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Exploring the impact of customer concentration on stock price crash risk

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This paper, rooted in agency theory, explores the intricate relationship between stock price crash risk and customer concentration within the context of Iran, a developing nation. Utilising innovative indicators to measure corporate and government customers, we address inconsistent findings in existing research and offer fresh insights into stock price crash risk dynamics. Focusing on 82 companies listed on the Tehran Stock Exchange from 2013 to 2020, our study employs a robust methodological framework, including panel data, multiple regression and three distinct metrics to measure customer concentration. Specifically, we introduce the proportion of significant customer sales, the Herfindahl-Hirschman Index, and a Ranking Index based on substantial customer sales. Our investigation reveals a noteworthy inverse relationship between the highest concentration level of corporate customer concentration, as measured by the Ranking Index, and stock price crash risk. Similarly, we establish an inverse association between the Ranking Index for government customer concentration and stock price crash risk. Moreover, institutional investors positively influence the correlation between corporate customer concentration and stock price crash risk but do not exert a discernible impact on the relationship between government customer concentration and stock price crash risk.

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Introduction

The capital market is a cornerstone of economic development, with investments playing a pivotal role in shaping economic equilibrium. However, the potential threat of stock price crash risk looms large, eroding investor confidence and prompting capital withdrawal (Feng and Li, 2022; Huang and Zhang, 2017; Kang et al., 2020; Sato et al., 2019). A critical factor influencing a company's capacity to generate cash flow, customer concentration, is central to this study. As per Statement 131 of the Financial Accounting Standards Board (SFAS), companies are mandated to disclose information about customers representing over 10% of their revenue, underscoring the operational risk associated with customer concentration. The existing literature presents mixed findings on the relationship between stock price crash risk and customer concentration, with differing perspectives on the impact of such engagement on a firm's volatility and risk management efficiency. This paper extends the investigation conducted by Lee et al. (2020) in the context of a developing nation, Iran. The study introduces three unique indicators to assess the influence of corporate and government customers on stock price crash risk, aiming to address the discrepancies in existing research findings. Our focus is on a sample of 82 companies listed on the Tehran Stock Exchange between 2013 and 2020, generating 656 instances of company-year data.

Our analytical approach introduces three metrics to measure corporate customer concentration: the proportion of significant customer sales, the Herfindahl-Hirschman Index, and a Ranking Index based on substantial customer sales. The study explores the intricate relationship between customer concentration and stock price crash risk and investigates the potential moderating influence of institutional investors on this relationship. Key findings from our investigation revealed a significant inverse relationship between the highest concentration level of corporate customer concentration, measured by the Ranking Index, and stock price crash risk. Similarly, we establish an inverse association between government customer concentration, measured by the Ranking Index, and stock price crash risk. Institutional investors positively influence the correlation between corporate customer concentration, measured through various indices, and stock price crash risk.

The subsequent sections of this paper delve into the theoretical framework, literature review, methodology, and empirical findings, shedding light on the nuances of customer concentration and its impact on stock price crash risk in a developing economy.

Theoretical framework and literature review

Adopting agency theory is a foundational framework for our study, "Exploring the Relationship between Stock Price Crash Risk and Customer Concentration." Agency theory, which focuses on the relationships between principals (shareholders) and agents (management), provides a robust lens through which to analyse the dynamics of customer concentration and stock price crash risk (Caers et al., 2006; Cuevas-Rodríguez et al., 2012; Panda and Leepsa, 2017). In the context of Iran, a developing nation, understanding these relationships becomes pivotal due to the unique economic landscape. As elucidated by agency theory, the potential conflicts of interest between shareholders and management become particularly relevant when examining how customer concentration, a critical factor in cash flow generation, impacts stock price crash risk (Guilding et al., 2005). By embracing agency theory, our study aims to uncover the intricate interplay between corporate and government customers and their influence on stock price crash risk. The study's focus on 82 companies listed on the Tehran Stock Exchange from 2013 to 2020 and its introduction of innovative indicators and statistical methodologies align with agency theory's emphasis on addressing inconsistent findings in existing research. Through this theoretical lens, we explore the nuanced relationships, providing valuable insights for investors, businesses, and policymakers navigating the complexities of customer concentration in a developing economy like Iran.

This study enhances our comprehension of stock price crash risk and its association with customer concentration (Abbasi and Tamoradi, 2020; Lee et al., 2020; Li et al., 2017; Meng, 2018; Shan et al., 2021). In forecasting REITs (Real Estate Investment Trusts), Li et al. (2017) developed a predictive model using the Group Method of Data Handling (GMDH) neural network approach to forecast the performance of REITs. Additionally, they explored applying the GMDH neural network approach to predicting the performance of stock indices. Stock indices represent the performance of a group of stocks traded on a particular stock exchange, providing insights into the overall market sentiment and trends. Overall, Li et al. (2017) focused on employing advanced computational techniques to predict the future movements of REITs and stock indices, aiming to assist investors and stakeholders in making informed decisions in the real estate and financial markets.

By examining the distinctive environment of Iran, a developing nation, we provide novel perspectives tackling the inconclusive outcomes observed in prior research. The motivation behind undertaking this study lies in the critical importance of understanding stock price crash risk and its correlation with customer concentration, particularly in the unique economic context of Iran. The capital market plays a fundamental role in economic development, and stock price crash risk can have detrimental effects, leading to a loss of investor confidence and capital withdrawal (Coşkun et al., 2017; Ngugi et al., 2006; Yadirichukwu and Chigbu, 2014). As a critical factor in a company's cash flow generation, customer concentration has yielded inconsistent findings in previous research (Huang et al., 2016; Kim and Luo, 2022; Saboo et al., 2017). This study aims to contribute fresh insights by employing an innovative approach, introducing three distinct indicators to evaluate the impact of corporate and government customers on stock price crash risk. Focusing on a sample of 82 companies listed on the Tehran Stock Exchange from 2013 to 2020, the research explores the interplay between corporate and government customer concentration and its relationship with stock price crash risk. The study also delves into the moderating influence of institutional investors on these relationships. The findings are expected to provide valuable guidance for businesses and investors navigating the complexities of customer concentration and its implications for stock price stability, especially in developing economies like Iran.

