Margin trading and short selling and firms' digital technology innovation -- empirical evidence based on a quasi-natural experiment

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Abstract. In recent years, China's digital economy has developed rapidly. As an important institutional design of the capital market, margin trading and short selling has an important impact on the digital technology innovation of firms in the new era. This paper selects Chinese A-share listed firms from 2008 to 2020 as a sample and applies a double difference model to analyze the impact of margin trading and short selling on digital technology innovation. The study shows that margin trading and short selling has a significant positive impact on digital technology innovation, and this finding still holds after a series of robustness tests. This effect is more pronounced in firms with a low proportion of sole directors, a low number of analysts to follow and a high degree of separation of powers. The mechanistic analysis suggests that the margin trading and short selling can contribute to the development of digital technology innovation in firms through two transmission paths: suppressing analyst disagreement and reducing share price synchronization. The findings of this paper not only enrich the literature in the field of margin trading and short selling and digital technology innovation, but also provide new ideas and paradigms for regulating the development of margin trading and short selling and guiding firms to improve their innovation efficiency.

Keywords: margin trading and short selling; digital technology innovation; analyst disagreement; stock price synchronization.

1. Introduction

With the in-depth development of the technological and industrial revolution, a new generation of digital technologies represented by cloud computing, artificial intelligence and big data are progressing rapidly and integrating more and more closely with the real economy, helping China's economy to release tremendous energy. Therefore, more and more firms have increased their investment in digital technology innovation, trying to find long-term profit growth points for their firms through technological innovation and digital transformation. The scale of China's digital economy reached 45.5 trillion yuan in 2021, accounting for 39.8% of domestic GDP, a year-on-year growth of 15.9%, significantly higher than the GDP growth rate, meanwhile, the digital economy is increasingly becoming an important force to help China's economic development of high quality. China's 14th Five-Year Plan clearly stated that we should "accelerate the construction of a digital economy, a digital society and a digital government, and use digital transformation as a whole to drive changes in production, lifestyle and governance", and the 20th Party Congress also emphasized the strategic goal of "accelerating the development of the digital economy and promoting the deep integration of the digital economy and the real economy", and these policy directions prove the high importance the country attaches to the construction of the digital economy. However, digital technology innovation is costly, time-consuming and has a long payback period, therefore many firms are still sceptical about investing in digital technology innovation. In order to better promote the rapid development of digital technology innovation and enable the sustainable and high-quality development of China's economy, it is of theoretical value and practical significance to find breakthroughs that affect digital technology innovation in firms.

The current academic community has paid high attention to digital technology-related topics. From the existing system of literature influencing digital transformation and corporate innovation, Zhang and Chen (2021)[1] argue that managers' own characteristics such as having a technology background have a significant contribution to corporate digital transformation. Li et al. (2022)[2] and Shen et al.

(2022) [3]argue that financial support and patent protection policies have a significant enhancing effect on firms' innovation performance. The margin trading and short selling, as an innovative trading system, can have a significant impact on corporate business governance. However, the relationship between the impact of Margin trading and short selling and digital technology innovation has been less explored in the existing literature. Therefore, this paper will conduct a theoretical analysis and empirical study on the impact and mechanism of the margin trading and short selling on digital technology innovation based on the logic of relevant literature.

The margin trading and short selling has a positive contribution to digital technology innovation. On the one hand, in terms of agency theory, the introduction of the margin trading and short selling strengthens the long-term incentives of management (Manso, 2011)[4], increases the external monitoring mechanism for short sellers (Hou et al., 2017)[5], and can curb the agency problem of management's hollowing out of innovation decisions, especially by major shareholders to minority shareholders, so that the saved funds can be used for the development of innovation projects and stimulate their digital technology innovation in value investments. On the other hand, in terms of information theory, the introduction of the margin trading and short selling provides incentives for the information-seeking and monitoring behaviour of major shareholders, reinforces the monitoring function of major shareholders over management, and therefore promotes management's management of innovation projects (Boehmer et al., 2008)[6], enhances the efficiency of corporate innovation, and thus promotes corporate digital technology innovation.

At the same time, the margin trading and short selling has a reverse disincentive effect on digital technology innovation. The introduction of short selling puts significant short-term price pressure on a firm's share price (Mitchell et al., 2004)[7], reinforces management's short-term behaviour and short-sighted problem, reduces management's tolerance for failure, and thus encourages management to avoid risky behaviour. Digital technology innovation has a more pronounced "high risk, long investment horizon" characteristic, so the stress hypothesis of the margin trading and short selling may neglect long-term value investment such as digital technology innovation.

Based on the above analysis, the direction of the effect of the margin trading and short selling on digital technology innovation cannot be determined yet. Therefore, this paper will further clarify the direction and mechanism of the effect through empirical analysis, so as to provide a boost to digital technology innovation. This paper selects data of Chinese A-share listed firms from 2008 to 2020 as data samples and applies a double difference model to analyse the impact of the margin trading and short selling on digital technology innovation. This result remains robust after changing the explained variables, using different data samples, propensity score matching, parallel trend tests, adding individual fixed effects and changing the reduced tail interval. In addition, this boost is more pronounced in firms with a low proportion of sole directors, a low number of analysts to follow and a high degree of separation of powers. The mechanism study also finds that the margin trading and short selling can facilitate the input and output of firms' digital technology innovation through two transmission paths: inhibiting analyst disagreement and reducing stock price synchronization.

The possible contributions of this paper are: First, in terms of digital technology innovation, the existing literature has only studied the influencing factors of digital transformation or corporate innovation performance, but few articles have analyzed digital technology innovation from the perspective of digital technology innovation. This paper provides a new empirical and analytical paradigm for understanding the role of digital technology innovation channels. Second, in terms of the margin trading and short selling, this paper is the first to explore the role of the margin trading and short selling on digital technology innovation, expanding the role of the margin trading and short selling on corporate governance decisions and enriching the literature related to financial services for the real economy. Third, this paper analyses the heterogeneity of firms with different percentages of sole directors, the number of analysts tracking and the degree of separation of the two powers respectively, and analyzes the transmission path of the margin trading and short selling on digital technology innovation from two major paths: analyst disagreement and stock price synchronization,

which has strong practical significance for firm shareholders and management to formulate corporate development plans and promote the process of corporate digital transformation.

The paper is structured as follows: Part 2 is a literature review on margin trading and short selling and digital technology innovation, Part 3 is the research hypothesis and empirical design, Part 4 is the main empirical tests and analysis, Part 5 is a further mechanistic test and Part 6 is the conclusion.

2. Review of the literature

2.1 margin trading and short selling

In 2010, China's financial markets officially opened for financing and securities financing, introducing a short selling mechanism. As an innovative trading system, the margin trading and short selling can have an impact on corporate management through direct external governance and indirect information transmission.

