Ownership Networks and Firm Growth: What Do Forty Million Companies Tell Us About the Chinese Economy?*

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Abstract

The finance–growth nexus has been a central question in understanding the unprecedented success of the Chinese economy. With unique data on all the registered firms in China, we build extensive ownership networks, reflecting firm-to-firm equity investment relationships, and show that these networks have been expanding rapidly since the 2000s, with more than five million firms in at least one network by 2017. Entering a network and increasing network centrality, both globally and locally, are associated with higher firm growth. Such positive network effects tend to be more pronounced for high productivity and privately owned firms. The RMB 4 trillion stimulus, mostly in the form of newly issued bank loans and launched by the Chinese government in November 2008 in response to the global financial crisis, partially 'crowded out' the positive network effects. Our analysis suggests that equity ownership networks and bank credit tend to act as substitutes for state-owned enterprises, but as complements for privately owned firms in promoting growth.

Key Words: Ownership network; Centrality; Equity capital; Firm growth; Bank credit.

JEL Codes: G10; G30; L14.

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1. Introduction

The Chinese economy has been performing extraordinarily well over the past four decades. One enduring puzzle surrounding this economic growth is how it has been achieved without well-developed financial and legal systems. One view is that the dominant force in the Chinese financial system—large state-owned banks—have played a critical role in funding state-owned enterprises (SOEs) and large government-initiated investment projects, while the main driver for China's growth 'miracle' has been the "Hybrid Sector," including non-SOEs with different ownership structures (Allen, Qian and Qian, 2005). A central question then is how firms in this sector finance their growth in a credit-constrained environment without sufficient access to formal financing, including bank credit and the bond market, as well as equity financing through the stock market.

In this paper, with unique data on all the registered firms—over 40 million firms in total—we are the first to build and map out the entire set of *equity* ownership networks of the Chinese economy. We examine how the networks of firms evolve over time and investigate how capital is allocated within and across different networks. We extend the literature on networks by showing that the entrance into an equity network and rise in network centrality, both locally and globally, are associated with higher firm growth. We also examine how the positive network effects differ across different types of firms and interact with other forms of financing.

Economic networks connect firms and agents via financing relationships, social ties, and other activities. A network also serves as a conduit for inter-organizational support and can influence and reflect resource allocation among firms (Jackson, 2014). Through examining the structure of the equity ownership networks of all the registered firms in China, we shed light on issues that are key to understanding China's finance-growth nexus. First, we show how firms' bilateral equity investments evolve over time. Does capital mainly flow to risky industries, such as real estate?

The leading role of the banking system in supporting large firms and mature industries has been widely documented (e.g. Allen, Gu and Qian, 2017; Song and Xiong, 2018). Recent firm and loan data have shown signs of deteriorating efficiency of credit allocation (e.g. Bai, Hsieh and Song, 2016; Chen and Wen, 2017; Cong et al., 2019); the recent rise of the shadow banking sector also contributes to the growth in the real estate sector (e.g. Allen et al., 2019). However, little evidence has been shown on the allocation of equity capital—whether it has followed a similar pattern in the credit market, or it has been more efficient.

Second, how does a firm's position in ownership networks contribute to its growth? In particular, does equity capital complement or substitute bank loans in terms of promoting growth? Does equity capital also favor SOEs, like bank credit, and how accessible is it to non-SOEs? Answering these questions helps provide a better understanding of the underlying mechanisms driving the growth of the non-state sectors. Using the ownership information of all the registered firms in China, most of which are unlisted, privately owned firms, we are the first to show how the equity holding network contributes to the growth of these firms over time, and how the equity networks interact with other types of networks and debt financing in promoting growth.

We construct our ownership networks using a large dataset on bilateral and dynamic firm-to-firm equity investments dating back to the early 1950s. According to the "Company Law" and "Companies' Registration Rules," firms of all types must register with the State Administration for Industry and Commerce (SAIC) when they are founded.[1] Registration information includes the date (of registration), location, capital, industry, ownership type, and key information such as the status of the firm (either existing or bankrupt) must be updated with SAIC in a timely fashion when changes to the firms occur.

[1] According to the *Company Law* (2005 version), the registered capital must be fully paid within the first two years since the registration date.

In the process of building the dynamic, firm-to-firm equity ownership networks, we begin in 2017 and gather information of all the ownership stakes and linkages for all the registered firms. We then work backwards to track all the changes in the registration system, including firms (entry and exit) and ownership stakes, until the year when a firm was first founded (or 1950). We exclude *individual* businesses, as these small businesses are not registered as corporations.[2] By the end of 2017, the entire set of networks covers over 40 million firms: more than 35 million out-of-network firms and 5.6 million in-network firms.

Using the equity ownership networks constructed, our aggregate stylized facts show that, equity capital follows a similar pattern as bank credit, with the largest amount of funds flowing to risky and credit-constrained industries. Real estate and construction sectors have attracted the most capital among all non-financial industries, followed by mining.

Equity ownership networks can facilitate the sharing of information, contacts and resources among firms (e.g., Hochberg, Ljungqvist and Lu, 2007). On one hand, joining a network can be particularly beneficial to small firms and firms from new industries, as they face tight credit constraints in part due to severe degrees of information asymmetry. Retaining a large equity ownership stake in such a firm can facilitate monitoring and protecting control rights for investors, especially in an environment with weak legal institutions (Lerner and Schoar, 2005; Kaplan, Martel, and Stromberg, 2007). More influential network positions, on the other hand, imply differences in access to equity capital or related resources, investment opportunities, and clout, which can further affect 'core' firms' future growth. Hence, the concept of well-connectedness in a system of networks is inherently multidimensional.

[2] We also drop the equity ownership of *individuals* for all the firms in the database, because these individuals are difficult to identify and trace. The equity investment amounts by all the individual and corporate shareholders for each firm add up to the firm's total registered capital at SAIC.

Network theory has developed multiple related and distinct measures for connectedness. We utilize the centrality measures including *degree*, *betweenness*, and *eigenvector* centrality. A firm is connected if it is invested or it invests in many other firms through equity capital (*degree* centrality). A firm is well-connected if it lies on relatively more paths between pairs of other firms in the ownership network, promoting this firm as a key 'broker' of resource exchanges (*betweenness* centrality). A firm's position in the networks is further enhanced when its directly linked firms also occupy central positions in the networks and are well-connected (*eigenvector* centrality). While "degree centrality" measures local connectedness, "betweenness centrality" and "eigenvector centrality" capture global connectedness across the entire set of networks.

The summary statistics of China's equity ownership networks suggest that they have been expanding dramatically since the beginning of 2000s, with the number of in-network firms more than tripled. Larger firms are more likely to connect to other firms, either as investors or investees. New entrant firms tend to attract and make few investments, hence have low global importance. Both the mean degree and betweenness centralities show an upward trend over the years, whereas the mean *eigenvector* centrality falls. These results suggest that networks are becoming larger (with more firms) on average, but new entrants are likely to be peripheral and less well-connected, and thus with negligible *eigenvector* centrality.

In order to analyze how a firm's network position affects the firm's future growth, we merge the data on ownership networks with the Annual Industry Surveys (AIS) published by the National Bureau of Statistics (NBS), which allows us to have detailed information about a subset of firms' financial and accounting information and operating performance. For industrial firms, on average, a large proportion (roughly 43%) of financing comes from equity capital. More importantly, we find that entering a network is associated with higher growth rates (in assets) comparing to out-of-network firms, and higher network centrality further improves growth among in-network firms.

Specifically, of the three sets of network centrality measures, *eigenvector* centrality has the largest economic impact, suggesting that a firm benefits from having many ties, especially when the ties involve other well-connected firms. One-standard-deviation increase in eigenvector centrality can improve firm growth by approximately 23.7 percent. The time-series analysis suggests that given the paths of network evolution, the total effects of network entrance *and* network centrality on firm growth has decreased in the past two decades, with the sum of in-network and eigenvector centrality regression coefficients turned negative after 2009.

Our findings also suggest that the positive effects of network positions on firm growth tend to be more pronounced for highly productive firms, especially those with financial constraints, and less pronounced for SOEs. Controlling for local centrality, we find that the effect of global centrality in promoting growth remains positive and significant, and is further strengthened when the firm entered the networks earlier.

In order to establish a causal relationship between network centrality and firm growth, we need to address potential endogeneity concerns. For instance, there might be unobservable variables that are correlated with both the centralities and growth of firms. To address this problem, we create *pseudo* networks by dropping the top 100 firms with the highest eigenvector centrality values in the networks (as of 2017); this change is exogenous to other non-directly connected firms.[3] In a 2SLS (two-step, least square) procedure with a firm's centrality instrumented by the change in the network positions (between the original structure and the revised structure after dropping the 100 firms), we continue to find that the centrality-growth nexus remains statistically significant and economically meaningful. These results suggest that it is the network structure, not

[3] For robustness, we also drop firms that are directly connected to these top 100 firms, and investigate how the further revised network structure affects the remaining firms' growth; our main results continue to hold.

the identities of the firms (in central positions) alone, that matters for promoting growth.

Using the 4-trillion RMB stimulus plan, announced in November 2008 in response to the global financial crisis, as a shock to the networks, we find that the positive effect of network centrality on firm growth is diminished post-stimulus. Since the majority of the stimulus was actually newly issued loans by large, state-owned banks, we conclude that this wave of large credit expansion *crowds out* the positive effects of equity networks.[4] In order to further examine the interaction between equity networks and bank credit and its effects on firms, we use whether a firm is affiliated with a bank, within the three steps of the entire ownership network, as a measure for repeated relationship with banks. Hence, a firm is identified as bank-affiliated only if a bank is its direct shareholder or indirect shareholder within the three steps of the entire ownership network.[5]

Our results show that after 2009, the positive effect of network centrality on growth becomes stronger for bank-affiliated non-SOEs, while this effect becomes statistically insignificant for SOEs. Since the stimulus plan and bank credit allocation favored SOEs, these results suggest that the network effect is diminished for firms with more access to bank loans. Taken together, our results indicate that the equity ownership networks serve as a substitute for bank credit for SOEs, but they act as a complement to bank credit for non-SOEs, in supporting growth.

Our paper extends the existing literature on the finance–growth nexus for the Chinese economy. Recent papers explain the finance-growth relationship in China from an industrial-cluster point of view based on proximity measures (e.g., Long and Zhang, 2011), document the misallocation of credit from the banking sector to the state sector (e.g. Cong et al, 2019; Ljungqvist

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[4] The Chinese government introduced a two-pronged economic stimulus plan. Among the 4 trillion RMB, almost 3 trillion were in the form of newly issued bank loans and only about 1 trillion RMB was spending from the fiscal side (see, e.g., Acharya, Qian, Su and Yang, 2020; Cong et al., 2019).

[5] We use the ownership network to trace shareholder information of all firms and identify whether the shareholder or indirect shareholder within three steps of the network is a bank or not.

et al., 2016), and show that the rise of the shadow banking sector as a result of 'regulation arbitrage', so as to satisfy the financing needs of credit-constrained industries or government projects, especially after the massive stimulus (e.g., Chen, He and Liu, 2020; Acharya, Qian, Su and Yang, 2020; Allen et al, 2020a; Allen et al, 2019). However, little evidence has been shown on the role of equity capital, in the form of equity networks, in the Chinese economy, especially its effects on unlisted firms. Through mapping out the entire ownership networks of all the registered firms, we demonstrate these networks, including network structure and positions, promote growth.

Our paper contributes to the growing literature on different types of social or economic networks and their effects on firms and economic activities. For example, Herskovic, et al. (2019) study how firm-level product market connections influence the firm size distribution and the volatilities of firms' growth rates. Ahern and Harford (2014) represent the economy as a network of industries connected through customer and supplier trade flows, and show stronger product-market connections lead to a great incidence of cross-industry mergers. Liu (2019) emphasizes that the market distortions can be significantly amplified through the input-output links, and argues that an efficient industrial policy should subsidize sectors with the highest distortionary centrality in the networks.[6]

Our results on the positive effects of equity networks on growth are robust to controlling for firms' positions in supply and product chains. In particular, some of our results may be driven by the channels documented in Liu (2019), if the subsidized sectors are those in the center of the ownership networks. Accordingly, we absorb the possible effects from this channel by directly control for the sector-times-year fixed effects.

[6] Other recent papers on networks include Laumann et al. (1977), Larcker, So and Wang (2013), Gao (2015), Hochberg, Ljungvist and Lu (2007), Bailey et al. (2018), Ahern (2017), Ahern and Harford (2014) and Ahern (2019), Rossi, et al. (2018), Larcker, So, and Wang (2013), Acemoglu, Akcigit and Kerr (2016), Barrot and Sauvagnat (2016).

A few recent papers also use the ownership information of all the registered firms in China as the main database for empirical analysis. For example, Allen et al. (2020c) analyze the evolution of state ownership networks in China and their effects on in-network firms (both SOEs and non-SOEs). Bai et al. (2020) examine the SOEs and their private owners with equity linkages. Shi, Townsend, and Zhu (2019) show that equity-holding linkages play a role in propagating bank credit supply shocks through the holding companies to their subsidiaries via equity transfers. By contrast, our study is the first to build the entire equity ownership networks and explore how the network structure and positions (of firms) affect real outcomes of in-network firms.

The remainder of the paper is organized as follows. Section 2 provides an overview of our network analysis methodology. Section 3 describes the construction of our datasets. Section 4 provides the stylized facts of the aggregate-level evidence and the summary statistics of the equity ownership network. Section 5 discusses the empirical methodology and results. Section 6 concludes.

