Ownership Network and Firm Growth:

What Do Five Million Companies Tell About Chinese Economy

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Abstract

The finance-growth nexus has been a central question in interpreting the unprecedented success of Chinese economy. This paper employs an equity ownership network, reflecting the firm-to-firm equity investment relationship, of all the registered firms in China and shows that the network has been expanding rapidly since 2000s, with five million firms being in network by 2017. We find that entering the network and increase in network centrality are associated with higher future firm growth. Such effect of network position tends to be more pronounced for high-productivity firms and non-state-owned enterprises (non-SOEs). The massive Stimulus Plan, launched by Chinese government in November 2008, crowds out the effect of equity capital. Taken together, our analysis suggests that equity ownership network and bank credit tend to act as substitutes for SOEs, while as complements for non-SOEs in promoting growth.

Key words: Ownership network Equity capital Firm growth Bank credit

JEL codes: G10; G30; L14

1. Introduction

The Chinese economy has been performing extraordinarily well in the last four decades, while an enduring puzzle surrounding it is that how it was achieved without a well-developed financial and legal system. One view is that a defining feature of China's growth is a hybrid sector with different ownership structure rather than the state sector (Allen, Qian, Qian, 2005; Song, Storesletten, and Zilibotti, 2011). Under state capitalism, the dominant state-owned banks have played a critical role in funding state-owned enterprises (SOEs), and large government projects. A central question is, how the private sector was able to emerge and grow in a credit constrained environment without sufficient access to formal financing.

In this paper, we investigate how capital is allocated under state capitalism and how it contributes to growth through mapping out the entire ownership network of Chinese economy. Economic networks can show how agents are connected to each other via economic activities. The network serves a conduit for interorganizational support and influence and can be a reflect of resource allocation (Jackson, 2014). Through examining the structure of equity ownership network of all the registered firms in China, we shed light on issues that are key to understanding Chinese economic growth. 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 growth has been widely documented (e.g. Allen, Qian, Gu, 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 shadow banking sector also contributes significantly to the real estate, which is key to growth in China in recent years (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 a firm's position in ownership network contributes to its growth? In particular, does equity capital complement or substitute bank loans in terms of promoting real growth? Does the equity capital favor more SOEs or non-SOEs? Answering these questions help understand the underlying mechanisms driving the growth of the private sector. For the listed sector, recent literature has shown that during the first 15 years of the stock market, SOEs enjoyed the privilege of being listed, while private firms were able to get listed only in recent years. This selection issue makes the stock market has offered disappointing returns to investors despite the remarkable performance of the real economy (e.g. Carpenter, Lu and Whitelaw, 2018; Allen et al., 2018b). Using the ownership information of all the registered firms in China, we provide a first evidence showing how the equity holding network contributes to the real growth of the economy over time.

Our ownership network is built using bilateral and dynamic firm-to-firm equity investment information back to early 1950 for all the registered firms in China. By the end of 2017, the whole network covers over 35 million out-of-network firms and 5.6 million in-network firm. The equity investment amounts by all the shareholders for each firm add up to the firm's total registered capital at China's State Administration for Industry and Commerce (SAIC). According to the *Corporate Law (2005)* in China, the registered capital must be fully paid within the first two years since the firm is registered at SAIC.[1] Using the equity ownership network, our aggregate industry-level stylized facts show that, equity capital seems to follow a similar pattern with bank credit, with the largest amount of funds flowing to risky and credit constrained industries. Across industry, real estate and construction have attracted the most capital among all non-financial industries, followed by mining.

Equity ownership network can facilitate the sharing of information, contracts and resources

[1] For more details on registered capital, please see Section 3.2.

of among firms (Hochberg, Ljungqvist and Lu, 2007). Hence, more influential network positions imply differences in access to equity capital or related resources, investment opportunities, and clout, which can further affect firms' future growth. The concept of well-connectedness in network position is inherently multidimensional. Network theory has developed multiple related and distinct measures for connectedness. In this paper, we mainly utilize the centrality measures including *degree*, *betweenness*, and *eigenvector* centrality. A firm might be well-connected if it is invested or invests in many other firms through equity capital (*degree* centrality). A firm might be well-connected if it lies on relatively more paths between pairs of other firms in the ownership network, making this firm as a key broker of resource exchange (*betweenness* centrality). Other than these, a firm might also be well-connected when its direct linked firm is also well-connected (*eigenvector* centrality).

Our analysis of the network structure suggests that the network has been expanding dramatically since the beginning of 2000s, with the in-network firm number 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 less investments, hence have low global importance. Both the *degree* centrality and *betweenness* centralities show an upward trend over years, whereas *eigenvector* centrality reduces.

We find that a firm's network position affects firm's future growth. Entering the ownership network is associated with significantly higher real growth; moreover, in-network firms with higher network centrality tend to have improved real growth. Specifically, of the five network measures, *eigenvector* has the largest economic impact, closely followed by *degree* centrality, 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 16.9 percent. Having the ability to act as a broker between other firms has smaller effect. The time-varying analysis suggests that given the in-network reality, the average effect of network centrality on real growth decrease over the years, and has been diminishing since 2009.

Our findings suggest that the effect of network position on real growth tend to be more pronounced for high-productivity firms and less pronounced for firms with state-ownership connections. Using the Economic Stimulus Plan, the so-called *"Four-trillion"* Plan, announced in November 2008 as a shock, we find that the network centrality tends to have less pronounced impact on real growth after the Stimulus Plan than before, suggesting a *crowding-out* effect of the Stimulus Plan on equity capital.[2]

In order to further identify the role of equity capital relative to bank credit, we use whether a firm is affiliated with a bank, within the three layers of the entire ownership network, as a measure for repeated relationship with banks. A firm is identified as bank-affiliated firm only if a bank is its shareholder within the three layers of the entire ownership network. The results show that since 2009 the effect of network centrality on growth is more pronounced for bank-affiliated non-SOEs, and has been offset by state ownership connections. Since the Stimulus Plan in 2009 favored more SOEs, this demonstrates the diminishing network effect for firms with more access to bank loans. Taken together, this indicates that the equity ownership network serves as a substitute to bank credit for SOEs, while as a complement to bank credit for non-SOEs, in promoting real growth.