At the external governance level, through a review of the existing relevant literature, the monitoring and deterrent effect induced by short sellers can effectively improve corporate governance by promoting executive self-regulation to curb surplus management, reduce financial restatement and improve the quality of information disclosure. In terms of surplus management, Massa et al. (2015)[8] used an instrumental variables approach and exogenous regulatory experiments to argue that short selling has a binding effect on firm managers and can force them to reduce surplus management. Fang et al. (2016)[9] used one-third of the Russell 3000 index as a pilot stock exempted from short selling tests and concluded that short selling helped to detect fraud, improve price efficiency and curb surplus management. In terms of financial restatement, Zhang et al. (2016)[10] argued that firms which became the subject of a securities financing could reduce the likelihood of financial restatement by increasing the effectiveness of incentive contracts and attracting analysts to follow them, while this governance effect was more pronounced in firms with less developed financial markets and poorer levels of governance. With regard to the quality of information disclosure, Li et al. (2017) [11] argued that the margin trading and short selling could improve the quality of information disclosure of listed firms by increasing incentives for management and reducing information asymmetry to create constraints on managers, and this phenomenon had a more significant effect in regions with a more developed intermediary market and a better legal environment. Li et al. (2017) [12] argued that the margin trading and short selling improved the quality of the stock exchange market by influencing the behaviour of management and analysts and thus improving the disclosure environment of firms.

At the level of information transmission, the margin trading and short selling has good information discovery and dissemination functions, which can accelerate the integration of negative corporate information into the stock price, improve the efficiency of stock pricing, and alleviate the proxy problem, so as to better utilize the feedback mechanism of the securities market, enhance the rationality of shareholders' and investors' decisions, and improve the value of the firm. In terms of the integration of negative corporate information into share prices, Bris (2007) [13] argued that short selling transactions could allow share prices to reflect negative information more quickly and that short selling restrictions could reduce the relative severity of market panic. Callen and Fang (2015) [14] argued that short selling was positively associated with the risk of share price collapse in the coming year, with the positive effect being more pronounced for firms with weak governance mechanisms, excessive risk-taking behaviour and high information asymmetry. Karpoff and Lou (2010)[15] argued that short selling helped to detect misconduct in a timely manner and curbed the stock price inflation that occurred when firms misreported earnings. In terms of stock pricing efficiency, Li et al. (2014) [16] used event analysis to conclude that the margin trading and short selling helped to correct stock prices that deviated from the actual price, thus improving pricing efficiency. Li et al. (2015) [17] argued that margin trading and short selling could improve market pricing efficiency in three ways: by increasing stock liquidity, reducing the degree of information asymmetry and increasing the breadth of shareholdings. In terms of enhancing the rationality of shareholders' and investors' decisions, Pang et al. (2019) [18] argued that the margin trading and short selling influenced

corporate investment decisions mainly through two channels: constrained investment and the transmission of private information to management. Zhou and Gu (2020) [19] argued that the margin trading and short selling could improve the sensitivity of investment and share prices and promoted management to optimize corporate investment decisions, thus enhancing the value of the firm itself.

2.2 Digital technology innovation

Innovation is not only a source of core competitive advantage for firms, but also an important "fulcrum" for promoting high-quality economic development. The report of the 20th Party Congress pointed out the goal of achieving "a high level of scientific and technological self-sufficiency and self-improvement and entering the forefront of innovative countries" by 2035. However, as innovation is characterized by high investment in research and development, long investment cycles and high investment risks, there are large opportunity costs and risks of failure for firms to innovate independently. In terms of factors affecting corporate innovation, Li and Zheng (2016)[20] argue that industrial policies increased the number of non-inventor patents in firms, more significantly in the SOE group and non-high-tech group. Miao et al. (2019)[21] concluded that financial investment in science and technology had a significant positive impact on corporate innovation. Long et al. (2018)[22] argued that strengthening judicial protection of IPRs and integrating judicial and administrative "dual-track" protection could stimulate R&D and innovation in firms. Quan and Yin (2017)[23] argued that capital market reform had a positive effect on corporate innovation, with the margin trading and short selling having a greater impact on innovation output than innovation input. He et al. (2017)[24] argued that executive career experience had a positive effect on corporate innovation, which was more significant in firms with low marketization and low financing constraints. Wang et al. (2019) [25] argued that corporate leverage had an inverted U-shape in relation to innovation input and innovation output, and a U-shape in relation to innovation risk. Jimenez-Jimenez and Sanz-Valle (2011) [26]argued that organizational learning had a positive relationship with corporate innovation. Ederer and Manso (2013) [27] suggested that pay-for-performance principles had a negative effect on creativity and innovation. In addition, Manso (2011) [4] and Tian and Wang (2014)[28] both argued that increasing the risk-reward of innovation and reducing the loss of innovation failure were two fundamental directions to promote innovation in firms.

Digital technology innovation is the technological part of digital development, however, most of the existing papers have studied digital transformation of firms and less on digital technology innovation. Qian and He (2021) [29]argued that firm digital transformation included technological transformation, personnel restructuring and hardware facility renewal, which usually refered to the application of digital technologies such as big data, artificial intelligence and cloud computing to drive innovation in firm production methods. Digital transformation of firms can bring favourable conditions and competitive advantages to the development of firms. Chen and Yang (2022) [30] argued that firm digital transformation could improve the efficiency of business operations by promoting business model innovation. Hu et al. (2022)[31] believed that digital transformation could enhance the economic, social and environmental benefits of firms, thus promoting high-quality development. Ni and Liu (2021) [32] argued that digital transformation promoted firm growth by improving labour efficiency and reducing business costs, and that this effect was more obvious in state-owned firms and manufacturing industries. At the same time, the digital transformation of firms also had multiple development dilemmas, which seriously restricted the transformation and further development of firms. Tan et al. (2022) [33] identified the shortage of capital as one of the difficulties in digital development and the "time lag effect" in realizing the value of digital transformation. Li and Lv (2021) [34] argued that the obstacles to digital transformation were mainly at the micro level, with human resources and organizational structure being of particular concern. Wu (2021)[35] summarized the theoretical framework of digital transformation in the context of the "input-process-output" model, and argued that technology and talent were the factors limiting the transformation of firms.

In contrast to innovation, the digital technology innovation in firms studied in this paper is not only reflected in the application of end products, but also contributes to the development and

transformation of the entire firm process. As digital technology innovation is still an emerging technology, the cycle and uncertainty of its final transformation requires the cooperation of talents from various fields such as computing and finance. Therefore, as a technological factor in the digital transformation of firms, digital technology innovation extends the characteristics of "high risk, high investment and long investment period" in innovation, and its measurement indicators are more difficult to quantify, so it is of theoretical and applied significance to analyze the influencing factors and mechanisms of digital technology innovation separately.

3. Research Hypothesis and Empirical Design

3.1 Research Hypothesis

Margin trading and short selling, also known as securities credit trading, refers to the act of investors providing collateral to securities firms qualified to finance and finance securities, borrowing funds to buy securities or borrowing securities to sell them. The margin trading and short selling has the effect of improving the price discovery function (Chang et al., 2014) [36]and reducing the probability of market collapse (Charoenrook and Daouk, 2003) [37], which has brought about a greater impact on both the market and corporate development.