2. Network Analysis Methodology

Network analysis aims to describe the network structure using graph theory. One way to describe the network structure is to identify how each actor is connected to others and further how "important" the position of each actor is in the whole network, based on its involvement in relationship with his neighbors. To understand this, we use centrality measures from graph theory. A number of measures have been developed to quantify centrality in economic networks, which include, degree, betweenness, and eigenvector centrality (Jackson, 2008) as well as hub and authority centrality (Kleinberg, 1999). Borgatti (2005) reviews these centrality measures and classifies them based on assumptions about the manner in which traffic flows through a network. Formally, in graph theory a network is presented by a "adjacency" matrix, the cells of which reflect the strength of the tie among each actor in the network. In our setting, the matrix representing the ownership network is asymmetric, which indicates directional equity investments. The edges, which reflect the strength of the connections among nodes, are weighted using either investment amount or ownership percentage. To illustrate, Figure 1visualizes the two-level subtree of the equity ownership network of a significant SOE in China.[7] We report the main results using centrality measures weighted by share percentage and those weighted by investment amount in Appendix.

[FIGURE 1]

Here, we briefly formalize the network and the definition for various measures of centrality. Suppose there are N firms denoted as $[N] = \{1,2 \dots N\}$. Denote $C = \{c_{ij}, (i,j) \in [N] \times [N]\}$ as the set of edges, with c_{ij} being interpreted as the share or equity of firm j held by firm i. Denote s_i as the size of firm i. For convenience, we also define $x_i = (x_{i1}, \dots, x_{ip})$ as a firm i's p dimensional characteristics. Those characteristics could be firm size, age, profit, output, inputs and any other features we are interested in. In abstract, the whole network can be fully described as

$$G = \{[N], C, (x_i, s_i)_{i \in [N]}\}$$

2.1 Degree Centrality

We define unweighted *in degree* as $In\ degree_i = \sum_{j \in V} I\{c_{ij} > 0\}$, where $I\{x\}$ is an indicator function which equals to 1 if the condition is true, or 0 otherwise. Hence, unweighted *in degree* also represents the number of investors for firm i. In a similar way, *weighted in degree* is defined as $weighted\ In\ degree_i = \sum_{j \in V} c_{ij} s_j$. Unweighted *out degree* is defined as $Out\ degree_i = \sum_{j \in V} I\{c_{ji} > 0\}$; and weighted out degree is defined as weighted $out\ degree_i = \sum_{j \in V} c_{ji} s_j$.

[7] This is just an example of sub-network for the purpose of illustration, so we did not plot the networks including the ultimate controlling shareholder.

2.2 Betweenness

One potential issue with the degree measures is that they depend only on the local information, rather than the global information of the network. To capture the global dependence, we calculate betweenness, eigenvector, hub and authority centrality. Betweenness reflects how well situated a node is in terms of the shortest paths that it lies on Freeman, L. C. (1977), usually used to measure the information flow or relationship across the network. Specifically, a firm j is connected to a firm k, if there exist an equity holding chain $(jl \ldots piq \ldots mk)$ such that $I_{jl} .. I_{pi} I_{iq} \ldots I_{mk} > 0$, where I_{ls} is a linkage based dummy if firms l and s are connected via equity holding, otherwise is 0. The betweenness of a node i is defined as

$$Betweenness_i = \sum_{j \neq k,i} \frac{g_{jk}(i)}{g_{jk}}$$

where g_{jk} is the number of shortest paths between j and k. $g_{jk}(i)$ is the number of shortest paths between *j* and *k* that pass through the node i.

2.3 Eigenvector Centrality

The eigenvector centrality is defined recursively as

$$Cx^* = \lambda x^*$$

where $x^* = (x_1^*, x_2^*, \ldots, x_N^*)'$ is the centrality vector of the companies given the undirected holding matrix C. (Bonacich, 1987; Bonacich and Lloyd, 2001; Bonacich, 2007) use the eigenvector associated with the largest eigenvalue as a measure of centrality. To see the recursive of the definition, we write it as $\lambda x_i^* = \sum_j x_j^* C_{ji}$. Thus, the importance of firm i, captured by the eigenvector centrality, relies on the importance of its holding firms.

2.4 Hub and Authority Centrality

The authority centrality is proposed to identify the most relevant and authoritative webpages of search topics using link structures (Kleinberg, 1999). The hub centrality is coupled with the authority centrality to identify webpages that points to the authorities. Two types of central webpages are thus defined: authorities, that contain informative resources on the topic of interest; and the hubs, that point to the authoritative information. Similar concepts are also proposed in bibliometrics. A paper is an authority if it is highly co-cited by hubs (e.g. a seminal paper) and is a hub if it highly co-references to authorities (e.g. a comprehensive survey). To extend the notion of hub and authority to our context, a firm is an authority if it is heavily co-invested by important investors and is a hub if it heavily co-invests to important firms. Note that a firm can be an authority and a hub at the same time. Again let C denote the holding matrix. The authority centrality a_i of firm i is given by

$$a_i = c_1 \sum_j C_{ji}\, h_j$$

and the hub centrality h_i of firm i is given by

$$h_i = c_2 \sum_j C_{ij}\, a_j$$

where c_1 and c_2 are some constants. In matrix form,

$$a = c_1\, C^T\, h \text{ and } h = c_2 C\text{a}.$$

Combine the above two equations yields,

$$a = \lambda C^T C\, a \text{ and } h = \lambda C C^T h$$

where $\lambda = c_1 c_2$. The authority matrix $C^T C$ and the hub matrix CC^T share the same eigenvalues.

3. Sample and Data Description

3.1 Data Source and Sample Construction

The Firm Registration and Ownership Database, comes from iFind, further originated from

China's State Administration for Industry and Commerce (SAIC). This database contains two parts of information. The first is the registration information, which covers registration date, registered capital, industry, ownership type, status of the firm (either existing or bankrupt), and location information of each firm as of 2017. Firms can be traced back to as early as 1950 and the number of registered firms is up to 90 million, including individual self-employed entity.

Meanwhile, SAIC also provides detailed information on shareholders and ownership structure in terms of equity investments of all the registered firms. Updates of shareholders and their equity investment since 1950 are also provided. Each update records the time of the update, all the shareholders, and their corresponding nature of legal person (natural person/individual or institutional), investment amount, share percentage of the invested firm before and after the update.

To construct our firm-to-firm equity ownership networks, we only keep firms who historically invested other firms/institutions or were invested by other firms/institutions. Thus, firms who have been only held by individuals and have not invested in other firms/institutions are not included in our sample for the purpose to construct the networks. This process allows us to have 5.6 million firms in the network up till 2017.[8] Overall, firms in the equity ownership networks is much larger than those out of the networks, the total registered capital of these firms accounts for approximately 80% of the total capital of all the registered firms in China. We trace the networks dynamically. In each year *t*, we construct an equity ownership network based on the equity investment linkages between firms observed in year *t-1*. We then use the resulting adjacency matrices to construct the centrality measures described in Section 2. We find that the network expands rapidly in our sample from 1999 to 2017. The network in 2017 includes more than 5.60 million firms or institutions,

[8] Firms that went bankrupt (deactivated) in the past are still in our sample by the end of 2017. When we construct the dynamic networks over years, we drop the firms that went bankrupt (or deactivated) before the current year. Therefore, our dynamic networks have captured all active firms at each given year.

with the remaining firms (over 35 million firms/institutions) out of network. By our definition, the in-network firms/institutions are either investors or investees (or both). The out-of-network firms/institutions, on the other hand, are neither investors nor investees.

Though SAIC covers all the registered firms in China, it only has limited information on firm operation and performance. In order to obtain this information, we match the SAIC registration and ownership database with the Annual Industry Surveys (AIS) published by China's National Bureau of Statistics (NBS).[9] AIS covers industrial firms with annual sales over RMB 5 million (about US$800K) before 2010 and over RMB 20 million after 2010. Matching these two datasets allows us to obtain a panel dataset of industrial firms with dynamic network structure from 2000 to 2013. For example, in 2013 there are 79,627 in-network and 169,617 out-of-network industrial firms.

3.2 Variables

3.2.1 What is "registered capital" in China?

Our ownership networks are directed and weighted by either equity shares (in percentage) of shareholders or the amount of equity investments. The amount of equity investments by all the shareholders for each firm add up to the total *registered capital* of the firm. According to the *Company Law (2005)* in China, registered capital, the capital that all the shareholders commit to invest when the firm is registered at SAIC, must be fully paid within first two years after the firm is registered.[10]

According to the *Company Law (2005; 2014)* in China, for limited liability companies (LLCs),

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[9] Limited by data availability, we only have access to AIS in 2013 as the latest. We drop 2010's AIS for our analysis because of its poor data quality, which is widely documented in literature.

[10] In the past (before 2014), the firm registration system in China was based on a paid-in system, meaning that all the registered capital has to be fully paid within the first two years after the firm is registered at the SAIC. Since 2014, according to the *Company Law (2014),* the old paid-in system has been changed to a subscription system, meaning that the registered capital might be different from the actual paid-in capital. The *Company Law (2005)* can be accessed here: http://www.gov.cn/flfg/2005-10/28/content_85478.htm

all the shareholders and their share changes are required to be recorded at the SAIC; for incorporated companies, all the original shareholders and their holdings are required be recorded, while there is no mandatory requirement that the changes of holdings afterwards need to be recorded. However, shareholders are motivated to be registered at the SAIC to get the government endorsement. By checking the sample of AIS firms, for which we have access to both registered and paid-in capital, we do not observe significant differences between these two. The actual paid-in capital by each shareholder, represents shareholder's cash flow rights and voting rights.

3.2.2 Firm characteristics

Our main dependent variable is *Firm growth*, defined as the growth rate of firm total assets. We consider an assortment of firm financial and other characteristics in the analysis. *Firm size* is the natural logarithm of the book value of total assets; *Firm age* is the natural logarithm of the years that the firm has operated since its establishment; *ROA* is defined as the net income before extraordinary items from the main business as a percentage of total assets; *Leverage* is the ratio of total liabilities to total assets; *Reg cap* is firm's registered capital at SAIC. To calculate *TFP*, we estimate the logarithm linear production function at the 2-digit Chinese Industry Classification (CIC)

$$y_{it} = \beta_0 + \beta_m m_{it} + \beta_l l_{it} + \beta_k k_{it} + \mu_{it}$$

where l_{it}, m_{it}, k_{it} represent the natural logarithm of labor, intermediate input and capital, respectively. We run the regressions with year ×2-digit CIC (industry) fixed effects. The *TFP* of firms i at year *t* is estimated as $\hat{\mu}_{it}$.

Bank subs is a dummy variable that equals one for firms with banks as their shareholder if tracing up within three steps in the entire ownership network, and zero otherwise. *SOE* is a dummy variable that equals one for state-owned enterprises, and zero otherwise, including collectively-owned and privately-owned enterprises.[11] The definition of all the centrality measures are described in Section 2. Table A.1 in the Appendix provides a detailed list of variable definitions.

4. Aggregate-level Evidence and Summary of the Ownership Network

4.1 Stylized Facts: Industry-level Evidence

To understand how equity capital flows across industries, we aggregate the equity investments by industry. Figure 2 plots the heatmap of industry-level capital flows among pairs of industries using the equity ownership network in 2012. Transportation and postal services, manufacturing, rental and business services are the top three industries in terms of absorbing investments in the same industry. Table 1 further reports the cross-industry investment amounts and total investment amounts, scaled by firm number in each industry. If we exclude the equity investments in the same industry, financial industry has attracted the most capital among all industries, followed by construction and real estate industry, and then mining and utilities. Existing studies show that majority of the funds raised by shadow banking in China flowed to real estate and over-capacity industries including mining (e.g. Allen et al., 2020a; Chen, He and Liu, 2018), and here the results point to a similar trend for equity capital, that real estate and construction have attracted the most capital among all non-financial sectors. Additionally, roughly 30% of the funds flowed to real estate industry come from transportation and financial industry.

[TABLE 1]

[FIGURE 2]

4.2 Descriptive Statistics

4.2.1 Summary Statistics of Network Centralities

[11] For simplicity, we use non-SOEs to incorporate both collectively-owned and privately-owned enterprises.

Table 2 provides summary statistics of centrality measures of the entire ownership networks as well as its matched sample with AIS firms. Panel A shows that in 2017, the entire set of networks contains 5.60 million in-network firms and institutions. The statistics reveal substantial heterogeneity. The degree centralities are unweighted. *In degree* centrality ranges from 0.00 to 350, with a sample mean of 0.90 and a standard deviation of 1.17, suggesting that on average of each firm is directly connected to 0.9 investors. *Out degree* centrality ranges from 0.00 to 32,415, with a sample mean of 0.90 and a standard deviation of 21.90, suggesting that on average each firm is investing in 0.9 firms. The mean value and standard deviation of *Betweenness* centrality weighted by share percentage is 1.75 and 573.63, respectively. *Betweenness* centrality weighted by investment amount presents lower mean value (0.16) and standard deviation (32.44). *Eigenvector* centrality weighted by share percentage and that weighted by investment amount shows similar feature, ranging from 0.00 to 1.00, with a sample mean and a standard deviation both very close to 0. *Hub* and *Authority* centralities weighted by investment amount also ranges from 0 to 1.00, with a sample mean and a standard deviation both very close to 0.[12] Table 2 Panel B reports the summary statistics for firm characteristics of in-network firms in the complete network of 2017. Firms as both investor and investee tend to have largest firm size (measured by registered capital) and oldest firm age; firms as only investors have slightly larger size than firms as only investees, on average.

[TABLE 2]

Figure 3 plots the network size in terms of the number of in-network firms, showing that the

[12] As documented by Jackson (2010) and many other studies, the distribution of centralities follows the power law, i.e., $f(x) = cx^{-k}$, where a larger k indicates a faster exponential delay. The power law captures the distribution of the centralities where the number of firms with small centralities is immerse and plunges exponentially as the centralities increase. Note that the mean value of Eigenvector, Hub and Authority centralities is all close to zero. Hence, in the regressions we use natural logarithm of standardized centrality variables for them.

ownership has been continuously expanding over 1999 to 2017. The total number of firms in at least one network in 2017 is more than tripled compared to the number in 1999. Panel B presents the mean value of centralities of all the in-network firms over the years of 1999 to 2017, for the entire set of ownership networks. Both the unweighted degree centralities and betweenness centrality weighted by share percentage show an upward trend over the years, suggesting the increase of equity investment activities. The eigenvector, hub and authority centralities show a downward trend overall, indicating that the new entrant firms may have low global importance, hence tend to attract or make fewer investments, compared to the existing in-network firms.