Our paper complements and extends the existing literature on the finance-growth nexus for Chinese economy. China's financial system has been dominated by a state-owned banking sector

[2] To mitigate the impact of the 2008 global financial crisis, the Chinese government introduced an economic stimulus plan, which covers two folds. One is an increase in government spending of RMB four trillion from the fiscal side; the other is a set of credit expansion policies, from the banking side (see e.g. Acharya, Qian and Yang, 2018; Cong et al., 2019).

which was reformed and guided to fund mostly SOEs. Therefore, a central question is how financial supports have been extended to private businesses. A seminal paper, Allen, Qian, and Qian (2005) raise that alternative financing channels and governance mechanisms, such as reputation and relationship, support the growth of the private sector. Long and Zhang (2011) explain the finance-growth relationship in China from a clustering point of view. More recent studies document the misallocation of credit via the standard banking sector to the state sector (e.g. Cong et al, 2019; Ljungqvist et al., 2016), and the rise of shadow banking sector, as a complement to the traditional banking sector to satisfy the financing needs of the credit-constrained industries or government projects, especially after the massive Stimulus Plan (Chen, He and Liu, 2018; Acharya, Qian and Yang, 2018; Allen et al, 2018a; Allen et al, 2018b). However, little evidence has been shown on the equity capital. Through mapping out the entire ownership network of all the registered firms in China, we are able to explain how the equity capital plays a role in promoting growth, under Chinese-model state capitalism.

Our paper is also related to a growing literature on social or economic networks and their economic outcomes, covering a wide range of topics including the influence of social network and economic network on decision making (Laumann et al., 1977; Larcker, So and Wang, 2013; Gao, 2015; Hochberg, Ljungvist and Lu, 2007), information diffusion (Ahern, 2017), industrial organization (Ahern and Harford, 2014) and asset pricing (Ahern, 2019; Rossi, et al., 2018). Closely related is Herskovic, et al. (2019), which study how firm-level product market connections influence the firm size distribution and the volatility of firm-level 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 a great incidence of cross-industry mergers. Larcker, So and Wang (2013) use the director network and show firms with central boards

experience higher future growth of profitability and more positive analyst forecast errors. Using the ownership information of all the registered firms in China, Cai et al. (2019) construct an entire equity ownership network for Chinese economy and review the formation and development of the network structure. Our study is the first to employ such equity ownership network, and explore how the network structure affects the real outcomes of in-network firms.

The reminder of the paper is organized as follows. Section 2 provides an overview of network analysis methodology. Section 3 describe 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 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 square "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 1 gives an example of a portion

of the directed equity ownership network. 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 definition for different measures of centrality. Suppose there are N firms denoted as $[N] = \{1,2 \dots N\}$. Denote $C = \{c_{ij}, (i,j) \in V \times V\}$ as the set of edges, with c_{ij} being interpreted as the share 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 p dimensional firm i's characteristics. For example, 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 $Out\ degree_i = \sum_{j \in V} c_{ji} s_j$.

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 also employ betweenness, eigenvector, hub and authority centrality. Betweenness reflects how well situated a node is in terms of the shortest paths that it lies on (Bonacich, 1972). Betweenness is usually used to measure the information flow or relationship across the network. In our setting,

firm-pair j and k are connected through i if there exists a shortest equity holding chain denoted as $(jl \dots piq \dots mk)$ such that

$$c_{jl} \dots c_{pi} c_{iq} \dots c_{mk} > 0$$

and

$$P_i = \{(j,k) \in V \times V, \exists (jl \dots piq \dots mk)\ s.t.\ c_{jl} \dots c_{pi} c_{iq} \dots c_{mk} > 0\}$$

Then, betweenness is defined as

$$Betweenness_i = \frac{\sum_{(j,k)} I\{(j,k) \in P_i\}}{\sum_i \sum_{j,k} I\{(j,k) \in P_i\}}$$

2.3 Eigenvector Centrality

The centrality is defined recursively as

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

where $x^* = (x_1^*, x_2^*, \dots, x_N^*)'$ is the centrality of the company given the holding matrix C. In the literature, given matrix C describing the network, they usually use the eigenvector corresponding to the largest eigenvalue as a measure of centrality. To see the recursive of the definition,

$$\lambda x_i^* = \sum_{j \in [N]} C_{ij} x_j^*$$

the importance of firm i depends on the importance of firms held by itself (Bonacich, 1987; Bonacich and Lloyd, 2001; Bonacich, 2007).

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 $C C^T$ share the same eigenvalues.

3. Sample and Data

3.1 Data Source and Sample Construction

The Firm Registration and Ownership Database, originated from China's State Administration for Industry and Commerce (SAIC), 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 shareholder 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.

We then exclude the firms only invested by individual shareholders from our analysis based on the equity ownership record, ending up with over 40 million registered firms invested by either other firms or institutions. The total registered capital of these firms accounts for approximately 80% of the total capital of all the registered firms in China. Over years the ownership network experienced substantial entry and exit and thus a considerable reordering of relationships. To capture the dynamics of these processes, we construct a new ownership network for each year *t*. Specifically, for each firm we build up connections (edges) between this firm and its shareholders for each update and fill in the years using the corresponding latest updates. We then use the resulting adjacency matrices to construct the centrality measures described in Section 2. The dynamic ownership network in 2017 includes 5.60 million firms or institutions, with the remaining firms (over 35 million firms) out of network. The in-network firms or institutions are either investors or investees (or both). The out-of-network firms or 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 Survey (AIS) published by China's National Bureau of Statistics.[3] 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 get 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

Our ownership network is a directed one, weighted by either equity investment amount or holding percentage of each shareholder. The equity investment amounts by all the shareholders for each firm add up to the total *registered capital* of the firm. According to the *Corporate 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.[4] The actual paid-in capital by each shareholder, represents shareholder's cash flow rights (i.e. the right to receive dividends).

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

[3] 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, widely documented in literature.

[4] In the past, 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 *Corporate 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 *Corporate Law (2005)* can be accessed here: http://www.gov.cn/flfg/2005-10/28/content_85478.htm

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. *TFP,* the total factor productivity, is calculated by dividing output by the weighted average of labor (70%) and capital (30%) input.

Bank subs is a dummy variable that equals one for firms with banks as their shareholder if tracing up within three layers 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.[5] 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 and investigate how capital flows across industries. Figure 2 plots the heatmap of industry-level capital flows among pairs of industries. 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., 2018a; Chen He and Liu, 2018),

[5] In this paper, for simplicity, we use non-SOEs to incorporate both collectively-owned and privately-owned enterprises.

