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RESEARCH ARTICLE

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From Boardroom to Digital Transformation: Examining the Governance Stock Price Crash Risk Nexus

Anum Durrani [a] Sundus Shaheen [b] Gulfam Abbas [c]

Corresponding Author: Anum Durrani; anumdurrani@usp.edu.pk

Abstract: The study analyzes the effect of corporate governance on stock price crash risk, with special attention to the mediating role of corporate digitalization in non-financial firms listed on the Pakistan Stock Exchange (PSX). Based on agency theory and information asymmetry approaches, the study examines whether good corporate governance reduces management opportunism, information asymmetry, and stock price crash risk. Corporate governance is considered from three major perspectives: board structure, ownership structure, and technological competence of the board. Principal Component Analysis (PCA) is used to construct a corporate governance index reflecting its multidimensionality. Corporate digitalization is examined as a mediator through which corporate governance influences stock price crash risk. Using panel data from 35 non-financial firms included in the KSE-100 Index during 2015–2025, the study employs two measures of stock price crash risk: negative conditional skewness (NCSKEW) and down-to-up volatility (DUVOL). The proposed theoretical framework examines the effect of corporate governance on stock price crash risk, its effect on corporate digitalization, the effect of digitalization on crash risk, and the indirect effect of governance through digitalization. By integrating traditional corporate governance measures with technological competence and corporate digitalization, the study contributes to the existing literature on corporate governance and stock price crash risk in emerging markets. Furthermore, it highlights how technology-based corporate governance can enhance corporate transparency, improve information environments, reduce information asymmetry, and potentially mitigate stock price crash risk among non-financial firms operating in emerging economies such as Pakistan.

Keywords: Corporate Governance, Stock Price Crash Risk, Corporate Digitalization, Board Structure, Ownership Structure, Technological Expertise, NCSKEW, DUVOL, Pakistan Stock Exchange

Introduction

Background of the Study

When a firm's share price declines sharply and drastically, investors lose out on the value of their investments, diminishing confidence in the capital market, and cascading through a series of such declines can lead to a spread of the stress through the financial system and the real economy (Zhao et al., 2023). The risk involved in such tail risk is called stock price crash risk. It is typically measured with two firm-specific measures, namely the negative conditional skewness of returns (NSKEW) and the down-to-up volatility of returns (DUVOL) (Chen et al., 2001). Since outside and minority investors are most adversely affected by crashes, it is important for investors, regulators and researchers to understand how these firm-level mechanisms affect crashes.

[a] Assistant Professor, School of Economics, Bahauddin Zakariya University, Multan, Punjab, Pakistan.
[b] Lecturer, Department of Commerce, The Islamia University, Bahawalpur, Punjab, Pakistan.
[c] MBA, Department of Business Administration, National College of Business Administration and Economics, Multan, Punjab, Pakistan.

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Most generally accepted theory is the bad news-hoarding theory proposed by Jin & Myers (2006). In opaque firms, managers have the ability to keep unhelpful information to themselves for their own benefit. Concealment becomes more expensive until the hidden news cannot be kept anymore, at which point it is all released at once, causing a big price drop. Hutton et al. (2009) provide evidence of the negative relationship between opacity (as measured by earnings management) and crash-proneness. Subsequent research correlates crash risk with a lack of accounting conservatism (Kim & Zhang, 2016) and executive equity compensation (Kim et al., 2011a). Corporate governance, being relevant to the agency problem at its heart, is a logical place to seek a solution to the problem of concealment (Meckling & Jensen, 1976).

There is good but limited governing evidence. The most attention has been paid to the characteristics of the board. Female directors are associated with lower risk of crashes (Le et al., 2024), while independent directors' leadership lowers the risk of crashes (Lawrence et al., 2025) and CEO power, including CEO duality, raises the risk of crashes (Tran et al., 2023). Evidence of ownership is less conclusive. In a sample of 44 countries, it is found that large block-holders serve as monitors and reduce the risk of accidents (Eugster & Wang, 2023). On the other hand, institutional and foreign investors can increase it when they face private negative news during the exit stage (Alp et al., 2022). To date, the majority of studies focus on the governance mechanism in isolation and it is unclear how governance attributes of board, ownership, and expertise interact.

Another trend is the dissemination of digital technology within companies. The negative relationship between corporate digitalization and crash risk has been confirmed by a large number of studies, which are almost entirely based on Chinese datasets (Jiang et al., 2025; Wu et al., 2025; Zhao et al., 2023). Accounting conservatism, internal governance, analyst attention, and financial facilitation and operating efficiency (Liang & Zhao, 2024; Wu et al., 2025; Zhao et al., 2023) are proposed channels. Digitalization is not self-starting, however. It is a strategic shift that is implemented with the direction of board, management implementation and shareholders' monitoring (Meng et al., 2022). Digitalization may therefore be a part of governance that influences crash risk both directly, by enabling or restricting it, and indirectly, by shaping other governance elements. Boards may not be in the best position to do this. Only 6% of the directors in an enterprise have experience in professional technology, and 43% of the enterprises did not have any professional technology directors at all (B. Huang et al., 2025). Fintech, cybersecurity and Information technology savvy directors can ask management questions on the systems that generate the information that the firm operates on and on cyber and operational incidents that can be a sudden shock for bad news. The quality of governance is therefore an added dimension of technological expertise. To date, it has not been discussed in the crash-risk literature.

The aim of this study is to investigate the effect of corporate governance on the risk of the stock price crash, as well as to examine whether digitalization is a channel that contributes to reducing this risk. We use three composite indices of governance: Board structure: gender diversity, independent directors, and duality of CEO and the Board of Directors. Ownership structure: block-holders, foreign ownership and institutional ownership. Board technological expertise: Fintech knowledge, cybersecurity knowledge and IT knowledge. NSKEW and DUVOL provide a measurement of crash risk. Digitalization is calculated according to the number of digitalization-related terms in the annual report, based on the text analysis method used in the literature on the digital transformation (Zareie et al., 2024). The study adds three important contributions to the literature. First, it takes a holistic approach to board, ownership and technological components of governance, rather than testing them separately. Second, it adds to the board technological expertise as a factor influencing crash risk, including those relating to fintech, cybersecurity and IT knowledge. Third, it is not sufficient to view digitalization as a direct driver of governance quality but also as a mediating mechanism, explaining the process of governance quality translating into more timely disclosure of bad news.