In terms of corporate innovation decisions, the constraining effect under the margin trading and short selling usually promotes management's development and commitment to corporate innovation through agency theory and information theory. In terms of agency theory, Jensen and Meckling (1976)[38]proposed in a contractual framework that a principal-agent relationship exists between shareholders and management, so that in corporate business decisions, management may behave in a moral-risk manner that is contrary to corporate development out of a private profit mentality, i.e. an agency problem between management and shareholders arises in the firm. With the development of the shareholding system, Johnson et al. (2000) [39] defined "majority shareholder hollowing out" as a situation where the majority shareholder played an absolute controlling role in a firm with a high concentration of shareholding, and therefore the majority shareholder may transfer funds for corporate development into his personal account out of a personal profit motive, thus infringing on the overall interests and long-term development of the firm. Claessens et al. (2002) [40] argued that the short-selling behaviour of major shareholders seriously infringed on the interests of minority shareholders and inhibited the potential development of the firm, which created an agency problem between major shareholders and minority shareholders. Furthermore, to a certain extent, the introduction of the margin trading and short selling can curb the agency problems of management in innovation decisions and the emptying behaviour of major shareholders. This is reflected in: First, the introduction of the margin trading and short selling has strengthened long-term incentives for management and can curb management's agency problems in innovation decisions. Raith (2001) [41] argued that the most important function of the short selling mechanism is price discovery, and Zhou and Gu (2020)[19] argued that the short selling mechanism could improve the sensitivity of share prices. Manso (2011)[4] rgued that tolerance for failure and long-term incentives for management could stimulate innovation. Therefore, the margin trading and short selling is conducive to correcting management's short-sightedness and thus increasing the preference for decision-making on digital technology innovation. Second, the introduction of margin trading and short selling enhances the external monitoring power of short sellers and can curb the emptying out of minority shareholders by major shareholders. According to Hou et al. (2017)[5], when short sellers discovered that a firm's shareholders were engaging in short-selling, small and medium shareholders would sell short the firm's shares on a large scale, causing the share price to plummet, resulting in a negative market reaction and costing large shareholders a lot of money. Thus, short sellers, as an external monitoring force of the firm, can effectively restrain the selfish behaviour of major shareholders, thus using the saved funds for the development of innovative projects and stimulating their investment in digital technology innovation.

Information theory suggests that longer-cycle innovation projects are undervalued by shareholders due to information asymmetries in capital markets. Digital technology innovations have higher risks, longer cycles and less observable outputs than product innovations. To mitigate this effect, management generally reduces investment in innovation projects, especially digital innovations. The introduction of margin trading and short selling has increased market activity and information transmission efficiency (Wang, 2020)[42], while Boehmer et al. (2008)[6] argued that short selling increased the attention of institutional investors and professional analysts to firms, driving the market to deepen the valuation of firms' innovative projects. Thus, the implementation of the margin trading and short selling induces shareholders to increase their preference for investment in innovative projects that can yield long-term returns, provides incentives for information-seeking and monitoring behaviour of major shareholders, strengthens the monitoring function of major shareholders over management, promotes management's management of innovative projects, and enhances the efficiency of corporate innovation, thus facilitating the development of digital technology innovation. Therefore, the following hypothesis is proposed in this paper.

H1: There is a "binding effect" of the margin trading and short selling, i.e. the margin trading and short selling has a catalytic effect on digital technology innovation.

However, the pressure effect brought about by the introduction of margin trading and short selling can change management's investment decision making behaviour and thus have a dampening effect on digital technology innovation. Mitchell et al. (2004)[7] argued that margin trading and short selling could put significant short-term price pressure on firms, reinforcing management's short-term behaviour and short-sightedness problems and reducing management's tolerance for failure. Whereas tolerance of failure in the short term is a necessary factor for firm innovation (Tian and Wang, 2014)[28], the effect of this pressure can drive a greater preference for management to invest in short-term, low-risk projects. Since digital technology innovation is a high-risk, high-investment project with long lead times and uncertain outcomes, management will be influenced by price pressure to focus more on short-term operational strategies and stock prices, thus neglecting long-term value investments such as digital technology innovation.
Therefore, the following hypothesis is proposed in this paper.

H2: There is a "pressure effect" of the margin trading and short selling, i.e. the margin trading and short selling has a dampening effect on digital technology innovation.

3.2 Empirical design

To test whether the margin trading and short selling can promote or inhibit digital technology innovation, this paper sets up the following double difference model with reference to Quan and Yin (2017)[23] and Xu (2022)[43]:

$$Digital_{i,t+1} = \alpha + \beta_1 Treat_{i,t} + \beta_2 Treat_{i,t} * Post_{i,t} + \beta_3 Control_{i,t} + \sum Industry + \sum Year + \varepsilon_{i,t} \quad (1)$$

As for the measurement of explained variables, since the measurement of digital technology innovation is a relatively cutting-edge issue in academia, the current research on digital technology innovation is mainly based on theoretical qualitative analysis, such as the connotation and characteristics of digital innovation (Yu et al., 2017)[44] and the review of domestic and international digital innovation research (Liu et al., 2020)[45], while less empirical evidence based on digital technology innovation is used. Among them, Zhang et al. (2022)[46] used "digital information transmission corresponding to IPC classification number H04L" as a proxy variable for digital technology innovation. However, as digital technology innovation involves many fields, the choice of digital information transmission patents alone is too narrow and may result in inappropriate data for the explained variables, thus affecting the final empirical results. Therefore, this paper refers to Tao et al. (2021)[47], who used the number of digital technology patents as a proxy variable for digital technology innovation, and finally chose the logarithm of the number of digital technology patents as the explained variable for digital technology innovation in combination with the empirical content of this paper.

As for the measurement of explanatory variable , this paper sets the dummy variable Treat to 1 when the firm is included in the margin trading and short selling list for the whole sample period and 0 otherwise. The dummy variable Post is set to 1 when the firm is margin trading and short selling underlying stock in the current year and 0 otherwise. If the β_2 in the final model is significantly positive, it indicates that hypothesis one holds and the margin trading and short selling has a "binding effect", i.e. the margin trading and short selling has a catalytic effect on digital technology innovation. If β_2 is significantly negative, then hypothesis two is valid, and there is a "pressure effect" of the margin trading and short selling, i.e. the margin trading and short selling has a dampening effect on digital technology innovation. With reference to previous studies, this paper selects firm size (Size), net profit ratio of total assets (ROA), equity concentration (Top1), Tobin's Q(TobinQ), growth rate of revenue (Growth), ratio of tangible assets (FixedAssets), gearing ratio (LEV), nature of ownership (Ownership) and annual stock Return (Return) as control variables. Year and Industry fixed effects are also controlled for, taking into account the impact of yearly trend changes and industry differences on firms' digital technology innovation. Also, to control for potential cross-sectional correlation issues, this paper clusters the standard errors in all regressions for the firm dimension. Table 1 shows the specific definitions.