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 Summary Statistics

4.2.1 Summary Statistics of Centralities

Table 2 provides summary statistics of centrality measures of the entire ownership network as well as its matched sample with AIS firms. In 2017, the entire network 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. *Out degree* centrality ranges from 0.00 to 32,415, with a sample mean of 0.90 and a standard deviation of 21.90. 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 .00 to 1.00, with a sample mean and a standard deviation both very close to 0.[6] Table 3 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

[6] 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.

size than firms as only investees, on average.

[TABLE 2]

Figure 3 presents the feature of the entire ownership network over the years of 1999 to 2017. Panel A reports the network size in terms of the in-network firm number, showing that the ownership has been continuously expanding over the last two decades. The total in-network firm number 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 ownership network. 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 less investment, compared to the existing in-network firms.

[FIGURE 3]

Figure 4 presents the relationship between centrality and registered capital, using the ownership network 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 network 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 siz*e 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.

5. Empirical Methodology and Results

5.1 Empirical Methodology

We start by examining the effects of ownership network centrality on firm growth using Model (1) 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 network, 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 to the network is associated with significantly higher firm growth; and moreover, better-connected firms in the ownership network are associated with significantly improved firm 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 the network can improve firm growth by approximately 16.6 (=0.0220/0.137) percent; given the in-network position, one standard-deviation increase in *Log eigen* can improve firm growth by approximately 16.9 (=0.0220*1.052/0.137) percent, 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 hopefully 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 4.2 (=0.00549*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 in unweighted in-degree centrality (hence more diversified ownership structure), given in network, doesn't help improve firm growth, as that in 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 the network is associated with 34.1 (=0.0467/0.137) percent increase in firm growth, when controlling for *Log indeg*; given in network, one-standard deviation increase in *Log indeg* is associated with 3.6 (=0.00568*0.866/0.137) percent reduce 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.

[TABLE 4]

To explore the time-varying effect of network centrality on real growth, we 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 5, which shows given the position in network, the average effect of network centrality. 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.[7] We assume this is related to the impact of the Economic Stimulus Plan in 2009, which we investigate in Section 5.4.

[FIGURE 5]

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 low in-degree firms. Table 6 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 in *Log deg* is associated with 10.5 (=0.0144*0.998/0.137) percent increase in firm growth for firms with high in-degree centrality, and additional 9.2 (=0.0141*0.998/0.137) percent increase in firm growth for firms with low in-degree. Column (3) shows that there is no significant difference for the impact of eigenvector centrality between high and low in-degree firms. 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 Heterogenous Effects

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

5.3.1 State Ownership Connection

We then investigate the heterogenous effects of network position on real outcomes across firms with different types of state ownership. Table 6 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 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 14.3 (=0.196*0.998/0.137) percent for non-SOEs, while such effect is 7.4 (=0.0101*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.4.

[TABLE 6]

5.3.2 Firm Productivity

The effect of network position on real outcomes may also depend on firm productivity. Table 7 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, 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) for the interaction of *HTFP* and Log

eigen shows that one-standard-deviation increase in *Log eigen* tend to improve firm growth by 5.7 (=0.00748*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 7]

5.4 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 layers 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 8 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 1998 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.

[TABLE 8]

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 9, PANEL A reports the results for bank-affiliated firms. First, for bank-affiliated firms, the double difference 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 (-0.0542 versus 0.0318) 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 9]

6. Conclusion

The finance-growth nexus has been a central question in interpreting the unprecedented success of Chinese economy. In a state-controlled economy, a state-dominant banking system mainly serves for the financing needs of SOEs. An enduring puzzle is how the private sector was 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 provide a first evidence showing how capital is allocated in the network and how it contributes to real growth under state capitalism. Our analysis suggests that the network has been expanding rapidly since 2000s, though new entrant firms tend

to attract and make less investments so obtain less global importance. Equity ownership network can help facilitate the sharing of information, contracts and resources among firms. Our study shows that entering the network is associated with higher real growth; 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 high-productivity firms and non-SOEs.

Over time, the average effect of network centrality on real growth decreases, and has been diminishing since the Economic Stimulus Plan in 2009, suggesting a crowding-out effect of the sudden increase in bank credit on equity capital. Further investigations show that the equity ownership network serves as a substitute to bank credit for SOEs, while as 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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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	2,046,440	0.137	0.076	0.445	-1.970	2.343
Firm age	2,046,265	2.024	2.079	0.865	0.000	4.143
Total assets	2,046,440	123,732	16,917	1,927,914	1	900,000,000
Firm size	2,046,440	9.901	9.736	1.482	0.000	20.618
ROA	2,045,310	0.102	0.035	0.197	-0.359	1.700
Leverage	2,046,416	0.569	0.583	0.295	0.000	2.187
SOE	2,046,440	0.078	0.000	0.269	0.000	1.000
In net	2,046,440	0.286	0.000	0.452	0.000	1.000
Log indeg	2,046,440	-0.164	-0.524	0.866	-0.525	4.489
Log outdeg	2,046,440	0.066	-0.391	1.075	-0.391	5.702
Log deg	2,046,440	-0.071	-0.619	0.998	-0.619	4.509
Log btw	2,046,440	0.009	-0.186	1.038	-0.187	19.841
Log eigen	2,046,440	-0.028	-0.448	1.052	-0.449	9.868
Log btw cash	2,046,440	-0.009	-0.038	0.871	-0.038	26.176
Log eigen cash	2,046,440	0.016	-0.044	1.169	-0.044	28.170
Log hub cash	2,046,440	0.096	0.000	0.329	0.000	4.615
Log authority cash	2,046,440	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 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)
ROA	0.347***	0.348***	0.348***	0.347***	0.348***
	(0.00362)	(0.00362)	(0.00362)	(0.00362)	(0.00362)
Leverage	0.0189***	0.0186***	0.0188***	0.0189***	0.0190***
	(0.00256)	(0.00256)	(0.00256)	(0.00256)	(0.00256)
Firm age	0.00749***	0.00772***	0.00787***	0.00776***	0.00791***
	(0.00108)	(0.00108)	(0.00108)	(0.00108)	(0.00108)
Firm size	-0.472***	-0.473***	-0.473***	-0.472***	-0.473***
	(0.00152)	(0.00152)	(0.00152)	(0.00152)	(0.00153)
SOE	0.00148	0.00114	0.00267	0.00279	0.00209
	(0.00420)	(0.00419)	(0.00420)	(0.00420)	(0.00419)
In net	0.0467***	0.0143***	0.0177***	0.0425***	0.0227***
	(0.00239)	(0.00288)	(0.00334)	(0.00226)	(0.00244)
Log indeg	-0.00568***				
	(0.00139)				
Log outdeg		0.0198***			
		(0.00125)			
Log deg			0.0167***		
			(0.00169)		
Log btw				0.00549***	
				(0.000821)	
Log eigen					0.0220***
					(0.00116)
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
# of obs.	1,850,213	1,850,213	1,850,213	1,850,213	1,850,213
R-squared	0.443	0.443	0.443	0.443	0.443

