Cross-Owner and Corporate Digital Technology Innovation

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Abstract. In the context of the rapid development of the digital economy, corporate digital technology innovation has become a key driver for promoting high-quality economic development. We base our study on the data of Chinese A-share listed companies from 2010 to 2023 and empirically examine the impact of cross-owners on corporate digital technology innovation and its mechanism of action. We find that cross-owners have a significant positive effect on corporate digital technology innovation, and this conclusion remains robust after a series of robustness tests, such as the instrumental variable method and propensity score matching. Our heterogeneity analysis indicates that the positive effect of cross-owners is more pronounced in companies with a lower proportion of institutional ownership, higher audit quality, and a higher degree of separation of ownership and control. Mechanism analysis reveals that cross-owners mainly enhance the digital technology innovation capability of corporates through two pathways: improving internal control quality and curbing earnings management. Our findings are consistent with the theoretical logic that cross-owners optimize the allocation of innovation resources and mitigate agency problems through collaborative governance mechanisms. This study provides new evidence for understanding the governance effects of cross-owners and has important implications for improving corporate innovation governance mechanisms.

Keywords: cross-owners, synergy effect, corporate digital technology innovation.

1. Introduction

In recent years, digital technology innovation has flourished globally and become a key driver for high-quality economic development. Digital technology fundamentally transforms corporate products, production processes, organizational models, and business models [1], creating new growth opportunities for corporates and generating significant economic value for society. Despite the growing importance of digital innovation, corporates in many regions still face numerous challenges, such as insufficient R&D investment and low innovation efficiency. Against this backdrop, how to optimize corporate governance to promote digital technology innovation has become an important issue of common concern in both academic and practical circles.

Existing research has explored the impact of corporate governance on corporate digital technology innovation from multiple perspectives. For example, top management teams with digital backgrounds[2] and digital mergers and acquisitions[3] have positive effects on corporate digital technology innovation. In recent years, the governance effects of cross-owners(i.e., shareholders who hold shares in multiple companies) have gradually attracted attention. Some scholars argue that cross-owners can promote corporate innovation through information flow[4-6]. However, other studies have found that cross-owners may reduce governance efficiency due to conflicts of interest[7, 8]. These divergences indicate that the impact of cross-owners on digital technology innovation may involve complex transmission mechanisms that urgently need to be empirically tested.

Theoretically, there are two possible pathways through which cross-owners may affect digital technology innovation. On the one hand, cross-owners may promote innovation through a “synergy effect.” By building cross-corporate network relationships, cross-owners can effectively promote knowledge sharing and resource integration[9]. At the same time, the professional governance experience of cross-owners helps to restrain managerial short-term behavior[8]. Moreover, their cross-corporate resource allocation capabilities can alleviate innovation financing constraints[10]. On the other hand, cross-owners may also generate a “collusion effect,” thereby suppressing corporate

digital technology innovation. To avoid the impact of high-risk innovation projects on overall investment returns, cross-owners may strategically raise funding thresholds[11], thereby exacerbating corporate innovation financing constraints. When corporates can obtain excess profits through market collusion facilitated by cross-owners[7], their intrinsic motivation to engage in high-risk technological innovation will be significantly reduced. From a market competition perspective, market collusion coordinated by cross-owners weakens competitive pressure[12], and lack of competition reduces corporates' enthusiasm for exploring new technologies, which is not conducive to digital technology innovation.

To clarify this theoretical controversy, we use A-share listed companies from 2010 to 2023 as a sample to empirically test the impact of cross-owners on corporate digital technology innovation. Our findings are as follows: (1) First, cross-owners have a significant positive effect on corporate digital technology innovation, and this conclusion remains robust after a series of robustness tests. Specifically, we verify the robustness of the results by replacing the measurement method of core variables, changing regression models and samples, and conducting propensity score matching (PSM). At the same time, to alleviate potential endogeneity issues, we use the Heckman two-step method and instrumental variable estimation, and the results still support the innovation-promoting effect of cross-owners; (2) Mechanism analysis shows that cross-owners mainly promote innovation through two pathways: improving internal control quality and curbing earnings management. On the one hand, with their rich cross-corporate governance experience, cross-owners can effectively strengthen corporate internal control quality and reduce the interference of managerial short-term behavior in innovation activities. On the other hand, the presence of cross-owners significantly curbs corporate earnings management behavior, reduces information asymmetry, and thus provides more stable financial support for high-risk, long-term digital technology innovation; (3) Heterogeneity analysis finds that the promoting effect of cross-owners is more significant in companies with a lower proportion of institutional ownership, higher audit quality, and a higher degree of separation of ownership and control.

The marginal contributions of this paper are as follows: First, we expand the research on the economic consequences of corporate cross-ownership. There is a clear divergence in existing research on cross-owners[8], with some studies confirming their "synergy effect" and others revealing the existence of a "collusion effect." By systematically analyzing the impact mechanism of cross-owners on corporate digital technology innovation, we further verify the dominant role of the "synergy effect" and provide new empirical evidence and theoretical supplements for research on cross-owners. Second, we expand the research field of corporate digital technology innovation. Existing studies have examined the factors affecting digital technology innovation[2, 13, 14], while this paper innovatively examines the impact mechanism of cross-owners on corporate digital technology innovation from the micro-level of equity structure, providing a new theoretical perspective for understanding corporate innovation behavior. Third, our research findings have important implications for improving corporate governance practices in the digital economy era. In pursuit of maximizing profits, cross-owners' behaviors such as joint pricing[15] and earnings management[16] may have adverse effects on market fair competition and high-quality corporate development. This study provides a policy basis for regulatory authorities to guide cross-owners to play a positive role.

