Research on the Impact of Government Venture Capital Guidance Fund on the Firm Systemic Stability: Empirical Evidence from the Stock Correlation Network of Beijing Stock Exchange

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Abstract. During the Central Economic Work Conference held in November 2023, it was explicitly stated that amidst growing global economic uncertainties, the stability of the financial market is central to national economic security. Government Venture Capital Guidance Fund, serving as a bridge between government and private capital, not only fills the financing gap for innovative enterprises but also promotes technological innovation and business growth, thereby enhancing steady economic development. This paper constructs a stock correlation network of the Beijing Stock Exchange and employs a difference-in-differences model with semi-annual data from 2018 to 2022 to empirically test the influence of Government Venture Capital Guidance Fund on firm systemic stability. This paper reveals that, firstly, Government Venture Capital Guidance Fund significantly enhances firm systemic stability within the network of stocks listed on the Beijing Stock Exchange. Secondly, compared to the conventional general equipment manufacturing industry, this influence is particularly pronounced in the dedicated equipment manufacturing, internet-related services, and technology promotion and application services industries, reflecting significant industry-level heterogeneity. This research highlights the positive role of Government Venture Capital Guidance Fund in maintaining financial market stability and offers policy insights for policymakers to mitigate financial risks and sustain economic stability.

Keywords: Government Venture Capital Guidance Fund; Firm Systemic Stability; Beijing Stock Exchange; Network Entropy.

1 Introduction

In the current context of global economic uncertainties, maintaining financial market stability has become a focal point for governments worldwide. At the Central Economic Work Conference held in China, it was explicitly stated that stabilizing financial markets and preventing systemic financial risks is crucial for national economic security. In 2021, China officially established the Beijing Stock Exchange (BSE) to better serve the innovation-driven development strategy, particularly supporting enterprises with core competitiveness in fields such as next-generation information technology, high-end equipment manufacturing, and biopharmaceuticals.

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The Government Venture Capital Guidance Fund, initiated or participated in by the government as a venture capital fund, aims to drive technological innovation, enterprise growth, and steady regional economic development through collaboration with private capital. The establishment of GVCGF is of great importance. Alperovych et al. noted that these funds effectively narrow the equity financing gap for young innovative companies [1]. Standaert and Manigart further demonstrated the positive effects of GVCGF as fund-of-funds and venture capital sponsors on employment in invested companies [2]. These funds not only promote technological innovation and growth within enterprises but also play a role in driving sustainable development and environmental protection. Owen examined how GVCGF supported the transition to a low-carbon economy in a UK case, emphasizing the application value of these funds in environmental protection projects [3]. Wu et al. found that government R&D subsidies significantly encouraged venture capital investments in renewable energy [4]. Although numerous studies have focused on the impact of GVCGF on innovation and environmental protection, their role in enhancing financial market systemic stability has not yet received sufficient attention.

The Entropy of Stock Correlation Networks can be defined as the network resilience of the stock correlation network after variability occurs [5]. Argyroudis and Siokis developed a dynamic network framework based on the Tsallis entropy method, which effectively reflects market risks [6]. Liu et al. utilized Shannon, Renyi, and Tsallis entropy measurement methods to quantify the stability of the organizational evolution of stock networks in the new energy market, which can reflect the anomalous fluctuations of financial networks [7]. Jiang et al. measured the stability of highly correlated financial networks using network entropy, where the calculation of network entropy depends on the eigenvector centrality and Shannon entropy [8]. Few scholars have measured firm systemic stability using network entropy by constructing the stock correlation network of the Beijing Stock Exchange.

To explore how GVCGF impacts firm systemic stability, this paper employs data from semi-annual reports of 84 listed companies from 2018 to 2022, constructs the BSE stock correlation network using complex network theory, and applies the Difference-in-Differences (DID) model to reveal the mechanisms by which GVCGF influences firm systemic stability. The marginal contributions of this paper are threefold: firstly, it uses the BSE stock samples, where the impact of GVCGF is particularly evident, providing data with high typicality and innovativeness; secondly, it innovatively constructs the BSE stock correlation network and measures firm systemic stability using Shannon and Renyi entropies; thirdly, it identifies the industry-level heterogeneity effects of GVCGF in the dedicated equipment manufacturing, internet-related services, and technology promotion and application services industries, offering practical guidance for policy-making.