[FIGURE 3]

Figure 4 presents the relationship between centrality and registered capital, using the ownership networks in 2017. We take natural logarithm for both centralities and registered capital for this plot. Overall, firm size measured by firm registered capital is positively correlated to centrality measures, suggesting that larger firms are more likely to connect to other firms, either as investors or investees.

[FIGURE 4]

Table 3 provides summary statistics for firm characteristics (including centralities) of the matched sample with AIS (2000-2013). On average, the mean value of *In net* is 0.29, suggesting that on average 29% firms are in network over the sample period. Note that some firms may enter into or exit from the networks in a specific year during our sample period. *Log indeg* ranges from -0.53 to 4.49, with a sample mean of -0.16 and a standard deviation of 0.87. *Log outdeg* ranges from -0.39 to 5.70, with a sample mean of 0.07. *Log deg* has a sample mean of -0.07 and a sample median of -0.62. *Log btw* and *Log btw cash* range from -0.19 to 19.84 and from -0.04 to 26.18 respectively. *Log eigen* and *Log eigen cash* range from -0.45 to 9.87 and from -0.04 to 28.17. *Log* *hub cash* ranges from 0.00 to 4.62, with a sample mean of 0.10 and a standard deviation of 0.33. *Log authority cash* ranges from 0.00 to 20.72, with a sample mean of 0.48 and standard deviation of 1.51.

[TABLE 3]

4.2.2 Summary Statistics of Other Firm Characteristics

Table 3 also reports descriptive statistics of other firm characteristics. *Firm age* ranges from 0.00 to 4.14, with a sample mean and median of 2.05 and 2.08, suggesting that the average length of time since firm establishment is 7.7 (=$e^{2.05}$) years. *Total assets* ranges from RMB 1 thousand to RMB 950 billion; correspondingly, *Firm si*ze ranges from 0.00 to 20.62, with a sample mean of 9.90. *ROA* has a sample mean of 10% and a standard deviation of 20%. *Leverage* ranges from 0.00 to 2.19, with a sample mean of 0.57. *SOE* has a sample mean of 0.08, indicating that roughly 8% firms are state-owned in our AIS matched sample.

4.2.3 Equity Capital, State Ownership and Network Position

Figure 5 reports the ratio of equity capital over total assets for all the industrial firms, as well as its relationship with state ownership and network position. Overall, the figures show that a large proportion (roughly 43%) of financing comes from equity capital. The mean value of the ratio of equity capital has been increasing continuously, and remained above 40% since 2001. From 2004, the mean value of equity ratio of SOEs was higher than that of non-SOEs; while such relationship has changed since the launch of Fiscal Stimulus Plan in the end of 2008. In-network and out-of-network firms have the mean equity ratio of 41.9% and 43.8% relatively. Before 2008, more central (higher eigenvector) firms had on average higher equity ratio than less central (lower eigenvector) firms do, while such trend has changed since 2008.

[FIGURE 5]

4.2.4 Cross-shareholding

Cross-shareholding refers to inter-locking share ownership between firms. It has been widely documented that cross-shareholding has been prevalent in Japan, Germany and several other European countries, though such cross-holding is found to a lesser extent in the US (e.g. Fedenia, Hodder and Triantis, 1994). Figure A.1 plots the number of equity investments as well as number of firms involved in equity cross-holding, suggesting that overall the percentage of firms involved in such cross-holding has been remained below 0.5%. For example, in 2012, 87,921 firms (2.4% of the total registered capital of all the in-network firms were involved cross share-holding.

[FIGURE A.1]

5. Empirical Methodology and Results

5.1 Empirical Methodology

We start by examining the effects of ownership network centrality on firm growth using Model below:

$$Firm\ growth_{i,t} = \alpha_i + \delta_t + \beta_0 + \beta_1 \cdot Centrality_{i,t-1} + \beta_2 \cdot (In\_net)_{i,t-1} + \beta_3 \cdot (Firm\ characteristics)_{i,t-1} + \varepsilon_{i,t} \quad (1)$$

where *Firm growth* is the dependent variable and α_i, δ_t are firm and year fixed effects respectively. The key explanatory variable is centrality measures of the ownership networks, where we expect a positive value for the coefficient β_1. We also incorporate an assortment of firm financial and ownership characteristics as control variables. Firm financial characteristics included are *Firm size*, *Firm age*, *ROA*, *Leverage*; firm ownership characteristics included are *SOE* and *Bank subs*. We incorporate year and firm fixed effects into all the regressions to account for time- and firm-heterogeneities.

5.2 *Baseline Results*

Does a firm's network position in the previous year affect firm future growth? The baseline results, reported in Table 4, indicate that it does. In columns (1) to (5) we use *Log indeg*, *Log outdeg*, *Log deg*, *Log btw*, and *Log eigen*, as the key explanatory variables, each measuring network centrality. We add each of them at a time given the relatively high degree of correlation among them. In all specifications, we control for whether the firm is in network or not (*In net*), as well as other firm characteristics including *ROA*, *Leverage*, *Firm age*, *Firm size*. Both firm and year fixed effects have been included. The centrality measures (excluding in-degree) and *In net* all enter with significant and positive coefficients, suggesting that, entering a network is associated with significantly higher firm growth; and moreover, better-connected firms in the ownership network are likely to have significantly higher firm further growth.

The impact of network position on firm growth is also economically meaningful. Of the five network measures, eigenvector has the largest economic effect, closely followed by out-degree and degree centrality. To illustrate, the estimation in column (5) using *Log eigen* shows that, *ceteris paribus*, entering a network is associated with approximately 3.4 (=0.00463/0.137) percent increase in firm growth; given the in-network position, one standard-deviation increase in *Log eigen* is associated with approximately 23.7 (=0.0308*1.052/0.137) percent increase in firm growth, all else equal. Therefore, a firm benefits from having many ties (*degree*), especially when the ties involve other well-connected firms (*eigenvector*), and from investing more in other firms (*out-degree*). Out-degree can capture a firm's investment in future reciprocity, meaning that the investing in others can bring profitability or possibly result in co-investment opportunities in the future. Having the ability to act as a broker between other firms (*betweenness*) has smaller effect, with a one-standard-deviation increase in *Log btw* being associated with only 3.9 (=0.00489*1.08/0.137) percent increase in firm growth. This indicates that indirect relationships, which require intermediation, play a lesser role in promoting firm growth. This proves to be the case throughout our analysis. The coefficient of *Log indeg* is slightly negative, suggesting that the increase of unweighted in-degree centrality (hence more diversified ownership structure), given in network, doesn't seem to help improve firm growth, as that of other centrality measures. The estimation in column (1) shows that the effect of *in-degree* is absorbed by the effect of in-network position, which is economically much larger than those in column (2) to (5). *Ceteris paribus*, entering a network is associated with 36.9 (=0.0505/0.137) percent increase in firm growth, when controlling for *Log indeg*; given in network, one-standard deviation increase in *Log indeg* is associated with 5.2 (=0.00821*0.866/0.137) percent reduction in firm growth. For robustness, we use the centrality measures weighted by investment amount instead of those weighted by share percentage, and the results still hold, shown in Appendix Table A.2.

It is possible that our positive network effect only reflects the industry or city trend since firms in certain industries or locations are more likely to be connected. In our robustness check, we address this concern by directly incorporating the 2-digit industry× year two dimensional fixed effects and the city× year two dimensional fixed effects, and our results stay robust.

[TABLE 4]

To explore the time-varying effects of network centrality on real growth, we then introduce the interactions of *In net* and year dummies as well as those of centrality and year dummies. The average treatment effect is plotted in Figure 6, which shows the average effect of network centrality given the position in network. The figure suggests that the effect of the network centrality on real growth has been diminishing over the years in our sample period. In particular, the average effect becomes negative since 2009.[13] This might be related to the impact of the Economic Stimulus Plan

[13] The effect of centrality using in-degree still shows slightly positive after 2009.

in 2009, which we investigate in Section 5.5.

[FIGURE 6]

It is possible that firms with low in-degree are expected by investors to be less profitable and grow at a slower rate, and hence are selected by fewer investors. If so, it may be instructive to use variations in in-degree and examine whether the remaining network centralities affect firm growth for lower in-degree firms. Table 5 reports the results. *Low indeg* is defined as one a firm's in-degree is 0, and 0 otherwise. We interact this classification with the other three measures of centrality. Note that zero-in-degree firms also have zero betweenness. Hence, we skip *Log btw* for this analysis. The results suggest that, controlling for *Low indeg* does not change our main result, that on average higher network centrality is associated with higher firm growth. The coefficients on centralities show that eigenvector centrality still has the largest economic effect. For firms with low in-degree, the impact of network centrality is still significant or even more pronounced. For example, estimation in column (2) suggests that one standard-deviation increase in *Log deg* is associated with 11.7 (=0.0160*0.998/0.137) percent increase in firm growth for firms with high in-degree centrality, and an additional 13.6 (=0.0187*0.998/0.137) percent increase in firm growth for firms with low in-degree. Column (3) shows that even for low-in-degree firms, the effect of eigenvector centrality on growth is less pronounced than that for high-in-degree firms, the total effect is still positive: one standard deviation increase in *Log eigen* is associated with 24.8 ((0.0371-0.00474)*1.052/0.137) percent increase in firm growth. Overall, the results suggest that the effect of network position on firm growth is robust after taking into account the possible selection issue.

[TABLE 5]

5.3 Identification Challenges

It is possible that firms with high expected growth in the future are more likely to join the network, though we have controlled for the observable firm characteristics and different dimensions of fixed effects. In order to address this endogeneity concern, we propose an identification strategy by constructing a pseudo network. Specifically, we drop the top 100 firms with the highest eigenvector centrality from the actual (whole) network of 2017, and then calculate the difference between the eigenvector centralities from the actual networks and the pseudo networks over years. Compared to the pseudo networks without these 100 firms, incorporating these 100 firms creates an exogeneous variation in the global centrality (i.e. eigenvector centrality) for others. To facilitate our justification, consider our baseline model (equation (1)) when using *Log eigen* as a key explanatory variable:

$$\text{Firm growth}_{\text{it}} = \beta\, \text{Log eigen}_{\text{it}} + \gamma \text{X}_{\text{it}} + \epsilon_{\text{it}}. \tag{2}$$

where X_{it} are the control variables including other firm characteristics. The endogeneity comes from the correlation between $\log\_eigen_{it}$ and error term, ϵ_{it}, that is, $cov(Log\ eigen_{it}, \epsilon_{it}|X_{it}) \neq 0$. Suppose we can decompose $\text{Log}\, eigen_{it}$ into two components, denoted as,

$$\text{Log eigen}_{\text{it}} = \text{Log eigen drop}_{\text{it}} + \Delta\text{log \_eigen}_{\text{it}} \tag{3}$$

where $Log\ eigen\ drop_{it}$ is the centrality based on the pseudo network dropping the central 100 firms, and $\Delta\text{log}\ \_eigen_{it}$ is the variation of the eigen-centrality created by the entry of the central 100 firms. If the following two conditions:

i) $\text{cov}(\Delta\,\text{log eigen}_{\text{it}}\,, \text{Log eigen drop}_{\text{it}}|\text{X}_{\text{it}}) = 0$,

ii) $\text{cov}(\Delta\,\text{log eigen}_{\text{it}}\,, \epsilon_{\text{it}}|\text{X}_{\text{it}}) = 0$

We can rewrite our baseline equation as

$$\text{Firm growth}_{\text{it}} = \beta\, \Delta\, \text{Log eigen}_{\text{it}} + \gamma \text{X}_{\text{it}} + \text{u}_{\text{it}} \tag{4}$$

with $\text{u}_{\text{it}} = \beta \text{Log eigen drop}_{\text{it}} + \epsilon_{it}$. Note that $\text{cov}(\Delta\,\text{log eigen}_{\text{it}}\,, \text{u}_{\text{it}}|\text{X}_{\text{it}}) = 0$ from conditions i) and ii), therefore, a regression following (4) will provide us an unbiased estimate about the coefficient β.

Before justifying the validity of conditions i) and ii), let us emphasize one point that our identification, essentially, is the approach of instrumental variables (IVs) – create an exogenous variation Log $\mathrm{eigen_{it}}$ which is orthogonal to the unobservable ϵ_{it} conditional on X_{it}.[14] Specifically, suppose z_{it} are the instrumental variables, in the usual IV approach, we make a decompose:

$$\log \mathrm{eigen_{it}} = \mathrm{Proj_z}(\log \mathrm{eigen_{it}}) + \mathrm{Ortho_z}(\log \mathrm{eigen_{it}})$$

where$\mathrm{Proj_z}(\log \mathrm{eigen_{it}})$ is the projection of $\log \mathrm{eigen_{it}}$ onto $\mathrm{z_{it}}$, while $\mathrm{Ortho_z}(\log \mathrm{eigen_{it}})$ is the component of $\log \mathrm{eigen_{it}}$ orthogonal to $\mathrm{z_{it}}$. In our setting, we can interpret $\Delta\,\mathrm{Log\ eigen_{it}}$ as z_{it}.

Our identification strategy depends on the validity of conditions i) and ii). Condition i) can be tested directly from the data. Column (1) in table 6 shows that conditional on X_{it}, the regression coefficient of $\Delta \log eigen_{it}$ on the $\log eigen\ drop_{it}$ is -0.0135 (s.d = 0.0555) that is statistically insignificant.

On the condition $Cov(\Delta \log eigen_{it}, \epsilon_{it} | X_{it}) = 0$, though we cannot test this condition directly, we find this would not be our main concern. One sufficient condition for the uncorrelation between ϵ_{it} and $\Delta \log eigen_{it}$ is that the entry of these 100 firms in the ownership networks is not driven by the growth of the rest of the firms (sample excluding these 100 firms). If this is true, the second condition is valid. That is, the entry of these 100 firms should create variations in the structure of the networks, resulting in an exogeneous variation of the eigenvector centrality for the rest of the firms in the ownership networks.