2. Literature Review

Review of Literature on Cross-Owners. Cross-owners refer to shareholders who hold equity in multiple companies[6]. According to portfolio investment theory, compared with single-investment shareholders, cross-owners have two distinct characteristics: First, the objective of cross-owners is typically not the maximization of value for a single corporate, but rather the maximization of the overall value of their entire investment portfolio. This objective may lead cross-owners to engage in investment collusion[15]. Second, because cross-owners hold equity in multiple companies, they possess richer industry investment experience and information resources that can be shared across

firms, thereby exerting a synergistic effect in corporate governance[17]. Based on these two characteristics, existing research from a micro perspective mainly divides the role of cross-owners into two categories:

The first is the collusion effect. Cross-owners can increase the pricing power of co-industry corporates in the product market, thereby significantly reducing the level of market competition[7]. This reduction in market competition can lead to decreased sensitivity to investment opportunities among corporates[17]. In listed companies with cross-owners, managerial incentives are often less sensitive to performance in order to avoid excessive competition among firms within the portfolio[18]. Additionally, cross-owners may use earnings management techniques to conceal excess profits from collusion, which in turn reduces the quality of corporate earnings information[16]. Cross-owners can also enhance firms' market monopoly positions, significantly lowering their ESG (Environmental, Social, and Governance) performance[19]. Beyond these findings, other negative impacts of cross-owners include “over-supervision” by large shareholders, which can reduce the enthusiasm of management[20], and the increased risk of individual stock price crashes due to the interconnection networks formed by cross-owners[21].

The second is the synergy effect. From the perspective of monitoring effects, cross-owners can restrain managerial opportunistic behavior[22]. Cross-owners with cross-shareholdings are more likely to vote against management in shareholders' meetings, thereby playing a more active supervisory role[23]. They can also promote CEO turnover and dismiss incompetent CEOs[24]. From the perspective of information flow, cross-owners can improve the efficiency of corporate mergers and acquisitions and have a positive impact on long-term M&A performance[5]. Cross-owners can facilitate the transfer of professional information and management experience across different firms, thereby promoting strategic cooperation and increasing the market share of firms within the portfolio[6]. They can enhance market information efficiency and reduce the risk of stock price crashes[4]. Additionally, cross-owners can encourage the “internalization” of corporate information disclosure and prompt firms to voluntarily disclose more information by following the example of other firms within the portfolio[25, 26]. Cross-owners can also improve the quality of earnings information in listed companies and curb corporate earnings management[27].

Review of Literature on Corporate Digital Technology Innovation. Corporate digital technology innovation refers to the process of fundamentally transforming corporate products, production processes, organizational models, and business models based on digital technology as the underlying foundation[1, 28, 29]. Digital technology innovation can alleviate information asymmetry between various organizational units within corporates and enhance their capability of resource integration[30]. It also improves corporate production efficiency, R&D innovation, and market value[31, 32] and enhances corporate financial performance by improving operational efficiency[33]. Existing research on the influencing factors of corporate digital technology innovation mainly focuses on two aspects:

First, macro-level influencing factors. Government subsidies and industry entry regulations are conducive to corporate digital technology innovation[13]. Regional economic development levels, agglomeration of innovative talents, capital intensity, digital connectivity, and infrastructure construction have significant positive effects on local corporate digital technology innovation, while environmental pollution has a significant negative impact[14]. The dual pilot programs of innovative cities and intellectual property demonstration cities promote the simultaneous improvement of both the quality and quantity of regional digital technology innovation[34]. Low-carbon city pilot policies significantly promote urban digital technology innovation[35]. The interaction between R&D human capital investment and information infrastructure is a key driver of regional digital technology innovation[36].

Second, micro-level influencing factors. Knowledge acquisition is a key driving force for corporate digital technology innovation[37]. Information flow with external entities such as supply chain partners facilitates knowledge acquisition and helps corporates identify opportunities for digital technology innovation[38]. An increase in market integration level can significantly promote the

quality and quantity of corporate digital innovation[39]. A digital background of top management teams is conducive to corporate digital technology innovation[2]. Digital mergers and acquisitions help establish a digital knowledge base for industrial-era corporates, thereby promoting corporate digital technology innovation[3].

Overall, the academic community has yet to reach a unified conclusion on the economic impact of cross-owners on corporate governance. Current research on corporate digital technology innovation mostly focuses on its economic consequences, while exploration of its influencing factors is relatively limited, especially those at the corporate level. Few studies have delved into how equity structure factors, particularly cross-owners, affect corporate performance in digital technology innovation. Given the importance of digital technology innovation in today's corporate competition, understanding the role of equity structure, especially that of cross-owners, becomes particularly crucial. Therefore, conducting empirical research on the impact of cross-owners on corporate digital technology innovation can enrich the existing literature and provide theoretical support and practical guidance for optimizing corporate governance structures and promoting digital technology innovation.

3. Research Hypotheses and Empirical Design

Research Hypotheses. Theoretically, cross-owners have a dual impact mechanism on corporate digital technology innovation: On the one hand, cross-owners can positively promote digital technology innovation through enhanced governance supervision, shared information resources, and alleviated financing constraints, generating a "synergy effect." On the other hand, driven by the motivation to maximize portfolio benefits, cross-owners may trigger a "collusion effect," thereby potentially inhibiting digital technology innovation.

