-0.450 ***	-0.427 ***
	(0.033)	(0.049)	(0.036)	(0.065)	(0.050)	(0.105)
NF	-0.200 ***	-0.112 **	-0.154 ***	-0.187 ***	-0.142 **	-0.169
	(0.043)	(0.051)	(0.040)	(0.062)	(0.060)	(0.126)
Constant	0.003	0.080 ***	0.027	0.141 ***	-0.005	0.046 *
	(0.008)	(0.011)	(0.018)	(0.028)	(0.018)	(0.028)
No. Obs	31587	10021	6764	3247	4532	1397
Adj. R^2	0.1806	0.1809	0.1887	0.1885	0.1934	0.2115

	Central Customers v. Non-central Firms		Central Suppliers v. Non-central Firms		Central Suppliers v. Central Customers	
	No LTCR	Has LTCR	No LTCR	Has LTCR	No LTCR	Has LTCR
	(7)	(8)	(9)	(10)	(11)	(12)
dC	1.007 ***	0.834 ***	1.004 ***	0.822 ***	0.910 ***	0.833 ***
	(0.059)	(0.084)	(0.059)	(0.083)	(0.078)	(0.148)
dE	0.561 ***	0.396 ***	0.576 ***	0.440 ***	0.529 ***	0.404 ***
	(0.032)	(0.058)	(0.037)	(0.062)	(0.045)	(0.086)
dNA	0.406 ***	0.223 ***	0.414 ***	0.222 ***	0.360 ***	0.221 ***
	(0.027)	(0.031)	(0.028)	(0.035)	(0.024)	(0.039)
dRD	0.898 ***	-0.643 *	0.879 ***	-0.425	0.568	-0.952
	(0.213)	(0.374)	(0.223)	(0.447)	(0.548)	(0.918)
dI	-2.066 ***	-1.655 ***	-2.214 ***	-1.445 ***	-1.841 ***	-1.373 *
	(0.407)	(0.529)	(0.434)	(0.474)	(0.451)	(0.724)
dD	3.566 ***	1.338 **	3.514 ***	1.318 **	1.661 **	1.429
	(0.412)	(0.627)	(0.464)	(0.625)	(0.744)	(1.124)
lC	0.158 ***	0.402 ***	0.150 ***	0.396 ***	0.203 ***	0.372 ***
	(0.039)	(0.050)	(0.039)	(0.066)	(0.041)	(0.059)
L	-0.447 ***	-0.561 ***	-0.440 ***	-0.519 ***	-0.474 ***	-0.556 ***
	(0.032)	(0.048)	(0.034)	(0.053)	(0.036)	(0.066)
NF	-0.191 ***	-0.136 ***	-0.193 ***	-0.120 **	-0.153 ***	-0.179 ***
	(0.037)	(0.044)	(0.040)	(0.050)	(0.038)	(0.053)
CenCustvNC	0.021 *	0.031 **				
	(0.012)	(0.014)				
CenCustvNC x dC	-0.101	-0.011				
	(0.072)	(0.136)				
CenSuppvNC			-0.006	-0.010		
			(0.012)	(0.017)		
CenSuppvNC x dC			-0.068	0.134 *		
			(0.096)	(0.080)		
CenSuppvCenCust					-0.030	-0.038
					(0.021)	(0.023)
CenSuppvCenCust x dC					0.039	0.140
					(0.108)	(0.157)
Constant	0.003	0.088 ***	0.002	0.076 ***	0.026 *	0.122 ***
	(0.008)	(0.012)	(0.008)	(0.012)	(0.015)	(0.028)
No. Obs	38351	13268	36119	11418	11296	4644
Adj. R^2	0.1816	0.1826	0.1821	0.1850	0.1906	0.1918

Table VII: Investment during crisis. We follow the Duchin, Ozbas, and Sensoy (2010) procedure using the financial crisis of 2008 to calculate changes in investment behavior for firms in non-central industries, firms in central customer industries, and firms in central supplier industries. Non-central firms denote firms that are in industries with centrality below the top 10%. Central customers denote firms in industries with customer centrality measures in the top 10%. Central suppliers denote firms in industries with supplier centrality measures in the 10%. Significance at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

