Ownership Network and Innovation Competition: Evidence from patent invalidation in China †

Wenzheng Niu
School of Finance, Renmin University of China
nwz@ruc.edu.cn

Yichu Wang
Nottingham University Business School
wangych.18@pbcsf.tsinghua.edu.cn

Abstract

We investigate how overlapping corporate ownership affect competition in the case of technological innovation. We find that cross-ownership has a positive effect on innovation competition, as manifested by the issuance of patent invalidation claims. The effect is more pronounced in industries with greater innovation intensity and competitive pressure, and robust to various identification attempts. Moreover, we document underlying mechanisms that institutional cross-ownership networks facilitate informational leakage and lead to innovation herding (and thus competition) between portfolio firms. Our evidence further suggests that patent invalidation is followed by enhanced portfolio returns of cross-owners and higher innovation output of within-network firms, which appears to rationalize the cross-owners' behavior of increasing the within-network exposure of portfolio firms' patents. Our paper sheds new light on the pro-competitive effect of overlapping ownership in terms of innovation competition.

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1 Introduction

Cross-ownership, or shared ownership, has become increasingly prevalent over the past decades (He and Huang, 2017; Antón et al. , 2025). Concerns have grown that common shareholders may induce collusive behavior that maximizes the total value of their portfolios (Azar et al., 2018), potentially harming the values of the portfolio companies (Posner et al., 2016; Ederer and Pellegrino, 2022). On the other hand, recent studies document a pro-competitive effect of cross-ownership at the product level, in the spirit that cross-ownership may facilitate knowledge spillovers, thereby accelerating product iteration in the market (Aslan, 2024; Antón et al., 2024; Kini et al., 2024). Compared to production innovation, patent-based innovation competition reflects a more pronounced winner-takes-all dynamic, and has become a focal point in the study of market competition (Galasso and Schankerman, 2015; Chattergoon and Kerr, 2022; Gaessler et al., 2024). By far, the advantages and disadvantages of cross-ownership in innovation competition are still not fully understood by existing studies, largely due to the lack of consensus in the academic literature on its competitive effects and underlying mechanisms (Koch et al., 2021; Lewellen and Lowry, 2021; Kini et al., 2024).

This study investigates the effect of cross-ownership on innovation competition. To illustrate why cross-ownership could be relevant to competition in technological innovation, we begin with a motivating case hinting that the shared ownership of Hillhouse capital on both Zhuhai Gree and Guangdong Midea is likely to lead to the patent invalidation claim from Gree against Midea's patent named "Axial Flow Fan Blade".[1] Figure 1 presents the event timeline of this case. First, Hillhouse Capital initiated a site visit to Midea on August 31, 2017, during which Midea discloses a new project titled and the "Axial Flow Fan Blade" patent is identified as a core component of the project (see Figure A3 and Figure A4 for details); seventeen days later, on September 17, 2017, Hillhouse team visited Gree. Then, on June 24, 2018, Gree held a general meeting of shareholders and initiated an invalidation claim against Midea's "Axial Flow Fan Blade" patent on August 3, 2018. During the litigation process, in the third quarter of 2019, Hillhouse Capital increased its shareholding on Gree by 15%, while sold its share in Midea to the level that the firm was no longer on the list of Midea's top ten shareholders. Finally, on June 3, 2021, CNIPA announced the success of Gree's patent invalidation claim. While there is no

[1] This case comes from the top 10 patent invalidation cases disclosed by China National Intellectual Property Administration (CNIPA) in 2021. We present detailed information on this case in Appendix A.

direct evidence linking Hillhouse Capital with Gree's decision to initiate the patent invalidation, the timeline of thie event suggests that Hillhouse, as a cross-owner, might have both acquired and transferred information about innovation across portfolio companies.

[Insert Figure 1 about here]

Motivated by the above case, we develop our main hypotheses. In particular, we posit that cross-ownership could intensify innovation competition by promoting information flows within the ownership network. Specifically, existing literature finds that institutional investors usually establish frequent communication channels with their portfolio firms, such as site visits, conference calls, and other investor engagement activities, to get better access to or exchange innovation-related information (e.g., Kang et al., 2018). The institutional cross-owners could thereby give rise to cross-firm knowledge spillovers within the ownership network (González-Uribe, 2020; Antón et al., 2024), which in turn may promote more active innovation competition among cross-held firms. Moreover, the "secret leakage" by institutional investors may be out of the maximization of the overall returns of their portfolio holdings.

To measure innovation competition between firms, we leverage firm-level patent invalidation claims in China as the manifestation.[2] Patent invalidation is one of the most effective proxies for measuring innovation competition and has been widely used in the existing literature (Galasso and Schankerman, 2015, 2018; Gaessler et al., 2024). We manually collect and check patent invalidation cases from the China National Intellectual Property Administration (CNIPA), yielding an initial sample of 52,343 cases. After removing cases with missing information or with non-listed firms as petitioners, we are left with 2,316 valid cases. We aggregate all subsidiary cases to the parent firms. At the firm level, we obtain data corporate ownership, as well as firm financials, for all the listed firms from CSMAR. Following He and Huang (2017), we use three measures on cross-ownership: (1) the proportion of unique institutional investors (out of the top ten shareholders) holding shares in both the focal firm and

[2] We use China as a laboratory for three reasons. First, as an emerging economy, China's capital market exhibits a significantly higher degree of ownership concentration than developed markets. Second, legal defense costs are significantly higher in China, which may lead firms to be more cautious when making innovation-related decisions. For example, we collect final decisions on patent invalidation petitions from the CNIPA and the USPTO for 2020–2022. In 2022, the CNIPA reports that 27.9% of invention patents, 41.4% of utility model patents, and 53.8% of design patents are fully invalidated, compared to just 12% of challenged patents invalidated by the USPTO in the same year. These figures suggest that the invalidation success rate in China is more than twice that in the United States. Moreover, the invalidation rates in 2020 and 2021 remain similar to those in 2022. This evidence indicates that patent invalidation claims in China are unlikely to be random, reducing concerns about sample noise. (CNIPA: https://www.cnipa.gov.cn/col/col94/index.html; USPTO: https://www.uspto.gov/patents/ptab/statistics) Third, the exogenous shocks in China's capital markets help establish causal identification. The "2015 stock market crash" and the subsequent government-led intervention significantly altered firms' institutional ownership structures. We exploit this quasi-natural experiment to evaluate how changes in institutional cross-ownership affect a firm's decision to initiate patent invalidation claims. Section 4 presents our empirical strategy in detail and analyzes the intervention's effects on ownership structures and firm behavior.

its peers; (2) log of one plus the number of unique institutional investors jointly holding shares in the focal firm and its peer firms; and (3) the log of one plus the number of peer firms that cross-holding institutional investors with the focal firm. Then, we merge the cross-ownership and firm-level financial data with the patent invalidation data using standardized firm names; we manually check for match accuracy and construct the sample. After dropping observations with missing data, we are left with 4,828 unique firms, among which 680 have initiated at least one patent invalidation claim. Our sample is largely representative in terms of both institutional cross-ownership and patent invalidation in China.[3]

We begin with an empirical model to examine how institutional cross-ownership affects innovation competition using a sample of Chinese listed firms from 2010 through 2022, where the focal firms are the initiators of patent invalidation claims. The main results show that one extra co-shareholder (equivalent to 10% increase in the proportion of co-shareholders among the firm's top ten shareholders) is associated with the number of patent invalidation claims filed by the firm by about 0.23%, which is statistically significant at the 1% level. Our findings continue to hold in a variety of robustness checks with alternative matching procedures, alternative model specifications and alternative variable definitions.

While the baseline results appear to suggest a positive relationship between institutional cross-ownership and innovation competition, the causal interpretation is subject to potential endogeneity concerns. For example, although we control for a range of firm-level variables that may affect a firm's participation in innovation competition, the observed relationship between institutional cross-ownership and patent invalidation could still be driven by unobserved factors that simultaneously affect both behaviors. In addition, firms that frequently initiate patent invalidation claims may be perceived by institutional investors as having strong innovation potential, which could in turn attract institutional investors to form cross-ownership.

To address these endogeneity concerns, we take a step further and conduct two additional identification attempts. First, following He and Huang (2017), we employ an instrumental variable (IV) approach, using as an instrument the number of absorption mergers initiated by a firm's top ten shareholders. On the one hand, when a shareholder initiates an absorption merger, it exogenously (for the focal firm) acquires an equity stake in the merged firm, thereby increasing its shareholding in a peer firm and creating institutional cross-

[3] Figure B1 illustrates the rise of cross-ownership in China from 2010 to 2022, showing both the proportion of listed firms with cross-holders and the median ownership share held by institutional investors.

ownership (He and Huang, 2017). This satisfies the relevance condition. On the other hand, shareholders make absorption and merger decisions based on their own strategic objectives, which are independent of the focal firm's decision-making behavior (Freeman, 2023). This satisfies the exclusion restriction. Consequently, this instrumental variable should not directly affect a firm's decision to initiate patent invalidation. The IV regression results continue to support a significant positive relationship between institutional cross-ownership and firms' initiation of patent invalidation, suggesting that the effect is likely running from cross-ownership to innovation competition.

Second, we exploit China's unique context by using the so-called "national team bailout" during the "2015 stock market crash" as an additional identification strategy. In 2015, China's stock market experienced a sharp crash triggered by irrational price surges followed by abrupt policy tightening, which created systemic risks and prompted the "national team" to intervene on a large scale to stabilize the market. This intervention led to a substantial increase in institutional cross-ownership and provided an ideal quasi-experimental setting for causal identification. To begin with, as noted above, the market crash and subsequent intervention were driven by market irrationality and abrupt policy tightening, factors that were unrelated to firms' innovation strategies. Moreover, the urgency of the crisis left the "national team" with little time for deliberate stock selection. Dang et al. (2024) suggests that the "national team" primarily followed a simple buy-low-sell-high principle rather than targeting firms with high innovation potential. This setting creates plausibly exogenous variation in institutional cross-ownership across firms. We then construct a difference-in-differences (DiD) test based on this event. Specifically, we define a binary treatment indicator $Treat_i$, which equals 1 if firm i was held by state-owned financial institutions (the "national team") during 2015–2018 yet was not during 2012–2014, and 0 otherwise. Second, we define a binary time indicator $Post_t$, which equals 1 for fiscal years from 2015 onward, representing the post-intervention period. We use the interaction term DiD_{it}, which equals to $Treat_i \times Post_t$, to capture the treatment effect of this event. We find that the "national team bailout" significantly increases the number of patent invalidation claims filed by firms in the treatment group. Taken together, these results suggest that the effect running from institutional cross-ownership to innovation competition is likely causal.

To better understand how institutional cross-ownership affects firms' innovation competition, we examine the cross-sectional heterogeneity in this effect. Specifically, the baseline effect is more pronounced when firms face stronger competitive pressure (e.g., lower industry concentration or non-regulated sectors) or greater innovation pressure (e.g., high-tech

or technology-intensive industries). Overall, these tests further reinforce our causal interpretation, as it is unlikely that an omitted variable would systematically bias the results across all these dimensions.

Next, we explore a plausible economic channel through which institutional cross-ownership promotes firms' participation in innovation competition: institutional investors acquire and transfer innovation-related knowledge within the ownership network, internalizing knowledge spillovers. In this process, the ownership network functions as an information network, fostering greater knowledge flow and technological proximity within the network, which increases the likelihood that firms engage in innovation competition. To test this channel, we first examine whether institutional cross-ownership positively affects knowledge flow and technological proximity between focal firms and other firms in the network. Specifically, we find that institutional cross-ownership significantly increases knowledge flow and technological proximity, and this effect is more pronounced for firms with lower ex-ante levels of both. To ensure that our results are not driven by governance effects, we measure governance using the appointment of directors, supervisors, and executives by institutional shareholders. We find that stronger governance tends to reduce the number of patent invalidation claims, suggesting that the positive baseline effect is not due to governance. Furthermore, we test the motivation for institutional investors to acquire and transfer information and find that site visits within the ownership network significantly improve overall portfolio performance, consistent with classic industrial organization theory (Azar et al., 2018). Moreover, we find that more active information acquisition—through frequent on-site visits, innovation-intensive reports, or executive participation—reinforces the positive effect on patent invalidation and the underlying channel variables.

Finally, we systematically examine how patent invalidation affects market reactions, institutional shareholders with cross-ownership, peer networks, and firms' own innovation and operating performance. First, firms that successfully invalidate a competitor's patents experience a clear positive market response, while firms whose own patents are successfully invalidated face negative market reactions. Second, we find that patent invalidation occurring among cross-held firms raises the market value and Tobin's Q of institutional shareholders' portfolios in the following period. This evidence suggests that portfolio arbitrage can be a relevant motivation for institutional cross-ownership to encourage patent invalidation. Third, we analyze how initiating or receiving a patent invalidation affects the focal firm's own innovation activities and financial outcomes. The results imply that initiating invalidation can strengthen a firm's future

R&D and operating performance, whereas being targeted does not significantly alter outcomes. Lastly, we assess whether a focal firm's involvement in patent invalidation affects its peer network, defined as firms held by the same institutional investors. When a focal firm initiates patent invalidation, average R&D expenditure and innovation quality within the peer network increase in the following period, although average innovation conversion efficiency declines. In contrast, receiving invalidation does not produce any detectable spillover on peers' innovation or performance. This pattern is consistent with He and Huang (2017), which provides comparable evidence of the welfare effects of cross-ownership in product markets.

Our paper contributes to two strands of literature. First, we directly contribute to the recent literature on the competitive effects of ownership network. This literature casts long debate on the anti-competitive effect of cross-ownership, that is, firms with common ownership are more likely to coordinate, which improve the overall welfare of the network. On one hand, the anti-competitive effect of cross-ownership is substantially supported by empirical studies in various fields, such as product market competition (He and Huang, 2017; Kini et al., 2024), genetic drug (Schmalz and Xie, 2022), airlines (Azar et al., 2018), and banking (Azar et al., 2022), etc. Notwithstanding this stream of literature, however, other studies provide rather mixed evidence – either documenting pro-competition effect (He et al., 2019; He et al., 2020) or even questioning the existence of a robust relation between cross-ownership and competition (Koch et al., 2021; Lewellen and Lowry, 2021; Dennis et al., 2022; Antón et al. , 2023). This debate is heated and largely valuable since it is closely relevant to the impactful antitrust policy (López and Vives, 2019). We contribute to this literature by focusing on an important and more nuanced category of competition on technological innovation. Unlike product market competition that allows the coexistence of competing firms' seizing market shares in a long period, corporate innovation is usually materialized in the form of patents, of which the protection is exclusive; as such, innovation competition is usually a one-time game where the winner takes all, instead of a continuous one, and is often largely affected by information asymmetry. Moreover, the setting of patenting system provides richness of direct and micro-level observation on firms' exact action of competition, that is, patent invalidation claims. By investigating the role of ownership overlaps in the world of technological innovation, we document a procompetitive effect of cross-ownership, where the information spillovers induced by overlapping owners give rise to R&D overlaps and thereby intensify innovation competition. Our study might help reconcile the debate by suggesting that the net competitional effect of

overlapping ownership could be subject to both the role of information spillover and the maximization of the cross-owners.

Second, our study contributes to the literature on the role of institutional investor in shaping corporate behavior (Anton et al., 2022; Freeman, 2023; He et al., 2019) and innovation (Aghion et al., 2013). The existing studies mainly investigate on firms' routine investments and activities (e.g., mergers and acquisitions, see Matvos and Ostrovsky (2008) and Harford et al. (2011), among others). Several studies extend the focus to technological innovation and find that various institutional investors significantly enhance corporate innovation via governance channels (Luong et al., 2017; Zhang et al., 2023). On top of the existing research, we document a novel channel where institutional investors serve as an informational intermediary and consequently lead to intensified innovation competition, due to the maximization of their own investment portfolio returns. We investigate how cross-ownership affects competition on intellectual properties and highlight the role of the interaction between institutional investors and the portfolio companies in shaping innovation competition. Furthermore, we assess the impact of such attacks on the overall portfolio returns of institutional investors and on the returns of the involved firms. Our study provides new insights into how cross-ownership shapes corporate decision-making and performance.

Our paper closely related with, but clearly distinct from, two papers. First, Geng et al. (2015) find that ownership overlap reduces patent litigation risks and thereby enhances innovation and its quality. Although their research also documents a positive effect of cross-ownership on innovation, we document an exactly opposite channel that the information spillovers induced by cross-owners intensify innovation competition, allowing the issuers of invalidation claims to better exploit the surplus from innovation, and thereby increasing follow-on R&D investments and outputs. Second, focusing on product iteration, Aslan (2024) shows a similar pro-competition effect that ownership overlaps speed up product iteration. Unlike this relatively short-term focus, technological innovation is much more long-term and riskier. Our study sheds new light on the role of cross-owners in long-scope competition, yet echoes Aslan (2024) by documenting a similar effect of declined production/patent diversity.

2 Data, sample, and variable construction

2.1 Data

We detect inter-firm innovation competition based on patent invalidation claims as manifestation. To this end, we manually collect all patent invalidation cases from the China National Intellectual Property Administration (CNIPA) between 2010 and 2022, which constructs an initial sample of 52,343 cases.[4] We then manually check and standardize the names of the petitioners and respondents for each case.[5] We remove 2,313 cases due to duplication, data errors, or missing values (such as patent details, invalidation dates, or information on petitioners or respondents) and retain 50,030 valid cases. We further remove cases in which the petitioners or respondents are individuals or non-listed firms and ultimately obtain 2,136 patent invalidation cases involving listed firms. Based on the initial patent invalidation sample, we aggregate subsidiary cases at the parent-firm level to construct the final patent invalidation measure. Figure 2 shows the annual trend in the number of patent invalidation cases initiated by all firms and by listed firms from 2010 to 2022. Both the number of cases initiated by listed firms and the total number increase over time, indicating that the sample is broadly representative.

We measure institutional cross-shareholdings using data on the top ten shareholders disclosed in the CSMAR database. To capture cross-shareholdings among peer firms, we classify each listed firm into an industry based on the 2012 industry classification standard issued by the China Securities Regulatory Commission (CSRC). For manufacturing firms, we use the two-digit industry code; for all other industries, we use the broad industry code. In addition, we obtain firm-level characteristics from CSMAR. We merge the two datasets using standardized firm names and fiscal years. In line with common practice, we then exclude observations with missing values.[6] Our sample consists of 4,828 unique firms listed on the Shanghai and Shenzhen Stock Exchanges from 2010 through 2022. To mitigate the effect of outliers, we winsorize all continuous variables at the 1% and 99% levels.

[4] We use 2010 as the starting year of our sample for two main reasons. First, starting in 2010 avoids distortions caused by the global financial crisis. Second, in October 2009, the China National Intellectual Property Administration (CNIPA) announced that the third revision of the Patent Law would take effect, expanding the scope of patent invalidation and increasing compensation. To avoid noise from this legal change, we start our sample in 2010.

[5] The firm names are processed as follows: (1) We retrieve the historical names of all listed firms and their subsidiaries in batches from the Qixinbao platform and incorporate them into the listed firm dataset. (2) For both the patent invalidation dataset and the listed firm dataset, we convert all firm names to UTF-8 encoding, translate Arabic and Chinese formal numerals into simplified Chinese numerals, extract all Chinese characters, and standardize the results to form the "full firm name." (3) We remove the following terms from each full firm name to construct the "abbreviated firm name": "shares", "limited", "responsibility", "firm", "factory", "province", "city", "county", "Hui Autonomous Region", "Zhuang Autonomous Region", "Uygur Autonomous Region", "autonomous region", and "district." (4) We apply a fuzzy matching algorithm to compare abbreviated firm names, retaining records with a matching score of 1 (i.e., exact matches) and manually verifying those with matching scores between 0.5 and 1.

[6] Specifically, we process the sample as follows: (1) excluding financial firms, PT firms (i.e., those that have been delisted), and ST/*ST firms (i.e., those that report negative net profits for two or more consecutive years); (2) removing observations with missing values for key control variables required in the analysis.

2.2 Patent invalidation

The dependent variable in this paper is *Patent invalidation*, which we measure as the number of patent invalidation claims initiated by each firm in a given year, following Galasso and Schankerman (2015) , Galasso and Schankerman (2018), and Gaessler et al. (2024). In our sample of 4,828 listed firms, 680 firms have initiated at least one patent invalidation claim, raising concerns about a highly skewed distribution of the innovation competition measure. To address this issue, following Tian et al. (2024), we use the natural logarithm of one plus the number of patent invalidation claims. In robustness checks, we also test regressions using the raw count without taking the logarithm.