Table 1 Definition and construction of variables

Variable symbols	Variable name	Variable construction notes
Digital	Digital technology innovation	Logarithm of the number of digital technology patents
Treat	Dummy variables for Margin trading and short selling firms	Firms included in the margin trading and short selling list during the sample period take a value of 1, otherwise 0
Post	Dummy variables for the Margin trading and short selling year	The year after the firm enters the list of margin trading and short selling takes the value of 1, otherwise is 0
Size	Total assets	Total assets of the firm at the end of the year
ROA	Net profit margin on total assets	Total net profit of the firm / Total assets of the firm
Top1	Concentration of shareholding	Percentage of shareholding of the largest shareholder
TobinQ	Tobin's Q	Current market value of the business/book value
Growth	Operating income growth rate	(Operating income for the year - operating income for the previous year)/operating income for the previous year
FixedAssets	Tangible assets ratio	(Fixed Assets+ Inventory) / Total Assets
LEV	Gearing ratio	Total liabilities/total assets
Ownership	Nature of ownership	State firms take 1, otherwise take 0
Return	Annual stock returns	Individual stock returns for the past 12 months

3.3 Data sources

This paper selects data of Chinese A-share listed firms during the period 2008-2020 as the data sample and uses a double difference model to analyse the impact of the margin trading and short selling on digital technology innovation. Among them, non-financial firms among A-share listed firms that entered the list of Margin trading and short selling securities were used as the treatment group, and non-financial firms that did not enter the list were used as the control group.

In order to ensure the accuracy and reasonableness of the empirical results, the data were processed in accordance with the following principles (1) Exclude listed firms in the financial category. (2) Excluding the data of listed firms with ST and ST* for three consecutive years. (3) Select listed firms

with complete indicator data and exclude samples with serious missing data. (4) To carry out the necessary tailoring process for the relevant variables and select the data of listed firms within the (1%,99%) quantile to ensure the accuracy of the data. At the end of the processing, the data of 30371 listed firms were finally obtained.

3.4 Descriptive statistics

Table 2 reports the results of the descriptive statistical analysis of the main variables in this paper. Among them, the explained variable Digital has a mean of 0.538 and a standard deviation of 0.859, and its maximum and minimum values are 3.961 and 0 respectively, indicating that there are large differences in digital technology innovation between different firms, and therefore the research in this paper has some practical significance. The mean and standard deviation of the explanatory variable Treat are 0.535 and 0.499 respectively. As for the control variables, the mean value of firm size (Size) is 22.09, the mean value of total net profit margin (ROA) is 0.0391 and the mean value of gearing ratio (LEV) is 0.429, and there are 39.4% State-owned firms. The standard deviation of shareholding concentration (Top1) is 15.03, indicating that there is some variation in the shareholding governance structure of the sample firms.

Table 2 Descriptive statistics results

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Observations	mean	sd	min	max
Digital	30,371	0.538	0.859	0	3.951
Treat	30,371	0.535	0.499	0	1
Size	30,371	22.090	1.315	18.970	26.070
ROA	30,371	0.039	0.062	-0.268	0.213
Top1	30,371	35.240	15.030	8.830	75.100
TobinQ	30,371	2.026	1.320	0.870	8.938
Growth	30,371	0.398	1.091	-0.675	7.902
FixedAssets	30,371	0.929	0.086	0.534	1
LEV	30,371	0.429	0.212	0.050	0.933
Ownership	30,371	0.394	0.489	0	1
Return	30,371	0.004	0.014	-0.024	0.070

4. Empirical Results and Analysis

4.1 Analysis of baseline regression results

Table 3 shows the regression results of the double difference model between the margin trading and short selling and digital technology innovation, with the inclusion of control variables in column (2). The regression results show that columns (1) and (2) control for year and industry fixed effects, and the regression coefficients of the cross product term Treat*Post on firms' digital technology innovation (Digital) are 0.163 and 0.065, and both remain significant at the 1% level. Meanwhile, the regression results of the control variables in model (2) show that Size, ROA, TobinQ, Growth, FixedAssets and Return are positively related to digital technology innovation, while Top1, LEV and Ownership are negatively related to digital technology innovation. The empirical results show that the margin trading and short selling has a significant positive relationship with digital technology innovation, so the hypothesis H1 is valid.

Table 3 Double difference model regression results

VARIABLES	(1) Digital	(2) Digital
Treat	0.121***	0.013
	(5.763)	(0.574)
Treat*Post	0.163***	0.065***
	(6.092)	(2.789)
Size		0.130***
		(9.560)
ROA		1.013***
		(8.611)
Top1		-0.000
		(-0.452)
TobinQ		0.017**
		(2.441)
Growth		0.002
		(0.486)
FixedAssets		0.151
		(1.486)
LEV		-0.042
		(-0.856)
Ownership		-0.056**
		(-2.493)
Return		0.601
		(1.569)
Constant	-0.212***	-3.017***
	(-3.845)	(-9.676)
Observations	30,371	30,371
R-squared	0.278	0.301
Industry FE	YES	YES
Year FE	YES	YES

Note: *, ** and *** denote 10%, 5% and 1% significance levels respectively. Values of t-statistics are in parentheses. Same as below.

4.2 Robustness tests

4.2.1 Replacement of explained variables

To test the robustness of the regression results, this paper uses the logarithm of digital patent invention applications and the logarithm of digital patent utility applications as proxy variables for the explained variables digital technology innovation, named Digital1 and Digital2 respectively, for regression analysis, as shown in Table 4. The results show that the regression coefficients of the cross product term Treat*Post on the explained variables Digital1 and Digital2 are 0.060 and 0.033 respectively, and are significant at the 1% and 5% levels respectively, which are consistent with the previous findings, thus the conclusions of this paper remain robust.

Table 4 Robustness tests for replacement of explained variables

VARIABLES	(1) Digital1	(2) Digital2
Treat	0.006	-0.002
	(0.307)	(-0.098)
Treat*Post	0.060***	0.033**
	(3.097)	(1.971)
Size	0.117***	0.084***
	(9.663)	(8.482)
ROA	0.742***	0.684***
	(7.662)	(8.248)
Top1	-0.001	0.000
	(-1.431)	(0.574)
TobinQ	0.021***	0.007
	(3.607)	(1.543)
Growth	0.005	-0.005
	(1.330)	(-1.549)
FixedAssets	0.139	0.114*
	(1.601)	(1.754)
LEV	-0.052	0.028
	(-1.287)	(0.851)
Ownership	-0.028	-0.042***
	(-1.485)	(-2.677)
Return	0.328	0.386
	(1.044)	(1.451)
Constant	-2.684***	-2.004***
	(-9.700)	(-9.032)
Observations	30,371	30,371
R-squared	0.276	0.259
Industry FE	YES	YES
Year FE	YES	YES

4.2.2 Replacing regression samples

As there are firms in the sample that do not have the number of digital technology patents, i.e. there is a difference between firms with and without digital technology innovation. Therefore, in order to avoid the existence of systematic differences, the sample with Digital taking the value of 0 is excluded from the paper and regressed again, and the results are shown in Table 5. The conclusion shows that the regression coefficient of the cross product term Treat*Post on the explained variable Digital after replacing the regression sample is 0.070, which is significant at the 10% level and consistent with the previous findings, therefore the conclusion of this paper remains robust.

4.2.3 Propensity score matching

To address the problem of sample selection bias, this paper uses the propensity score matching (PSM) method to conduct robustness tests. This paper firstly regresses the explained variables, explanatory variables and control variables and calculates the propensity scores. The results are shown in Table 5. The conclusion shows that the regression coefficient of the cross product Treat*Post on the explained variable Digital after the PSM treatment is 0.046, which is significant at the 10% level and is consistent with the previous findings.