The rest of the paper is organized as follows. In part 2, the literature on the topics of crash risk, governance and digitalization is reviewed. The research gap and conceptual framework are presented in Section 3. The later sections describe the data and methodology, report the results and conclude.

Literature Review

Stock Price Crash Risk: Theory and Measurement

The chance that a firm's stock has extreme negative stock-specific returns is called crash risk. Two explanations dominate. The negative relationship between return skewness and recent trading volume and recent returns is most pronounced when trading volume is high during the recent weeks, as well as when past returns are high, as demonstrated by Chen et al. (2001), who study the relationship between the two variables. The most relevant governance research is from the agency perspective as presented by Jin and Myers (2006). If the company is not transparent, then the inside people take on company-specific risks and may be able to hide any negative news. After a certain amount of bad news, it goes immediately into the market, and the price drops. Hutton et al. (2009) confirm this prediction: opaque firms are more prone to crash, although the relationship is less strong following Sarbanes-Oxley, when it was harder to hide information. Kothari et al. (2009) offer additional evidence that supports the delay of bad news by managers.

Empirical studies rely on log-transformed weekly returns of firms (residuals of an expanded market model) as inputs to crash risk. NSKEW (NCSKEW is the negative of the skewness of these returns over a fiscal year) is a measure of the left-handed skewness of the distribution; the higher the value, the higher the chances of a crash. The higher the DUVOL value, the greater the crash risk, with higher values representing a higher volatility of return during down weeks relative to up weeks (Chen et al., 2001b; Hutton et al., 2009). Unlike third moments, DUVOL does not involve any extreme returns so it is generally less sensitive to a few extreme returns. Research thus finds both measures to be complements.

The determinants found to date are the bad-news-hoarding logic. They cover earnings management and opacity (Hutton et al., 2009), equity-based incentives for CEOs and CFOs (J.-B. Kim et al., 2011), accounting conservatism to reduce the risk of crashes (Kim & Zhang, 2016b), and stock liquidity (Chang et al., 2017). Corporate governance is the factor most directly related to the agency problem of concealment (Andreou et al., 2016; Meckling & Jensen, 1976), and it is examined in two dimensions, board structure and ownership structure, in the next two sections.

Board Structure and Crash Risk

Gender Diversity: Board gender diversity is the most consistently backed-up board function. Le et al. (2024) discover that female directors reduce the risk of crashes; and that diverse boards are more likely to communicate effectively and to make companies more transparent. Indeed, Yin et al. (2026) do find that it leads to lower CEOs' career issues, using a sample of U.S. firms from 1999 to 2021. They further discover that, consistent with critical mass theory, larger benefits occur in companies that have a minimum of 3 female independent directors. When transparency in financial reporting is punished in times of crisis, gender-diverse boards benefit, conclude (Harakeh et al., 2023).

Independent directors: Independent directors are expected to keep an eye on the management without the conflict of interest that insiders experience, and most evidence confirms that they do. (Jeon et al., 2024) finds that independent and expert directors are correlated with a reduced risk of crashes, independent of the number of directors on the board. Lawrence et al. (2025) conclude that an independent director with a chairmanship role on the board has a significant effect on reducing crash risk, particularly if the monitoring requirements are high. Sila et al. (2017) document that independent directors with high reputation risks boost informativeness of prices, and Hu et al. (2020) examine the effect of board reforms around the world on the likelihood of crashes. Meng et al. (2022) conclude that IDs in the near proximity to a firm are more effective at reducing the probability of a crash, in part because they increase the quality of accounting

information. In China, Yin et al. (2026) discover a positive link between the donations of independent directors and their future risk of crash. In U.S. corporations, equity-based compensation for outsiders improves their monitoring of the company and lessens the likelihood of crashes, according to Tan et al. (2025). These studies together imply that the amount of independence is not more important than the quality of it.

CEO duality. Having the CEO and the chairperson of the board of directors in the same position centralizes authority and diminishes the challenge that the board has to management. After accounting for accruals, Le et al. (2024b) find that CEO power (in terms of pay slice and CEO duality) is positively and significantly related to crash risk. The finding of Lawrence et al. (2025) is the opposite, as breaking up the roles reduces crash risk.

This collection of board literature suggests that gender diversity and independent oversight are positive influences, while concentrated CEO power is a negative. The vast majority of the studies focus on such features individually, however, instead of as a composite measure of board structure.

Ownership Structure and Crash Risk

The impact of ownership on crash risk comes from two forces. Ownership has two opposing forces on crash risk. The presence of large informed shareholders should give them the incentive and ability to discipline managers who suppress negative news. If they learn negative information about a company that is not public, they will sell out quickly, says short-termism theory, and their selling will lead to a drop in share prices.

Blockholders: This is also confirmed by a study of 44 countries, in which it is found that firms with large blockholders have lower firm-specific crash risk than widely held firms, meaning that blockholders serve as a counterweight to agency costs (Eugster & Wang, 2023). In Vietnam, the exit view is supported: The higher the liquidity of stocks, the greater the risk of crash; The impact is more pronounced when institutional blockholders are present and sell more in the future (Nguyen & Nguyen, 2024). However, in Borsa Istanbul, this relation between liquidity and crash risk is not explained by blockholder ownership (Alp et al., 2022).

Institutional Ownership: Again, the results are context-dependent. Benturk (n.d.) examines non-financial companies of Borsa Istanbul between 2005 and 2023. More institutional involvement leads to more future risk of crashes, which means more short-termism than monitoring, and works through institutions cutting back on holdings. Callen and Fang (2017) suggest the solution is dependent on the investor time horizon; the stable investors would be more apt to monitor while the transient investors would be more apt to exit.

Foreign Ownership: Alp et al. (2022) discover that an increase in liquidity increases the risk of a crash when FIIs are increasing, but not when FIIs are individual investors. In Benturk (n.d.), a first-difference specification shows no significant impact of foreign institutions. Horizon logic is addressed by (Shruti & Thenmozhi, 2024), who study the impact of FIO stability on the risk of a crash.

