# Institutional investor networks and firm innovation: Evidence from China

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**Abstract**

We examine the impact of institutional investor networks on firm innovation in China. Employing the unexpected departure of mutual fund managers and the inclusion of the Shanghai-Shenzhen 300 index as identifications, we find that institutional investor networks have a positive impact on firm innovation. Specifically, firms that are hold by well-connected institutional investors are motivated to make R&D investments and receive greater patents than their counterparts. This positive influence is more pronounced for non-SOEs and for firms located in less-developed regions, indicating that institutional investor networks act as information flow facilitator and a value certifier to encourage innovation activities.

**Keywords**: Institutional investor networks; Innovation; Mutual funds; China.

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## 1 Introduction

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Innovation serves as a vital role in spurring economic growth particularly for a transitory market like China, and so has attracted growing debate on the factors that foster such activities (Rong et al., 2017; Jiang and Yuan, 2018; Choi et al., 2011； Kang et al., 2018; Chang et al., 2019). Over the past decade, China's innovation ecosystem has evolved substantially. A report from World Bank presents that China has become one of the rising stars of global innovation, who spends more than 2.2 percent of GDP on R&D, above the average for the European Union (Medvedev et al., 2020). On the demand side, the large population base and hyper-adaptive consumers have powered innovation willingness of Chinese firms. For example, by 2018, Chinese WeChat Pay did 1.2 billion transactions a day, whereas Apple Pay did one billion a month (Dychtwald, 2021). Meanwhile, on the supply side, the development of capital market and the emergence of institutional investors have enhanced the innovation power of listed firms.

Extant literature suggests that institutional investors can play as active monitors that could reduce information asymmetry and improve corporate governance, thus increase firm innovation (see Kaplan and Minton, 1994; Bushee, 1998; Eng and Shackell, 2001; Aghion et al., 2013). And most show that greater institutional ownership is associated with more innovation (Kahn and Winton, 1998; Gillan and Starks, 2003; Aghion et al., 2013; Luong et al., 2017). However, in practice, institutional investors ownership is often diffuse, thus recedes this relationship (Mathers et al., 2014; Fuente and Marin, 1996). Moreover, Chinese listed firms are facing stronger agency problems due its complicated ownership structures (Rong et al., 2017; Firth et al., 2010). Resulting in most institutional investors either have low power (e.g., more diffused ownership compared to US, thus weakening the monitoring efforts) or have low incentives (e.g., managers of SOEs do not benefit from innovation thus unwilling to R&D) to monitor or foster firms to engage into risky innovation activities (Mathers et al., 2014; Fuente and Marin, 1996). Therefore, innovation mechanism in China maybe not like developed markets such US and Europe, which makes this research topic special and vital.

Social networks, on the contrary, have proved to be influential on firm activities and such effect is supposed to be more pronounced in China due to its "Guanxi" culture (Westphal, 1999; Hwang and Kim, 2009; Fracassi and Tate, 2012; Khanna et al., 2015;

Fu et al., 2013;  Hwang, 1987; Kang et al., 2018;). Institutional investors could build a widespread network through the dispersion of ownership and utilize such social networks to help the investee firms gather timely, valuable information and foster knowledge transfer between firms to increase efficiency into long-gestational risky R&D intensive projects (Hoitash, 2011; Krishnan et al., 2011; Fan et al., 2021). Beyond that, the overall market cap, together with the whole social network size of Chinese institutional investors has grown exponentially over the last decade. The dynamic of social network of institutional investors and the unique country's culture regarding “Guanxi” provides enlightenment and meaningful insight into the specific impact of social networks on firm innovation. Thus, our study attempts to bridge this gap by examining how institutional investor networks influence firm innovation.

Social network theory suggests that networks could provide information advantage, facilitate information diffusion, and therefore enhance innovation. For example, Chuluun et al.(2017) find that firms with a well-connected network through board interlocks invest more R&D expense and receive more patents because board members can transmit tacit knowledge and information when advising on strategic decisions of innovation. Social networks also affect other corporate decisions such as dividend policy (Bouwman and Xuan, 2010), earnings management (Chiu et al., 2013), financing policy (Fracassi, 2015) and is proved to be beneficial for communication between connected firms(Cai and Sevilirm., 2012; Hwang and Kim, 2012). Similarly, Mathers et al. (2020) find that institutional investors' coordination is positively associated with firm innovation output because such collaboration effectively enhances monitoring and reduces information asymmetry. Institutional investors may act as a bridge for owned firms, facilitating knowledge spillovers and business networks. Building on this insight, we investigate whether firms owned by well-connected institutional investors exhibit more substantial innovation and R&D propensity. In addition, we hypothesize that institutional investors can promote firm innovation via social networks. We refer to this channel as the "information channel".

Social networks created by institutional investors are similar to those formed by CEOs and board directors while possessing unique features. The "certification effect" is uniquely provided by institutional investors' networks to the firm. By using their reputation, experience, and trustworthiness, institutional investors send out a positive signal to other investors and reduce asymmetric information to the investee firm (Chemmanur et al., 2011). Furthermore, such influence is more substantial for institutional investors that sit in a more central position within the network (Davis and Robbins, 2005; Bajo et al., 2020). Suppose a central institutional investor invests a firm by a significant stake (more than 5% in the portfolio). In that case, this serves as a positive signaling mechanism to certify the firm's quality, especially for intangible ability like R&D. In addition, this effect should be more salient in a less developed market like China, considering the majority in the stock market are individual investors, who suffer more from information asymmetry disadvantage compared to institutional investors. As a result, the focal firm's innovation could be enhanced because their research quality has been certified. We call this view the "certification channel".

Our hypothesis is tested using the Chinese listed firms and mutual fund data from 2007 to 2017. Our data sample starts from 2007 because institutional investors may face external political pressures from regulators to unvoluntary support split share structure reform of SOEs that implemented between 2005 and 2007(Firth et al., 2010). Financial data and mutual fund data are from China Stock Market & Accounting Research (CSMAR) database. Following Jiang and Yuan (2018) and Tan et al. (2020), we obtain firm-level patent grant and citation data from China's State Intellectual Property Office (SIPO) database. Our final sample consists of 18679 firm-year observations for 2196 non-financial firms over ten years.

Our baseline results show a positive and significant relation between institutional investor network centrality and firm innovation, consistent with our hypothesis. Specifically, an increase of one standard deviation in institutional investor network centrality is associated with a 4.7% rise in innovation output and an 8.3% rise in innovation quality the following year, which is economically significant.

Although this evidence supports our hypothesis, it is crucial to clean out potential endogeneity issues that could bias the relationship between institutional investor network centrality and firm innovation. Specifically, the result could be biased by unobservable firm characteristics correlated with institutional investor networks and firm innovation or by the possibility that firms with greater innovation potential attract more institutional investors, thus obtaining a larger social network. To address these endogeneity concerns, we use three separate identification strategies.

First, we design a difference-in-difference strategy that surrounding the event of departures of mutual fund managers. Specifically, we search out all departure events of fund managers in our sample and mark those unexpected departures (leave for "personnel reasons") as an arguably exogenous shock on our social network centrality measure. We manually collect all fund manager departure events between 2007 and 2016 from the China Stock Market & Accounting Research(CSMAR). Among all events, we find that if a mutual fund manager left for "personnel reasons", the investees would experience a sudden drop in social network connectedness and this effect is stronger compared to other regular departures of fund managers. Since fund managers usually cite "personnel reasons" as an excuse for leaving the mutual fund industry, such moves cannot be predicted as easily as other regular turnovers. However, it is difficult to distinguish whether effects are from unexpected departure or departure itself. We then solve this issue by applying all other regular departure events of fund managers as control group, thus we could control for potential confounding influence caused by the turnover of fund managers. Then, we can observe the clean effect of unexpected change in institutional investors network centrality on firms' innovation.

Second, we use all departure events as an instrument on institutional investors network centrality and estimate the 2SLS regressions. Firm-level institutional investors network centrality may be considerably reduced by turnovers of related mutual fund managers because departures of fund managers may cause fund outflows hence negatively affect its power in the network. More importantly, it is reasonable to believe that the departure of a fund manager is less likely to depend on a firm's innovation. However, fund managers may be forced to turnover because of poor performance, which may correlate to firm innovation. We have attempted to address this issue in DID analysis in the first identification strategy that solely considering all departure events into the analysis. As a supplement, this IV allows us to gauge the magnitude of effect of institutional investor network centrality on firm innovation.

Third, inspired by Ferreira and Matos(2008), Aggarwal et al. (2011), Aghion et al.(2013), Luong et al.(2017), and Rong et al. (2017), we further use the inclusion of the Shanghai-Shenzhen 300 index as an exogenous variation on firms' market exposure, which may attract institutional investors' attention therefore increase institutional investor networks to further address endogeneity issues. There is no evidence showing that the inclusion of the Shanghai-Shenzhen 300 index materially changes a firm's innovation incentive and abilities. Our IV-approach analysis continues to find a positive effect of institutional investor network centrality on firm innovation.

We next examine two plausible underlying economic mechanisms through which institutional investor networks enhance firm innovation. First, we test the information effect by studying the relationship between the institutional investor network centrality, the speed of information flow, and firm innovation. We expect that institutional investors may participate in the on-site visit and such behavior may attract other institutional investors in the network to research and visit. This will essentially promote innovation of the focal firm by speeding up the flow of information through institutional investor networks. Consistent with our conjecture, we find that the association between institutional investor network centrality and firm innovation become stronger if the firms are less visited by institutional investors, showing that social network exerts greater influence if the underlying firms are less covered or studied. In addition, we find institutional investor network centrality is positively correlated with site visits, indicating social networks indeed boost information exchange among all institutional investors. Our evidence suggests that institutional investor networks promote innovation by facilitating the information flow of firms.

Second, we test the certification channel. We expect certification effect to be stronger among non-state-owned-enterprises(non-SOEs), because SOEs are already certified by government and have been documented to have easier access to research funding(Rong et al., 2017). We find that the association between institutional investor network centrality and firm innovation become stronger if the firms are non-SOEs. This finding supports our hypothesis that institutional investors certify the quality of firms(Bajo et al., 2020). In addition, we find companies that headquartered in less developed economic regions benefit more from social networks provided by institutional investors, showing that the certification power of institutional investors is more salient and beneficial where there is scarce innovation supports. These findings are consistent with our conjecture and suggest that institutional investor network centrality fosters innovation by certified the quality of investee firms.

Finally, we test alternative channels such as monitoring. We do not find a statistically significant coefficient between institutional investor network centrality and forced CEO turnover/internal control quality/internal control report disclosure. This result is consistent with Jiang and Kim (2015), who argue that Chinese institutional investors lack monitoring power and incentives due to limited ownership size and short-termism. This finding is important as we discover a rather important mechanism between institutional investors and firm innovation from social network perspective.

To the best of our knowledge, we are the first to examine the impact of institutional investor networks on firm innovation. Our paper contributes to two strands of the literature. First, our article adds to the emerging literature on the economic impact of the social network. Existing evidence shows that social networks affect firm value and performance(Larcker et al., 2013; El-Khatib et al., 2015； Chahine et al., 2019; Bajo et al., 2020), improve corporate governance(Crane et al., 2019), and reduce the cost of capital(Larcker et al., 2013; Ferris et al., 2017). However, most prior studies tend to discover social networks from CEOs or board members, which could be subject to agency problems. Our study proposes a new perspective to study social networks from institutional investors. Our study documents the positive effect of institutional investor networks in promoting innovation, and this evidence is consistent with the findings of Chuluun et al.(2017). Using various dimensions of firms' social network measured by board interlocks, they show that social network fosters firm innovation. Our article differs from theirs by providing extensive evidence on firm innovation and exploring possible underlying economic mechanisms.

Second, our article contributes to the literature on innovation by investigating a vital driver of innovation from institutional investors. Previous studies document a strong association between institutional ownership and firm innovation(Kahn and Winton, 1998; Gillan and Starks, 2003; Aghion et al., 2013). However, institutional ownership is often diffused in practice, hence weakening such associations (Mathers et al.，2020; Fuente and Marin, 1996). Our goal is to investigate a new dimension whereby institutional investors could utilize their social networks to improve firm decision-making, such as innovation, without simply relying on their monitoring power. Our study complements the limited but increasingly popular work of innovation studies in China. Rong et al.(2017) find mutual fund ownership enhances firm innovation, but this effect does not exist among majority state-owned firms. Jiang and Kim (2015) contend that Chinese institutional investors may have limited monitoring power hence have limited influence in investee firms because they are relatively short-termism and have rather small ownership. Our study reconciles this puzzle by showing that institutional investors could enhance firm innovation by facilitating information diffusion and certifying the quality of firms.

The remainder of the paper is organized as follows. Section 2 discusses the relevant literature and describes our hypotheses. Section 3 discusses data, empirical methods, variables, and summary statistics. Section 4 presents the main results, resolves the potential endogeneity concerns, and reports the cross-sectional findings. Section 5 draws conclusions.

## 2 Hypothesis development

In this section, we hypothesize that institutional investor networks increase firm innovation via two channels: information flow and certification effect.

### 2.1 Institutional Background

The institutional investor may engage in shareholder activism or monitoring due to their status as large shareholders (Gillan and Starks,1998; Brav et al., 2018). Although the overall ownership percentage of institutional investors has been increased over the last decade in China, their monitoring effect remains limited (Jiang and Kim, 2015, 2020).

Firstly, institutional investors still hold a lower and more dispersed share of stocks compared to Western countries in China. Specifically, it is forbidden for institutional investors to hold more than 10% of the total shares of a listed company due to existing regulations[2]. As Jiang and Kim(2020) reported, on average, institutional investors own

[2] Regulations concerning institutional investor ownership can be found at:

only 6% of publicly traded firms, while the controlling shareholders possess about 36%. Secondly, institutional investors in China have shorter investment horizons (Jiang and Kim, 2015). In 2020, the turnover ratio of mutual funds on average was 314%, which means that mutual funds only held a stock for four months on average[3]. Such short-termism behavior discourages institutional investors to engage into firm governance. Thirdly, institutional investors may face external political pressures from regulators to unvoluntary support split share structure reform of SOEs that implemented between 2005 and 2007(Firth et al., 2010). In summary, institutional investors may not have the motivation and power to act as a "responsible" shareholder due to China's institutional environment.