Under the perspective of the "synergy effect," cross-owners, with their rich governance experience and cross-corporate resource allocation capabilities, can significantly enhance the digital technology innovation level of invested firms. First, the corporate network formed through equity linkages can effectively promote information sharing and knowledge flow among firms within the investment portfolio. On one side, there exists a peer effect of digital transformation within the common equity network[27]. When core firms in the network take the lead in digital technology innovation, they exert a significant demonstration effect. Other firms within the portfolio can obtain innovation experience at a low cost through equity ties, reducing trial-and-error costs and ultimately enhancing their willingness and capability for digital technology innovation. On the other side, knowledge is a core element in the process of digital technology innovation[37]. Through knowledge interaction with other network entities, firms can more accurately identify opportunities for digital technology innovation[38]. In this process, cross-owners build bridges for the cross-organizational flow and integration of digital technology innovation knowledge, which is conducive to firms' engagement in digital technology innovation. Additionally, as cross-corporate strategic investors, cross-owners have significant information and resource advantages compared to ordinary shareholders[23], which helps improve the efficiency of digital technology innovation.

Second, cross-owners can effectively alleviate agency problems in digital technology innovation through enhanced corporate governance supervision mechanisms[17]. There is information asymmetry and agency problems between shareholders and managers. Compared with digital transformation, digital technology innovation may pose more challenges to firms[2], with long-term and high-risk characteristics, or even forming unstable factors[40]. Managers may reduce investment in digital technology due to short-term behavior or risk-averse tendencies. By exercising voting rights and participating in strategic decision-making[23, 24], cross-owners can restrain the conservative tendencies of managers and promote the adoption of more forward-looking digital technology innovation strategies.

Finally, cross-owners can alleviate funding shortages and reduce financing costs for firms during the process of digital technology innovation[10]. On one hand, with their substantial financial resources, cross-owners can provide stable cash flow support for corporate R&D activities through

direct investment or coordinating resources within the portfolio. On the other hand, relying on their market reputation and credit endorsement effects, cross-owners can attract external investors, thereby expanding financing channels and improving the efficiency of capital allocation.

Based on the above theoretical mechanism analysis, this study proposes the following hypothesis:

H1a: Cross-owners will promote corporate digital technology innovation.

Under the perspective of the "collusion effect," cross-owners, driven by the motive to maximize portfolio benefits, may actively coordinate competitive behaviors among co-industry invested firms, such as colluding to control product prices, to reduce overall competition intensity within the portfolio and achieve collusive profits[15]. First, cross-owners may increase the financing constraints faced by corporates in digital technology innovation[10]. Digital technology innovation requires substantial capital investment and sunk costs, with long cycles and high risks[40]. To avoid risk, cross-owners may strategically withhold funding and increase the required rate of return on investment, thereby raising the level of financing constraints for corporates[11]. This is detrimental to the digital technology innovation activities of invested firms.

Second, cross-owners may reduce the willingness of corporates to engage in digital technology innovation. By facilitating collusion among firms to enhance market share, bargaining power, and profitability[6, 7], cross-owners create an alternative to value creation through digital technology innovation. When firms can easily obtain excess profits through collusion, their intrinsic motivation to pursue high-risk, high-investment digital technology innovation is correspondingly weakened.

Third, the market protection formed by cross-owner collusion can reduce innovation efficiency. There is a significant positive relationship between market competition and corporate innovation and R&D[41]. In the absence of competitive pressure, firm managers tend to maintain existing technological pathways rather than explore digital technology innovation, ultimately hindering the improvement of the firm's innovation capabilities.

Based on the above theoretical mechanism analysis, this study proposes the following hypothesis:

H1b: Cross-owners will inhibit corporate digital technology innovation.

Empirical Design. To examine the impact of cross-owners on corporate digital technology innovation, this study employs an econometric model based on the methodologies of prior research[17, 25]:

$$DigiInno_{i,t+1} = \beta_0 + \beta_1 CR_{i,t} + \gamma Controls_{i,t} + \sum Year_t + \sum Ind_j + \varepsilon_{i,t} \quad (1)$$

$DigiInno_{i,\,t+1}$ measures the level of corporate digital technology innovation. Patents are widely used as a key indicator of corporate innovation activities. This study identifies technological characteristics related to digital innovation using the International Patent Classification (IPC) system and selects patents that meet the criteria for digital technology innovation[42]. These patents are then aggregated at the firm-year level to construct the digital technology innovation measure, $DigiInno_{i,t}$. Given that corporate R&D and innovation typically require time to result in patent output, this study uses a one-period lagged variable, $DigiInno_{i,t+1}$ as the dependent variable.

$CR_{i,t}$ indicates the presence of cross-owners. A dummy variable $CR_{i,t}$ is constructed such that if a major shareholder holds at least 5% of the shares in two or more listed companies within the same industry (according to the 2012 industry classification guidelines of the China Securities Regulatory Commission) at the quarterly level, that shareholder is considered a cross-owner[6, 8, 22, 27]. If a firm has a cross-owner in a given year, $CR_{i,t}$ takes the value of 1; otherwise, it is 0. The primary focus is on the estimated coefficient β. A significantly positive β suggests that cross-owners have a positive impact on digital technology innovation, supporting Hypothesis H1a. Conversely, a negative β indicates an inhibitory effect, supporting Hypothesis H1b.