Column 2 in Table 6 reports our baseline results where the sample covers firms in the ownership network, the coefficient for the $logeigen_{it}$ is 0.0271 (s.d = 0.000971). Column 3 in Table 6 reports the results using the variation $\Delta logeigen_{it}$, the coefficient is 0.0214 (s.d = 0.00141) that is very close to our baseline result, suggesting that the estimate in our baseline should not significantly biased.

Some may argue that the entry of these 100 firms is driven by the performance of other firms. One weaker hypothesis about the condition ii) is that the entry of these 100 firms is only driven by the performance of their directly connected firms, but not by the remotely connected firms. In this case, we can further identify the causal effect by rerunning the regressions based on Model (4) using the subsample excluding all the firms directly connected to the top 100 firms that we dropped in the ownership network of 2017. Column 4 in table 6 shows the results excluding all firms directly linked to the top 100 firms. Our results are quite robust, and the coefficient increases from 0.0217 to 0.0256 (s.d. = 0.00147).

As we argue above that the variation in the eigen-centrality, $\Delta \log eigen_{it}$, created by the top100 firms are exogeneous. If this is true, we can estimate the coefficient of $\log eigen_{it}$ directly using $\Delta \log eigen_{it}$ as IV. The results are reported in column 5 and 6 in Table 6. Column 5 reports the first stage results suggesting that our IV is strong, the coefficient of $\Delta logeigen_{it}$ is 0.999 (very close to 1), suggesting that there is one-to-one adjustment between $\Delta logeigen_{it}$ and $logeigen_{It}$, conforming the fact that $\mathrm{cov}(\Delta \log \mathrm{eigen}_{\mathrm{it}}, \mathrm{Log\ eigen\ drop}_{\mathrm{it}} | \mathrm{X}_{\mathrm{it}}) = 0$. Column 6 reports the coefficient of $\log eigen_{it}$, which is quite similar to that of coefficient in column 3 where we use the variation to identify the coefficient.

[TABLE 6]

5.4 Heterogenous Effects

5.4.1 State Ownership

We then investigate the heterogenous effects of network position on real outcomes across firms with different types of state ownership. Table 7 reports the results. We use similar specifications as baseline regressions and also include the interactions of SOE dummy and centralities. Our main results still hold, that a firm's network position affects real growth. In-network firms and firms with higher centralities tend to have higher future real growth. However, state-ownership connections tend to mitigate such effect, meaning that the effect of network position is significantly less pronounced for SOEs. This estimated effect is also economically large. Taking column (3) as an example, one-standard-deviation increase in *Log deg* would improve firm growth by 14.7 (=0.0202*0.998/0.137) percent for non-SOEs, while such effect is 8.7 (=0.0119*0.998/0.137) percent less for SOEs. Such effect for SOEs is similar when we use different measures of network centrality, though less significant for eigenvector. Again, for robustness, we rerun the regressions using centrality measures weighted by investment amount and the results stay consistent, shown in Appendix Table A.3.

[TABLE 7]

5.4.2 Firm Productivity

Resource allocation can affect firms' productivity (Hsieh and Klenow, 2009). It is possible that firms' productivity may also influence the effect of network position on real outcomes. Table 8 reports the results examining the heterogenous effect across firms with different total factor productivity (TFP). *HTFP* is defined as one if the TFP value is above median within the same 2-digit CIC and year cohort, or zero otherwise. We use similar specifications but instead interact *HTFP* with network centrality measures. Our main results about the effect of network position on firm growth still hold. All the interactions enter with positive and significant signs at the 1% level, suggesting that the effect of network centrality on real growth is more pronounced for firms with higher productivity, all else equal. In terms of economic magnitude, the efficient in column (5) of the interaction of *HTFP* and *Log eigen* shows that one-standard-deviation increase in *Log eigen* tend to improve firm growth by 6.2 percent (=0.00804*1.052/0.137) for high-productivity firms. In column (3), after incorporating the interaction of *Log btw* and *HTFP*, the coefficient of *Log btw* becomes less significant, indicating that the role of broker between other firms tends to be stronger and more significant for high-productivity firms.

[TABLE 8]

5.4.3 Financial Constraints

Then we examine how network centrality affects the growth of firms with different financial vulnerability. To measure the financial vulnerability and constraint, we use a variable industrial-level *external finance dependence*, which can reflect financial vulnerability embodied in the technology beyond the firms' choice once firms were established (e.g. Manova et al, 2015). Specifically, the external finance dependence is defined as the share of capital expenditure not financed by the cash flow in operations. As a result, these investments are more likely to be long-term. To address the concern that external financing might reflect firms' financing decisions rather than financial constraints, we follow Manova et al. (2015) and use the counterparts in the US to construct the variable. *Fin constraint* is defined one if the external financing dependence is above the median in the same 2-digit industry × year cohort, or zero otherwise.

To capture the heterogenous effects for firms with different financial constraint, we introduce the triple interactions of productivity, financial constraint and centrality measures. Table 9 reports the results. First, the coefficients of the triple interactions, are significantly positive for all the centralities measures except *out-degree*, which capture the outbound equity investments of a given firm. This suggests that the positive effect of network centralities on firm growth is more significant for financially constrained firms with high productivity. Second, the coefficients of the double interactions of *HTFP* and *Fin constraint*, are significantly positive, showing that financially-constrained firms with high productivity on average grow fasters than other firms.

[TABLE 9]

5.4.4 Global vs. Local Effect and its Persistency

Is the network effect on firm growth persistent over time? In this subsection we examine the time effect of network centrality by interacting the centrality measures with the duration of being in network. The duration of being in network is defined as the difference between natural year and the year when the firm first enters the network (*Year- Entry Year*). We also differentiate investors with investees to examine whether there exists heterogeneity between these two groups of agents in the ownership networks.

Table 10 reports the results. To identify the global effects in addition to local effects, in each regression we control for local centralities (both *Log indeg* and *Log outdeg*) and then further incorporate global centralities (either *Log btw* or *Log eigen*). We also split our sample based on the firms' role in equity investments, either investors or investees. Column (1) and (2) show the results for investees and (3) and (4) show those for investors. First, the time of being in network enters with significant and positive signs, suggesting the longer being in the network, the higher the growth rate. Second, the interaction terms of duration of being in network and local centralities all enter with significant and negative signs, suggesting that over time the positive effect of local centrality on firm growth decline over time. In contrast, the interaction terms of duration of being in network and global centralities all enter with significant and positive signs, meaning that the positive effect associated with global centrality rise over time. Third, compared to betweenness centrality, eigenvector centrality has stronger effect, when controlling for the impact of local centralities, *in-degree* and *out-degree*. Overall the results suggest that joining the network itself promotes firm future growth, and over time such positive effect is stronger if the firm is important throughout the network globally.

[TABLE 10]

5.4.5 The Impact of Possible Industrial Linkages

It is possible that other industrial linkages (e.g. production networks) might also affect firm growth. A number of studies have been examining production networks (e.g. Antras et al., 2012; Antras, 2016) For example, Liu (2019) examines the relationship between economic policies and production networks via input-output linkages and finds there is an incentive for government to support upstream sectors. Bernard, Moxnes and Saito (2019) examines the importance of buyer-supplier relationships for firm performance. Ahern and Harford (2014) find that stronger product market connections through customer and supplier trade flows lead to a greater incidence of cross-industry mergers. In order to consider the possible influence from other forms of industrial linkages, we further include the fixed effects of the industry linkages between the investor and the investee (the firm itself). The results are reported in Table 11. In addition, we also incorporate one more variable, whether the firm is located in the largest sub-network of the whole networks[15], in the regressions. We find that controlling for the influence of industrial linkages does not change our

[15] A sub-network is defined as a connected graph, i.e., for every pair of nodes, there is a path from each other regardless of the direction of the edges. In graph theory, a sub-network in our definition is termed as weakly connected directed graph. For our equity holding network, every pair of firms in a sub-network has an investment path between each other regardless of the direction of the investment(s). In 2017, the largest sub-network has 1.7 million firm, accounting for 38% of in-network firms but 80% of the in-network total registration capital and 85% of the total in-network investments. For more details, please see Allen et al. (2020d).

main results, that network centrality affects firm growth significantly. This suggests that after considering the possible effects from production networks or other types of industrial linkages, network centrality in equity ownership networks is an important determinant of firm growth. In addition, we also find that firms located in the largest sub-network also have on average higher firm growth. Controlling for whether the firm is located in the largest sub-network also does not change our main results.

[TABLE 11]

5.5 The Impact of the Economic Stimulus Plan in 2009

The massive economic stimulus plan, a combination of fiscal and credit program, officially announced in November 2008, featured spending RMB 4 trillion (US$ 586 billion) on a wide array of national infrastructure and social welfare projects, as well as encouraging increase in credit supply to the real economy by banks. While Chen, He and Liu (2019) estimate that the fiscal investment targets were largely financed by local government financing vehicles (LGFVs) in the form of bank loans, Cong et al. (2019) document that the credit expansion had a much broader impact on Chinese economy beyond supporting LGFVs. Moreover, this stimulus-driven credit expansion disproportionately favored SOEs. Acharya, Qian and Yang (2018) show that Bank of China (BOC) became the most aggressive in the expansion of new loans during 2009-10. Hence, the stimulus plan provides a shock to the financing of SOEs, especially those with repeated relationship with banks. Using the equity holding information, we define firm as bank-affiliated, denoted by *Bank subs*, if they have banks as their shareholders within at most three steps of the ownership network. Existing literature shows that dual holding can internalize the conflicts between shareholder and creditor and hence lead to more favorable loan terms (e.g. Jiang, Li and Shao, 2010). We use *Bank subs* as a proxy for repeated relationship with banks and assume that firms are more likely to obtain loans from banks if they are affiliated with banks. We interact *Bank subs* with network centrality measures as well as the time indictor of the Economic Stimulus Plan, *Post FS*. *Post FS* is defined as one for the time period 2009 to 2013, and zero otherwise. Table 12 reports the results. The specifications are the same in column (1) to (5), using five different centrality measures. We didn't incorporate the time indicator itself as year fixed effects are included in the model. The results show that, first, our main results still hold, that in-network firms or firms have higher centrality tend to grow faster. Note that *Log indeg* also enters with significant and positive signs in column (1), suggesting that the effect of in-degree is positive on firm growth over the sample period 2000 to 2008. Second, the interaction of *Post FS* and centrality measures enter with significant and negative signs, in all the specifications, suggesting that network centrality tends to have less pronounced impact on real growth after the Economic Stimulus Plan in 2009 than before. Third, the strong positive coefficients of triple interactions of *Post FS*, *Bank Subs* and centrality measures show that since 2009, the effect of network centrality on real growth is more pronounced for firms affiliated with banks, indicating that on average the network position may complement bank loans in promoting real growth.[16]

[TABLE 11]

We then further split our full sample into firms owned by banks and those not owned by banks. In the regressions we introduced the triple difference term (the interaction of *Post FS*, *SOE* and centrality measures) as well as the double difference term of any two of them. In Table 12, PANEL A reports the results for bank-affiliated firms. First, for bank-affiliated firms, the double difference

[16] We also examine how the network centrality affects leverage and its influence before and after the stimulus, with the results reported in Appendix Table A.4 (Panels A and B). In Panel A, we find that network centrality is positively associated with firm leverage for out-degree, degree and betweenness; however, such relationship is not significant between eigenvector centrality and leverage. In addition, the size of the coefficients on network centralities is smaller than those in baseline results (Table 4). In Panel B, we find such relationship is more pronounced since the Stimulus Plan was launched in 2009. Overall, these suggest that it's less likely that the effects of network centrality on firm growth is driven by debt financing.

of *Post FS* and centralities all enter with significant and positive signs, suggesting that the effect of network centrality on growth is more pronounced since 2009 for bank-affiliated non-SOEs. Second, the strong negative coefficient of the triple difference terms suggest that such effect is less strong for bank-affiliated SOEs. In terms of economic magnitude, take column (3) as an example, the relative size of the coefficients (-0.0415 versus 0.0329) implies that such effect is actually offset by state-ownership. These findings further indicate that after the announcement of the Stimulus Plan in 2009, it is easier for bank-affiliated SOEs to obtain loans hence the network effect is less pronounced for them.

PANEL B reports the results for non-bank-affiliated firms. In the opposite, the double difference of *Post FS* and centralities all enter with significant and negative signs while the triple difference all enter with significant and positive signs, suggesting that the effect of network centrality on real growth is less pronounced since 2009 for non-bank-affiliated non-SOEs, while such impact is mitigated again by state ownership. Put differently, given firms with weak bank relationship (hence less access to loans), state ownership appears to strengthen the network effect since 2009; whereas given firms with strong bank relationship (hence more access to loans), state ownership tends to mitigate the network effect since 2009. Taken together, these indicate that the ownership network may substitute loans in promoting growth for SOEs, whereas complement loans in promoting growth for non-SOEs.

[TABLE 12]

6. Conclusion

The finance–growth nexus has been a central question in interpreting the unprecedented success of the Chinese economy. In a state-controlled economy, a state-dominant banking system mainly serves the financing needs of SOEs. An enduring puzzle is how the private sector has been able to grow in a credit-constrained environment. In this paper, using a complete equity ownership network for all the registered firms in China, we are the first to show how capital is allocated in and across networks and how it contributes to real growth. Our analysis suggests that the entire set of networks has been expanding rapidly since the 2000s, though new entrant firms tend to attract and make fewer investments, so achieve less global importance. Equity ownership networks can help facilitate the sharing of information, contacts and resources among firms. Our study shows that entering a network is associated with higher real growth; more specifically, in-network firms with higher centrality tend to have higher growth. Such effect of network position on real growth tends to be more pronounced for highly productive and financially constrained firms and non-SOEs. The global effect of network centrality is still positive and significant after controlling for the local effect.