Table 5 Robustness tests for replacing regression samples and PSM treatments

	Replacing regression samples	PSM
VARIABLES	Digital	Digital
Treat	0.010	0.046*
	(0.253)	(1.819)
Treat*Post	0.070*	0.046*
	(1.943)	(1.810)
Size	0.240***	0.130***
	(11.217)	(8.493)
ROA	0.988***	1.032***
	(4.772)	(6.776)
Top1	-0.001	-0.001
	(-0.657)	(-0.777)
TobinQ	0.028***	0.017**
	(2.780)	(2.289)
Growth	0.017	-0.001
	(1.308)	(-0.218)
FixedAssets	0.024	0.196*
	(0.147)	(1.664)
LEV	0.037	-0.051
	(0.443)	(-0.861)
Ownership	-0.027	-0.037
	(-0.688)	(-1.404)
Return	-0.086	0.444
	(-0.162)	(0.834)
Constant	-4.880***	-3.128***
	(-9.725)	(-8.887)
Observations	11,308	21,920
R-squared	0.296	0.314
Industry FE	YES	YES
Year FE	YES	YES

4.2.4 Parallel trend test

As this paper uses a double difference model for the analysis, it needs to ensure that there is a common trend between the treatment and control groups prior to the implementation of the policy, that is the parallel trend hypothesis holds. Therefore, in this paper, two years before policy implementation (Before2), one year before policy implementation (Before1), the year of policy implementation (Current) and one year after policy implementation (After1) are selected as explanatory variables and regression analyses are conducted on the original sample and the PSM-treated sample respectively. The results are shown in Table 6. The findings show that the regressions for the year of policy implementation and the year after the policy implementation have positive significance at the 10% and 1% levels for digital technology innovation in the original sample, while the regressions for the year before the policy implementation and the two years before the policy implementation are not significant, that is the regressions are not significant before the event, and the regressions are significant after the margin trading and short selling event. Therefore, in line with the parallel trend hypothesis and consistent with the previous findings, the conclusions of this paper remain robust.

Table 6 Parallel trend test

VARIABLES	Original sample Digital	After PSM treatment Digital
Treat	0.007	0.043
	(0.282)	(1.572)
Before2	0.022	0.007
	(1.131)	(0.366)
Before1	0.015	0.006
	(0.677)	(0.232)
Current	0.048*	0.025
	(1.872)	(0.914)
After1	0.082***	0.057*
	(2.627)	(1.648)
Size	0.129***	0.129***
	(9.322)	(8.269)
ROA	1.016***	1.037***
	(8.623)	(6.810)
Top1	-0.000	-0.001
	(-0.417)	(-0.749)
TobinQ	0.016**	0.017**
	(2.371)	(2.246)
Growth	0.002	-0.001
	(0.499)	(-0.208)
FixedAssets	0.148	0.192
	(1.458)	(1.636)
LEV	-0.039	-0.049
	(-0.811)	(-0.823)
Ownership	-0.057**	-0.038
	(-2.529)	(-1.437)
Return	0.619	0.473
	(1.614)	(0.887)
Constant	-2.977***	-3.099***
	(-9.406)	(-8.612)
Observations	30,371	21,920
R-squared	0.301	0.314
Industry FE	YES	YES
Year FE	YES	YES

4.2.5 Individual fixed effects

In order to make the regression model more rigorous, a more stringent individual fixed effect is chosen for the regression analysis in this paper, as shown in Table 7. The conclusions show that the regression coefficient of the cross product term Treat*Post on the explained variable Digital under individual fixed effects is 0.073, which is significant at the 1% level and consistent with the previous findings, so the conclusions of this paper remain robust.

4.2.6 Replacement of the reduction interval

In order to make the data more rigorous, the 5% shrinkage treatment is chosen to replace the 1% shrinkage treatment in this paper, and regression analysis is conducted as shown in Table 7. The conclusions show that the regression coefficient of the cross product term Treat*Post on the explained variable Digital under the 5% shrinkage treatment is 0.043, which is significant at the 5% level and consistent with the previous findings, so the conclusions of this paper remain robust.

Table 7 Individual fixed effects with 5% tail reduction treatment

	Individual fixed effects	5% tail reduction
VARIABLES	Digital	Digital
Treat		0.022
		(1.124)
Treat*Post	0.073***	0.043**
	(4.263)	(2.209)
Size	0.038***	0.100***
	(2.753)	(9.615)
ROA	0.379***	1.380***
	(4.683)	(8.747)
Top1	-0.002**	0.000
	(-2.559)	(0.198)
TobinQ	0.005	0.012
	(1.149)	(1.431)
Growth	-0.000	0.030**
	(-0.004)	(2.552)
FixedAssets	0.011	0.030
	(0.132)	(0.275)
LEV	0.192***	-0.030
	(4.293)	(-0.682)
Ownership	-0.007	-0.047***
	(-0.211)	(-2.637)
Return	0.264	0.926*
	(0.836)	(1.879)
Constant	-0.601*	-2.305***
	(-1.917)	(-9.136)
Observations	30,371	30,371
R-squared	0.116	0.309
Industry FE	YES	YES
Year FE	YES	YES

5. Further Analysis

5.1 Heterogeneity analysis

5.1.1 Proportion of sole directors

Fama and Jensen (1983)[48] argued that corporate independent directors had an external monitoring function, i.e., the monitoring by independent directors will enhance corporate governance by restraining management's agency behaviour, thus bringing about a positive impact on corporate innovation. Wu and Dong (2020)[49] also argued that independent directors had a significant positive driving effect on firms' technological innovation behaviour. In contrast, the explanatory variable of this paper, the margin trading and short selling, also positively contributes to corporate digital innovation by improving corporate governance; therefore, the number of corporate independent directors and the margin trading and short selling show a substitution effect. Therefore, the paper concludes that the role of Margin trading and short selling in promoting digital innovation is more significant in firms with a small number of independent directors.

Referring to Wang and Song (2010)[50], this paper measures the ratio of the number of independent directors to the total number of board of directors to measure the proportion of sole directors in a firm. This paper further analyses the impact of the margin trading and short selling on digital technology innovation by dividing the total sample into two sub-samples based on the median ratio of sole

directors into two groups of high and low sole director ratios, and the regression results are shown in columns (1) and (2) of Table 8 respectively. The regression results show that the cross product term Treat*Post is positively significant at the 1% level in the model with a low proportion of sole directors, while Treat*Post is not significant in the model with a high proportion of sole directors. Therefore, the promotion effect of the margin trading and short selling on digital technology innovation is more significant in firms with a low proportion of sole directors.