Drawing on prior research on corporate digital technology innovation[10, 20], the following control variables $Controls_{i,t}$ are selected: $Size_{i,t}$, $Leverage_{i,t}$, $ROA_{i,t}$, $Top1_{i,t}$, $Growth_{i,t}$, $Cash_{i,t}$, $Age_{i,t}$, $Boardsize_{i,t}$, $TobinQ_{i,t}$, $Turnover_{i,t}$, $Loss_{i,t}$. The specific definitions of these variables are provided in Table 1. To address potential cross-sectional correlation issues, standard errors are clustered at the firm level in all regressions.

Table 1 Variable Definitions and Construction

Variable Type	Variable	Construction
Dependent Variable	*DigiInno*	Natural logarithm of the number of digital technology invention patents
Independent Variable	*CR*	1 if a major shareholder holds 5% or more in at least two listed companies; 0 otherwise
Control Variable	*Size*	Total assets at year-end
	Leverage	Total liabilities divided by total assets
	ROA	Net profit at the end of the period divided by total owners' equity
	Top1	Shareholding ratio of the largest shareholder
	Growth	(Current year's operating revenue - Previous year's operating revenue) / Previous year's operating revenue
	Cash	Cash and cash equivalents divided by total assets
	Age	Number of years the firm has been in operation
	Boadsize	Number of directors on the board
	TobinQ	Market value to book value ratio
	Turnover	Turnover rate
	Loss	1 if the firm has a loss at the end of the year; 0 otherwise

Data Sources. This study selects A-share listed companies from 2010 to 2023 as the initial research sample and processes the sample data as follows: ① Exclusion of samples from the financial industry; ② Exclusion of ST and *ST stocks; ③ Exclusion of samples with missing values in the core variables. After the above processing, a total of 34,688 firm-year observations across 4,485 companies are obtained. The patent data of listed companies in this study are derived from the WinGo Financial Text Data Platform, while other data are sourced from the China Stock Market & Accounting Research Database (CSMAR).

Descriptive Statistics. Table 2 reports the descriptive statistics of the main variables. From 2009 to 2022, the sample includes 34,688 observations, covering the vast majority of A-share listed companies. The dependent variable *DigiInno* has a mean value of 1.184, a standard deviation of 1.508, and a range from 0 to 5.835, indicating significant differences in digital technology innovation levels among firms. The independent variable *CR* has a mean value of 0.113, suggesting that a relatively small proportion of firms in the sample have cross-owners.

Table 2 Descriptive Statistics

Variable	N	Mean	SD	Min	Max
DigiInno	34,688	1.184	1.508	0.000	5.835
CR	34,688	0.113	0.317	0.000	1.000
Size	34,688	22.240	1.278	19.990	26.060
Leverage	34,688	0.426	0.202	0.056	0.874
ROA	34,688	0.038	0.057	-0.195	0.188
Top1	34,688	0.343	0.148	0.090	0.727
Growth	34,688	0.349	0.869	-0.659	5.630
Cash	34,688	0.160	0.121	0.011	0.594
Age	34,688	2.906	0.337	1.792	3.526
Boadsize	34,688	2.126	0.199	1.609	2.708
TobinQ	34,688	2.037	1.245	0.850	7.750
Turnover	34,688	625.500	490.600	57.760	2536.000
Loss	34,688	0.082	0.274	0.000	1.000

4. Empirical Results and Analysis

Baseline Regression Results Analysis. The baseline regression results for Hypothesis H1 are presented in Table 3. Column (1) shows the regression results without control variables and fixed effects. The regression coefficient for *CR* is 0.420, which is significantly positive at the 1% significance level. This indicates that firms with cross-owners exhibit higher levels of digital technology innovation on average. Column (2) includes industry and year fixed effects, and the regression coefficient increases to 0.505, further strengthening the positive impact of cross-owners on digital technology innovation. Columns (3) and (4) add control variables to the model, and while the significance of the regression coefficient decreases, it remains significantly positive at the 1% level. This suggests that the inclusion of control variables is crucial for the accuracy of the model. Overall, the results demonstrate that cross-owners have a significantly positive impact on digital technology innovation, consistent with the "synergy effect" discussed in the theoretical analysis (H1a) and supporting the positive role of cross-owners in promoting corporate innovation.

Table 3 Baseline Regression Analysis

	(1)	(2)	(3)	(4)
	DigiInno	*DigiInno*	*DigiInno*	*DigiInno*
CR	0.420***	0.505***	0.207***	0.171***
	(5.398)	(8.528)	(2.912)	(3.240)
Size			0.289***	0.301***
			(11.249)	(13.803)
Leverage			-0.598***	-0.044
			(-5.077)	(-0.460)
ROA			1.313***	1.949***
			(5.083)	(9.311)
Top1			-0.831***	-0.040
			(-5.358)	(-0.347)
Growth			-0.062***	-0.008
			(-4.224)	(-0.766)
Cash			0.563***	0.409***
			(3.643)	(3.521)
Age			-0.411***	-0.307***
			(-6.760)	(-5.190)
Boardsize			-0.340***	0.175**
			(-3.218)	(2.112)
TobinQ			0.068***	0.049***
			(5.088)	(4.191)
Turnover			0.000***	0.000***
			(9.547)	(2.736)
Loss			-0.171***	-0.184***
			(-5.709)	(-7.311)
Constant	1.136***	-0.159***	-3.206***	-6.402***
	(50.128)	(-2.707)	(-5.765)	(-12.522)
Industry FE	NO	YES	NO	YES
Year FE	NO	YES	NO	YES
N	34688	34688	34688	34688
R-squared	0.008	0.341	0.061	0.395

Notes: The regression models used are Probit models, which are appropriate for binary dependent variables. The symbols ***, **, and * represent significance levels at the 1%, 5%, and 10% thresholds, respectively. Standard errors, clustered at the firm level, are reported in parentheses. This convention applies to the tables that follow.