Customer concentration. Customer concentration in this paper refers to the extent to which a company relies on a small number of customers for a significant portion of its revenue (Mao et al., 2022). It measures the distribution of a company's sales across its customer base. The paper highlights that customer concentration is essential for a company's ability to generate current and future cash flow (Mao et al., 2022). Specifically, it emphasises the impact of customer concentration on stock price crash risk. The concentration is measured using three indicators: the proportion of significant customer sales, the Herfindahl-Hirschman Index (HHI), and a Ranking Index based on substantial customer sales.

The study proposes an inverse relationship between corporate customer concentration and stock price crash risk. In other words, we expect companies with higher concentration levels of

significant customers (measured by the Ranking Index) to experience lower stock price crash risk. This contradicts some existing research and emphasises the unique dynamics in the context of Iran.

Stock price crash risk. In this paper, stock price crash risk refers to the likelihood of an unforeseen, large-scale drop in a firm's stock price without a significant economic event (Mauboussin, 2002; Pástor and Veronesi, 2009; Sornette, 2003). It represents the potential for a sudden and substantial decline in stock value. The paper anticipates the adverse effects of stock price crash risk on the economy, including the loss of investor confidence and withdrawal of capital from the market. Understanding the factors influencing stock price crash risk, especially in developing economies like Iran, is crucial for economic development.

The study investigates the relationship between stock price crash risk and customer concentration, focusing on corporate and government customers. Notably, it reveals a negative association between stock price crash risk and customer concentration, indicating that higher concentration levels are linked to lower stock price crash risk, at least in the Iranian context. This study draws on agency theory and prior research by Lee et al. (2020). Agency theory focuses on the relationships between principals (shareholders) and agents (management) and how conflicts of interest may arise (Shapiro, 2005). The study examines the role of institutional investors in influencing the relationship between customer concentration and stock price crash risk.

Hypotheses developments. In recent years, stock price crash risk has attracted considerable attention in the literature (Feng and Li, 2022; Hasan et al., 2022; Huang and Zhang, 2017; Kang et al., 2020; Sato et al., 2019). Hasan et al., (2022) have tested the association between brand capital (as one feature of organisations) and stock price crash risk and found that brand capital is significantly and negatively related to crash risk. This study examines the association between customer concentration (another feature of organisations) and stock price crash risk.

The relationship between stock price crash risk and customer concentration. The main research questions addressed in the paper can be inferred from the hypotheses presented in this section. The hypotheses are structured around investigating the relationships between various factors related to customer concentration and stock price crash risk. Here are the main research questions corresponding to each hypothesis:

Is there a meaningful relationship between corporate customer concentration and stock price crash risk (H1)?

Is there a significant negative relationship between stock price crash risk and government customer concentration (H2)?

How does the presence of institutional investors affect the relationship between the concentration of corporate (non-governmental) customers and the risk of falling stock prices (H3)?

How does the presence of institutional investors affect the relationship between the concentration of government clients and the risk of falling stock prices (H4)?

These research questions aim to explore the nuanced connections between customer concentration, institutional investors, and stock price crash risk in the context of the Iranian market. The study employs multiple indicators and models to understand these relationships comprehensively. The following section presents a background on the development of the above research questions and hypotheses:

Corporate customer concentration and stock price crash risk. Stock price crash risk is the likelihood of a sudden, large-scale drop in a company's stock price. It typically occurs due to managerial actions such as the tendency to withhold bad news (Graham et al., 2005). The main incentive for such activities is managers' concern for job security, performance-based compensation, and tax planning (Jin and Myers, 2006). The bad news is withheld to paint a brighter picture of the firm's performance and encourage more investment (Askarany and Spraakman, 2020; Dow et al., 2021). However, bad news cannot remain hidden forever. As accumulated bad news reaches a certain threshold, the cost of withholding such information exceeds its benefits, and the management will be forced to publish all bad news simultaneously. This can lead to a large-scale and unexpected drop in the company's stock price, i.e., a stock price crash (Jin and Myers, 2006; Ni and Zhu, 2016).

Customer concentration is one of the factors associated with the accumulation of bad news and, ultimately, stock price crash risk. Here, customer concentration refers to the percentage of customers that make up the central part of a company's revenue. Over time, companies have realised that customers are their most valuable assets and need to satisfy customers' needs and establish stable customer relationships to achieve their goals (Berrios, 2006; Teklay et al., 2023). Given the above, government customer concentration refers to the extent to which a company relies on government entities as its primary source of revenue or clientele. In other words, it measures the proportion of a company's business derived from government contracts, purchases, or services. A high level of government customer concentration indicates that a significant portion of a company's sales or revenue comes from government agencies or departments. This can pose both opportunities and risks for the company, as it may benefit from stable, long-term contracts with government entities but also face challenges related to changes in government spending priorities, regulations, or political factors.

There are two competing views regarding the impact of significant corporate (non-governmental) customer concentration on stock price crash risk. The first view states that heavy reliance on a few key customers for a major portion of sales can be dangerous for firms. Four arguments are generally made in support of this view. First, suppose any main customers experience financial difficulties, switch to another supplier, or internally develop the product. In that case, the supplier company will lose a significant portion of its sales, causing a sharp decrease in its cash flows (Dhaliwal et al., 2016; Dhaliwal et al., 2020; Huang et al., 2016). Supporting this view, Hertzel et al. (2008) and Kolay et al. (2016) state that suppliers will experience negative abnormal returns if major customers declare bankruptcy. Major customers in this study refer to individual customers who account for 10% (or more) of the company's sales (Gosman et al., 2004). The second argument suggests that managers of companies with a high customer concentration tend to invest in relationship-specific assets due to their foresight and increased demand from major customers (Banker et al., 2014; Kang et al., 2009). Examples include investment in specialised inventory management systems, improving product delivery capabilities, and purchasing machinery tailored to specific customer needs (Chang et al., 2015). Such investments are inherently risky; only a clear, long-term contract with major customers can fully compensate for

investment costs. If any parties to the agreement default, the long-term business relationship between the supplier and major customers will end, and the supplier company will suffer losses from such investments (Dou et al., 2013; Raman and Shahrur, 2008). The third argument states that major customers often have high bargaining power and thus receive significant benefits such as price concessions. This will decrease the company's profit margin and ultimately reduce the supplier's profitability (Schumacher, 1991; Snyder, 1996). The fourth argument believes that a company with higher customer concentration faces higher demand uncertainty and fixed costs, leading to increased operational risk (Irvine et al., 2016). In all existing arguments, reliance on significant customers increases the company's business and cash risks, thus accumulating bad news. Eventually, stock price crash risk increases as bad news is published simultaneously.