Table 8 Heterogeneity analysis of the proportion of sole directors

VARIABLES	(1) Digital	(2) Digital
	High proportion of sole directors	Low percentage of sole directors
Treat	0.045	-0.011
	(1.365)	(-0.428)
Treat*Post	0.007	0.114***
	(0.206)	(3.736)
Size	0.146***	0.115***
	(8.065)	(7.221)
ROA	0.956***	1.062***
	(6.237)	(6.547)
Top1	-0.000	-0.000
	(-0.320)	(-0.422)
TobinQ	0.014	0.021**
	(1.604)	(2.260)
Growth	0.005	-0.002
	(0.771)	(-0.258)
FixedAssets	0.108	0.198
	(0.778)	(1.544)
LEV	-0.100	0.023
	(-1.566)	(0.379)
Ownership	-0.069**	-0.046*
	(-2.274)	(-1.713)
Return	0.475	0.722
	(0.858)	(1.350)
Constant	-3.313***	-2.722***
	(-8.020)	(-7.246)
Observations	15,054	15,317
R-squared	0.303	0.307
Industry FE	YES	YES
Year FE	YES	YES

5.1.2 Number of analysts tracked

Han et al. (2016)[51] argued that analyst tracking could help investors reduce the investment disadvantages caused by information asymmetry at all stages of information acquisition, identification and use. Han et al. (2021)[52] argued that analyst tracking had an "information" effect on corporate technological innovation, and that overall analyst tracking significantly contributed to corporate technological innovation. Therefore, the number of analysts tracking has a certain degree of contribution to corporate innovation. What's more, the explanatory variable of this paper, the margin trading and short selling, also has a positive effect on digital innovation by improving information asymmetry, and therefore the number of analysts tracking firms has a substitution effect with the margin trading and short selling. In this regard, the paper suggests that the role of margin trading and short selling in promoting digital innovation is more significant in firms with fewer analysts.

This paper uses the number of analysts tracked as a proxy variable for analyst tracking and divides the total sample into two sub-samples based on the median number of analysts tracked into two groups of high and low trackers to further analyse the impact of the margin trading and short selling on digital technology innovation, the regression results are shown in columns (1) and (2) of Table 9 respectively. The regression results show that the cross product term Treat*Post is positively significant at the 5% level in the model with a small number of analysts, while Treat*Post is not significant in the model with a large number of analysts. Therefore, the contribution of the margin trading and short selling to digital technology innovation is more significant in firms with a small number of analysts following them.

Table 9 Analysis of heterogeneity in the number of analysts followed

VARIABLES	(1) Digital	(2) Digital
	Large number of analysts tracked	Small number of analysts tracked
Treat	-0.025	0.039*
	(-0.731)	(1.727)
Treat*Post	0.010	0.068**
	(0.319)	(2.429)
Size	0.160***	0.036***
	(7.461)	(2.731)
ROA	0.876***	0.564***
	(3.505)	(5.726)
Top1	-0.001	0.001
	(-1.299)	(1.428)
TobinQ	0.032***	-0.031***
	(3.067)	(-4.505)
Growth	0.006	0.002
	(0.687)	(0.376)
FixedAssets	0.453***	-0.006
	(3.238)	(-0.052)
LEV	-0.059	-0.002
	(-0.642)	(-0.035)
Ownership	-0.064*	-0.013
	(-1.674)	(-0.671)
Return	-0.731	1.203**
	(-1.106)	(2.552)
Constant	-3.941***	-0.895***
	(-8.281)	(-2.941)
Observations	14,949	15,422
R-squared	0.332	0.274
Industry FE	YES	YES
Year FE	YES	YES

5.1.3 Degree of separation of powers

The degree of separation of the two powers refers to the extent to which the ownership and control of the effective controlling shareholder are separated from each other. Xu and Tang (2013)[53] argued that concentration of control usually resulted in collusion between the ultimate controlling shareholder and the business managers of the firm, which caused the firm to engage in fewer high-risk, long-cycle corporate technology innovations. Liu and Sheng(2018)[54] argued that the higher the degree of separation of powers, the more severe the firm's second type of agency problem, while a low degree of separation of powers helped to enhance the firm's innovation capacity by reducing agency problems and increasing the supply of resources. Therefore, a high degree of separation of powers can inhibit corporate innovation by enhancing the second type of agency problems, i.e. the degree of separation of powers and the margin trading and short selling show complementary effects.

For this reason, the paper argues that the role of margin trading and short selling in promoting digital technology innovation is more significant in firms with a high degree of separation of powers.

Referring to Xu and Tang (2013)[53], this paper uses the difference between control and ownership to measure the degree of separation of two powers. The regression results are shown in columns (1) and (2) of Table 10, respectively. The regression results show that the cross product term Treat*Post is positively significant at the 5% level in the model with high separation of powers, while Treat*Post is not significant in the model with low separation of powers. Therefore, the promotion effect of the margin trading and short selling on digital technology innovation is more significant in firms with a high degree of separation of powers.

Table 10 Heterogeneity analysis of the degree of separation of the two powers

VARIABLES	(1) Digital	(2) Digital
	High degree of separation of powers	Low degree of separation of powers
Treat	0.043	-0.004
	(1.333)	(-0.136)
Treat*Post	0.084**	0.039
	(2.564)	(1.196)
Size	0.110***	0.148***
	(5.707)	(8.222)
ROA	1.156***	0.840***
	(7.617)	(4.940)
Top1	0.000	-0.001
	(0.161)	(-0.791)
TobinQ	0.003	0.033***
	(0.433)	(3.011)
Growth	-0.009	0.012*
	(-1.558)	(1.659)
FixedAssets	0.153	0.118
	(1.129)	(0.801)
LEV	0.006	-0.088
	(0.104)	(-1.208)
Ownership	-0.046	-0.063*
	(-1.325)	(-1.899)
Return	1.482***	-0.444
	(2.763)	(-0.818)
Constant	-2.486***	-3.370***
	(-5.665)	(-8.189)
Observations	15,025	15,346
R-squared	0.314	0.301
Industry FE	YES	YES
Year FE	YES	YES

5.2 Mechanism analysis

According to the previous section, the margin trading and short selling does have a catalytic effect on digital technology innovation. Next, this paper will examine the mechanism of its effect in terms of both analyst disagreement and stock price synchronization.

Chen et al. (2017)[55] argued that the margin trading and short selling might enhance firm innovation performance by suppressing the degree of analyst disagreement and improving the information content of firms. Liu and Lu (2021)[56] argued that the margin trading and short selling might also enhance firm innovation performance by reducing stock price synchronization and attenuating its information asymmetry effect.

Therefore, this paper tests whether the margin trading and short selling affects digital technology innovation by inhibiting analyst disagreement and reducing stock price synchronization through

constructing a mechanism of action model. In the mechanism analysis, this paper refers to Chu et al.(2019)[57] who chose the ratio of the standard deviation of all analysts' most recent earnings per share forecast for the year to the firm's opening stock price as a measure of analyst disagreement (AD) and to Gul et al. (2010)[58] and Xu et al. (2013)[59] who measure stock price synchronicity (Syn), with the following metrics:

$$R_{i,w,t} = \beta_0 + \beta_1 R_{M,w,t} + \beta_2 R_{M,w-1,t} + \beta_3 R_{I,w-1,t} + \beta_4 R_{I,w-1,t} + \varepsilon_{i,w,t} \quad (2)$$

Where $R_{i,w,t}$ is the return on reinvestment of cash dividends for stock i in week w of year t; $R_{M,w,t}$ is the weighted average return on market capitalization of all A-share firms in week w of year t; $R_{I,w,t}$ is the weighted average return on market capitalization of other stocks in stock i's industry excluding stock i in week w of year t. The industry classification in this paper is based on the 2012 classification standard of the Securities and Futures Commission, and R^2 is obtained by logarithmizing R^2. The next step is to logarithmize R to obtain the stock price synchronicity index Syn.

$$\text{Syn}=\ln\left(\frac{R_{i,t^2}}{(1-R_{i,t^2})}\right) \quad (3)$$

The regression analysis leads to the conclusions shown in Table 11. In column (1), the coefficient of the cross multiplier Treat*Post is significantly negative at the 5% level, indicating that there is a mediating effect of analyst disagreement and a negative correlation with the margin trading and short selling. In column (2), the cross product Treat*Post coefficient is significantly negative at the 1% level, suggesting that there is also a mediating effect of share price synchronisation and a negative correlation with the margin trading and short selling.

