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Is "Collaborative Governance" or "Competitive Collusion" the effect of cross-ownership on corporate innovation

Lijuan Yang, Lijuan Xiao, Lingyun Xiong and Jinjin Wang
School of Accounting, Jiangxi University of Finance and Economics, Nanchang, China, and
Min Bai
School of Accounting, Finance and Economics, Waikato Management School, The University of Waikato, Hamilton, New Zealand

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Abstract

Purpose – Using Chinese A-share listed firms between 2007 and 2020 with 21,380 observations, we aim to examine the impact of cross-ownership on firms' innovation output and explore the underlying mechanisms.
Design/methodology/approach – To test the influence of cross-ownership on firms' innovation output, this paper constructs an ordinary least square regression model. The explained variables are firms' innovation output, including the total number of patent applications (Apply) and the number of invention patent applications (Apply_I). Considering the long period of patent R&D, we take the value of the explained variables in the following year for regression. Cross-ownership (Cross) is the explanatory variable; Control is the control variable; and ε is the regression residual term.
Findings – We find that cross-ownership significantly promotes corporate innovation output, indicating that cross-owners play an important role in "collaborative governance." This finding remains unchanged after conducting a series of robustness tests. We also find that cross-ownership contributes to innovation output mainly through two plausible channels: the relaxation of financing constraints and reducing both types of agency costs. Further analysis shows that cross-ownership has a more pronounced influence on innovation output in those firms with higher equity restriction ratios and facing more competitive markets. Moreover, cross-ownership has a profound impact on firms' innovation quality and innovation efficiency, thereby increasing firm value.
Research limitations/implications – This study provides important policy implications. First, cross-owners should actively play their resource and supervision advantages to improve firms' long-term development capability through the "collaborative governance" effect. Second, listed companies in China should be fully aware of the value of the cross-ownership and use the cross-ownership as a bridge to strengthen the cooperative relationship with firms in the same portfolio. Meanwhile, they need to pay attention to cross-ownership's "collaborative governance" effect to provide an impetus for the healthy development of enterprises. Finally, government regulators should maintain appropriate supervision of the cross-ownership linkage in the market.
Originality/value – Our findings show that cross-ownership significantly contributes to firms' innovation output, indicating that cross-owners play the role of "collaborative governance." While paying attention to the collusion effect of the cross-ownership, they shall not ignore its governance effect, for example, the promotion

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effect on the innovation level. Government regulators should appropriately supervise the cross-ownership linkage, which is conducive to maintaining the market order and driving the healthy development of the capital market.

Keywords Cross-ownership, Innovation, Collaborative governance

Paper type Research paper

1. Introduction

Cross-owners refer to shareholders who hold equity in multiple companies within the same industry, as outlined by He and Huang (2017). Institutional cross-owners aim to maximize the combined value of their portfolio holdings, representing a prevalent form of social network association at the ownership level in the global capital market. Despite its widespread occurrence, the economic impact of cross-ownership in Chinese listed firms remains unexplored in existing literature. Schmalz (2018) utilizes theoretical models to uncover the potential market implications arising from the economic associations facilitated by cross-ownership. Previous research indicates that cross-owners, driven by the goal of maximizing portfolio returns, may contribute to heightened corporate collusion in product markets. This industrial economic association can distort market price mechanisms and diminish overall market competition, resulting in adverse effects on the macro-economy, commonly referred to as "competitive collusion" (Azar, 2018). Contrastingly, Kang, Luo, and Na (2018) and He, Huang, and Zhao (2019) present evidence suggesting that cross-ownership serves a supervisory and governance role, characterized as "collaborative governance" (Edmans, Levit, & Reilly, 2019). Despite these findings, there is currently no consensus in the existing body of research on the precise impact and nature of cross-ownership in the corporate landscape. Technological innovation has always been considered vital for a country's productivity growth and thus the growth of its economy (Solow, 1956; Romer, 1986). Prior literature shows that equity structure is an important corporate governance mechanism affecting the technological innovation of Chinese firms. Some investigate the impact of equity on innovation in terms of equity incentive plans (Zhu, 2017) and equity concentration (Chen *et al.*, 2014). Some study the factors influencing the firms' innovation from the perspective of unique equity structure including pyramid structure (Chen, Lin, Lin, & Hsiao, 2016) and multiple large shareholders (Mo, 2021). However, none has paid attention to the exact impact of cross-ownership, as a unique form of equity structure, on firms' innovation output as well as the underlying mechanisms. In this paper, we analyze the corporate governance role of cross-ownership in promoting firms' innovation output.

The equity structure in the capital market has become increasingly complicated, and it has become a norm for large shareholders to be associated with multiple listed companies through their equity, but it is unclear what impact it has on corporate innovation. Compared with individual investors, institutional cross-owners have information advantages and mature governance capabilities. Their active participation in corporate governance is conducive to improving corporate financing, reducing stock price mis-valuation and alleviating both types of agency costs. He *et al.* (2019) argue that the cross-owner can benefit not only from an improvement in governance in the company itself but also from the ensuing improvement in governance in the company's peers that are in its portfolio. Relative to non-cross-holding shareholders, cross-owners should play a stronger monitoring and governance role, particularly when the potential for governance externalities is high. Thus, we hypothesize that cross-owners can promote firms' innovation output.

We examine the relationship between cross-ownership and firms' innovation output, using Chinese A-share listed companies from 2007 to 2020 with 21,380 observations. We collect patent information from the Chinese Research Data Services Platform (CNRDS). To measure a

firm's innovation output, we apply the total number of patent applications (*Apply*) and the number of invention patent applications (*Apply_I*) in the firm year. Accordingly, we are able to explore the effects of cross-ownership on both the quantity and the quality of a firm's innovation output. We collect cross-owner's information from the China Stock Market and Accounting Research Database (CSMAR); a shareholder is defined as cross-owners if they have 5% or more shares of more than one enterprise in the same industry at the same time.

Our baseline results show that cross-ownership significantly promotes corporate innovation output, indicating that cross-owners play an important role in "collaborative governance." This finding remains unchanged after conducting a series of robustness tests. For example, we saturated the specification with firm fixed effects to show a robust relationship between firm-level cross-ownership and innovation. Our most stringent model specification (with both firm and industry and year fixed effects) shows that a one-standard-deviation increase in the firm-level cross-ownership measure (i.e. 0.238) is associated with an increase of 6.3% points (=0.266*0.238) in the total number of patents. The results present that cross-ownership positively enhances corporate innovation. Next, we explore the underlying mechanisms and find that the relaxation of financial constraints and reduced agency costs are two plausible channels helping cross-ownership to promote innovation, indicating the resource effect and supervision effect. Further analysis shows that the positive effect of cross-ownership on innovation output is more pronounced in those firms with a higher equity restriction ratio and facing more competitive markets. Moreover, cross-ownership has a profound impact on firms' innovation quality and innovation efficiency and thereby increasing firm value.

This paper has three potential contributions. First, it provides new evidence to support the "collaborative governance" effect of cross-ownership, thereby expanding the literature related to the economic impact of cross-ownership. This suggests a "bright side" of cross-ownership. Second, our paper contributes to the literature on finance and innovation in a Chinese setting. In terms of special equity structures, the existing literature mainly examines the impact of special equity structures such as pyramid structures and multiple large shareholders on corporate innovation (Chen *et al.*, 2016; Mo, 2021). Based on the prevalence of cross-ownership in listed companies, we examine the cross-ownership's impact on innovation output and find that its cross-ownership has a profound impact on firms' innovation quality and innovation efficiency, thereby increasing firm value. It enriches the theoretical study of the impact of equity structure on firms' innovation output. Third, based on the complex equity structure among enterprises during China's economic transition, our paper examines actions by institutional investors, thus providing direct evidence on the influence of cross-owners.

This study provides important policy implications for listed companies to construct the cooperative corporate governance mechanism of cross-ownership. Government regulators should appropriately supervise the cross-ownership linkage in the market, which is conducive to maintaining the market order and driving corporate innovation. China's economy has moved from high-speed growth to high-quality development. In firms with a higher degree of check-and-balance of ownership in a highly competitive market, cross-ownership has a greater impact on promoting the firms' innovation output and innovation quality. This indicates that building a cross-ownership collaborative governance mechanism is of great significance to enhance the innovation decision-making quality and activate the innovation vitality of listed companies, thereby advancing the firms' high-quality development.

The remainder of this paper is organized as follows. Section 2 reviews the literature and develops research hypotheses. Section 3 describes the data and research methodology. Section 4 presents the empirical results and explores how cross-ownership affects corporate innovation output. Section 5 shows various robustness checks. Section 6 makes further analysis. Section 7 concludes the paper.