In contrast, the second view considers customer concentration as a factor in reducing business risk. Researchers who agree with this view believe that companies with a high customer concentration can reduce their operating expenses, such as inventory and administrative costs while increasing their asset utilisation under good customer-supplier relationships (Kalwani and Narayandas, 1995; Patatoukas, 2012). Since maintaining inventories entails high costs for storage costs, rent, personnel, etc., cost savings from carrying less inventory will lead to the development and greater profitability of the firm (Lee et al., 2020). According to this view, reliance on a few significant customers improves the company's performance (Teklay et al., 2023). It reduces its business and cash flow risks, thus preventing the accumulation of bad news and ultimately reducing the company's stock price crash risk.

Government customer concentration and stock price crash risk. Contrary to the competing views for corporate customers, it is widely believed that government customers positively impact supplier companies' performance. Government customers are those for whom more than 50% of the shares are owned by the government or state-owned enterprises. However, the view on state-owned enterprises is mixed. Sun et al. (2020) investigated the link between employee quality and Corporate Social Responsibility (CSR) in Chinese A-share-listed companies from 2012 to 2016. Analysing data through ordinary least squares, their research identifies a positive association between the educational level of the workforce (a proxy for employee quality) and CSR implementation. This positive correlation is particularly notable in non-state-owned enterprises, regions with lower marketisation processes, and firms with fewer independent directors. The findings emphasise the strategic significance of considering employees' educational backgrounds in CSR analysis for sustainable corporate development, contributing to knowledge on human capital and CSR in the context of an emerging economy like China.

In another study, Xie et al. (2023) found a negative association between state control and future stock price crash risk. This effect is explained by adopting conservative corporate policies as a mechanism. The influence of state control is more significant in strategic industries and when the ultimate controller is a non-corporate government agency or the central government. This aligns with Xu et al.'s (2014) observations, which reveal that state-owned enterprises tend to withhold unfavourable information, contributing to heightened future stock price crash risk. Their study supports this notion by identifying a positive association between excess benefits and crash risk. Meanwhile, Zhang et al. (2016) found that the negative relation between corporate philanthropy and crash risk is less pronounced for state-owned enterprises than non-state-owned enterprises after firms accomplish the split share reform.

Xiao et al. (2022) investigated the influence of oil price uncertainty on stock price crash risk in China from 2000 to 2019. Findings indicate a positive correlation between oil price uncertainty and stock price crash risk. This impact is more pronounced for non-state-owned enterprises, although it remains significant for both state-owned and non-state-owned enterprises. This study suggests that corporate risk-taking and a highly competitive market can mitigate the positive impact of oil price uncertainty on stock price crash risk, contributing micro-level evidence to understanding the oil-stock relationship.

Given the above, it seems that government customers are less likely to declare bankruptcy and tend to provide stable cash flows to the supplier (Dhaliwal et al., 2016). In addition, they often make long-term contracts with suppliers, which reduces the likelihood of switching suppliers. Third, a significant portion of government contracts uses cost-plus pricing. These contracts are usually associated with an increased operational risk to government customers but not to their suppliers (Lee et al., 2020). Government customer concentration generally reduces the supplier's business and cash flow risks. It prevents managers from hoarding bad news, reducing stock price crash risk.

The present research investigates the effect of government/corporate customer concentration on stock price crash risk and the moderating effect of institutional investors on this relationship. There are generally two competing views regarding the role of institutional investors. In line with the efficient monitoring hypothesis, the first view considers institutional investors critical in solving agency problems. It holds that a higher concentration of institutional investors leads to better monitoring of the management as well as increased quality disclosures. This monitoring role is critical in the relationship between stock price crash risk and customer concentration (Cornett et al., 2007). It can prevent managers' bad news hoarding and lead to a reduction in stock price crash risk. The second view is consistent with the convergence of interests hypothesis, which posits a unique strategic alliance between large institutional owners and managers.

In some cases, institutional owners' interests are aligned with managers' interests at the cost of the interests of minority shareholders. Institutional investors often cannot oppose the management or play an influential monitoring role. Such supervision will negatively affect their business relationships, which could result in collusion between institutional owners and managers (Pound, 1988; Sundaramurthy et al., 2005). This situation may also facilitate bad news hoarding, which increases the company's stock price crash risk.

In line with the first view about the positive relationship between corporate customer concentration and stock price crash risk, Itzkowitz (2013) investigated the effect of customer concentration on cash holding by suppliers. The results showed that the amount of cash held by suppliers increases with customer concentration. Dhaliwal et al. (2016) studied the impact of corporate customer concentration on the cost of equity capital, emphasising accounting standards and the Securities and Exchange Commission (SEC) regulations. Their findings showed a positive relationship between corporate customer concentration and the cost of equity capital.

Campello and Gao (2017) examined the effect of customer concentration on loan contract terms. They found that high customer concentration leads to higher interest rate spreads and more restrictive provisions in loan contracts. They showed that the financial distress of major customers and the level of relation-specific investments exacerbate this effect.

Lee et al. (2020) investigated the relationship between stock price crash risk and corporate customer concentration and found a positive relationship between these two variables. However, in line with the second view about the negative relationship between corporate customer concentration and stock price crash risk, Patatoukas (2012) found a positive relationship between customer concentration and firm performance. The results showed that as the customer base becomes more concentrated, administrative expenses and inventory costs decrease while working capital increases, thus enhancing the company's financial performance. Highlighting customers' bargaining power, Hui et al. (2012) argued that companies with higher customer concentration are more responsive to customers' demand for better (more conservative) accounting practices, which allow major customers to monitor the supplier company's management.

Using sales data, Irvine et al. (2016) showed that supplier companies face significant operational risks in the early stages of their relationship with major customers since establishing and maintaining relationships with influential customers requires significant, fixed investments in the early stages. However, as the relationship matures, these costs decrease, and companies can benefit from various operating efficiencies. Cohen and Li (2016) studied the impact of government customer concentration on stock price crash risk. They found that companies with higher government customer concentration hold less cash due to their more stable operating cash flows. Dhaliwal et al. (2016) investigated the impact of government customers on the cost of equity capital. By examining a sample of 44,218 firm-years, they observed a negative relationship between government customer concentration and cost of equity capital, arguing that government customers reduce the risk to suppliers due to their negligible risk of bankruptcy and long-term contracts.