Robustness Tests. First, we tested the robustness by using an alternative measure of the dependent variable. The dependent variable for corporate digital technology innovation was lagged by an

additional period (resulting in a total lag of two periods), and the regression analysis was re-conducted. As shown in column (1) of Table 4, the coefficient for *CR* remains significantly positive. After considering the lagged effect, the original research conclusion is still effectively validated, and the positive relationship between corporate digital technology innovation and its performance remains unchanged.

For the independent variable, we constructed three alternative measures of cross-owners based on prior research[6, 22]: ① *CR5*: The number of cross-owners at the 5% threshold is calculated for each quarter, and the annual average is taken, then incremented by 1 and logged; ② *CR5_Share*: The sum of the proportions of shares held by cross-owners for each firm in each quarter is calculated, and the annual average is taken; ③ *CR10*: The threshold is increased to 10%, and the number of cross-owners is similarly calculated at the quarterly level, with the annual average incremented by 1 and logged. After substituting the original independent variable with these three measures, the regression analysis was conducted again. Columns (2), (3), and (4) of Table 4 show that the regression coefficients for all three measures are significant, indicating that the main conclusions of this study remain robust after replacing the measurement method for cross-owners.

Table 4 Robustness Tests: Replacing the Dependent and Independent Variables

	(1)	(2)	(3)	(4)
	Replace the Dependent Variable	Replace the Independent Variable		
	F. DigiInno	*DigiInno*	*DigiInno*	*DigiInno*
CR	0.160***			
	(2.810)			
CR5		0.234***		
		(2.882)		
CR5_Share			0.578***	
			(2.955)	
CR10				0.174**
				(2.484)
Size	0.305***	0.302***	0.304***	0.303***
	(12.934)	(13.802)	(13.916)	(14.043)
Leverage	-0.021	-0.044	-0.044	-0.045
	(-0.197)	(-0.459)	(-0.463)	(-0.469)
ROA	2.322***	1.958***	1.978***	1.983***
	(9.296)	(9.360)	(9.476)	(9.398)
Top1	-0.051	-0.042	-0.076	-0.055
	(-0.415)	(-0.364)	(-0.665)	(-0.477)
Growth	-0.017	-0.008	-0.008	-0.008
	(-1.440)	(-0.762)	(-0.773)	(-0.720)
Cash	0.498***	0.411***	0.415***	0.389***
	(3.971)	(3.539)	(3.575)	(3.339)
Age	-0.282***	-0.306***	-0.310***	-0.294***
	(-4.491)	(-5.181)	(-5.234)	(-4.972)
Boardsize	0.219**	0.173**	0.173**	0.181**
	(2.445)	(2.091)	(2.086)	(2.168)
TobinQ	0.047***	0.050***	0.052***	0.050***
	(3.715)	(4.246)	(4.383)	(4.226)
Turnover	0.000*	0.000***	0.000***	0.000***
	(1.728)	(2.734)	(2.746)	(2.728)
Loss	-0.186***	-0.184***	-0.186***	-0.185***
	(-6.584)	(-7.324)	(-7.367)	(-7.356)
Constant	-6.557***	-6.426***	-6.443***	-6.504***
	(-11.857)	(-12.533)	(-12.582)	(-12.797)
Industry FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
N	29190	34688	34688	34175
R-squared	0.394	0.395	0.395	0.394

Given that the dependent variable (*DigiInno*) in this study is a censored variable, we re-conducted the regression analysis using the Tobit model. Column (1) of Table 5 shows that the regression coefficient remains significantly positive at the 1% significance level, confirming the robustness of the original conclusion. Furthermore, considering that many firms do not have digital technology patents, we excluded samples with a dependent variable value of zero and re-ran the regression analysis using the remaining 17,140 firm-year observations. The coefficient in column (2) of Table 5 remains significant, consistent with the original findings.

To mitigate potential sample selection bias and omitted variable issues, this study employed propensity score matching to re-examine the relationship between cross-owners and corporate digital technology innovation. First, the sample was divided into a treatment group (firms with cross-owners) and a control group (firms without cross-owners). Second, using covariates such as firm size, financial leverage, profitability, and growth opportunities, we performed 1:1 nearest-neighbor matching within a caliper. Finally, the balance test showed that the standardized differences of all variables were less than 5% after matching, and the differences between groups were no longer significant. The regression results are presented in column (3) of Table 5, which still show a significant positive effect of cross-owners on digital technology innovation, thus verifying the robustness of the baseline conclusion.