However, the operation mechanism and real impact of mutual fund industry have improved significantly in capital market. According to Asset Management Association of China (AMAC)[4], during the period of 2003 and 2020, the percentage of total market value held by mutual funds has increased from 1.4% to 7%, and the number of public funds increased from 1173 to 7913. The rapid expansion of the overall mutual fund industry has generated extensive connections among institutional investors, resulting in a greater and more complex network. And such network may play a critical role in capital market due to the unique culture regarding to "Guanxi" in China.

In China, the relations generated from social networks are called "Guanxi", a culture-specific term that an English-language equivalent of one word can not adequately express(Parnell, 2005). Guanxi is defined as a personalized, high-quality, and potentially resourceful connection(Fu et al., 2013; Hwang, 1987). From personal career development to business sustainability, the diverse ties and potential resources derived from the "Guanxi" play an essential and unreplaceable role in Chinese culture. Existing evidence shows that the embeddedness of the "Guanxi" affects firm performance and efficiency (Gu and Nolan, 2017; Luo et al., 2012; Fan, 2002; Zhang and Zhang, 2006; Bajo et al., 2020), enhances innovation capability(Fu et al., 2013; Zhang and Hartley, 2017), increases firm competitiveness advantage(Wiegel and Bamford, 2015) and eases

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http://www.csrc.gov.cn/pub/newsite/flb/flfg/bmgz/jjl/201505/t20150511_276612.html and http://www.csrc.gov.cn/pub/zjhpublic/G00306226/201806/t20180606_339229.htm

[3] Source: https://cj.sina.com.cn/articles/view/5949960719/162a5320f001017okt

[4] Source: https://www.wind.com.cn/ and https://www.amac.org.cn/

financing constraints(Chen and Wu, 2011). A few but growing number of studies have been targeted on network and firm innovation. Fu et al. (2013) show that informal network plays a vital role in firm innovation activities. Zhang and Hartley (2017) further measure the relationship between the use of Guanxi and innovative capabilities. However, there is little empirical study into the causal effect of institutional investor network and firm innovation. In this paper, we try to fill this gap by showing that institutional investor networks are a vital driver for firm innovation, particularly in China.

### 2.2 Information flow

Prior literature argues that organizations, who have a more central position in the social network can better benefit from trust, sharing, and cooperation that exist among connected firms which in turn dictate the volume, diversity, and richness of information that travel through network. Investors connectedness through the network of institutional holdings has a material impact on firm's corporate governance showing that centrally positioned institutional investors have greater opportunities to build long-lasting, stable relationships with firm stakeholders such as customers and suppliers and can acquire information faster and more accurately thus take advantage of information transfer within the network. (Crane et al. 2019; Larcker et al. 2013; Chuluun et al.2017; Burt, 1997). Align with the interest of institutional investors, they shall utilize such advantage within the network and spur firm innovation.

There is abundant empirical evidence referring that greater institutional ownership is associated with more innovation (Aghion et al., 2013; Luong et al., 2017). Institutional investors with large ownership have more incentive to actively monitor and ways to intervene corporate governance compared to individual investors (Shleifer and Vishny, 1986; Caprio et al., 2007; He et al., 2019) Such association should be buffed via institutional investor network as valuable information matters for firm innovation.

Institutional investor could advise and encourage investments into long-gestational risky R&D intensive projects that risk-averse managers might not be willing to undertake (Manso, 2011; Hart, 1983). Network plays a vital role in such process as institutional investors could borrow experience from successful R&D intensive firms in designing suitable objects to motivate top managers to invest in innovative projects. By taking advantage of information, such institutional investors could also help firms setup risk-tolerance criterion that does not penalize failures related to innovation attempts. He and Huang (2017) find evidence suggesting that cross-ownership by institutional blockholders offers strategic benefits to commonly held firms, in the form of product market collaboration, innovation and operating profitability. Extant studies indicate social network is influential to firm governance. Fracassi(2017) shows that companies are indeed influenced in their policy decisions by their nearest social neighbors. Godlewski et al.(2012) show that banks located in the more central area of the syndicated loan network charge lower loan spreads. And, directors tend to hire advisory firms with whom they had a past relationship, even though no detrimental effects are detected (Bajo et al., 2016; Kuhnen, 2009).

Empirically, there is a strand of fruitful evidence showing that social network between firms, CEOs and Board directors increase firm innovation(Chuluun et al. 2017; Cai and Sevilir, 2012). Helmers et al.(2015) use corporate governance reforms in India as an exogenous shock to examine the effect of board interlocks on patenting and R&D spending among publicly traded companies in India. Dasgupta et al.(2015) study the effect of prior social connections between managers or board members and supplier and customer firms on innovation of upstream firms. Alternatively, Kang et al.(2014) use CEO-director social connections as a measure of board friendliness to investigate how 'friendly' boards affect firm innovation. Oh and Barker (2015) find that when CEOs serve as independent board members on other firms, they imitate the R&D intensity of firms they are interlocked within their own firm's R&D decisions. However, these prior studies do not look at the various dimensions of network connectedness, which goes beyond documenting the existence of interlocks and describes a firm's position within the broader interfirm network and the quality and structure of its immediate network.

Overall, well-connected institutional investors, comparing to other counterparts, can gather valuable information via network and more efficiently utilize their exit option to (1) pressure managers to make optimal innovation decisions meanwhile act as an insurance when innovation projects face early failures (Edmans, 2009; Edmans and Manso, 2011); (2) alleviate managers' pressure from external market to choose projects that are more visible in short-term (Ferreira and Matos, 2008; Bushee 1998, 2001); (3) bring in collaborative innovation opportunities from commonly held firms.

Hence, we hypothesize that institutional investor networks could spur firm innovation by providing unique information advantage.

**2.3 Certification effect**

The certification effect comes with institutional investors' reputation, experience, and trustworthiness(Ferreira and Laux, 2016; Fahlenbrach et al.,2019, Bajo et al., 2020). Information asymmetries are more salient when financing R&D projects compared with other projects(Guiso, 1998). Thus, signals become important particular in a less-developed capital market like China. Outside investors often rely on perceptions of a firm's trustworthiness to determine the quality of the information and hence the value of innovative projects. By receiving investments from institutional investors can serve as a signal to outside investors because institutional investors can reduce information asymmetry and institutional investment itself may contain quality information of firms' future prospective (Glaeser et al., 2000). This is so-called the certification effect.

We posit that certification effect should increase by the increase of network connectedness of institutional investors for two reasons. First, institutional investors investment decisions are more likely to be covered by media and followed by other investors. The position of each institutional investor in the network may serve as a proxy of its relative influence, prominence and prestige, and correlate with their actions to be more or less visible through the network (Andres and Lehmann, 2013; Di Maggio et al., 2019;). Hence, firms' exposure can increase by obtaining investment from a well-connected institutional investor. We refer it as "observability". Second, institutional investors can gather and process valuable information via network and diligently make investment decision, especially for a big stake in their portfolio (e.g., represent more than 5% in the portfolio). Focarelli et al.(2008) posit that the certification effect should be amplified when information asymmetry increases. Bajo et al.(2020) find blockholders' networks can increase firm value because block holdings covey strong positive signaling effect to the market. Such certification effect should be stronger in a transitory economy like China, because investors face more asymmetric information issue due to less-developed capital market compared to developed markets. We refer it as "Creditability". In sum, the certification benefits brought by institutional investors could encourage firm innovation activities.

Hence, we hypothesize that institutional investor networks could spur firm innovation by acting as a certifier to the market.

## 3. Sample construction and description statistics

### 3.1 Data

Our sample is derived from multiple data sources. We obtain financial information for Chinese listed firms and mutual funds from the China Stock Market & Accounting Research (CSMAR) database. Similar to Jiang and Yuan(2018) and Tan et al.(2020)， we collect patent information from China's State Intellectual Property Office (SIPO)[5]. For each patent, information is available on application I.D., application date, publication date, granting I.D., granting Date, application entity name, inventor, IPC, address, patent name, and patent type.

Following the procedure in Bessen(2009), Jiang and Yuan(2018), and Tan et al.(2020), we match patent data and firm financial data by firm name. First, we use the fuzzy match package in Stata to generate all possible pairs of firm (subsidiary) names and application entity names. The syntax in stata “Matchit” returns a numeric variable (similscore) containing the similarity score, ranging from 0 to 1. Specifically, A similscore value of 1 indicates a perfect similarity and 0 otherwise. Second, we manually check all pairs with fuzzy matching scores below 0.7 to ensure the firm (subsidiary) name is indeed a match to an application entity（Tan et al., 2020). Our final sample consists of 18679 firm-year observations of 2196 non-financial firms for 11 years between 2007 and 2017[6]. Our data sample starts from 2007, because institutional

[5] Source: http://chinaip.cnipa.gov.cn/
[6] The officer examination of invention patents and utility patents in China last 18-36 months and 3-6 months, respectively. Since our data cover all Chinese patents granted by the end of 2020, following Hirshleifer et al. (2012), we end our sample period three years before 2020 to address potential truncation issues.

investors may face external political pressures from regulators to unvoluntary support split share structure reform of SOEs that implemented between 2005 and 2007(Firth et al., 2010), and 2007 is also the year in which China adopted a new consistent and unified set of accounting and auditing standards for publicly traded firms.

### 3.2 Measures of institutional investor connection

A central point of interest in our study is the connections between institutional investors. In social network analysis, each node's position within the network serves as a proxy of their relative influence, prominence, and prestige. Compared with nodes at the edge of the network, nodes at the center of the network have a greater influence and better reputation. There are four common centrality measures, including closeness, degree, betweenness, and eigenvector centrality, which are extensively applied to measure a node's importance within the network (El-Khatib et al., 2015; Bajo et al.,2020). We construct institutional investor networks and compute network centrality taking the following steps: (1) Exclude index funds that adopt passive investment strategies from the sample; (2) Construct a bipartite network using the links between the institutional investors (representing at least 5% of the portfolio) and the firms; (3) Transform bipartite networks into projected networks (only contain institutional investors); (4) Compute four different measures of centrality. Our methodology is close to Bajo et al. (2020). In consist with Matthew and Benjamin(2013) and Cruz et al.(2017), we use eigenvector centrality as the main proxy for institutional investor network centrality. As one of the most intuitive measures of centrality, eigenvector centrality not only considers the number of ties but also whether these ties are themselves well-linked (Jackson, 2010). In other words, compared to other measures, eigenvector centrality gives different weights to different nodes, which can better measure the importance of nodes in the network(Matthew and Benjamin, 2013; El-Khatib et al., 2015; Cruz et al., 2017). Hence, it can better measure the status of institutional investors in the network. Formally, *Eigenvector* is calculated as:

$$e_i = \lambda \sum_{j \neq i}^{N} x_{ij} e_j \tag{1}$$

Where λ is a constant represented by the most significant eigenvalue of the adjacency matrix, e is the eigenvector centrality score (Bonacich,1972, 1987). In the robustness analysis, we also employ other three common measures of network centrality into estimation. The first variable is *Degree* centrality, which measures the number of direct connections a fund has with the other funds in the network through common ownership. Formally, *Degree* centrality is calculated as:

$$d_i = \frac{c(i)}{(N-1)} \tag{2}$$

Denote *c(i)* as the number of fund *i*'s connections and *N* as the number of funds in the network. The second variable is *Betweenness,* measuring how much control a fund could have on the information flow. It can be defined as the sum of shortest paths between all the pairs of funds in the network that pass through the focal fund, normalized by the number of all possible fund pairs. Formally, *Betweenness* centrality is calculated as:

$$b_i = \sum_{i \neq j \neq z} \frac{b_{jz}(i)}{b_{jz}} \tag{3}$$

Denote $b_{jz}(i)$ as the total number of the shortest paths between funds *j* and *z* passing through *i* and $b_{jz}$ as the total number of the shortest paths between funds *j* and *z*. The third variable is *Closeness,* measuring how quickly can a fund could contact others. Formally, *Closeness* centrality is calculated as:

$$c_i = \frac{(N-1)}{\sum_{j \in U} d(i, j)} \tag{4}$$

Define *U* as the set of all funds in the network other than *i* and *d(i, j)* as the number of edges in the shortest path connecting funds *i* and *j*. The institutional investor network is necessarily dynamic as new relations may be continuously created or dissolved, and funds may join or leave the network due to various reasons. To account for such variation, we first build network measures using quarterly data of mutual fund holdings and then collapse it into annual figures by summing up the quarterly fund-level eigenvector centrality and then scaled by four. In Appendix B, we demonstrate a graphical representation of the institutional investor network. During the last decade, we observe a significant expansion of the overall network size composed of institutional investors. Specifically, in 2007 the network is less integrated with a relatively small number of nodes inside. This status has evolved by the end of 2017. The network has grown considerably, showing more complex integration and diversions among different cohorts. The dynamic and robust evolution of institutional investor networks provides a meaningful scene for our study.

### 3.3 Measures of firm innovation

Following Fang et al.(2017), Jiang and Yuan(2018), and Tan et al.(2020), we use innovation and utility patents to measure firm-level innovation. Under the Chinese patent system, there are three different types of patents: innovation, utility, and design patents. Among three of them, design patents only protect the "look" of the product that makes it recognizable. Because design patents only contain slight improvements of technology, we only focus on innovation and utility patents. Following Jiang and Yuan(2018) and Tan et al.(2020), our measurement of innovation output *Pat* is defined as the natural logarithm of one plus the total number of invention and utility patent applications filed (and eventually granted) by a firm in a given year. According to Chinese patent law, to be granted, the application for an invention patent must meet a series of rigorous requirements(Rong et al.,2017; Fang et al.,2017; Tan et al.,2020). We further use *Invpat*, calculated as the total number of invention patent applications filed (and eventually granted) by a firm in a given year, as a proxy for innovation quality.