Zhang et al. (2020) investigated the effect of customer concentration on over-investment. Using a sample of U.S. companies, they found that companies with a higher degree of customer concentration are more likely to over-invest beyond the optimal investment level. In addition, they showed that this relationship weakens when the most significant customer is a government entity. Similarly, Lee et al. (2020) found a negative relationship between government customer concentration and stock price crash risk. Therefore, the following hypotheses are proposed:

H1: There is a meaningful relationship between corporate customer concentration and stock price crash risk.

H2: A significant negative relationship exists between stock price crash risk and government customer concentration.

Here are key points to consider in justifying our reliance on Lee et al. (2020) and addressing contradictory findings:

Contextual relevance. Our study focuses on Iran, which uniquely contributes to the literature by exploring the dynamics of a developing nation. Iran's economic, political, and regulatory context differs significantly from developed countries, potentially influencing the observed relationships.

Extension and replication. Rather than merely replicating Lee et al.'s study, we expand upon it by introducing three distinct indicators to evaluate the impact of both corporate and government customers on stock price crash risk. This approach allows for a more nuanced understanding of customer concentration's effects, potentially explaining variations in findings.

Methodological rigour. We employed a robust methodological framework, utilising panel data, multiple regression and innovative indicators. This meticulous testing enhances our results' reliability and addresses the existing literature's inconsistent findings.

Diversity of metrics. Unlike some studies that may focus on a single metric for customer concentration, we propose and employ three distinct metrics, namely the proportion of significant customer sales, the Herfindahl-Hirschman Index, and a Ranking Index based on substantial customer sales. This diversity allows for a comprehensive examination of the relationship between customer concentration and stock price crash risk.

Discussion of contradictory results. In our paper, we acknowledge the contradictory results between Lee et al. (2020) and our findings, explicitly noting the inverse relationship we observe between corporate customer concentration and stock price crash risk. This acknowledgement is a testament to our commitment to transparency and intellectual rigour.

The role of institutional Investors on the relationship between customer concentration and stock price crash risk. As noted earlier, the present research also investigates the effect of institutional investors as a monitoring mechanism on the relationship between government/corporate client concentration and stock price crash risk. There are competing views regarding the role of institutional investors. The first view considers institutional investors as a factor for further monitoring. In this regard, Ramalingegowda and Yu (2012) investigated the effect of institutional ownership on conservatism using a sample of 16,911 firm-years from 1995–2006. They found that greater ownership by institutional investors is associated with more conservative financial reporting.

The second view states that institutional investors do not perform their monitoring role effectively and may collude with managers to hoard bad news. In this regard, Bhattacharya and Graham (2007) investigated the impact of institutional ownership on firm performance and, unlike previous studies that considered institutional owners as a single entity, divided institutional investors into two groups: pressure-sensitive (both investment and business relations with the company) and pressure-resistant (only investment relations with the company). The result indicated a two-way, asymmetric relationship between institutional ownership and firm performance. In other words, institutional investors that had both investment and business relations with the company had a negative impact on the firm performance.

Vadeei Noghabi and Rostami (2014) divided institutional investors into passive and active categories based on their investment horizons. They argue that active investors with a long-term horizon act like a monitoring system, reducing stock price crash risk. In contrast, passive investors have a short-term horizon and only consider current profits. Therefore, they act as an incentive for managers to hoard bad news, thus increasing the risk of a stock price crash.

Enayatpour et al. (2020) report the positive effect of institutional ownership on firm value and risk. They argue that although the efficient monitoring hypothesis suggests that institutional owners can improve firm performance, they are ineffective in solving agency problems between managers and shareholders, which could reduce the accountability of managers towards minority shareholders and erode their trust.

Finally, based on the theoretical foundation and the literature review, the third and fourth hypotheses of the present research are proposed as follows:

Table 1 The frequency of excluded industries.

Description	Number of companies
The entire statistical population (on the date of data collection)	328
Member companies of financial intermediation, holding banks and insurance industries	−63
Companies that have been active in the stock market for less than three years	−21
Companies that have been active in the stock market for less than three years	−162
The statistical population under investigation	82

H3: the presence of institutional investors affects the relationship between the concentration of corporate (non-governmental) customers and the risk of falling stock prices.

H4: the presence of institutional investors affects the relationship between the concentration of government clients and the risk of falling stock prices.

Methodology

The statistical population of the present study includes all companies listed on the Middle East stock exchange market from 2011 to 2018. The population consists of all the companies listed on the Tehran Stock Exchange (TSE) from 2011 to 2020. Data are primarily based on the TSE's audited financial statements and board reports, a reliable source of information (Daryaei et al., 2022; Namakavarani et al., 2021; Nassirzadeh et al., 2023; Nassirzadeh et al., 2022; Shandiz et al., 2022; Tileal et al., 2023; Zadeh et al., 2023).The selected firms needed to meet the following three conditions to be included in the current study:

1. Having been accepted on the stock exchange for at least three years between 2013 and 2020.
2. Having major customers. Major customers in this study refer to individual customers who account for 10% (or more) of the company's sales (Gosman et al., 2004).
3. Not belonging to financial intermediaries, holdings, and banks since these entities are different in their operations and do not disclose information about their significant customers. This means excluding banks and financial institutions from the selected sample.

According to these conditions, out of 328 active companies listed on the stock market at the time of the study, 82 companies ($82 \times 8 = 656$ company-years) were selected as the sample.

Sample selection and data collection process. Our study focuses on companies listed on Iran's Tehran Stock Exchange (TSE) between 2013 and 2020. We selected 82 companies based on specific criteria, including a minimum of three years of activity on the stock exchange, having major customers, and excluding financial intermediaries, holdings, and banks. The names of industries and the frequencies of firms in each sector, both excluded and included in the sample, are presented in Tables 1 and 2.

Data for the research were primarily sourced from the TSE's audited financial statements and board reports. These reports are widely recognised as reliable sources of information, ensuring the robustness of our dataset.

Statistical techniques. We used panel data multiple regression analysis using the "R" software to test our hypotheses rigorously. Using panel data allows us to account for individual and time-specific effects, providing a more nuanced understanding of the relationships under investigation.