Over time, the average effect of network centrality on real growth decreases and has been diminishing since the economic stimulus plan instituted in 2009, suggesting a crowding-out effect of the sudden increase in bank credit on equity capital. Further investigations show that equity ownership networks serve as a substitute for bank credit for SOEs, and a complement to bank credit for non-SOEs in promoting real growth. This may imply that the allocation of equity capital might be more efficient than credit.

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Figure 1: Network visualization of a significant SOE (Central Huijin Investment) in China
To illustrate, this figure visualizes the equity ownership network of the 2-layer sub-network of a significant SOE (Central Huijin Investment) in China. There are 857 firms in the 2-layer sub-network, out of 80K affiliated firms in the whole network of Central Huijin Investment. The nodes represent firms/institutions as investors/investees. The node size represents the eigenvector centrality throughout the entire equity ownership network. The node color indexes communities detected within the sub-network. For more details on community detection of the equity ownership network, please see Cai et al. (2020), The edges represent equity investment flows among firms/institutions. The arrows represent the investment direction, from investors to investees.

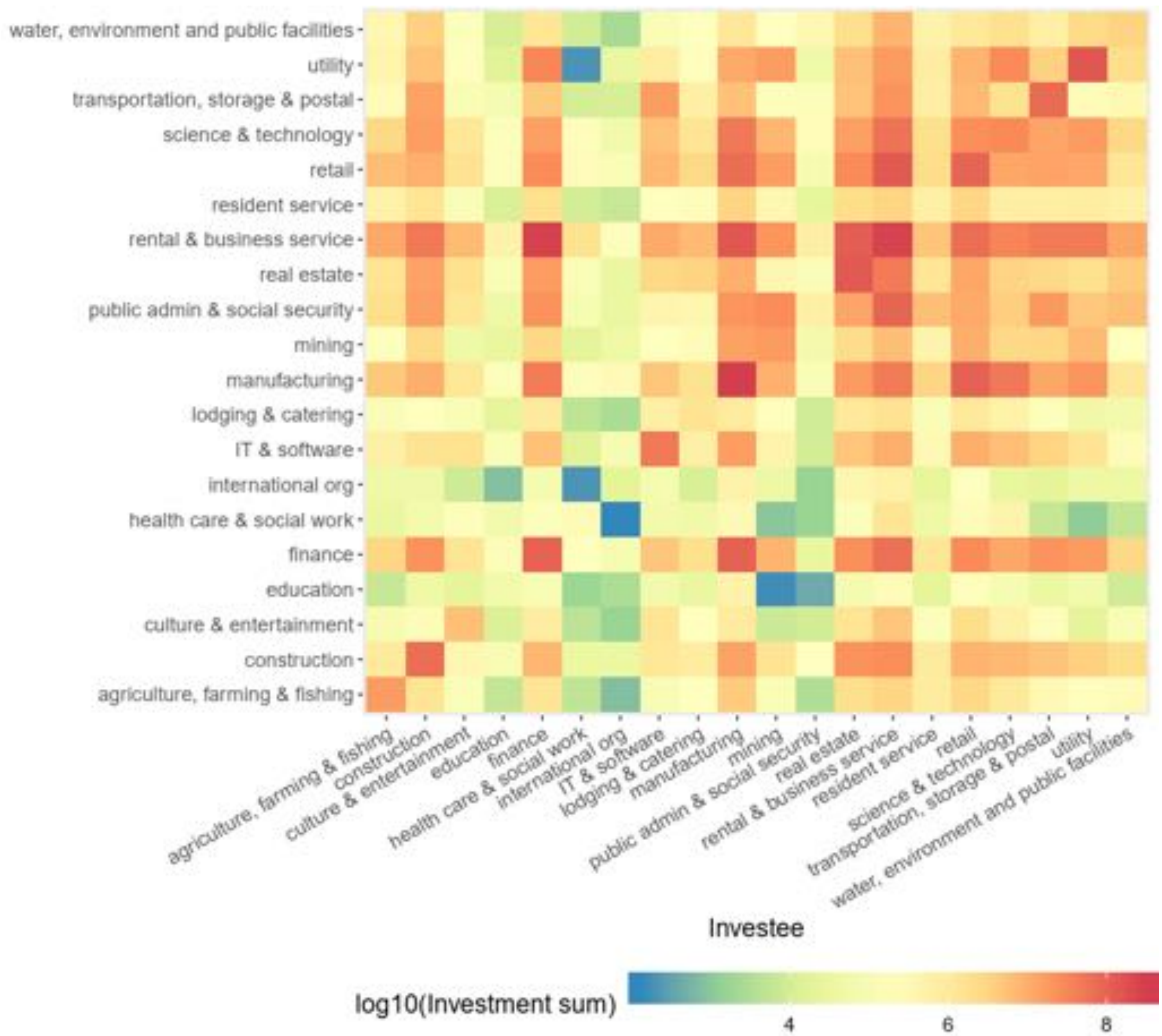

Figure 2: Equity investments across industry

This figure plots the investment amount (in 10K) between pairs of industries (from X-axis industries to Y-axis industries) in 2012.

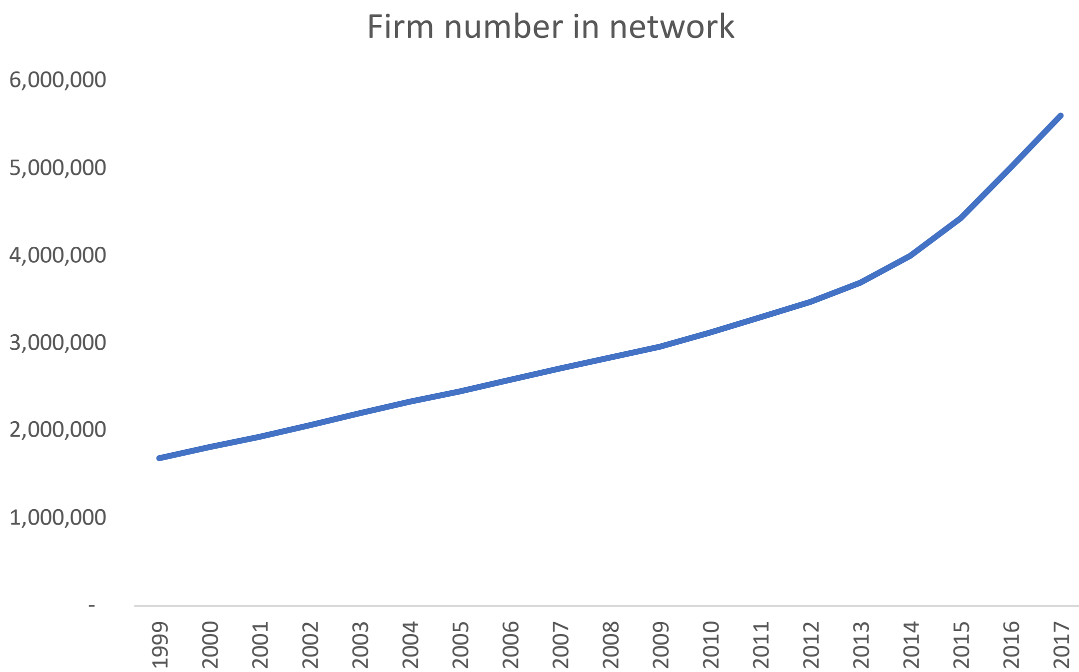

Figure 3: Size of the ownership network
This figure plots the number of firms in the ownership network over 1999 to 2017.

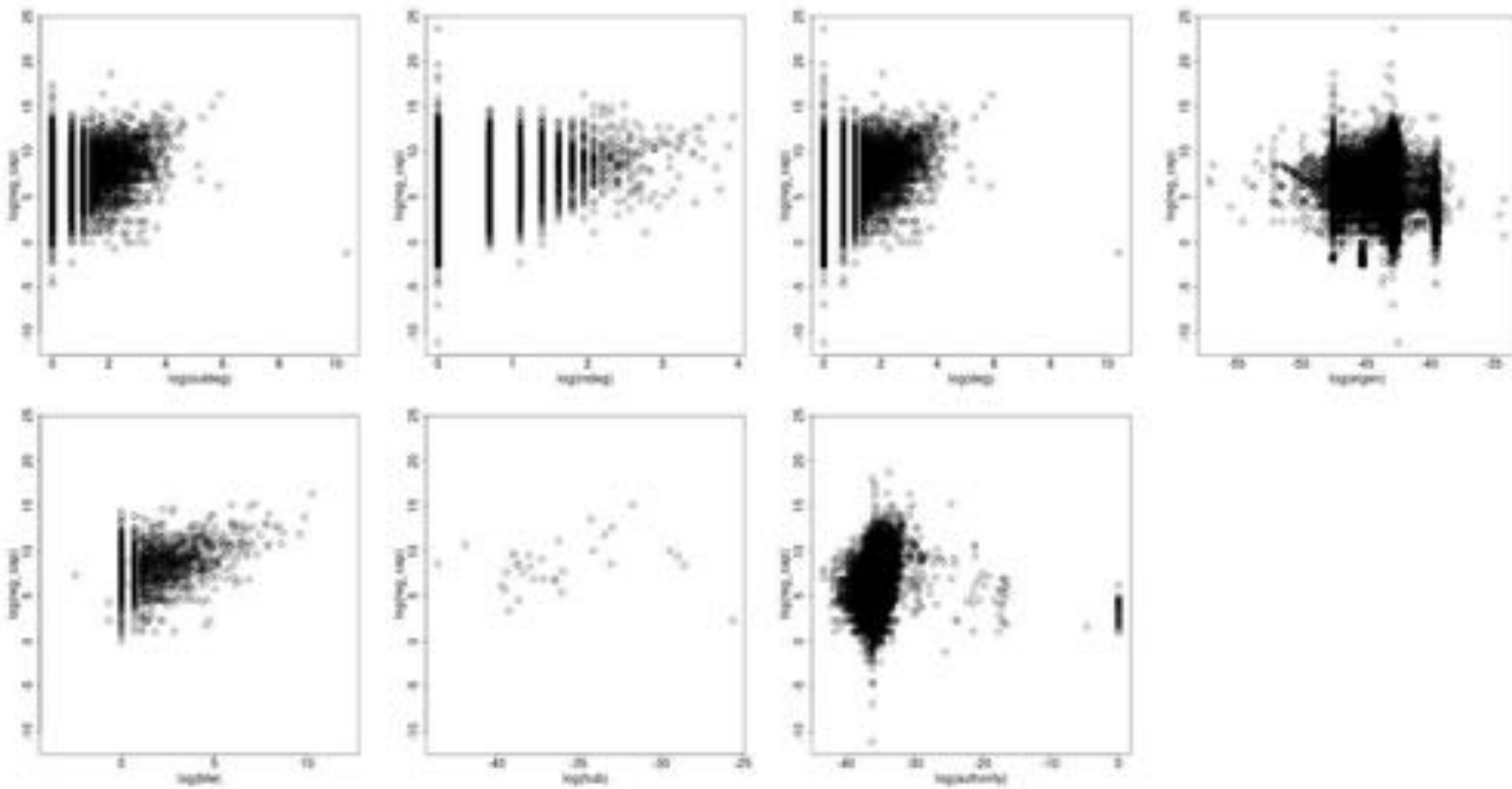

Figure 4: Registered capital and centralities
This figure plots the relationship of ownership network centralities and firm registered capital.

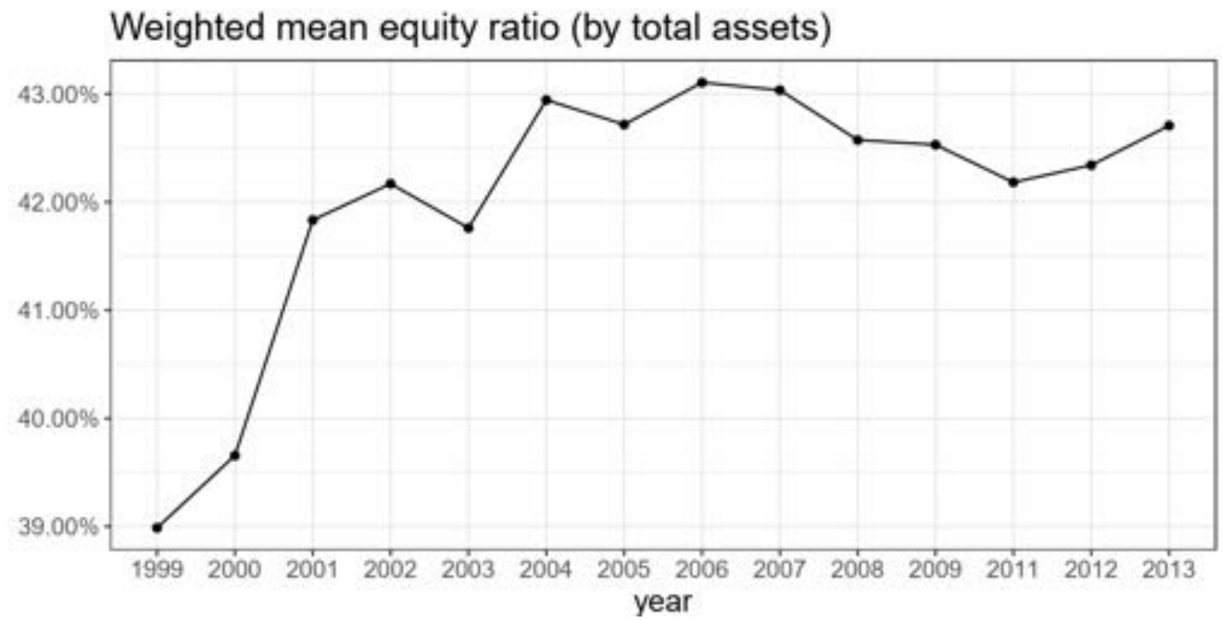

Figure 5: Equity ratio, state ownership and network position
This figure plots mean value of equity ratio, weighted by firm assets. The plot shows that weighted mean equity ratio in our sample period is roughly 43%.