### 3.4 Empirical methods and other variables

To examine the impact of institutional investor social connections on firm innovation, we estimate the following fixed-effect panel model:

$$Innovations_{i,t+1} = \beta_0 + \beta_1 Connections_{i,t} + \beta_2 Controls_{i,t} + \beta_3 Firm_{i,t} + \beta_4 Year_{i,t} + \varepsilon_{i,t+1} \quad (5)$$

The dependent variable $innovation_{i,t+1}$ represents either *Pat* and *InvPat* measured at year *t+1*. *Connections*, our interested factor, is *Eigenvector*. Following Fang et al.(2017), Jiang and Yuan(2018), Yuan and Wen(2018), Bajo et al.(2020), and Tan et al.(2020), we include a series of control variables that could impact firm innovation in our regressions: *Size*(more prominent and mature firm are expected to have the ability to innovate more), *Leverage*(financial leverage may inhibit firm innovation), *Tangibility*(more asset tangibility might be associated with low innovation propensity), *Profitability(*measured by ROA*)*, *Sales*(to measure the company's sales ability), *SalesGrowth*(as proxies for growth opportunities), *TobinQ*(as proxies for firm value), *Board size, Board Independence %*(measured as the total number of the independent directors divided by the total number of board members), *CEO duality*(A dummy variable that takes the value of one for the firm that CEO is also the chair of the board), *Age*, and *SOE*(A dummy variable that takes the value of one for the firm's state ownership is more than 25%). The description of the control variable construction is reported in Appendix A. We also include *Firm* and *Year* dummies to control for firm and year fixed effects, respectively. Besides, we cluster standard errors by firm-level in all regressions.

### 3.5 Descriptive statistics

Table 1 reports mean values of firm characteristics of our sample. To mitigate the effect of outliers, we winsorize all continuous variables at the 1st and 99th percentiles. During 2007 to 2017, on average, firms generate 22.9 patents per year, 6.1 of which are invention patents, this figure is three times bigger than findings in Tan et al.(2020)[7] showing that innovation activities of Chinese firms have been accelerated. The mean and standard deviation of control variables are similar to other research based on Chinese background (Fang et al., 2017; Jiang and Yuan, 2018; Yuan and Wen, 2018; Tan et al., 2020).

Regarding to independent variables, we find that 29.9% of firm-observation that has institutional investor networks, showing that nearly 70% of firm-observations are not connected. The overall mean value of *Eigenvector* is 0.015, which is smaller compared

[7] In their paper, Tan et al.(2020) use a sample of 1289 Chinese firms over 12 years from 2000 to 2011.

to figures in the US based study of Bajo et al. (2020). It indicates Chinese institutional investor networks are still underdeveloped compared to matured market like US.

The last column of Table 1 shows the mean differences of firm innovation and other characteristics between firms with or without institutional investor networks. The univariate tests indicate that, firms with institutional investor networks have a significantly higher innovation output and quality, lower leverage ratio, better firm performance, faster growth, and higher board independence ratio. Specifically, The mean of total patents (innovation patents) is 45.355 (12.588) for firms with institutional investor networks and 13.322 (3.361) for firms without institutional investor networks, and the difference is statistically significant at the 1% level. It suggests that firms with institutional investor networks perform better in both innovation output and quality than firms without such networks.

<insert table 1>

## 4. Empirical results

### 4.1 Baseline findings

We start by examining how Institutional investors networks affect firm innovation. Table 2 reports estimates from the baseline regressions. We include year and firm fixed effects (or industry fixed effects) in various specifications. In all regressions, we report in parentheses robust standard errors clustered at the firm level.

Columns (1) to (6) of Table 2 report the results from pooled OLS regressions. We include controls, industry fixed effects, and firm fixed effects step by step to estimate the influence of institutional investor networks on firm innovation. The coefficient estimates are positive and significant at the 1% level across all specifications, suggesting a positive relationship between institutional investor network centrality and innovation output. Furthermore, this association is not driven by the unobserved time-invariant firm or industry  characteristics.

In terms of economic significance, a coefficient estimate of 1.422 in column (3) suggests that a one standard deviation increase in institutional investor network centrality of its distribution is associated with a 4.7%(=1.422*0.052/1.578) increase in innovation output in the following year. Likewise, the coefficient estimate of 1.808 in column (6) indicates that an increase of a standard deviation in institutional investor network centrality increases innovation quality by 8.3%(=1.808*0.052/1.134) in the following year. These results are economically significant.

Regarding firm-level control variables, the coefficient estimates on *Size*, *Sale* are positive and significant in all regressions, which is constant with the finding of Jiang and Yuan(2018), Rong(2017), and Tan et al.(2020). The result suggests that large firms with outstanding accounting performance have better innovation output than other firms. Firms with higher leverage are associated with lower innovation output and quality. Younger firms also tend to innovate more, which is in line with the results of Atanassov(2013). Tangibility has a negative relationship with corporate innovation. These findings suggest that growing investments in PP&E might compete with the investments in innovation for limited financial resources (Jiang and Yuan, 2018). The coefficient of SalesGrowth is negative, indicating that it is difficult for firms to strike a balance between innovation and short-term benefits. Firms that have more growth potential(*TobinQ*) are more innovative, which is consistent with the result of Tian and Wang(2011). Powerful CEOs tend to innovate more, which indicates that powerful CEOs are more confident about themself and more likely to invest in risky projects (Hirshleifer et al.,2012). Overall, our baseline regression results suggest a positive association between institutional investor network centrality and firm innovation activity. Moreover, we further provide the results after employing various network measures in Table 9 to show that this relation is not driven by the metric we deliberately choose.

<insert table 2>

### 4.2 Identification strategy

Our results so far suggest a positive association between institutional investor network centrality and firm innovation activity. However, the results may be subject to endogeneity issues because baseline specification cannot control for time-varying, unobservable characteristics. For example, implicit government support on firms' R&D activities may increase innovation meanwhile attract investment from institutional investors. As in Table 2, we find SOEs are associated with higher innovation, although such association is not significant. Alternatively, reverse causality may also bias the inference if firms with high innovation attract well-connected institutional investors.

In this section, we try to address endogeneity issues by applying three separate identification strategies. First, we design a difference-in-difference strategy that surrounds the events of departure of mutual fund managers. Specifically, we search out all departure events of fund managers in our sample and mark those unexpected departures as an arguably exogenous shock on our network centrality measure. Then, we use all the other regular departure events of fund managers as a control group to eliminate potential influences that might result from the departure itself. Thus, we can observe the clean effect of unexpected change in institutional investor network centrality on firms' innovation.

Second, we use all departure events of mutual fund managers as an instrument on institutional investor networks centrality measures and estimate the 2SLS regressions. Firms' institutional investor network may be plausibly reduced by turnovers of related mutual fund managers because such events may cause fund outflows hence negatively affect its power in the network. This IV estimation is a complement test to the DID approach. The merit is that we can gauge the magnitude of impact of institutional investor networks on firm innovation output.

Third, inspired by Ferreira and Matos(2008), Aggarwal et al. (2011), Aghion et al.(2013), Luong et al.(2017), and Rong et al. (2017), we further use the inclusion of the Shanghai-Shenzhen 300 index as an exogenous variation on firms' institutional investor network centrality. The inclusion of the Shanghai-Shenzhen 300 index may attract institutional investors' attention to further address endogeneity issues, but it does not materially change a firm's innovation incentive and abilities.

### 4.2.1 Difference-in-difference approach: unexpected departures of fund managers

Our first identification strategy is to exploit a plausibly exogenous variation in institutional investor network centrality: the unexpected departure of fund managers. departures of fund managers may cause fund outflow therefore decrease the social network connectedness. However, it is still plausible that the departure of fund managers could be driven by the firm or fund performance that may be related to innovation output. To address this issue, we then solely select those departure events caused by "personnel reasons" as our treatment, and we use the rest of other departure events as control groups to implement a DID analysis. This approach essentially compares the innovation output of treatment firms and control firms just before and after the departure of fund managers.

This design has two merits: first, the departure of fund managers generates plausibly exogenous variation in institutional investor network centrality. Because departure of mutual fund managers is unlikely to be correlated with a firm's innovation output, However, the portfolio of shareholdings of mutual funds may change substantially following the departure of fund managers. This may result in a reduction of institutional investor network centrality. In addition, the departure of fund managers may induce outflows of funds, which may force selling-off of stocks in portfolio hence further reduce networks. Second, our strategy can alleviate reverse causality issues. Mutual fund managers may be forced to leave if their investment performance below the benchmark and firms' innovation performance may be negatively correlated with performance therefore indirectly linked to mutual fund managers turnover. We attempt to alleviate such concern by only selecting departure events caused by "personnel reasons" as our treatments. Conventionally in China, if a fund manager leaves for "personnel reasons", she/he will no longer work in the mutual fund industry, and such action is more difficult to predict in advance. In our dataset, we find that those fund managers who leave for "personnel reasons" usually have longer working experience and may have a more extensive network, we also find that these departures have more adverse impacts on funds, compared to regular departures. It is reasonably to believe that these departures are unlikely to be driven by poor investment performance. Therefore, we expect these unexpected departures of fund managers create an exogenous shock to the underlying fund and then reduce institutional investor networks.

We begin by searching with all departure events of mutual fund managers between 2007 and 2016 in China, and we end up with 1969 such events[8]. First, we manually collect all departures information regarding fund managers' working experience and reasons for departures from CSMAR. In table 3, we report the summary statistics, the total number of funds increases substantially from 257 in 2007 to 1154 in 2016, suggesting mutual funds as active institutional investors are growing to play an essential role in China's stock market. The total number of departures increases accordingly by the time, with an overall departure rate ranging from 5.6% to 28.5%. In most of the years, fund managers who leave their jobs due to personal reasons account for approximately 30% of all departures. However, in 2015, this figure skyrockets to 70.9%. This abnormal turnover rate is because most fund managers gained excess returns during the bull market of 2015, that allows them to retire early. It is also consistent with our conjecture that fund managers usually cite "personnel reasons" as an excuse for leaving the mutual fund industry. The average years of working experience of departed fund managers are within 8 to 11 years, indicating that most departed fund managers are experienced, and their departure may indeed impact fund negatively. Then, we identify the departure events labeled as "personnel reasons" among all departures events as our treatment. This filter leaves us with 871 treatment events over a total of 1969 events. In Panel B of Table 3, we reported the mean differences in fund *AUM* and fund-level *Eigenvector* between subsamples without departure and departure for personal reasons. The mean value does not differ significantly between the two groups, indicating that fund managers' turnover is not due to fund status.

Next, we use the rest departure events as a control group, ending with 1075 control events. Finally, we map all treatment and control events to the underlying firms to perform a DID analysis. In figure 1, we plot the average Eigenvector of treatment and control firms over seven years around the departures of fund managers. The two lines trend closely in parallel in the years before the departure event, which suggests the satisfaction of the parallel-trend assumption. However, after the departure, the line representing treatment firms trend downward more than the line representing control

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[8] According to CSMAR, the reason for the fund manager's departure involves leaving the mutual fund industry for personal reasons, retirement, accepting another position in the mutual fund industry elsewhere, and fired.

firms, suggesting that treatment funds experience a substantial decrease in network centrality. In figure 2, we plot the average patents of treatment and control firms over seven years around the departures of fund managers. Although there is a solid upward trend of patents over time, it is clear that treatment firms experience a more significant drop in innovation output than control firms.

<insert Figure 1 & 2>

<insert table 3>

Then we use DID approach, and the specific formula is presented below:

$$Innovations_{i,t+1} = \beta_0 + \beta_1 Treat_i * After_{i,t} + \beta_2 After_{i,t} + \beta_3 Controls_{i,t} + \beta_4 Firm_{i,t} + \varepsilon_{i,t+1} \quad (6)$$

We define *Treat* as a dummy variable that equals one if the firm experiences departure of fund managers for "personnel reasons" that hold more than 5% shareholdings in their portfolio and zero otherwise. We define *After* as a dummy variable that equals one for years after the firm experiences departure of fund managers holding more than 5% shareholdings in their portfolio and zeroes otherwise. The coefficient $\beta_2$ on *After* captures the average within-firm effect of departures of mutual fund managers on firm innovation. As our primary interest, the coefficient $\beta_1$ on the interaction term $Treat_i *After_{i,t}$ captures the incremental impact of departures of mutual fund managers between "personnel reasons" and other reasons on firm innovation. $Treat_i$ is not included in the model as it is subsumed by firm fixed effects. In all DID regressions, we only include firms for at least one observation before and after the event.

The regression results of the DID specification are presented in the first two Columns of Table 4, while those for the two-year window and three-year window are presented in column (3) to column (6). In addition, we employ a PSM strategy that matches each treatment firm with five control firms using the nearest neighbor method and report the results in Columns (7) and column(8). The coefficients on $After_{i,t}$ are negative and significant in most Columns, indicating that firm innovation decreases after departures of mutual fund managers. More importantly, the coefficients on the interaction term

$Treat_i * After_{i,t}$ are negative and significant at the 5% level or above. It suggests that the unexpected departure of mutual fund managers causing the loss of institutional investor networks experience a more obvious drop in firm innovation than other events. Thus, this evidence further supports our baseline results that higher (or lower) institutional investor networks lead to higher (or lower) firm innovation.