"R" is a powerful and versatile programming language and software environment for statistical computing and data analysis (Hadley and Garrett, 2017). Employing "R" software, we use panel data multiple regression to examine four dimensions rigorously: (1) the interplay between corporate customers and stock price crash risk, (2) the linkage between government customer concentration and stock price crash risk, (3) the role of institutional investors in influencing the relationship between corporate customer concentration and stock price crash risk, and (4) the involvement of institutional investors in the connection between government customer concentration and stock price crash risk.

The statistical significance of our models was assessed through the *F*-statistic, and the adjusted coefficient of determination was calculated to measure the explanatory power of the independent and control variables.

Table 2 The frequency of included industries.

Type of industry	Number of selected samples
Pharmaceutical materials and products	11
Chemical and petrochemical products	9
Automobile and parts manufacturing (including automobiles, machinery and equipment)	18
Cement, lime and plaster	5
Non-metallic mineral products	5
Agriculture and food and beverage products (including sugars and non-sugars)	7
Basic metals	9
Other manufacturing firms	18
Total	82

Indicators for customer concentration. We introduced three indicators to measure corporate and government customer concentration: the proportion of significant customer sales, the Herfindahl-Hirschman Index (HHI), and a Ranking Index based on major customer sales.

Each indicator uniquely captures different dimensions of customer concentration, contributing to a comprehensive analysis of the phenomenon.

Control variables. We incorporated various control variables, including SIZE, ROA, LEV, DTURNOVER, SIGMA, RET, MB, PCF, and CIM. These controls are essential for mitigating potential confounding effects and ensuring the robustness of our findings (Lee et al., 2020).

By providing these additional details, we aim to address the gaps in our methodology and offer a more comprehensive understanding of the research design. We value your feedback and believe these clarifications strengthen our study's quality and transparency.

Models. Following Lee et al. (2020), we used the following model (Model 1) to test the first and second hypotheses and measure the

impact of corporate and government customer concentration on stock price crash risk:

$$Risk_{j.t} = \alpha + \beta_1 CC_{j.t-1} + \beta_2 GC_{j.t-1} + \beta_3 SIZE_{j.t-1} + \beta_4 ROA_{j.t-1} + \beta_5 LEV_{j.t-1} + \beta_6 DTURNOVER_{j.t-1} + \beta_7 MB_{j.t-1} + \beta_8 PCF_{j.t} + \beta_9 CIM_{j.t} + \beta_{10} RET_{j.t-1} + \beta_{11} SIGMA_{j.t-1} + Industry + Year + \varepsilon \quad (1)$$

In model 1, the first hypothesis is confirmed if the β_1 coefficient is significant at the 5% level, and the second hypothesis is confirmed if the β_2 coefficient is negative and significant.

Indicator variable institutional investors that equal 1 if a supplier firm's percentage of institutional investors is below the median rate of institutional investors of all firms, and 0 otherwise. To examine the moderating effect of institutional investors, we interact with the dummy variable "institutional investors" with the corporate (government) customer concentration measures. Specifically, we augment Eq. (1) by adding the percentage of institutional investors and their interaction with each of the corporate(government) customer concentration measures as follows in Eq. (2).

$$Risk_{j.t} = \alpha + \beta_1 CC_{j.t-1} + \beta_2 GC_{j.t-1} + \beta_3 IST_{j.t-1} + \beta_4 CC_{j.t-1} \times IST_{j.t-1} + \beta_5 GC_{j.t-1} \times IST_{j.t-1} + \beta_6 Size_{j.t-1} + \beta_7 ROA_{j.t-1} + \beta_8 LEV_{j.t-1} + \beta_9 DTURNOVER_{j.t-1} + \beta_{10} MB_{j.t-1} + \beta_{11} PCF_{j.t} + \beta_{12} CIM_{j.t} + \beta_{13} RET_{j.t-1} + \beta_{14} SIGMA_{j.t-1} + Industry + Year + \varepsilon \quad (2)$$

In model 2, the third and fourth hypotheses are confirmed if the β_4 and β_5 coefficients are significant at the 5% level and institutional investors affect the relationship between corporate and government customer concentration.

Measuring the variable

Dependent variable: stock price crash risk (risk). Stock price crash risk is the possibility of an unforeseen, large-scale drop in a firm's stock price without a significant economic event. Following Chen et al. (2001) and Kim et al. (2011), the present research uses negative conditional return skewness as a reliable basis for measuring stock price crash risk:

$$NCSKEW_{j.t} = -[n(n-1)^{3/2}\sum W_{j.t}^3]/[(n-1)(n-2)(\sum W_{j.t}^2)^{3/2}]$$

where $NCSKEW_{j.t}$ is negative conditional return skewness; n is the number of observations on monthly returns during the fiscal year; and $W_{j.t}$ is the demeaned monthly return of firm j in month t, which is calculated using the following equation:

$$W_{j.t} = \ln(1 + \varepsilon_{j.t})$$

In the equation above, $\varepsilon_{j.t}$ is the residual return of firm j in month t and is calculated as the residual of the following Model:

$$R_{j.t} = \alpha_j + \beta_{1.j} r_{m.t-2} + \beta_{2.j} r_{m.t-1} + \beta_{3.j} r_{m.t} + \beta_{4.j} r_{m.t+1} + \beta_{5.j} r_{m.t+2} + \varepsilon_{j.t}$$

where $R_{j.t}$ is the return on stock j in month t and $r_{m.t}$ is the market return in month t, calculated by dividing the difference between the beginning and ending index values by the beginning index value.

Independent variable: corporate customer concentration (CC). According to 'Statement of Financial Accounting Standards No. 131', companies should disclose information about their significant customers, who account for more than 10% of the firm's revenues. In the present research, this standard is used to calculate customer concentration, and the information about the company's customers is extracted from their financial statements. Three measures of customer concentration are used as follows:

1. A measure based on sales to significant customers, which is calculated from the following equation following Lee et al. (2020):

$$Major\ Corp\ Customer\ Sales_{i.t} = \sum_{j=1}^{J} (Revenue_{i.j.t}/Revenue_{i.t})$$

where $Revenue_{i.j.t}$ is the revenue of firm i from customer j in year t, and $Revenue_{i.t}$ is the total revenue of firm i in year t.

2. The Herfindahl-Hirschman Index (HHI) considers the number of significant customers and each customer's importance based on the revenue. Following Patatoukas (2012) and Chang et al. (2015), this measure is calculated as follows:

$$Corp\ Customer\ HHI_{i.t} = \sum_{j=1}^{J} \left(\frac{Revenues_{i.j.t}}{Revenues_{i.t}}\right)^2$$

3. The percentage of significant customers ranked based on quintiles, with higher ranks, indicating greater customer concentration, was used.