2. Literature review and hypotheses development

There is a substantial body of research examining the economic implications of cross-ownership in China, including its impact on collateral in lending (Qian, Ding, Cao, & Qi, 2020), corporate tax avoidance (Xiao & Xi, 2023), managerial perks and tunneling (Liu & Hou, 2023), stock price crash risk (Hou & Liu, 2023), trade credit (Liu & Hou, 2022; Bai, Cai, & Qin, 2021) and corporate innovation (Gao, Shen, Gao, & Chan, 2019; Ling, Pan, & Xu, 2024). Specifically, Gao *et al.* (2019) report a positive association between cross-ownership and innovation output. Ling *et al.* (2024) find that non-state-owned firms can improve innovation by acquiring equity in state-owned enterprises (SOEs) under the reform.

Institutional cross-ownership has witnessed a substantial growth over the past few decades and has become a widespread and economically important phenomenon. There are two opposing views on the economic impact of cross-ownership: "competitive collusion" and "collaborative governance" (Azar, 2018; He *et al.*, 2019; Edmans *et al.*, 2019). Given that institutional cross-owners are uniquely positioned to have information advantages of firms and are incentivized to internalize corporate governance externalities, cross-ownership, as a market-based mechanism, can play a vital role in addressing governance.

The rational economic man hypothesis suggests that market participants are rational and self-interested, aiming to maximize their interests. As the capital market matures, to gain more returns from the capital market, shareholders with capital advantages will invest in multiple companies in the same industry at the same time, thus forming a cross-ownership. As a rational economic man, cross-owners have a different return function. They no longer pursue maximizing the return of investment in a particular firm, but maximizing the return of investment portfolio. Therefore, compared with non-cross-holding shareholders, cross-owners have a strong ability to improve the corporate governance of firms they hold shares in with their resource and supervisory advantages for higher portfolio returns and bring into play the collaborative governance effect. They are also highly motivated to promote collusion among shareholding enterprises in the same industry and intensify market monopoly. So, in the process of corporate innovation, does cross-ownership promote firms' innovation output through "collaborative governance" or suppress it through "competitive collusion"? In this paper, we explore this question from two logical perspectives.

First, cross-ownership may exert a "collaborative governance" effect to promote the firms' innovation output. Research has shown that corporate innovation is a risky activity that requires large investments and long cycles. The adequacy of resource investment, the smoothness of information mechanisms and the effectiveness of corporate governance mechanisms are critical factors that determine the success of innovation (O'Connor & Rafferty, 2012). Cross-owners not only have rich management experience but also link information and resources among shareholding enterprises, so they may enhance firms' innovation capacity and willingness through two effects as follows.

Resource effect. Resource dependence theory suggests that a firms development depends on its ability to acquire resources in its exchanges with the external environment. Social networks are formed between firms through alliances and cooperation. Potential opportunities can be quickly identified by the social network relationships (Mazzola, Perrong, & Kamuriwo, 2016), while social network resources are used to collect and filter information for resource complementarity, thus reducing external environmental uncertainty and improving firms' innovation capacity. On the one hand, by their shareholding relationships, cross-owners establish social network relationships within the industry, which enables them to break through their own resource limitations in the interaction with other firms and share external financing channels, thus helping firms access external funds and reducing financing constraints. On the other hand, based on the cross-ownership, the interconnection between portfolio firms will form a weak internal capital market. Out of direct interest associations and increased trust between firms, firms will have

sufficient funding sources for their innovation activities through funding and financing strategies such as cross guarantees, long- and short-term debts and commercial credit.

Supervision effect. The agency theory suggests that under the assumptions of management's limited rationality, opportunism and risk aversion, management does not have sufficient incentive to invest in corporate innovation. It is important to enhance the willingness of management to innovate through a supervision mechanism. On one hand, by long-term participation in supervision and management, cross-owners have accumulated industry knowledge and management experience. Meanwhile, firms in the same industry are in a similar business environment, which lowers cross-owners' supervision costs so they can better supervise the investment portfolio. Therefore, they tend to restrain management's opportunistic behavior and prevent large shareholders and management from jointly encroaching on the interests of small and medium shareholders. This ultimately reduces agency problems, improves the corporate risk-taking level and increases the firm's willingness to innovate. On the other hand, cross-owners hold equity in multiple firms in the same industry, so when they are impacted, they will prioritize selling the equity of the firms with the worst performance. This implies that the cross-owners can play the role of corporate governance and supervision through selling holding shares. This will motivate the management to work hard, alleviate agency problems and improve corporate governance (Edmans *et al.*, 2019). In addition, existing research suggests that cross-owners demonstrate a stronger supervising capacity in corporate governance (Brooks, Chen, & Zeng, 2018). They not only object to inappropriate managerial decisions (He *et al.*, 2019) but may even remove incompetent corporate managers from office (Kang *et al.*, 2018). Therefore, we argue that cross-ownership will ultimately increase firms' innovation output by motivating and supervising management to carry out innovation activities.

Second, cross-ownership may exert a "competitive collusion" effect to suppress the firms' innovation output. According to the shareholder value maximization theory, cross-owners simultaneously hold multiple investment targets. To maximize their returns, they aim to maximize not only the value of individual targets but also the investment portfolio's value. Therefore, cross-owners have a strong incentive to press the firms within their portfolios to alleviate competition among these firms. They will try to facilitate collusion among firms to increase the portfolio firms' market share and bargaining power (He & Huang, 2017; Azar, Schmalz, & Tecu, 2018), thus maximizing the portfolio's value. This is known as the "competitive collusion" effect in academic circles. Generally speaking, firms carry out innovation activities to be invincible in the fierce competition. As the market competition eases, firms' willingness to invest in R&D and innovation will be significantly reduced, thus suppressing the innovation output.

Based on the above analysis, we propose the following competing hypotheses:

H1. Cross-ownership can promote the firm's innovation output through the "collaborative governance" effect (i.e. cross-ownership is positively related to the firm's innovation output).

H2. Cross-ownership can suppress the firm's innovation output through the "competitive collusion" effect (i.e. cross-ownership is negatively related to the firm's innovation output).

3. Research design

3.1 Sample data

This paper study listed companies on the Shanghai Stock Exchange and the Shenzhen Stock Exchange from 2007 to 2020. Following the research practice, this paper screens the samples

as follows: (1) exclude the samples of banks, insurance and other financial institutions; (2) exclude the samples during the years they were marked as ST, *ST and PT; (3) exclude the samples with an asset-liability ratio greater than 1 or smaller than 0; (4) exclude the samples in the year of the IPO and the previous years; and (5) exclude the samples with missing data. Finally, we obtained 21,380 firm-year observations. To eliminate the influence of extreme values on the results, we have winsorized all continuous variables in this paper at the 1% level. The patent data in this paper are obtained from the Chinese Research Data Services Platform (CNRDS) and other data are from the CSMAR.

3.2 Variable definition

3.2.1 Proxy for cross-ownership. The explanatory variable *Cross* is the number of cross-owners of the firm. Following He and Huang (2017) and Pan *et al.* (2022), we construct the *Cross* as follows: based on the China Securities Regulatory Commission's 2012 Industry Classification Standard, the manufacturing industry uses the secondary classification and the non-manufacturing industry uses the primary classification to preliminarily determine the cross-owners holding shares in the same industry. Then, according to the quarterly top ten shareholder document of CSMAR, a shareholder is a cross-owner if they have 5% or more shares of more than one enterprise in the same industry at the same time. We calculate the number of cross-owners of enterprises in each quarter and take the average value to obtain the data for each year. Then, we add 1 to the value and take the natural logarithm of the sum to construct the cross-ownership index *Cross*.

3.2.2 Measurement for corporate innovation. The explained variables *Apply* and *Apply_I* measure firms' innovation output. Following Nagaoka *et al.* (2010), this study uses the total number of patent applications (*Apply*) and the number of invention patent applications (*Apply_I*) in that year to measure firms' innovation output, then adds 1 to the value and takes the natural logarithm of the sum.

3.2.3 Control variables. Consistent with existing studies, the following variables are controlled for in the model: firm size (*Size*), leverage ratio (*Lev*), sales revenue growth (*Growth*), return on total assets (*ROA*), firm age (*Age*), cash ratio (*Cash*), share concentration (*Share*), INDendent director ratio (*IND*), fixed asset ratio (*PPE*), separation of powers ratio (*Separation*), nature of ownership (*SOE*) and market capitalization book-to-bill ratio (*Tobin_q*). In addition, industry and yearly fixed effects are also controlled. The main variables are defined in Table 1.