2.3 Cross-ownership

The key explanatory variable in this paper is cross-ownership. Following He and Huang (2017), we measure cross-ownership in three ways. First, we calculate the proportion of unique institutional investors that simultaneously hold shares in both the focal firm and its peers among the top ten shareholders (represented by white circles in Figure 3), denoted as *Prop Cross*.[7] (2) We count the number of unique institutional investors that jointly hold shares in the focal firm and its peer firms, add one, and take the natural logarithm, denoted as *Num Cross*; (3) We count the number of peer firms that share cross-holding institutional investors with the focal firm (represented by dark gray rectangles in Figure 3), add one, and take the natural logarithm, denoted as *Num Connected*. For each measure, we first calculate quarterly values and then average them to obtain the annual institutional cross-ownership variables.

Figure 3 provides an illustrative example of the peer network formed by institutional cross-ownership within an industry. In Figure 3, the dashed lines on the left represent the ownership network created through institutional cross-shareholdings. Within this network, white circles denote institutional investors that hold shares in multiple firms within the same industry. The black square represents the focal firm, while gray squares indicate other peer firms inside the ownership network. White squares outside the dashed lines represent peer firms within the same industry that are not connected through institutional cross-ownership.

2.4 Control variables and summary statistic

[7] We focus on the network effect generated by institutional cross-ownership; therefore, this measure captures the proportion of overlapping shareholders among the top ten shareholders rather than their shareholding ratios. For example, if three out of ten top shareholders are overlapping investors, then prop cross equals 0.3.

We control for a set of firm characteristics that may affect a firm's decision to initiate patent invalidation claims. Following He and Huang (2017), we control for life-cycle-related characteristics. Firms that are more mature, defined by larger size (*Assets*), slower sales growth (*Sales growth*), and older age (*Firm age*), typically have greater resources and capacity to initiate patent invalidation claims and expand their market presence. Moreover, to isolate the effect of cross-ownership from overall ownership or institutional holdings, we control for total institutional ownership (*Institutional investors shareholding*) and the ownership concentration of the top ten shareholders (*Top10 ownership concentration*). We also control for cash flow (*Cash/Assets*), since when control rights exceed cash flow rights, controlling shareholders may engage in riskier, more aggressive activities, including patent invalidation claims (Claessens et al., 2002; Lyandres and Palazzo, 2016; Ma and Shleifer, 2025). We further include leverage (*Leverage*) to capture the firm's financial risk and debt burden, which may constrain its willingness to compete through innovation (O'brien, 2003). Furthermore, we control for profitability using return on assets (*ROA*), calculated as net income divided by total assets, since more profitable firms may have stronger incentives and resources to compete through innovation (Kini et al., 2024). We also control for patent grants (*Grant patent*), since investors can infer innovation activities from granted patents, which may affect investor behavior in capital markets and foster the formation of cross-ownership ties (Kogan et al., 2017; Zheng, 2025). Firms with more granted patents are also more likely to be innovation-oriented and therefore more likely to initiate patent invalidation claims. In addition, audit fees (*Audit fee*) reflect firm-level risk factors and aggressive strategic goals (Bentley et al., 2013), potentially increasing the likelihood of innovation competition. Finally, prior research shows that female executives differ from male executives in corporate decision-making, as women tend to be less overconfident in their expectations (Barber and Odean, 2001; Huang and Kisgen, 2013; Croson and Gneezy, 2009; Griffin et al., 2021). Therefore, the proportion of female executives (*Female executives*) may affect a firm's decision to participate in innovation competition. We present detailed definitions of all control variables in Table B1.

Table 1 presents descriptive statistics for our final sample, which includes 34,825 firm-year observations. The medians of *Prop Cross*, *Num Cross*, and *Num Connected* are 0.200, 1.099, and 4.025, respectively, while their means are 0.252, 1.102, and 3.730. This pattern indicates that institutional cross-ownership is now fairly common in the Chinese capital market. Among the 4,828 listed firms in the sample, 680 initiated at least one patent invalidation claim between 2010 and 2022, representing 14.1% of the total. The remainder of Table 1 reports

descriptive statistics for the control variables, which are generally consistent with the findings in the existing literature.

3 Results

3.1 Baseline model

We base our analysis on the regression model at the firm-year level with two-way fixed effects:

$$Patent\ invalidation_{i,t} = \alpha + \beta \cdot Cross\text{-}ownership_{i,t} + \boldsymbol{\gamma}'\boldsymbol{X_{i,t}} + Firm_i + Year_t + \varepsilon_{i,t} \quad (1)$$

where $Patent\ invalidation_{i,t}$ presents the logarithm of the number of patent invalidation claims initiated by firm i in year t.[8] The key explanatory variable is $Cross\text{-}ownership_{i,t}$, which represents the three cross-ownership measures, i.e., *Prop Cross*, *Num Cross*, and *Num Connected.* The coefficient of interest β captures the effect of institutional cross-ownership on a firm's engagement in innovation competition. $\boldsymbol{X_{i,t}}$ refers to the set of control variables we introduce in Section 2.4. We include firm fixed effects and year fixed effects in the regressions to account for the effect of time-invariant firm characteristics and aggregate time trends, respectively. Standard errors are clustered at the firm level to address within-firm correlation.

We present the baseline regression results in Table 2. In columns (1)-(3), we regress a firm's engagement in innovation competition only on the fixed effects and key variable of interest: *Prop Cross*, *Num Cross*, and *Num Connected*. The coefficient estimates are positive and statistically significant at the 1% level, indicating that periods of institutional cross-ownership exhibit higher levels of innovation competition even before controlling for additional firm-level characteristics. Columns (4)-(6) present the baseline results with the full set of control variables. The coefficient estimates on *Prop Cross*, *Num Cross*, and *Num Connected* are positive and significant at the 1% level across all specifications, suggesting that greater institutional cross-ownership leads firms to initiate more patent invalidation claims. Moreover, the positive β estimator is not only statistically significant but also economically sizable. Specifically, in Column (4), the coefficient on *Prop Cross* (0.023) indicates that a 10% increase in the proportion of co-shareholders among the top ten shareholders (equivalent to adding one more co-shareholder) increases the number of claims by about 0.23%. Columns (5) and (6) present

[8] Our results remain robust if we measure the dependent variable in year $t + 1$. We present this result in Section 3.2.

consistent results: the logarithmic forms of *Num Cross* and *Num connected* are also positively associated with the number of claims initiated (0.006 and 0.001, respectively).

3.2 Robustness Check

We perform a number of additional tests to ensure that our baseline results are robust. First, one potential concern is that cross-held and non-cross-held firms are not randomly assigned. This non-random assignment could make our results vulnerable to selection bias if systematic differences between the two groups affect innovation competition. To address this concern, we match cross-held and non-cross-held firms and use the matched sample throughout our regression analyses. Specifically, we construct a binary variable, *Cross dummy*, which equals 1 if a firm is cross-held and 0 otherwise. Firms with *Cross dummy* = 1 constitute the treatment group, while firms with *Cross dummy* = 0 serve as the control group. On the one hand, following Chang et al.(2019), we apply one-to-one nearest-neighbor propensity score matching without replacement. On the other hand, we implement entropy balancing as in Tian et al. (2024). To further alleviate concerns that the determinants of innovation competition might also affect the likelihood of cross-ownership formation, we include all relevant control variables in $\boldsymbol{X_{i,t}}$. Panel A of Table 3 presents the diagnostic test results evaluating the effectiveness of our matching procedures. Columns (1)-(3) report the regression results for the sample matched by propensity score matching. The coefficients on cross-ownership remain positive and statistically significant at the 10% level (0.022, 0.006, and 0.001, respectively). Columns (4)–(6) show the results for the entropy-balanced sample, where the coefficients on cross-ownership are positive and statistically significant at the 5% or 10% levels (0.043, 0.012, and 0.003, respectively).[9]

Second, another concern is omitted variable bias. Although we control for a standard set of firm-level covariates in Eq. (1) that may affect firms' innovation activities, the observed relationship between cross-ownership and innovation competition could still be spurious if unobserved factors simultaneously affect both a firm's innovation behavior and the likelihood of forming cross-ownership ties. To mitigate this concern, we augment the baseline model by replacing simple year fixed effects with two pairs of more granular fixed effects: province-by-year and industry-by-year fixed effects. Specifically, the province-by-year fixed effects account for unobserved, time-varying province-level factors, such as differences in local political

[9] Table B3 reports the balance test for the propensity score matching, showing that none of the firm characteristics significantly predicts cross-ownership formation, confirming the effectiveness of our matching procedure. Table B4 presents the balance test for the entropy balancing matching, indicating that the coefficients on all covariates become insignificant in the post-matched (weighted) sample, confirming the effectiveness of our matching procedure.

conditions or regional economic cycles (Amore et al., 2013; Chang et al., 2019). We determine each firm's province based on the location of its headquarters, which typically reflects where its main operations are located. The industry-by-year fixed effects control for potential variation in innovation behavior and cross-ownership patterns across industries over time. Panel B of Table 3 shows that the coefficients on *Prop Cross*, *Num Cross*, and *Num Connected* remain positive and statistically significant at the 1% level, indicating that our main results are robust to including both province-by-year and industry-by-year fixed effects.

Moreover, we conduct a series of additional robustness checks using alternative model specifications and variable definitions. None of these adjustments materially changes our main results: (1) to address the fact that the number of patent invalidation claims is a non-negative, discrete count variable, we re-estimate our baseline regressions using negative binomial models instead of OLS. Since the dependent variable contains a substantial number of zeros, we further employ zero-inflated negative binomial regressions to account for excess zeros.[10] (2) following Brunnermeier et al. (2020), we account for potential correlation in the panel structure by clustering standard errors in two dimensions: by firm and year or by industry and year. (3) given that major public health events can affect firms' operations and innovation activities (Cong et al., 2024), we exclude all observations during the COVID-19 period (2020-2022) to rule out the impact of this exogenous shock. (4) To test for possible lagged effects, we use patent invalidation measures in period $t + 1$ (rather than t) as the dependent variables to account for the fact that institutional cross-ownership may take more than one year to affect innovation competition. In addition, we re-estimate the regressions using the actual counts of patent invalidation claims instead of the natural logarithm of the count plus one. (5) We refine the classification of the key independent variables. In the baseline models, manufacturing industries are classified using the CSRC's 2-digital level codes, while other industries use category level codes. Here, we apply 3-digital level industry codes to all sectors to provide a more detailed classification.

3.3 Further identification attempts

While we show a robust positive relationship between institutional cross-ownership and firms' initiation of patent invalidation, its causal interpretation remains hypothetical. Beyond the selection issue and omitted variable bias discussed in Section 3.2, a plausible endogeneity issue

[10] Because the mean and median of the patent invalidation variable differ significantly, we use negative binomial rather than Poisson regressions. Due to the non-concavity issue associated with fixed effects in count models, we include industry and year fixed effects instead of firm fixed effects in these regressions.

is reverse causality: firms that frequently initiate patent invalidation may attract cross-holding institutional investors, thereby reinforcing cross-ownership links. To further address endogeneity concerns, we adopt two additional identification strategies. First, we use an instrumental variables approach to account for residual endogeneity. Second, we exploit a quasi-natural experiment to further mitigate potential bias.

3.3.1 IV estimation

To further alleviate endogeneity concerns, we employ an instrumental variable approach similar to He and Huang (2017). Specifically, we employ the number of absorption mergers initiated by the top ten shareholders of the focal firm (*Merge*) as an instrumental variable. This variable, *Merge*, serves as a valid instrument for two main reasons. First, when a shareholder initiates an absorption merger, it automatically obtains an equity stake in the merged firm, thereby increasing its ownership in the target firm. This process leads to greater institutional cross-ownership, as shown by He and Huang (2017), suggesting that *Merge* is positively correlated with institutional cross-ownership. Second, the decision to initiate an absorption merger is primarily driven by the strategic objectives of shareholders and is independent of managerial decisions within the firms they invest in (Freeman, 2023). Therefore, our instrumental variable is likely to be exogenous and reasonably satisfies the exclusion restriction.

Table 4 presents the instrumental variable regression results. In the first stage, *Cross-ownership* is regressed on the instrumental variable, along with all the controls and fixed effects in our baseline regression. The coefficient estimates on *Merge*, the instrumental variable, are all statistically significant at the 1% level and economically sizable (0.007, 0.021, 0.049). Additionally, the F statistics of the weak instrument test are significantly larger than 10, and the p-values of the under-identification test are less than 0.01. Taken together, the relevance condition of the instrumental variable approach is satisfied. In the second stage, we use the instrumented cross-ownership variable in the regressions estimating Eq. (1) and observe that the coefficient estimates on the instrumented *Prop Cross*, *Num Cross*, and *Num Connected* are all positive and significant, consistent with our main results.

3.3.2 Quasi-natural experiment: 2015 stock market crash and "national team" bailout

We construct a quasi-natural experiment using the 2015 Chinese stock market crash and the subsequent government-led intervention, widely known as the "national team's bailout."[11]

[11] In early 2015, China's stock market experienced a rapid rally driven by the expansion of both regulated margin trading and unregulated leveraged financing. Between January and May 2015, the SSE 50 and CSI 300 indices rose by 17.4% and 32.9%,

Third-quarter financial reports for 2015 show that state-owned financial institutions, collectively known as the "national team" ("NT"), appeared among the top ten shareholders of 1,401 listed firms in China. These holdings covered more than half of all listed firms, providing ideal conditions for identification. First, the large-scale equity purchases during the intervention substantially increased institutional cross-ownership among listed firms. Second, there is evidence that the "national team's bailout" was plausibly exogenous: the crash and subsequent intervention were triggered by irrational stock price surges and abrupt policy tightening—factors exogenous to firms' innovation strategies. Additionally, the "national team's" stock selection appears to have been largely random. Its four main branches held shares in 2,412 firms by the third quarter of 2015, and the urgency of the crisis left little room for deliberate targeting. Dang et al.(2024) suggests that the primary motivation behind the "national team's" massive stock purchases was to stabilize the financial market, and its portfolio selection followed a straightforward "buy-low-sell-high" strategy rather than targeting firms with high innovation potential.[12]

To evaluate the effect of the "national team's bailout" on firms' patent invalidation activities, we estimate the following difference-in-differences (DiD) regression model:

$$Patent\ invalidation_{i,t} = \alpha + \beta_1 DiD_{i,t} + \beta_2 Treat_i + \beta_3 Post_t + \boldsymbol{\gamma' X_{i,t}} + Firm_i + Year_t + \varepsilon_{i,t} \quad (2)$$

where $Treat_i$ is a binary indicator equal to one if firm i was held by state-owned financial institutions (the "national team") and constructed cross-ownership during 2015-2018 and was not held during 2012-2014; such firms constitute the treatment group. Firms that were never held by common institutional investors between 2012 and 2018 serve as the control group ($Treat_i = 0$). $Post_t$ is a time indicator equal to one for fiscal years from 2015 onward, representing the post-intervention period. The coefficient on the interaction term $DiD_{i,t}$ (β_1) captures the

respectively. Concerned about mounting risks from excessive leverage and informal securities lending, the CSRC issued a directive on June 12, 2015, prohibiting securities firms from engaging in such activities. In response, major indices declined by 13% during the week of June 15-19, marking the largest weekly loss since the 2008 global financial crisis. This sharp correction triggered widespread investor panic and intensified a month-long selloff that erased roughly 40% of the market's total capitalization. To contain the downturn, the government launched a series of stabilization policies, including suspending IPOs, restricting index futures trading, and directing state-owned financial institutions to purchase equities. Among these interventions, the large-scale equity acquisitions by these institutions became known as the "national team".

[12] Following Dang et al. (2024), we collect the full list of "national teams" institutions. Specifically, the "national team" consists of four financial institutions: (1) China Securities Finance Corporation (CSF), which played a central role by investing in 1,017 firms in 2015Q3, representing about 70% of the NT's total portfolio; (2) CSF Mutual Funds, which invested RMB 200 billion in five mutual funds in July 2015, allocating RMB 94.1 billion to 253 stocks; (3) Central Huijin Investment (HJ), which invested in 1,122 stocks, accounting for about 20% of the NT's portfolio; and (4) investment platforms funded by the State Administration of Foreign Exchange (SAFE), which invested in about 20 stocks valued at RMB 50 billion. We provide detailed information in Appendix B2.

treatment effect and is expected to be positive and statistically significant. Other control variables and model specifications follow the baseline regression unless otherwise specified.

Table 5 reports the DiD estimation results. The coefficient estimate for the key interaction term *DiD* is positive and statistically significant at the 1% level, indicating that firms cross-held due to the "national team's bailout" experienced a greater increase in the number of patent invalidation claims initiated than comparable firms that were not cross-held during this period. To test the parallel trends assumption underlying the DiD design, we conduct an event study-style pre-trend test. The results, shown in Figure 4, support the validity of our identification strategy.

To summarize, while endogeneity is a perennial issue that no empirical test can entirely rule out, we conduct a battery of tests to alleviate the endogeneity concerns and find that our main conclusion holds. Although each test can be subject to criticism, the balance of evidence points to a causal relation running from institutional cross-ownership to firms' initiation of patent invalidation.

4 Further analysis

Our baseline results suggest a positive and likely causal relationship between institutional cross-ownership and firms' engagement in innovation competition. In this section, we conduct additional tests to examine the channels through which institutional cross-ownership affects firms' decisions to initiate patent invalidation claims. If the knowledge spillover mechanism plays a significant role in this relationship, the effect of institutional cross-ownership should be stronger in industries that face higher levels of innovation or competitive pressure, where firms rely more heavily on external knowledge to support their invalidation strategies. In addition, once an institutional cross-ownership network is established and cross-holding investors actively share information within this network, firms should experience greater knowledge flows and higher technological proximity. We also implement various tests to examine how cross-holding institutional investors collect and disseminate information, particularly through site visits within the ownership network. These analyses clarify the incentives and roles of institutional investors in facilitating information transfer. Finally, we evaluate the economic consequences of the link between institutional cross-ownership and patent invalidation at the investor, firm, and network levels.

4.1 Cross-sectional heterogeneity in result

To investigate how our results vary across firms, we use different industry-level criteria to partition the sample into several groups. We report the results in Table 6, where the regressions include the same control variables as in the baseline specification. To test for differences in coefficients across groups, we report Inter-group difference p-value based on 1,000 bootstrap permutation tests.

We first examine how competitive pressures at the industry level affect our results. In highly competitive environments, firms often engage in a "race to the bottom", to gain dominance in the "patent competition", which leads to a proliferation of low-quality patents (Hill and Stein, 2025). Due to the redundancy of patent information, patent invalidation in such industries relies more heavily on access to innovation-related information and knowledge. Therefore, if institutional cross-ownership facilitates information flows and knowledge spillovers, its effect on patent invalidation should be more pronounced in industries facing greater competitive pressure. We use industry-level market concentration data from the CSMAR database, which defines concentration as the share of total industry revenue accounted for by the eight largest firms. We split the sample at the median concentration level, classifying industries with higher concentration as low-competition and those with lower concentration as high-competition. As shown in Panel A of Table 6, the positive effect of institutional cross-ownership on patent invalidation is more pronounced in highly competitive industries. Moreover, we examine whether the effect varies with the degree of administrative monopoly. Industries with significant regulatory constraints are classified as regulated, while the rest are categorized as competitive. The results presented in Panel B of Table 6 show that the positive relationship between institutional cross-ownership and patent invalidation is stronger in competitive industries than in regulated ones.

Second, we examine how industry-level innovation pressures affect our results. In industries with higher levels of innovation, firms tend to apply patents more frequently, which also increases the number of firms initiating patent invalidation claims against each other. Similarly, we hypothesize that the positive relationship between institutional cross-ownership and patent invalidation is more pronounced in industries facing greater innovation pressure. To test this, we first distinguish between high-tech and non-high-tech industries using firms' industry classifications.[13] The results in Panel D of Table 6 indicate that the positive relationship between institutional cross-ownership and patent invalidation is stronger in high-

[13] We present details of the industry definitions in TableB1.

tech industries. Next, we categorize all industries in the sample into technology-intensive and non-technology-intensive sectors using the CSRC 2012 industry classification standard. This classification is based on the intensity of production factors used in the industry. Panel E of Table 6 shows that the positive relationship between institutional cross-ownership and patent invalidation is more pronounced in technology-intensive industries than in non-technology-intensive industries.