<insert table 4>

#### 4.2.2 Instrumental variable approach: departures of fund managers and index-inclusion of firms

Our second identification strategy is IV estimation. We introduce two IVs to capture the exogenous variation in institutional investor network centrality. First, we use all departure events of fund managers as an instrument to institutional investor network centrality. Unlike the DID approach above, we allow all departure events to be applied as they create a reduction in network centrality. This approach complements the previous strategy, which can estimate the overall effect of the departure of fund managers on institutional investor network centrality across our sample period. *Departure* is a dummy variable that equals one if the firm-year experiences departure of fund managers that holding more than 5% shareholdings in their portfolio and zero otherwise. Second, we use a time-varying index-inclusion dummy as the instrument for institutional investor network centrality (Aggarwal et al.,2011; Aghion et al., 2013; Rong et al., 2017). *Index* is a dummy variable that equals one if a stock has been included in the Shanghai-Shenzhen 300 in year *t* and zero otherwise. The inclusion of a stock attracts institutional investors (see Ferreira and Matos., 2008; Luong et al., 2017) and therefore may increase the network of the stock. However, the inclusion criterion is mainly about the representativeness of stock in a particular sector and is unlikely to be predetermined by a firm's innovation potential (Rong et al., 2017).

Table 5 reports the regression results for IV estimations. We present first-stage regression results with Eigenvector as the dependent variable and the instruments (*departure/Index*) as the main independent variable in Columns (1) and (4) using the baseline model. The coefficient on *departure(Index)* is negative(Positive) and significant at 1% level, suggesting that *departure(Index)* is negatively(Positively) associated with firms' institutional investor network centrality. The F-statistics of the instruments are both more than 20, indicating the validity of instruments. Since there is only one instrument for one endogenous variable, we can reject the null hypothesis that the instrument is weak. In Columns (2),(3),(5), and (6), the coefficients of the fitted values of Eigenvector are positive and statistically significant above 5% level, indicating that institutional investor networks have a positive effect on innovation. In terms of economic impact, A coefficient of 7.423 (5.868) in column(2)(column (5)) suggests that a one standard deviation increase in institutional investor network centrality of its distribution is associated with a 24.5% (26.9%) increase in the innovation output the following year. We find the coefficients of 2SLS are significantly larger than baseline results in Table 2, which suggests that OLS results may underestimate the positive effects of institutional investor networks on firm innovation.

<insert table 5>

### 4.3 Information flow: Institutional investor network centrality and corporate site visits

In this session, we conduct additional tests to study the mechanisms through which well-networked institutional investors are associated with an increase in firm innovation. One possible mechanism through which well-networked investors spur firm innovation is to attract institutional investors for corporate site visits. Through site visiting, institutional investors can facilitate their information acquisition by observing firms' operations and engaging in direct dialogues with the managers, which effectively reduces information asymmetry(Cheng et al.,2015, 2016). As for the relationship between institutional investors' corporate site visits and firm innovation, Jiang and Yuan(2018) argue that institutional investors can more effectively understand and tolerate managers' short-term failures with information acquired through site visits, thus improving managers' incentives to innovate. If firms with well-networked institutional investors are more likely to attract the attention of other institutional investors, we expect that firms with well-networked investors may lead to more frequent institutional site visits. Thus, the frequent visits by institutional investors are likely an underlying economic mechanism through which well-networked investors promote firm innovation.

To test this conjecture, we first partition our sample into two subsamples based on whether the number of institutional investors' corporate site visits(*Visit*) in the previous year is above or below the sample median. We define *Visit* as the natural logarithm of one plus firm i's the total number of institutional investors' site visits in year t[9]. If our conjecture is valid, firms with below-median site visits are considered to have a lower speed of information flow. These firms should benefit more from the attractive effect derived from well-networked investors. We then re-estimate our main regression results on subsamples of firms with *Visit* below and above the median and present the result in Panel A of Table 6. We report the results for firms with below-median *Visit* in Columns (1) and (3) and those for firms with above-median *Visit* in Columns (2) and (4).

The estimation results in Table 6 Panel A confirm our expectation. The effect of between institutional investor networks and firm innovation is significantly stronger for firms with fewer site visits. To further ensure the robustness of the results, we performed a Chow-test to test for equality of coefficients between subsamples. The test result also rejects the equality of the coefficients across the two subgroups, suggesting that well-networked investors' positive effect on firm innovation is less pronounced for firms with an ex-ante higher speed of information flow.

The above analysis is based on the premise that firms may benefit from institutional investor networks by attracting site visits. To verify this assumption, we regress firm-level *Visits* on *Eigenvector* and the same set of control variables in our main specification presented in Eq. (5) and present the result in Panel B of Table 6. The coefficient of *Eigenvector* is positive and significant at the 1% level, suggesting that the frequency of institutional investors' corporate site visits indeed increases if a firm’s network expands. The evidence reported in this subsection supports the view that the frequent visits by institutional investors are a plausible underlying mechanism through which well-networked investors promote firm innovation.

<insert Table 6>

[9] We obtain institutional investors' site visit data from the Wind database.

### 4.4 Certification effect: Non-SOEs and regional economic development

Consistent with the fact that the promotion mechanism for managers of SOEs is not fully correlated with corporate performance and are less likely to be replaced, most studies support the view that managers of SOEs are less motivated to engage in innovation(Megginson, 2005; Hu and Jefferson, 2009; Lin et al., 2010; Boeing et al., 2016). Rong et al.(2017) further find that institutional investors' shareholding can significantly promote innovation in non-SOEs, but does not affect the innovation output of SOEs, which is consistent with the view that managers of SOEs are less sensitive to market reaction. One reason is that government could provide certification benefit for SOEs and they have natural advantage in access to government subsidies. Therefore, we expect that non-SOEs should benefit more from certification benefits provided by institutional investors, and such effect should be amplified if the institutional investor is well-networked.

To test our conjecture, we partition the whole sample into SOEs and non-SOEs and present the regression result in Table 7. Columns (1) and (2) in Table 7 represent the empirical results of SOEs and non-SOEs with firm innovation output(*Pat*). Both the coefficients estimated on the well-networked investors are significant and positive, which shows that well-networked investors can enhance the firm innovation output(*Pat*) for SOEs and non-SOEs. From Columns (3) and (4), the finding still holds with firm innovation quality(*InvPat*) as the dependent variable. Together with the Chow-test result of coefficients, we find that the positive relationship between well-networked investors is more prominent for non-SOEs than SOEs. In short, we can see clearly from Table 7 that there is a stronger positive and economically significant relationship between institutional investor networks and firm innovation among non-SOEs, which is consistent with the certification effect hypothesis.

We further hypothesize that certification effect to be more salient in less-developed economic regions. We partition the sample based on whether a firm's regional marketization index(*Marketization*) is above or below the sample median. The regional marketization index(*Marketization*) is a summary index that measures institutional transformation across China's 31 provinces and shows the differences in institutional policies and economic policies between the provinces. A high index value indicates a better legal environment and a higher level of social trust(Xu et al., 2014). Therefore, we conjecture that if well-networked investors can provide a certification benefit for the firm, the positive effect of institutional investor centrality on firm innovation should become stronger for firms with an ex-ante low regional marketization index. The coefficient estimates from Columns (5) and (6) in Table 7 show that the relationship between institutional investor networks and firm innovation output(*Pat*) is more significant and for firms with a regional marketization index below the median. From Columns (3) and (4) in Table 9, we can find a similar conclusion using firm innovation quality(*InvPat*) as the dependent variable. Together with the Chow-test result of coefficients, we find that the positive relationship between institutional investor networks and firm innovation is more prominent in lower marketization regions, consistent with our conjecture that institutional investor networks provide a certification benefit to the firm.

<insert Table 7>

### 4.5 Alternative explanation: Monitoring effect

Another explanation for innovation enhancement is based on the monitoring effect of institutional investors. Previous studies suggest that specific types of institutional investors may have a supervisory role over listed companies(Kim et al., 2019). Aghion et al.(2013) point out that institutional investors monitor and motivate CEOs to innovate by "insulating" the manager against the reputational consequences of bad income realizations. Consistent with the monitoring view, Rong et al.(2017) find a similar conclusion based on Chinese market. In contrast, Bajo et al.(2020) find that central institutional investors do not impact firm value via better monitoring based on the institutional investor network. According to the monitoring view, well-networked investors should have better capabilities and incentives to monitor and supervise due to their privileged position in the network and ease of information transmission.

To test whether institutional investor networks impact firm innovation via better monitoring, we use employ three different monitoring proxies. The first proxy is the internal control index(*ICI*)[10]. The internal control index(ICI) is a composite index with five components: control environment, risk assessment, control activities, information & communication, and monitoring. Institutional investors may improve internal control thus enhance firm innovation (Chan et al., 2020). The second proxy is the disclosure of internal control reports(*DICR*). *DICR* is a dummy variable, which equals one if the firm disclosed the internal control report in year t and 0 otherwise. If the monitoring effect exists, then institutional investors should help firms improve internal controls and pressure them to provide relevant reports. The last proxy is CEO forced turnover(*Forced Turnover),* which is widely applied to test internal governance of a firm(Guo and Masulis, 2015). *Forced Turnover* equal to one in year t if the incumbent CEO is in office for the large part of year t but no longer in year t+1, and the departure was involuntary[11].

As reported in Table 8, there is no statistically significant relationship between institutional investor network centrality and three monitoring proxies, suggesting that institutional investor networks do not promote firm innovation through better monitoring.

<insert Table 8>

## 5 Robustness checks

### 5.1 Alternative measures of network centrality

In this section, we employ three alternative popular network measures for robustness check: *Degree*, *Betweenness*, and *Closeness*. *Degree* measures the number of links incident upon a node. *Betweenness* measures the ability to act as a bridge between otherwise unconnected investors, and *Closeness* measures the average length of the

[10] We obtain the internal control index from the internal control database developed by DIB Business Risk Management Inc. in China. Source: http://www.dibdata.cn/

[11] We follow You and Du(2011) to classify the turnover types of CEOs.

shortest path between the node and all other nodes within the whole network. In addition, we apply the first principal component analysis on our four network centrality variables for further robustness. Table 9 presents the results of our analysis. All the regression models confirm our findings and show that the relationship between the institutional investor network and firm innovation is not driven by different network variables.

<insert Table 9>

### 5.2 Alternative measures of firm innovation

Although the proxy of firm innovation(patent eventually granted) is widely established and employed in the literature, it is still not free from possible measurement errors(Tan et al. 2020). Among the several existing different proxies for firm innovation. We further use R&D expenditures(*RDSize*) to capture the innovation input and the total number of invention and utility model patent applications(*PatA*), and the number of invention patent applications(*IPatA*) as alternative innovation output proxies. To further address the concern that well-connected institutional investors may push firms to switch to the strategy of producing a more significant number of patents at the expense of quality, we examine this possibility using future citations(*Citation*) and the average maintenance year of invention patents(*TermY*) as a measure of patent quality. As reported in Table 10, our main results hold after switching to other innovation proxies.

<insert Table 10>

### 5.3 Defeered impact on innovation from institutional investor networks

Since it generally takes time to cultivate firm innovation, we use different ahead years of innovation outputs. We run an OLS regression where the dependent variable represents either *Pat* or *InvPat* measured from year t+2 to t+4. Table 11 presents the regression results. Columns (1)-(4) report the result with *Pat* as the dependent variable. Columns (5)-(8) report the result with *InvPa*t as the dependent variable. The coefficient estimates are all positive and significant in all the Columns.

<insert Table 11>

**6 Conclusions**

Our study investigates how the networks of institutional investors impact firm innovation. We hypothesize that institutional investor network centrality boost firm innovation. This is because networks foster mutual caring, trust, positive impression, and tolerance of failure among actors (Glaeser et al., 2000). Using a merged dataset comprising 2196 unique Chinese listed firms for the 2007-2017 period, we document a positive effect of institutional investor network centrality on firm innovation. Findings also show the economic importance of this result. We use both a DID approach and an IV approach that relies on a plausibly exogenous variation in institutional investor networks generated by unexpected departure of mutual fund managers to address endogeneity concerns. Our identification tests suggest that this positive effect is casual.

We further explore two possible underlying economic mechanisms through which institutional investor networks promote innovation. We find that institutional investor networks foster firm innovation mainly by facilitating information diffusion, by certifying the quality of firms. Our article provides the first empirical study to examine the importance of the social network of institutional investors in enhancing firm innovation. Prior studies have concerned the monitoring incentive and power of Chinese institutional investors, while our study reveals the vital role of social network of institutional investors in China.