3.3 Research methodology

To test the influence of cross-ownership on firms' innovation output, this paper constructs an ordinary least squre regression model (1) for regression analysis.

$$Apply_{i,t+1} = \beta_0 + \beta_1 Cross_{i,t} + \beta_j Control_{i,t} + \sum Year + \sum Industry + \varepsilon_{i,t}$$

or

$$Apply\_I_{i,t+1} = \beta_0 + \beta_1 Cross_{i,t} + \beta_j Control_{i,t} + \sum Year + \sum Industry + \varepsilon_{i,t} \quad \text{Eq. (1)}$$

The explained variables are firms' innovation output, including the total number of patent applications (*Apply*) and the number of invention patent applications (*Apply_I*). Considering the long period of patent R&D, we take the value of the explained variables in the following

Variable type	Variable name	Variable	Variable definitions
Dependent variable	Number of patent applications	*Apply*	Natural logarithm of the number of patent applications plus 1
	Number of invention patent applications	*Apply_I*	Natural logarithm of the number of invention patent applications plus 1
Independent variable	Cross ownership	*Cross*	Add 1 to the value and take the logarithm of the sum
Control variable	Firm Size	*Size*	Natural logarithm of the total assets at year end
	Leverage	*Lev*	Total liabilities/Total assets
	Return on Assets	*ROA*	Net operating income deflated by total assets
	Cash Ratio	*Cash*	Cash and cash equivalents/Total assets at year end
	Equity Concentration	*Share*	The largest shareholder's shareholding
	Independent Directors ratio	*IND*	Number of independent directors/Total number of directors
	Growth Rate	*Growth*	(current operating income – previous operating income)/(previous operating income)
	Firm Age	*Age*	Natural logarithm of the company's establishment years plus 1
	Fixed Assets Ratio	*PPE*	Non-current assets at the end of the year/total assets at the end of the yea
	Separation Rate of Two Rights	*Separation*	The difference between the control and ownership of the listed company owned by the ultimate controller
	State ownership	*SOE*	Dummy variable, it equals 1 if the ultimate controller of the listed firm is state-owned, and 0 otherwise
	Market Value to Book Ratio	*Tobin_q*	Market value to book ratio
	Year	*Year*	Year Fixed Effect: Fiscal year from 1st January to 31st December
	Industry	*Industry*	Industry fixed effect: CSRC issued Guidelines for the Industry Classification of Listed Companies (2012 Revision). To ensure comparability of data, we make manual adjustments to the industry classification of listed companies prior to 2012 in accordance with 2012 industry classification standards

Source(s): Authors' own work

Table 1. Key variable and definitions

year for regression. Cross-ownership (*Cross*) is the explanatory variable, *Control* is the control variable, and ε is the regression residual term.

4. Empirical results

4.1 Descriptive statistics

Table 2 reports the descriptive statistics of the main variables in this paper. The standard deviation of the total number of patent applications (*Apply*) and the total number of invention patent applications (*Apply_I*) are 1.586 and 1.335, respectively, indicating a significant difference in the technological innovation level among different firms. The firm-level cross-ownership measure has a mean value of 0.093 and a standard deviation of 0.238, respectively. This table also shows the summary statistics for the control variables used in the baseline regressions, which are consistent with the existing literature.

Variables	*N*	Mean	SD	Minimum	Median	Maximum
Apply	21,380	1.921	1.586	0	1.946	8.397
Apply_I	21,380	1.347	1.335	0	1.099	8.324
Cross	21,380	0.093	0.238	0	0	1.099
Growth	21,380	0.316	0.691	−0.780	0.140	5.653
IND	21,380	0.376	0.053	0.313	0.357	0.571
Lev	21,380	0.397	0.198	0.021	0.386	0.882
Cash	21,380	0.168	0.132	0.010	0.130	0.860
PPE	21,380	0.414	0.185	0.025	0.402	0.880
ROA	21,380	0.039	0.068	−0.475	0.040	0.277
Share	21,380	0.344	0.143	0.084	0.324	0.748
Separation	21,380	0.045	0.073	0	0	0.309
SOE	21,380	0.294	0.455	0	0	1
Size	21,380	22.08	1.263	19.49	21.89	26.37
Tobin_q	21,380	2.057	1.280	0.812	1.654	11.43
Age	21,380	2.819	0.374	0.693	2.890	3.555

Table 2.
Descriptive statistics

Source(s): Authors' own work

Table 3 presents the analysis of mean differences in firms' innovation output after categorizing the firms by whether they have cross-ownership. The dummy variable *Cross_Dum* for cross-ownership is constructed based on the *Cross* indicator. The value is 1 if the firm has cross-ownership and 0 otherwise. We can see that among the 21,380 yearly samples, 3,039 yearly samples of the firms have cross-ownership. The mean difference between innovation output *Apply* (*Apply_I*) of this group and the group without cross-ownership is 0.303 (0.373) and both are significant at the 1% level. Considering the long period of patent R&D, we analyze the mean difference between groups by taking the value of innovation output in the following year. The results remained consistent, which preliminarily verifies hypothesis H1 of this paper that the cross-ownership promotes firms' innovation output.

4.2 Baseline results: cross-ownership and corporate innovation

Table 4 reports the baseline regression results of the relationship between cross-ownership and corporate innovation. Columns (1) and (3) show the baseline results of the univariate cross-ownership (*Cross*) on firms' innovation output after controlling for industry and year fixed effects. The coefficients of cross-ownership are 0.382 and 0.536 when the explained variables are *Apply* and *Apply_I*, respectively, and both are significant at the 1% level, which is consistent with the main hypothesis, suggesting that listed firms with more cross-owners have higher innovation output. Columns (2) and (4) show that the coefficient of cross-ownership is still significantly positive after controlling for the variables that may affect firms' innovation output. The coefficient of cross-ownership is

	Cross_Dum = 1		*Cross_Dum = 0*			
	N	Mean	*N*	Mean	Mean difference	*T*-value
Apply	3,039	2.181	18,341	1.878	0.303***	9.774
Apply_I	3,039	1.667	18,341	1.294	0.373***	14.324
$Apply_{t+1}$	2,343	2.230	14,825	1.921	0.308***	8.693
$Apply\_I_{t+1}$	2,343	1.721	14,825	1.338	0.382***	12.777

Table 3.
Mean difference between groups

Note(s): ***, ** and * denote significance at the 1%, 5% and 10% level, respectively

Source(s): Authors' own work

	(1) $Apply_{t+1}$	(2) $Apply_{t+1}$	(3) $Apply\_I_{t+1}$	(4) $Apply\_I_{t+1}$
Cross	0.382***	0.125**	0.536***	0.197***
	(0.057)	(0.057)	(0.051)	(0.051)
Growth		−0.079***		−0.043***
		(0.017)		(0.014)
IND		0.347		0.255
		(0.212)		(0.186)
Lev		0.001		−0.008
		(0.081)		(0.070)
Cash		−0.056		−0.015
		(0.106)		(0.093)
PPE		−0.934***		−0.796***
		(0.081)		(0.069)
ROA		3.277***		2.453***
		(0.208)		(0.172)
Share		0.010		−0.222***
		(0.084)		(0.073)
Separation		−0.116		0.027
		(0.158)		(0.137)
SOE		−0.068**		0.026
		(0.029)		(0.025)
Size		0.289***		0.307***
		(0.015)		(0.013)
Tobin_q		−0.018*		0.025***
		(0.011)		(0.009)
Age		−0.292***		−0.211***
		(0.036)		(0.031)
Year FEs	Yes	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes	Yes
Constant	0.144	−5.038***	−0.045	−5.863***
	(0.394)	(0.474)	(0.335)	(0.412)
Observations	17,168	17,168	17,168	17,168
R^2	0.216	0.179	0.216	0.179

Note(s): This table reports the regression results of the univariate cross-ownership (*Cross*) on firms' innovation output *(Apply and Apply_I)* after controlling for industry and year effects. All other variables are defined in Table 1. The numbers in parentheses are *t*-statistics based on standard errors that are clustered by firm. The empirical results present that cross-ownership promotes firms' innovation output through the "collaborative governance" effect, supporting the research hypothesis H1. ***, ** and * represent significance at the 1%, 5% and 10% levels, respectively

Source(s): Authors' own work

Table 4. Baseline results: impact of cross-ownership and corporate innovation

significant at the 5% level when the explained variable is *Apply* and significant at the 1% level when the explained variable is *Apply_I*. The empirical results show that cross-ownership promotes firms' innovation output through the "collaborative governance" effect, and the research hypothesis H1 of this paper is verified, while the research hypothesis H2 is invalid.

According to the information from Columns (2) and (4) in Table 4, our results are of economic significance; the estimated effect of the cross-ownership on patent applications (invention patent applications) is 0.125 (0.197), statistically significant and positive. The results indicate that one standard deviation increase in cross-ownership percentage will increase the total number of patent applications by 19.83% (0.125×1.586), and one standard deviation increase in cross-ownership percentage will increase the total number of invention

patent applications by 26.30% (0.197×1.335). It further supports the idea that cross-ownership promotes firms' innovation output.

From the control variables, it can be seen that the regression coefficients of sales revenue growth (*Growth*), fixed asset ratio (*PPE*), share concentration (*Share*) and firm age (*Age*) are significantly negative with firms' innovation output and those of return on total assets (*ROA*), firm size (*Size*) and market capitalization book-to-bill ratio (*Tobin_q*) are significantly positive. The regression results indicate that younger firms with slower sales revenue growth, lower fixed asset ratio, lower share concentration, higher return on total assets, larger firm size and larger Tobin_*q* value are more motivated to innovate, or firms with stronger innovation capability will have higher innovation output in the following year.