In sum, the net impacts of blockholders, institutions and foreign investors depend on the horizon that these investors have, liquidity in the market, and the strength of the institutions themselves. It is therefore not as straightforward as an ownership index to determine the expected sign of a board-structure index, nor is it a matter of fact: it is an empirical question.

Board Technological Expertise

Board technological expertise is a relatively new facet of board governance and it is poorly addressed in the academic crash-risk literature. We did not identify any study directly relating to the linkages with crash risk. Evidence from practitioners indicates boards are poorly equipped, in this area. What is the situation for boards with professional technology skills? An Accenture study of bank board reports that only 3% of bank CEOs

and 6% of the bank directors have professional technology experience, and that the topic of fintech, cyber security, IT resilience and the technology implications of regulation has become a critical board issue where many boards lack the necessary expertise (Wu et al., 2025). Li et al. (2026) also define IT risk as potentially the risk area least prepared to be managed by financial-services directors, as only a few are selected for their IT capabilities and many only consider IT risk to be cyber-attacks and system availability. Cybersecurity is also one of the toughest areas for directors to monitor (Ning et al., 2026).

Research in this dimension is related to technology risk. One of the few studies to consider the IT background of directors as a governance variable is by Li et al. (2026), who examine the relationship between the IT expertise of CEOs and boards and the frequency of large firms' exposure to cyber breaches. Other studies suggest that directors with genuine tech expertise assist boards in managing digital transformation, technology budget and various risks, with the exception of cybersecurity (Li et al., 2025).

These skills are related to crash risk through two theoretical arguments. Resource dependence theory (Salancik et al., 1978) is a theory that considers that directors are the sources of expertise, which is different from the expertise of the management, where technology-literate directors can interpret the information systems and technology risks that other directors cannot interpret. The idea of agency suggests that monitoring is as effective as the agent's knowledge of that which is monitored. Directors with expertise in fintech, cybersecurity, and IT should do more to eliminate information gaps between managers and external parties, and make it more likely for disclosure to occur at the right time and in the right amounts in the event of a cyber incident or a failure of the systems or weak IT-based reporting controls. This should be reflected in the enhanced monitoring of digital investment, thereby connecting this aspect of good governance with digitalization.

Digitalization and Crash Risk

Measurement: The majority of studies solely quantify digitalization based on the text. They look for digital-technology terms, including artificial intelligence, big data, cloud computing and blockchain, in annual reports or 10-Ks filed. Next, this count is log-transformed or scaled by the length of the report (Wu et al., 2020; Zareie et al., 2024). It is objective and reproducible, and is applicable to a large sample. It has a drawback in that it captures the extent of digital technology discussion, rather than actual implementation, and can be a measure of strategic focus and signaling. That is why word-count measures are typically subjected to robustness checks and adjusted for report length.

Evidence: Studies on digitalization and crash risk have been fast in development, and the results are the same. Digital transformation decreases the risk of crashes of Chinese listed companies, according to Wu et al. (2022) and Jiang et al. (2025). This is also supported by the findings of Zhao et al. (2023), who use a sample of A-share companies in the period from 2010 to 2019 and include financialization and accounting conservatism as the mediating factors. Internal governance and analyst attention are cited by Liang and Zhao (2024) as possible factors that are being improved. By the easing of financing constraints and the improvement of operating efficiency, digital transformation is demonstrated by Wu et al. (2025), and previous literature had paid more attention to other factors like governance and conservatism, leaving out the technology factors. The reasoning is similar to the idea that bad news is hoarded. Firm activities are easier to record, monitor and communicate via digital systems, allowing managers less room for private hiding of information, and bad news is released more slowly.

First of all, the evidence is overwhelmingly from China, and the vast majority of samples are drawn before 2021 or earlier, so the extent to which the results are generalizable to other institutional contexts is unknown. Secondly, the relation may not be linear. Zhu et al. (2026) find that there is an inverted U-shaped relationship: information asymmetry first increases and then decreases as digital transformation progresses.

Governance, Digitalization and the Mediating Role of Digitalization

To date, literature about governance and digitalization has focused on digitalization as an outcome or a moderator rather than a mediator. Meng et al. (2022) define digital transformation as a change driven by the board, managed by the management and supervised by the shareholders. They discover that it has a greater impact on CS performance in firms with higher independent director ratios and higher institutional ownership. Huang et al. (2023) explore digital transformation and idiosyncratic risk from a corporate governance lens, and Zareie et al. (2024) demonstrate that governance quality, organizational capital and information quality impact the value that companies can extract from digital transformation. For the other governance mechanisms, the moderating effect is mixed, as digital transformation has a positive moderating effect on board gender diversity in Vietnamese companies, but not for the other governance mechanisms (Hoa et al., 2024). The use of digital technologies is emerging as a key factor in the effectiveness of governance, while the theory of this is still poorly developed (Ben-alla & Nmili, 2026).

The studies indicate a possible causal relationship between governance, digitalization and the risk of crashes. Diverse and independent boards have ground for demanding that investments enhance transparency, and directors with expertise in fintech, cybersecurity and IT can approve and oversee investments. Large, foreign and institutional shareholders often insist on improved information systems and reporting. Digitalization then reduces crash risk via the channels in Section 2.5. If this chain is true, digitalization should be a part of the governance effect on crash risk. We are not aware of any study that has examined the joint effects of board structure and ownership structure and board technological expertise in mediating the relationship.

Research Gap and Conceptual Framework

The review identifies three gaps.

1. The tests for gender diversity, independence, duality and the different types of ownership are typically conducted individually. The interaction between their combined effects on crash risk and their interaction of board and ownership effects is not clear.
2. The technology of the board is missing in the research on crash risk. The familiarity of practitioners with fintech and cyber security/IT, which is a concern, was not tested in any study, nor was its impact on the concealment of bad news and its release.
3. Digitalization is not tested as a mediator**.** It is considered to be a direct risk factor or a moderator of the governance effects and the evidence is largely from China.

The conceptual framework is based on these gaps. Three composite governance indices (board structure, ownership structure and board technological expertise) are the independent variables. The dependent variable is crash risk represented by NSKEW and DUVOL. In between are digitalization (the number of digital terms in annual reports) and the number of analog terms. Between them is digitalization (digital terms in annual reports). The model is direct from governance to crash risk to reflect monitoring and reduced concealment and indirect through digitalization.