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)
ROA	0.348***	0.348***	0.348***
	(0.00362)	(0.00362)	(0.00362)
Leverage	0.0187***	0.0187***	0.0190***
	(0.00256)	(0.00256)	(0.00256)
Firm age	0.00765***	0.00767***	0.00765***
	(0.00108)	(0.00108)	(0.00108)
Firm size	-0.473***	-0.473***	-0.473***
	(0.00153)	(0.00153)	(0.00153)
SOE	0.000726	0.00118	0.000335
	(0.00420)	(0.00420)	(0.00419)
In net	-0.000570	0.00953**	0.0338***
	(0.00456)	(0.00418)	(0.00287)
Low indeg	-0.0107**	0.0170***	0.0425***
	(0.00499)	(0.00522)	(0.00392)
Log outdeg	0.0151***		
	(0.00149)		
Log outdeg*Low indeg	0.0126***		
	(0.00227)		
Log deg		0.0144***	
		(0.00227)	
Log deg *Low indeg		0.0141***	
		(0.00298)	
Log eigen			0.0252***
			(0.00138)
Log eigen* Low indeg			-0.000825
			(0.00211)
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: 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)
ROA	0.347***	0.348***	0.348***	0.347***	0.348***
	(0.00362)	(0.00362)	(0.00362)	(0.00362)	(0.00362)
Leverage	0.0189***	0.0187***	0.0189***	0.0190***	0.0190***
	(0.00256)	(0.00256)	(0.00256)	(0.00256)	(0.00256)
Firm size	-0.472***	-0.473***	-0.473***	-0.473***	-0.473***
	(0.00152)	(0.00152)	(0.00152)	(0.00152)	(0.00152)
Firm age	0.00727***	0.00766***	0.00761***	0.00757***	0.00789***
	(0.00108)	(0.00108)	(0.00108)	(0.00108)	(0.00108)
SOE	0.00601	0.00817*	0.0144***	0.00747*	0.00418
	(0.00432)	(0.00447)	(0.00454)	(0.00430)	(0.00441)
In net	0.0468***	0.0136***	0.0163***	0.0427***	0.0225***
	(0.00239)	(0.00288)	(0.00334)	(0.00227)	(0.00244)
Log indeg	-0.00371***				
	(0.00142)				
SOE*Log indeg	-0.0148***				
	(0.00287)				
Log outdeg		0.0213***			
		(0.00128)			
SOE*Log outdeg		-0.0101***			
		(0.00199)			
Log deg			0.0196***		
			(0.00174)		
SOE*Log deg			-0.0188***		
			(0.00238)		
Log btw				0.00687***	
				(0.000829)	
SOE*Log btw				-0.0122***	
				(0.00193)	
Log eigen					0.0226***
					(0.00121)
SOE* Log eigen					-0.00310
					(0.00192)
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
# of obs.	1,850,213	1,850,213	1,850,213	1,850,213	1,850,213
R-squared	0.443	0.443	0.443	0.443	0.443

Table 7: 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. 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)
ROA	0.327***	0.329***	0.329***	0.328***	0.329***
	(0.00376)	(0.00376)	(0.00376)	(0.00376)	(0.00376)
Leverage	0.0178***	0.0177***	0.0179***	0.0178***	0.0179***
	(0.00259)	(0.00259)	(0.00259)	(0.00259)	(0.00259)
Firm size	-0.472***	-0.473***	-0.473***	-0.472***	-0.473***
	(0.00152)	(0.00152)	(0.00152)	(0.00152)	(0.00152)
Firm age	0.00650***	0.00688***	0.00700***	0.00678***	0.00698***
	(0.00108)	(0.00108)	(0.00108)	(0.00108)	(0.00108)
SOE	0.00417	0.00413	0.00541	0.00547	0.00496
	(0.00421)	(0.00420)	(0.00421)	(0.00421)	(0.00420)
In net	0.0474***	0.0157***	0.0198***	0.0429***	0.0239***
	(0.00240)	(0.00288)	(0.00333)	(0.00227)	(0.00245)
HTFP	0.0401***	0.0375***	0.0395***	0.0385***	0.0387***
	(0.00101)	(0.00100)	(0.001000)	(0.000999)	(0.000999)
Log indeg	-0.0110***				
	(0.00154)				
HTFP * Log indeg	0.00864***				
	(0.00106)				
Log outdeg		0.0117***			
		(0.00134)			
HTFP * Log outdeg		0.0127***			
		(0.000841)			
Log deg			0.00718***		
			(0.00177)		
HTFP * Log deg			0.0147***		
			(0.000921)		
Log btw				-0.00130	
				(0.00105)	
HTFP * Log btw				0.00948***	
				(0.000896)	
Log eigen					0.0167***
					(0.00130)
HTFP * Log eigen					0.00748***
					(0.000933)
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
# of obs.	1,802,758	1,802,758	1,802,758	1,802,758	1,802,758
R-squared	0.443	0.443	0.443	0.443	0.443

Table 8: Ownership 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 ownership layers; 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)
ROA	0.345***	0.346***	0.345***	0.347***	0.345***
	(0.00362)	(0.00363)	(0.00363)	(0.00362)	(0.00362)
Leverage	0.0191***	0.0190***	0.0192***	0.0190***	0.0196***
	(0.00256)	(0.00256)	(0.00256)	(0.00256)	(0.00256)
Firm size	-0.473***	-0.474***	-0.474***	-0.473***	-0.474***
	(0.00153)	(0.00153)	(0.00153)	(0.00152)	(0.00153)
Firm age	0.00691***	0.00630***	0.00624***	0.00741***	0.00635***
	(0.00108)	(0.00108)	(0.00108)	(0.00108)	(0.00108)
SOE	0.00181	0.000881	0.00282	0.00290	0.00157
	(0.00421)	(0.00419)	(0.00420)	(0.00420)	(0.00419)
In net	0.0443***	0.00956***	0.00767**	0.0424***	0.0152***
	(0.00240)	(0.00292)	(0.00339)	(0.00227)	(0.00249)
Bank subs	0.00528	0.0119	-0.00489	-0.0228*	0.0217
	(0.0229)	(0.0131)	(0.0202)	(0.0134)	(0.0144)
Post FS* Bank subs	-0.146***	-0.0718***	-0.121***	-0.0844***	-0.0910***
	(0.0203)	(0.0109)	(0.0174)	(0.0117)	(0.0121)
Log indeg	0.00250*				
	(0.00152)				
Post FS * Log indeg	-0.0230***				
	(0.00122)				
Bank subs* Log indeg	0.00395				
	(0.00853)				
Post FS*Bank subs*Log indeg	0.0719***				
	(0.00824)				
Log outdeg		0.0281***			
		(0.00134)			
Post FS * Log outdeg		-0.0158***			
		(0.000825)			
Bank subs* Log outdeg		0.00805*			
		(0.00465)			
Post FS*Bank subs*Log outdeg		0.0282***			
		(0.00415)			
Log deg			0.0303***		
			(0.00179)		
Post FS * Log deg			-0.0227***		
			(0.000944)		
Bank subs* Log deg			-0.000562		
			(0.00748)		
Post FS*Bank subs*Log deg			0.0581***		
			(0.00699)		
Log btw				0.00861***	