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**Table 1**

**Summary statistics**

This table reports descriptive statistics for the variables of 2196 Chinese firms during 2007-2017 used in our models. Measures of firm innovation and institutional investor network centrality are defined in Section 3. Definitions of all variables are presented in Appendix A.

| | **Total Sample** (18679 observations) | | **Subsample (1) with investor networks** ( 5582 observations) | | **Subsample (2) without investor networks** (13097 observations) | | **Subsample (1)-(2)** |
|---|---|---|---|---|---|---|---|
| Variables | Mean | SD | Mean | SD | Mean | SD | Mean Difference |
| Dependent variable | | | | | | | |
| Pat | 22.895 | 67.595 | 45.355 | 104.116 | 13.322 | 39.878 | 32.032*** |
| InvPat | 6.118 | 19.012 | 12.588 | 29.565 | 3.361 | 10.843 | 9.227*** |
| ln(Pat) | 1.741 | 1.578 | 2.414 | 1.714 | 1.454 | 1.423 | 0.960*** |
| ln(InvPat) | 1.003 | 1.134 | 1.538 | 1.334 | 0.775 | 0.951 | 0.762*** |
| Independent variables | | | | | | | |
| Eigenvector | 0.015 | 0.052 | 0.050 | 0.085 | 0.000 | 0.000 | 0.050*** |
| Degree | 0.061 | 0.447 | 0.205 | 0.800 | 0.000 | 0.000 | 0.205*** |
| Betweenness | 0.003 | 0.013 | 0.011 | 0.021 | 0.000 | 0.000 | 0.011*** |
| Closeness | 0.095 | 0.157 | 0.319 | 0.107 | 0.000 | 0.000 | 0.319*** |
| Control variable | | | | | | | |
| Size | 22.032 | 1.264 | 22.599 | 1.274 | 21.790 | 1.179 | 0.809*** |
| Leverage | 0.459 | 0.217 | 0.432 | 0.194 | 0.471 | 0.225 | -0.038*** |
| Tangibility | 0.253 | 0.173 | 0.218 | 0.159 | 0.268 | 0.176 | -0.050*** |
| Profitability | 0.036 | 0.058 | 0.059 | 0.053 | 0.026 | 0.058 | 0.032*** |
| Sales | 21.398 | 1.482 | 22.013 | 1.501 | 21.136 | 1.394 | 0.876*** |
| SalesGrowth | 0.215 | 0.568 | 0.300 | 0.580 | 0.179 | 0.559 | 0.120*** |
| TobinQ | 2.264 | 1.586 | 2.556 | 1.771 | 2.140 | 1.483 | 0.415*** |
| Board size | 2.272 | 0.180 | 2.272 | 0.184 | 2.272 | 0.178 | 0.000 |
| Board independence | 0.371 | 0.053 | 0.374 | 0.055 | 0.369 | 0.051 | 0.005*** |
| CEO duality | 0.213 | 0.410 | 0.243 | 0.429 | 0.201 | 0.401 | 0.042*** |
| Age | 2.267 | 0.601 | 2.246 | 0.601 | 2.277 | 0.601 | -0.031*** |
| SOE | 0.477 | 0.500 | 0.414 | 0.493 | 0.504 | 0.500 | -0.090*** |

**Table 2**

**Institutional investor network centrality and firm innovation**

This table reports panel regression results of firm innovation on institutional investor network centrality during the sample period from 2007 to 2017. Columns (1) and (4) control for year fixed effects. Columns (2) and (5) control for industry and year fixed effects. Columns (3) and (6) control for firm and year fixed effects. Definitions of all variables are presented in Appendix A. In all columns, firm and year fixed effects are controlled. The standard errors are clustered at the firm level, and t-statistics are shown in parentheses. *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

| Dependent Variables | **F.ln(Pat)** | **F.ln(Pat)** | **F.ln(Pat)** | **F. ln(InvPat)** | **F. ln(InvPat)** | **F. ln(InvPat)** |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| **Eigenvector** | 6.042*** | 1.548*** | 1.422*** | 5.450*** | 1.896*** | 1.808*** |
| | (9.646) | (3.258) | (3.016) | (10.855) | (4.605) | (4.447) |
| Size | | 0.289*** | 0.339*** | | 0.282*** | 0.308*** |
| | | (6.559) | (7.454) | | (8.631) | (9.099) |
| Leverage | | -0.032 | -0.058 | | -0.076 | -0.081 |
| | | (-0.295) | (-0.533) | | (-0.946) | (-1.022) |
| Tangibility | | -1.203*** | -0.666*** | | -0.819*** | -0.474*** |
| | | (-8.146) | (-3.851) | | (-7.471) | (-3.806) |
| Profitability | | 0.020 | 0.044 | | 0.239 | 0.270 |
| | | (0.063) | (0.143) | | (1.053) | (1.214) |
| Sales | | 0.249*** | 0.211*** | | 0.134*** | 0.113*** |
| | | (7.214) | (5.959) | | (5.449) | (4.437) |
| SalesGrowth | | -0.043** | -0.051** | | -0.020 | -0.026* |
| | | (-2.141) | (-2.548) | | (-1.360) | (-1.813) |
| TobinQ | | 0.011 | 0.002 | | 0.038*** | 0.030*** |
| | | (0.861) | (0.171) | | (4.106) | (3.238) |
| Board size | | -0.034 | -0.035 | | 0.049 | 0.050 |
| | | (-0.230) | (-0.236) | | (0.425) | (0.447) |
| Board independence | | 0.248 | 0.169 | | 0.465 | 0.412 |
| | | (0.547) | (0.372) | | (1.333) | (1.186) |
| CEO duality | | 0.087* | 0.089* | | 0.100*** | 0.101*** |
| | | (1.889) | (1.933) | | (2.790) | (2.875) |
| Age | | -0.317*** | -0.265*** | | -0.171*** | -0.130*** |
| | | (-7.968) | (-6.656) | | (-5.887) | (-4.446) |
| SOE | | 0.044 | 0.048 | | 0.083* | 0.086** |
| | | (0.772) | (0.844) | | (1.948) | (2.065) |
| Constant | 1.731*** | -8.917*** | -10.166*** | 0.980*** | -7.835*** | -8.593*** |
| | (56.183) | (-13.159) | (-13.622) | (45.363) | (-14.054) | (-14.241) |
| Industry FE | No | Yes | No | No | Yes | No |
| Firm FE | No | No | Yes | No | No | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 15,632 | 15,632 | 15,632 | 15,632 | 15,632 | 15,632 |
| adj. R-sq | 0.106 | 0.409 | 0.813 | 0.114 | 0.379 | 0.800 |

**Table 3**

**Overview of Funds and fund-level network centrality**

Panel A presents the summary statistics on the funds. Panel B shows the mean difference on the null hypotheses of an equal mean of asset under management and eigenvector centrality between groups of Subsample 1 and Subsample 2. *AUM* is defined as the natural logarithm of one plus total assets under the management of the focus fund. *Eigenvector* is the eigenvector centrality of connection with other institutional investors holding a significant stake(e.g., represent more than 5% in the portfolio) in the same firms. *, ** and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

***Panel A: Summary Statistics on the funds***

| | **Total number of funds** | **Sum of AUM** | **Average of AUM** | **average years of working experience** | **Average of fund-level Engenvector** | **Fund with manager Departure (for personal reasons)** |
|---|---|---|---|---|---|---|
| 2007 | 257 | 1690652.270 | 6578.414 | 8.886 | 0.057 | 107 (20) |
| 2008 | 250 | 999001.750 | 3996.007 | 8.984 | 0.053 | 98 (14) |
| 2009 | 330 | 1395688.602 | 4229.359 | 9.690 | 0.048 | 113 (40) |
| 2010 | 406 | 1341111.583 | 3303.231 | 9.292 | 0.035 | 134 (60) |
| 2011 | 493 | 1207561.743 | 2449.415 | 10.076 | 0.033 | 140 (61) |
| 2012 | 606 | 1240214.633 | 2046.559 | 10.011 | 0.031 | 153 (73) |
| 2013 | 709 | 1270729.640 | 1792.284 | 11.207 | 0.028 | 191 (69) |
| 2014 | 822 | 1254877.448 | 1526.615 | 10.519 | 0.024 | 273 (105) |
| 2015 | 1,051 | 1492960.004 | 1420.514 | 10.442 | 0.018 | 423 (300) |
| 2016 | 1,154 | 1221995.526 | 1058.922 | 9.043 | 0.017 | 314 (129) |

***Panel B: Comparisons of AUM and Eigenvector between fund manager Departure for personal reasons and without fund manager Departure for personal reasons***

| | **AUM** | | | **Eigenvector** | | |
|---|---|---|---|---|---|---|
| | | **Departure with personnel** | **Mean Difference** | **Without Departure** | **Departure with personnel** | **Mean Difference** |
| | **(1)** | **(2)** | **(1)-(2)** | **(3)** | **(4)** | **(3)-(4)** |
| 2007 | 6565.876 | 7026.183 | -460.307 | 0.058 | 0.052 | 0.006 |
| 2008 | 3997.133 | 3715.626 | 281.507 | 0.053 | 0.058 | -0.005 |
| 2009 | 4246.655 | 3612.474 | 634.182 | 0.048 | 0.057 | -0.009 |
| 2010 | 3353.858 | 1485.240 | 1868.618 | 0.035 | 0.026 | 0.009 |
| 2011 | 2437.069 | 3113.353 | -676.284 | 0.033 | 0.033 | 0.000 |
| 2012 | 2048.364 | 1975.422 | 72.942 | 0.031 | 0.032 | 0.000 |
| 2013 | 1770.607 | 2731.199 | -960.592 | 0.028 | 0.027 | 0.001 |
| 2014 | 1513.534 | 2025.577 | -512.043 | 0.024 | 0.023 | 0.001 |
| 2015 | 1464.522 | 1024.020 | 440.502 | 0.018 | 0.020 | -0.002 |
| 2016 | 1061.815 | 966.427 | 95.387 | 0.017 | 0.014 | 0.003 |

**Table 4**

**Institutional investor network centrality and firm innovation: DID**

This table reports the panel regression results of firm innovation on institutional investor network centrality dynamics during the sample period 2007 to 2017. *Treat* is a dummy variable that equals one if the fund holds a listed firm at more than 5% of the total portfolio with fund manager departure for personal reasons and zero otherwise. *After* is a dummy variable equals one for years after fund manager departure for personal reasons, and zero otherwise. The interaction term *Treat*After* captures the effect of the dynamics of Institutional investor network centrality on firm innovation. *Avgproportion* is calculated as the average proportion of funds that hold the same listed firm at more than 5% of the total portfolio. *Avgfundage* is calculated as the average age of funds that hold the same listed firm at more than 5% of the total portfolio. *Avgmanagementfee* is calculated as the average management fee of funds that hold the same listed firm at more than 5% of the total portfolio. *AvgAUM* is calculated as the average total asset under management of funds that hold the same listed firm at more than 5% of the total portfolio. *AvgReturn* is calculated as the average return of funds that hold the same listed firm at more than 5% of the total portfolio. Definitions of all variables are presented in Appendix A. In all columns, firm and year fixed effects are controlled. The standard errors are clustered at the firm level, and t-statistics are shown in parentheses. *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

| | DID | | Year(-2,2) | | Year(-3,3) | | PSM-DID | |
|---|---|---|---|---|---|---|---|---|
| Dependent Variables | **F.ln(Pat)** | **F.ln(InvPat)** | **F.ln(Pat)** | **F.ln(InvPat)** | **F.ln(Pat)** | **F.ln(InvPat)** | **F.ln(Pat)** | **F.ln(InvPat)** |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| **Treat*After** | -0.322*** | -0.259*** | -0.451*** | -0.354*** | -0.375*** | -0.311*** | -0.199*** | -0.159** |
| | (-4.605) | (-4.273) | (-5.046) | (-4.501) | (-4.672) | (-4.415) | (-2.614) | (-2.406) |
| **After** | -0.210*** | -0.166*** | -0.236** | -0.087 | -0.234*** | -0.138* | -0.200*** | -0.140** |
| | (-2.996) | (-2.689) | (-2.431) | (-1.006) | (-2.731) | (-1.809) | (-2.688) | (-2.135) |
| Size | 0.412*** | 0.413*** | 0.484*** | 0.464*** | 0.447*** | 0.422*** | 0.451*** | 0.451*** |
| | (7.234) | (8.218) | (5.978) | (6.432) | (6.255) | (6.650) | (7.350) | (8.339) |
| Leverage | 0.390* | -0.032 | 0.410 | -0.065 | 0.419* | -0.069 | 0.384* | -0.084 |
| | (1.869) | (-0.172) | (1.455) | (-0.261) | (1.676) | (-0.312) | (1.715) | (-0.423) |
| Tangibility | -1.855*** | -1.449*** | -1.521*** | -1.357*** | -1.470*** | -1.228*** | -1.975*** | -1.557*** |
| | (-9.281) | (-8.228) | (-5.433) | (-5.448) | (-6.003) | (-5.637) | (-9.188) | (-8.225) |
| Profitability | -1.331** | -1.072* | -1.003 | -1.341 | -0.533 | -1.007 | -1.423* | -0.850 |
| | (-1.998) | (-1.825) | (-1.066) | (-1.602) | (-0.641) | (-1.362) | (-1.925) | (-1.307) |
| Sales | 0.268*** | 0.194*** | 0.216*** | 0.175*** | 0.262*** | 0.216*** | 0.253*** | 0.185*** |
| | (5.327) | (4.382) | (2.985) | (2.722) | (4.099) | (3.799) | (4.660) | (3.874) |
| SalesGrowth | -0.075* | -0.070* | -0.079 | -0.058 | -0.058 | -0.064 | -0.071 | -0.063 |
| | (-1.698) | (-1.775) | (-1.386) | (-1.144) | (-1.082) | (-1.348) | (-1.462) | (-1.473) |
| TobinQ | -0.029 | 0.025 | 0.010 | 0.050** | -0.006 | 0.035* | -0.018 | 0.030 |
| | (-1.557) | (1.489) | (0.405) | (2.183) | (-0.263) | (1.715) | (-0.857) | (1.635) |
| Board size | 0.024 | 0.249 | 0.159 | 0.288 | 0.118 | 0.254 | 0.149 | 0.368** |
| | (0.134) | (1.582) | (0.621) | (1.270) | (0.525) | (1.264) | (0.789) | (2.207) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Board independence | -0.440 | 0.359 | -0.454 | 0.772 | -0.315 | 0.798 | -0.555 | 0.042 |
| | (-0.808) | (0.748) | (-0.619) | (1.182) | (-0.481) | (1.371) | (-0.943) | (0.082) |
| CEO duality | 0.110* | 0.141** | 0.107 | 0.163** | 0.153** | 0.196*** | 0.159** | 0.206*** |
| | (1.706) | (2.486) | (1.248) | (2.139) | (1.992) | (2.860) | (2.247) | (3.312) |
| Age | -0.371*** | -0.191*** | -0.515*** | -0.278*** | -0.539*** | -0.296*** | -0.386*** | -0.197*** |
| | (-7.123) | (-4.165) | (-7.190) | (-4.356) | (-8.474) | (-5.236) | (-6.852) | (-3.971) |
| SOE | -0.115* | 0.017 | 0.018 | 0.132 | -0.000 | 0.124* | -0.091 | 0.041 |
| | (-1.703) | (0.281) | (0.184) | (1.551) | (-0.002) | (1.682) | (-1.271) | (0.648) |
| Avgproportion | -2.656 | -1.006 | -1.970 | -0.122 | -1.030 | 2.227 | -3.721 | -0.999 |
| | (-0.438) | (-0.188) | (-0.194) | (-0.014) | (-0.121) | (0.293) | (-0.568) | (-0.173) |
| Avgfundage | 0.331*** | 0.192* | 0.313 | 0.031 | 0.287* | 0.020 | 0.328** | 0.226* |
| | (2.685) | (1.768) | (1.577) | (0.178) | (1.708) | (0.136) | (2.469) | (1.936) |
| Avgmanagementfee | -20.859 | -22.798 | -8.526 | -11.498 | -30.070 | -32.397 | -18.024 | -22.694 |
| | (-1.043) | (-1.293) | (-0.217) | (-0.330) | (-0.844) | (-1.022) | (-0.855) | (-1.223) |
| AvgAUM | -0.011 | 0.021 | 0.037 | 0.085 | -0.073 | 0.014 | -0.043 | -0.028 |
| | (-0.163) | (0.352) | (0.362) | (0.944) | (-0.836) | (0.179) | (-0.539) | (-0.407) |
| AvgReturn | -0.202 | -0.080 | -0.515** | -0.122 | -0.261 | 0.034 | -0.254 | -0.122 |
| | (-1.151) | (-0.519) | (-2.026) | (-0.538) | (-1.125) | (0.166) | (-1.371) | (-0.745) |
| Constant | -10.918*** | -11.794*** | -11.842*** | -12.929*** | -11.341*** | -12.432*** | -11.511*** | -12.348*** |
| | (-12.562) | (-15.394) | (-9.623) | (-11.808) | (-10.592) | (-13.056) | (-12.275) | (-14.950) |
| Fund FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 2,390 | 2,390 | 1,056 | 1,056 | 1,426 | 1,426 | 2,063 | 2,063 |
| adj. R-sq | 0.808 | 0.798 | 0.806 | 0.797 | 0.813 | 0.807 | 0.824 | 0.816 |