4.2 Plausible underlying channel: knowledge spillover

4.2.1 Evidences from knowledge flow and technological proximity

In markets characterized by patent information overload and private information asymmetry, firms face constraints on their ability to monitor and evaluate the innovations of their peers. The knowledge spillover channel posits that, within an institutional cross-ownership network, cross-holding institutional investors can internalize knowledge spillovers between firms by transmitting information, thereby helping firms alleviate informational constraints. Specifically, when a firm joins an ownership network through institutional cross-ownership, it is more likely to participate in this spillover channel, either as an initiator or recipient. We hypothesize that when the knowledge spillover channel functions effectively, firms within the network will exhibit greater knowledge flow and higher technological proximity, which in turn increases the likelihood of initiating patent invalidation claims. Moreover, based on the principle of diminishing marginal returns, this effect should be more pronounced for firms that initially have lower levels of knowledge flow or technological proximity within the network.

Following prior studies (Alcacer and Gittelman, 2006; Ahmadpoor and Jones, 2017; Tian et al., 2025), we use patent citations to measure knowledge flow. Specifically, we define a focal firm's knowledge flow as the percentage of its patent citations made to other firms within its ownership network in period $t + 1$, relative to its total patent citations in the same period. We denote this metric as $Network\ citation_{t+1}/All\ citation_{t+1}$.[14] To capture the firm's ex-ante knowledge flow within its peer network, we use the frequency with which its patents were cited by network firms during period $t - 1$. In addition, we manually construct each focal firm's peer network by identifying and compiling a list of firms within its ownership network. We classify patents using the first four digits of the International Patent Classification (IPC) code, following Lee et al. (2019); Singh et al. (2021). To conduct further analysis, we apply the method

[14] When calculating knowledge flow, we exclude firms that did not file any patent applications in the relevant year.

developed by Byun et al. (2021), which evaluates the similarity between patents from different pools based on technological proximity. We build patent pools from patents filed by peer firms within the same year, using patents filed by the focal firm in that year as the reference set. This approach allows us to assess the degree of technological overlap between patents filed by the focal firm in the following year and those filed by other firms in the network during the same period. We use this measure to capture patent similarity, denoted as *Network patent similarity*$_{t+1}$.[15] To further validate our findings, we analyze knowledge flow and technological similarity at the link level. Specifically, we use the variable *Link dummy* to indicate whether the focal firm has established technological connections with its peers through institutional cross-ownership. We then use *Link citation*$_{t+1}$/*All citation*$_{t+1}$ and *Link patent similarity*$_{t+1}$ to measure the degree of knowledge flow and technological similarity at the link level, respectively.

Panel A of Table 7 presents the results for knowledge flow. In columns (1)-(3), we use knowledge flow in period $t + 1$ as the dependent variable. The results show that the formation of institutional cross-ownership increases the focal firm's subsequent knowledge flow within its peer network. As shown in columns (4)-(6), the relationship between institutional cross-ownership and patent invalidation is more pronounced for firms with lower ex-ante knowledge flow within their peer networks. Panel B of Table 7 reports the results for technological proximity. In columns (1)-(3), we use technological proximity in period $t + 1$ as the dependent variable. The findings indicate that the formation of institutional cross-ownership also increases the focal firm's subsequent technological proximity with firms in its peer network. Columns (4)-(6) show that the relationship between institutional cross-ownership and patent invalidation is stronger for firms with lower ex-ante technological proximity within their peer networks. To mitigate the effect of potential firm-level noise, we additionally conduct the analysis at the link level. Panel C of Table 7 presents the corresponding regression results. The effect of institutional cross-ownership on the focal firm's knowledge flow and technological proximity to peer firms remains evident at the link level.

4.2.2 From ownership network to information network by site visits

Cabezon and Hoberg (2025) find that firms with densely overlapping director networks are quicker to disseminate technology to their competitors, which diminishes product differentiation among firms within the board network. Similarly, Figure 1 illustrates that cross-

[15] When calculating patent similarity, we exclude observations where the focal firm did not file any patent applications in the relevant year. We also exclude cases where no firm in the peer network filed a relevant patent. Thus, if the focal firm filed a patent but no peer firm did so in that year, the observation is omitted.

holding institutional investors access and share innovation-related information across firms through the ownership network. Information flow effectively transforms the ownership network into an information network. What drives this behavior of institutional investors? One plausible explanation is that institutional investors internalize innovation knowledge within the ownership network to enhance innovation efficiency and improve portfolio performance (Li et al., 2023). If visits by cross-holding institutional investors facilitate the formation of such an innovation information network, we propose three testable hypotheses: (1) Institutional investors who visit more frequently transfer information more effectively than those who visit less often, leading to a stronger positive relationship between institutional cross-ownership and patent invalidation. (2) On-site visits foster more private information exchange than off-site visits, thus promoting patent invalidation by focal firms. (3) Visits involving richer information exchange—through deeper innovation discussions or higher executive attendance—make information transfer more effective and further strengthen the link between institutional cross-ownership and patent invalidation.

In Panel A of Table 8, we investigate whether an increased number of site visits by common shareholders leads to a higher volume of patent invalidation claims filed by the focal firm, in order to examine the site-visit channel of cross-ownership. Specifically, we measure the visit frequency of cross-holding shareholders as the ratio of visits made by such shareholders to the total number of institutional visits to the firm, denoted as *Cross Visit*/*All Visit*. We interact the value of *Cross Visit*/*All Visit* lagging by one period with the key explanatory variables and all control variables[16]. As shown in Panel A of Table 8, the empirical results reveal that the interaction terms between *Cross Visit*/*All Visit* and *Prop Cross*, *Num Cross*, and *Num Connected* are significantly positive for both *Patent invalidation*$_t$ and *Patent invalidation*$_{t+1}$. This suggests that firms receiving more site visits from common shareholders are more likely to initiate patent invalidation claims. These findings provide preliminary support for our conjecture that site visits serve as a specific mechanism through which common shareholders facilitate knowledge spillover. Further evidence will be presented in the subsequent analysis.

In Panel B of Table 8, we use a panel dataset at the institutional shareholders' portfolio level. We use institutional shareholders' shareholdings in each firm as weights to calculate the market capitalization and *Tobin's Q* of their portfolios.[17] We define two dummy variables:

[16] We set the samples that have not undergone research to 0.

[17] Annual market capitalization is calculated as the average of daily market capitalization. Daily market capitalization is computed as: (total equity - domestically listed foreign shares (B shares)) × the closing price of A shares that day + (closing price of B shares × the price of B shares in the Shanghai market, converted to RMB using the CNY/USD exchange rate) + total liabilities at the

Cross dummy, which indicates cross-ownership by institutional shareholders, and *Visit dummy*, which shows whether they conducted firm visits. Because information flow requires interaction with at least two distinct firms, we set *Visit dummy* to 1 if an institutional shareholder visits two or more portfolio firms within the same industry, and 0 otherwise. The regression results show that visits by cross-holding institutional investors significantly increase their portfolios' value in both the current and next periods. This finding supports the notion that cross-holding institutional investors transmit information through their visits.

In Panel C of Table 8, we categorize institutional shareholders based on their prior visiting activities as either informative (active) or uninformative (inactive). Specifically, we classify an institutional investor as "informative", if, before becoming a shareholder of target firm A, it conducted a site visit and issued at least one related report on a previous holding in firm B, where it was among the top ten shareholders. Otherwise, the investor is classified as an "uninformative", shareholder. The regression results indicate that institutional shareholders who actively conduct visits strengthen the positive relationship between institutional cross-ownership and patent invalidation in both the current and next periods, compared to those who do not engage in such activities. In particular, actively visiting shareholders have a stronger effect on the focal firm's knowledge flow and technological proximity with peer network firms in the next period.

In Panel D of Table 8, we focus on the samples where site visits occurred to explore how on-site visits and off-site visits affect firms' behavior of initiating patent invalidation claims. Additionally, we provide supplementary evidence from the perspectives of receiving patent invalidation claims and knowledge spillover. Specifically, we compare the number of on-site visits and off-site visits initiated by institutional cross-ownership with the total number of visits in the current period to obtain *Prop on-site visit* and *Prop off-site visit*, respectively. Then, we incorporate both variables into the same econometric model and perform regressions on different outcome variables. The regression results indicate that onsite visits by institutional shareholders more strongly reinforce the positive relationship between institutional cross-ownership and patent invalidation for the focal firm in the next period, compared to offsite visits. Furthermore, onsite visits have a greater effect on the focal firm's knowledge flow and technological proximity with peer network firms in the following period.

period end. Tobin's Q is calculated as the ratio of annual market capitalization to total assets minus net intangible assets and net goodwill.

In Panel E of Table 8, we distinguish whether institutional shareholders' visits are information-intensive or characterized by high-level executive attendance, based on the content and structure of their visit activities. We measure the innovation focus of these visits by counting the number of innovation-related terms in visit reports when cross-holding shareholders visit firms within the peer network during the three years preceding their visit to the focal firm. This measure, denoted as *Innovation words*, reflects the innovation intensity of the visit activities. In addition, we track whether executives participated in these visits and measure executive engagement by counting how often executives were present, denoted as *Executive attendance times*. The regression results indicate that innovation-focused visits by institutional shareholders increase the number of patent invalidation claims initiated by the focal firm in the subsequent period. However, these visits do not significantly affect the focal firm's likelihood of receiving patent invalidation claims in either the current or the following period. Moreover, innovation-focused visits enhance the focal firm's technological similarity with peer network firms after the event but do not have a significant effect on the firm's knowledge flow or overall technological proximity with those peers.

4.3 Ruling out alternative channels

While the above evidence aligns with the knowledge spillover channel, an alternative interpretation is that institutional cross-ownership may primarily work through governance effects. As noted by Li et al. (2023), co-shareholders may coordinate innovation activities across firms they hold to maximize portfolio returns. In the context of patent competition, when co-shareholders identify a flawed patent held by one portfolio firm, they may encourage other firms in the same portfolio to challenge it, thereby reducing the risk of future challenges against themselves. Moreover, a stream of studies argues that the primary effect of active governance by co-shareholders is anti-competitive (Azar et al., 2018; Newham et al., 2018; He et al., 2019, 2020; Cheng et al., 2024). This implies that institutional shareholders may actively discourage portfolio firms from initiating patent invalidation claims to protect overall portfolio value. This logic aligns with the view that initiating patent invalidation is a costly competitive strategy that may reduce portfolio performance (Walsh et al., 2016; Gaessler et al., 2024). Whether governance effects override the knowledge spillover channel is therefore an empirical question that requires further testing.

To test whether our proposed channel is driven by governance effects, we use the appointment of managerial personnel (directors, supervisors, and executives) by institutional

shareholders as a proxy for corporate governance. Specifically, we measure the share of directors, supervisors, and executives appointed by institutional shareholders relative to the firm's total (*Cross DSE/All DSE*) and interact this with the main cross-ownership variable and control variables in the baseline regression. Table 9 presents the results for this test. Columns (1)–(3) use *Patent invalidation*$_t$ as the dependent variable and show a negative and significant coefficient on the interaction term (*Cross DSE/All DSE* × *Prop Cross*, *Cross DSE/All DSE* × *Num Cross*, and *Cross DSE/All DSE* × *Num Connected*). Columns (4)–(6), which use *Patent invalidation*$_{t+1}$ as the dependent variable, show that the interaction term is near zero and insignificant. Together, these results suggest that board-level governance by institutional shareholders significantly reduces the number of patent invalidation claims initiated by the focal firm in the current period but does not have a lasting effect. Overall, the evidence suggests that institutional investors with cross-ownership internalize knowledge spillovers by acquiring and sharing innovation-related information within the ownership network, which represents a plausible channel through which cross-ownership promotes firms' engagement in innovation competition.

4.4 Economic consequences

Our findings indicate that institutional cross-ownership has a positive effect on the number of patent invalidation claims initiated by the focal firm, and the relationship may reflect a causal effect. Building on this finding, we propose a hypothesis about the role of the knowledge spillover channel, drawing on documented cases in China and providing supporting empirical evidence. To explore the economic consequences of the positive association between institutional cross-ownership and patent invalidation, we first identify the resolution dates of patent invalidation cases and classify them into four categories: (1) initiating and succeeding, (2) initiating and failing, (3) receiving and succeeding, and (4) receiving and failing. For each category, we calculate the corresponding cumulative abnormal returns (CARs) and test whether they significantly differ from zero to evaluate market reactions to patent invalidation events.[18] Because the outcome of a patent invalidation cannot be reliably predicted before the decision is announced, and early information leakage is unlikely, we use multiple event windows: [0, 1], [0, 3], [0, 7], [0, 15], [0, 30], [0, 60], [0, 120], [0, 180], and [0, 360]. The window [-185, -6] serves as the estimation period for calculating expected returns.

[18] If a firm initiates or receives multiple patent invalidation cases on the same day, we treat them as a single event. To avoid bias from partial outcomes, we exclude cases in which only a subset of the challenged patents is invalidated

Panel A of Table 10 shows that when firms initiate patent invalidation claims and win, the CARs for the event windows [0, 3], [0, 7], [0, 15], [0, 30], [0, 60], and [0, 120] are positive and statistically significant. This indicates that successful challenges generate sustained positive market reactions. In contrast, when firms initiate invalidation claims and lose, the CARs across all windows are not significantly different from zero. When firms receive patent invalidation claims and lose, the CARs for the windows [0, 1], [0, 3], and [0, 7] are negative and statistically significant, suggesting that the market reacts negatively in the short term when a firm's patent is invalidated. However, when firms receive invalidation claims and win, the CARs remain statistically indistinguishable from zero across all windows. To illustrate the market impact, the event study results are presented in Figure 5. Overall, the findings indicate that successfully invalidating a competitor's patent creates positive market value for the initiator, while losing a patent through invalidation generates negative market effects for the targeted firm. Moreover, the market responds to successful invalidation more quickly and the effect persists longer than for unsuccessful attempts.

We next examine how a firm's patent invalidation behavior affects the investment portfolio returns of institutional shareholders. Specifically, we analyze the economic consequences of initiating or receiving patent invalidation claims for the portfolio returns of these shareholders. To do so, we define two dummy variables based on the results in Table 10. The first variable, *Initiate patent invalidation dummy*, equals 1 if an institutional shareholder's portfolio includes a firm that initiates a patent invalidation claim, and 0 otherwise. The second variable, *Receive patent invalidation dummy*, equals 1 if a portfolio firm receives a patent invalidation claim, and 0 otherwise. The results in Panel B of Table 10 show that, compared to portfolios without institutional cross-ownership, the presence of patent invalidation activity in cross-held firms significantly increases the market value and Tobin's Q of institutional shareholders' portfolios in the following period ($t + 1$). This evidence implies that portfolio arbitrage could be an important motivation for institutional cross-ownership to promote patent invalidation, and that the market's reaction provides valuable insight into this channel.

Then, we examine how initiating or receiving patent invalidation claims affects a focal firm's innovation and economic performance. Specifically, we use *Patent invalidation* and *Receive patent invalidation* as independent variables, with the firm's subsequent innovation and economic outcomes as dependent variables. The results are presented in Panels C and D of Table 10. For innovation performance, we find that initiating a patent invalidation significantly increases R&D investment, innovation conversion efficiency (measured as patent applications

divided by R&D spending), and innovation quality (measured by patent citations) in the following period. However, initiation does not significantly affect the total number of new patent applications. By contrast, receiving a patent invalidation has no significant impact on any of these innovation indicators. Regarding economic performance, initiation has a positive and significant effect on the firm's total factor productivity in the next period, whereas receiving an invalidation does not. Taken together, these results suggest that initiating a patent invalidation boosts a firm's subsequent R&D activities and operational efficiency, while being targeted by a patent invalidation does not meaningfully alter its innovation or economic outcomes.

Finally, we assess how a focal firm's engagement in patent invalidation affects the innovation and economic performance of its peer network—defined as firms held by the same institutional shareholders. We aggregate innovation and financial indicators at the firm level and calculate their averages for the peer network. Panels E and F of Table 10 present the results. We find that when a focal firm initiates a patent invalidation, peer firms' R&D spending and innovation quality (measured by patent citations) significantly increase in the following period. However, the peer network's average innovation conversion efficiency declines. No significant effect is observed on the average number of patent applications or total factor productivity. In contrast, when a focal firm receives a patent invalidation, there is no significant impact on any peer-level innovation or economic outcomes. Overall, these findings suggest that firms initiating patent invalidation tend to engage in strategic rather than opportunistic competition. Within the peer network, this form of rivalry appears to shift innovation strategies from a focus on quantity to an emphasis on quality.

5 Conclusion

In this paper, we investigate the relationship between institutional cross-ownership and firms' engagement in innovation competition. Using manually collected patent invalidation claims data and a large sample of Chinese listed firms, we find that institutional cross-ownership increases the number of patent invalidation claims initiated by cross-held firms. The positive effect is more pronounced in industries facing greater innovation or competitive pressure, where firms rely more heavily on information flows to challenge rivals' patents. Further analysis shows that institutional investors strengthen the role of ownership networks as information networks through activities such as on-site visits, which facilitate the sharing of innovation-related knowledge among cross-held firms. This information transfer enhances knowledge spillovers and technological proximity within the ownership network, which in turn intensifies innovation

competition. These dynamics generate higher portfolio returns for institutional investors with cross-holdings, suggesting that both the initiating firms and their institutional shareholders benefit from intensified innovation rivalry. While firms targeted by patent invalidation may experience a short-term market benefit if they successfully defend their patents, repeated patent competition within cross-ownership networks appears to shift innovation strategies from quantity to quality. Overall, our study sheds new light on institutional cross-ownership by showing that it positively affects competitive behavior in technological innovation among cross-held firms.

While our evidence supports a robust and likely causal link between institutional cross-ownership and increased innovation competition, two important caveats should be noted when interpreting or generalizing these results. First, because our analysis relies on data from publicly listed firms, the conclusions may not fully apply to smaller or early-stage firms and should therefore be viewed with caution. Second, although the findings suggest that institutional cross-ownership encourages firms to compete more actively through patent invalidation and creates private economic gains for both firms and investors, the broader welfare implications are less clear. Existing research shows that institutional cross-ownership can produce both desirable and undesirable outcomes for society. Our results indicate that institutional investors primarily aim to maximize portfolio returns, not necessarily to enhance overall social welfare. Therefore, the private benefits we document should be understood as reflecting portfolio optimization rather than guaranteed welfare improvements. Furthermore, although the evidence suggests that patent invalidation within ownership networks generally helps raise patent quality rather than restrict competition, some investors or firms could still engage in opportunistic challenges that weaken overall innovation incentives. This limitation highlights the need for additional research to examine how institutional cross-ownership affects the economic and legal environment in which firms operate. Future studies should also investigate how cross-ownership affects innovation competition across different industries, firm sizes, and regulatory systems. At minimum, this study contributes to the broader debate on how institutional investors shape corporate innovation strategies and demonstrates that patent invalidation can serve as a mechanism for shifting innovation efforts from quantity to quality.

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Table 1 Summary statistics of core variables

This table reports the summary statistics of the sample for the variables used in our baseline analysis. For each variable, we report the mean, standard deviation, minimum value, 25th percentile, median, 75th percentile, and maximum value. The sample includes listed firms in China from 2010 to 2022, which contains 34,825 firm-year observations of each variable. *Num patent invalidation* refers to the total number of patent invalidation claims initiated by the focal firm and its subsidiaries in a given year. *Patent invalidation* refers to the natural logarithm of one plus the total number of patent invalidation claims initiated by the focal firm and its subsidiaries in a given year. *Prop Cross* refers to the proportion of institutional investors who are common shareholders among the top ten shareholders of the focal firm in a given year. *Num Cross* refers to the natural logarithm of one plus the number of institutional investors who are common shareholders among the top ten shareholders of the focal firm in a given year. *Num Connected* refers to the natural logarithm of one plus the number of other firms connected to the focal firm through cross-holding institutional investors in a given year. *Assets* refers to the natural logarithm of the total assets of the focal firm in a given year. *Leverage* refers to the ratio of the total liabilities to total assets of the focal firm in a given year. *Cash/Assets* refers to net cash flow from operating activities divided by average total assets of the focal firm in a given year. *ROA* refers to return on assets, calculated as net income divided by total assets of the focal firm in a given year. *Sales growth* refers to the annual growth rate of operating income of the focal firm. *Grant patent* refers to the natural logarithm of one plus the number of patents granted to the focal firm in a given year. *Firm age* refers to the natural logarithm of one plus the number of years since the establishment of the focal firm. *Institutional investors shareholding* refers to the proportion of shares held by institutional investors in the focal firm in a given year. *Top10 ownership concentration* refers to the ownership share held by the top ten shareholders of the focal firm in a given year. *Separation of ownership and control* refers to the difference between the control rights and cash flow rights of the ultimate controller of the focal firm in a given year. *Audit fee* refers to the natural logarithm of one plus the audit fee paid by the focal firm in a given year. *Female executives* refers to the proportion of female executives in the focal firm in a given year.