Table 11 Mechanism test

	(1)	(2)
VARIABLES	AD	Syn
Treat	0.000	-0.060***
	(0.472)	(-3.824)
Treat*Post	-0.001**	-0.069***
	(-2.159)	(-4.190)
Size	0.001***	0.190***
	(6.453)	(21.073)
ROA	-0.001	0.342***
	(-0.274)	(3.627)
Top1	-0.000***	-0.002***
	(-5.493)	(-3.609)
TobinQ	-0.001***	0.003
	(-12.319)	(0.478)
Growth	0.000	-0.020***
	(0.657)	(-4.094)
FixedAssets	0.004***	0.476***
	(3.577)	(6.380)
LEV	0.010***	-0.420***
	(12.110)	(-11.897)
Ownership	-0.001***	0.104***
	(-4.022)	(7.119)
Return	0.355***	-20.698***
	(22.337)	(-33.972)
Constant	-0.017***	-3.346***
	(-4.178)	(-14.472)
Observations	14,750	29,617
R-squared	0.309	0.347
Industry FE	YES	YES
Year FE	YES	YES

6. Conclusion

With the rapid development of the digital economy, digital technology is increasingly becoming an important force to help China's sustainable economic development. How to achieve high-quality development of digital technology innovation is currently an important issue for the market and firms to ponder. At the same time, with the gradual expansion of the pilot short selling mechanism in China, more and more firms' stocks are included in the underlying of the financing securities. Therefore, this paper analyzes the impact of the margin trading and short selling on digital technology innovation, and examines the impact of the margin trading and short selling on digital technology innovation through a double difference method based on the data information of Chinese A-share listed firms from 2008 to 2020, and conducts a heterogeneity analysis and identifies its mechanism path respectively.

The empirical study finds that: First, the core hypothesis of this paper, "there is a 'binding effect' of the margin trading and short selling, i.e. the margin trading and short selling has a facilitating effect on digital technology innovation", remains significant after multiple robustness tests; Second, the impact of the margin trading and short selling on digital technology innovation is heterogeneous depending on firm attributes. Specifically, for firms with a low proportion of sole directors, a small number of analysts and a high degree of separation of powers, the margin trading and short selling can promote digital technology innovation more significantly, while for firms with a high proportion of sole directors, a large number of analysts and a low degree of separation of powers, the impact of the margin trading and short selling on digital technology innovation is relatively weak. Third, the margin trading and short selling promotes firms' digital technology innovation through two mechanisms of action: inhibiting analyst disagreement and reducing stock price synchronization.

This paper reveals that the margin trading and short selling promotes corporate digital technology innovation by improving the internal and external governance mechanisms of firms, increasing analyst attention and effectively restraining the behaviour of major shareholders and managers, thus providing a feasible solution for guiding digital technology innovation in China and providing theoretical and empirical evidence for further promoting the reform of the margin trading and short selling mechanism.

References

[1] Zhang Kunxian, Chen Xiaorong, Who is driving digitalization? --An empirical study based on higher-order theory and branding theory perspectives [J], Economic and Management Studies, 2021(10): 68-87.

[2] Li Yuanyuan, Chen Wenjing, Wang Hui, Research on the Innovation Performance of Science and Technology Finance Policy under Double Network Effect [J], East China Economic Management, 2022(3): 55-62.

[3] Shen Minghao, Tan Weijie, Chen Zhaoyong, The impact of digital economy development on corporate innovation - empirical evidence based on A-share listed firms [J], Southern Finance, 2022(2): 30-44.

[4] Manso, G, Motivating Innovation [J], Journal of Finance, 2011, vol. 66. pp. 1823-1860.

[5] Hou Qingchuan, Jin Qinglu, Su Ling et al., Short-selling deregulation and large shareholders' "emptying" [J], Economics (Quarterly), 2017, 16(03): 1143-1172.

[6] Boehmer E., Jones M., Zhang X., Which Shorts Are Informed? [J], Journal of Finance, 2008, 63(2), pp. 491-527.

[7] Mitchell, M., T. Pulvino and E. Stafford, Price Pressure Around Mergers [J], Journal of Finance, 2004, Vol. 59, pp. 31-63.

[8] Massa, M., B. Zhang and H. Zhang, The Invisible Hand of Short Selling: Does Short Selling Discipline Earnings Management? [J], Review of Financial Studies, 2015, 28 (6): 1701-1736.

[9] Fang, V., A. Huang and J. M. Karpoff, Short Selling and Earnings Management: A Controlled Experiment [J], Journal of Finance,2016,71(3): 1251-1292

[10] Zhang Xuan, Zhou Peng, Li Chuntao, Short selling and surplus quality-evidence from financial restatements [J], Financial Research, 2016, No.434(08): 175-190.

[11] Li, Chuntao, Liu, Beibei, Zhou, Peng, Short selling and information disclosure: Evidence from a quasi-natural experiment on securities financing [J], Financial Research, 2017, No.447(09): 130-145.

[12] Li Zhisheng, Li Hao, Ma Weili et al., Information governance effects of margin trading and short selling [J]., Economic Research, 2017, 52(11): 150-164.

[13] Bris A, Goetzmann W N, Zhu N., Efficiency and the bear: short sales and markets around the world [J]., The Journal of Finance, 2007, 62(3): 1029-1079

[14] Callen JL, Fang XH., Short interest and stock price crash risk [J], Journal of Banking&Finance, 2015, 60: 181-194

[15] Karpoff J. M. and X. Lou, Short Sellers and Financial Misconduct, The Journal of Finance, 2010, 65(5): 1879-1913.

[16] Li Ke, Xu Longbing, Zhu Weihua, Short-selling restrictions and stock mispricing - Evidence from margin trading and short selling [J], Economic Research, 2014, 49(10): 165-178.

[17] Li Zhisheng, Chen Chen, Lin Bingxuan. Has the short selling mechanism improved the pricing efficiency of the Chinese stock market?--Evidence based on a natural experiment [J], Economic Research, 2015, 50(4): 165-177.

[18] Pang Jiaren, Chen Dapeng, Wang Wei, margin trading and short selling and corporate investment behavior--an analysis based on "external governance" and "information learning" channels[J], Investment Research, 2019, 38(4): 4-29.

[19] Zhou Yanli, Gu Naikang, Can the introduction of short selling mechanism enhance firm value?--Test evidence from the margin trading and short selling [J], Finance and Trade Research, 2020.31(3): 81-96.

[20] Li, Wenjing, Zheng Manni, Substantive or strategic innovation?--The impact of macro-industrial policy on micro-firm innovation [J], Economic Research, 2016, 51(04): 60-73.

[21] Miao Wenlong, He Dexu, Zhou Chao, Differences in firms' innovation behavior and the effect of government technological innovation spending [J]. Economic Research,2019, 54(01): 85-99.