**Table 5**

**Institutional investor network centrality and firm innovation: Departure and INDEX as IVs**

This table reports the panel regression results of firm innovation on institutional investor network centrality employing two instrumental variables: departure of socially connected fund managers(*Departure*) and indexing or not(*Index*), which are defined in Section 4.2.2. Definitions of all variables are presented in Appendix A. In all columns, firm and year fixed effects are controlled. The standard errors are clustered at the firm level, and *t*-statistics are shown in parentheses. *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

| | First Stage | Second Stage | | First Stage | Second Stage | |
|---|---|---|---|---|---|---|
| Dependent Variables | | **F.ln(Pat)** | **F.ln(InvPat)** | | **F.ln(Pat)** | **F.ln(InvPat)** |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| **Departure** | -0.013*** | | | | | |
| | (-8.599) | | | | | |
| **Index** | | | | 0.022*** | | |
| | | | | (4.287) | | |
| **Eigenvector** | | 7.423** | 12.324*** | | 5.868*** | 8.871*** |
| | | (2.501) | (4.587) | | (3.812) | (7.006) |
| Size | 0.006*** | 0.152*** | 0.077** | 0.008*** | 0.295*** | 0.233*** |
| | (4.270) | (3.587) | (2.002) | (9.385) | (9.775) | (9.386) |
| Leverage | 0.004 | 0.079 | 0.084 | -0.001 | -0.186*** | -0.216*** |
| | (1.190) | (1.228) | (1.442) | (-0.217) | (-2.909) | (-4.118) |
| Tangibility | 0.003 | 0.281*** | 0.150* | 0.005 | -0.801*** | -0.581*** |
| | (0.654) | (2.971) | (1.750) | (1.291) | (-8.625) | (-7.606) |
| Profitability | 0.061*** | 0.215 | -0.375* | 0.161*** | -1.232*** | -1.380*** |
| | (6.974) | (0.891) | (-1.713) | (19.372) | (-3.964) | (-5.399) |
| Sales | 0.004*** | 0.082*** | -0.017 | 0.003*** | 0.192*** | 0.079*** |
| | (3.033) | (3.142) | (-0.716) | (5.089) | (10.366) | (5.154) |
| SalesGrowth | -0.000 | -0.056*** | -0.031*** | 0.001 | -0.063*** | -0.054*** |
| | (-0.452) | (-4.443) | (-2.716) | (1.164) | (-3.354) | (-3.495) |
| TobinQ | 0.004*** | -0.051*** | -0.074*** | 0.007*** | -0.031* | -0.029** |
| | (11.854) | (-2.798) | (-4.480) | (22.288) | (-1.926) | (-2.193) |
| Board size | -0.002 | 0.021 | 0.102 | -0.004 | 0.044 | 0.153*** |
| | (-0.508) | (0.258) | (1.383) | (-1.399) | (0.616) | (2.631) |
| Board independence | 0.014 | 0.114 | 0.118 | -0.002 | 0.386* | 0.621*** |
| | (1.250) | (0.538) | (0.615) | (-0.204) | (1.708) | (3.339) |
| CEO duality | -0.004*** | 0.040 | 0.054** | 0.002* | 0.106*** | 0.102*** |
| | (-3.196) | (1.566) | (2.325) | (1.860) | (3.877) | (4.536) |
| Age | -0.002 | 0.215*** | 0.154*** | -0.000 | -0.323*** | -0.156*** |
| | (-0.686) | (3.946) | (3.122) | (-0.582) | (-15.479) | (-9.086) |
| SOE | -0.003 | 0.074 | 0.087** | -0.007*** | 0.030 | 0.094*** |
| | (-1.397) | (1.552) | (2.030) | (-7.129) | (1.103) | (4.213) |
| Constant | -0.215*** | -7.049*** | -5.190*** | -0.261*** | -9.536*** | -6.333*** |
| | (-8.316) | (-10.579) | (-10.025) | (-18.971) | (-15.681) | (-13.343) |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 15,632 | 15,632 | 15,632 | 15,632 | 15,632 | 15,632 |
| F-test of instruments | 28.879 | | | 23.548 | | |

**Table 6**

**Institutional investor network centrality and corporate site visits**

This table reports the results from our cross-sectional tests based on institutional investors' corporate site visits. The panel regression results in Panel A are estimated on median partitioned subsamples, using the innovation outcome variables as the dependent variables. The partition variable *Visit* is defined as the natural logarithm of one plus firm i's the total number of institutional investors' site visits in year t. The Chow-test result reported at the bottom of Panel A tests the equivalence of the coefficients for *Eigenvector* between the low and high groups. Variable definitions used in the analysis can be found in Appendix A. The panel regression results in Panel B are estimated on the whole sample, using *Visit* as the dependent variable. All regressions are estimated with firm and year fixed effects. The t-statistics reported in parentheses are based on standard errors clustered by firm. ***, **, and * indicate significance at the 1%, 5% and 10% levels, respectively.

***Panel A: Subsample analysis***

| Dependent variables | **F.ln(Pat)** | **F.ln(Pat)** | **F.ln(InvPat)** | **F.ln(InvPat)** |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Partition variables | | **Visit** | | |
| | Low | High | Low | High |
| **Eigenvector** | 2.061*** | 0.795 | 2.176*** | 0.791 |
| | (2.583) | (1.342) | (2.837) | (1.464) |
| Size | 0.327*** | 0.432*** | 0.348*** | 0.441*** |
| | (4.263) | (4.847) | (4.573) | (5.154) |
| Leverage | -0.099 | 0.771*** | -0.363 | 0.479* |
| | (-0.397) | (2.835) | (-1.597) | (1.907) |
| Tangibility | -0.093 | -0.570 | 0.142 | -0.690* |
| | (-0.285) | (-1.559) | (0.448) | (-1.862) |
| Profitability | -0.435 | 1.216 | 0.107 | 1.531** |
| | (-0.485) | (1.391) | (0.138) | (1.996) |
| Sales | 0.184*** | 0.140* | 0.137** | 0.096 |
| | (2.822) | (1.850) | (2.067) | (1.294) |
| SalesGrowth | 0.103 | 0.051 | 0.102 | 0.002 |
| | (1.629) | (0.553) | (1.546) | (0.027) |
| TobinQ | -0.025 | -0.007 | 0.030 | 0.017 |
| | (-0.974) | (-0.235) | (1.313) | (0.688) |
| Board size | -0.261 | -0.091 | -0.078 | -0.008 |
| | (-1.045) | (-0.348) | (-0.299) | (-0.032) |
| Board independence | -1.525** | -1.528* | -0.082 | -0.896 |
| | (-2.042) | (-1.923) | (-0.111) | (-1.006) |
| CEO duality | 0.159** | 0.067 | 0.094 | 0.044 |
| | (2.083) | (0.904) | (1.323) | (0.568) |
| Age | -0.304*** | -0.051 | -0.218*** | -0.038 |
| | (-3.927) | (-0.558) | (-3.020) | (-0.390) |
| SOE | 0.091 | -0.050 | 0.139 | 0.066 |
| | (0.980) | (-0.483) | (1.418) | (0.594) |
| Constant | -8.277*** | -9.745*** | -9.494*** | -10.380*** |
| | (-6.321) | (-6.412) | (-6.467) | (-7.335) |
| | | | | |
| Firm FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| Difference of coefficients | (1)-(2) | | (3)-(4) | |
| On Eigenvector | 3.23*** | | 3.88*** | |
| Observations | 1,381 | 1,336 | 1,381 | 1,336 |
| adj. R-sq | 0.812 | 0.845 | 0.821 | 0.843 |

| ***Panel B: The effect of Eigenvector on institutional investor site visit*** | |
|---|---|
| Dependent variables | **Visit** |
| | (1) |
| **Eigenvector** | 1.023*** |
| | (3.749) |
| Size | 0.482*** |
| | (5.889) |
| Leverage | 0.025 |
| | (0.126) |
| Tangibility | -0.389 |
| | (-1.421) |
| Profitability | 2.827*** |
| | (5.202) |
| Sales | -0.011 |
| | (-0.154) |
| SalesGrowth | 0.038 |
| | (0.807) |
| TobinQ | 0.123*** |
| | (6.772) |
| Board size | 0.174 |
| | (0.738) |
| Board independence | 0.342 |
| | (0.564) |
| CEO duality | 0.037 |
| | (0.574) |
| Age | -1.289*** |
| | (-7.157) |
| SOE | -0.216 |
| | (-1.330) |
| Constant | -5.604*** |
| | (-3.583) |
| | |
| Firm FE | Yes |
| Year FE | Yes |
| Observations | 4,871 |
| adj. R-sq | 0.508 |

**Table 7**

**Certification effect**

Columns (1)-(4) reports the regression results of the impact of institutional investor network centrality on firm innovation for SOEs and non-SOEs. Columns (5)-(8) reports the regression results of the impact of institutional investor network centrality on firm innovation of firms with high or low regional marketization index. The Chow-test result reported at the bottom of this table tests the equivalence of the coefficients for *Eigenvector* between two groups. All regressions control for the firm- and year-fixed effects. Standard errors reported in parentheses are clustered by firm. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. The descriptions of these variables are provided in Appendix A.

| Dependent variables | **F.ln(Pat)** | **F.ln(Pat)** | **F.ln(InvPat)** | **F.ln(InvPat)** | **F.ln(Pat)** | **F.ln(Pat)** | **F.ln(InvPat)** | **F.ln(InvPat)** |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Partition variables | SOE | | | | Marketization | | | |
| | Non-SOE | SOE | Non-SOE | SOE | Low | High | Low | High |
| **Eigenvector** | 2.465*** | 0.255 | 2.634*** | 0.805*** | 1.625*** | 0.903** | 2.197*** | 1.038*** |
| | -8.12 | -0.726 | -11.914 | -3.032 | -5.294 | -2.413 | -9.477 | -3.794 |
| Size | 0.288*** | 0.433*** | 0.286*** | 0.367*** | 0.419*** | 0.259*** | 0.412*** | 0.207*** |
| | -9.471 | -14.521 | -12.919 | -16.252 | -14.254 | -8.13 | -18.554 | -8.9 |
| Leverage | 0.111 | -0.283*** | 0.076 | -0.325*** | 0.157* | -0.168* | 0.02 | -0.129** |
| | -1.361 | (-3.184) | -1.274 | (-4.842) | -1.748 | (-1.892) | -0.301 | (-1.978) |
| Tangibility | -0.122 | -1.011*** | -0.170* | -0.653*** | -0.327** | -0.840*** | -0.321*** | -0.599*** |
| | (-0.909) | (-8.523) | (-1.746) | (-7.284) | (-2.521) | (-6.266) | (-3.278) | (-6.116) |
| Profitability | 0.793*** | -0.522* | 0.912*** | -0.328 | 1.040*** | -0.869*** | 0.980*** | -0.308 |
| | -2.79 | (-1.714) | -4.405 | (-1.423) | -3.342 | (-2.797) | -4.169 | (-1.356) |
| Sales | 0.174*** | 0.183*** | 0.081*** | 0.105*** | 0.170*** | 0.231*** | 0.072*** | 0.148*** |
| | -7.429 | -7.372 | -4.766 | -5.571 | -6.973 | -8.941 | -3.895 | -7.813 |
| SalesGrowth | -0.052** | -0.021 | -0.022 | -0.01 | -0.043 | -0.031 | -0.028 | 0.002 |
| | (-2.259) | (-0.724) | (-1.337) | (-0.462) | (-1.445) | (-1.181) | (-1.261) | -0.105 |
| TobinQ | -0.014 | 0.012 | 0.017** | 0.044*** | 0.016 | -0.018 | 0.036*** | 0.023*** |
| | (-1.368) | -0.871 | -2.288 | -4.036 | -1.422 | (-1.509) | -4.178 | -2.586 |
| Board size | 0.076 | -0.183** | 0.197*** | -0.129* | 0.031 | -0.002 | 0.096 | 0.091 |
| | -0.746 | (-2.081) | -2.634 | (-1.950) | -0.312 | (-0.024) | -1.285 | -1.26 |
| Board independence | -0.23 | 0.468 | 0.076 | 0.717*** | 0.099 | 0.415 | 0.298 | 0.654*** |
| | (-0.718) | -1.589 | -0.324 | -3.223 | -0.324 | -1.29 | -1.286 | -2.778 |
| CEO duality | 0.147*** | -0.045 | 0.130*** | 0.064* | 0.087** | 0.064 | 0.068*** | 0.127*** |
| | -4.858 | (-0.954) | -5.924 | -1.775 | -2.521 | -1.561 | -2.611 | -4.235 |
| Age | -0.319*** | -0.198*** | -0.158*** | -0.143*** | -0.226*** | -0.257*** | -0.097*** | -0.129*** |
| | (-12.182) | (-6.125) | (-8.306) | (-5.868) | (-8.136) | (-8.360) | (-4.619) | (-5.713) |
| SOE | | | | | 0.038 | 0.144*** | 0.111*** | 0.136*** |
| | | | | | -1.055 | -3.943 | -4.069 | -5.091 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Constant | -8.416*** | -11.412*** | -7.606*** | -9.368*** | -11.290*** | -9.045*** | -10.177*** | -7.290*** |
| | (-16.175) | (-22.748) | (-20.070) | (-24.697) | (-21.891) | (-18.430) | (-26.123) | (-20.318) |
| | | | | | | | | |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Difference of coefficients | (1)-(2) | | (3)-(4) | | (5)-(6) | | (7)-(8) | |
| On Eigenvector | 9.62*** | | 10.56 *** | | 10.11*** | | 12.11*** | |
| Observations | 7,824 | 7,808 | 7,824 | 7,808 | 7,776 | 6,662 | 7,776 | 6,662 |
| adj. R-sq | 0.786 | 0.841 | 0.763 | 0.836 | 0.826 | 0.808 | 0.828 | 0.787 |