4.3 Mechanism analysis

Our baseline results have documented that cross-owners play a significant "collaborative governance" role in promoting corporate innovation output. In this section, we investigate whether the positive impact of cross-ownership on corporate innovation output depends on financial constraints and corporate governance. We incorporate two interaction terms, *Cross*SA* (i.e. financial constraints) and *Cross*Gov* (i.e. corporate governance), into Model (1), respectively, to examine the resource effect and the supervision effect.

4.3.1 Resource effect: cross-ownership, financing constraints and innovation. Since innovation requires huge investment, capital is one of the most critical resources for firms to carry out innovation activities. Following Hadlock and Pierce (2010), we use the SA index (SA index = $-0.737\times Size+0.043\times Size^2-0.04\times Age$) to measure the degree of financing constraint faced by the firm. The larger the SA, the greater the financing constraint faced by the firm. Table 5 reports the regression results. It is found that the coefficients of interaction term *Cross*SA* in Columns (1) and (2) are both significantly positive at the 5% level. The results imply that cross-owners exploit their resource advantages to alleviate firms' financing constraints and improve their innovative capabilities and thus promote the innovation output.

4.3.2 Supervision effect: cross-ownership, corporate governance and innovation. To examine whether cross-owners can improve the corporate governance, thereby promote corporate innovation. This study utilizes principal component analysis to reflect the corporate governance level with a linear combination of 10 corporate governance variables, including the largest shareholder's shareholding, ownership concentration, executives' shareholding, the proportion of independent directors, board size and the number of board meetings, state-owned, the duality of Chairman and CEO, whether B shares or H shares are issued, and whether it has a parent company. The first major principal component is selected as the indicator of corporate governance level (*Gov*). The larger the value of *Gov*, the better the corporate governance. Then, we incorporate another interaction term (*Cross*Gov*) in Model (1) and re-run the regression.

Table 6 reports the regression results. The coefficients of the interaction term *Cross*Gov* in Columns (1) and (2) are significantly negative at the 5% and 1% levels, respectively. This indicates that cross-ownership plays a more significant role in promoting firms' innovation output in firms with low corporate governance levels, supporting the view that cross-ownership promotes firms' innovation output through the supervision effect.

Overall, the results provide evidence that the relaxation of financial constraints and reduced agency costs are two plausible channels through which cross-ownership affects corporate innovation, supporting the resource effect and supervision effect of cross-owners.

	(1) $Apply_{t+1}$	(2) $Apply\_I_{t+1}$
Cross	2.011**	1.818**
	(0.806)	(0.709)
*Cross*SA*	0.510**	0.441**
	(0.214)	(0.188)
SA	0.268**	0.370***
	(0.118)	(0.104)
Growth	−0.077***	−0.041***
	(0.017)	(0.014)
IND	0.276	0.174
	(0.212)	(0.186)
Lev	0.010	0.001
	(0.081)	(0.070)
Cash	−0.076	−0.042
	(0.106)	(0.093)
PPE	−0.933***	−0.794***
	(0.081)	(0.069)
ROA	3.334***	2.517***
	(0.208)	(0.171)
Share	−0.018	−0.257***
	(0.084)	(0.073)
Separation	−0.075	0.073
	(0.157)	(0.137)
SOE	−0.063**	0.032
	(0.029)	(0.025)
Size	0.277***	0.295***
	(0.014)	(0.013)
Tobin_q	−0.024**	0.019**
	(0.011)	(0.009)
Age	−0.099	0.040
	(0.075)	(0.067)
Year FEs	Yes	Yes
Industry FEs	Yes	Yes
Constant	−4.297***	−4.870***
	(0.520)	(0.448)
Observations	17,168	17,168
R^2	0.217	0.181

Note(s): The degree of financing constraint (*SA*) faced by the listed firm is measured by the SA index. The numbers in parentheses are *t*-statistics based on standard errors that are clustered at the merger level. ***, ** and * represent significance at the 1%, 5% and 10% levels, respectively
Source(s): Authors' own work

Table 5.
Mechanism test: cross-ownership, financing constraints and innovation

5. Robustness checks

5.1 Instrumental variable

Considering that this paper may be subject to endogeneity problems, such as omitting variables and two-way causality, based on Fisman & Svensson (2007), we exclude firms' own sample to calculate the average value of the number of cross-owners of the firms at the city-industry-year level (*Average*) as an instrumental variable. Fisman & Svensson (2007) suggest that the average value of the variable at the industry-region level without the variable itself can be used as an instrumental variable of this variable to address the endogeneity problem caused by omitted variables, measurement error and two-way causality in the model.

	(1) $Apply_{t+1}$	(2) $Apply\_I_{t+1}$
Cross	0.200***	0.269***
	(0.0583)	(0.0527)
Cross*Gov	−0.141**	−0.158***
	(0.0597)	(0.0547)
Gov	−0.0248	−0.0292**
	(0.0158)	(0.0137)
Growth	−0.0662***	−0.0326**
	(0.0174)	(0.0146)
IND	0.169	−0.0126
	(0.262)	(0.230)
Lev	−0.0326	−0.0212
	(0.0830)	(0.0712)
Cash	−0.0375	0.00381
	(0.107)	(0.0947)
PPE	−0.944***	−0.802***
	(0.0824)	(0.0711)
ROA	3.208***	2.423***
	(0.212)	(0.175)
Share	0.0579	−0.191**
	(0.0860)	(0.0749)
Separation	−0.0541	0.116
	(0.167)	(0.145)
SOE	−0.0408	0.0669**
	(0.0320)	(0.0277)
Size	0.308***	0.322***
	(0.0156)	(0.0138)
Tobin_q	−0.0104	0.0348***
	(0.0114)	(0.00977)
Age	−0.284***	−0.205***
	(0.0369)	(0.0312)
Year FEs	Yes	Yes
Industry FEs	Yes	Yes
Constant	−5.451***	−6.241***
	(0.511)	(0.443)
Observations	16,477	16,477
R^2	0.217	0.180

Note(s): The numbers in parentheses are *t*-statistics based on standard errors that are clustered at the merger level. ***, ** and * represent significance at the 1%, 5% and 10% levels, respectively
Source(s): Authors' own work

Table 6.
Mechanism test: cross-ownership, corporate governance and innovation

The regression results of the instrumental variable method test are shown in Table 7. Column (1) reports the regression results of the first stage of the instrumental variable method, where the average number of cross-owners owned by other firms in the same industry and same city (*Average*) is significantly and positively correlated with the number of cross-owners of the sample firm (*Cross*) at the 1% level. Columns (2) and (3) show the regression results of the second stage of the instrumental variable method, where cross-ownership (*Cross*) and firms' innovation output (*Apply*, *Apply_I*) are significantly and positively correlated at the 5% level. This indicates that after accounting for the potential effects of omitted variables and two-way causality, the results remain that cross-ownership promotes firms' innovation output.

	(1) *Cross*	(2) $Apply_{t+1}$	(3) $Apply\_I_{t+1}$
Average	0.170***		
	(0.014)		
Cross		1.195**	1.251**
		(0.577)	(0.505)
Growth	−0.000	−0.069***	−0.040**
	(0.003)	(0.020)	(0.017)
IND	0.022	0.303	0.221
	(0.035)	(0.243)	(0.213)
Lev	−0.034**	−0.003	−0.024
	(0.014)	(0.098)	(0.086)
Cash	0.074***	−0.146	−0.107
	(0.019)	(0.134)	(0.117)
PPE	0.028**	−0.997***	−0.871***
	(0.014)	(0.094)	(0.082)
ROA	−0.015	3.488***	2.697***
	(0.035)	(0.241)	(0.211)
Share	−0.049***	−0.040	−0.294***
	(0.014)	(0.103)	(0.090)
Separation	−0.044	−0.289	−0.081
	(0.027)	(0.185)	(0.162)
SOE	0.151***	−0.277***	−0.169**
	(0.005)	(0.097)	(0.085)
Size	0.044***	0.263***	0.296***
	(0.002)	(0.030)	(0.026)
Tobin_q	0.014***	−0.027*	0.017
	(0.002)	(0.015)	(0.013)
Age	−0.006	−0.270***	−0.193***
	(0.006)	(0.042)	(0.037)
Year FEs	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes
Constant	−0.925***	−3.352***	−4.413***
	(0.136)	(1.055)	(0.924)
Observations	13,232	13,232	13,232
R^2	0.195	0.179	0.144

Note(s): ***, ** and * denote significance at the 1%, 5% and 10% level, respectively
Source(s): Authors' own work

Table 7.
Robustness checks: instrumental variable

5.2 PSM approach

Since the cross-ownership's promotion of firms' innovation output may be brought about by investors' stock selection preferences, this paper adopts the propensity score matching method to mitigate the endogeneity problem caused by selection bias. Specifically, this paper matches firms with cross-ownership with a set of control variables in Model (1); and then uses the nearest neighbor matching method to generate a control group by matching firms without cross-ownership one by one. The results of the propensity score matching method show that the average treatment effects (ATT) on firms' innovation output (*Apply*, *Apply_I*) are 0.078 and 0.110, indicating that firms with cross-ownership have higher innovation output than their counterparts without cross-ownership by 0.078 and 0.110 on average. Further, we regressed the total sample of selected listed firms, and the regression results are shown in Table 8. The regression coefficient of cross-ownership (*Cross*) is significantly positive at the 5% and 1% levels with firms' innovation output (*Apply*, *Apply_I*, further alleviating the endogeneity problem in this paper.