Variable	Mean	Standard deviation	Minimum	25^{th}	Median	75^{th}	Maximum
Num patent invalidation	0.042	0.283	0.000	0.000	0.000	0.000	9.000
Patent invalidation	0.025	0.150	0.000	0.000	0.000	0.000	2.303
Prop Cross	0.252	0.189	0.000	0.100	0.200	0.375	0.775
Num Cross	1.102	0.579	0.000	0.693	1.099	1.558	2.169
Num Connected	3.730	2.093	0.000	2.197	4.025	5.583	6.800
Assets	22.204	1.292	19.585	21.276	22.013	22.938	26.430
Leverage	0.421	0.207	0.027	0.254	0.413	0.575	0.925
Cash/Assets	0.046	0.069	-0.224	0.007	0.045	0.086	0.266
ROA	0.040	0.067	-0.375	0.014	0.039	0.073	0.254
Sales growth	0.166	0.398	-0.653	-0.027	0.106	0.268	3.808
Grant patent	1.474	1.529	0.000	0.000	1.099	2.565	8.505
Firm age	2.915	0.336	1.099	2.708	2.944	3.135	3.611
Institutional investors shareholding	0.435	0.247	0.001	0.230	0.449	0.633	0.924
Top10 ownership concentration	0.585	0.151	0.208	0.477	0.593	0.702	0.910
Separation of ownership and control	4.914	7.554	0.000	0.000	0.000	8.025	63.812
Audit fee	13.833	0.714	11.695	13.353	13.710	14.208	21.417
Female executives	0.645	0.512	0.000	0.000	0.693	1.099	2.485

Table 2 Institutional cross-ownership and patent invalidation

This table examines the impact of institutional cross-ownership on patent invalidation. The sample includes listed firms in China from 2010 to 2022. Controls indicate that we include the same control variables as defined in Table 1, but their coefficients are not reported for brevity. Columns (1)-(3) report regressions without control variables. Columns (4)-(6) include control variables as well as firm and year fixed effects. *Patent invalidation* refers to the natural logarithm of one plus the total number of patent invalidation claims initiated by the focal firm and its subsidiaries in a given year *t*. *Prop Cross* refers to the proportion of institutional investors who are common shareholders among the top ten shareholders of the focal firm in a given year *t*. *Num Cross* refers to the natural logarithm of one plus the number of institutional investors who are common shareholders among the top ten shareholders of the focal firm in a given year *t*. *Num Connected* refers to the natural logarithm of one plus the number of other firms connected to the focal firm through cross-holding institutional investors in a given year *t*. Standard errors are clustered at the firm level. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	Patent invalidation$_t$					
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Prop Cross	0.033***			0.023***		
	(0.008)			(0.008)		
Num Cross		0.010***			0.006***	
		(0.002)			(0.002)	
Num Connected			0.002***			0.001***
			(0.000)			(0.001)
Controls	No	No	No	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	34,293	34,293	34,293	34,293	34,293	34,293
R-squared	0.261	0.261	0.261	0.264	0.264	0.264

Table 3 Robustness check

This table contains a number of empirical attempts to examine the robustness of our baseline results. The sample includes Chinese listed firms from 2010 to 2022. *Patent invalidation* refers to the natural logarithm of one plus the total number of patent invalidation claims initiated by the focal firm and its subsidiaries in a given year *t*. *Prop Cross* refers to the proportion of institutional investors who are common shareholders among the top ten shareholders of the focal firm in a given year *t*. *Num Cross* refers to the natural logarithm of one plus the number of institutional investors who are common shareholders among the top ten shareholders of the focal firm in a given year *t*. *Num Connected* refers to the natural logarithm of one plus the number of other firms connected to the focal firm through cross-holding institutional investors in a given year *t*. Controls indicate that we include the same control variables as presented in Table 1, but their coefficients are not reported for brevity. In Panel A, we report results after altering matching procedures. Specifically, we run propensity score matching and OLS regressions (PSM-OLS) in columns (1)–(3), and entropy balancing with OLS regressions (EB-OLS) in columns (4)–(6). Standard errors are clustered at the firm level. In Panel B, we report results after changing the fixed effects. Columns (1)–(3) replace Year fixed effects in the baseline with Industry × Year fixed effects. Columns (4)–(6) add the Province × Year fixed effects to Industry × Year fixed effects. Standard errors are clustered at the firm level. In Panel C, we report the results using alternative regression models. Specifically, we use *Num patent invalidation* as the dependent variable. Columns (1)–(3) run the Negative Binomial model, and columns (4)–(6) run the Zero-Inflated Negative Binomial model. Standard errors are clustered at the firm level. In Panel D, we report results using alternative cluster levels. Columns (1)–(3) cluster standard errors at the firm-year level; columns (4)–(6) cluster at the industry-year level. In Panel E, we report results using alternative measures of the dependent variable. *Patent invalidation*$_{t+1}$ refers to the natural logarithm of one plus the total number of patent invalidation claims initiated by firm *i* and its subsidiaries in the year *t* + 1. *Num patent invalidation*$_t$ refers to the total number of patent invalidation claims initiated by the focal firm and its subsidiaries in the current year. Standard errors are clustered at the firm level. In Panel F, we report results using alternative measures of the independent variables. Specifically, we use 3-digit industry codes for manufacturing firms and broad codes for other industries. Under this classification, *3-digit ind Prop Cross* refers to the proportion of institutional investors who are common shareholders among the top ten shareholders. *3-digit ind Num Cross* refers to the natural logarithm of one plus the number of institutional investors who are common shareholders. *3-digit ind Num Connected* refers to the natural logarithm of one plus the number of other firms connected through cross-holding institutional investors. Standard errors are clustered at the firm level. In Panel G, we report results after excluding observations during the COVID-19 period. Standard errors are clustered at the firm level. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Panle A: Alternative matching procedures

	Patent invalidation$_t$					
	PSM-OLS regression			EB-OLS regression		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Prop Cross	0.043*			0.022*		
	(0.026)			(0.012)		
Num Cross		0.012**			0.006*	
		(0.005)			(0.003)	
Num Connected			0.003**			0.001*
			(0.001)			(0.001)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,330	4,330	4,330	28,277	28,277	28,277
R-squared	0.384	0.385	0.385	0.337	0.337	0.337

Panle B: Adding high-dimensional fixed effects

	Patent invalidation$_t$					
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Prop Cross	0.024***			0.024***		
	(0.008)			(0.008)		
Num Cross		0.007***			0.007***	

		(0.002)			(0.002)	
Num Connected			0.002***			0.002***
			(0.001)			(0.001)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry × Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Province × Year fixed effects	No	No	No	Yes	Yes	Yes
Observations	34,286	34,286	34,286	34,285	34,285	34,285
R-squared	0.268	0.268	0.268	0.274	0.274	0.274

Panle C: Alternative regression model

	Num patent invalidation$_t$					
	Negative binomial			Zero-inflated negative binomial		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Prop Cross	0.819***			0.769***		
	(0.242)			(0.235)		
Num Cross		0.392***			0.364***	
		(0.088)			(0.087)	
Num Connected			0.107***			0.108***
			(0.024)			(0.024)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	34,825	34,825	34,825	34,825	34,825	34,825

Panle D: Alternative cluster level

	Patent invalidation$_t$					
	Cluster at firm and year levels			Cluster at industry and year levels		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Prop Cross	0.023**			0.023**		
	(0.009)			(0.010)		
Num Cross		0.006**			0.006*	
		(0.003)			(0.003)	
Num Connected			0.001**			0.001**
			(0.001)			(0.001)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	34,293	34,293	34,293	34,293	34,293	34,293
R-squared	0.264	0.264	0.264	0.264	0.264	0.264

Panle E: Excluding samples during COVID-19

	Patent invalidation$_t$		
Variable	(1)	(2)	(3)
Prop Cross	0.024***		
	(0.008)		
Num Cross		0.007***	
		(0.002)	
Num Connected			0.002**
			(0.001)
Controls	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	22,690	22,690	22,690
R-squared	0.269	0.269	0.268

Panle F: Alternative independent variable measures

	Patent invalidation$_t$		
Variable	(1)	(2)	(3)
3-digit ind Prop Cross	0.019**		
	(0.009)		
3-digit ind Num Cross		0.005**	
		(0.002)	
3-digit ind Num Connected			0.002***
			(0.001)
Controls	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	34,293	34,293	34,293
R-squared	0.264	0.264	0.264

Panle G: Alternative dependent variable measures

	Patent invalidation$_{t+1}$			*Num patent invalidation*$_t$		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Prop Cross	0.018**			0.042***		
	(0.009)			(0.015)		
Num Cross		0.006**			0.012***	
		(0.002)			(0.004)	
Num Connected			0.001**			0.003***
			(0.001)			(0.001)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	28,277	28,277	28,277	34,293	34,293	34,293
R-squared	0.271	0.271	0.271	0.268	0.268	0.268

Table 4 Addressing endogeneity by IV method based on the shock of absorptive mergers from shareholders

This table reports the results of the 2SLS regression using absorptive mergers from shareholders as an instrumental variable approach to address potential endogeneity issues. The sample includes Chinese listed firms from 2010 to 2022. *Patent invalidation* refers to the natural logarithm of one plus the total number of patent invalidation claims initiated by the focal firm and its subsidiaries in a given year *t*. *Prop Cross* refers to the proportion of institutional investors who are common shareholders among the top ten shareholders of the focal firm in a given year *t*. *Num Cross* refers to the natural logarithm of one plus the number of institutional investors who are common shareholders among the top ten shareholders of the focal firm in a given year *t*. *Num Connected* refers to the natural logarithm of one plus the number of other firms connected to the focal firm through cross-holding institutional investors in a given year *t*. Controls indicate that we include the same control variables as those presented in Table1 but their coefficients are not reported for brevity. Panel A presents the effect of the instrumental variable on the dependent variable in the first-stage regressions. *Merge* refers to the number of absorption mergers initiated by the top ten shareholders of the focal firm. Panel B presents the effect of the fitted values of the independent variable on the dependent variable in the second-stage regressions. Standard errors are clustered at the firm level. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Panle A: First stage regression

	Prop Cross$_t$	*Num Cross*$_t$	*Num Connected*$_t$
Variable	(1)	(2)	(3)
Merge	0.007***	0.021***	0.049***
	(0.000)	(0.001)	(0.004)
Controls	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	34,293	34,293	34,293
R-squared	0.712	0.672	0.614
F-statistic	119.298	122.397	63.469

Panle B: Second stage regression

	Patent invalidation$_t$		
Variable	(1)	(2)	(3)
Prop Cross	0.127**		
	(0.061)		
Num Cross		0.042**	
		(0.020)	
Num Connected			0.018**
			(0.009)
Controls	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	34,293	34,293	34,293
R-squared	0.264	0.264	0.264

Table 5 Addressing endogeneity by DiD model based on the shock of "Stock market crash"

This table reports the results of the DiD regression of a quasi-natural experiment based on the "national team" intervention during the "2015 Chinese stock market crash". The sample includes Chinese listed firms from 2010 to 2022. Controls indicate that we include the same control variables as those presented in Table 1, but their coefficients are not reported for brevity. *DiD* is defined as *Treat* × *Post* and serves as a proxy for the "national team" intervention. *Patent invalidation*$_t$ refers to the natural logarithm of one plus the total number of patent invalidation claims initiated by the focal firm *i* and its subsidiaries in the current year *t*. Standard errors are clustered at the firm level. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	Patent invalidation$_t$	
Variable	(1)	(2)
DiD	0.024***	0.057***
	(0.007)	(0.018)
Controls	No	Yes
Firm fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Observations	4,973	4,973
R-squared	0.463	0.466

Table 6 Heterogeneity in results

This table contains a number of empirical attempts to examine the heterogeneity of our baseline results. The sample includes Chinese listed firms from 2010 to 2022. Controls indicates that the same control variables as those presented in Table 1 are controlled for, and their coefficients are omitted for brevity. In Panel A, we present the test results based on the heterogeneity of industry concentration. Industry concentration data come from the CSMAR database and are measured as the ratio of the total revenues of the eight largest firms to total industry revenues. We divide the sample into two groups based on the median concentration level, classifying industries with higher concentration as low-competition (High CR) and those with lower concentration as high-competition (Low CR). In Panel B, we present the test results for whether the focal firm operates in a government-regulated industry. Specifically, a firm is marked as Yes if it is in a government-regulated industry and No otherwise. Relevant information on government-regulated industries is provided in Table B1 of this paper. In Panel C, we present the test results for whether the focal firm operates in a high-tech industry. Specifically, a firm is marked as Yes if it is in a high-tech industry and No otherwise. Relevant information on high-tech industries is provided in Table B1. In Panel D, we present the test results for whether the focal firm operates in a technology-intensive industry. Specifically, a firm is marked as Yes if it is in a technology-intensive industry and No otherwise. Relevant information on technology-intensive industries is provided in Table B1. Standard errors are clustered at the firm level. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. The Inter-group difference p-value reports the results of a permutation test conducted using bootstrap with 1,000 repetitions.

Panle A: Test based on the heterogeneity of industrial Concentration Ratio (CR)

	Patent invalidation$_t$					
	High CR	Low CR	High CR	Low CR	High CR	Low CR
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Prop Cross	0.009	0.034**				
	(0.010)	(0.014)				
Num Cross			0.001	0.011***		
			(0.002)	(0.004)		
Num Connected					-0.001*	0.003***
					(0.001)	(0.001)
Inter-group difference p-value	0.069*		0.005***		0.000***	
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17,102	16,825	17,102	16,825	17,102	16,825
R-squared	0.251	0.317	0.251	0.317	0.251	0.317

Panle B: Test based on whether the focal firm's industry is government-regulated

	Patent invalidation$_t$					
	Yes	No	Yes	No	Yes	No
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Prop Cross	-0.003	0.032***				
	(0.011)	(0.010)				
Num Cross			-0.003	0.009***		
			(0.003)	(0.003)		
Num Connected					-0.002*	0.002***
					(0.001)	(0.001)
Inter-group difference p-value	0.048**		0.013**		0.004***	
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8,557	25,680	8,557	25,680	8,557	25,680
R-squared	0.204	0.283	0.204	0.283	0.204	0.283

Panle C: Test based on whether the focal firm is in the high-tech industry

	Patent invalidation$_t$					
	Yes	No	Yes	No	Yes	No
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Prop Cross	0.031***	0.008				
	(0.011)	(0.011)				
Num Cross			0.011***	-0.000		
			(0.003)	(0.003)		
Num Connected					0.002***	-0.000
					(0.001)	(0.001)
Inter-group difference p-value	0.087*		0.004***		0.013**	
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	20,116	14,137	20,116	14,137	20,116	14,137
R-squared	0.289	0.218	0.289	0.218	0.289	0.218

Panle D: Test based on whether the focal firm is in the technology-intensive industry

	Patent invalidation$_t$					
	Yes	No	Yes	No	Yes	No
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Prop Cross	0.037**	0.014				
	(0.015)	(0.009)				
Num Cross			0.013***	0.002		
			(0.004)	(0.002)		
Num Connected					0.003***	0.000
					(0.001)	(0.001)
Inter-group difference p-value	0.060*		0.003***		0.007***	
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,125	19,050	15,125	19,050	15,125	19,050
R-squared	0.306	0.224	0.306	0.224	0.306	0.224

Table 7 Plausible underlying channel: knowledge flow and technological proximity

This table contains a number of empirical attempts to examine the plausible underlying channel of knowledge flow and technological proximity. The sample includes Chinese listed firms from 2010 to 2022. Controls indicate that the same control variables as those in Table 1 are included but not reported. In Panel A, we use patent citations as a proxy for knowledge flow. *Network citation/All citation* presents the ratio of citations to a focal firm's patents made by peer firms within the institutional cross-ownership network to its total patent citations. Details of the calculation are provided in Table B1. This variable captures the degree of knowledge flows from other firms in the network to the focal firm. In the calculation process, we excluded samples with no common shareholders and no patent applications, resulting in a decrease in the observations. Columns (1)-(3) show the effect of institutional cross-ownership on the knowledge flow from peer firms in the network to the focal firm. Columns (4)-(6) classify firms based on their prior knowledge flow and test how institutional cross-ownership affects their initiation of patent invalidation claims across different types of firms. In Panel B, we use patent similarity to measure technological proximity. *Network patent similarity* captures the degree of technological similarity between the patents of the focal firm and its peers within the cross-ownership network. Details of the calculation are provided in Table B1. In the calculation process, we excluded samples that have no common shareholders, no patent applications, and no peer firm within the cross-ownership networks that have filed for patents in the current time, leading to a decrease in the number of observations. Columns (1)-(3) test the effect of institutional cross-ownership on the technological proximity between the focal firm and its peers. Columns (4)-(6) classify firms based on prior technological proximity and test how institutional cross-ownership affects their initiation of patent invalidation claims for different types of firms. Panel C shows how institutional cross-ownership affects knowledge flow and technological proximity at the firm-link level. *Link dummy* indicates whether two firms are linked through institutional cross-ownership. *Link citation/All citation* and *Link patent similarity* are respectively the results of knowledge flows and technological proximity calculated using the same method at the firm-link level. Details of the calculation are provided in Table B1. Standard errors are clustered at the firm level. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Panle A: Evidence on knowledge flow

	Network citation$_{t+1}$/All citation$_{t+1}$			*Patent invalidation$_t$*		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Prop Cross × Network citation/All citation				-0.087***		
				(0.028)		
Prop Cross	0.243***			0.039***		
	(0.018)			(0.011)		
Num Cross × Network citation/All citation					-0.039***	
					(0.012)	
Num Cross		0.105***			0.015***	
		(0.007)			(0.004)	
Num Connected × Network citation/All citation						-0.007**
						(0.003)
Num Connected			0.045***			0.003***
			(0.001)			(0.001)
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	25,679	25,679	25,679	25,241	25,241	25,241
R-squared	0.282	0.283	0.300	0.278	0.278	0.278

Panle B: Evidence on technological proximity

	Network patent similarity$_{t+1}$			*Patent invalidation*$_t$		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Prop Cross × Network patent similarity				-0.117**		
				(0.051)		
Prop Cross	0.040***			0.078***		
	(0.009)			(0.021)		
Num Cross × Network patent similarity					-0.049**	
					(0.019)	
Num Cross		0.014***			0.031***	
		(0.004)			(0.008)	
Num Connected × Network patent similarity						-0.009*
						(0.005)
Num Connected			0.005***			0.006***
			(0.001)			(0.002)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,776	18,776	18,776	18,722	18,722	18,722
R-squared	0.434	0.434	0.435	0.304	0.304	0.304

Panle C: Alternative dependent variable measures

	Link citation$_{t+1}$*/All citation*$_{t+1}$	*Link patent similarity*$_{t+1}$
Variable	(1)	(2)
Link dummy ($\times 10^{-4}$)	0.246**	5.033***
	(0.113)	(1.310)
Controls	Yes	Yes
Firm Link fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Observations	0.218	0.646
R-squared	8,905,113	6,075,090