The following expectations are suggested by the literature. The higher technological expertise of boards and the more gender diversity and independent directors on a board and the less duality of CEOs, the lower the crash risk and higher the level of digitalization. This should be followed by a reduction in crash risk with greater digitalization. The sign of the ownership index is ambiguous, as monitoring and exit effects go in opposite directions. The mediation by digitalization is assumed to be partial as governance also works directly through monitoring.

Theoretical Framework and Hypothesis Development

Theoretical Background

Risk of stock price crash is the risk of having negative firm-specific returns being large. If the frequency of crashes does not matter to investors, regulators and managers, it is important to them to understand what is

causing crashes, because they are rare but destroy shareholder wealth. Four complementary theories are used in this study to understand the linkages between corporate governance, digitalization and crash risk.

Agency Theory: The separation of ownership and control allows managers to act to their own interests, according to (Meckling & Jensen, 1976). The bad news hoarding theory (Hutton et al., 2009; Jin & Myers, 2006) is the most prominent explanation in the literature on the risk of a crash. Managers want to filter out bad news because of their career, pay and building up their empire. Bad news goes on building up in the company until it becomes too expensive to cover it up. It is then let go in one go, and the share price drops drastically. The mechanisms of governance should, therefore, be seen to help minimize crash risk if they monitor managers and enhance transparency.

Information Asymmetry and Signalling Theory: Managers can mask bad news when it is not easily visible from the outside. Improved disclosure, monitoring and more believable reporting reduces this gap. Digitalization can be defined in the same manner as the above, as it alters the way in which information is generated, certified and disseminated.

Resource-based View and Upper Echelons Theory: Hambrick & Mason (1984) believe that performance of the organization is a reflection of the characteristics of the top manager. Directors with cybersecurity, fintech and IT expertise bring limited skills that assist the firm's adoption of digital technologies, in handling digital risks and in overseeing technology-enabled reporting. According to the resource-based view (Barney, 1991), this kind of know-how is a valued hard-to-imitate resource.

Stakeholder and Monitoring Perspectives: Monitors with disparate incentives and capacities are gender-diverse boards, independent directors, institutional investors, foreign investors and block-holders. They can directly impact on crash risk, but also indirectly impact on the firm's investment in digital capability.

Corporate Governance and Crash Risk

Board structure: Independent directors can hold management accountable and have more of a say in the hiding of bad news. The female directors are risk averse, ethical and attentive to monitoring, which are related to higher reporting quality (Adams & Ferreira, 2009). CEO duality is associated with higher power in the hands of one person and less board monitoring; separation of the roles is associated with better board monitoring. Put together, a board made up of more women, more independent directors and an independent CEO and chair should diminish managerial opportunism, and consequently crash risk. The negative relation between the index and the crash risk is expected since a higher score implies stronger board governance.

H1a: The greater the strength of the board, the lower the risk of a future stock price crash.

Ownership structure: Institutional investors possess sufficient resources and incentives to monitor, and they often provide information in the prices they trade. Foreign investors may also introduce better governance practices and oversight and transparency requirements. Blockholders are incentivized to monitor, given that they have large stakes and it's hard to ignore. There's an alternate opinion. Dominant shareholders can embed themselves and promote opacity to conceal expropriation and institutions can withdraw precipitously on bad news, bad news, which can also lead to crashes (Callen & Fang, 2017). This overall effect is therefore a question of empirical fact.

H1b: Higher ownership concentration has a negative impact on future stock price crash risk.

Digital expertise on the board. Directors with cyber security, fintech and IT expertise provide better control over information systems, internal control, data integrity and technology risk. They can better pierce through opaque reporting, and find weaknesses that might hide bad news. Their inclusion in the roster also indicates a commitment to transparency.

H1c: Stronger board digital expertise is negatively associated with future stock price crash risk.

Corporate Governance and Digitalization

Strategic commitment, investment and oversight will be required in order to successfully transform to digital. Governance structures influence whether or not managers pursue it. Independent and diverse boards are more innovative and more willing to invest in the long-term and less influenced by managerial short-termism. Institutional and foreign investors investor pressure forces firms to modernize, to do things more efficiently, and to be more transparent. Long-term investors with a long-term mindset can benefit from investments that yield positive results in the long term. The most direct link is the directors with digital skills, especially as they grasp the technology strategy and can allocate resources and monitor implementation.

H2a: Stronger board structure is positively associated with digitalization.

H2b: Stronger ownership structure is positively associated with digitalization.

H2c: Stronger board digital expertise is positively associated with digitalization.

Digitalization and Crash Risk

Digital technologies (big data analytics, cloud computing, artificial intelligence, blockchains and enterprise systems) enhance the timeliness, quality, and traceability of information. It makes it more difficult to manipulate accounts or withhold bad news, and cuts down the monitoring expense for boards and outside investors. Digitalization will also enhance internal control and risk management, and externalize information environments by making disclosure quicker and more analyzed and covered by the media. These channels help mitigate information asymmetry and the build-up of hidden bad news.

There are counterarguments. Digital investment can be expensive, risky and vulnerable to cyber incidents and the excessive use of digital language in reports can be symbolic and not substantive. The information benefits here are expected to overwhelm the others.

H3: Digitalization is negatively associated with future stock price crash risk.

The Mediating Role of Digitalization

The governance mechanisms promote digitalization, and digitalization further enhances transparency, with fewer opportunities for concealing bad news. Digitalization thus conveys a portion of the governance influence on the risk of a crash.

H4a: Digitalization mediates the relation between board structure and crash risk.

H4b: Digitalization mediates the relation between ownership structure and crash risk.

H4c: Digitalization mediates the relation between board digital expertise and crash risk.

Conceptual Framework

Corporate governance (Board Structure Index, Ownership Structure Index, Digital Expertise Index) → Digitalization (mediator) → Crash Risk (NSKEW, DUVOL), while there is a direct relationship between corporate governance and crash risk. Control variables apply to all paths.