**Table 8**

**Alternative explanation: Monitoring effect**

Column (1) report the regression results of the impact of institutional investor network centrality on the internal control index(*ICI*). Column (2) reports the result of the probit regression where the dependent variable(*DICR*) is a dummy variable that takes the value one if the firm disclosed the internal control report in year t. Column (3) reports the result of the probit regression where the dependent variable is the *Forced turnover*. The standard errors are clustered at the firm level, and t-statistics are shown in parentheses. Definitions of all variables are presented in Appendix A. *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

| Dependent Variables | **F.ICI** | **F.DICR** | **F.Forced turnover** |
|---|---|---|---|
| | (1) | (2) | (3) |
| **Eigenvector** | -0.042 | -0.307 | -0.066 |
| | (-0.685) | (-1.051) | (-0.154) |
| Size | 0.012 | 0.153*** | -0.007 |
| | (0.797) | (5.889) | (-0.204) |
| Leverage | -0.118*** | -0.294*** | 0.126 |
| | (-2.790) | (-3.833) | (1.248) |
| Tangibility | -0.023 | 0.088 | 0.072 |
| | (-0.522) | (0.792) | (0.464) |
| Profitability | -0.079 | 0.728*** | -1.364*** |
| | (-0.538) | (2.752) | (-4.042) |
| Sales | 0.047*** | 0.023 | 0.002 |
| | (2.653) | (1.095) | (0.077) |
| SalesGrowth | -0.016** | -0.034 | 0.039 |
| | (-2.003) | (-1.519) | (1.390) |
| TobinQ | -0.002 | 0.012 | 0.019 |
| | (-0.374) | (1.278) | (1.453) |
| Board size | 0.047 | 0.256*** | -0.177 |
| | (1.382) | (3.051) | (-1.499) |
| Board independence | 0.011 | 0.465* | 0.144 |
| | (0.118) | (1.754) | (0.377) |
| CEO duality | -0.009 | 0.018 | -0.022 |
| | (-0.906) | (0.612) | (-0.486) |
| Age | 0.023 | 0.171*** | 0.043 |
| | (1.256) | (7.113) | (1.227) |
| SOE | 0.037 | 0.531*** | -0.178*** |
| | (1.258) | (17.242) | (-4.154) |
| Constant | 0.614** | -7.042*** | -1.005* |
| | (1.969) | (-16.202) | (-1.716) |
| | | | |
| Industry FE | No | Yes | Yes |
| Firm FE | Yes | No | No |
| Year FE | Yes | Yes | Yes |
| Observations | 13,495 | 15,514 | 15,632 |
| adj. R-sq(Pseudo R-sq) | 0.133 | 0.306 | 0.025 |

**Table 9**

**Institutional investor network centrality and firm innovation: alternative measures of centrality**

This table reports panel regression results of firm innovation on institutional investor network centrality during the sample period 2007 to 2017 using alternative centrality measures. The institutional investor network centrality is measured by the degree in Columns (1) and (5), betweenness in Columns (2) and (6), Closeness in Columns (3) and (7), the first principal component score in Columns (4) and (8). Definitions of all variables are presented in Appendix A. In all columns, firm and year fixed effects are controlled. The standard errors are clustered at the firm level, and *t*-statistics are shown in parentheses. *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

| Dependent Variables | **F.ln(Pat)** | **F.ln(Pat)** | **F.ln(Pat)** | **F.ln(Pat)** | **F.ln(InvPat)** | **F.ln(InvPat)** | **F.ln(InvPat)** | **F.ln(InvPat)** |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| **Degree** | 0.477*** | | | | 0.519*** | | | |
| | (4.127) | | | | (4.187) | | | |
| **Betweenness** | | 17.031*** | | | | 15.641*** | | |
| | | (3.592) | | | | (3.864) | | |
| **Closeness** | | | 2.223*** | | | | 1.930*** | |
| | | | (14.109) | | | | (15.458) | |
| **Principal component** | | | | 0.185*** | | | | 0.168*** |
| | | | | (5.298) | | | | (5.668) |
| Size | 0.430*** | 0.330*** | 0.327*** | 0.332*** | 0.367*** | 0.269*** | 0.269*** | 0.271*** |
| | (8.073) | (7.357) | (7.303) | (7.394) | (7.156) | (8.160) | (8.140) | (8.156) |
| Leverage | -0.399*** | -0.457*** | -0.442*** | -0.456*** | -0.329** | -0.369*** | -0.353*** | -0.367*** |
| | (-2.804) | (-3.853) | (-3.735) | (-3.845) | (-2.312) | (-4.130) | (-3.965) | (-4.117) |
| Tangibility | -0.799*** | -0.658*** | -0.641*** | -0.662*** | -1.327*** | -0.756*** | -0.745*** | -0.757*** |
| | (-3.977) | (-3.885) | (-3.793) | (-3.909) | (-7.811) | (-7.044) | (-6.953) | (-7.055) |
| Profitability | 0.523 | -0.269 | -0.323 | -0.265 | 0.553 | -0.101 | -0.132 | -0.113 |
| | (1.371) | (-0.798) | (-0.964) | (-0.787) | (1.446) | (-0.394) | (-0.517) | (-0.444) |
| Sales | 0.241*** | 0.199*** | 0.197*** | 0.199*** | 0.292*** | 0.131*** | 0.130*** | 0.131*** |
| | (5.596) | (5.611) | (5.588) | (5.620) | (7.046) | (5.319) | (5.321) | (5.319) |
| SalesGrowth | -0.066** | -0.079*** | -0.081*** | -0.077*** | -0.069*** | -0.068*** | -0.070*** | -0.066*** |
| | (-2.477) | (-3.544) | (-3.644) | (-3.470) | (-2.604) | (-4.110) | (-4.214) | (-4.005) |
| TobinQ | 0.060*** | 0.025 | 0.025 | 0.028* | 0.060*** | 0.043*** | 0.046*** | 0.045*** |
| | (3.134) | (1.546) | (1.556) | (1.688) | (3.141) | (3.393) | (3.581) | (3.479) |
| Board size | 0.127 | 0.065 | 0.066 | 0.066 | 0.132 | 0.156 | 0.156 | 0.157 |
| | (0.761) | (0.454) | (0.455) | (0.457) | (0.794) | (1.370) | (1.362) | (1.376) |
| Board independence | 0.379 | 0.460 | 0.457 | 0.462 | 0.405 | 0.649* | 0.647* | 0.651* |
| | (0.745) | (1.052) | (1.048) | (1.057) | (0.792) | (1.818) | (1.818) | (1.825) |
| CEO duality | 0.077 | 0.070 | 0.068 | 0.071 | 0.077 | 0.095*** | 0.094** | 0.096*** |
| | (1.455) | (1.540) | (1.497) | (1.556) | (1.455) | (2.591) | (2.550) | (2.606) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Age | -0.365*** | -0.298*** | -0.296*** | -0.300*** | -0.384*** | -0.157*** | -0.156*** | -0.159*** |
| | (-8.017) | (-7.790) | (-7.731) | (-7.834) | (-8.512) | (-5.404) | (-5.349) | (-5.456) |
| SOE | 0.100 | 0.049 | 0.047 | 0.048 | 0.100 | 0.076* | 0.073* | 0.076* |
| | (1.527) | (0.895) | (0.856) | (0.870) | (1.526) | (1.804) | (1.717) | (1.786) |
| Constant | -12.098*** | -9.515*** | -9.470*** | -9.552*** | -11.319*** | -7.810*** | -7.830*** | -7.808*** |
| | (-15.666) | (-13.883) | (-13.578) | (-13.647) | (-15.201) | (-14.096) | (-13.800) | (-13.754) |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 15,487 | 15,487 | 15,487 | 15,487 | 15,487 | 15,487 | 15,487 | 15,487 |
| adj. R-sq | 0.812 | 0.812 | 0.813 | 0.812 | 0.799 | 0.799 | 0.799 | 0.799 |

**Table 10**

**Institutional investor network centrality and firm innovation: alternative measures of firm innovation**

This table reports panel regression results of firm innovation on institutional investor network centrality during the sample period 2007 to 2017 using alternative measures of firm innovation. *RDSize* is calculated as the R&D expenditures scaled by the total asset. *PatA* is defined as the total number of invention and utility model patent applications filed by a firm in a given year. *IPatA* is defined as the total number of invention patent applications filed by a firm in a given year. *Citation* is calculated as the natural logarithm of one plus the number of future citations received by the invention patents applied by a firm in a given year that are eventually granted. To address the citation truncation problem, we further scaled *Citation* by the mean value of the number of future citations received by the invention patents applied by other firms in the same year and industry. *TermY* is calculated as the logarithm of one plus the average maintenance year of invention patents. Definitions of all variables are presented in Appendix A. In all columns, firm and year fixed effects are controlled. The standard errors are clustered at the firm level, and *t*-statistics are shown in parentheses. *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

| Dependent Variables | **F.RDSize** | **F.ln(PatA)** | **F.ln(IPatA)** | **F.Citation** | **F.TermY** |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| **Eigenvector** | 0.007*** | 0.915*** | 0.913*** | 0.308** | 0.561*** |
| | (3.125) | (4.713) | (5.177) | (2.218) | (3.725) |
| Size | -0.001*** | 0.247*** | 0.253*** | 0.014 | 0.025 |
| | (-4.179) | (8.766) | (9.826) | (1.369) | (1.062) |
| Leverage | -0.001 | 0.095 | 0.129** | -0.012 | 0.176*** |
| | (-1.036) | (1.404) | (2.079) | (-0.396) | (3.139) |
| Tangibility | 0.001 | 0.158* | 0.025 | -0.133*** | 0.051 |
| | (1.287) | (1.828) | (0.312) | (-3.872) | (0.706) |
| Profitability | 0.003* | 0.702*** | 0.541*** | 0.080 | -0.125 |
| | (1.774) | (4.095) | (3.463) | (0.727) | (-0.882) |
| Sales | 0.002*** | 0.139*** | 0.063*** | 0.026*** | -0.017 |
| | (6.839) | (5.921) | (2.963) | (3.042) | (-0.893) |
| SalesGrowth | -0.000** | -0.067*** | -0.046*** | -0.003 | -0.009 |
| | (-2.454) | (-5.094) | (-3.802) | (-0.306) | (-0.814) |
| TobinQ | 0.000* | -0.012 | -0.009 | -0.004 | -0.018*** |
| | (1.653) | (-1.637) | (-1.363) | (-1.004) | (-2.969) |
| Board size | 0.001 | 0.068 | 0.187** | 0.078** | 0.198*** |
| | (1.179) | (0.781) | (2.363) | (2.213) | (2.766) |
| Board independence | -0.003 | 0.173 | 0.231 | -0.042 | -0.150 |
| | (-1.355) | (0.766) | (1.122) | (-0.375) | (-0.805) |
| CEO duality | -0.001** | 0.055** | 0.072*** | 0.007 | -0.016 |
| | (-2.547) | (2.032) | (2.939) | (0.539) | (-0.713) |
| Age | -0.005*** | 0.236*** | 0.264*** | -0.058*** | 0.557*** |
| | (-8.028) | (4.254) | (5.207) | (-5.656) | (12.134) |
| SOE | 0.001** | 0.019 | 0.013 | -0.019 | 0.065* |
| | (2.427) | (0.389) | (0.293) | (-1.515) | (1.656) |
| Constant | 0.012** | -7.055*** | -6.471*** | -0.531*** | -1.221*** |
| | (2.087) | (-14.116) | (-14.209) | (-3.534) | (-2.957) |
| Firm FE | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes |
| Observations | 15,632 | 15,632 | 15,632 | 15,632 | 15,632 |
| adj. R-sq | 0.713 | 0.814 | 0.797 | 0.119 | 0.473 |