Independent variable: government customer concentration (G.C.). A state-owned enterprise (SOE) is an entity created by the government to engage in commercial activities on its behalf. In the present research, if the government or an SOE holds at least 50% of a company's shares, the company is classified as a government customer. The three measures listed above for corporate customer concentration are used to measure government customer concentration.

Moderating variable: institutional investors (IST). This variable is measured by dividing the shares of institutional investors by the company's total shares. A dummy variable includes institutional shareholders as a moderating variable, equal to one if the percentage of institutional shareholders is above the median and zero otherwise.

Control variables. Table 3 describes the control variables included in the models.

Findings

This section provides the results of testing the hypotheses, including descriptive and inferential statistics.

Descriptive statistics. Table 4 provides the descriptive statistics of the variables, including mean, median, maximum, minimum, and standard deviation. The mean and median stock price crash risk are 0.307 and 0.175, respectively. 65% of the shares of companies are held by institutional investors, with a minimum of 0 and a maximum of 99%. Using the Sales-based Index, the mean corporate customer concentration is 20%, and the mean government customer concentration is 33%. On average, 67% of financial resources are financed through debt. The mean ROA is 8%, with a minimum of −1.203 and a maximum of 0.627.

The variable of institutional investors has been used in a dummy form to be in the Model as a moderating variable, and for this purpose, the Median Index is used. In addition, Crash risk above the industry average is also a dummy variable; Table 5 shows each category's frequency percentage.

Inferential statistics

Testing the first and second hypotheses. The type of regression model is determined using Chow and Hausman tests to test the first and second hypotheses.

Table 3 Variables definition.

Variables	Description
CC	Significant customers account for more than 10% of the firm's revenues.
GC	The government or an SOE holds at least 50% of a company's shares.
IST	A dummy variable includes institutional shareholders as a moderating variable, equal to one if the percentage of institutional shareholders is above the median and zero otherwise.
SIZE:	Natural log of total assets.
ROA (return on assets)	Net income divided by total assets.
LEV (financial leverage)	Total assets minus stockholder equity divided by total assets.
DTURNOVER	Average monthly share turnover for the current fiscal year minus the average monthly share turnover for the last fiscal year. Monthly share turnover is calculated as the total monthly trading volume divided by the total monthly number of shares outstanding.
SIGMA	The standard deviation of firm-specific abnormal returns.
RET	Firm-specific average monthly returns.
MB	Market-to-book ratio.
PCF	Percentage of floating shares.
CIM	A dummy variable equals one if the company's stock price crash risk is above the industry average and zero otherwise.

Sources: Chen et al. (2001) and Kim et al. (2011).
- SIZE: natural log of total assets.
- ROA (return on assets): net income divided by total assets.
- LEV (financial leverage): total assets minus stockholder equity divided by total assets.
- DTURNOVER: Average monthly share turnover for the current fiscal year minus the average monthly share turnover for the last fiscal year. Monthly share turnover is calculated as the total monthly trading volume divided by the total monthly number of shares outstanding.
- SIGMA: The standard deviation of firm-specific abnormal returns.
- RET: Firm-specific average monthly returns.
- MB: Market-to-book ratio.
- PCF: Percentage of floating shares.
- CIM: A dummy variable equal to one if the company's stock price crash risk is above the industry average and zero otherwise.

Table 4 Descriptive statistics.

Variable type	Variable	Proxy	Mean	Median	Min.	Max.	SD
Dependent	Stock price crash risk	NCSKEW	0/307	0/175	−3/876	3/980	1/720
Moderator	Institutional investors	Ist	0/650	0/768	0/000	0/996	0/299
Independent (corporate)	Sales to major customers	CCS_C	0/203	0/108	0/000	1/000	0/274
	Herfindahl-Hirschman Index	HHI_C	0/086	0/011	0/000	1/000	0/205
Independent (government)	Sales to major customers	CCS_g	0/333	0/193	0/000	0/990	0/359
	Herfindahl-Hirschman Index	HHI_g	0/190	0/032	0/000	0/998	0/287
Control	Firm size	Size	14/568	14/519	10/825	20/194	1/499
	Return on assets	ROA	0/083	0/075	−0/289	0/627	0/184
	Financial leverage	LEV	0/674	0/643	0/122	2/434	0/347
	Monthly turnover difference	DTUNOVER	0/014	0/001	−0/303	0/412	0/057
	Market-to-book ratio	MB	3/770	2/264	−2/637	32/883	5/265
	SD of abnormal returns	SIGMA	0/198	0/158	0/007	0/944	0/146
	Average monthly returns	RET	0/007	−0/001	−0/271	0/230	0/075
	Percentage of floating shares	PCF	0/217	0/189	0/001	0/876	0/152

Source (Lee et al. 2020; Sun et al. 2020).

Table 5 Descriptive statistics of a dummy variable.

Variable	Proxy	category	count	Frequency (%)
Institutional investors	Ist	1	354	48
		0	384	52
Crash risk above the industry average	CIM	1	324	44
		0	414	56

The choice to employ the Hausman test in our research was driven by the need to determine the appropriate model for our analysis, specifically whether a fixed-effect or random-effect model was more suitable. This decision is crucial in panel data analysis as it helps ensure the robustness and accuracy of our findings.

The Hausman test is a well-established econometric tool that assists researchers in choosing between fixed and random-effects models by evaluating the consistency of the estimators under the null hypothesis that both models are consistent. In our case, we aimed to assess whether firm-specific effects were correlated with the explanatory variables, making a fixed-effect model more appropriate. This consideration is essential in understanding the dynamics of customer concentration and its impact on stock price crash risk within our specific context—companies listed on the Tehran Stock Exchange in Iran.

While our study focuses on customer concentration and stock price crash risk, we believe that the choice of the Hausman test was instrumental in ensuring the validity and reliability of our results. It allows us to account for unobserved heterogeneity across firms and accurately depicts the relationship we are exploring. Indeed, the choice between fixed and random-effects models is a common consideration in various empirical studies, and the Hausman test serves as a valuable tool in this decision-making process (please see Table 6).

Table 6 Chow and Hausman tests.