Table 5 Robustness Tests: Replacing the Regression Model, Regression Sample, and PSM

	(1)	(2)	(3)
	Replace the Regression Model	Replace the Regression Sample	PSM
	DigiInno	*DigiInno*	*DigiInno*
CR	0.171***	0.214***	0.179***
	(3.245)	(3.720)	(2.980)
Size	0.301***	0.447***	0.358***
	(13.824)	(19.018)	(8.856)
Leverage	-0.044	-0.048	-0.087
	(-0.461)	(-0.404)	(-0.374)
ROA	1.949***	1.376***	1.991***
	(9.325)	(5.200)	(3.584)
Top1	-0.040	0.009	0.149
	(-0.348)	(0.071)	(0.613)
Growth	-0.008	0.013	-0.007
	(-0.767)	(0.629)	(-0.252)
Cash	0.409***	0.414***	0.584**
	(3.527)	(3.026)	(2.116)
Age	-0.307***	-0.111*	-0.344***
	(-5.198)	(-1.759)	(-2.692)
Boardsize	0.175**	0.071	0.413**
	(2.116)	(0.742)	(2.296)
TobinQ	0.049***	0.075***	0.071***
	(4.197)	(5.403)	(2.967)
Turnover	0.000***	0.000	0.000
	(2.740)	(1.300)	(0.533)
Loss	-0.184***	-0.086**	-0.190***
	(-7.322)	(-2.492)	(-2.689)
Constant	-6.402***	-9.068***	-8.425***
	(-12.541)	(-16.387)	(-8.955)
Industry FE	YES	YES	YES
Year FE	YES	YES	YES
N	34688	17140	7008
R-squared	0.1374	0.360	0.460

Endogeneity Tests. To address potential sample selection bias arising from missing patent data and investor preference, this study employs the Heckman two-stage model[8]. In the first-stage selection model, a Probit model is constructed that includes $Size_{i,t}$, $Leverage_{i,t}$, $ROA_{i,t}$, $Top1_{i,t}$, $Growth_{i,t}$, $Cash_{i,t}$, $Age_{i,t}$, $Boardsize_{i,t}$, $TobinQ_{i,t}$, $Turnover_{i,t}$, $Loss_{i,t}$,and industry and year fixed effects to calculate the inverse Mills ratio (*IMR*). The regression results in columns (1) and (2) of Table 6 show that the *IMR* is significantly positively correlated with *DigiInno* at the 1% level, with a coefficient of 1.637, confirming the existence of sample selection bias. After controlling for this endogeneity, the positive effect of cross-owners (*CR*) on digital technology innovation (*DigiInno*) remains significant at the 5% level. This indicates that the empirical data still support the conclusion that cross-owners have a positive impact on digital technology innovation after eliminating the estimation bias caused by sample selection.

To further address the potential endogeneity between cross-owners and digital technology innovation, the instrumental variable (IV) method is employed[4]. The "average number of cross-owners in the same industry and year" is used as an instrumental variable. This variable satisfies the following conditions: (1) Relevance: The number of cross-owners in the same industry and year reflects industry characteristics and may influence the number of cross-owners in a specific firm; (2) Exogeneity: The overall level of cross-ownership in the industry does not directly affect the digital technology innovation activities of a particular firm. The two-stage least squares (2SLS) regression results, controlling for industry and year fixed effects, are presented in columns (3) and (4) of Table 6. The first-stage Hansen J test results show that the p-value for the over-identification test is 0.000, rejecting the null hypothesis. Additionally, the F-statistics for under-identification and weak instrument tests are significantly higher than the threshold of 16.38, indicating that the instrumental variable used in this study is valid. The second-stage estimation results show that after controlling for endogeneity, the positive impact of cross-owners (*CR*) on digital technology innovation (*DigiInno*) remains significantly positive at the 1% level. This confirms the robustness of the baseline results.

Table 6 Endogeneity Tests

	(1)	(2)	(3)	(4)
	Heckman		IV	
	CR	*DigiInno*	*CR*	*DigiInno*
CR		0.125**		0.560**
		(2.369)		(2.517)
IMR		1.637***		
		(3.403)		
IV			0.898***	
			(13.717)	
Size	0.453***	0.901***	0.091***	0.265***
	(38.835)	(4.883)	(17.365)	(8.771)
Leverage	-0.100	-0.137	-0.057***	-0.022
	(-1.299)	(-1.339)	(-2.585)	(-0.225)
ROA	0.350	2.504***	-0.003	1.949***
	(1.491)	(9.814)	(-0.059)	(9.318)
Top1	-0.254***	-0.414***	-0.020	-0.031
	(-3.361)	(-2.642)	(-0.785)	(-0.271)
Growth	-0.036**	-0.057***	-0.007**	-0.006
	(-2.567)	(-3.067)	(-2.300)	(-0.514)
Cash	0.424***	0.985***	0.066***	0.382***
	(4.131)	(4.679)	(2.586)	(3.241)
Age	0.156***	-0.091	0.022*	-0.315***
	(4.112)	(-1.066)	(1.704)	(-5.324)
Boardsize	0.183***	0.417***	0.030	0.163*
	(3.307)	(3.712)	(1.601)	(1.951)
TobinQ	0.147***	0.243***	0.030***	0.037***
	(14.952)	(4.083)	(11.084)	(2.745)
Turnover	-0.000***	-0.000**	-0.000	0.000***
	(-4.557)	(-2.415)	(-0.576)	(2.784)
Loss	-0.008	-0.199***	0.001	-0.185***
	(-0.181)	(-7.950)	(0.088)	(-7.339)
Constant	-12.293***	-23.883***		
	(-36.417)	(-4.487)		
Industry FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
N	34688	34688	34688	34688
R-squared		0.397	0.201	0.394