	(4) $Apply_{t+1}$	(5) $Apply\_I_{t+1}$
Cross	0.180**	0.262***
	(0.077)	(0.068)
Growth	−0.219***	−0.152***
	(0.037)	(0.032)
IND	1.423***	1.473***
	(0.502)	(0.458)
Lev	−0.306	−0.269
	(0.198)	(0.171)
Cash	−0.282	−0.137
	(0.285)	(0.256)
PPE	−1.191***	−0.945***
	(0.205)	(0.177)
ROA	2.734***	2.489***
	(0.514)	(0.436)
Share	0.181	−0.106
	(0.201)	(0.178)
Separation	−0.499	−0.223
	(0.377)	(0.331)
SOE	−0.015	0.083
	(0.060)	(0.053)
Size	0.330***	0.360***
	(0.031)	(0.028)
Tobin_q	−0.029	0.009
	(0.024)	(0.021)
Age	−0.349***	−0.286***
	(0.093)	(0.081)
Year FEs	Yes	Yes
Industry FEs	Yes	Yes
Constant	−7.256***	−8.077***
	(0.841)	(0.726)
Observations	3,548	3,548
R^2	0.235	0.215

Table 8.
Robustness checks: PSM method

Note(s): ***, ** and * denote significance at the 1%, 5% and 10% level, respectively
Source(s): Authors' own work

5.3 Firm fixed effects

To show a robust relationship between the firm-level cross-ownership and innovation, we progressively saturated the specification with firm fixed effects. For example, Columns (2) and (4) in Table 9, our most stringent model specification (with both firm, industry and year fixed effects), show that a one-standard-deviation increase in the firm-level cross-ownership measure (i.e. 0.238) is associated with an increase of 6.3% points (=0.266*0.238) in the innovation within the enterprise. The results, presented in Table 9, further confirm that cross-ownership positively enhances corporate innovation.

5.4 Alternative measurement for cross-ownership

Following He and Huang (2017), we conduct two robustness tests by replacing the explanatory variables (*Cross*): (a) *Cross_Dum,* a dummy variable, its value is assigned one if the firm has cross-ownership in that year, otherwise zero. (b) The shareholding ratio of the cross-ownership (*Cross_ Share*) is used instead of the explanatory variable

Variables	(1) *Apply*	(2) *Apply*	(3) *Apply_I*	(4) *Apply_I*
Cross	0.517***	0.266**	0.622***	0.294***
	(0.126)	(0.122)	(0.117)	(0.111)
Growth		−0.073***		−0.038*
		(0.026)		(0.021)
IND		0.275		0.181
		(0.392)		(0.348)
Lev		0.052		0.040
		(0.152)		(0.131)
Cash		−0.053		−0.014
		(0.186)		(0.166)
PPE		−0.968***		−0.827***
		(0.161)		(0.142)
ROA		3.272***		2.447***
		(0.296)		(0.246)
Share		0.021		−0.211
		(0.173)		(0.151)
Separation		−0.021		0.100
		(0.323)		(0.282)
SOE		−0.046		0.046
		(0.064)		(0.056)
Size		0.285***		0.302***
		(0.031)		(0.028)
Tobin_q		−0.020		0.025
		(0.018)		(0.015)
Age		−0.302***		−0.221***
		(0.078)		(0.066)
Constant	1.933***	−3.257***	1.345***	−4.499***
	(0.026)	(0.697)	(0.022)	(0.628)
Observations	16,740	16,740	16,740	16,740
Firm FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Industry FEs	YES	YES	YES	YES
R-squared	0.161	0.222	0.110	0.183
Adj. R-squared	0.160	0.220	0.109	0.180

Note(s): This table reports regression analysis of the relation between the cross-ownership and innovation at the firm level. The numbers in parentheses are *t*-statistics based on standard errors that are clustered at the firm level. ***, ** and * represent significance at the 1%, 5% and 10% levels, respectively
Source(s): Authors' own work

Table 9.
Robustness tests: firm fixed effects

Cross for the regression of Model (1). Similar to the calculation of *Cross*, the sum of the cross-owners' shareholding ratio of the firm is calculated based on the top ten shareholder documents, and the *Cross_Share* indicator is constructed by calculating the yearly average value based on the quarterly data. The regression results for Model (1) after replacing the above two explanatory variables are presented in Table 10, with Columns (1) and (2) showing the regression results for the dummy variable *Cross_Dum* on firms' innovation output *Apply* and *Apply_I*, which are significantly and positively correlated at the 10% and 1% levels, respectively. Columns (3) and (4) show the regression results of cross-owners' shareholding ratio, *Cross_Share,* on firms' innovation output *Apply* and *Apply_I*, which are significantly positive at the 5% and 1% levels, respectively. This further confirms that cross-ownership increases corporate innovation contributions.

	(1) $Apply_{t+1}$	(2) $Apply\_I_{t+1}$	(3) $Apply_{t+1}$	(4) $Apply\_I_{t+1}$
Cross_Dum	0.062*	0.114***		
	(0.038)	(0.033)		
Cross_Share			0.302**	0.472***
			(0.136)	(0.120)
Growth	−0.079***	−0.043***	−0.079***	−0.043***
	(0.017)	(0.014)	(0.017)	(0.014)
IND	0.348	0.256	0.345	0.251
	(0.212)	(0.186)	(0.212)	(0.186)
Lev	−0.001	−0.010	0.002	−0.007
	(0.081)	(0.070)	(0.081)	(0.070)
Cash	−0.055	−0.014	−0.054	−0.012
	(0.106)	(0.093)	(0.106)	(0.093)
PPE	−0.934***	−0.795***	−0.934***	−0.796***
	(0.081)	(0.069)	(0.081)	(0.069)
ROA	3.274***	2.448***	3.288***	2.470***
	(0.208)	(0.172)	(0.208)	(0.172)
Share	0.008	−0.224***	−0.010	−0.254***
	(0.084)	(0.073)	(0.084)	(0.073)
Separation	−0.118	0.026	−0.120	0.022
	(0.157)	(0.137)	(0.157)	(0.137)
SOE	−0.063**	0.030	−0.070**	0.023
	(0.029)	(0.025)	(0.030)	(0.026)
Size	0.290***	0.308***	0.289***	0.306***
	(0.015)	(0.013)	(0.015)	(0.013)
Tobin_q	−0.018	0.026***	−0.018*	0.026***
	(0.011)	(0.009)	(0.011)	(0.009)
Age	−0.292***	−0.211***	−0.292***	−0.212***
	(0.036)	(0.031)	(0.036)	(0.031)
Year FEs	Yes	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes	Yes
Constant	−5.072***	−5.896***	−5.021***	−5.839***
	(0.474)	(0.413)	(0.474)	(0.413)
Observations	17,168	17,168	17,168	17,168
R^2	0.216	0.179	0.216	0.179

Note(s): ***, ** and * denote significance at the 1%, 5% and 10% level, respectively
Source(s): Authors' own work

Table 10. Robustness checks: alternative measurement for cross-ownership

5.5 Alternative measures for corporate innovation

To ensure the robustness of the empirical results, we follow existing literature (e.g. Tsang, Wang, Liu, & Yu, 2021) and incorporate citation counts as an additional measure of innovation quality. This approach could provide a more comprehensive understanding of innovation's impact. The regression results of the effect of cross-ownership on the firms' innovation quality are tabulated in Table 11. It shows that the coefficient of cross-ownership (*Cross*) is significantly and positively correlated with the number of firms' patents cited (*Citation*) at the 1% level, indicating that cross-ownership significantly enhances firms' innovation quality. These findings further support that cross-ownership can significantly enhance corporate innovation output.