Figure 6: Effect of network centrality over time

This figure plots the average treatment effect of network centrality over the years of 2000 to 2013, using the coefficients of *In net* and those of Centralities (*Log indeg, Log outdeg, Log btw, Log eigen*) in the regressions examining the effect of ownership network centrality on firm growth. The value plotted in the figure shows the mean values of centralities × coefficients of centralities + coefficients of *In net*.

Table 1: Equity capital by industry

This table reports the amount of equity investments aggregated at the industry level. Investment amount/Firm amount (across industry) only considers the investments across industry (in RMB), scaled by firm number in the industry Total investment amount/Firm number considers the total investment in a given industry (in RMB), scaled by firm number in the industry.

	Invested amount/Firm number (across industry)	Total investment amount/Firm number (both across and within industry)	Firm number
Financial industry	7,369	10,825	136,020
Construction/Real estate	4,342	6,557	482,433
Mining	4,280	5,147	31,256
Utilities	3,659	7,075	67,576
Water, Environmental Services and Infrastructure Services	3,316	3,628	34,440
Transportation, Warehousing and Postal Services	2,628	8,966	121,430
Rental and Business Services	2,235	4,236	878,427
Education	1,612	1,660	12,914
Health Care and Social Assistance	1,469	1,639	16,357
Professional, Scientific and Technical Services	1,153	1,461	396,993
Public Services, Social Welfare and Social Organization	1,013	1,307	3,711
Information, Software and Technology Services	914	1,654	194,360
Household Services, Repairing and Other Services	883	936	105,194
Arts, Entertainment and Recreation	776	968	88,378
Manufacturing	684	1,271	845,650
Wholesale and Retail Trade	560	768	1,120,982
Agriculture, Forestry, Fishing and Hunting	531	649	845,650
Accommodation and Food Services	429	468	95,004
International Organizations	384	393	4,303

Table 2: Summary statistics of the entire equity ownership network in 2017

This table presents the descriptive statistics for network centrality measures and firm characteristics for the complete equity ownership network in 2017. Both *In-degree* and *Out-degree* show how connected a firm is; Degree is the sum of In-degree and Out-degree; *Betweenness* presents how important a firm is in terms of connecting other firms; *Eigenvector centralities*, the principal eigenvector of the network's adjacency matrix, reflects the importance of firms. *Hub* and *authority* centralities, the principal eigenvector of hub and authority matrix respectively, captures the important investors and investees. We calculate the centralities weighted either by the share percentage of investees or the investment RMB amount.

PANEL A: Summary statistics of network centralities

Centrality measures	Obs.	Mean	Std. Dev.	Min	25%	50%	75%	Max
In-degree	5,604,486	0.90	1.17	0.00	0.00	1.00	1.00	350
Out-degree	5,604,486	0.90	21.90	0.00	0.00	0.00	1.00	32,415
Degree	5,604,486	1.81	21.92	1.00	1.00	1.00	2.00	32,416
Betweenness	5,604,486	1.75	573.63	0.00	0.00	0.00	0.00	1,000,000
Betweenness cash	5,604,486	0.16	32.44	0.00	0.00	0.00	0.00	63,299
Eigenvector	5,604,486	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Eigenvector cash	5,604,486	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Hub cash	5,604,486	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Authority cash	5,604,486	0.00	0.00	0.00	0.00	0.00	0.00	1.00

PANEL B: Firm characteristics of in-network firms

Variable	Obs.	Mean	Median	Std. Dev.	Min	Max
Investors						
Reg cap (mn)	877,663	45.95	5.00	2,949.31	0.00	900,000.00
Firm age (years)	891,722	10.05	8.00	8.56	0.00	67.00
Investees						
Reg cap (mn)	2,982,000	36.29	2.00	2,332.02	0.00	1,000,000.00
Firm age (years)	3,010,000	10.35	8.00	9.42	0.00	67.00
Investors & Investees						
Reg cap (mn)	836,526	115.46	5.70	2,281.41	0.00	836,000.00
Firm age (years)	855,125	13.54	13.00	10.13	0.00	67.00

Table 3: Summary statistics for the matched sample with AIS: 2000-2013

This table presents the descriptive statistics for firm characteristics and network centrality measures for the matched sample with AIS (2000-2013). We calculate the centralities weighted either by the share percentage of investees or the investment RMB amount. All variables are defined in Appendix Table A.1.

Variables	Obs	Mean	Median	Std. Dev.	Min	Max
Firm growth	2,336,536	0.137	0.076	0.445	-1.970	2.343
Firm age	2,336,536	2.024	2.079	0.865	0.000	4.143
Total assets	2,336,536	123,732	16,917	1,927,914	1	900,085,215
Firm size	2,336,536	9.901	9.736	1.482	0.000	20.618
ROA	2,336,536	0.102	0.035	0.197	-0.359	1.700
Leverage	2,336,536	0.569	0.583	0.295	0.000	0.999
SOE	2,336,536	0.078	0.000	0.269	0.000	1.000
In net	2,336,536	0.286	0.000	0.452	0.000	1.000
Log indeg	2,336,536	-0.164	-0.524	0.866	-0.525	4.489
Log outdeg	2,336,536	0.066	-0.391	1.075	-0.391	5.702
Log deg	2,336,536	-0.071	-0.619	0.998	-0.619	4.509
Log btw	2,336,536	0.009	-0.186	1.038	-0.187	19.841
Log eigen	2,336,536	-0.028	-0.448	1.052	-0.449	9.868
Log btw cash	2,336,536	-0.009	-0.038	0.871	-0.038	26.176
Log eigen cash	2,336,536	0.016	-0.044	1.169	-0.044	28.170
Log hub cash	2,336,536	0.096	0.000	0.329	0.000	4.615
Log authority cash	2,336,536	0.480	0.000	1.512	0.000	20.723

Table 4: Ownership network and firm growth: baseline results

This table reports the baseline results of the regressions examining the impact of ownership network centrality on firm growth. The dependent variable is *Firm growth*, defined as the growth rate of firm total assets. The key explanatory variable is the centrality measures, including *Log indeg*, *Log outdeg*, *Log deg*, *Log btw*, and *Log eigen*. All variables are defined in Appendix Table A.1. Robust standard errors clustered at firm level are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Dep. Var	*Firm growth*				
	(1)	(2)	(3)	(4)	(5)
ROA	0.372***	0.373***	0.373***	0.373***	0.373***
	(0.00313)	(0.00313)	(0.00313)	(0.00313)	(0.00313)
Leverage	0.0116***	0.0114***	0.0116***	0.0117***	0.0119***
	(0.00211)	(0.00211)	(0.00211)	(0.00211)	(0.00211)
Firm age	-0.00208**	-0.00183**	-0.00162*	-0.00177*	-0.00155*
	(0.000914)	(0.000913)	(0.000914)	(0.000914)	(0.000913)
Firm size	-0.426***	-0.427***	-0.427***	-0.426***	-0.427***
	(0.00106)	(0.00106)	(0.00106)	(0.00106)	(0.00106)
SOE	-0.00770**	-0.00804**	-0.00628*	-0.00628*	-0.00663*
	(0.00373)	(0.00372)	(0.00372)	(0.00373)	(0.00372)
In net	0.0505***	0.0120***	0.0145***	0.0431***	0.00463**
	(0.00205)	(0.00227)	(0.00278)	(0.00189)	(0.00230)
Log indeg	-0.00821***				
	(0.00108)				
Log outdeg		0.0239***			
		(0.000974)			
Log deg			0.0188***		
			(0.00137)		
Log btw				0.00489***	
				(0.000646)	
Log eigen					0.0308***
					(0.00113)
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
# of obs.	2,336,536	2,336,536	2,336,536	2,336,536	2,336,536
R-squared	0.429	0.430	0.429	0.429	0.430

Table 5: Ownership network and firm growth: conditional on in-degree centrality

This table reports the results of the regressions examining the impact of ownership network centrality on firm growth conditional on low in-degree firms. *Low indeg* is defined as 1 if a firm's in-degree equals 0; and 0 otherwise. *SOE* is defined as 1 if the firm is state-owned; or 0 (either collective or private firms) otherwise. The dependent variable is *Firm growth*, defined as the growth rate of firm total assets. The key explanatory variable is the centrality measures, including *Log outdeg, Log deg*, and *Log eigen*. All variables are defined in Appendix Table A.1. Robust standard errors clustered by firm are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Dep. Var	*Firm growth*		
	(1)	(2)	(3)
In net	-0.00746*	0.00367	0.0226***
	(0.00409)	(0.00365)	(0.00285)
Low indeg	-0.0161***	0.0160***	0.0538***
	(0.00417)	(0.00411)	(0.00346)
Log outdeg	0.0151***		
	(0.00149)		
Log outdeg*Low indeg	0.0126***		
	(0.00227)		
Log deg		0.0160***	
		(0.00173)	
Log deg *Low indeg		0.0187***	
		(0.00239)	
Log eigen			0.0371***
			(0.00137)
Log eigen* Low indeg			-0.00474**
			(0.00186)
Other controls	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	1,850,213	1,850,213	1,850,213
R-squared	0.443	0.443	0.444

Table 6: Creating Pseudo Networks: Identifying the Effect of Eigenvector Centrality

This table reports the results of the regressions identifying the causal effect of eigenvector centrality on firm growth, using the sample of firms in networks. We create pseudo networks by dropping the top 100 firms with the highest eigenvector centrality in the actual ownership network of 2017. The dependent variable is *Firm growth*, defined as the growth rate of firm total assets. The key explanatory variables are *Log eigen*, *Log eigen drop*, $\Delta log\ eigen$. $\Delta log\ eigen$ are defined as the difference between the actual and pseudo eigenvector centrality. All the other variables are defined in Appendix Table A.1. Robust standard errors clustered at firm level are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

	$\Delta Log\ eigen$		Firm Growth		1st stage	Firm Growth
	(1)	(2)	(3)	(4)	(5)	(6)
Log eigen		0.0271***				0.0217***
		(0.000971)				(0.00123)
Log eigen drop	-0.00135					
	(0.00555)					
$\Delta Log\ eigen$			0.0217***	0.0256***	0.998***	
			(0.00141)	(0.00143)	(0.00147)	
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	801,593	857,566	801,593	794,311	852,804	852.804
R-squared	0.817	0.410	0.405	0.406		0.0245
F-statistics					40025.93	

Table 7: Ownership network and firm growth: SOEs vs. non-SOEs

This table reports the results of the regressions examining the impact of ownership network centrality on firm growth for SOEs vs. non-SOEs. SOE is defined as 1 if the firm is state-owned; or 0 (either collective or private firms) otherwise. The dependent variable is *Firm growth*, defined as the growth rate of firm total assets. The key explanatory variable is the centrality measures, including *Log indeg*, *Log outdeg, Log deg*, *Log btw*, and *Log eigen*. All variables are defined in Appendix Table A.1. Robust standard errors clustered by firm are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Dep. Var	*Firm Growth*				
	(1)	(2)	(3)	(4)	(5)
In net	0.0505***	0.0117***	0.0139***	0.0432***	0.00441*
	(0.00205)	(0.00227)	(0.00278)	(0.00189)	(0.00230)
Log indeg	-0.00757***				
	(0.00110)				
SOE*Log indeg	-0.00674***				
	(0.00243)				
Log outdeg		0.0249***			
		(0.000998)			
SOE*Log outdeg		-0.00847***			
		(0.00181)			
Log deg			0.0202***		
			(0.00140)		
SOE*Log deg			-0.0119***		
			(0.00214)		
Log btw				0.00578***	
				(0.000672)	
SOE*Log btw				-0.00703***	
				(0.00149)	
Log eigen					0.0313***
					(0.00116)
SOE* Log eigen					-0.00333*
					(0.00192)
Other controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
# of obs.	2,336,536	2,336,536	2,336,536	2,336,536	2,336,536
R-squared	0.429	0.430	0.429	0.429	0.430

Table 8: Ownership network and firm growth: the impact of firm productivity

This table reports the results of the regressions examining the impact of firm productivity (TFP) on the relationship among network centrality and firm growth. *TFP* is firm total factor productivity calculated by year and industry at the three-digit level. We then generate a HTFP dummy, which is 1 if the TFP is above the median of the 3-digit industry at given year, otherwise 0. The dependent variable is *Firm growth*, defined as the growth rate of firm total assets. The key explanatory variable is the centrality measures, including *Log indeg*, *Log outdeg, Log deg*, *Log btw*, and *Log eigen*. All variables are defined in Appendix Table A.1. Robust standard errors clustered by firm are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Dep. Var	*Firm Growth*				
	(1)	(2)	(3)	(4)	(5)
In net	0.0510***	0.0128***	0.0160***	0.0432***	0.00586**
	(0.00206)	(0.00228)	(0.00278)	(0.00190)	(0.00231)
HTFP	0.0355***	0.0355***	0.0352***	0.0358***	0.0354***
	(0.000818)	(0.000818)	(0.000820)	(0.000817)	(0.000818)
Log indeg	-0.0134***				
	(0.00116)				
HTFP * Log indeg	0.00830***				
	(0.000723)				
Log outdeg		0.0180***			
		(0.00106)			
HTFP * Log outdeg		0.00922***			
		(0.000710)			
Log deg			0.0108***		
			(0.00144)		
HTFP * Log deg			0.0124***		
			(0.000732)		
Log btw				-0.000324	
				(0.000800)	
HTFP * Log btw				0.00773***	
				(0.000746)	
Log eigen					0.0252***
					(0.00124)
HTFP * Log eigen					0.00804***
					(0.000744)
Other controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
# of obs.	2,281,558	2,281,558	2,281,558	2,281,558	2,281,558
R-squared	0.429	0.430	0.430	0.429	0.430