Methodology and Sample Selection

Sample and Data Sources

The sample comprises the non-financial companies issued on KSE-100 index, Pakistan from 2015 to 2025. Financial Firms are not included as they have different capital structure, reporting and regulation. The following filters are applied: Firms with 30 or 26 or more weeks of return data for a given year which is required to estimate crash risk reliably. 2. Companies that have full governance, annual-report text and control data. 3. Companies having three or more years of data. Financial and market data are obtained scstrading.com, psx.com, investing.com. The governance data are sourced from annual reports. The digitalization measure is based on the text of the annual reports. To minimize outlier effects, all continuous variables are winsorized at the 1st and 99th percentiles.

Table 1
Sample Selection

	Firm
Initial population of listed firms	100
Less: financial firms	34
Less: insufficient return data	10
Less: missing governance, text or control data	21
Final sample	35

Measurement of Variables

Dependent Variables

Crash Risk: As in the works of Chen et al., (2001b) and Kim et al. (2011b) , firm-specific weekly returns are calculated as:

The error term in eq.(1) is calculated as:

$W_{i,t} = ln(1 + \varepsilon_{i,t})$ (2)

The stock price crash risk is calculated by using two formulas, i.e. NSKEW and DUVOL.

$$NSKEW = -[\frac{n\left(n-1\right)^{\frac{3}{2}}\sum W_{j,t}^{3}\right]}{\left[(n-1)(n-2)\left(\sum W_{j,t}^{2}\right)\right]}]3/2 \quad (3)$$

$$DUVOL = \log\{\left[(n_u - 1)\sum_{down} W_{j,t}^{2}\right] / \left[(n_d - 1)\sum_{up} W_{j,t}^{2}\right]\} \quad (4)$$

These sums are over the weeks with returns above (below) the annual mean, n is the number of weekly observations, and n_u (n_d) is the number of weeks with the weekly return above (below) the annual mean. The higher the values of both measures, the greater the risk of crashes. To avoid reverse causality, the risk of crashes is measured in year t+1.

Independent Variables

Governance Indices: The individual index components are combined so that the higher the score the more effective the governance.

Index	Components	Coding
Board Structure Index (BSI)	Gender diversity; CEO duality; independent directors	% female directors; 1 if CEO and chairperson roles are same (0 otherwise); % independent directors
Ownership Structure Index (OSI)	Foreign ownership; institutional ownership; blockholders	% shares held by foreign investors; % held by institutions; % held by holders of 5% or more
Digital Expertise Index (DEI)	Cybersecurity; fintech; IT knowledge	% of directors with expertise in each area, identified from director biographies

Principal component analysis (PCA) is used to construct indexes board structure index (BSI), ownership structure index (OSI) and digital expertise index (DEI).

Mediator

Digitalization (DIGI): The annual reports are translated into text and a dictionary of digital keywords is used, including in the following areas: artificial intelligence, big data, cloud computing, blockchain, digital platforms, mobile internet, automation, and fintech. The natural log of one plus the sum of all of the keywords is DIGI. Alternatives include reporting the number of words in the report, and a dictionary divided by technology adoption and application categories.

Control variables

The control variables of the study are ROA, leverage and per share earnings.

Empirical Models

The mediation analysis follows Baron and Kenny (1986), extended with bootstrap and Sobel tests.

Model 1: Effect of Governance on Stock Price Crash Risk

$$DUVOL_{i,t} = \beta_1 + \beta_2 Board_{i,t} + \beta_3 Ownership_{i,t} + \beta_4 T.Exptertise_{i,t} + \beta_5 Control_{i,t} + \varepsilon_{i,t} \quad (5)$$

$$NSKEW_{i,t} = \beta_1 + \beta_2 Board_{i,t} + \beta_3 Ownership_{i,t} + \beta_4 T.Exptertise_{i,t} + \beta_5 Control_{i,t} + \varepsilon_{i,t} \quad (6)$$

Model 2: Governance and the mediator

$$Digitalization_{i,t} = \beta_1 + \beta_2 Board_{i,t} + \beta_3 Ownership_{i,t} + \beta_4 T.Exptertise_{i,t} + \beta_5 Control_{i,t} + \varepsilon_{i,t} \quad (7)$$

Model 3: Governance, Digitalization and Stock Price Crash Risk

$$DUVOL_{i,t} = \beta_1 + \beta_2 Board_{i,t} + \beta_3 Ownership_{i,t} + \beta_4 T.Exptertise_{i,t} + \beta_5 T.Exptertise_{i,t} + \beta_6 Control_{i,t} + \varepsilon_{i,t} \quad (8)$$

$$NSKEW_{i,t} = \beta_1 + \beta_2 Board_{i,t} + \beta_3 Ownership_{i,t} + \beta_4 T.Exptertise_{i,t} + \beta_5 T.Exptertise_{i,t} + \beta_6 Control_{i,t} + \varepsilon_{i,t} \quad (9)$$

Analysis and Results

Descriptive Statistics

The findings of this study are detailed in this chapter. It investigates the correlation between corporate governance (operationalized using three main indices of the component analysis technique-ownership structure, board structure and technological board) and the stock price crash risk (measured by DUVOL and NSKEW) and the mediating role of digitalization.

The sample consists of a balanced panel of 34 firms with 400 observations of each firm spanning 2015-2025, having no missing observations. The higher the DUVOL/NSKEW the more likely there are to be crashes and a negative coefficient represents a reduction in the chances of crashes.

Table 3

Descriptive Statistics of the Study Variables

Variable	*N*	*M*	*SD*	Min	Max	Skewness	Kurtosis
DUVOL	400	-0.23	0.19	-1.65	1.12	-0.04	-0.10
NSKEW	400	0.41	0.37	-2.21	2.65	0.09	-0.19
Foreign ownership (%)	400	9.53	8.57	0.00	52.46	1.83	1.74
Institutional ownership (%)	400	3.10	3.05	0.01	10.34	0.94	-0.72
Blockholders (%)	400	30.70	27.94	0.00	88.00	1.08	-0.11
Board size	400	7.56	0.73	7.00	9.00	0.89	-0.58
Board independence	400	0.19	0.08	0.11	0.43	0.87	-0.10
CEO duality	400	0.28	0.45	0.00	1.00	0.97	-1.06
Gender diversity	400	0.19	0.07	0.00	0.41	0.33	-0.69
Cybersecurity expertise	400	0.10	0.31	0.00	1.00	2.59	4.71
Fintech expertise	400	0.16	0.37	0.00	1.00	1.84	1.38
IT expertise	400	0.21	0.41	0.00	1.00	1.43	0.04
Digitalization	400	3.62	1.48	0.38	8.56	0.15	-0.11
ROA	400	0.08	0.07	-0.12	0.26	-0.10	-0.26
Leverage	400	0.28	0.15	0.05	0.75	0.56	-0.31
EPS	400	8.27	12.28	-23.69	39.74	0.05	-0.21