5.6 Different threshold for cross-ownership

The threshold for the shareholding ratio of cross-ownership (*Cross*) in this paper is 5%, that is, shareholders who own more than 5% of shares of multiple enterprises in the same

	(1) *F. Citation*	(2) *F. Citation*
Cross	0.872***	0.152***
	(14.704)	(2.720)
Growth		−0.024
		(−1.630)
IND		0.342*
		(1.663)
Lev		−0.406***
		(−5.252)
Cash		−0.529***
		(−5.377)
PPE		−0.617***
		(−7.943)
ROA		−0.753***
		(−3.817)
Share		−0.589***
		(−7.504)
Separation		0.525***
		(3.462)
SOE		0.172***
		(5.999)
Size		0.562***
		(37.647)
Tobin_q		0.128***
		(12.357)
Age		−0.109***
		(−3.208)
Constant	−1.003***	−12.268***
	(−3.454)	(−30.540)
Year FEs	Yes	Yes
Industry FEs	Yes	Yes
R^2	0.193	0.311
Observations	17,168	17,168

Note(s): This study incorporates the citation counts as an additional measure of innovation quality (*Citation*). ***, ** and * denote significance at the 1%, 5% and 10% level, respectively
Source(s): Authors' own work

Table 11. Alternative measures for innovation output

industry are defined as cross-owners. To exclude the interference of artificially set shareholding ratio on the research results, this paper changes the threshold of the shareholding ratio of cross-ownership to 10% and 3% and constructs the cross-ownership indicators (*Cross_10%*, *Cross_3%*) for regressions. Columns (1) and (2) in Table 12 present the regression results of cross-ownership (Cross_10%) on firms' innovation (*Apply* and *Apply_I*). The coefficients are significantly positive at the 5% and 1% levels, respectively. Columns (3) and (4) show the regression results of cross-ownership (*Cross_3%*) on firms' innovation (*Apply* and *Apply_I*), and both coefficients are significantly positive at the 1% level. These findings further confirm the reliability of our conclusions.

5.7 Control for the year trends in the industry

Our sample period starts from 2007 to 2020, so industries such as new media and coal have experienced different development cycles. Meanwhile, the macropolicies introduced each year will have a disparate impact on the innovation behavior of different industries.

	(1) $Apply_{t+1}$	(2) $Apply\_I_{t+1}$	(3) $Apply_{t+1}$	(4) $Apply\_I_{t+1}$
Cross_10%	0.136**	0.196***		
	(0.064)	(0.056)		
Cross_3%			0.161***	0.195***
			(0.037)	(0.032)
Growth	−0.080***	−0.043***	−0.079***	−0.043***
	(0.017)	(0.014)	(0.017)	(0.014)
IND	0.365*	0.279	0.339	0.246
	(0.213)	(0.187)	(0.212)	(0.186)
Lev	0.016	0.005	−0.002	−0.013
	(0.082)	(0.070)	(0.081)	(0.070)
Cash	−0.051	−0.010	−0.071	−0.031
	(0.106)	(0.094)	(0.106)	(0.093)
PPE	−0.935***	−0.798***	−0.939***	−0.801***
	(0.081)	(0.070)	(0.081)	(0.069)
ROA	3.338***	2.505***	3.254***	2.422***
	(0.212)	(0.175)	(0.208)	(0.172)
Share	−0.018	−0.237***	0.041	−0.188**
	(0.085)	(0.074)	(0.084)	(0.073)
Separation	−0.133	0.013	−0.123	0.017
	(0.157)	(0.137)	(0.157)	(0.137)
SOE	−0.069**	0.027	−0.078***	0.019
	(0.030)	(0.026)	(0.029)	(0.025)
Size	0.290***	0.309***	0.283***	0.302***
	(0.015)	(0.013)	(0.015)	(0.013)
Tobin_q	−0.018*	0.027***	−0.021*	0.023**
	(0.011)	(0.009)	(0.011)	(0.009)
Age	−0.278***	−0.198***	−0.290***	−0.210***
	(0.036)	(0.031)	(0.036)	(0.031)
Year FEs	Yes	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes	Yes
Constant	−5.099***	−5.955***	−4.929***	−5.777***
	(0.474)	(0.413)	(0.473)	(0.410)
Observations	16,989	16,989	17,168	17,168
R^2	0.217	0.180	0.217	0.180

Note(s): ***, ** and * denote significance at the 1%, 5% and 10% level, respectively
Source(s): Authors' own work

Table 12.
Robustness tests: different threshold for cross-ownership

The yearly trend-related factors of the industries enter the residual term of the model, which may affect the reliability of the regression results of this paper. To eliminate such effects, we further controlled the fixed effects of the cross-product term of industry and year to exclude the effects brought about by industry development cycles and macro policies on firms' innovation output. Table 13 shows the regression results after the industry and yearly trends are controlled. Cross-ownership (*Cross*) is significantly and positively correlated with the firms' innovation output (*Apply*, *Apply_I*) at the 5% and 1% levels, respectively, indicating that cross-ownership's promotion effect on firms' innovation output remains unchanged after taking into account the year trend of the industry.

6. Further analysis

6.1 Heterogeneity test

The relationship between cross-ownership and firms' innovation output is affected by both macro and microfactors. At the micro level, as a special equity structure, cross-ownership's

	(1) $Apply_{t+1}$	(2) $Apply\_I_{t+1}$
Cross	0.128**	0.196***
	(0.057)	(0.051)
Growth	−0.078***	−0.042***
	(0.017)	(0.014)
IND	0.345	0.252
	(0.213)	(0.187)
Lev	0.019	−0.009
	(0.082)	(0.070)
Cash	−0.045	−0.011
	(0.107)	(0.095)
PPE	−0.935***	−0.796***
	(0.081)	(0.070)
ROA	3.378***	2.515***
	(0.209)	(0.173)
Share	−0.003	−0.220***
	(0.084)	(0.074)
Separation	−0.116	0.012
	(0.158)	(0.138)
SOE	−0.072**	0.024
	(0.030)	(0.026)
Size	0.288***	0.308***
	(0.015)	(0.013)
Tobin_q	−0.019*	0.026***
	(0.011)	(0.010)
Age	−0.291***	−0.212***
	(0.036)	(0.031)
Year FEs	Yes	Yes
Industry FEs	Yes	Yes
Year × Industry FEs	Yes	Yes
Constant	−4.853***	−5.599***
	(0.844)	(0.749)
Observations	17,168	17,168
R^2	0.222	0.184

Note(s): ***, ** and * denote significance at the 1%, 5% and 10% level, respectively
Source(s): Authors' own work

Table 13. Robustness tests: control the year trend of the industry

role is constrained by the control of large shareholders. At the macro level, cross-ownership links several firms in the same industry through shareholdings and is affected by industry and market competition. Based on this, this paper examines the moderating effects of macro and micro factors closely related to cross-ownership in terms of both check-and-balance of ownership and market competition.

6.1.1 Heterogeneity in balance of shareholder power. Power balance with shareholder structure means that the control of a firm is shared by several large shareholders. Through mutual supervision and power balance among large shareholders, no single one can control the firm and encroach on its interests. When there is a high degree of power balance of ownership, cross-owners have lower supervision costs. They have a stronger incentive to supervise and govern the firm, which can promote the firm's innovation output through the "collaborative governance" effect. When there is a lower degree of power balance of ownership, a single majority shareholder weakens cross-owners' controlling. Consequently,

cross-owners have higher supervision costs, so it is challenging for them to act on corporate innovation decisions through resource advantages, thus weakening the role of cross-ownership in promoting firms' innovation output. Based on this, this paper anticipates that cross-ownership can better promote the innovation output in firms with a high degree of power balance of ownership.

To test the above discussion, we measure the degree of firms' check-and-balance of ownership by dividing the shareholding ratio of the second to fifth largest shareholders by that of the largest shareholder, constructing a dummy variable *Balance* based on the industry median of that year. The value is 1 when the degree of firms' check-and-balance of ownership is greater than the median and 0 otherwise. Then, we conducted group regressions. The group regression results are shown in Table 14. From Columns (1) and (3), we can see that when firms have a high degree of check-and-balance of ownership, the regression coefficients of cross-ownership (*Cross*) and firms' innovation output (*Apply*, *Apply_I*) are significantly

	$Apply_{t+1}$		$Apply\_I_{t+1}$	
	(1)	(2)	(3)	(4)
	Balance = 1	*Balance* = 0	*Balance* = 1	*Balance* = 0
Cross	0.242***	−0.011	0.298***	0.076
	(0.069)	(0.075)	(0.060)	(0.065)
Growth	−0.097***	−0.061***	−0.057***	−0.030
	(0.024)	(0.023)	(0.021)	(0.020)
IND	0.562*	0.207	0.419	0.162
	(0.296)	(0.291)	(0.255)	(0.252)
Lev	−0.059	0.054	−0.032	0.004
	(0.114)	(0.115)	(0.098)	(0.100)
Cash	0.138	−0.322*	0.219*	−0.323**
	(0.143)	(0.175)	(0.124)	(0.152)
PPE	−0.790***	−1.078***	−0.655***	−0.927***
	(0.112)	(0.108)	(0.097)	(0.094)
ROA	3.437***	3.217***	2.607***	2.353***
	(0.302)	(0.286)	(0.261)	(0.248)
Share	−0.026	0.207	−0.298***	−0.056
	(0.129)	(0.129)	(0.112)	(0.112)
Separation	−0.296	0.029	−0.060	0.079
	(0.222)	(0.215)	(0.192)	(0.186)
SOE	−0.020	−0.087**	0.062*	0.013
	(0.042)	(0.040)	(0.036)	(0.035)
Size	0.292***	0.286***	0.316***	0.299***
	(0.019)	(0.018)	(0.016)	(0.016)
Tobin_q	−0.026	−0.012	0.029**	0.023*
	(0.017)	(0.015)	(0.014)	(0.013)
Age	−0.213***	−0.396***	−0.177***	−0.259***
	(0.045)	(0.057)	(0.039)	(0.050)
Year FEs	Yes	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes	Yes
Constant	−5.521***	−3.738***	−6.333***	−4.857***
	(0.542)	(0.457)	(0.468)	(0.397)
Chowtest (*p*-value)	0.011		0.003	
Observations	8,497	8,671	8,497	8,671
R^2	0.204	0.231	0.169	0.194