Table 8 From ownership network to information network by site visit

This table contains a number of empirical attempts to explore how institutional cross-ownership transforms ownership networks into information networks by the channel of site visit. The sample includes Chinese listed firms from 2010 to 2022. Controls indicate that the same control variables as those presented in Table 1 are included, but their coefficients are not reported. In Panel A, we report the impact of site visits initiated by institutional cross-ownership on the results of the baseline, aiming to provide preliminary evidence for the research channel of site visits. We use the proportion of institutional investor visits, *Cross Visit/All Visit*, as a proxy for firm-level visits. *Cross Visit/All Visit* denotes the ratio of visits by common shareholders to the total number of institutional visits to the focal firm. Columns (1)-(3) report the effect on *Patent invalidation*$_t$, and columns (4)-(6) report the corresponding effect on *Patent invalidation*$_{t+1}$. In Panel B, we present the impact of access activities by cross-holding institutional investors on their portfolio returns, in order to explore whether institutional cross-ownership has the motivation to conduct site visits. *Portfolio value* refers to the result obtained by weighted aggregation using the annual market capitalization of portfolio firms and their respective investment shareholding ratios. *Portfolio TobinQ* refers to the result obtained by weighted aggregation using the annual Tobin'Q of portfolio firms and their respective investment shareholding ratios. *Cross dummy* is a dummy variable capturing institutional shareholders' cross-ownership. *Visit dummy* is a dummy variable indicating whether institutional shareholders conducted firm visits. Since information flow requires interaction with at least two distinct firms, *Visit dummy* is coded as 1 only when institutional shareholders visit two or more portfolio firms within the same industry, and 0 otherwise. In Panel C1-C3, we present the impact of informative versus uninformative institutional investors on the initiation and receipt of patent invalidation claims by focal firms; we also examine their effect on knowledge flow and technological proximity between focal firms and their "peer networks". *Informative shareholders* refer to common institutional shareholders who issued at least one visit-related report on a firm in which they were among the top ten shareholders prior to the ownership date of the focal firm. Otherwise, the shareholder is classified as an *Uninformative shareholders*. *Informative Prop Cross*, *Informative Num Cross*, and *Informative Num Connected* are the results calculated using *Informative shareholders*, with the calculation method consistent with baseline. *Uninformative Prop Cross*, *Uninformative Num Cross*, and *Uninformative Num Connected* are the results calculated using *Uninformative shareholders*, with the calculation method consistent with baseline. *Receive patent invalidation*$_t$ and *Receive patent invalidation*$_{t+1}$ refer to the total number of patent invalidation claims received by focal firm *i* and its subsidiaries in the year *t* and *t* + 1, respectively. In Panels D1-D3, we report the impacts of off-site visits and on-site visits on the initiation of patent invalidation, receipt of patent invalidation, and knowledge spillover. *Prop off-site visit* represents the result of the times of off-site visits initiated by common shareholders divided by all the times of site visit, while *Prop on-site visit* represents the result of the times of on-site visits initiated by common shareholders divided by all the times of site visit. During the regression process, samples without site visit were excluded, resulting in a decrease in the number of observations. We incorporated both variables into the econometric model simultaneously and regressed them against different outcome variables, aiming to provide evidence for our conclusions. In Panels E1-E3, we demonstrate how, during interactions with cross-holding institutional investors, the frequency of innovation-related keywords and the involvement of focal firm executives impact whether the firms initiate or receive patent invalidation claims. Moreover, we show that these factors also affect focal firms' focus on innovation within their peer networks and the convergence of their innovation efforts. *Innovation words* refers to the number of innovation-related terms found in visit reports when common shareholders visit peer network firms during the three years preceding a visit to the focal firm. *Executive attendance times* refers to the frequency with which the focal firm's executives participated in the surveys conducted when common shareholders visited firms within the peer network during the three years prior to visiting the focal firm. Additionally, we added one to both of the aforementioned variables and applied a natural logarithm transformation to them. Standard errors are clustered at the firm level. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Panle A: Tests on site visit of cross-holding institutional shareholders

	Patent invalidation$_t$			*Patent invalidation*$_{t+1}$		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Prop Cross × Cross Visit/All Visit	1.391*			1.646**		

	(0.802)			(0.694)		
Prop Cross	0.023***			0.013		
	(0.009)			(0.010)		
Num Cross × Cross Visit/All Visit		0.484*			0.638***	
		(0.286)			(0.247)	
Num Cross		0.008***			0.005*	
		(0.002)			(0.003)	
Num Connected × Cross Visit/All Visit			0.137**			0.144**
			(0.065)			(0.070)
Num Connected			0.002**			0.001*
			(0.001)			(0.001)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	28,277	28,277	28,277	23,406	23,406	23,406
R-squared	0.272	0.272	0.272	0.296	0.296	0.296

Panle B: Tests on information transfer incentives of cross-holding institutional investors

	Portfolio value$_t$	*Portfolio value$_{t+1}$*	*Portfolio TobinQ$_t$*	*Portfolio TobinQ$_{t+1}$*
Variable	(1)	(2)	(3)	(4)
Visit dummy × Cross dummy	0.245**	0.220*	0.042***	0.022*
	(0.097)	(0.115)	(0.010)	(0.012)
Visit dummy	0.113	-0.070	0.003	0.009
	(0.086)	(0.101)	(0.006)	(0.007)
Cross dummy	0.876***	0.162***	0.021***	0.002
	(0.016)	(0.021)	(0.002)	(0.003)
Shareholder-industry fixed effects	Yes	Yes	Yes	Yes
Shareholder × Year fixed effects	Yes	Yes	Yes	Yes
Shareholder × Industry fixed effects	Yes	Yes	Yes	Yes
Observations	71,884	42,173	71,884	42,173
R-squared	0.917	0.912	0.847	0.856

Panle C1: Tests on information acquisition initiative of cross-holding institutional investors (patent invalidation initiation perspective)

	Patent invalidation$_t$			*Patent invalidation$_{t+1}$*		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Informative Prop Cross	0.027***			0.027***		

	(0.009)			(0.010)		
Uninformative Prop Cross	0.016			0.007		
	(0.010)			(0.011)		
Informative Num Cross		0.008***			0.008***	
		(0.002)			(0.003)	
Uninformative Num Cross		0.006***			0.005*	
		(0.002)			(0.003)	
Informative Num Connected			0.002***			0.002**
			(0.001)			(0.001)
Uninformative Num Connected			0.001**			0.001*
			(0.001)			(0.001)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	34,293	34,293	34,293	28,277	28,277	28,277
R-squared	0.264	0.264	0.264	0.272	0.272	0.271

Panle C2: Tests on information acquisition initiative of cross-holding institutional investors (patent invalidation receipt perspective)

	Receive patent invalidation$_t$			*Receive patent invalidation$_{t+1}$*		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Informative Prop Cross	0.023*			0.033***		
	(0.012)			(0.013)		
Uninformative Prop Cross	-0.009			-0.001		
	(0.012)			(0.013)		
Informative Num Cross		0.005*			0.007**	
		(0.003)			(0.003)	
Uninformative Num Cross		-0.002			-0.001	
		(0.003)			(0.003)	
Informative Num Connected			0.001*			0.002**
			(0.001)			(0.001)
Uninformative Num Connected			-0.000			0.000
			(0.001)			(0.001)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	34,293	34,293	34,293	28,277	28,277	28,277
R-squared	0.350	0.350	0.350	0.359	0.359	0.359

Panle C3: Tests on information acquisition initiative of cross-holding institutional investors (knowledge spillover perspective)

	Network citation$_{t+1}$/All citation$_{t+1}$			*Network patent similarity$_{t+1}$*		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Informative Prop Cross	0.251***			0.061***		
	(0.019)			(0.009)		
Uninformative Prop Cross	0.226***			-0.004		
	(0.022)			(0.011)		
Informative Num Cross		0.073***			0.019***	
		(0.005)			(0.003)	
Uninformative Num Cross		0.055***			0.005*	
		(0.006)			(0.003)	
Informative Num Connected			0.024***			0.006***
			(0.001)			(0.001)
Uninformative Num Connected			0.020***			0.003***
			(0.001)			(0.001)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	25,679	25,679	25,679	18,776	18,776	18,776
R-squared	0.282	0.282	0.292	0.436	0.436	0.437

Panle D1: Tests on institutional cross-ownership's on-site visits and off-site visits (patent invalidation initiation perspective)

	Patent invalidation$_t$	*Patent invalidation$_{t+1}$*
Variable	(1)	(2)
Prop on-site visit	-0.019	0.220*
	(0.090)	(0.125)
Prop off-site visit	-0.044	0.101
	(0.052)	(0.096)
Controls	Yes	Yes
Firm fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Observations	12,097	9,499
R-squared	0.324	0.334

Panle D2: Tests on institutional cross-ownership's on-site visits and off-site visits (patent invalidation receipt perspective)

	Receive patent invalidation$_t$	*Receive patent invalidation$_{t+1}$*
Variable	(1)	(2)
Prop on-site visit	0.016	0.190*
	(0.074)	(0.100)
Prop off-site visit	-0.057	0.365
	(0.089)	(0.395)
Controls	Yes	Yes
Firm fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Observations	12,097	9,499
R-squared	0.442	0.437

Panle D3: Tests on institutional cross-ownership's on-site visits and off-site visits (knowledge spillover perspective)

	Network citation$_{t+1}$/All citation$_{t+1}$	*Network patent similarity$_{t+1}$*
Variable	(1)	(2)
Prop on-site visit	0.235*	0.168*
	(0.132)	(0.093)
Prop off-site visit	-0.014	-0.267
	(0.121)	(0.203)
Controls	Yes	Yes
Firm fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Observations	11,021	8,777
R-squared	0.318	0.505

Panle E1: Tests on information density in site visits by cross-holding institutional investors (patent invalidation initiation perspective)

	Patent invalidation$_t$		*Patent invalidation$_{t+1}$*	
Variable	(1)	(2)	(3)	(4)
Innovation words	-0.001		0.004*	
	(0.001)		(0.002)	
Executive attendance times		-0.003		0.007*
		(0.002)		(0.004)

Controls	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	27,353	27,353	22,320	22,320
R-squared	0.281	0.281	0.294	0.294

Panle E2: Tests on institutional cross-ownership's on-site visits and off-site visits (patent invalidation receipt perspective)

	Receive patent invalidation$_t$		*Receive patent invalidation$_{t+1}$*	
Variable	(1)	(2)	(3)	(4)
Innovation words	0.000		0.002	
	(0.001)		(0.002)	
Executive attendance times		0.001		0.002
		(0.003)		(0.003)
Controls	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	27,353	27,353	22,320	22,320
R-squared	0.373	0.373	0.382	0.382

Panle E3: Tests on institutional cross-ownership's on-site visits and off-site visits (knowledge spillover perspective)

	Network citation$_{t+1}$/All citation$_{t+1}$		*Network patent similarity$_{t+1}$*	
Variable	(1)	(2)	(3)	(4)
Innovation words	0.002		0.002***	
	(0.002)		(0.001)	
Executive attendance times		0.004		0.005***
		(0.004)		(0.001)
Controls	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	23,760	23,760	17,364	17,364
R-squared	0.287	0.287	0.442	0.442

Table 9 Testing alternative explanation

This table examines the impact of cross-shareholders' direct intervention on firms' patent invalidation claims, based on institutional cross-ownership appointing directors, supervisors, or senior executives (DSE) to the firms in which it holds shares. The purpose is to rule out the interference of the governance mechanism of direct intervention on the knowledge spillover channel studied in this paper. The sample includes Chinese listed firms from 2010 to 2022. Controls indicates that the same control variables as those presented in Table 1 are included but their coefficients are not reported. We examine how the appointment of DSE by cross-holding institutional investors affects the focal firm's initiation of patent invalidation claims. *Cross DSE/All DSE* refers to the proportion of DSE appointed by institutional shareholders relative to the total number of DSE in the focal firm. Standard errors are clustered at the firm level. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	Patent invalidation$_t$			*Patent invalidation*$_{t+1}$		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Prop Cross × Cross DSE/All DSE	-0.089**			0.004		
	(0.045)			(0.052)		
Prop Cross	0.029***			0.020*		
	(0.010)			(0.011)		
Num Cross × Cross DSE/All DSE		-0.034*			0.007	
		(0.019)			(0.022)	
Num Cross		0.011***			0.010**	
		(0.004)			(0.004)	
Num Connected × Cross DSE/All DSE			-0.002			-0.006
			(0.004)			(0.005)
Num Connected			0.002***			0.003***
			(0.001)			(0.001)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	29,989	29,989	29,989	24,836	24,836	24,836
R-squared	0.268	0.268	0.268	0.280	0.280	0.280

Table 10 Economic consequences test

This table contains a number of empirical attempts to explore the economic consequences of institutional cross-ownership promoting firms to initiate invalidation claims and participate in innovation competition. The sample includes Chinese listed firms from 2010 to 2022. Controls indicate that the same control variables as those presented in Table 1 are included, but their coefficients are not reported. In Panel A, we examine the impact on the cumulative abnormal returns (CARs) of focal firms, depending on their roles and scenarios in patent invalidation events. Specifically, we categorize patent invalidation into two types: one in which the focal firm acts as the initiator, and the other in which the focal firm is the recipient. Each of these events is further divided based on whether the outcome was a success or a failure. Since the outcome of a patent invalidation cannot be reliably predicted before the decision is announced, and given the low likelihood of early information leakage, we employ multiple event windows: [0, 1], [0, 3], [0, 7], [0, 15], [0, 30], [0, 60], [0, 120], [0, 180], and [0, 360]. The window [-185, -6] is used as the estimation period for calculating expected returns. In Panel B, we present how a firm's involvement in patent invalidation affects the investment portfolio returns of its common institutional shareholders. Specifically, we construct two interaction variables: *Cross dummy × Initiate patent invalidation dummy*, which equals 1 if an institutional shareholder's portfolio includes a firm that initiates a patent invalidation; and *Cross dummy × Receive patent invalidation dummy*, which equals 1 if the portfolio includes a firm that receives a patent invalidation. Both variables equal 0 otherwise. In Panel C, we investigate how initiating or receiving a patent invalidation affects the focal firm's innovation. *RD input* is defined as R&D expenditure divided by operating income. *RD output* refers to the natural logarithm of the total number of patents filed by the focal firm add one. *RD output*/*RD input refers to RD output* divided by *RD input*. *Patent citation* represents the natural logarithm of the total number of the focal firm's citation add one. In Panel D, we investigate how initiating or receiving a patent invalidation affects the focal firm's economic performance, measured as total factor productivity. *LP TFP*, *OP TFP*, *OLS TFP*, and *FE TFP* refer to total factor productivity measured using the Levinsohn-Petrin, Olley-Pakes, Ordinary Least Squares, and Fixed Effects methodologies, respectively. In Panel E, we investigate how initiating or receiving a patent invalidation affects the innovation behavior of peer firms within institutional cross-ownership network. We measure the relevant network innovation behaviors using the average values of the corresponding variables within the institutional cross-ownership network, which are denoted as *Network RD input* , *Network RD output*, *Network RD input*/*Network RD output*, and *Network patent citation*. In Panel F, we investigate how initiating or receiving a patent invalidation affects the economic performance of peer firms within institutional cross-ownership network. We measure the relevant network economic performance using the average values of the corresponding variables within the institutional cross-ownership network, which are denoted as *Network LP TFP*, *Network OP TFP*, *Network OLS TFP*, and *Network FE TFP*. Standard errors clustered at firm level.*, **, and *** represent significance at the 10%, 5%, and 1% levels respectively.

Panle A: Tests based on the market reaction to the emission and Receipt of patent invalidation

	The events of initiating patent invalidation		The events of receiving the patent invalidation	
	Succeed	Failed	Succeed	Failed
	(1)	(2)	(3)	(4)
CAR [0,1]	0.004***	-0.002	-0.002	-0.000
	(0.001)	(0.001)	(0.004)	(0.001)
CAR [0,3]	0.008***	-0.001	-0.007*	0.001
	(0.002)	(0.002)	(0.004)	(0.002)
CAR [0,7]	0.006***	-0.002	-0.009**	0.000
	(0.002)	(0.002)	(0.004)	(0.003)

CAR [0,15]	0.008***	-0.005	-0.008	-0.000
	(0.003)	(0.003)	(0.005)	(0.004)
CAR [0,30]	0.011***	-0.002	-0.004	0.003
	(0.004)	(0.004)	(0.005)	(0.005)
CAR [0,60]	0.010*	-0.000	-0.001	-0.000
	(0.006)	(0.007)	(0.007)	(0.007)
CAR [0,120]	0.016**	-0.002	0.007	0.005
	(0.008)	(0.009)	(0.009)	(0.010)
CAR [0,180]	0.014	-0.004	0.012	0.001
	(0.010)	(0.011)	(0.011)	(0.012)
CAR [0,360]	0.005	-0.019	0.016	-0.024
	(0.015)	(0.017)	(0.017)	(0.019)

Panle B: Tests based on the portfolio return of cross-holding institutional investors

	Portfolio value$_{t+1}$		*Portfolio TobinQ*$_{t+1}$	
Variable	(1)	(2)	(3)	(4)
Cross dummy × Initiate patent invalidation dummy	0.124**		0.042***	
	(0.054)		(0.009)	
Cross dummy × Receive patent invalidation dummy		0.119*		0.054***
		(0.065)		(0.011)
Cross dummy	0.156***	0.161***	0.000	0.001
	(0.021)	(0.021)	(0.003)	(0.003)
Initiate patent invalidation dummy	0.085*		0.000	
	(0.048)		(0.006)	
Receive patent invalidation dummy		0.025		-0.001
		(0.058)		(0.007)
Shareholder-industry fixed effects	Yes	Yes	Yes	Yes
Shareholder × Year fixed effects	Yes	Yes	Yes	Yes
Shareholder × Industry fixed effects	Yes	Yes	Yes	Yes
Observations	42,173	42,173	42,173	42,173
R-squared	0.912	0.912	0.857	0.857

Panle C: Tests based on the innovation performance of the focal firm

	RD input$_{t+1}$		*RD output*$_{t+1}$		*RD output*$_{t+1}$/*RD input*$_{t+1}$		*Patent citation*$_{t+1}$	
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

Patent invalidation	0.333**		0.004		0.003*		0.087**	
	(0.144)		(0.038)		(0.001)		(0.044)	
Receive patent invalidation		-0.024		0.001		0.002		0.026
		(0.102)		(0.035)		(0.002)		(0.047)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	23,132	23,132	28,277	28,277	23,723	23,723	28,197	28,197
R-squared	0.867	0.867	0.807	0.807	0.740	0.740	0.764	0.764

Panle D: Tests based on the economic performance of the focal firm

	LP TFP_{t+1}		*OP* TFP_{t+1}		*OLS* TFP_{t+1}		*FE* TFP_{t+1}	
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Patent invalidation	0.033**		0.022*		0.036***		0.039***	
	(0.013)		(0.012)		(0.013)		(0.013)	
Receive patent invalidation		0.015		0.015		0.020		0.021
		(0.013)		(0.012)		(0.013)		(0.013)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	27,734	27,734	27,734	27,734	27,734	27,734	27,734	27,734
R-squared	0.914	0.914	0.889	0.889	0.941	0.941	0.945	0.945

Panle E: Tests based on the innovation performance of the peer firms within institutional cross-ownership network

	Network RD input$_{t+1}$		*Network RD output*$_{t+1}$		*Network RD output*$_{t+1}$ / *Network RD input*$_{t+1}$		*Network patent citation*$_{t+1}$	
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Patent invalidation ($\times 10^{-2}$)	3.545**		-0.574		-0.033**		1.739*	
	(1.782)		(0.362)		(0.017)		(0.961)	
Receive patent invalidation ($\times 10^{-2}$)		-2.987		-0.317		-0.017		-0.750
		(2.533)		(0.478)		(0.026)		(0.938)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	25,180	25,180	25,213	25,213	25,196	25,196	25,290	25,290
R-squared	0.610	0.610	0.587	0.587	0.499	0.499	0.843	0.843

Panle F: Tests based on the economic performance of the peer firms within institutional cross-ownership network

	Network LP TFP_{t+1}		*Network OP* TFP_{t+1}		*Network OLS* TFP_{t+1}		*Network FE* TFP_{t+1}	
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Patent invalidation	0.014		0.010		0.018		0.020	
	(0.010)		(0.007)		(0.013)		(0.013)	
Receive patent invalidation		-0.007		-0.004		-0.007		-0.008
		(0.011)		(0.008)		(0.014)		(0.015)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	25,278	25,278	25,278	25,278	25,278	25,278	25,278	25,278
R-squared	0.668	0.668	0.720	0.720	0.649	0.649	0.642	0.642