**Table 11**

**Institutional investor network centrality and firm innovation: ahead dependent variables**

This table reports panel regression results of firm innovation on institutional investor network centrality during the sample period 2007 to 2017 using ahead firm innovation. Definitions of all variables are presented in Appendix A. In all columns, firm and year fixed effects are controlled. The standard errors are clustered at the firm level, and t-statistics are shown in parentheses. *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

| Dependent Variables | **F2.ln(Pat)** | **F3.ln(Pat)** | **F4.ln(Pat)** | **F5.ln(Pat)** | **F2.ln(InvPat)** | **F3.ln(InvPat)** | **F4.ln(InvPat)** | **F5.ln(InvPat)** |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| **Eigenvector** | 1.491*** | 1.139*** | 0.926*** | 1.024** | 1.917*** | 1.632*** | 1.487*** | 1.336*** |
| | (5.517) | (3.864) | (2.755) | (2.504) | (9.436) | (7.293) | (5.770) | (4.229) |
| Size | 0.322*** | 0.314*** | 0.318*** | 0.292*** | 0.296*** | 0.299*** | 0.308*** | 0.291*** |
| | (14.098) | (12.383) | (11.180) | (9.073) | (17.255) | (15.517) | (14.123) | (11.686) |
| Leverage | -0.152** | -0.159** | -0.192** | -0.178** | -0.149*** | -0.194*** | -0.230*** | -0.244*** |
| | (-2.314) | (-2.201) | (-2.398) | (-2.011) | (-3.018) | (-3.547) | (-3.743) | (-3.572) |
| Tangibility | -0.714*** | -0.926*** | -1.000*** | -1.136*** | -0.533*** | -0.663*** | -0.731*** | -0.797*** |
| | (-7.318) | (-8.505) | (-8.257) | (-8.295) | (-7.271) | (-8.028) | (-7.870) | (-7.532) |
| Profitability | 0.006 | -0.332 | -0.441 | -0.606** | 0.231 | -0.118 | -0.191 | -0.377 |
| | (0.024) | (-1.310) | (-1.625) | (-2.036) | (1.338) | (-0.613) | (-0.918) | (-1.639) |
| Sales | 0.231*** | 0.255*** | 0.253*** | 0.271*** | 0.128*** | 0.146*** | 0.144*** | 0.163*** |
| | (12.441) | (12.401) | (10.992) | (10.421) | (9.168) | (9.355) | (8.133) | (8.139) |
| SalesGrowth | -0.035* | 0.029 | -0.001 | 0.003 | -0.015 | 0.026 | 0.005 | -0.010 |
| | (-1.715) | (1.202) | (-0.027) | (0.112) | (-0.956) | (1.451) | (0.278) | (-0.454) |
| TobinQ | 0.005 | 0.047*** | 0.063*** | 0.065*** | 0.036*** | 0.077*** | 0.084*** | 0.083*** |
| | (0.607) | (3.984) | (4.576) | (4.341) | (5.307) | (8.532) | (8.005) | (7.093) |
| Board size | 0.022 | 0.052 | 0.080 | 0.099 | 0.075 | 0.093 | 0.095 | 0.089 |
| | (0.305) | (0.643) | (0.903) | (0.992) | (1.360) | (1.529) | (1.391) | (1.147) |
| Board independence | 0.386 | 0.419 | 0.471 | 0.534 | 0.467*** | 0.423** | 0.376* | 0.517** |
| | (1.632) | (1.598) | (1.607) | (1.596) | (2.623) | (2.125) | (1.672) | (1.998) |
| CEO duality | 0.076*** | 0.076** | 0.052 | 0.054 | 0.093*** | 0.091*** | 0.068** | 0.063* |
| | (2.657) | (2.361) | (1.389) | (1.254) | (4.308) | (3.730) | (2.396) | (1.889) |
| Age | -0.302*** | -0.343*** | -0.366*** | -0.382*** | -0.162*** | -0.200*** | -0.215*** | -0.238*** |
| | (-13.818) | (-14.225) | (-13.328) | (-11.757) | (-9.873) | (-10.914) | (-10.231) | (-9.459) |
| SOE | 0.042 | 0.054* | 0.070** | 0.063* | 0.088*** | 0.090*** | 0.089*** | 0.077*** |
| | (1.597) | (1.850) | (2.151) | (1.744) | (4.416) | (4.044) | (3.592) | (2.735) |
| Constant | -10.270*** | -10.543*** | -10.579*** | -10.315*** | -8.516*** | -8.874*** | -8.969*** | -8.839*** |
| | (-28.529) | (-26.523) | (-23.986) | (-21.114) | (-31.461) | (-29.411) | (-26.523) | (-23.410) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 13,430 | 11,406 | 9,396 | 7,479 | 13,430 | 11,406 | 9,396 | 7,479 |
| adj. R-sq | 0.823 | 0.831 | 0.840 | 0.848 | 0.814 | 0.829 | 0.843 | 0.856 |

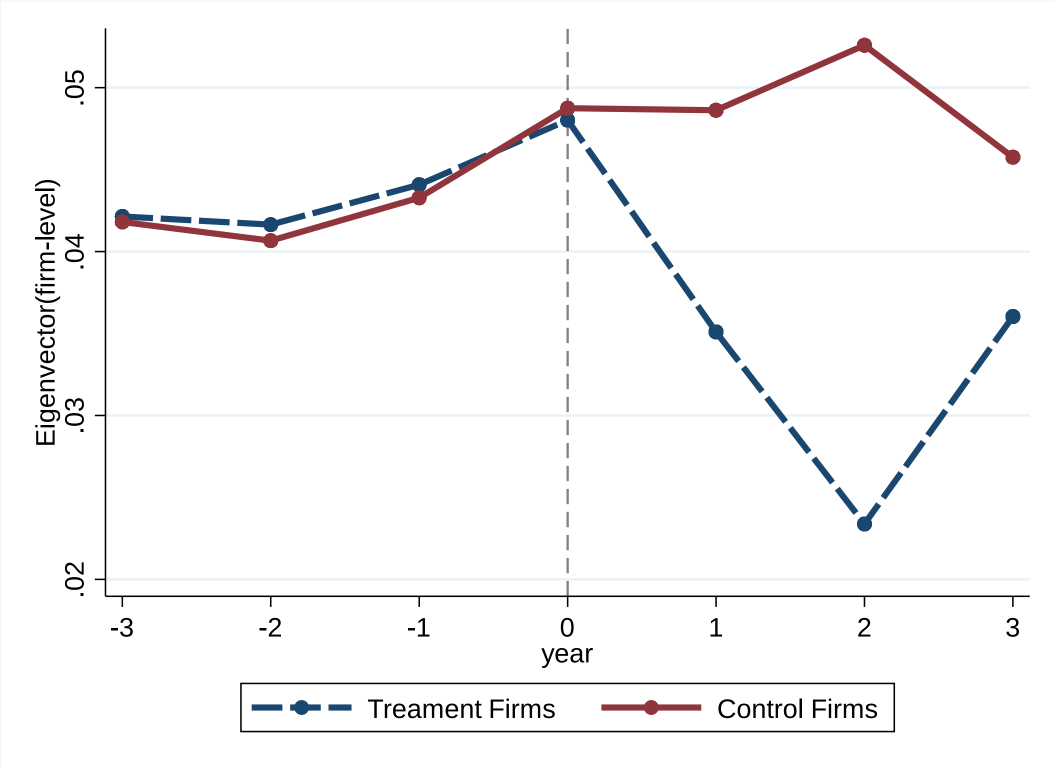



Figure 1 Firm-level eigenvector dynamics around the fund manager departure.

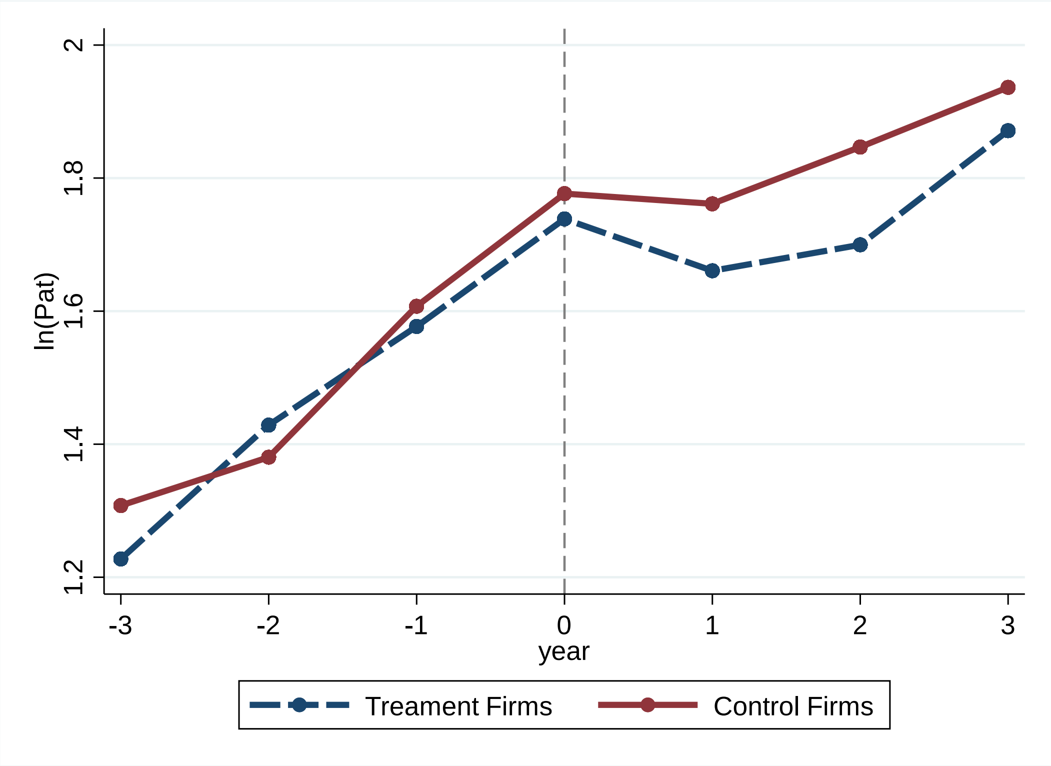


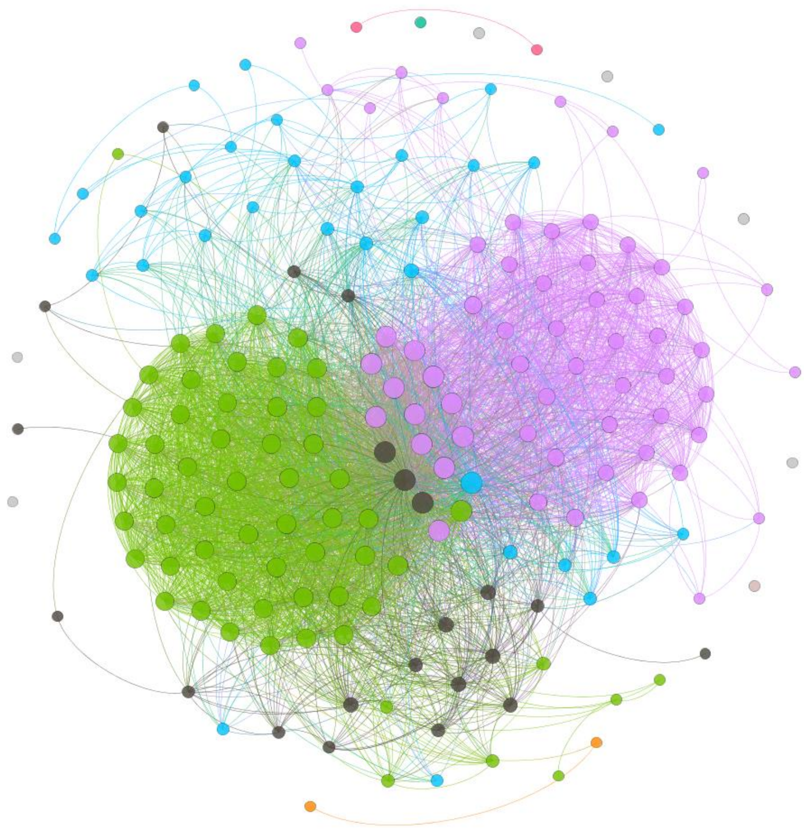

Figure 2 Firm-level innovation outputs dynamics around the fund manager departure.

**Appendix A. Variable definitions**

| | |
|---|---|
| **Measures of innovation** | |
| Pat | Total number of invention and utility model patent applications filed (and eventually granted) by a firm in a given year |
| InvPati | Total number of invention patent applications filed (and eventually granted) by a firm in a given year |
| **Measures of institutional investor network centrality** | |
| Eigenvector | The aggregate value of all fund fund-level eigenvector centrality for each quarter and converted to annual level by dividing it by four |
| Degree | The aggregate value of all fund fund-level degree centrality for each quarter and converted to annual level by dividing it by four |
| Betweenness | The aggregate value of all fund fund-level betweenness centrality for each quarter and converted to annual level by dividing it by four |
| Closeness | The aggregate value of all fund fund-level closeness centrality for each quarter and converted to annual level by dividing it by four |
| **Control variables** | |
| Size | Log(total asset) |
| Leverage | Total debt/Total assets |
| Tangibility | PP&E/Total assets |
| Profitability | Return/Total assets |
| Sales | Log (total sales) |
| SalesGrowth | Annual sales growth rate |
| TobinQ | (Market value of equity + Total debts)/Total assets |
| Board size | Natural logarithm of the number of directors on the board |
| Board Independence | The total number of the independent directors divided by the total number of board members |
| CEO duality | A dummy variable that equals to one if the CEO is the chair of the board,and zero other wise. |
| Age | log(number of years since the firm's IPO) |
| SOE | A dummy variable that equals to one if the firm's state ownership is more than 25%, and zero otherwise. |
| **Measures of institutional investors' site visits** | |
| Visit | Natural logarithm of one plus firm i's the total number of institutional investors' site visits in year t. |
| **Measures of regional marketization** | |
| Marketization | The marketization indexes measure the quality of market-supporting institutions at the provincial level, with higher index indicating higher quality of institutions |
| **Measures of corporate governance** | |
| ICI | A composite index with five components: control environment, risk assessment, control activities, information & communication, and monitoring. We obtain the internal control index from the internal control database developed by DIB Business Risk Management Inc. in China. Source: http://www.dibdata.cn/. |
| DICR | A dummy variable that equals to one if the firm disclosed the internal control report in year t and 0 otherwise |
| Forced turnover | A dummy variable that equals to one if the incumbent CEO is in office for the larger part of fiscal year t but no longer in fiscal year t + 1, and the departure was involuntary |

Appendix B, The evolvement of institutional investor networks

Date: 3/2007



Date: 12/2017