[22] Long Xiaoning, Yi Wei, Lin Zhifan, How valuable is intellectual property protection?--Empirical evidence from patent data of Chinese listed firms [J], Financial Research, 2018, No.458(08): 120-136.

[23] Quan Xiaofeng, Yin Hongying, Chinese-style short selling mechanism and corporate innovation--a natural experiment based on the stepwise expansion of Margin trading and short selling securities [J]., Management World, 2017, No.280(01): 128-144+187-188.

[24] He Ying, Yu Wenlei, Dai Yichi et al., Executive career experience and corporate innovation[J]. Management World, 2019, 35(11): 174-192.

[25] Wang Yuzhe, Luo Nengsheng, Liu Wenbin, what kind of leverage ratio is conducive to corporate innovation [J], China Industrial Economics, 2019, No.372(03): 138-155.

[26] Jimenez-Jimenez D., Sanz-Valle R., Innovation, organizational learning, and performance [J], Journal of Business Research, 2011, 64(4): 408-417.

[27] Ederer, F. and G. Manso. Is Pay for Performance Detrimental to Innovation? [J], Management Science, 2013, 59.

[28] Tian, X. and Wang, T.Y., Tolerance for Failure and Corporate Innovation [J], review of Financial Studies. 2014.vol.27. pp.211-255.

[29] Qian Jingjing, He Yun, A study on the mechanism of dynamic capability building and digital transformation of traditional firms [J], China Soft Science, 2021, No.366(06): 135-143.

[30] Chen Yingfei, Yang Mali, Research on the relationship between digital transformation, business model innovation and business operation efficiency [J], Economic Forum,2022, No.618(01): 135-146.

[31] Hu HaiBo, Zhou Jie, Lu Haitao, Digital transformation for high-quality development of manufacturing firms: foundation, challenges and countermeasures [J], firm Economics, 2022, 41(01): 17-23.

[32] Ni Kejin, Liu Xiuyan, Digital transformation and firm growth: theoretical logic and practice in China [J], Economic Management, 2021, 43(12): 79-97.

[33] Tan Zhidong, Zhao Xun, Pan Jun et al., The value of digital transformation: a perspective based on firms' cash holdings [J], Financial Research, 2022, 48(03): 64-78.

[34] Li Zaichi, Lv Tie, Digital transformation: a review of the literature and research perspectives [J], Learning and Exploration, 2021, No.317(12): 130-138.

[35] Wu Jiang, Chen Ting, Gong Yiwei et al., Theoretical framework and research perspectives on digital transformation of firms [J], Journal of Management, 2021, 18(12): 1871-1880.

[36] Chang, Eric C., Y. Luo and J. Ren, Short-Selling, Margin-Trading and Price Efficiency: Evidence from the Chinese Market [J], Journal of Banking and Finance, 2014, Vol. 48, pp. 411-424.

[37] Charoenrook, A. and Daouk H., The World Price of Short Selling [J], 2003, Working Paper.

[38] Jensen, M. and W. Meckling, Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure [J], Journal of Financial Economics, 1976, Vol. 3, pp. 305-360.

[39] Johnson S,Boone P,Breach A,et al., Corporate Governance in the Asian Financial Crisis [J], Journal of Financial Economics, 2000, 58 (1/2): 141-186.

[40] Claessens S, Djankov S, Fan J P H et al., Disentangling the Incentive and Entrenchment Effects of Large Shareholdings [J], The Journal of Finance, 2002,57 (6): 2741-2771.

[41] Raith M., Competition, Risk and Managerial Incentives, 2001, Working Paper.

[42] Wang Xueping, An empirical test of the impact of short selling mechanism on the efficiency of corporate investment [J], Statistics and Decision Making, 2020, 36(08): 156-159.

[43] Xu Yongmei, Zhao Qian, Ye Tao.,Can the threat of short selling enhance corporate innovation?--A quasi-natural experiment based on short-selling transactions [J], Technology Economics, 2022, 41(04): 72-85.

[44] Yu Jiang, Meng Qingshi, Zhang Yue, Zhang Xi, Chen Feng, Digital innovation: exploration of new perspectives on innovation research and insights [J], Scientology Research, 2017, (7): 1103-1111.

[45] Liu Yang, Dong Jiuyu, Wei Jiang, Digital innovation management: theoretical framework and future research [J], Management World, 2020, (7): 198-217.

[46] Zhang Mier, Li Haipeng, Ren Tengfei, A study on the strategic patenting behavior and interactions of digital innovation [J], Scientific Research, 2022, (3): 545-554.

[47] Tao Feng, Zhu Pan, Qiu Chuzhi et al., Research on the impact of digital technology innovation on the market value of firms[J/OL], Research in Quantitative Economics and Technology Economics:1-24 [2023-03-20].

[48] Fama EF, Jensen, Separation of Ownership and Control [J], Joumal of LawF&Economics, 1983, 26.

[49] Wu Yihan, Dong Bin, Independent directors' network location and firms' technological innovation behavior [J], Modern Economic Inquiry, 2020, No.465(09): 76-88.

[50] Wang Yongming, Song Yanwei, Research on the impact of independent directors on investment in technological innovation of listed firms [J], Science Management Research, 2010, 28(05): 94-97.

[51] Han Jie, Tian Gaoliang, Feng Hua, Research on the impact of analyst follow-up on M&A performance [J], Systems Engineering Theory and Practice, 2016, 36(02): 400-412.

[52] Han Meini, Wang, Fusheng, Lin Han, Does analyst tracking promote corporate technology innovation?--A case study of small and medium-sized board firms [J], Audit and Economic Research, 2021, 36(04): 90-97.

[53] Xu Xiangyi, Tang Yeguo, Analysis of the inhibitory effect of pyramid structure on technological innovation performance: An empirical study based on data from small and medium-sized listed firms in China[J], Journal of Theory, 2013(03): 62-66+129.

[54] Liu Yu, Sheng Yuhua, An empirical study on the degree of separation of two rights and corporate technological innovation--and the moderating effect of the nature of property rights and performance deviation [J], Scientific Decision Making, 2018, No.248(03): 60-82.

[55] Chen Qinyuan, Ma Lijun,Yi Zhihong, Analyst tracking and firm innovation performance--the logic of China[J],Nankai Management Review,2017,20(03):15-27.

[56] Liu Fei, Lv Panpan,Short-selling deregulation and stock price synchronization of listed firms: A test of the "ex ante deterrence" and "ex post punishment" effects[J], Finance and Accounting Monthly, 2021, No.912(20):135-143.

[57] Chu Jian, Qin Xuan, Fang Junxiong, Chinese style Margin trading and short selling institutional arrangements and analysts' earnings forecast optimism bias [J], Management World, 2019, 35(01): 151-166+228.

[58] Gul, F. A., J. B. Kim, and A. A. Qiu, Ownership Concentration, Foreign Shareholding, Audit Quality, and Stock Price Synchronicity: Evidence from China [J], Journal of Financial Economics, 2010, 95(3): 425-442.

[59] Xu, N., K.C. Chan, X. Jiang, and Z. Yi., Do Star Analysts Know More Firm-specific Information? Evidence from China [J], Journal of Banking & Finance, 2013, 37(1): 89-102.