Structure of the Remaining Sections The paper is structured as follows. Section 2 covers theoretical analysis and research hypotheses, constructing a research framework and proposing hypotheses based on theoretical analysis. Section 3 describes the empirical research design, including stock correlation network model, baseline regression model, data sources and descriptive statistics. Section 4 analyzes the empirical results, including baseline regression analysis, robustness analysis, and endogeneity analysis. Section 5 conducts further analysis focusing on industry-level heterogeneity. Section 6 is conclusions and recommendations.

2 Theoretical Analysis and Research Hypotheses

According to network theory, GVCGF often requires joint investments with other private investors, which fosters collaboration and network construction among firms, enhancing the overall network's cohesion and risk resistance [9]. From the perspective of opportunity cost theory, the presence of GVCGF makes firms more inclined to choose investment projects with long-term, stable returns improving the overall stability of the firms and their networks. Signaling theory suggests that the intervention of GVCGF brings a "signal" effect endorsed by the government, providing essential financial support and credibility endorsements for enterprises. This support helps enterprises gain more trust in the capital market, reduce financing costs, and thereby enhance their stability within the stock correlation network [10]. Based on this, the paper proposes Hypothesis 1:

H1: GVCGF has a positive impact on the firm systemic stability within the Beijing Stock Exchange stock correlation network.

Industry organization theory emphasizes the impact of market structures and behaviors of different industries on economic performance. In innovation-intensive industries, GVCGF is more likely to promote inter-firm cooperation and technology sharing, thereby enhancing the systemic stability of the entire industry [11]. Transaction cost theory focuses on the behavior of organizations seeking to reduce costs and risks in transaction processes. In industries with high demands for technology and knowledge, the injection of GVCGF effectively reduces information asymmetry and transaction costs, enhancing firms' market adaptability and systemic stability [12]. Based on this, the paper proposes Hypothesis 2:

H2: There is industry-level heterogeneity in the impact of GVCGF on firm systemic stability.

3 Empirical Research Design

3.1 Stock Correlation Network Model

In the stock network, nodes represent individual stocks and edges represent the correlation in price fluctuations between two stocks. Define N as the number of stocks, T as this paper period, and $\vartriangle t$ as the time span between two adjacent stock networks. Using the sample data from day $[1,\tau]$, the first stock network is constructed where the daily return series of stocks i and j are $Y_i(1)$ and $Y_j(1)(i,j=1,2\ldots,N)$ respectively, constructing $M=INT[(T+\vartriangle t-\tau)/\vartriangle t]$ stock networks (where X denotes the integer part of $INT(X)$) .The *m-th* network is denoted as $G^m(V,E), m=1,2,\ldots,M$, and the correlation coefficient of prices in the *m-th* network for stock is calculated as Eq (1).

$$\rho_{ij}(m)=\frac{\langle Y_i(m)Y_j(m)\rangle-\langle Y_I(m)Y_j(m)\rangle}{\sqrt{(\langle Y_i^2(m)\rangle-\langle Y_i(m)\rangle^2)(\langle Y_j^2(m)\rangle-\langle Y_j(m)\rangle^2)}} \quad (1)$$

The return series is calculated using logarithmic returns like Eq (2). $p_i^{'}(m)$ represents the closing price of stock i on day t .

$$Y_i^t(m) = ln\,p_i^t(m) - ln\,p_i^{t-1}(m) \tag{2}$$

Subsequently, $\rho_{ij}(m)$ is transformed into the corresponding distance metric $d_{ij}(m)$ like Eq (3); then the appropriate transformations are made to construct *m-th* stock networks $G^m(V,E)$ that reflect the complex price fluctuation correlation patterns of N stocks from $[1+(m-1)\triangle t,(m-1)\triangle t+\tau]$ days like Eq (4).

$$d_{ij}(m) = \sqrt{2(1 - \rho_{ij}(m))} \tag{3}$$

$$w_{ij}(m) = exp(-d_{ij}(m)), w_{ij}(m) \in \left[1/e^2, 1\right] \tag{4}$$

The network entropy, indicative of the level of firm systemic stability, is higher when the stock correlation network is more stable. To define the network entropy of the stock market, we transform the adjacency matrix into a stochastic matrix according to the method used by Demetrius and Manke [13].

$$p_{ij}(m) = \frac{w_{ij}(m)}{\sum_{j=1}^{N} w_{ij}(m)} \tag{5}$$

The *i-th* row of the stochastic matrix $\rho_{ij}(m)$ can be considered a transition probability distribution like Eq (5). Based on the Shannon and Renyi entropy formulas, we calculate the Shannon and Renyi entropies for firm i in the *m-th* stock network as follows. These entropies serve as measures of the firm systemic stability of the network constructed from the interactions among stocks, seeing Eq (6) and Eq (7).