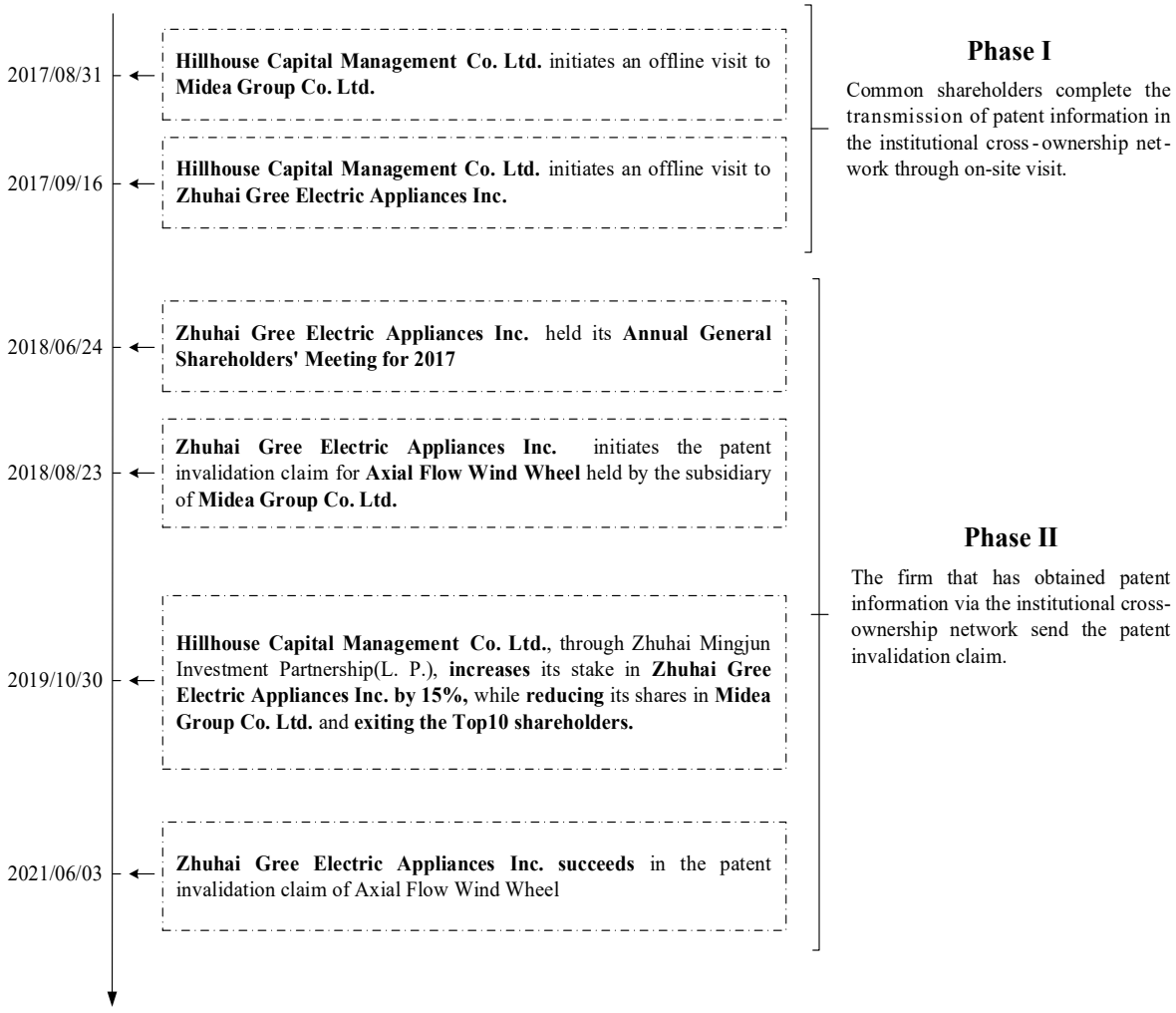


Figure 1. Timeline of the case on patent invalidation. This figure illustrates a representative case published by the National Intellectual Property Administration of China. It shows the patent invalidation process initiated by Gree against the "Key Technologies for Silent Air Conditioners" patent owned by Midea (for details, see Appendix A). The timeline marks the key activities and milestones of the common shareholder, Hillhouse Capital, during the entire patent invalidation process.

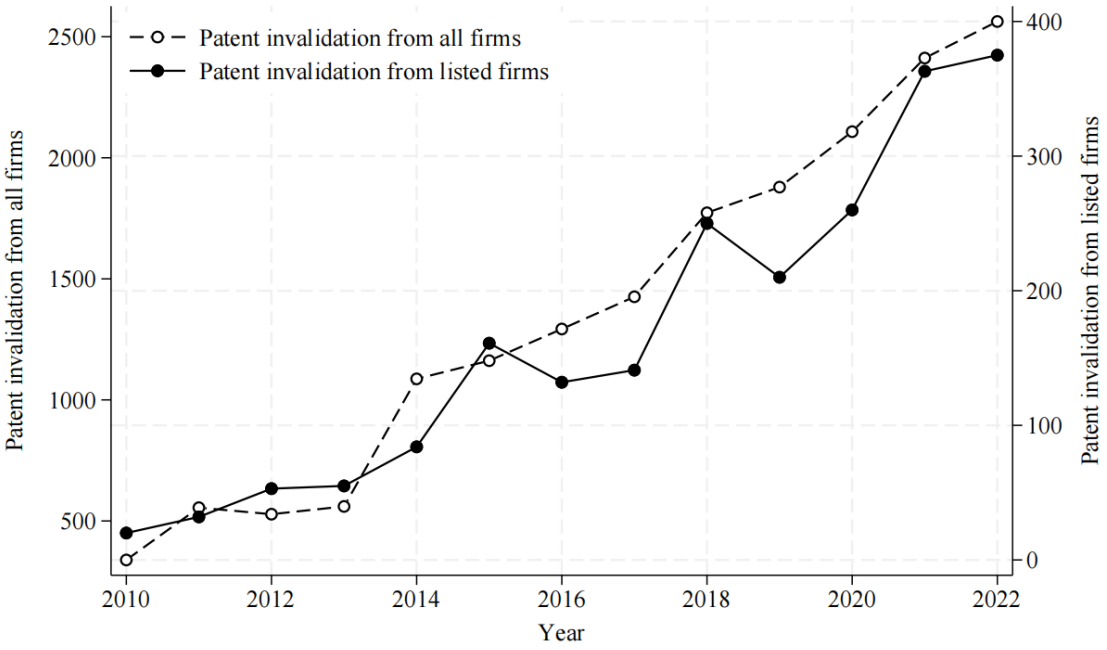


Figure 2. Time Trend Chart from 2010 through 2022. This figure illustrates the trend in the number of patent invalidation cases initiated by all Chinese firms and by listed firms. The horizontal axis represents the year; the left vertical axis (dotted line) shows the number of patent invalidation cases initiated by all Chinese firms, while the right vertical axis (solid line) indicates the number of cases initiated by Chinese listed firms.

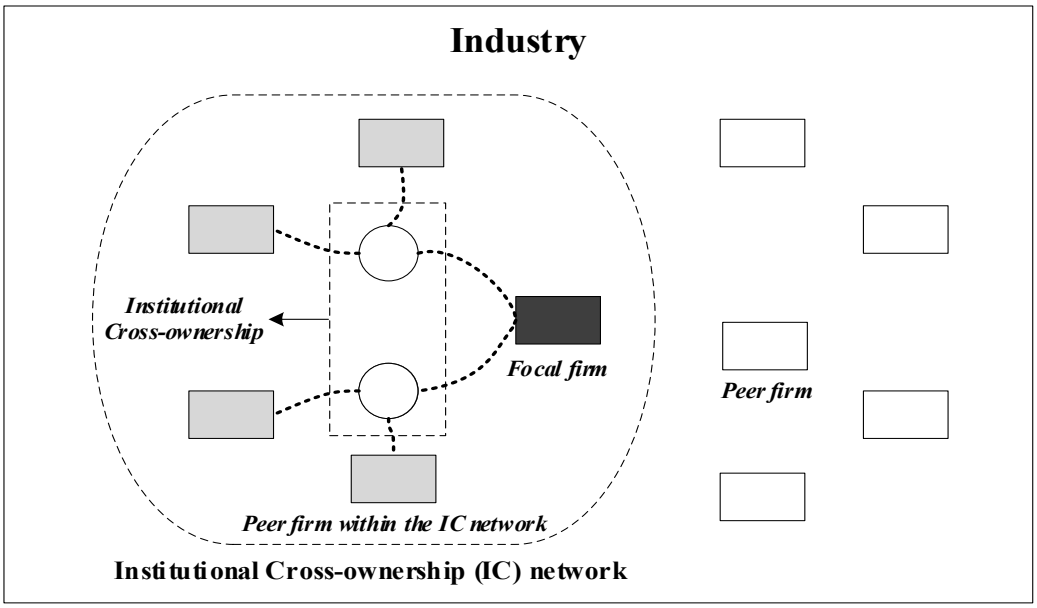


Figure 3. Classification of Competing Firms Based on Peer Networks. This figure illustrates the composition of the peer network, including focal firms, competing firms within the network, and firms outside the network. Distinct icons differentiate the entities: dark circles represent institutional shareholders, black squares represent focal firms, gray squares denote peer firms within the ownership network, and white squares represent peer firms outside the network. This diagram highlights the ownership connections among peer firms and the position of the focal firm within the network.

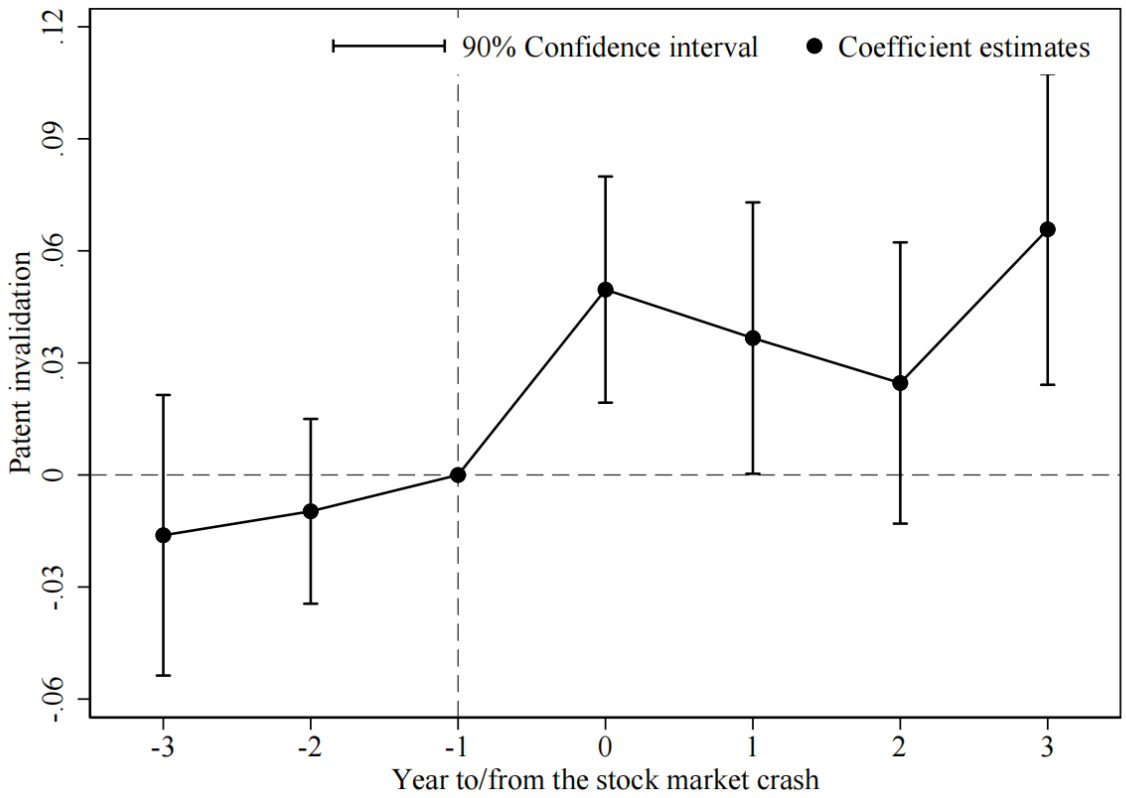
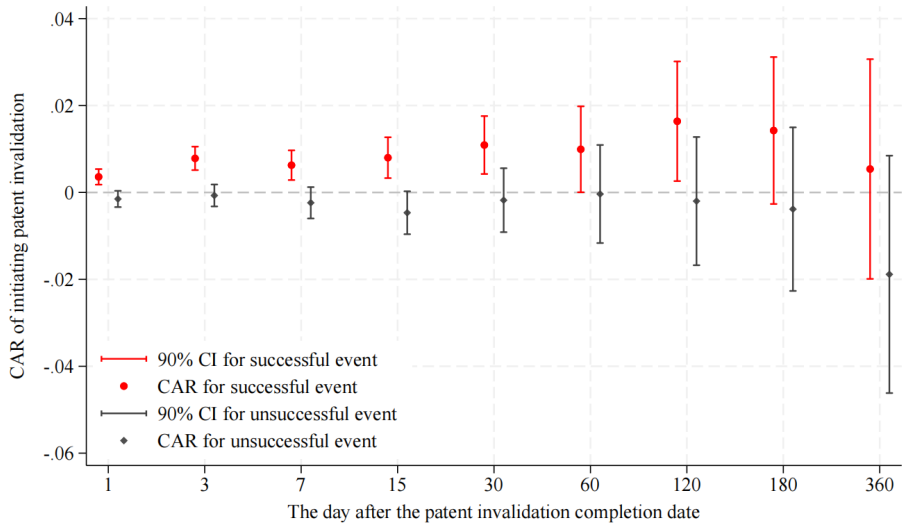
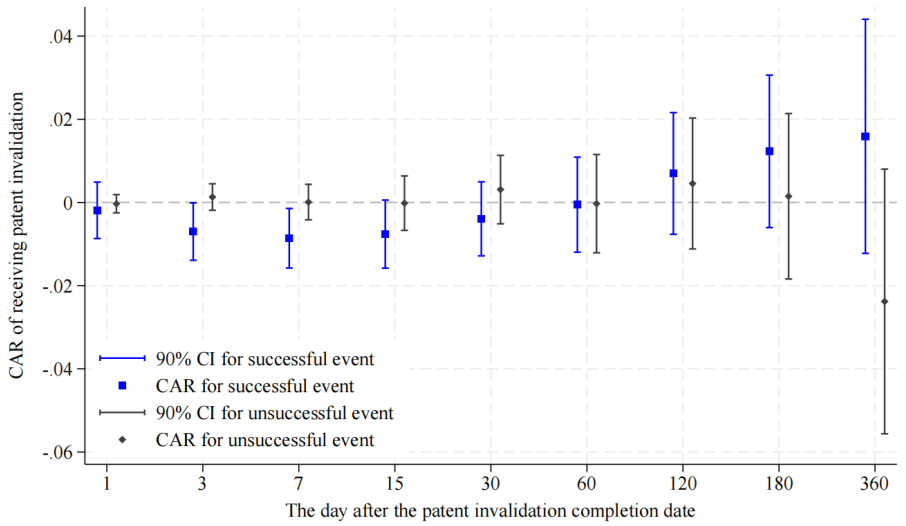


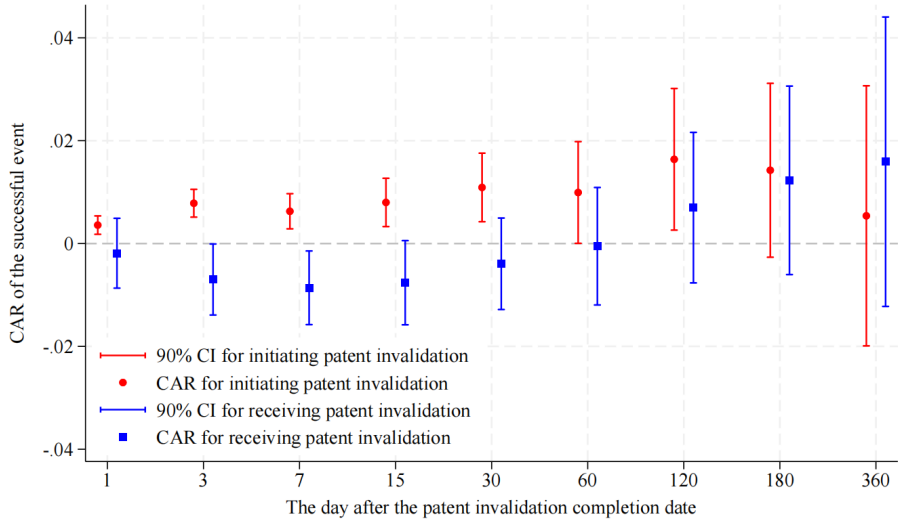
Figure 4. Event Study of the 2015 Stock Market Crash. This figure shows the dynamic DiD effects of the "national team" market rescue during the 2015 Chinese stock market crash. The base period is set as *t* -1 (before the event), with a 90% confidence interval. The horizontal axis indicates the time relative to the event, and the vertical axis shows the estimated treatment effects. The black dots represent the estimated coefficients at each time point.


CAR of initiating patent invalidation
.04
.02
0
-.02
-.04
-.06
90% CI for successful event
CAR for successful event
90% CI for unsuccessful event
CAR for unsuccessful event
1
3
7
15
30
60
120
180
360
The day after the patent invalidation completion date

(a)


CAR of receiving patent invalidation
.04
.02
0
-.02
-.04
-.06
90% CI for successful event
CAR for successful event
90% CI for unsuccessful event
CAR for unsuccessful event
1
3
7
15
30
60
120
180
360
The day after the patent invalidation completion date

(b)


CAR of the successful event
.04
.02
0
-.02
-.04
90% CI for initiating patent invalidation
CAR for initiating patent invalidation
90% CI for receiving patent invalidation
CAR for receiving patent invalidation
1
3
7
15
30
60
120
180
360
The day after the patent invalidation completion date

(c)

Figure 5. Cumulative Average Abnormal Returns in the Event Window. Panel (a) shows the dynamic effect of the focal firm acting as the initiator of a patent invalidation on its cumulative abnormal returns (CARs) after the invalidation completion date. The horizontal axis indicates the decision date by the China National Intellectual Property Administration (CNIPA) on whether the patent invalidation is upheld. The vertical axis shows the dynamic CARs: red indicates that the patent is invalidated by CNIPA, while gray denotes an unsuccessful attempt. Panel (b) shows the dynamic effect on the CARs when the focal firm is the recipient of a patent invalidation. The horizontal axis indicates the CNIPA's decision date. The vertical axis shows the dynamic CARs: blue indicates successful invalidation by CNIPA, while gray indicates that the attempt fails. Panel (c) compares the CARs of focal firms acting as initiators and recipients of patent invalidations at various time intervals after CNIPA's invalidation decision. Red represents initiators, blue represents recipients. The confidence interval is 90%.

Internet Appendix (Not to be published)

Internet Appendix A: The case of Axial Flow Wind Wheel

1 Patent Invalidation Case Analysis

The patentee of the *Axial Flow Wind Wheel* (Patent No.: *ZL200710026747.4*) is Guangdong Midea Refrigeration Equipment, a subsidiary of *Midea Group* (*Stock Code: SZ.000333,* referred as *Midea f*or short in the following text). The petitioner for the patent invalidation is *Zhuhai Gree Electric Appliances* (*Stock Code: SZ.000651*, referred as *Gree* for short in the following text). Gree initiated the patent invalidation claims on August 23, 2018. Ultimately, on June 3, 2021, the National Intellectual Property Administration (CNIPA) issued a ruling declaring the Axial Flow Wind Wheel patent invalid. As shown in Figure A1, the CNIPA selected this patent invalidation case as one of the top ten representative cases, and it was subsequently featured on its official website.

2 Common shareholders of Gree and Midea

Using the "Qixinbao" application platform to analyze the equity networks of Midea and Gree, we discovered that during the period of the case, the two firms shared three cross-holding shareholders: Hillhouse Capital, China Securities Finance Co., Ltd., and Central Huijin Investment Co., Ltd..