Model	Chow test			Hausman test		
	Test statistic	Sig.	Result	Test statistic	Sig.	Result
(1) Sales-based Index	1/26	0/08	Pooled	-	-	-
(2) HHI	1/29	0/064	Pooled	-	-	-
(3) Ranking Index	1/36	0/034	Panel	166/91	<0/001	Fixed effects

Table 7 Results of testing the first and second hypotheses using the Sales-based Index and the HHI.

Variable	Sales-based Index		HHI	
	Estimate (*t*-statistic)	VIF	Estimate (*t*-statistic)	VIF
Intercept	−1/664 (−1/529)	-	−1/411 (−1/240)	-
CC	0/196 (0/801)	1/23	0/055 (0/195)	1/12
GC	−0/072 (−0/383)	1/54	0/085 (0/414)	1/30
SIZE	0/138 (1/833)	1/39	0/124 (1/579)	1/36
ROA	1/662[a] (2/192)	1/75	1/637[a] (2/169)	1/76
LEV	0/281 (0/725)	1/60	0/254 (0/650)	1/61
DTURNOVER	0/954 (0/837)	1/18	0/960 (0/829)	1/18
MB	0/062[a] (3/275)	1/35	0/062[a] (3/245)	1/35
SIGMA	−0/493 (−0/608)	1/19	−0/652 (−0/790)	1/23
RET	−0/252 (−0/132)	1/48	0/348 (0/172)	1/58
CIM	0/109 (0/755)	1/19	0/145 (0/954)	1/23
PCF	−0/369 (−0/700)	1/23	−0/468 (−0/909)	1/21
Industry/year effects	Controlled			
R^2	0/11			
F-statistic	8/17			
Durbin-Watson	2/098			
R^2	0/11			
F-statistic	7/89			
Durbin-Watson	2/098			

[a]Significance at the 5% level. The coefficient for each variable is reported, and *t*-test values appear in brackets.

As can be seen, Model (3) is fitted using panel data, and other models will be fitted using pooled data. Moreover, the results of the Hausman test for Model (3) indicate that a fixed-effects model should be used. Table 7 provides the results of fitting the models for the first and second hypotheses.

Given the probability of the *F*-statistic (0.000), the fitted regression model is statistically significant. The adjusted coefficient of determination for the fitted models indicates that the independent and control variables explain 11% of stock price crash risk changes. Moreover, the Durbin-Watson statistic is between 1.5 and 2.5, suggesting no autocorrelation between the residuals. The variance inflation factor (VIF) for each variable is less than 5, indicating the absence of multicollinearity.

Testing the first hypothesis using the Sales-based Index and the HHI: According to the results, the corporate customer concentration measures (Sales-based Index and HHI) are insignificant at the 0.05 level ($p = 0.424$, $t = 0.801$ and $p = 0.845$, $t = 0.195$, respectively). Therefore, there is no meaningful relationship between corporate customer concentration and stock price crash risk, and the first hypothesis is not confirmed based on these two measures.

Testing the second hypothesis using the Sales-based Index and the HHI: The results also show that the government customer concentration measures (Sales-based Index and HHI) are insignificant at the 0.05 level ($p = 0.7$, $t = -0.383$ and $p = 0.679$, $t = 0.414$, respectively). Therefore, there is no meaningful relationship between government customer concentration and stock price crash risk, and the second hypothesis is not confirmed based on these two measures (please see Table 8).

Testing the first and second hypotheses using the Ranking Index: Using the Ranking Index as a measure of corporate customer concentration, the results indicate the significance of the Ranking Index (5th quintile) at the 0.05 level ($p = 0.015$, $t = -2.435$) and the coefficient is estimated at −1.31. Therefore, a significant negative relationship exists between corporate customer concentration (5th quintile) and stock price crash risk.

In addition, the results indicate the significance of the Ranking Index (5th quintile) at the 0.05 level ($p = 0.011$, $t = -2.556$) and the coefficient is estimated at −0.666, and the coefficient is estimated at −0.666. Therefore, a significant negative relationship exists between the government customer concentration criterion (5th quintile) and stock price crash risk. It must be noted that the 5th quintile represents the highest concentration level.

Testing the third and fourth hypotheses. The third and fourth hypotheses examine the effect of institutional investors on the relationship between customer concentration and stock price crash risk. First, the results of Chow and Hausman tests are provided in Table 9 to test these hypotheses.

Based on these results, only Model (3) (the Ranking Index) is fitted with panel data, and the other two models should be fitted with pooled data. The following results of fitting the third and

fourth hypothesis models based on three indicators of sales percentage, Herfindahl and ranking are presented.

Next, the third and fourth hypotheses are fitted using the other two measures of customer concentration, i.e., the Sales-based Index and the HHI (please see Table 10).

Testing the third hypothesis using the Sales-based Index and the HHI. The interaction' corporate customer concentration (Sales-based Index and HHI) × institutional investors' results are significant at 0.05 ($p = 0.003$, $t = 2.99$ and 0.002, $t = 3.09$, respectively). Therefore, the presence of institutional investors significantly affects the relationship between corporate customer concentration and stock price crash risk, and the third hypothesis is confirmed. The estimated coefficients are 1.67 and 1.89, respectively, indicating that institutional investors have a significant positive moderation effect on the relationship between corporate customer concentration and stock price crash risk.

Testing the fourth hypothesis using the Sales-based Index and the HHI. According to the results, the interaction' government customer concentration (Sales-based Index and HHI) × institutional investors' is insignificant at the 0.05 level ($p = 0.846$, $t = -0.195$ and 0.464, $t = -0.733$, respectively). Therefore, the presence of institutional investors does not affect the relationship between corporate/government customer concentration and stock price crash risk, and the fourth hypothesis is not confirmed based on these two measures (please see Table 11).

Table 8 Results of testing the first and second hypotheses using the Ranking Index.

Variable	Estimate (*t*-statistic)	VIF
Intercept	−1/664 (−1/529)	-
3rd Quintile (Corp)	0/052 (0/155)	1/08
4th Quintile (Corp)	−0/325 (−0/996)	1/08
5th Quintile (Corp)	−1/312[a] (−2/435)	1/08
3rd Quintile (Gov)	−0/666[a] (−2/556)	1/19
4th Quintile (Gov)	0/237 (0/851)	1/19
5th Quintile (Gov)	−0/184 (−0/493)	1/19
SIZE	1/179[a] (5/146)	1/41
ROA	1/191 (1/303)	1/76
LEV	−0/135 (−0/172)	1/62
DTURNOVER	1/042 (0/957)	1/18
MB	0/028 (1/206)	1/36
SIGMA	−0/037 (−0/040)	1/24
RET	−0/340 (−0/164)	1/60
CIM	−0/081 (−0/471)	1/23
PCF	−0/681 (−0/747)	1/24
Industry/year effects	Controlled	
F-statistic	11/6	
Durbin-Watson	2/24	
R^2	0/02	

[a]Significance at the 5% level. The coefficient for each variable is reported, and *t*-test values appear in brackets.