$$HSS_i(m) = -\sum_{j=1}^{N} p_{ij}(m) \log p_{ij}(m) \tag{6}$$

$$HRR_i(m) = \frac{1}{1-\alpha} \log\left(\sum_{j=1}^{N} p_{ij}^{\alpha}(m)\right) \tag{7}$$

3.2 Baseline Regression Model

GVCGF is a policy-driven fund. This paper aims to investigate its impact on firm systemic stability by examining the differences in firm systemic stability of enterprises before and after receiving funding from GVCGF. Given the varying timing of investments by GVCGF in innovative small and medium-sized enterprises, a progressive multi-time point Difference-in-Differences (DID) approach is constructed to analyze the fund's impact on firm systemic stability. The model constructed is specified as follows Eq (8).

$$HSS_{it} = \alpha_0 + \alpha_1 Treat_i \times Post_t + \alpha_2 X_{it} + \mu_i + \delta_t + \varepsilon_{it} \tag{8}$$

Where HSS_{it} represents the network entropy of firm i in year t , $Treat_i \times Post_t$ is the interaction of policy and time dummy variables indicating the effect of GVCGF. X_{it} represents control variables at the firm level that might affect the firm systemic stability. μ_i and δ_t are individual and time fixed effects, respectively. ε_{it} is the random error term capturing other influences on firm systemic stability that vary over time.

The interaction term ($Treat \times Post$) uses the interaction of the policy dummy ($Treat$) and the time dummy ($Post$) to effectively capture the impact of receiving GVCGF on firm systemic stability. The interaction term equals 1 only when both $Treat$ and $Post$ are equal to 1, and 0 otherwise. The coefficient of $Treat \times Post$ in the difference-in-differences analysis represents the net impact of GVCGF on firm systemic stability.

For control variables, this paper follows the methodologies of Jiang et al., Liu et al., Singhal et al., and Alfaro et al. [7][8][14][15]. Considering the availability of data, the following control variables are selected. Firm Size ($Size$) is represented by the natural logarithm of total assets; Return on Assets (ROA) is calculated as net profit divided by total assets at year-end; Fixed Asset Ratio ($Fixratio$) is calculated as total fixed assets divided by total assets at year-end; Leverage Ratio ($Level$) is calculated as total liabilities at year-end divided by total assets at year-end; Firm Age (Age) is calculated as the logarithm of the difference between the current year and the year of establishment; Tax (Tax) is calculated by dividing the taxes payable by the total operating revenue for the year; Share Concentration ($Share$) is calculated based on the proportion of shares held by the top ten shareholders in the total shares of the firm.

3.3 Data Sources and Descriptive Statistics

Table 1. Descriptive Statistics

Variables	Observations	Mean	Std.	Min	Max
HSS_{it}	840	4.728	0.015	4.638	4.754
$Treat$	840	0.119	0.324	0.000	1.000
$Post$	840	0.069	0.254	0.000	1.000
$Treat \times Post$	840	0.069	0.254	0.000	1.000
$Size$	840	19.811	0.800	17.246	23.262
ROA	840	0.088	0.065	-0.141	0.405
$Fixratio$	840	0.107	0.154	-2.368	0.511
$Level$	840	0.332	0.162	0.036	0.897
Age	840	8.685	0.349	7.271	9.684
Tax	840	0.023	0.024	-0.037	0.188
$Share$	840	79.357	14.162	40.220	100.010

The data for this paper is based on 147 firms listed on the Beijing Stock Exchange (BSE) as of the end of 2022. After excluding financial firms, firms treated as ST (special treatment due to financial difficulties), and firms with severely missing data, all firms that received investments from GVCGF are retained as the sample, totaling 10 firms. After excluding firms that received GVC investments, all remaining firms not receiving GVC investments are retained as the control group, totaling 74 firms. The empirical research covers the period from 2018 to 2022, with semi-annual data. The descriptive statistics for the variables are presented in Table 1.