	Non-central Firms (1)	Central Customers (2)	Central Suppliers (3)	Central Cust. - Non-central (4)	Central Supp. - Non-central (5)	Central Supp. - Central Cust. (6)
isCrisis	-0.0005	-0.0034 ***	0.0008	-0.0005	-0.0005	-0.0033 ***
	(0.0003)	(0.0008)	(0.0009)	(0.0003)	(0.0003)	(0.0008)
isCrisis x PriorCash	0.0022 **	0.0090 *	-0.0022	0.0022 **	0.0022 **	0.0092 *
	(0.0010)	(0.0053)	(0.0022)	(0.0010)	(0.0010)	(0.0053)
isCrisis x CenCustvNC				-0.0028 ***		
				(0.0009)		
isCrisis x PriorCash x CenCustvNC				0.0074		
				(0.0053)		
isCrisis x CenSuppvNC					0.0011	
					(0.0009)	
isCrisis x PriorCash x CenSuppvNC					-0.0041 *	
					(0.0024)	
isCrisis x CenSuppvCenCust						0.0040 ***
						(0.0012)
isCrisis x PriorCash x CenSuppvCenCust						-0.0113 **
						(0.0057)
MtB	0.0008 ***	0.0006	0.0009	0.0008 ***	0.0008 ***	0.0007 **
	(0.0002)	(0.0004)	(0.0006)	(0.0001)	(0.0002)	(0.0003)
CF / TA	-0.0007	-0.0063	0.0181	-0.0019	0.0016	0.0027
	(0.0047)	(0.0123)	(0.0121)	(0.0045)	(0.0044)	(0.0090)
Constant	0.0099 ***	0.0276 ***	0.0098 ***	0.0136 ***	0.0099 ***	0.0211 ***
	(0.0005)	(0.0012)	(0.0015)	(0.0005)	(0.0005)	(0.0009)
Firm Fixed Effects?	Y	Y	Y	Y	Y	Y
No. Obs	13513	3623	2061	17136	15574	5684
Adj. R^2	0.6556	0.7016	0.6571	0.7158	0.6559	0.7259

Table VIII: Customer investment during crisis using supplier-customer paired data. Firms are paired by supplier and customer. We follow the Duchin, Ozbas, and Sensoy (2010) procedure using the financial crisis of 2008 to calculate changes in customer investment behavior for firms without and with central suppliers. Non-central firms denote firms that are in industries with centrality below the top 10%. Central suppliers denote firms in industries with supplier centrality measures in the 10%. Significance at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

	Non-central Suppliers (1)	Central Suppliers (2)	Non-central Suppliers (3)	Central Suppliers (4)
isCrisis	-0.0008 ***	-0.0006	-0.0008 ***	-0.0013 *
	(0.0003)	(0.0006)	(0.0003)	(0.0008)
isCrisis x Cust_PriorCash	0.0025 *	-0.0001	0.0030 *	0.0005
	(0.0015)	(0.0021)	(0.0016)	(0.0022)
isCrisis x Supp_PriorCash			-0.0004	0.0019
			(0.0008)	(0.0015)
Cust_MtB	0.0005 ***	0.0000	0.0006 ***	0.0000
	(0.0001)	(0.0002)	(0.0001)	(0.0002)
Cust_CF / TA	0.0249 ***	0.0140	0.0261 ***	0.0125
	(0.0071)	(0.0154)	(0.0071)	(0.0163)
Constant	0.0113 ***	0.0096 ***	0.0112 ***	0.0096 ***
	(0.0005)	(0.0008)	(0.0005)	(0.0009)
Firm Fixed Effects?	Y	Y	Y	Y
No. Obs	4378	959	4071	897
Adj. R^2	0.8687	0.7948	0.8681	0.7969

Table IX: Customer trade credit during crisis using supplier-customer paired data. Firms are paired by supplier and customer. We use the financial crisis of 2008 to calculate changes in log of payable days for customers without and with central suppliers. Non-central firms denote firms that are in industries with centrality below the top 10%. Central suppliers denote firms in industries with supplier centrality measures in the 10%. Significance at the 10% level is indicated by *, 5% level by **, and 1% level by ***.

	All Suppliers (1)	Non-central Suppliers (2)	Central Suppliers (3)
isCrisis	-0.1001 ***	-0.1173 ***	-0.0120
	(0.0178)	(0.0242)	(0.0351)
isCrisis x Cust_PriorCash	0.1922 **	0.3379 ***	-0.0534
	(0.0793)	(0.1208)	(0.1140)
isCrisis x Cust_CenCustvNC	0.0540 *	0.0743 **	0.0144
	(0.0280)	(0.0352)	(0.1403)
isCrisis x PriorCash x CenCustvNC	0.0239	-0.1263	0.5644
	(0.2187)	(0.2752)	(1.4782)
Cust_MtB	0.0071	0.0340 ***	-0.0370 ***
	(0.0054)	(0.0071)	(0.0101)
Cust_CF / TA	-3.5663 ***	-3.7245 ***	-0.3701
	(0.3729)	(0.4609)	(0.9593)
Supp_MtB	-0.0048	-0.0048	0.0292 *
	(0.0056)	(0.0073)	(0.0151)
Supp_CF / TA	0.3890 *	0.5949 **	-0.0804
	(0.2217)	(0.2803)	(0.3908)
Constant	5.4264 ***	5.3322 ***	5.3882 ***
	(0.0274)	(0.0367)	(0.0534)
Customer-Supplier Fixed Effects?	Y	Y	Y
No. Obs	4205	2859	604
Adj. R^2	0.8401	0.8240	0.8867