				(0.00104)	
Post FS * Log btw				-0.00895***	
				(0.000923)	
Bank subs * Log btw				0.00307	
				(0.00193)	
Post FS*Bank subs*Log btw				0.0170***	
				(0.00191)	
Log eigen					0.0350***
					(0.00140)
Post FS * Log eigen					-0.0214***
					(0.000964)
Bank subs * Log eigen					-0.0155***
					(0.00395)
Post FS*Bank subs*Log eigen					0.0398***
					(0.00373)
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
# of obs.	1,850,213	1,850,213	1,850,213	1,850,213	1,850,213
R-squared	0.443	0.444	0.444	0.443	0.444

Table 9: 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 the 3 layers 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)
ROA	0.368***	0.366***	0.368***	0.369***	0.369***
	(0.0554)	(0.0551)	(0.0554)	(0.0550)	(0.0553)
Leverage	-0.0246	-0.0232	-0.0241	-0.0237	-0.0241
	(0.0267)	(0.0266)	(0.0267)	(0.0266)	(0.0267)
Firm size	-0.316***	-0.325***	-0.316***	-0.326***	-0.317***
	(0.0114)	(0.0116)	(0.0115)	(0.0117)	(0.0115)
Firm age	-0.0188**	-0.0175*	-0.0168*	-0.0158*	-0.0162*
	(0.00922)	(0.00934)	(0.00927)	(0.00934)	(0.00922)
SOE	-0.0481	0.0215	-0.00518	0.0205	0.00696
	(0.0450)	(0.0227)	(0.0346)	(0.0251)	(0.0248)
Post FS * SOE	0.0472	0.00243	0.0741*	0.00771	0.0123
	(0.0515)	(0.0280)	(0.0438)	(0.0299)	(0.0293)
Log indeg	-0.0500***				
	(0.0140)				
Post FS * Log indeg	0.0441***				
	(0.00706)				
SOE * Log indeg	0.0257				
	(0.0211)				
Post FS*SOE*Log indeg	-0.0380				
	(0.0248)				
Log outdeg		0.0423***			
		(0.00694)			
Post FS * Log outdeg		0.0100***			
		(0.00368)			
SOE * Log outdeg		-0.0120			
		(0.00883)			
Post FS* SOE* Log outdeg		-0.0243**			
		(0.0104)			
Log deg			0.00967		
			(0.0113)		
Post FS * Log deg			0.0318***		
			(0.00615)		
SOE *Log deg			0.00567		
			(0.0143)		
Post FS* SOE* Log deg			-0.0542***		
			(0.0177)		
Log btw				0.0142***	

				(0.00234)	
Post FS * Log btw				0.00676***	
				(0.00152)	
SOE * Log btw				-0.00337	
				(0.00380)	
Post FS* SOE*Log btw				-0.0101**	
				(0.00462)	
Log eigen					0.00166
					(0.00648)
Post FS * Log eigen					0.0168***
					(0.00324)
SOE*Log eigen					-0.000861
					(0.00769)
Post FS*SOE*Log eigen					-0.0227**
					(0.00913)
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	16,092	16,092	16,092	16,092	16,092
R-squared	0.448	0.450	0.447	0.450	0.447

PANEL B: Subsample of non-bank-affiliated firms

Dep. Var	*Firm Growth*				
	(1)	(2)	(3)	(4)	(5)
ROA	0.343***	0.344***	0.343***	0.345***	0.343***
	(0.00363)	(0.00364)	(0.00364)	(0.00363)	(0.00364)
Leverage	0.0199***	0.0198***	0.0201***	0.0199***	0.0203***
	(0.00257)	(0.00257)	(0.00257)	(0.00258)	(0.00257)
Firm size	-0.476***	-0.476***	-0.476***	-0.475***	-0.477***
	(0.00155)	(0.00155)	(0.00155)	(0.00154)	(0.00155)
Firm age	0.00609***	0.00560***	0.00552***	0.00642***	0.00559***
	(0.00109)	(0.00109)	(0.00109)	(0.00109)	(0.00109)
SOE	0.0138**	0.0166***	0.00824	0.0191***	0.0235***
	(0.00587)	(0.00577)	(0.00595)	(0.00572)	(0.00576)
In net	0.0450***	0.0100***	0.00317	0.0435***	0.0171***
	(0.00249)	(0.00307)	(0.00361)	(0.00235)	(0.00260)
SOE*In net	-0.00298	-0.00346	0.0308***	-0.00971	-0.0224***
	(0.00726)	(0.00755)	(0.00911)	(0.00640)	(0.00711)
Post FS * SOE	-0.0815***	-0.0769***	-0.0763***	-0.0854***	-0.0770***
	(0.00583)	(0.00645)	(0.00709)	(0.00560)	(0.00608)
Log indeg	0.00435***				
	(0.00160)				
Post FS * Log indeg	-0.0227***				
	(0.00127)				
SOE * Log indeg	-0.0143***				
	(0.00361)				
Post FS*SOE*Log indeg	0.0236***				
	(0.00481)				
Log outdeg		0.0286***			
		(0.00143)			
Post FS * Log outdeg		-0.0150***			
		(0.000861)			
SOE * Log outdeg		-0.00930***			