5. Further Discussion

Heterogeneity Analysis. Institutional investors, as professional market participants, have strong capabilities in information acquisition and analysis, which can effectively reduce information asymmetry between firms and external investors[43]. Institutional ownership concentration is positively correlated with the performance sensitivity of executive compensation and can suppress executive pay levels, indicating that institutional investors can exert positive governance and monitoring effects through compensation contract design[44]. Therefore, the monitoring and resource integration functions of institutional investors may partially substitute for the information transmission and governance supervision roles of cross-owners, creating a “substitution effect.” We hypothesize that when the proportion of institutional ownership is high, the marginal positive impact

of cross-owners on corporate digital technology innovation may be weakened. This study measures the level of institutional ownership as the proportion of institutional investor holdings in the total share capital of the firm and divides the sample into high and low institutional ownership groups based on the median value[45]. The regression results in Table 7 show that the positive effect of cross-owners on digital technology innovation is significantly reduced in firms with higher institutional ownership levels, with regression coefficients lower than those in firms with lower institutional ownership. This result confirms the hypothesis that the governance and information intermediary functions of institutional investors partially substitute for the synergy effect of cross-owners, supporting the existence of the “substitution effect”.

High-quality auditing, as an important corporate governance mechanism, can effectively improve the quality of financial reporting[46] and more fully disclose information related to corporate innovation[47], thereby enhancing the financing environment for digital technology innovatio[48]. High-quality auditors can exert stronger audit supervision effects and curb managerial earnings management behavior[49]. When firms engage high-quality auditors, their financial information transparency is higher and their corporate governance mechanisms are more robust. This would partially substitute for the functions of cross-owners in reducing financing costs and governance supervision, meaning that the promoting effect of cross-owners on digital technology innovation would be relatively weaker. This study uses the Big Four accounting firms as a measure of high-quality auditing and divides the sample into Big Four audit and non-Big Four audit groups. The regression results shown in Table 7 indicate that the regression coefficient in the non-Big Four audit group (Column 4) is significantly reduced to 0.001 and is no longer significant. This result suggests that when audit quality is high, the promoting effect of cross-owners on digital technology innovation is significantly weakened, confirming the substitution effect of audit quality on the impact of cross-owners.

The separation of ownership and control, as an important feature of modern corporate governance, reflects the deviation between controlling shareholders' control rights and cash flow rights[50]. When the separation is high, the agency conflict between controlling shareholders and minority shareholders tends to intensify. Controlling shareholders may be more inclined to adopt strategies that favor their short-term interests while neglecting investment decisions beneficial to the firm's long-term development. This is especially true for digital technology innovation, which requires high investment, a long-term cycle, and high risk[40]. Controlling shareholders may reduce support for digital technology innovation due to a focus on short-term returns, thereby affecting the firm's sustained innovation capability. Therefore, we expect that in firms with high separation of ownership and control, cross-owners can effectively mitigate agency problems in digital technology innovation, and their promoting effect will be more pronounced. This study measures the separation of ownership and control as the ratio of control rights to cash flow rights and divides the sample into high and low separation groups based on the median value. Columns (5) and (6) of Table 7 show that in the high separation sample, the promoting effect of cross-owners on corporate digital technology innovation is more significant.

Table 7 Heterogeneity Analysis

	(1)	(2)	(3)	(4)	(5)	(6)
	High Inst. Own.	Low Inst. Own.	Big Four Audit	Non-Big Four Audit	High Separatio	Low Separatio
	DigiInno	*DigiInno*	*DigiInno*	*DigiInno*	*DigiInno*	*DigiInno*
CR	0.126*	0.206***	0.001	0.140**	0.254***	0.099
	(1.921)	(3.144)	(0.006)	(2.549)	(3.249)	(1.559)
Size	0.305***	0.242***	0.539***	0.265***	0.285***	0.320***
	(10.517)	(9.911)	(6.301)	(12.206)	(10.122)	(10.838)
Leverage	-0.011	-0.063	-0.588	0.004	0.131	-0.165
	(-0.082)	(-0.599)	(-0.932)	(0.044)	(1.026)	(-1.286)
ROA	2.139***	1.389***	0.193	2.065***	1.909***	1.965***
	(6.529)	(6.507)	(0.150)	(9.948)	(6.805)	(6.918)
Top1	-0.218	0.227*	-0.963*	-0.012	0.054	-0.137
	(-1.327)	(1.946)	(-1.771)	(-0.106)	(0.349)	(-0.896)
Growth	-0.007	-0.010	-0.013	-0.008	-0.016	-0.001
	(-0.407)	(-0.950)	(-0.252)	(-0.763)	(-1.075)	(-0.044)
Cash	0.394**	0.363***	0.462	0.366***	0.530***	0.343**
	(2.371)	(2.915)	(0.666)	(3.200)	(3.289)	(2.252)
Age	-0.327***	-0.266***	0.015	-0.332***	-0.342***	-0.267***
	(-4.106)	(-4.283)	(0.044)	(-5.721)	(-4.479)	(-3.317)
Boardsize	0.236**	0.119	0.298	0.167**	0.187*	0.153
	(2.076)	(1.353)	(0.787)	(2.090)	(1.721)	(1.355)
TobinQ	0.044***	0.004	0.068	0.044***	0.042***	0.058***
	(2.930)	(0.271)	(1.210)	(3.726)	(2.762)	(3.459)
Turnover	-0.000	0.000***	0.000	0.000**	0.000**	0.000
	(-0.266)	(5.257)	(0.970)	(2.373)	(2.392)	(1.298)
Loss	-0.146***	-0.184***	0.018	-0.201***	-0.206***	-0.168***
	(-3.330)	(-6.537)	(0.130)	(-8.054)	(-5.536)	(-5.026)
Constant	-6.533***	-5.058***	-12.338***	-5.534***	-5.980***	-6.804***
	(-9.593)	(-9.007)	(-6.135)	(-10.663)	(-9.038)	(-9.876)
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
N	17361	17327	2146	32542	15935	18753
R-squared	0.420	0.365	0.531	0.391	0.409	0.395