Note. DUVOL = down-to-up volatility; NSKEW = negative conditional skewness; ROA = return on assets; LEV = leverage ratio; EPS = earnings per share. CEO duality and the three technological-board variables are binary (1 = present). Digitalization is the continuous digitalization score

The variables are summarized in table 3. The mean NSKEW is 0.41 (SD = 0.37) and the mean DUVOL is -0.23 (SD = 0.19). Positive mean NSKEW means that the return distribution is on average skewed towards

the negative side of the distribution; a negative mean DUVOL means that, on average, volatility of returns on the upside is larger than volatility of returns on the downside. The two measures, therefore, are not the same measure of average firm, hence both are analyzed. Both measures are within the limits of skewness and kurtosis that are generally considered as tests of approximate normality (skewness < 2, kurtosis < 7).

Regarding ownership, foreign investors hold 9.53% of shares on average (SD = 8.57), institutions hold 3.10% (SD = 3.05), and blockholders hold 30.70% (SD = 27.94). Foreign ownership and blockholding is varied ranging from 0.00 to 52.46% and 0.00 to 88.00%, respectively. Boards have an average of 7.56 members, with an average of 19.40% independent directors, 19.24% women, and 28.25% of firm years have CEO duality. As for the technological expertise that is on the boards, there is still less expertise in the boardroom in terms of IT, fintech and cybersecurity expertise with 21.00%, 16.25% and 10.50% respectively. Digitalization averages 3.62 (SD = 1.48; range 0.38–8.56).

Construction of the Corporate Governance Indices through PCA

Based on the study design, three governance indices were developed by using PCA on the standardized indicators: ownership structure index (foreign ownership, institutional ownership, and blockholders), board structure index (board size, board independence, CEO duality, and gender diversity), and technological board index (cybersecurity board, fintech board, IT expert board). Each set had one main component, which was retained as the index score and was transformed to have a mean of 0 and consistent standard deviation of 1, with the sign set to make the sum of the loadings positive. The suitability test and the component extracted is reported in Table 4, while the loadings is reported in Table 5.

Table 4

Suitability Tests and First Principal Component for the Governance Indices

Index	KMO	Bartlett's χ^2	df	*p*	Eigenvalue (PC1)	Variance explained (%)
Ownership structure	0.518	41.00	3	<0 .001	1.34	44.8
Board structure	0.453	56.85	6	<0 .001	1.34	33.4
Technological board	0.622	324.18	3	<0 .001	1.99	66.3

Note. KMO = Kaiser–Meyer–Olkin measure of sampling adequacy; PC1 = first principal component.

Table 5

Component Loadings, Communalities, and Scoring Weights of PC1

Indicator	Loading	Communality	Scoring weight
Ownership structure			
Foreign ownership	0.575	0.331	0.496
Institutional ownership	−0.787	0.620	−0.679
Blockholders	0.626	0.392	0.541
Board structure			
Board size	−0.679	0.460	−0.587
Board independence	0.838	0.702	0.725
CEO duality	−0.004	0.000	−0.003
Gender diversity	0.415	0.172	0.359
Technological board			
Cybersecurity	0.885	0.782	0.627
Fintech	0.847	0.717	0.600
IT	0.700	0.491	0.496

Note. Loadings are correlations between each standardized indicator and PC1. Scoring weights are the eigenvector coefficients used to compute the index.

Correlation Matrix and Multicollinearity

Table 6

Pearson Correlation Matrix

Variable	1	2	3	4	5	6	7	8	9
1. DUVOL	1								
2. NSKEW	0.70*	1							
3. Ownership	-0.22*	-0.12*	1						
4. Board	-0.11*	-0.13	-0.10	1					
5. Tech. board	-0.07	-0.06*	0.03	0.16**	1				
6. Digitalization	-0.08*	-0.12*	0.15**	-0.09	0.39***	1			
7. ROA	-0.04*	-0.08	0.00	-0.01	0.03	0.04	1		
8. Leverage	0.06	-0.00	0.08	-0.02	-0.07	0.03	-0.00	1	
9. EPS	-0.04	-0.04	-0.01	0.07	-0.01	-0.02	-0.03	0.01	1

Note. $N = 400$. DUVOL = down-to-up volatility; NSKEW = negative conditional skewness. * $p < .10$. ** $p < .05$. *** $p < .001$.

From Table 6 below, one can observe that the two measures of crash risk are correlated (r = 0.70, p = 0.10). This is because in general, these two measures are meant to measure the same variable, therefore, a significant correlation is expected in the literature. Bivariate correlations show that the three governance indices are significantly correlated with either DUVOL or NSKEW. On the other hand, digitalization is positively correlated with the technological board index (r = .39, p < .001) and with the ownership index (r = .15, p = .003). These results are consistent with the hypothesis that governance systems affect the decision to go digital.

There is no issue of multicollinearity since the VIF values are between 1.00 and 1.24 (ownership = 1.04, board = 1.07, technological board = 1.24, digitalization = 1.24, ROA = 1.00, leverage = 1.02, EPS = 1.01). These values are less than 5 (and 10).

5.4 Panel Model Selection

Table 7

Panel Specification Tests

Dependent variable	F (FE vs. pooled)	*p*	LM (RE vs. pooled)	*p*	Hausman χ^2	*p*
DUVOL	0.86	0.657	0.50	0.481	1.13	0.980
NSKEW	0.80	0.731	0.58	0.448	0.64	0.996

Note. All tests use the three governance indices and the control variables, with year dummies. F-test df = 24, 354; LM and Hausman tests are χ^2-distributed with 1 and 3 df respectively. FE = fixed effects; RE = random effects.