		(0.00254)			
Post FS* SOE* Log outdeg		0.00475			
		(0.00308)			
Log deg			0.0345***		
			(0.00193)		
Post FS * Log deg			-0.0225***		
			(0.000983)		
SOE *Log deg			-0.0290***		
			(0.00364)		
Post FS* SOE* Log deg			0.0142***		
			(0.00412)		
Log btw				0.00980***	
				(0.00108)	
Post FS * Log btw				-0.00866***	
				(0.000963)	
SOE * Log btw				-0.00939***	
				(0.00260)	
Post FS* SOE*Log btw				0.00824***	
				(0.00319)	
Log eigen					0.0363***
					(0.00150)
Post FS * Log eigen					-0.0212***
					(0.000994)
SOE*Log eigen					-0.00308
					(0.00245)
Post FS*SOE*Log eigen					0.00798**
					(0.00340)
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	1,833,401	1,833,401	1,833,401	1,833,401	1,833,401
R-squared	0.444	0.444	0.444	0.444	0.444

Figure 1: An example of the equity ownership network

To illustrate, this figure gives an example of a portion of the directed equity ownership network. The nodes represent firms/institutions as investors/investees. The edges represent equity investment flows among firms/institutions. The arrows represent the investment direction, from investors to investees.

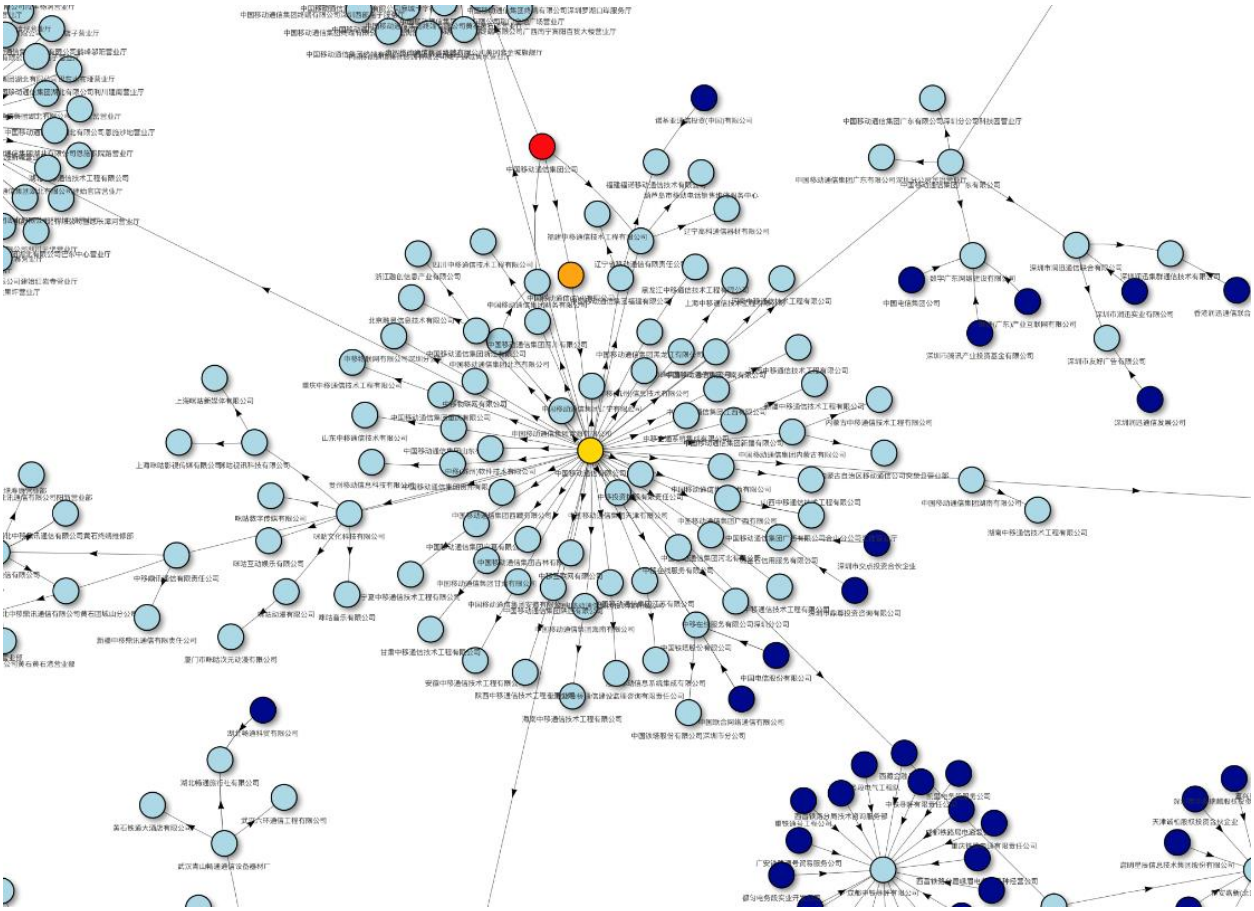


Figure 2: Equity investments across industry

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

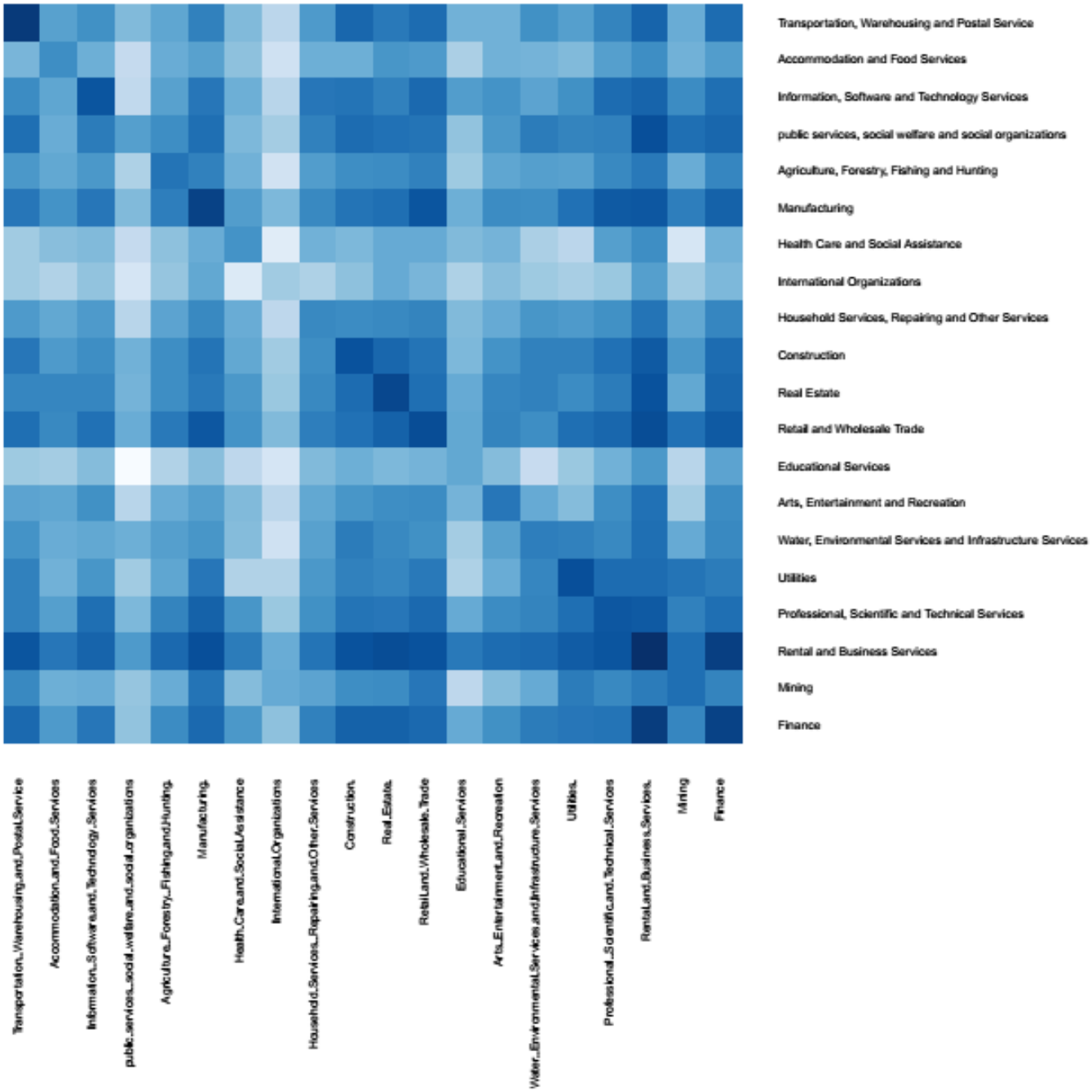
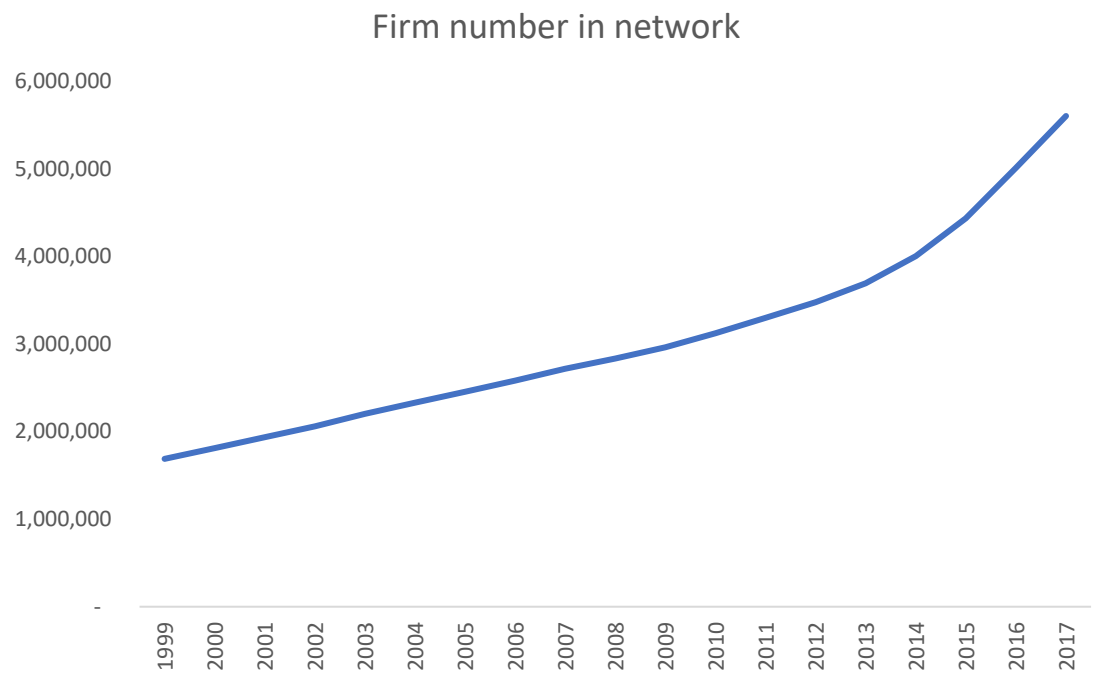


Figure 3: Ownership network feature: size and centrality

PANEL A: Size of the ownership network



PANEL B: Centrality change over year

This figure plots the mean value of centrality measures from 1999 to 2017 for the entire ownership network. The centrality measures shown in the figure include *Out degree*, *In degree*, *Degree*, *Eigenvector*, *Betweenness*, *Hub* and *Authority* centralities.