4 Analysis of Empirical Results

4.1 Baseline Regression Analysis

Table 2. Baseline Regression Results

	HSS (1)	*HSS* (2)	*HSS* (3)	*HSS* (4)
$Treat \times Post$	0.004***	0.006***	0.003	0.006**
	(0.001)	(0.001)	(0.003)	(0.003)
Size		-0.004***		-0.009***
		(0.001)		(0.003)
ROA		0.004		0.040***
		(0.008)		(0.012)
Fixratio		-0.002		-0.001
		(0.003)		(0.002)
Level		0.019***		0.032***
		(0.004)		(0.007)
Age		0.000		0.011
		(0.002)		(0.012)
Tax		0.020		0.024
		(0.021)		(0.022)
Share		0.000***		0.000***
		(0.000)		(0.000)
Cons	4.728***	4.789***	4.729***	4.773***
	(0.001)	(0.024)	(0.001)	(0.113)
Time Fixed	YES	YES	YES	YES
Individual Fixed	YES	YES	YES	YES
N	840	840	840	840
R^2	0.000	0.098	0.200	0.301

(Note: Parentheses indicate robust standard errors; *, **, *** denote significance at the 10%, 5%, and 1% levels, respectively.)

Following the model setup described earlier, the baseline regression results are presented in Table 2. Columns (1) and (2) use a random effects model, while columns (3) and (4) use a fixed effects model. Based on the Hausman test and goodness-of-fit analysis, this paper opts for the fixed effects model. In the regression results of column (3) without control variables, the coefficient estimates for the interaction term $Treat \times Post$ is 0.003; in column (4), where control variables are included, the coefficient estimate for $Treat \times Post$ is 0.006. The adjusted R^2 significantly improves from 0.200 to 0.301 after including control variables, indicating that the model fits better and is more rational with the inclusion of other influencing factors. Both coefficients are significant at the 95% confidence level, positively confirming that GVCGF can have a positive impact on the firm systemic stability within the Beijing Stock Exchange stock correlation network, thus validating H1.

Additionally, the estimated coefficients of some control variables are also quite significant, indicating that GVCGF is just one of the factors affecting firm systemic stability, which are also influenced by other factors. A higher return on assets indicates higher net profits, suggesting better business management, which is beneficial for enhancing firm systemic stability. A higher leverage ratio facilitates increased investment in research and development, stimulating business growth, which can, to some extent, enhance firm systemic stability. Furthermore, a higher share concentration held by the top ten shareholders gives them greater influence, aiding in swift decision-making and execution, thus improving operational efficiency and managerial capabilities, which can, in turn, enhance firm systemic stability.

4.2 Robustness Analysis

In the baseline regression, Shannon entropy (HSS) was used as the proxy variable for firm systemic stability. To ensure the robustness of the regression results, Renyi entropy (HRR) is now employed as an alternative proxy variable for the robustness checks. The data for this variable are derived using the formulas described previously. The results of this regression are presented in Table 3. Columns (1) and (2) utilize a random effects model, while columns (3) and (4) use a fixed effects model. The robustness of the results, after replacing the dependent variable, is shown in columns (2) and (4) of Table 3. Comparing columns (1) and (3) in Table 3, the coefficients of $Treat \times Post$ under both effects remain significant at the 99% confidence level after the dependent variable is switched, indicating that the baseline regression results are robust and further validating H1.

Table 3. Robustness Analysis Results

	HSS	HRR	HSS	HRR
	(1)	(2)	(3)	(4)
$Treat \times Post$	0.006***	0.001***	0.008***	0.001***
	(0.001)	(0.000)	(0.002)	(0.000)
Controls	YES	YES	YES	YES
Time Fixed	YES	YES	YES	YES
Individual Fixed	YES	YES	YES	YES
N	840	840	840	840
R^2	0.093	0.138	0.278	0.327

(Note: Parentheses indicate robust standard errors; *, **, *** denote significance at the 10%, 5%, and 1% levels, respectively.)

4.3 Endogeneity Analysis

The research by Liu et al. suggested that long-term consistent trends may not always hold, which introduced an endogeneity problem in the progressive Difference-in-Differences (DID) method [16]. To address this, a Propensity Score Matching DID (PSM-DID) model based on the counterfactual framework can emulate the conditions of a randomized experiment to some extent, thus mitigating endogeneity concerns. This analysis involves selecting all control variables as covariates, computing propensity scores using a Logit model, and conducting firm matching using a one-to-one nearest neighbor matching method. Following the matching, a balance test is performed to assess the quality of the matches. The results indicate a significant reduction in the standardized bias for most control variables after matching compared to before matching. Additionally, there is an increase in p-values, which implies that while there are significant differences before matching, these differences are no longer significant after matching. This indicates that post-matching, there are no systematic differences between the treatment and control group variables, suggesting that the matching was successful and the results satisfy the balance test.