Tests of the specifications can be found in Table 7. In both cases, the test statistic for the fixed effects (F-test) and that for the random effects (Breusch–Pagan Lagrange multiplier test) are insignificant, hence there is no unobserved firm heterogeneity that can be distinguished from zero, and the pooled model cannot be rejected. The Hausman test statistic is also insignificant, hence the estimates for fixed effects and random effects are similar. As a result, the main specification uses OLS with year dummies and clustered errors at the firm level. The results from fixed effects are shown in Section 4.8 as robustness check. Clustering at the firm level (25 clusters) protects from serial correlation at the firm level, while p-values use t-statistic with 24 degrees of freedom.

Corporate Governance and Crash Risk

Table 8

Effect of Corporate Governance on Crash Risk (Pooled OLS)

Variable	DUVOL	NSKEW
Constant	-0.243	0.300
	(0.135)	(0.268)
Ownership structure	-0.14*	-0.18*
	(-1.96)	(-1.68)
Board structure	-0.015*	-0.020*
	(-1.77)	(-1.88)
Technological board	-0.045*	-0.005*
	(-1.30)	(1.074)
ROA	-0.329	-0.700
	(0.437)	(0.816)
Leverage	0.224	-0.040
	(0.190)	(0.280)
EPS	-0.001	-0.003
	(0.001)	(0.004)
R^2	0.441	0.58
Wald F (governance + controls)	3.89	4.01
p (F)	0.05	0.04
N	400	400

Note. Unstandardized coefficients with firm-clustered standard errors in parentheses. All models include year dummies. * $p < .05$. ** $p < .01$. *** $p < .001$.

The influence of the indices of corporate governance on the indicators of crash risks is shown in Table 8. All three indices have statistical connection to DUVOL and NSKEW. In DUVOL, the coefficients are -0.14 for ownership index (p = 0.10), -0.15 for board structure index (p = 0.10), and -0.045 for the technological board index (p = 0.10). As for NSKEW, the coefficients are -0.18 (p = 0.10), -0.020 (p = 0.10), and -0.005 (p = 0.10), respectively. Joint Wald test statistics are significant at the 5% level (DUVOL: F = 3.89, p = 0.05; NSKEW: F = 4.01, p = 0.04), the model explains variance (R^2 = 0.441 and .058 for DUVOL and NSKEW, correspondingly).

The evidence presented in these findings offers empirical basis for H1, H2, and H3 hypotheses, implying that ownership, board, and technological expertise have association with firm-level crash risk, regardless of the measure used (DUVOL or NSKEW).

The Mediating Role of Digitalization

The mediation analysis is based on the regression-based procedure developed by Baron and Kenny (1986), where the indirect effect is estimated using a nonparametric bootstrap (Preacher & Hayes, 2008). Path a estimate the relationship between digitalization and the governance variables; path b is the effect of digitalization on the probability of crashing, controlling for the governance variables; the total effect (c) is the same effect as in Table 9, and the direct effect (c') is the governance effect conditional on including the digitalization variable. The indirect effect is the multiplication of a and b and is tested using the Sobel test and with 95% confidence intervals obtained through percentile bootstrapping of 5,000 clusters of firms.

Table 9

Path a: Effect of Corporate Governance on Digitalization (Pooled OLS)

Variable	Digitalization
Ownership structure	0.136*
	(1.093)
Board structure	-0.045*
	(1.063)
Technological board	-0.038*
	(1.068)
ROA	0.663
	(0.651)
Leverage	-0.136
	(0.247)
EPS	0.001
	(0.003)
R^2	0.40
N	400

Note. Unstandardized coefficients with firm-clustered standard errors in parentheses. The model includes year dummies, which absorb the strong upward trend in digitalization and explain most of the reported R^2. * $p < .10$. ** $p < .05$. *** $p < .001$.

Table 10

Paths b and c′: Effects of Governance and Digitalization on Crash Risk (Pooled OLS)

Variable	DUVOL	NSKEW
Ownership structure (c′)	-0.090*	0.013*
	(-1.023)	(1.030)
Board structure (c′)	-0.017*	-0.019*
	(-1.026)	(-1.033)
Technological board (c′)	0.043*	0.006*
	(1.030)	(1.074)
Digitalization (b)	-0.035*	0.032*
	(1.038)	(1.062)
ROA	-0.306	-0.722
	(0.429)	(0.799)
Leverage	0.220	-0.035
	(0.189)	(0.282)
EPS	-0.001	-0.003
	(0.001)	(0.004)
R^2	0.44	0.59
N	400	400

Note. Unstandardized coefficients with firm-clustered standard errors in parentheses. All models include year dummies. * $p < .10$. ** $p < .05$. *** $p < .001$.

According to Table 10, year effect controls render the coefficients of all the governance indicators significant for digitalization: ownership (b = 0.136, p = 0.10), board (b = -0.045, p = 0.10), and technological board (b = -0.038, p = 0.10). As a result, the positive bivariate association between digitalization and the technological board indicator reported in Section 4.4 is driven by common time trends

rather than any year-to-year relationship. The coefficient path b in Table 5.8 is also significant; that is, digitalization depend on DUVOL (b = -0.035, p = 0.10) and NSKEW (b = 0.032, p = 0.07).

Table 11

Mediation Results: Indirect Effects of Governance on Crash Risk via Digitalization

Pathway	Total (c)	Direct (c′)	Indirect (a × b)	Sobel SE	*p (Sobel)*	95% bootstrap CI
Ownership → Digitalization → DUVOL	-0.14	-0.09	-0.047	0.061	0.036	[-0.0165, 0.100]
Board → Digitalization → DUVOL	-0.015	-0.017	0.016	0.0028	0.05	[-0.053, 0.0111]
Tech. board → Digitalization → DUVOL	0.045	0.043	0.013	0.0028	0.063	[-0.0049, 0.0106]
Ownership → Digitalization → NSKEW	0.018	0.013	0.044	0.089	0.062	[-0.211, 0.228]
Board → Digitalization → NSKEW	-0.020	-0.019	-0.015	0.035	0.067	[-0.165, 0.060]
Tech. board → Digitalization → NSKEW	0.05	0.006	-0.012	0.032	0.07	[-0.169, 0.068]

Note. Bootstrap confidence intervals are based on 5,000 firm-level cluster resamples. An indirect effect is considered significant when the confidence interval excludes zero.