Hillhouse Capital, founded by Lei Zhang in 2005, began with an initial management fund of $20 million. By 2025, its assets under management have surpassed $60 billion, making it one of the largest investment funds in Asia in terms of assets. The funds it manages primarily come from global long-term institutional investors, such as university endowment funds and sovereign wealth funds. Hillhouse Capital began investing in Midea at the end of 2015, initially purchasing approximately 1 billion RMB worth of shares at an average cost of 18 RMB per share. In mid-2016, Hillhouse Capital increased its holdings by 39.775 million and 44 million shares in two consecutive quarters, reaching a total of 108 million shares in Midea by early 2018. Meanwhile, following the market downturn in early 2016, Hillhouse Capital began investing in Gree , with an initial investment of about 872 million RMB. In the third quarter of 2019, Hillhouse Capital significantly reduced its holdings in Midea, stepping out of the list of top ten shareholders. During the same period, Hillhouse Capital participated in Gree's mixed-ownership reform and ultimately became its major shareholder.

China Securities Finance Co., Ltd. was established on October 28, 2011, with the consent of the State Council of China and approval from the China Securities Regula-tory Commission. It is a national securities financial institution and a state-controlled enterprise. The firm is positioned as the sole operator of the refinancing business, providing specialized services

for securities firms' margin trading and short-selling activities, while regulating the supply of funds and securities in the market through market-oriented means. As the only legal entity in China engaged in refinancing,China Securities Finance Co., Ltd. plays a crucial role in maintaining market liquidity and mitigating systemic risks. It was also part of the "national team" that intervened during the 2015 stock market crash. Since 2015, China Securities Finance Co., Ltd. has been a stable institutional investor in both Midea and Gree, holding more than 1% of the shares in both firms.

Central Huijin Investment Co., Ltd. was established on December 16, 2003, and is an authorized state financial capital management platform by the State Council of China. After becoming a wholly-owned subsidiary of China Investment Corporation (CIC) in September 2007, its important shareholder responsibilities are still exercised directly by the State Council. Its core function is to make equity investments in key state-owned financial firms, exercising the rights of the investor up to the amount of capital contribution to achieve the preservation and appreciation of state-owned financial assets. Its operating principle is not to engage in commercial business activities and not to intervene in the daily operations of the holding firms. Central Huijin Investment Co., Ltd. stabilizes the capital market through methods such as increasing its holdings in state-owned large banks and is seen as a representative of the "national team." Since 2015, Central Huijin Investment Co., Ltd. has also been a stable institutional investor in Midea and Gree, with a holding ratio of more than 1% in both firms.

We compile the shareholding percentages of the three common shareholders in both firms from 2016 to 2018, which are presented in Table A1.

3 How co-shareholders can facilitate information transfer?

The evidence that co-shareholders facilitate information transfer stems from communication and exchange between investors and firms. Investor Relations Activities represent one of the most common forms of communication, encompassing targeted research, media interviews, press releases, site visits, analyst meetings, earnings presentations, and roadshow activities. In this section, we provide evidence of communication and exchange between the common shareholders of the two firms prior to the case and organize it to support the argument that communication among co-shareholders facilitates information transfer.

Hillhouse Capital attended Midea's earnings briefing and analyst meeting in Septem ber 2017, as well as Gree's investor research activity in October 2017, as documented in their respective investor relations records (see Figure A2, Figure A3, and Figure A4). In Midea's September 2017 investor relations record, the first question raised was: "*What progress has the firm made in technology research and development in the first half of the year?*" In response, Midea highlighted research projects, including "*Research and Industrializa tion of Key*

Technologies for Silent Integrated Air Conditioners". Upon further verifi cation, *the invalidated patent (Axial Flow Wind Wheel, patent number: 200710026747.4) was identified as a core intellectual property outcome of this project, ranking second in its importance* (see Figure A5).

Figure 1 presents a timeline that illustrates the relationship between the meeting initiation times of the two peer firms and the timing of the "Axial Flow Wind Wheel" patent invalidation, with Hillhouse Capital acting as a common shareholder. From August 31 to September 1, 2017, Hillhouse Capital attended Midea's analyst meeting and earnings presentation, where it obtained technical details about the "Axial Flow Wind Wheel" patent. Then, between September 16 and 29, 2017, Hillhouse Capital conducted investor research on Gree. On August 23, 2018, Gree filed a patent invalidation against Midea's "Axial Flow Wind Wheel" patent.

Additionally, we observe an intriguing post-fact phenomenon. In 2018, the same year that Gree initiated a patent invalidation against Midea, Hillhouse Capital began reducing its holdings in Midea. By the third quarter of 2019, as disclosed in Midea's shareholder report, Hillhouse Capital had completed its divestment from Midea, officially exiting the list of top ten shareholders. Similarly, in the fourth quarter of 2019, Hillhouse Capital acquired a 15% stake in Gree at a price of 46.17 RMB per share, with a total transaction value of 41.662 billion RMB, becoming the largest shareholder of Gree Electric Appliances. In June 2021, the China National Intellectual Property Administration (CNIPA) determined that Gree's patent invalidation of Midea's "Axial Flow Wind Wheel" patent was successful. This situation is also documented in the timeline shown in Figure 1.

Tables and Figures in Appendix A

Table A1 Shareholding proportion of CIO

Name	Year	Holds in Gree	Holds in Midea
Hillhouse Capital Management Co. Ltd.	2016	0.84%	1.76%
	2017	0.84%	1.74%
	2018	0.72%	1.07%
China Securities Finance Co. Ltd.	2016	2.08%	2.79%
	2017	2.78%	3.39%
	2018	2.99%	2.97%
Central Huijin Asset Management Co. Ltd.	2016	1.40%	1.22%
	2017	1.40%	1.20%
	2018	1.40%	1.18%



Figure A1. The case shown on official website of the China National Intellectual Property Administration.

证券代码：000333　　证券简称：美的集团

美的集团股份有限公司投资者关系活动记录表

Midea Group Co. Ltd. 's Investor Activity Relationship Record Form

编号：2017-12

投资者关系活动类别	□特定对象调研	■分析师会议 Analyst meeting
	□媒体采访	■业绩说明会 Earnings briefing
	□新闻发布会	□路演活动
	□现场参观	
	□其他	
参与单位名称	嘉实基金、高瓴资本 Hillhouse Capital Management Co. Ltd.、中银基金、建信基金、中金资管、中信自营、南方基金、景顺长城基金、高毅资产、中信建投、施罗德基金、平安资产、中金资管、富敦基金、法国巴黎投资管理、光富资产、工银安盛、嘉实基金、海富通基金、东方证券、中邮创业基金、银河基金、宏道投资、景林资产、汇添富基金、华泰资管、嘉实基金、光大保德信基金、鑫元基金、华安基金、復华基金、长金投资、阳光资产、奥氏资本、高毅资产、华夏创新、东方资管、平安资产、國泰投信、长信基金、长信基金、瀚伦投资、国泰基金、易方达基金、华泰资管、阳光资产、信达澳银基金、淡马锡富敦、交银施罗德基金、富国基金、光大保德信基金、泰达宏利基金、长金投资、南山人壽、元大证券、BROAD PEAK、信诚基金、野村资管、安本亚洲、上投摩根基金、中欧基金、华安基金、源和资产、鹏华基金、静远资本、毕盛资产、泓铭资本、纳静资产、光大保德信基金、富安达基金、光大证券、中国人保资产、中海基金	
Time 时间	2017 年 8 月 31 日-9 月 1 日	2017/08/31-2017/09/01
Site 地点	公司、上海	Firm, Shanghai
上市公司接待人 Names of the reception staff of the listed firm	公司管理层	Management personnel

Figure A2. The investor information section of Midea Group Co., Ltd.'s investor activity relationship record form

员姓名	1.What progress has the company made in technological R&D in the first half of the year? 1、公司上半年在科技研发方面取得哪些进展？
投资者关系活动主要内容介绍	坚持加大研发投入与研发机制创新，通过技术创新，用户创新，产品创新，开放式创新体系建设及技术创新规划体系等多个平台来支撑美的技术突破，继续深化美的四级研发体系管理模式，关注先行研究，布局中长期技术储备与长期竞争能力；在从事核心技术研究的同时，更加注重研发成果的转化，持续获得多项奖励及认定，2017 年上半年，包括整体式空调器静音关键技术研究及产业化、IH 电饭煲核态沸腾及焖香补炊关键技术研究和产业化、全变频准二级压缩技术及其在多联机上的应用、家用吸油烟机智能蒸汽清洗技术的研究与应用、微波炉用新一代变频电源关键技术研究、模块化易清洁材料及其在厨房电器的应用、交流无极变频技术等在内的共 14 项技术被鉴定为“国际领先水平”；在工业设计领域，14 项工业设计获 2017 年德国 IF 奖；16 项工业设计获 2017 年德国红点奖。 2017 年上半年，公司继续推动全球化研发布局，在整合全球研发资源，加速技术研究、实现本土化开发方面取得了进一步纵深发展：4 月硅谷未来技术中心办公大楼落成并挂牌、路易斯维尔研发中心新迁办公室；5 月日本研究所成立、美的欧洲研发和创新中心在奥地利格拉茨成立；6 月美的用户体验创新（上海）实验室挂牌；7 月新加坡研发中心入驻，目前美的已在全球建立 17 个研发中心，在强化全球研发中心布局的同时，美的更与 MIT, UC Berkeley，UIUC，Stanford、Purdue University、清华、中科院等国内外顶级科研机构签

Research and Industrialization of Key Technologies for Silent Operation of Unitary Air Conditioners

Figure A3. The investor inquiry and response section of Midea Group Co., Ltd.'s investor activity relationship record form

证券代码：000651　　证券简称：格力电器

珠海格力电器股份有限公司
投资者关系活动记录表

Zhuhai Gree Electric Appliances Inc. 's Investor Activity Relationship Record Form

编号：01

投资者关系活动类别	■特定对象调研　□分析师会议 Visit on Specific Objects □媒体采访　□业绩说明会 □新闻发布会　□路演活动 □现场参观 ■其他　投资者交流会　Other Investor Exchange Meetings
参与单位名称及人员姓名	EAST CAPITAL 傅迪明　GAM Michelle Lam　GSA Capital Colin Sim Pv Capital Siliang Jiang 建安投资 李申　Himalaya Capital 潘胤瑾 TT International 蔡昀浩　EurizonCapital HK 李树仁 毅恒资本 郭远山 中民资产 陈欣欣　施罗德投资 刘佳 万方资产 刘鎏 晋融资产 曹海研 富敦投资 李茂　北京高华 伊健　鸿森 陈名 EverPoint 钟捷 睿思资本 张蕴荷 MACKENZIE Darren Mckiernan Senrigan 李雪 华夏基金 潘中宁 行健资产 陈嘉燕 PeakRe 黎国梁 复星集团 曹敏 高华证券 糜宵菁 高瓴资本 徐睿　才华资本 唐毅 天平资产 郭莺 宝盈基金 肖肖 百川投资 伍思颖 泰达宏利 王鹏 鲍尔太平 罗贤润 中国人寿 周伟业　中原资产 崔哲语 稻草人投资 幸琳 禾其投资 吴迪 中原资产 李岩 Valinor Alex Hoffer 国泰人寿 王裕群 GIC 杜达成 UBS 诸纪琼　毅恒资本 闫萌　三井住友 卢亦卓 翰伦投资 汪帅 Comgest 陈学亮 石壁投资 区伟志 Pleiad 梁涵 路博万 邱敬媛 路博万 肖笛　Jefferies 福原捷 Fokger hill 小林阳介 广发证券 曾婵 新百信控股 陈天公　中原资产 翟宇 Invesco 钟颖旗 道富环球 杨子毅 UBS 彭燕燕 宏利资产 张一凡 UBS 孙宵宇 高观投资 史怀正 景林投资 高云程 上海奕慧投资 王殷超 国泰君安 李泽明 广州证券 叶文辉 广发资产 毛丁丁 高润资本 韩飞 多和美 曹小凤 Hillhouse Capital Management Co. Ltd.
Time 时间	2017 年 09 月 16 日-09 月 29 日　2017/09/16-2017/09/29
Site 地点	公司会议室、深圳、武汉、香港　Company meeting room, Shenzhen, Wuhan, Hong Kong
Names of the reception staff of the listed firm 上市公司接待人员姓名	公司副总裁、财务负责人、董事会秘书望靖东、证法部部长助理李明晶；投资者关系管理专员谭海雁、投资管理专员叶洁云、投资管理专员吴青青 Vice President of the company, Financial Controller, Board Secretary Wang Jingdong, Assistant Minister of the Legal Affairs Department for Securities Li Mingjing; Investor Relations Management Specialist Tan Haiyan, Investment Management Specialists Ye Jieyun and Wu Qingqing.

Figure A4. Zhuhai Gree Electric Appliances's investor activity relationship record form

科 技 成 果 登 记 表

Registration Form for Scientific and Technological Achievements

（应用技术类成果）

一、成果概况			
1．成果名称	整体式房间空调器静音关键技术研究及产业化 Research and Industrialization of Key Technologies for Silent Operation of Unitary Air Conditioners		
2．关键词	①静音	②整体式	③房间空调器
3．成果类别	应用技术	4．成果体现形式	新产品
5．成果属性	原始性创新	6．成果所处阶段	成熟应用阶段
7．成果水平	国际领先	8．转让范围	不转让
9．研究形式	独立研究	10．所属高新技术领域	新能源与高效节能
11. 主要应用行业	制造业		
12．学科分类	①470.40	②	
13．中图分类	①TM925.12	②	
14. 研究起始日期	2014-10	15. 研究终止日期	2016-06
16. 批准登记日期	2017-04-15		
二、立项情况			
1. 课题来源	自选	2. 国家科技计划子类别	
3．课题立项名称		4.课题立项编号	
5．经费实际投入额（万元）	2000.		
三、评价情况			
1. 评价方式	鉴定	2. 评价单位	中国轻工业联合会
3. 评价日期	2017-04-15	4. 评价报告编号	中轻联科鉴[2017]027
5. 评价委员会名单	王浚;石文星;田金文;谢磊;赵淦森;黄敏;赖静		
四、知识产权状况 Intellectual property status			
1. 知识产权形式	1 Patent number: 200710026747.4; Patent title: *Axial-flow wind wheel;* Patent status: Granted patent; Patent type: Invention patent NOTE: This is the ***Patent Invalidation*** related patent.	2. 专利状况	专利号：PCT/CN2016/104101;专利名称：移动空调;专利状况：已受理专利;专利类型：发明专利 专利号：200710026747.4;专利名称：轴流风轮;专利状况：已授权专利;专利类型：发明专利 专利号：201210083581.0;专利名称：离心风轮及其具有离心风轮的空气处理装置;专利状况：已授权专利;专利类型：发明专利 专利号：201210113831.0;专利名称：贯流风轮及其具有贯流风轮的空气处理装置;专利状况：已授权专利;专利类型：发明专利 专利号：201210160869.3;专利名称：一种导叶或静叶及具有该导叶或静叶的空气处理装置;专利状况：已授权专利;专利类型：发明专利 专利号：201310105081.7;专利名称：空调器及其出风温度控制方法;专利状况：已授权专利;专利类型：发明专利 专利号：201410456511.4;专利名称：空调室外机;专利状况：已授权专利;专利类型：发明专利 专利号：201210311278.1;专利名称：空调器;专利状况：已授权专利;专利

Figure A5. Registration form for scientific and technological achievements of research and industrialization of key technologies for silent operation of unitary air Conditioners.

Internet Appendix B: Additional Tables and Figures

Table B1 Definitions of variables

This table reports the main variables involved in this paper and their definitions. In Panel A, we report the variable definitions related to the baseline study. In Panel B, we report the variable definitions related to the robustness check. In Panel C, we report the definitions of the variables used for alleviating endogeneity. In Panel D, we report the variable definitions used for the heterogeneity check. In Panel E, we report the variable definitions related to the channel test. In Panel F, we report the variable definitions related to the economic consequences test.

Panel A: Variables related to the baseline regression

Variables	Definition
Num patent invalidation$_{i,t}$	Equals to ln(1+ total number of patent invalidation initiated by focal firm *i* and their subsidiaries in fiscal year *t*).
Prop Cross$_{i,t}$	The proportion of shareholders among the Top 10 shareholders of focal firm *i* in fiscal year *t* who also hold shares in other listed firms in the same industry. When calculating the number of annual cross-holding institutional investors, the average of the four quarters of each fiscal year *t* is used.
Num Cross$_{i,t}$	Equals to ln(1+ the number of shareholders among the Top 10 shareholders of focal firm *i* in fiscal year *t* who also hold shares in other listed firms in the same industry). When calculating the number of annual cross-holding institutional investors, the average of the four quarters of each fiscal year *t* is used.
Num Connected$_{i,t}$	Equals to ln(1+the number of the peer firms within the institutional cross-ownership network, whose focal firm is *i* and fiscal year is *t*). When calculating the number of other firms connected by cross-holding institutional investors, the average of the four quarters of each fiscal year *t* is used.
Assets$_{i,t}$	Equals to ln(the total assets of the focal firm *i* at the end of the fiscal year *t*).
Leverage$_{i,t}$	Equals to the ratio of the total liabilities to total assets of the focal firm *i* at the end of the fiscal year *t*.
Cash/Assets$_{i,t}$	Equals to the net cash flow from operating activities divided by the average total assets, for the focal firm *i* within the fiscal year *t*.
ROA$_{i,t}$	Equal to the earnings before interest and tax divided by the average total assets, for the focal firm *i* within the fiscal year *t*.
Sales growth$_{i,t}$	Equals to the annual growth rate of operating income of the focal firm *i* at the fiscal year *t*.
Grant patent$_{i,t}$	Equals to ln(1+the number of patents granted to the focal firm *i* within the fiscal year *t*).
Firm age$_{i,t}$	Equals to ln(1+the number of years that the focal firm *i* has experienced from its establishment time to the fiscal year *t*).
Institutional investors shareholding$_{i,t}$	Equals to the total number of shares held by institutional investors divided by the total number of shares, for the focal firm *i* within the fiscal year *t*.

Top10 ownership concentration$_{i,t}$	Equals to the number of shares hold by OCR shareholders divided by the total number of shares, for the focal firm *i* within the fiscal year *t*.
Separation of ownership and control$_{i,t}$	Equals to the proportion of control rights held by the actual controller subtract the proportion of ownership held by the actual controller, for the focal firm *i* within the fiscal year *t*.
Audit fee$_{i,t}$	Equals to ln(1+ the audit fee of the focal firm *i* within the fiscal year *t*).
Female executives$_{i,t}$	Equals to the number of female executives divided by the total number of executives, for the focal firm *i* within the fiscal year *t*.
Industry$_{i,t}$	The industry code of the CSRC in 2012. Among them, except for the manufacturing industry, the rest of the industries use the first-level class code. Manufacturing uses second-level classification codes.

Panel B: Variables related to the robustness check

Variables	Definition
3-digit ind Prop Cross$_{i,t}$	The proportion of shareholders among the Top 10 shareholders of focal firm *i* in fiscal year *t* who also hold shares in other listed firms in the same industry. When calculating the number of annual cross-holding institutional investors, the average of the four quarters of each fiscal year *t* is used. Besides, all of the industries use the third-level classification codes of the CSRC in 2012.
3-digit ind Num Cross$_{i,t}$	Equals to ln(1+ the number of shareholders among the Top 10 shareholders of focal firm *i* in fiscal year *t* who also hold shares in other listed firms in the same industry). When calculating the number of annual cross-holding institutional investors, the average of the four quarters of each fiscal year *t* is used. Besides, all of the industries use the third-level classification codes of the CSRC in 2012.
3-digit ind Num Connected$_{i,t}$	Equals to ln(1+the number of the peer firms within the institutional cross-ownership network, whose focal firm is *i* and fiscal year is *t*). When calculating the number of other firms connected by cross-holding institutional investors, the average of the four quarters of each fiscal year *t* is used. Besides, all of the industries use the third-level classification codes of the CSRC in 2012.

Panel C: Variables related to the robustness check

Variables	Definition
Merge$_{i,t}$	Equals to the number of absorption mergers initiated by the top 10 shareholders of the focal firm *i* within the fiscal year *t*.
Treat$_i$	If the focal firm *i* was held by the national team during 2015-2018 and constituted institutional shareholder cross-holdings, but was not held by the national team during 2012-2014, it was set as the experimental group, and *Treat*$_i$ was equal to 1. If the focal firm *i* has not been an institutional shareholder cross-holdings between 2012 and 2018, it is set as a control group, and *Treat*$_i$ was equal to 0.
Post$_t$	If the the fiscal year *t* is equal or greater than 2015, the year of the stock market crash, *Post*$_t$ is equal to 1. Otherwise, *Post*$_t$ is equal to 0.