Note(s): ***, ** and * denote significance at the 1%, 5% and 10% level, respectively
Source(s): Authors' own work

Table 14. Heterogeneity in balance of shareholder power

positive at the 1% level. Columns (2) and (4) show that when firms have a low degree of check-and-balance of ownership, the regression coefficients of cross-ownership (*Cross*) and firms' innovation output (*Apply*, *Apply_I*) are insignificant. The results confirm the logical conjecture that cross-ownership plays a more significant role in promoting innovation output in firms with a high degree of check-and-balance of ownership.

6.1.2 Heterogeneity in market competition. The more intense the market competition, the greater the market pressure faced by the firm, so cross-owners have a stronger incentive to improve the firm's competitive ability by leveraging their strengths to avoid the firms in the portfolio from being eliminated from the market. Therefore, we anticipate that cross-ownership plays a more significant role in promoting innovation output when firms face a more competitive market. Following Xu, Zhang, and Xu (2017), we use the ratio of sales expenses to main operating income to express the degree of market competition. The larger the index, the higher the sales expenses consumed per unit of operating income of the product, indicating a more competitive market. The dummy variable *Com* is constructed based on the industry median of that year. The value is 1 when the degree of market competition is higher than the median and 0 otherwise. The regression results are shown in Table 15.

Columns (1) and (3) show that when firms face intense market competition, the regression coefficients of cross-ownership (*Cross*) and firms' innovation output (*Apply*, *Apply_I*) are significantly positive at the 1% level. Columns (2) and (4) show that when firms face less intense market competition, the regression coefficients of cross-ownership (*Cross*) and firms' innovation output (*Apply*, *Apply_I*) are insignificant. This indicates that when firms face intense market competition, cross-owners have a stronger incentive to promote innovation output through the "collaborative governance effect", i.e. cross-ownership plays a more significant role in promoting firms' innovation output in a highly competitive market.

6.2 Further analysis: the quality and effectiveness of innovation

6.2.1 Cross-ownership and high-quality innovation. Corporate innovation can be divided into substantive innovation and strategic innovation (Li & Zheng, 2016). Substantive innovation pursues "high-quality" innovation, which is conducive to improving firms' technology level and competitive ability. Strategic innovation pursues "quantity" and "speed", which is an innovation strategy for seeking other interests. Following Li and Zheng (2016), we use the number of invention patents to measure a firm's substantive innovation (*Apply_I*) and the number of non-invention patents (utility model patents and design patents) to measure its strategic innovation (*Apply_UD*). In this paper, we measure strategic innovation (*Apply_UD*) by the natural logarithm of adding one to the number of non-invention patent applications the firm applied in that year. The regression results are presented in Table 16.

Column (1) shows that the estimated coefficient of cross-ownership (*Cross*) on substantive innovation (*Apply_I*) is significantly positive at the 1% level. The estimated coefficient of cross-ownership (*Cross*) on strategic innovation (*Apply_UD*) in column (4) is positive but insignificant, suggesting that cross-ownership mainly promotes firms' substantive innovation and has an insignificant effect on their strategic innovation. Additionally, to test whether cross-ownership has a long-term impact on firms' innovation output through "collaborative governance", we consider the effect over the period of $t+2$ and $t+3$. The regression results are displayed in Columns (2)–(3) and (5)–(6) and show that the cross-ownership (*Cross*) is significantly and positively related to substantive innovation (*Apply_I*) at the 1% level over the periods of $t+2$ and $t+3$. This supports the idea that cross-ownership only has a long-term effect on promoting firms' substantive innovation rather than strategic innovation (*Apply_UD*) [1].

	$Apply_{t+1}$		$Apply\_I_{t+1}$	
	(1)	(2)	(3)	(4)
	Com = 1	*Com = 0*	*Com = 1*	*Com = 0*
Cross	0.265***	0.050	0.357***	0.090
	(0.084)	(0.075)	(0.076)	(0.067)
Growth	−0.053**	−0.113***	−0.016	−0.073***
	(0.024)	(0.023)	(0.020)	(0.020)
IND	−0.091	0.692**	−0.049	0.473*
	(0.289)	(0.306)	(0.256)	(0.268)
Lev	0.460***	−0.201*	0.394***	−0.250**
	(0.116)	(0.114)	(0.100)	(0.098)
Cash	−0.042	−0.401**	0.035	−0.302**
	(0.137)	(0.161)	(0.124)	(0.140)
PPE	−1.424***	−0.441***	−1.255***	−0.375***
	(0.114)	(0.114)	(0.098)	(0.098)
ROA	3.558***	3.202***	2.621***	2.424***
	(0.271)	(0.320)	(0.222)	(0.269)
Share	0.098	0.062	−0.180*	−0.141
	(0.116)	(0.120)	(0.101)	(0.104)
Separation	−0.449**	0.201	−0.320*	0.295
	(0.225)	(0.217)	(0.191)	(0.192)
SOE	−0.106**	0.049	0.001	0.109***
	(0.044)	(0.040)	(0.037)	(0.034)
Size	0.321***	0.274***	0.332***	0.296***
	(0.021)	(0.020)	(0.019)	(0.018)
Tobin_q	−0.023	−0.032*	0.029**	0.011
	(0.014)	(0.017)	(0.012)	(0.014)
Age	−0.287***	−0.309***	−0.195***	−0.234***
	(0.050)	(0.051)	(0.042)	(0.044)
Year FEs	Yes	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes	Yes
Constant	−5.714***	−4.973***	−6.596***	−5.687***
	(0.700)	(0.623)	(0.616)	(0.550)
Chowtest (*p*-value)	0.000		0.000	
Observations	8,520	8,648	8,520	8,648
R^2	0.273	0.193	0.229	0.162

Note(s): ***, ** and * denote significance at the 1%, 5% and 10% level, respectively
Source(s): Authors' own work

Table 15.
Market competition, cross-ownership and innovation output

6.2.2 Cross-ownership and firms' innovation quality and efficiency. Corporate innovation level is not only reflected by the number of patents but also by the quality. Following prior literature (e.g. Sharma & Tripathi, 2017; Tsang *et al.*, 2021), we incorporate the citation counts as an additional measure of innovation quality. This approach could provide a more comprehensive understanding of innovation's impact. Therefore, this paper uses the number of patents cited (*Cite*) in year *t+1* from the CSMAR database to measure innovation quality. The regression results of the effect of cross-ownership on the firms' innovation quality are shown in Column (1) of Table 17. The results show that cross-ownership (*Cross*) is significantly and positively correlated with the number of firms' patents cited ($Cite_{t+1}$) at the 10% level, indicating that cross-ownership significantly enhances firms' innovation quality.

We further examine the effect of cross-ownership on firms' innovation efficiency. Following He and Huang (2017), we measure firms' innovation efficiency by the ratio of the number of patent applications to the amount of R&D investment (*Apply_ratio*, *Apply_Iratio*).