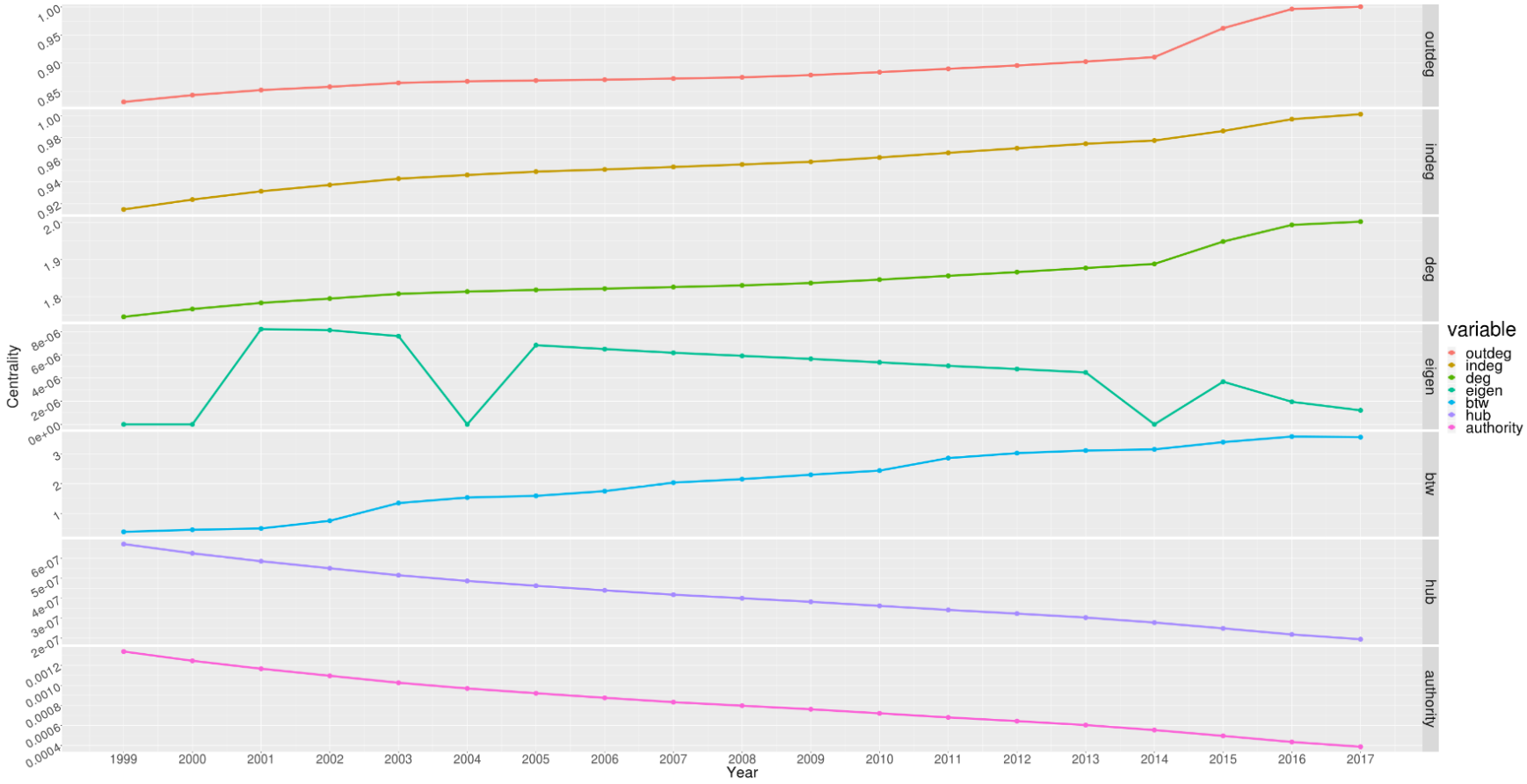


Figure 4: Centrality and Registered capital

This figure plots the relationship of ownership network centralities and firm registered capital.

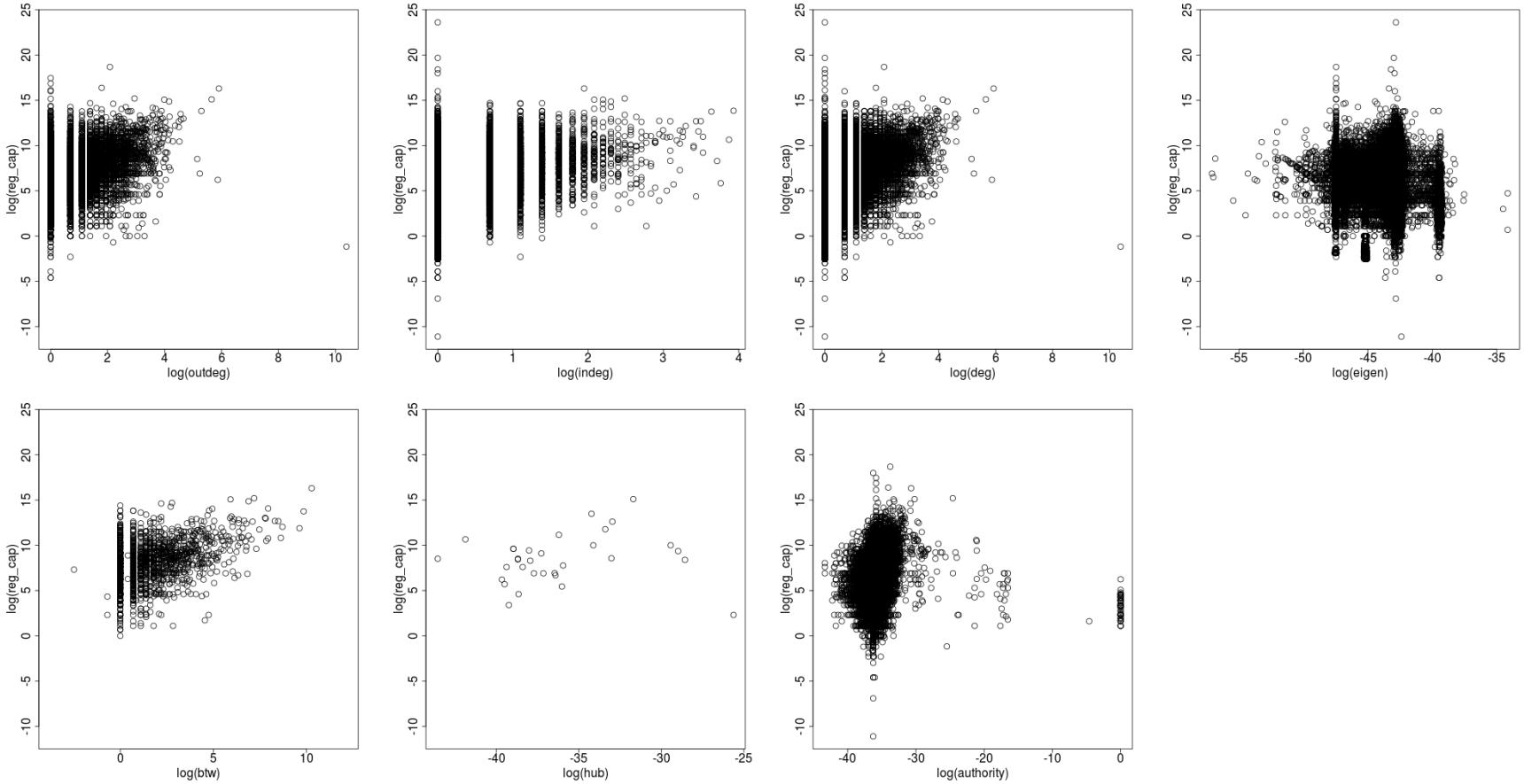


Figure 5: Effect of network centrality over time

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*.

Appendix

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 network, and 0 otherwise (out of the ownership network)	
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 layers in the network, and 0 otherwise.	
Reg cap	Firm registered capital at SAIC	

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

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 investment amount weighted centrality measures

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