$DiD_{i,t}$	Equals to $Treat_i \times Post_t$.

Panel D: Variables related to the heterogeneity check

Variables	Definition
$CR_{i,t}$	Equals to the ratio of total revenue of the Top 8 firms with the highest revenue in focal firm *i* 's industry during fiscal year *t* to the industry's total revenue. Categorized as a high *CR* group when this value exceeds the sample median, and a low *CR* group otherwise.
Government-regulated industry$_{i,t}$	Equals to 1 if the the focal firm *i*'s industry is government-regulated industry at the end of fiscal year *t*, otherwise equals to 0. In the 2012 industry classification of the CSRC, the industry codes corresponding to government regulated industries are as follows: B06, B07, B08, B09, B10, B11, C25, C31, C32, C36, C37, D44, D45, D46, E48, G53, G54, G55, G56, I63, I64, K70, R85, R86, R87, R88.
High-tech industry$_{i,t}$	Equals to 1 if the the focal firm *i* 's industry is high-tech industry at the end of fiscal year *t*, otherwise equals to 0. Based on the classification criteria of the Organization for Economic Co-operation and Development (OECD), we categorize the computer-related, electronic, information technology, bio-pharmaceutical, and communications industries as high-tech industries. In the 2012 industry classification of the CSRC, the industry codes corresponding to high-tech industries are as follows: C25, C26, C27, C28, C29, C31, C32, C34, C35, C36, C37, C38, C39, C40, C41, I63, I64, I65.
Technology-intensive industry$_{i,t}$	Equals to 1 if the the focal firm *i*'s industry is technology-intensive industry at the end of fiscal year *t*, otherwise equals to 0.Cluster analysis using Ward’s linkage method is performed based on the median values of two metrics in the industry: *Net fixed assets/Average total assets* and *R&D expenditure/employee compensation*. First, industries with a larger *Net fixed assets/Average total assets* are classified as capital-intensive, indicating high capital importance. Then, those with a higher *R&D expenditure /employee compensation*. are deemed technology-intensive, as technology outweighs labor for them. The rest are labor-intensive. In the 2012 industry classification of the CSRC, the industry codes corresponding to technology intensive industries are as follows: C27, C29, C33, C35, C36, C37, C38, C39, C40, C41, I63, I64, I65, M73, M74, M75, N77, N78.

Panel E: Variables related to the channel test

Variables	Definition
Network citation$_{i,t}$*/All citation*$_{i,t}$	In the peer network consisting of institutional shareholder cross-holdings, the number of times focal firm *i* cites patents from other firms in the network when applying for patents in fiscal year *t* divided by the total number of patent citations by focal firm *i* in fiscal year *t*.

Network patent similarity$_{i,t}$	In the peer network consisting of institutional shareholder cross-holdings, during a time period within the first foward of the fiscal year *t* the similarity between patents filed by the focal firm *i* and patents filed by other firms in the peer network.
Link citation$_{i,j,t}$*/All citation*$_{i,j,t}$	In the peer network consisting of institutional shareholder cross-holdings, the number of citing times filed by focal firm *i* that cite patents of the other firm *j* in the peer network in fiscal year *t* divided by the total number of patent citations by focal firm *i* in fiscal year *t*.
Link patent similarity$_{i,j,t}$	In the peer network consisting of institutional shareholder cross-holdings, during a time period within the the fiscal year *t*, the similarity between patents filed by the focal firm *i* and patents filed by the other firm *j* in the peer network.
Link dummy$_{i,j,t}$	Equals to 1 if common shareholder holds shares in focal firm *i* and their peer firm *j* within the the fiscal year *t*, and 0 otherwise.
Cross Visit$_{i,t}$*/All Visit*$_{i,t}$	Equals to the number of visits initiated by cross-holding institutional investors to focal firm *i* over the fiscal year *t* over on the number of visits initiated by all investors.
Portfolio value$_{s,ind,t}$	Equals to the annual market value of common shareholder *s*' portfolio in the fiscal year *t* and industry *ind*, calculated as the average of each firm's daily market value weighted by the shareholding ratio. Each firm's daily market value is computed as: (*Total equity - Domestically listed foreign shares* (i.e., *B shares*)) × *A-share closing price* + (*B-share closing price* × *B-share price in the Shanghai market*) + *Total liabilities as of the period-end*.
Portfolio TobinQ$_{s,ind,t}$	Equals to the *Tobin's Q* of common shareholder *s* ' portfolio in fiscal year *t* and industry *ind*, calculated as the average of each firm's *Tobin's Q* weighted by the shareholding ratio. Each firm's *Tobin's Q* is computed as: the ratio of annual market value to the difference between total assets and net intangible assets, minus net goodwill.
Cross dummy$_{s,ind,t}$	Equals to 1 if common shareholder *s* holds shares in more than two firms (including two firms) within the industry *ind*, and 0 otherwise.
Visit dummy$_{s,ind,t}$	Equals to 1 if common shareholder *s* visit two or more portfolio firms within the industry *s* and fiscal year *t*, and 0 otherwise.
Uninformative Prop Cross$_{i,t}$	The proportion of uninformative common shareholders among the Top 10 shareholders of focal firm *i* in fiscal year *t*. Uninformative common shareholders refer to all common institutional shareholders other than informative common shareholders in fiscal year *t*.
Informative Num Cross$_{i,t}$	Equals to ln(1+ the number of informative common shareholders among the Top 10 shareholders of focal firm *i* in fiscal year *t*).
Uninformative Num Cross$_{i,t}$	Equals to ln(1+ the number of uninformative common shareholders among the Top 10 shareholders of focal firm *i* in fiscal year *t*).
Informative Num Connected$_{i,t}$	Equals to ln(1+the number of the peer firms within the institutional cross-ownership network constructed by informative common shareholders, whose focal firm is *i* and fiscal year is *t*).
Uninformative Num Connected$_{i,t}$	Equals to ln(1+the number of the peer firms within the institutional cross-ownership network constructed by

	uninformative common shareholders, whose focal firm is *i* and fiscal year is *t*).
Receive patent invalidation$_{i,t}$	Equals to ln(1+ total number of patent invalidation received by focal firm *i* and their subsidiaries in fiscal year *t*).
Prop on-site visit$_{i,t}$	Equals to the number of on-site visits initiated by cross-holding institutional investors to focal firm *i* over the fiscal year *t* over on the number of visits initiated by all investors.
Prop off-site visit$_{i,t}$	Equals to the number of off-site visits initiated by cross-holding institutional investors to focal firm *i* over the fiscal year *t* over on the number of visits initiated by all investors.
Innovation words$_{i,t}$	Equals to ln(1+ The number of occurrences of innovation-related words in the visit reports, which they conduct on the peer firms of focal firm *i* in the previous three years (*t* - 1, *t* - 2, and *t* - 3), of common institutional shareholders who visit the focal firm *i* in the fiscal year *t*).
Executive attendance times$_{i,t}$	Equals to ln(1+ The times of executives' attendance in the visits, which they conduct on the peer firms of focal firm *i* in the previous three years (*t* - 1, *t* - 2, and *t* - 3), of common institutional shareholders who visit the focal firm *i* in the fiscal year *t*).
Cross DSE$_{i,t}$*/All DSE*$_{i,t}$	Equals to the number of directors, supervisors and executives delegated by cross-holding institutional investors divided by the total number of directors, supervisors and executives, for the focal firm *i* over the fiscal year *t*.

<u>*Panel F: Variables related to the economic consequences test*</u>

Variables	Definition
CAR[0, *N*]	Equals to the Cumulative Abnormal Return (*CAR*) from the date of completion of the patent invalidation to the *N* day thereafter. The market return is calculated as the value-weighted return of stocks in the market based on their free-float market capitalization; *N* = 1, 3, 7, 15, 30, 60, 120, 180, 360.
Initiate patent invalidation dummy$_{s,ind,t}$	Equals to 1 if the portfolio firms of common institutional shareholders *s* in industry *ind* initiate patent invalidation during year *t*, and 0 otherwise.
Receive patent invalidation dummy$_{s,ind,t}$	Equals to 1 if the portfolio firms of common institutional shareholders *s* in industry *ind* receive patent invalidation during year *t*, and 0 otherwise.
RD Input$_{i,t}$	Equals to the amount of research and development divided by operating income, for the focal firm *i* over the fiscal year *t*. When measuring the economic consequences at the institutional cross-ownership network level, use the median of the corresponding variables of other peers firms in the institutional cross-ownership network, excluding the focal firm, to describe it.
Network RD Input$_{i,t}$	In the network composed of the focal firm *i* and institutional cross-ownership in year *t*, the mean of the other firms' *RD Input* in the network is selected as the measurement method and denoted as *Network RD Input*$_{i,t}$.
RD Output$_{i,t}$	Equals to ln(1+the total number of patents filed by the focal firm *i* in the fiscal year *t*).
Network RD Output$_{i,t}$	In the network composed of the focal firm *i* and institutional cross-ownership in year *t*, the mean of the

	other firms' *RD Output* in the network is selected as the measurement method and denoted as *Network RD Output*$_{i,t}$.
RD output$_{i,t}$*/RD input*$_{i,t}$	Equals to *RD output*$_{i,t}$ divided by *RD input*$_{i,t}$.
Network RD output$_{i,t}$*/Network RD input*$_{i,t}$	In the network composed of the focal firm *i* and institutional cross-ownership in year *t*, the mean of the other firms' *RD output/RD input* in the network is selected as the measurement method and denoted as *Network RD output*$_{i,t}$*/Network RD input*$_{i,t}$.
Patent citation$_{i,t}$	Equals to ln(1 + the citating times of patents owned by focal firm *i* in the fiscal year *t*).
Network patent citation$_{i,t}$	In the network composed of the focal firm *i* and institutional cross-ownership in year *t*, the mean of the other firms' *Patent citation* in the network is selected as the measurement method and denoted as *Network patent citation*$_{i,t}$.
LP TFP$_{i,t}$	Equals to the total factor productivity of firm *i* in the fiscal year *t* calculated by the LP method.
Network LP TFP$_{i,t}$	In the network composed of the focal firm *i* and institutional cross-ownership in year *t*, the mean of the other firms' *LP TFP* in the network is selected as the measurement method and denoted as *Network LP TFP*$_{i,t}$.
OP TFP$_{i,t}$	Equals to the total factor productivity of firm *i* in the fiscal year *t* calculated by the OP method.
Network OP TFP$_{i,t}$	In the network composed of the focal firm *i* and institutional cross-ownership in year *t*, the mean of the other firms' O*P TFP* in the network is selected as the measurement method and denoted as *Network OP TFP*$_{i,t}$.
OLS TFP$_{i,t}$	Equals to the total factor productivity of firm *i* in the fiscal year *t* calculated by the OLS method.
Network OLS TFP$_{i,t}$	In the network composed of the focal firm *i* and institutional cross-ownership in year *t*, the mean of the other firms' OLS *TFP* in the network is selected as the measurement method and denoted as *Network OLS TFP*$_{i,t}$.
FE TFP$_{i,t}$	Equals to the total factor productivity of firm *i* in the fiscal year *t* calculated by the FE method.
Network FE TFP$_{i,t}$	In the network composed of the focal firm *i* and institutional cross-ownership in year *t*, the mean of the other firms' *FE TFP* in the network is selected as the measurement method and denoted as *Network FE TFP*$_{i,t}$.

Table B2 The "National Team" institutions

This table reports the Institutions and corresponding Accounts related to the "National Team" in the financial context. There are four main types of Institutions listed, namely China Securities Finance (CSF), CSF Funds, Central Huijin (HJ), and SAFE Investment Platforms. Specifically, for China Securities Finance (CSF), the Account is "CSF" and "10 CSF Asset Management Plans". Under CSF Funds, the Accounts include "Harvest New Opportunity Mixed Fund", "ChinaAMC New Economy Mixed Fund", "E-fund Ruihui Mixed Fund", "China Southern Consumption Vitality Mixed Fund", and "China Merchants Fengqing Mixed Fund". Regarding Central Huijin (HJ), the Accounts are "HJ Investment" and "HJ Asset Management". For SAFE Investment Platforms, the Accounts are "Buttonwood Investment", "Beijing Kunteng Investment", and "Beijing Fengshan Investment".

Institution	Accounts
China Securities Finance (CSF)	CSF; 10 CSF Asset Management Plans.
CSF Funds	Harvest New Opportunity Mixed Fund; ChinaAMC New Economy Mixed Fund; E-fund Ruihui Mixed Fund; China Southern Consumption Vitality Mixed Fund; China Merchants Fengqing Mixed Fund.
Central Huijin (HJ)	HJ Investment; HJ Asset Management.
SAFE Investment Platforms	Buttonwood Investment; Beijing Kunteng Investment;Beijing Fengshan Investment.

Table B3 The balance test results of propensity score matching (PSM)

This table reports the results of the balance test for propensity score matching (PSM). In the PSM process, we use the same control variables as those in the baseline, and select their lagged terms (i.e., *t* -1 period) as the covariates for the matching.

		Mean		%Reduce		T-test		
Variable	Sample	Treat	Control	%bias	| bias |	*t*	*p* > | *t* |	V(T)/V(C)
$Assets_{t-1}$	Unmatched	22.283	21.540	65.900	-	30.330	0.000	1.960
	Matched	21.571	21.601	-2.700	95.900	-1.240	0.215	1.000
$Leverage_{t-1}$	Unmatched	0.425	0.379	22.800	-	11.790	0.000	1.000
	Matched	0.379	0.381	-1.000	95.800	-0.360	0.716	0.970
$Cash_{t-1}/Assets_{t-1}$	Unmatched	0.048	0.036	17.700	-	9.030	0.000	1.070
	Matched	0.036	0.038	-3.200	82.100	-1.180	0.238	1.130
ROA_{t-1}	Unmatched	0.045	0.031	21.500	-	12.390	0.000	0.600
	Matched	0.036	0.035	1.700	92.100	0.650	0.514	0.990
$Sales\ growth_{t-1}$	Unmatched	0.184	0.167	4.000	-	2.200	0.028	0.730
	Matched	0.184	0.172	2.700	33.500	0.940	0.346	0.870
$Grant\ patent_{t-1}$	Unmatched	1.474	1.267	14.500	-	7.060	0.000	1.380
	Matched	1.266	1.299	-2.300	84.100	-0.930	0.354	0.990
$Firm\ age_{t-1}$	Unmatched	2.890	2.921	-9.200	-	-4.690	0.000	1.040
	Matched	2.905	2.914	-2.800	69.200	-1.060	0.291	0.950
$Institutional\ investors\ shareholding_{t-1}$	Unmatched	0.454	0.313	59.500	-	30.010	0.000	1.120
	Matched	0.326	0.327	-0.400	99.300	-0.150	0.879	0.970
$Top10\ ownership\ concentration_{t-1}$	Unmatched	0.588	0.584	2.600	-	1.290	0.196	1.100
	Matched	0.576	0.581	-3.300	-28.000	-1.230	0.219	1.030
$Separation\ of\ ownership\ and\ control_{t-1}$	Unmatched	5.040	4.132	12.400	-	6.140	0.000	1.250
	Matched	4.455	4.273	2.500	79.900	0.950	0.340	1.070
$Audit\ fee_{t-1}$	Unmatched	13.834	13.639	30.600	-	14.040	0.000	2.000
	Matched	13.613	13.641	-4.400	85.600	-1.930	0.054	1.120
$Female\ executives_{t-1}$	Unmatched	0.628	0.692	-12.600	-	-6.550	0.000	0.980
	Matched	0.693	0.687	1.100	91.200	0.420	0.677	0.960

Table B4 The balance test results of entropy balance (EB)

This table reports the results of the balance test for entropy balance (EB). In the EB matching process, we use the same control variables as those in the baseline, and select their lagged terms (i.e., t -1 period) as the covariates for the matching.

	Mean of unmatched sample		Mean of matched sample	
Variable	Treat	Control	Treat	Control
$Assets_{t-1}$	22.283	21.540	22.283	22.283
$Leverage_{t-1}$	0.425	0.379	0.425	0.425
$Cash_{t-1}/Assets_{t-1}$	0.048	0.036	0.048	0.048
ROA_{t-1}	0.045	0.031	0.045	0.045
Sales growth$_{t-1}$	0.184	0.167	0.184	0.184
Grant patent$_{t-1}$	1.474	1.267	1.474	1.474
Firm age$_{t-1}$	2.890	2.920	2.890	2.890
Institutional investors shareholding$_{t-1}$	0.454	0.313	0.454	0.454
Top10 ownership concentration$_{t-1}$	0.588	0.584	0.588	0.588
Separation of ownership and control$_{t-1}$	5.040	4.132	5.040	5.034
Audit fee$_{t-1}$	13.834	13.639	13.834	13.834
Female executives$_{t-1}$	0.628	0.693	0.628	0.628

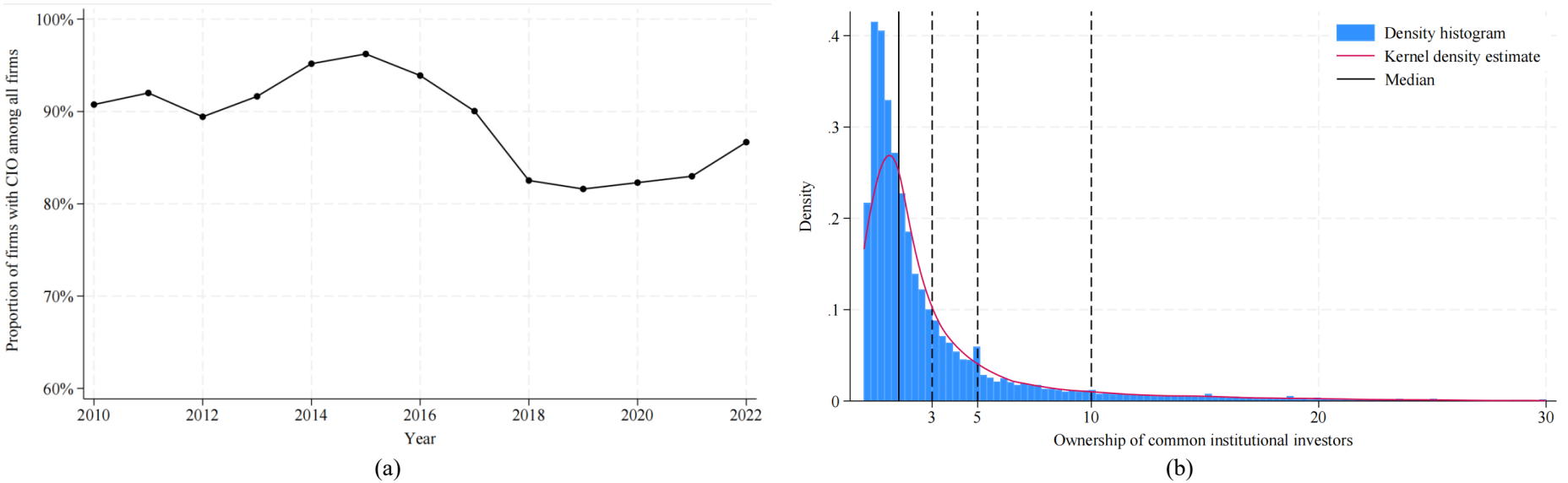


Figure B1. Distribution of top 10 institutional shareholder holdings between 2010 and 2022. In panel (a), the horizontal axis represents the sample period. The left vertical axis (solid line) shows the proportion of firms with institutional cross-ownership relative to the total number of firms, while the right vertical axis (dotted line) shows the median institutional shareholding ratio. This panel illustrates the temporal trends in both the proportion of firms with institutional cross-ownership and the median institutional shareholding ratio. In panel (b), the kernel density of the proportion of shareholders' individual holdings within a common institution. The blue boxes show histograms of kernel densities for every 0.3% increment between 0% and 30%, and the red curve indicates the fitted kernel density line. The solid vertical line represents the sample median, while the 3%, 5%, and 10% marks indicate the minimum thresholds for shareholders to submit ad hoc proposals, to be required to disclose shareholdings, and to call ad hoc shareholders' meetings, respectively.