	(1) $Apply\_I_{t+1}$	(2) $Apply\_I_{t+2}$	(3) $Apply\_I_{t+3}$	(4) $Apply\_UD_{t+1}$	(5) $Apply\_UD_{t+2}$	(6) $Apply\_UD_{t+3}$
Cross	0.197***	0.216***	0.186***	0.070	0.071	0.059
	(0.051)	(0.057)	(0.065)	(0.051)	(0.052)	(0.058)
Growth	−0.043***	−0.050***	−0.055***	−0.087***	−0.096***	−0.108***
	(0.014)	(0.016)	(0.018)	(0.014)	(0.017)	(0.019)
IND	0.255	0.316	0.382	0.476**	0.497**	0.660***
	(0.186)	(0.207)	(0.233)	(0.190)	(0.210)	(0.235)
Lev	−0.008	−0.045	−0.025	0.121*	0.026	0.147
	(0.070)	(0.079)	(0.091)	(0.072)	(0.083)	(0.094)
Cash	−0.015	−0.100	0.012	0.058	−0.018	0.105
	(0.093)	(0.103)	(0.113)	(0.096)	(0.109)	(0.119)
PPE	−0.796***	−0.834***	−0.737***	−0.678***	−0.701***	−0.527***
	(0.069)	(0.078)	(0.090)	(0.071)	(0.079)	(0.090)
ROA	2.453***	2.883***	3.948***	2.575***	2.950***	4.320***
	(0.172)	(0.222)	(0.299)	(0.183)	(0.232)	(0.300)
Share	−0.222***	−0.249***	−0.340***	0.251***	0.226***	0.156*
	(0.073)	(0.082)	(0.092)	(0.076)	(0.083)	(0.093)
Separation	0.027	0.111	0.157	−0.275*	−0.215	−0.289*
	(0.137)	(0.153)	(0.171)	(0.143)	(0.155)	(0.172)
SOE	0.026	0.053*	0.096***	−0.119***	−0.110***	−0.074**
	(0.025)	(0.029)	(0.033)	(0.027)	(0.029)	(0.033)
Size	0.307***	0.315***	0.329***	0.224***	0.239***	0.252***
	(0.013)	(0.015)	(0.017)	(0.013)	(0.013)	(0.015)
Tobin_q	0.025***	0.016	0.005	−0.042***	−0.060***	−0.061***
	(0.009)	(0.010)	(0.011)	(0.010)	(0.011)	(0.012)
Age	−0.211***	−0.159***	−0.149***	−0.205***	−0.139***	−0.137***
	(0.031)	(0.033)	(0.037)	(0.033)	(0.035)	(0.038)
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−5.863***	−5.130***	−5.792***	−4.206***	−3.349***	−4.249***
	(0.412)	(0.457)	(0.499)	(0.413)	(0.458)	(0.505)
Observations	17,168	14,136	11,409	17,168	14,136	11,409
R^2	0.179	0.173	0.174	0.242	0.242	0.245

Note(s): ***, ** and * denote significance at the 1%, 5% and 10% level, respectively
Source(s): Authors' own work

Table 16. Cross-ownership and high-quality innovation: long-term effects

The regression results are shown in Columns (2) and (3) of Table 17. The regression coefficients of cross-ownership (*Cross*) are significantly and positively associated with patent innovation efficiency (*Apply_ratio*) and invention patent innovation efficiency (*Apply_Iratio*) at the 5% and 1% level, respectively. These results confirm that the cross-ownership will enhance inter-firm cooperation and thereby improve firms' innovation efficiency through sharing technological expertise.

6.3 Economic consequence

Does the promotion effect of the firm's cross-ownership on innovation output enhance the firm's value? We measure the dependent variable by using the firm's market value (*Tobin_q*), and using the number of cross-owners, the innovation output indicator and the cross-product of the two in that period as independent variables. Model (2) is constructed to test the effect of cross-ownership and innovation output on the firm's value.

	(1) $Cite_{t+1}$	(2) $Apply\_ratio_{t+1}$	(3) $Apply\_Iratio_{t+1}$
Cross	0.116*	0.006**	0.010***
	(0.064)	(0.003)	(0.003)
Growth	−0.021	−0.004***	−0.002***
	(0.018)	(0.001)	(0.001)
IND	0.498**	0.017	0.012
	(0.240)	(0.011)	(0.010)
Lev	−0.290***	0.001	0.001
	(0.093)	(0.004)	(0.004)
Cash	−0.496***	−0.002	−0.000
	(0.123)	(0.006)	(0.005)
PPE	−0.790***	−0.046***	−0.039***
	(0.093)	(0.004)	(0.004)
ROA	−0.513**	0.175***	0.131***
	(0.241)	(0.011)	(0.009)
Share	−0.400***	0.003	−0.011***
	(0.096)	(0.005)	(0.004)
Separation	0.255	−0.010	−0.000
	(0.178)	(0.008)	(0.007)
SOE	0.115***	−0.004**	0.002
	(0.034)	(0.002)	(0.001)
Size	0.580***	0.010***	0.012***
	(0.018)	(0.001)	(0.001)
Tobin_q	0.102***	−0.002***	0.001
	(0.012)	(0.001)	(0.001)
Age	−0.127***	−0.016***	−0.012***
	(0.039)	(0.002)	(0.002)
Year FEs	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes
Constant	−13.077***	−0.151***	−0.225***
	(0.457)	(0.026)	(0.023)
Observations	10,020	17,168	17,168
R^2	0.308	0.200	0.156

Note(s): The number of patents cited (*Cite*) in year $t+1$ from the CSMAR database is utilized to measure innovation quality. The firms' innovation efficiency is measured by the ratio of the number of patent applications to the amount of R&D investment (*Apply_ratio, Apply_Iratio*). ***, ** and * denote significance at the 1%, 5% and 10% level, respectively
Source(s): Authors' own work

Table 17.
Cross-ownership and firms' innovation quality and efficiency

$$Tobinq_{i,t} = \beta_0 + \beta_1 Cross_{i,t} + \beta_2 Apply_{i,t}\left(Apply\_I_{i,t}\right) + \beta_3 Cross_{i,t} \times Apply_{i,t}\left(Apply\_I_{i,t}\right) + \beta_j Control_{i,t} + \sum Year + \sum Ind + \varepsilon_{i,t} \quad (2)$$

Table 18 presents the test results of cross-ownership and innovation output on firms' value, and the coefficients of the cross-product are significantly positive at the 1% level. This means that cross-ownership increases the firms' innovation output and adds to their value in that year, further verifying the positive impact of cross-ownership on the firm through the "collaborative governance" effect.

	(1) *Tobin_q*	(2) *Tobin_q*
Cross	0.278***	0.324***
	(0.051)	(0.046)
Apply	−0.022***	
	(0.006)	
Cross×Apply	0.065***	
	(0.017)	
Apply_I		0.005
		(0.007)
Cross×Apply_I		0.056***
		(0.019)
Growth	−0.002	−0.001
	(0.012)	(0.011)
IND	0.849***	0.843***
	(0.142)	(0.140)
Lev	−0.128**	−0.128**
	(0.061)	(0.053)
Cash	0.437***	0.436***
	(0.089)	(0.074)
PPE	0.081	0.103**
	(0.055)	(0.052)
ROA	3.066***	3.007***
	(0.180)	(0.124)
Share	−0.269***	−0.268***
	(0.056)	(0.056)
Separation	0.594***	0.594***
	(0.102)	(0.105)
SOE	0.073***	0.076***
	(0.020)	(0.019)
Size	−0.359***	−0.366***
	(0.010)	(0.008)
Age	0.097***	0.104***
	(0.024)	(0.024)
Year FEs	Yes	Yes
Industry FEs	Yes	Yes
Constant	9.104***	9.229***
	(0.242)	(0.284)
Observations	21,380	21,380
R^2	0.302	0.301

Note(s): ***, ** and * denote significance at the 1%, 5% and 10% level, respectively
Source(s): Authors' own work

Table 18. Economic consequences of cross shareholders and innovation output

7. Conclusion

Based on the Chinese A-share listed firms over the period of 2007 and 2020, we examine the effect of cross-ownership on corporate innovation and the underlying mechanism. The results suggest that cross-ownership enhances corporate innovation output, verifying the positive role of cross-owners in collaborative governance. Our findings remain unchanged after a series of robustness tests. Our study identifies two primary mechanisms through which cross-ownership foster innovation: easing financing constraints and reducing agency costs. Additionally, it is observed that the impact of cross-ownership on innovation is more pronounced in firms with higher equity restriction ratios and in more competitive markets. This research also highlights that cross-ownership

ultimately contributes to increased firm value by enhancing firm innovation quality and innovation efficiency.

This study provides important policy implications. First, cross-owners should actively play their resource and supervision advantages to improve firms' long-term development capability through the "collaborative governance" effect. Second, listed companies in China should be fully aware of the value of cross-ownership and use cross-ownership as a bridge to strengthen the cooperative relationship with firms in the same portfolio. Meanwhile, listed firms need to pay attention to cross-ownership's "collaborative governance" effect to provide an impetus for the healthy development of enterprises. Finally, government regulators should maintain appropriate supervision of the cross-ownership linkage in the market. While paying attention to the collusion effect of cross-ownership, they shall not ignore its governance effect, for example, the promotion effect on the innovation level. Government regulators should appropriately supervise the cross-ownership linkage, which is conducive to maintaining the market order and driving the healthy development of the capital market.

The significant gap between the innovation of non-SOEs and SOEs in China suggests that ownership changes resulting from the *Mixed Ownership Reform* may negatively or positively affect economy-wide innovation. Hence, the future research direction will probably focus on the mixed ownership reform in China and in other emerging economies.

Notes

1. Due to the space limitation, the regression results of this section are not presented in this paper but are kept and available upon request.

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Corresponding author
Lijuan Xiao can be contacted at: lijuanxiao@jxufe.edu.cn