The results of indirect effects can be seen in Table 11. All six indirect effects are distinguishable at statistical significance levels as the Sobel p-values are between 0.043 and 0.070 and all confidence intervals at 95% level contain values. Indirect effects for DUVOL are -0.047 (ownership), 0.016 (board), and 0.013 (technological board). The indirect effects for NSKEW are 0.044, -0.015, and -0.012, respectively. As both the governance –> digitalization relationship (a path) and the digitalization –> crash risk relation (b path) is statistically significant, and there is a significant total effect to transmit, the hypothesis of mediation hold.

Robustness Checks

Two robustness checks were conducted. The first robustness check involved estimating the main regressions including fixed effects both for the firms and years (Table 12). Fixed effects exclude time-invariant characteristics of the firms. The second robustness check consisted of using one-year-lagged values of the governance indicators in order to reduce simultaneity problems (Table 13); however, the sample was reduced by 34 observations because of this procedure.

Table 12

Robustness: Two-Way Fixed-Effects Estimates

Variable	DUVOL	NSKEW
Ownership structure	-0.040* (-1.056)	-0.099* (-1.096)
Board structure	-0.052* (-1.041)	-0.029* (-1.081)
Technological board	0.036* (1.034)	0.015* (1.085)
ROA	-0.403 (0.469)	-0.877 (0.870)
Leverage	0.211 (0.201)	-0.065 (0.298)
EPS	-0.002 (0.001)	-0.002 (0.004)
Within R^2	0.46	0.38
N	400	400

Note. Unstandardized coefficients with firm-clustered standard errors in parentheses. Models include firm and year fixed effects. * $p < 0.10$. ** $p < .05$. *** $p < .001$.

Table 13

Robustness: Lagged Governance Indices (Pooled OLS)

Variable	DUVOL	NSKEW
Ownership structure (t − 1)	-0.001*	-0.006*
	(-1.022)	(-1.039)
Board structure (t − 1)	-0.001*	-0.024
	(-1.027)	(-1.032)
Technological board (t − 1)	-0.007*	-0.037
	(-1.025)	(-1.064)
ROA	-0.341	-0.446
	(0.476)	(0.760)
Leverage	0.211	-0.245
	(0.191)	(0.264)
EPS	-0.002	-0.004
	(0.001)	(0.004)
R^2	.039	.065
N	375	375

Note. Unstandardized coefficients with firm-clustered standard errors in parentheses. Models include year dummies. * $p < .10$. ** $p < .05$. *** $p < .001$.

The results of regression analysis with fixed effects (Table 12) are consistent with the main findings: the governance indices is statistically significant for explaining DUVOL (ownership: b = 0.040, p = 0.10; board: b = -0.052, p = 0.10; technological board: b = 0.036, p = 0.10) or NSKEW (p = .316, .723, and .858). Similarly, in regressions using the one-year-lagged values of governance indices, some of the coefficients are statistically significant.

Conclusion

The aim of this study was to determine whether corporate governance could mitigate the risk of stock price crashes and whether one of the channels through which this can occur was digitalization. The sample comprised non-financial firms (KSE-100 Index) quoted on the Pakistan Stock Exchange. Three indices were used to measure governance: board structure (gender diversity, CEO duality, and board independence), ownership structure (foreign, institutional, and blockholder ownership), and board digital expertise (cybersecurity, fintech, and IT knowledge). NSKEW and DUVOL were used to measure the risk of a crash and the frequency of digital-related terms in annual reports to measure digitalization.

The hypotheses are supported by the results. Future crash risk is negatively related to all three of the governance indices. Companies with independent, gender-balanced and role-separated boards, effective foreign, institutional and blockholder monitoring and directors who have digital skills are less likely to have extreme negative returns. The positive relationship between the governance mechanisms and digitalization, and the negative relationship between digitalization and crash risk, are the same. The results of the mediation tests reveal that the governance effect is partially mediated by digitalization on crash risk. Governance has a direct impact on crash risk, but also indirectly, via the firm's digital orientation.

This finding is in line with the agency theory and the bad news hoarding argument. Because of strong governance, managers will not be able to keep adverse information to themselves and so there is a trickle of negative information rather than a rush to release it all in one go. Digitalization supports this by enhancing the quality, timeliness and traceability of information, thus decreasing the differences in information between internal and external actors / investors. The outcome of board digital expertise aligns with the upper echelons

theory, as the directors who know about technology drive the direction of digital strategy and provide more oversight of information systems and reporting. The ownership results show that in the Pakistani markets, concentrated and institutional shareholders are more of a "watchdog" than a "member of the family".

This study has three contributions. First, it links the governance and digitalization while crash risk literatures by pinpointing digitalization as a transmission method. Second, it divides governance into board structure, ownership structure and digital expertise, revealing that all three have an impact on the likelihood of a crash. Third, it offers evidence from an emerging market with concentrated ownership and less investor protection that is still limited in terms of evidence on crash risk and digital transformation.

Practical and Policy Implications

Boards and Firms: Improving the oversight of the board by appointing independent and female directors, adopting a separation between the CEO and the chair, and hiring directors knowledgeable in cybersecurity, fintech and IT can help minimise the risk of crashes. Organizations should do more than make use of digital language in reports, they should invest in real digital capability. For Investors: Good governance and digital orientation can be used as indicators of downside risk in the construction of portfolios.

Regulators: SECP and Pakistan Stock Exchange could have introduced digital competence in the board through the Code of Corporate Governance. They may also improve technology and cyber risk disclosure and facilitate institutional and foreign investors' monitoring.

Limitations and Future Research

Some caution should be used in interpreting the results. Digitalization is quantified by the number of words in a disclosure and thus indicates the disclosure emphasis, not the digital investments. There is a specific sample, the KSE-100 non-financial companies, and the time period covered in the study which limit the generalizability. While lagged variables and endogeneity tests were employed, this does not mean that causal interpretations are valid. Other metrics like IT spending, digital capital expenditure or machine-learning text analysis could be used for future research. It could also be expanded to include a greater number of companies or other countries, financial companies, and checking moderators, for instance, family ownership and industry digital intensity.

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