5 Further Analysis

This paper delves deeper into the impact of GVCGF on the firm systemic stability of various types of enterprises. With an original intention to align with national policy directions, GVCGF preferentially invests in sectors and companies that boosts the nation's comprehensive strength and the core creativity of relevant industries and enterprises. According to the 2023 National Economic Industry Classification Report, all industries in China are divided into 20 major-industries and 97 sub-industries. The data for this study include 84 publicly traded companies listed on the Beijing Stock Exchange, categorized according to the major industry based on their main business activities as disclosed in their profiles. These companies are further divided into three major-industries: manufacturing, information technology services, and scientific research and technical services. The classification is further refined into 10 sub-industries, showing that the majority of these listed companies are concentrated in four specific sub-industries: general equipment manufacturing, special equipment manufacturing, internet-related services, and technology promotion and application services. These sub-industries, representing more than 65% of the companies, hold significant importance in the stock market and play crucial roles in the economy, making their analysis particularly strategic.

Table 4. Results of the Heterogeneity Analysis

	HSS (1)	*HSS* (2)	*HSS* (3)	*HSS* (4)
$Treat \times Post$	-0.004	0.014**	0.007***	0.013*
	(0.006)	(0.006)	(0.002)	(0.007)
Controls	YES	YES	YES	YES
Time Fixed	YES	YES	YES	YES
Individual Fixed	YES	YES	YES	YES
N	120	130	160	110
R^2	0.126	0.141	0.397	0.357

(Note: Parentheses indicate robust standard errors; *, **, *** denote significance at the 10%, 5%, and 1% levels, respectively.)

Therefore, this paper conducts a heterogeneity analysis of these four sub-industries, comparing the differences among them. The results are shown in Table 4. The first column represents the general equipment manufacturing industry, the second column represents the special equipment manufacturing industry, the third column represents the internet-related services industry, and the fourth column represents the technology promotion and application services industry. Among these, the coefficient for the general equipment manufacturing industry is not significant, while the coefficient for the special equipment manufacturing industry is significant at the 95% confidence level. The "13th Five-Year Plan" specifically supports and promotes the localization of special equipment. Compared to general equipment manufacturing, special equipment manufacturing has an increasingly prominent strategic position in future economic and social development. The Chinese government has increased industry support to accelerate the development of this sector and build national scientific and technological core competitiveness. GVCGF has played a key role in promoting the development of the special equipment manufacturing industry, creating a favorable business environment for the industry and enhancing firm systemic stability of enterprises within this sector.

The coefficients for the internet-related services industry and the technology promotion and application services industry are significant at the 99% and 90% confidence levels, respectively. This significance is due to these industries being knowledge and technology-intensive. Historically, social capital has shown low willingness to invest in these fields, yet they require continuous technological innovation and R&D investments. In these scenarios, GVCGF plays a crucial role by providing necessary R&D funding or risk mitigation. The government often supports industries that align with national strategic objectives, and the fund has significantly influenced these sectors by attracting social capital, fostering stable industry development, and enhancing firm systemic stability within these industries. H2 is validated.

6 Conclusions and Recommendations

This paper, grounded in theoretical analysis, utilizes semi-annual panel data from 84 publicly listed firms on the Beijing Stock Exchange from 2018 to 2022 to build a stock correlation network. It empirically examines the impact of government venture capital guidance fund on the systemic stability of firms and investigates the heterogeneity of this impact across different industries. The empirical results indicate that, firstly, government venture capital guidance fund can enhance firm systemic stability within the stock correlation network of the Beijing Stock Exchange; Secondly, compared to the conventional general equipment manufacturing industry, this influence is particularly pronounced in the dedicated equipment manufacturing, internet-related services, and technology promotion and application services industries, reflecting significant industry-level heterogeneity.

Therefore, this paper offers the following policy recommendations. Firstly, policymakers should focus on the role of government venture capital guidance fund in stabilizing the stock market and the economy. There is a need to optimize the supervision and evaluation mechanisms of government venture capital guidance fund to ensure that the funds are used precisely and effectively to promote corporate innovation and growth. Secondly, it is recommended that the government pays more attention to industries that are fast in technological updates and heavily dependent on innovation funds in future fund allocations. Especially for high-tech industries such as internet-related services, and technology promotion and application services, the government should strengthen the development of these industries through financial support, reduce the development risks of these industries with government venture capital guidance fund, and promote stable and healthy economic development.

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