Table 9: Ownership network and firm growth: the impact of financial constraints

This table reports the regressions examining the heterogenous effects of financial constraints on firm productivity, network centrality and firm growth. *TFP* is firm total factor productivity calculated by year and industry at three-digit level. We then generate a HTFP dummy, which is 1 if the TFP is above the median of the 3-digit industry at given year, otherwise 0. *Fin constraint* is defined by the dependence on external financing for a given industry. The dependent variable is *Firm growth*, defined as the growth rate of firm total assets. The key explanatory variable is the centrality measures, including *Log indeg*, *Log outdeg, Log deg*, *Log btw*, and *Log eigen*. All variables are defined in Appendix Table A.1. Robust standard errors clustered by firm are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Dep. Var	*Firm growth*			
	(1)	(2)	(3)	(4)
HTFP * Fin constraint	0.0395***	0.0298***	0.0365***	0.0343***
	(0.00218)	(0.00211)	(0.00204)	(0.00208)
HTFP* Fin constraint* In net	-0.0394***	-0.0112***	-0.0341***	-0.0273***
	(0.00333)	(0.00407)	(0.00303)	(0.00346)
Log indeg	-0.00507**			
	(0.00209)			
HTFP * Log indeg	-0.0151**			
	(0.00188)			
Fin constraint * Log indeg	-0.00401			
	(0.00266)			
HTFP* Fin constraint * Log indeg	0.0213***			
	(0.00266)			
Log outdeg		-0.0230***		
		(0.00145)		
HTFP * Log outdeg		-0.00364***		
		(0.00133)		
Fin constraint * Log outdeg		-0.00122		
		(0.00180)		
HTFP*Fin constraint * Log outdeg		-0.000937		
		(0.00207)		
Log btw			-0.00620***	
			(0.00140)	
HTFP * Log btw			-0.00454***	
			(0.00141)	
Fin constraint * Log btw			-0.000268	
			(0.00175)	
HTFP* Fin constraint * Log btw			0.00393**	
			(0.00177)	
Log eigen				-0.0174***
				(0.00171)
HTFP * log eigen				-0.00878***
				(0.00149)
Fin constraint * Log eigen				-0.000837
				(0.00207)
HTFP* Fin constraint * Log eigen				0.00794***
				(0.00204)
Other controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes

Year FE	Yes	Yes	Yes	Yes
# of Obs.	1,106,001	1,106,001	1,106,001	1,106,001
R-squared	0.197	0.198	0.197	0.197

Table 10: Ownership network and firm growth: time effect and global effect

This table reports the results of the regressions examining the global effect of the network as well as the heterogenous effect between investors and investees. The difference between natural year and entry year identifies the duration of entering a network. The dependent variable is *Firm growth*, defined as the growth rate of firm total assets. The key explanatory variable is the centrality measures, including *Log indeg*, *Log outdeg, Log deg*, *Log btw*, and *Log eigen*. All variables are defined in Appendix Table A.1. Robust standard errors clustered by firm are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Dep. Var	*Firm growth*			
	(1)	(2)	(3)	(4)
	Investees		Investors	
Investee	-0.0501***	-0.0359***		
	(0.00741)	(0.00764)		
Investors			-0.118***	-0.0912***
			(0.00548)	(0.00590)
Year – Entry year	0.00866***	0.00770***	0.0131***	0.0135***
	(0.000780)	(0.000765)	(0.000618)	(0.000621)
Log indeg	0.0323***	0.0202***	0.0114***	0.0187***
	(0.00357)	(0.00387)	(0.00187)	(0.00274)
(Year – Entry year)* Log indeg	-0.00576***	-0.00577***	-0.00430***	-0.00770***
	(0.000441)	(0.000442)	(0.000371)	(0.000513)
Log outdeg	0.0230***	0.0200***	0.0612***	0.0491***
	(0.00151)	(0.00227)	(0.00261)	(0.00367)
(Year – Entry year)* Log outdeg	-0.00270***	-0.00450***	-0.00963***	-0.0137***
	(0.000288)	(0.000441)	(0.000404)	(0.000558)
Log btw	-0.00452***		0.000444	
	(0.00160)		(0.00144)	
(Year – Entry year)* Log btw	0.00229***		0.00101***	
	(0.000354)		(0.000326)	
Log eigen		0.00638***		-0.00724*
		(0.00243)		(0.00393)
(Year – Entry year)* Log eigen		0.00342***		0.00817***
		(0.000474)		(0.000760)
Other controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
# of Obs.	437,157	437,157	553,698	553,698
R-squared	0.402	0.403	0.392	0.393

Table 11: Network and firm growth: the impact of industry chain

This table reports the results of the regressions examining the effect of ownership network position on firm growth when controlling for the impact of industry chain. The dependent variable is *Firm growth*, defined as the growth rate of firm total assets. The key explanatory variable is the centrality measures, including *Log indeg*, *Log outdeg*, *Log deg*, *Log btw*, and *Log eigen*. *Largest sub-network* is a dummy variable indicating whether the firm lies in the largest sub-network of the whole networks in a given year. Industry-chain dummy indicates the linkage between the investor and the firm itself. In the regressions we include industry chain fixed effects in addition to firm and year fixed effects. All variables are defined in Appendix Table A.1. Robust standard errors clustered at firm level are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Dep. Var	*Firm growth*				
	(1)	(2)	(3)	(4)	(5)
In net	0.0475***	0.0110***	0.0141***	0.0411***	0.0292***
	(0.00210)	(0.00234)	(0.00284)	(0.00197)	(0.00199)
Largest sub-network	0.0129***	0.00614**	0.00559**	0.00774***	0.00137
	(0.00243)	(0.00240)	(0.00243)	(0.00243)	(0.00242)
Log indeg	-0.00866***				
	(0.00113)				
Log outdeg		0.0255***			
		(0.00107)			
Log deg			0.0183***		
			(0.00143)		
Log btw				0.00582***	
				(0.000734)	
Log eigen					0.0244***
					(0.000936)
Other controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Industry chain FE	Yes	Yes	Yes	Yes	Yes
# of obs.	2,336,536	2,336,536	2,336,536	2,336,536	2,336,536
R-squared	0.429	0.429	0.429	0.429	0.429

Table 12: Network and firm growth: the impact of the Economic Stimulus Plan in 2009

This table reports the results of the regressions examining the impact of the Fiscal Stimulus Plan in 2009 on the relationship among network centrality, firm growth and bank ownership. *Bank subs* is defined as 1 if the firm has a bank as its shareholder tracing up within three steps of ownership; or 0 otherwise. *Post FS* is defined as 1 for the sample period 2009-2013; and 0 for 2000-2008. The dependent variable is *Firm growth*, defined as the growth rate of firm total assets. The key explanatory variable is the centrality measures, including *Log indeg*, *Log outdeg, Log deg*, *Log btw*, and *Log eigen*. All variables are defined in Appendix Table A.1. Robust standard errors clustered by firm are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Dep. Var	*Firm Growth*				
	(1)	(2)	(3)	(4)	(5)
In net	0.0444***	0.0124***	0.00472*	0.0431***	-0.00630***
	(0.00206)	(0.00229)	(0.00284)	(0.00189)	(0.00237)
Bank subs	0.00348	0.0177**	0.0148	-0.00540	0.0322***
	(0.0168)	(0.00770)	(0.0132)	(0.00800)	(0.0106)
Post FS* Bank subs	-0.0975***	-0.0371***	-0.0994***	-0.0487***	-0.0834***
	(0.0163)	(0.00664)	(0.0123)	(0.00706)	(0.00950)
Log indeg	0.00399***				
	(0.00116)				
Post FS * Log indeg	-0.0356***				
	(0.000799)				
Bank subs* Log indeg	0.00395				
	(0.00687)				
Post FS*Bank subs*Log indeg	0.0727***				
	(0.00692)				
Log outdeg		0.0249***			
		(0.00105)			
Post FS * Log outdeg		-0.00399***			
		(0.000699)			
Bank subs* Log outdeg		0.00687**			
		(0.00323)			
Post FS*Bank subs*Log outdeg		0.0208***			
		(0.00300)			
Log deg			0.0321***		
			(0.00146)		
Post FS * Log deg			-0.0250***		
			(0.000764)		
Bank subs* Log deg			-0.00776		
			(0.00548)		
Post FS*Bank subs*Log deg			0.0648***		
			(0.00544)		
Log btw				0.00904***	
				(0.000861)	
Post FS * Log btw				-0.00509***	
				(0.000799)	
Bank subs * Log btw				0.00168	
				(0.00139)	
Post FS*Bank subs*Log btw				0.0137***	
				(0.00138)	
Log eigen					0.0456***
					(0.00130)

Post FS * Log eigen					-0.0254***
					(0.000802)
Bank subs * Log eigen					-0.0206***
					(0.00399)
Post FS*Bank subs*Log eigen					0.0557***
					(0.00389)
Other controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
# of obs.	2,336,536	2,336,536	2,336,536	2,336,536	2,336,536
R-squared	0.430	0.430	0.430	0.429	0.430

Table 13: Heterogeneous effects of the Fiscal Stimulus Plan in 2009

This table reports the regressions examining the heterogenous effect of the Fiscal Stimulus Plan in 2009 on the relationship among centralities, state ownership and firm growth. PANEL A reports the results for the subsample of bank-owned firms; PANEL B reports the results for the subsample of non-bank-owned firms. We define bank-owned firms as firms with banks as shareholders within 3 steps of the ownership network. *Post FS* is defined as 1 for the sample period 2009-2013; and 0 for 2000-2008. The dependent variable is *Firm growth*, defined as the growth rate of firm total assets. The key explanatory variable is the centrality measures, including *Log indeg*, *Log outdeg, Log deg*, *Log btw*, and *Log eigen*. In PANEL A, *In net* is dropped out because all bank-affiliated firms are located in ownership network. All variables are defined in Appendix Table A.1. Robust standard errors clustered by firm are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

PANEL A: Subsample of bank-affiliated firms

Dep. Var	*Firm Growth*				
	(1)	(2)	(3)	(4)	(5)
In net	-0.0136	-0.167***	-0.106*	-0.0978*	-0.0875
	(0.0611)	(0.0525)	(0.0575)	(0.0515)	(0.0562)
SOE	0.0179	0.0244	0.00765	0.0117	0.0159
	(0.0421)	(0.0201)	(0.0321)	(0.0211)	(0.0268)
Post FS * SOE	-0.00235	-0.0320	0.0337	-0.0177	0.00623
	(0.0458)	(0.0238)	(0.0405)	(0.0252)	(0.0318)
Log indeg	-0.0183*				
	(0.0108)				
Post FS * Log indeg	0.0290***				
	(0.00657)				
SOE * Log indeg	-0.00861				
	(0.0198)				
Post FS*SOE*Log indeg	-0.0199				
	(0.0221)				
Log outdeg		0.0390***			
		(0.00492)			
Post FS * Log outdeg		0.0145***			
		(0.00287)			
SOE * Log outdeg		-0.0135*			
		(0.00762)			
Post FS* SOE* Log outdeg		-0.0163*			
		(0.00965)			
Log deg			0.0106		
			(0.00827)		
Post FS * Log deg			0.0329***		
			(0.00524)		
SOE *Log deg			-0.00177		
			(0.0132)		
Post FS* SOE* Log deg			-0.0415**		
			(0.0172)		
Log btw				0.00955***	
				(0.00243)	
Post FS * Log btw				0.00643***	
				(0.00176)	
SOE * Log btw				-0.00166	
				(0.00470)	

	(1)	(2)	(3)	(4)	(5)
Post FS* SOE*Log btw				-0.0110**	
				(0.00529)	
Log eigen					0.00531
					(0.00646)
Post FS * Log eigen					0.0254***
					(0.00371)
SOE*Log eigen					-0.00553
					(0.00948)
Post FS*SOE*Log eigen					-0.0269**
					(0.0122)
Other controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	32,023	32,023	32,023	32,023	32,023
R-squared	0.459	0.463	0.460	0.461	0.461

PANEL B: Subsample of non-bank-affiliated firms

Dep. Var	*Firm Growth*				
	(1)	(2)	(3)	(4)	(5)
In net	0.0457***	0.0124***	0.00218	0.0436***	-0.00591**
	(0.00215)	(0.00240)	(0.00301)	(0.00196)	(0.00249)
SOE*In net	-0.00357	-0.00427	0.0247***	-0.00770	-0.0217***
	(0.00650)	(0.00662)	(0.00822)	(0.00562)	(0.00696)
Post FS * SOE	-0.0373***	-0.0217***	-0.0277***	-0.0340***	-0.0239***
	(0.00533)	(0.00596)	(0.00655)	(0.00511)	(0.00596)
Log indeg	0.00422***				
	(0.00124)				
Post FS * Log indeg	-0.0370***				
	(0.000816)				
SOE * Log indeg	-0.0122***				
	(0.00313)				
Post FS*SOE*Log indeg	0.0367***				
	(0.00440)				
Log outdeg		0.0251***			
		(0.00111)			
Post FS * Log outdeg		-0.00307***			
		(0.000731)			
SOE * Log outdeg		-0.00502**			
		(0.00233)			
Post FS* SOE* Log outdeg		-0.00707**			
		(0.00284)			
Log deg			0.0351***		
			(0.00156)		
Post FS * Log deg			-0.0262***		
			(0.000790)		
SOE *Log deg			-0.0242***		
			(0.00340)		
Post FS* SOE* Log deg			0.0166***		
			(0.00380)		
Log btw				0.00845***	

				(0.000930)	
Post FS * Log btw				-0.00836***	
				(0.000811)	
SOE * Log btw				-0.00626***	
				(0.00186)	
Post FS* SOE*Log btw				0.00753***	
				(0.00248)	
Log eigen					0.0478***
					(0.00140)
Post FS * Log eigen					-0.0266***
					(0.000836)
SOE*Log eigen					-0.00389
					(0.00266)
Post FS*SOE*Log eigen					0.0103***
					(0.00333)
Other controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	2,302,746	2,302,746	2,302,746	2,302,746	2,302,746
R-squared	0.431	0.431	0.431	0.430	0.431