Mechanism Analysis. The effectiveness of cross-owners in promoting digital innovation depends crucially on whether firms have a high-quality internal control system. A robust internal control system can optimize information flow, ensuring the timeliness and accuracy of information transmission; restrain managers' short-term behavior, preventing excessive pursuit of short-term gains at the expense of long-term development; and enhance the efficiency of capital allocation, providing sufficient and precise resource support for innovation activities. Cross-owners enhance firms' digital technology innovation capabilities by improving internal control quality, creating a favorable environment for innovation. To test this mechanism, following prior research[51], we use the “Dibo China Listed Companies Internal Control Index (ICI)” as a measure of internal control quality. A higher index score indicates better internal control quality, smoother information flow, higher decision-making transparency, more standardized managerial behavior, and more effective constraints on short-term actions, thus providing a more stable and favorable environment for digital innovation. The regression results in column (1) of Table 8 show that the proportion of cross-owners

is significantly positively correlated with the internal control index score at the 1% level, with a correlation coefficient of 11.542. This indicates that cross-owners can significantly enhance firms' digital technology innovation capabilities by improving internal control quality.

We further examine the mediating role of earnings management in the relationship between cross-owners and digital technology innovation. Theoretical analysis suggests that cross-owners can promote innovation by curbing firms' earnings management behavior: First, reducing earnings management improves financial information quality and mitigates information asymmetry in innovation activities[52]; second, restraining earnings management constrains managers' short-term orientation, encouraging a greater focus on long-term value creation; and third, reducing earnings manipulation optimizes resource allocation, ensuring the continuity and stability of R&D investment. To test this logic, we measure earnings management using discretionary accruals, employing the modified Jones model[53]. The regression results in column (2) of Table 8 show that cross-owners are significantly negatively correlated with discretionary accruals at the 5% level, indicating that cross-owners can effectively curb firms' earnings management behavior. Combined with the baseline regression results, this suggests that earnings management partially mediates the positive effect of cross-owners on digital technology innovation.

Table 8 Mechanism Analysis

	(1)	(2)
	ICI	*Discretionary Accruals*
CR	11.542***	-0.004**
	(7.030)	(-2.357)
Size	16.550***	0.002***
	(20.876)	(2.629)
Leverage	6.348	-0.022***
	(1.582)	(-5.589)
ROA	442.013***	0.636***
	(40.878)	(50.781)
Top1	23.873***	-0.009**
	(6.301)	(-2.285)
Growth	1.351***	0.004***
	(2.667)	(4.655)
Cash	13.779***	-0.109***
	(3.246)	(-21.162)
Age	-6.521***	-0.004**
	(-3.490)	(-2.028)
Boardsize	1.406	0.000
	(0.508)	(0.163)
TobinQ	1.034**	-0.003***
	(2.283)	(-5.704)
Turnover	0.007***	0.000***
	(6.881)	(3.544)
Loss	-10.511***	-0.011***
	(-5.678)	(-5.815)
Constant	300.348***	-0.034**
	(16.045)	(-2.015)
Industry FE	YES	YES
Year FE	YES	YES
N	33042	34090
R-squared	0.275	0.259

6. Conclusion

In the strategic context of the accelerated development of the digital economy, corporate digital technology innovation has become a key driver for promoting high-quality economic development. This study examines the impact of cross-owners on corporate digital technology innovation. The findings are as follows: First, cross-owners significantly enhance the level of digital technology innovation in corporates, a conclusion that remains robust after endogeneity treatments such as instrumental variable methods and propensity score matching. Second, heterogeneity analysis indicates that the positive effect of cross-owners is more pronounced in firms with lower institutional ownership ratios, higher audit quality, and a higher degree of separation of ownership and control. Third, mechanism tests reveal that cross-owners primarily enhance corporate digital technology innovation capabilities through two pathways: improving internal control quality and curbing earnings management. This study confirms the "synergy effect" of cross-owners, which effectively promotes the process of corporate digital technology innovation through three key channels: facilitating information flow and knowledge sharing, strengthening governance supervision mechanisms, and alleviating financing constraints.

This research holds significant theoretical and practical value. On the theoretical front, the study not only enriches the literature on the economic consequences of cross-ownership but also provides a new perspective for understanding the corporate governance mechanisms of digital technology innovation. In practical terms, the findings offer important insights for regulatory authorities to improve corporate governance systems: First, the positive role of cross-owners in promoting corporate innovation should be fully recognized, and restrictions on cross-shareholding by institutional investors should be appropriately relaxed. Second, it is essential to establish and improve the internal control information disclosure system to guide corporates in optimizing their innovation governance mechanisms. Third, regulatory oversight of corporate earnings management practices should be strengthened to create a favorable institutional environment for digital technology innovation.

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