Online Appendix

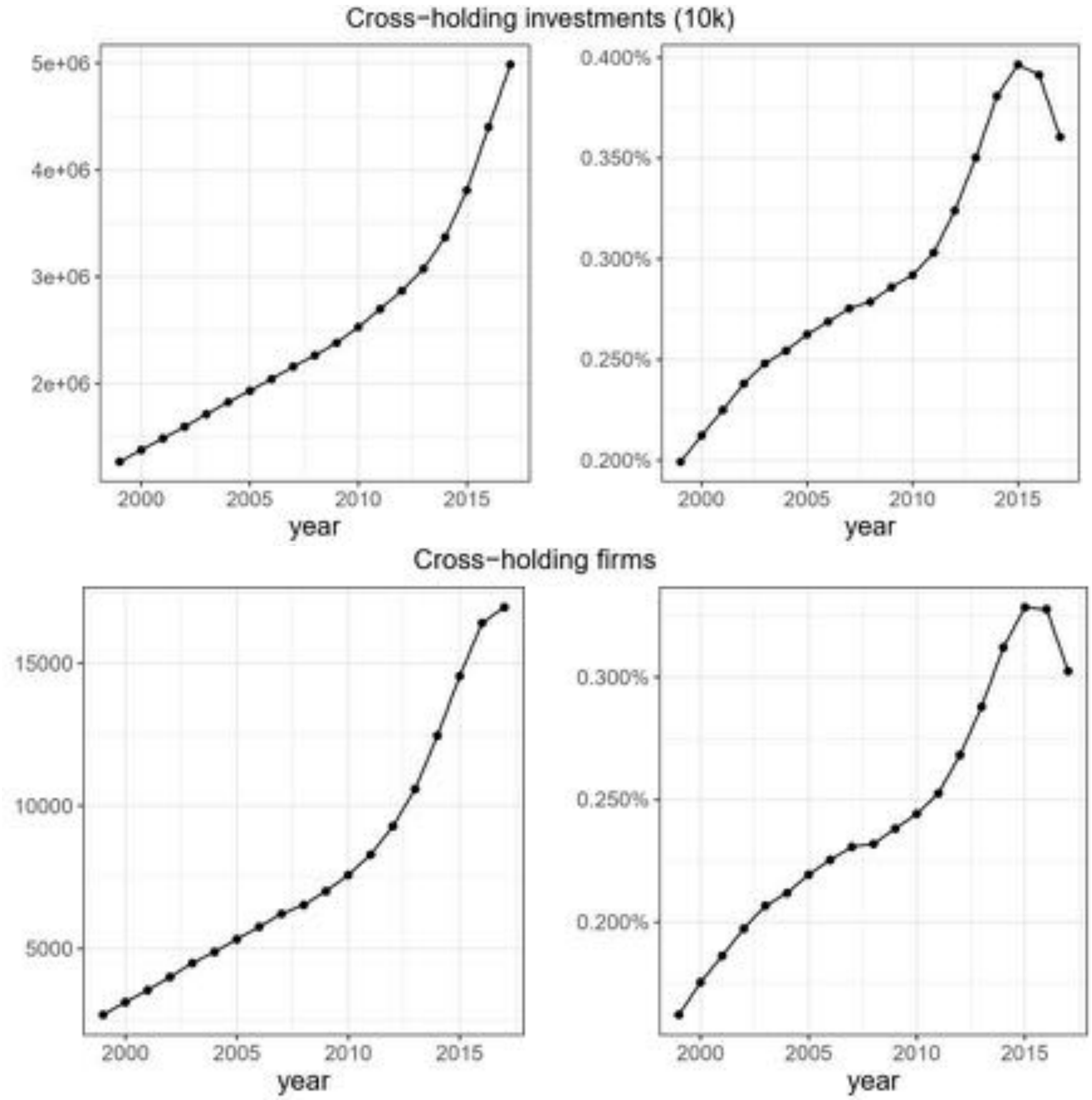

Figure A.1: Equity cross-holding in China
This figure plots the number of equity investments as well as number of firms involved in equity cross-holding. The plots suggest that on average the percentage of firms involved in equity cross-holding has remained low (below 0.5%) in the last decades.

Table A.1 Variables and definitions

Variable	Definition	Source
Network characteristics		
Inv amt	RMB amount for each pair (investor-investee)	
Inv share	Share percentage of the investee for each investment pair (investor-investee)	
Log indeg	Natural logarithm of unweighted in-degree centrality	
Log outdeg	Natural logarithm of unweighted out-degree centrality	
Log deg	Natural logarithm of unweighted total degree centrality	
Log btw	Natural logarithm of betweenness centrality weighted by investment share percentage	SAIC; Own calculations
Log btw cash	Natural logarithm of betweenness centrality weighted by investment amount	
Log eigen	Natural logarithm of eigenvector centrality weighted by investment share percentage	
Log eigen cash	Natural logarithm of eigenvector centrality weighted by investment amount	
Log eigen rev	Natural logarithm of eigenvector centrality weighted by investment amount with the reversed direction	
Log eigen rev cash	Natural logarithm of eigenvector centrality weighted by investment share percentage with the reversed direction	
Log hub	Natural logarithm of hub centrality, weighted by investment share percentage	
Log hub cash	Natural logarithm of hub centrality, weighted by investment amount	
Log authority	Natural logarithm of authority centrality, weighted by investment share percentage	
Log authority cash	Natural logarithm of authority centrality, weighted by investment amount	
In net	Dummy variable that equals one if the firm is in the ownership networks, and 0 otherwise (out of the ownership network)	
Largest sub-network	Dummy variable that equals one if the firm is in the largest sub-network of the whole ownership networks, and 0 otherwise.	
Firm characteristics		
ROA	Net income before extraordinary items/Total assets	
Leverage	Total liabilities/Total assets	
Firm age	Natural logarithm of firm age (current year- firm established year)	
Firm size	Natural logarithm of firm total assets in thousand RMB	
HTFP	Dummy variable that equals one if TFP is above median, or zero otherwise. TFP is calculated by dividing output by the weighted average of labor (70%) and capital (30%) input.	AIS
SOE	Dummy variable that equals one for state-owned enterprises, and 0 otherwise (collectively owned and private enterprises).	
Bank subs	Dummy variable that equals one for firms with banks as their shareholder if tracing up within three ownership steps in the network, and 0 otherwise.	
Reg cap	Firm registered capital at SAIC	

Table A.2 Ownership network and firm growth: robustness results using centrality measures weighted investment amounts

This table reports the baseline results of the regressions examining the impact of ownership network centrality on firm growth. The dependent variable is *Firm growth*, defined as the growth rate of firm total assets. The key explanatory variable is the centrality measures, including *Log btw cash*, *Log eigen cash*, *Log hub cash*, and *Log authority cash*. All variables are defined in Appendix Table A.1. Robust standard errors clustered by firm are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Dep. Var	*Firm growth*			
	(1)	(2)	(3)	(4)
ROA	0.347***	0.347***	0.346***	0.347***
	(0.00362)	(0.00362)	(0.00362)	(0.00362)
Leverage	0.0190***	0.0190***	0.0191***	0.0189***
	(0.00256)	(0.00256)	(0.00256)	(0.00256)
Firm age	0.00759***	0.00758***	0.00702***	0.00746***
	(0.00108)	(0.00108)	(0.00108)	(0.00108)
Firm size	-0.472***	-0.472***	-0.473***	-0.472***
	(0.00152)	(0.00152)	(0.00153)	(0.00152)
SOE	0.00212	0.00225	0.00222	0.00239
	(0.00420)	(0.00420)	(0.00420)	(0.00420)
In net	0.0430***	0.0430***	0.0381***	0.0408***
	(0.00226)	(0.00226)	(0.00229)	(0.00234)
Log btw cash	-0.000154			
	(0.000459)			
Log eigen cash		0.000709***		
		(0.000270)		
Log hub cash			0.0193***	
			(0.00161)	
Log authority cash				0.00161***
				(0.000415)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
# of obs.	1,850,213	1,850,213	1,850,213	1,850,213
R-squared	0.443	0.443	0.443	0.443

Table A.3 Ownership network and firm growth for SOEs vs. non-SOEs: robustness results using centrality measures weighted by investment amounts

This table reports the results of the regressions examining the impact of ownership network centrality on firm growth for SOEs vs. non-SOEs. SOE is defined as 1 if the firm is state-owned; or 0 (either collective or private firms) otherwise. The dependent variable is *Firm growth*, defined as the growth rate of firm total assets. The key explanatory variable is the centrality measures, including *Log btw cash*, *Log eigen cash*, *Log hub cash*, and *Log authority cash*. All variables are defined in Appendix Table A.1. Robust standard errors clustered by firm are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Dep. Var	*Firm growth*			
	(1)	(2)	(3)	(4)
ROA	0.347***	0.347***	0.346***	0.347***
	(0.00362)	(0.00362)	(0.00362)	(0.00362)
Leverage	0.0190***	0.0189***	0.0191***	0.0190***
	(0.00256)	(0.00256)	(0.00256)	(0.00256)
Firm age	-0.472***	-0.472***	-0.473***	-0.472***
	(0.00152)	(0.00152)	(0.00153)	(0.00152)
Firm size	0.00744***	0.00744***	0.00690***	0.00733***
	(0.00108)	(0.00108)	(0.00108)	(0.00108)
SOE	0.0173***	0.0175***	0.0189***	0.0182***
	(0.00566)	(0.00566)	(0.00567)	(0.00567)
In net	0.0455***	0.0455***	0.0403***	0.0424***
	(0.00234)	(0.00234)	(0.00237)	(0.00242)
SOE*In net	-0.0260***	-0.0260***	-0.0246***	-0.0204***
	(0.00613)	(0.00614)	(0.00628)	(0.00638)
Log btw cash	0.000203			
	(0.000489)			
SOE * Log btw cash	-0.00302**			
	(0.00137)			
Log eigen cash		0.000705**		
		(0.000297)		
SOE * Log eigen cash		-1.47e-05		
		(0.000661)		
Log hub cash			0.0213***	
			(0.00173)	
SOE * Log hub cash			-0.00760**	
			(0.00319)	
Log authority cash				0.00219***
				(0.000449)
SOE * Log authority cash				-0.00302***
				(0.000830)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
# of obs.	1,850,213	1,850,213	1,850,213	1,850,213
R-squared	0.435	0.435	0.435	0.435

Table A.4 Ownership network and firm leverage

This table reports the results of the regressions examining the impact of ownership network centrality on firm leverage. The dependent variable is *Firm leverage*, defined as the book value to firm debt over totoal assets. The key explanatory variable is the centrality measures, including *Log indeg*, *Log outdeg*, *Log deg*, *Log btw*, and *Log eigen*. All variables are defined in Appendix Table A.1. Robust standard errors clustered at firm level are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

PANEL A Ownership network and firm leverage

Dep. Var	*Firm leverage*				
	(1)	(2)	(3)	(4)	(5)
ROA	-0.159***	-0.159***	-0.159***	-0.159***	-0.159***
	(0.00129)	(0.00129)	(0.00129)	(0.00129)	(0.00129)
Firm age	0.0176***	0.0177***	0.0177***	0.0177***	0.0176***
	(0.000521)	(0.000521)	(0.000521)	(0.000521)	(0.000521)
Firm size	-0.00698***	-0.00717***	-0.00703***	-0.00698***	-0.00697***
	(0.000438)	(0.000439)	(0.000439)	(0.000438)	(0.000439)
SOE	0.0314***	0.0315***	0.0319***	0.0319***	0.0318***
	(0.00236)	(0.00236)	(0.00236)	(0.00236)	(0.00236)
In net	0.00183*	-0.00715***	-0.00727***	-0.00101	-0.00105
	(0.00107)	(0.00123)	(0.00150)	(0.00100)	(0.00102)
Log indeg	-0.00337***				
	(0.000603)				
Log outdeg		0.00515***			
		(0.000553)			
Log deg			0.00416***		
			(0.000748)		
Log btw				0.00124***	
				(0.000373)	
Log eigen					0.000287
					(0.000479)
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
# of obs.	3,381,008	3,381,008	3,381,008	3,381,008	3,381,008
R-squared	0.737	0.737	0.737	0.737	0.737

PANEL B Ownership network and firm leverage: the impact of the stimulus in 2009

Dep. Var	*Firm leverage*				
	(1)	(2)	(3)	(4)	(5)
ROA	-0.159***	-0.159***	-0.158***	-0.159***	-0.159***
	(0.00129)	(0.00129)	(0.00129)	(0.00129)	(0.00129)
Firm age	0.0177***	0.0180***	0.0181***	0.0177***	0.0180***
	(0.000521)	(0.000523)	(0.000522)	(0.000521)	(0.000522)
Firm size	-0.00684***	-0.00710***	-0.00681***	-0.00696***	-0.00681***
	(0.000439)	(0.000439)	(0.000439)	(0.000438)	(0.000439)
SOE	0.0313***	0.0318***	0.0320***	0.0319***	0.0319***
	(0.00236)	(0.00236)	(0.00236)	(0.00236)	(0.00236)

In net	0.00240**	-0.00601***	-0.00498***	-0.000881	6.49e-05
	(0.00107)	(0.00123)	(0.00150)	(0.00100)	(0.00103)
Log indeg	-0.00458***				
	(0.000629)				
Log indeg* Post FS	0.00235***				
	(0.000390)				
Log outdeg		0.00293***			
		(0.000597)			
Log outdeg * Post FS		0.00324***			
		(0.000371)			
Log deg			0.00130*		
			(0.000780)		
Log deg * Post FS			0.00390***		
			(0.000370)		
Log btw				0.000334	
				(0.000473)	
Log btw * Post FS				0.00111***	
				(0.000393)	
Log eigen					-0.00237***
					(0.000529)
Log eigen * Post FS					0.00422***
					(0.000389)
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
# of obs.	3,381,008	3,381,008	3,381,008	3,381,008	3,381,008
R-squared	0.737	0.737	0.737	0.737	0.737