Testing the third and fourth hypotheses using the Ranking Index. The interaction' corporate/government customer focus (Ranking Index) × institutional investment' results indicate that ranking levels are insignificant at 0.05. Therefore, institutional shareholders do not affect the relationship between corporate/government customer concentration and stock price crash risk. The third and fourth hypotheses are not confirmed based on this measure.

Additional tests. The preceding models conducted A singular test for corporate and government customers separately. To further validate the results, the primary customer concentration criterion encompassing corporate and government customers was employed in implementing the mode (please see Table 12).

The results in Table 12 indicate an absence of a statistically significant relationship between major customer concentration and stock price crash risk.

Table 13 tests previous hypotheses using the Ranking Index:

Table 13 demonstrates a noteworthy and statistically significant relationship between major customer concentration, based on ranking criteria in the fourth and fifth quartiles, and stock price crash risk. These findings reaffirm the earlier conclusions, suggesting a substantial association between significant customer concentration in the upper quartiles and the risk of stock price crashes.

Testing the third and fourth hypotheses using the Sales-Based Index and the HHIs:

All significant customers were considered for the supplementary examination concerning the third and fourth hypotheses, encompassing adjustment variables, and the test was executed (please see Table 14).

The outcomes in Table 14 reveal a statistically significant relationship between major customer concentration, institutional investors, and the risk of stock price declines.

Table 15 tests previous hypotheses using the Ranking Index:

Table 15 illustrates a significant relationship between major customer concentration (ranking) and institutional investment concerning stock price crash risk in the fourth and fifth quartiles. This indicates that institutional investment moderates the relationship between significant customer concentration, particularly at higher concentration levels.

The results. The study introduces three indicators to assess the impact of corporate and government customers on stock price crash risk, aiming to provide fresh insights and address inconsistent findings in existing research.

The analysis involves testing four key dimensions: the interplay between corporate customers and stock price crash risk, the linkage between government customer concentration and stock price crash risk, the role of institutional investors in influencing the relationship between corporate customer concentration and stock price crash risk, and the involvement of institutional investors in the connection between government customer concentration and stock price crash risk.

The paper uses a sample of 82 companies listed on the Tehran Stock Exchange from 2013 to 2020, generating 656 instances of

Table 9 Results of Chow and Hausman tests.

Model	Chow test			Hausman test		
	Test statistic	Sig.	Result	Test statistic	Sig.	Result
(1) Sales-based Index	1/23	0/1	Pooled	-	-	-
(2) HHI	1/27	0/082	Pooled	-	-	-
(3) Ranking Index	1/34	0/044	Panel	86/33	<0/001	Fixed effects

Table 10 Results of testing the third and fourth hypotheses using the Sales-based Index and the HHI.

Variable	Sales-based Index		HHI	
	Estimate (*t*-statistic)	VIF	Estimate (*t*-statistic)	VIF
Intercept	−1/561 (−1/349)	-	−1/46 (−1/272)	-
CC	−0/619 (−1/727)	1/77	−0/747[a] (−2/175)	1/50
GC	−0/084 (−0/306)	1/98	0/125 (0/450)	1/61
IST	−0/397 (−1/473)	2/23	−0.2 (−0/928)	1/55
CC × IST	1/675[a] (2/999)	1/81	1/899[a] (3/092)	1/45
GC × IST	−0/071 (−0/195)	1/93	−0/245 (−0/733)	1/44
SIZE	0/143[a] (2/999)	1/42	0/130 (1/659)	1/38
ROA	1/850 (−0/195)	1/76	1.875[a] (2/408)	1/77
LEV	0/472 (1/784)	1/62	0.445 (1/132)	1/64
DTURNOVER	1/027[a] (2/417)	1/18	1/01 (0/871)	1/18
MB	0/061 (1/235)	1/35	0.061[a] (3/131)	1/36
SIGMA	−0/505 (0/891)	1/19	−0/663 (−0/804)	1/23
RET	−0/093[a] (3/136)	1/48	0/517(0/256)	1/59
CIM	0/105 (−0/621)	1/19	0/138 (0/933)	1/23
PCF	−0/722 (−0/047)	1/39	−0/698 (−1/165)	1/36
Industry/year effects	Controlled			
R^2	0/12			
F-statistic	7/5			
Durbin-Watson	2/1			
R^2	0/11			
F-statistic	7/67			
Durbin-Watson	2/1			

[a]Significance at the 5% level. The coefficient for each variable is reported, and *t*-test values appear in brackets.

Table 11 Results of testing the third and fourth hypotheses using the Ranking Index.

Variable	Estimate (*t*-statistic)	VIF
Intercept	−1/664 (−1/529)	-
3rd Quintile (Corp)	−0/519 (−0/943)	1/42
4th Quintile (Corp)	−0/548 (−1/336)	1/42
5th Quintile (Corp)	−1/939[a] (−4/258)	1/42
Ist	0/210 (0/533)	1/83
3rd Quintile (Gov)	−0/780[a] (−2/452)	1/7
4th Quintile (Gov)	0/052 (0/129)	1/7
5th Quintile (Gov)	−0/104 (−0/206)	1/7
3rd Quintile (Corp) × Ist	1/256 (1/794)	1/38
4th Quintile (Corp) × Ist	1/083 (1/134)	1/38
5th Quintile (Cor) × Ist	1/274 (1/338)	1/38
3rd Quintile (Gov) × Ist	0/144 (0/326)	1/61
4th Quintile (Gov) × Ist	0/068 (0/139)	1/61
5th Quintile (Gov) × Ist	−0/494 (−0/888)	1/61
Size	1/159[a] (5/204)	1/43
ROA	1/056 (1/222)	1/79
LEV	−0/129 (−0/170)	1/67
DTUNOVER	1/161 (1/040)	1/20
MB	0/030 (1/274)	1/37
SIGMA	−0/128 (−0/138)	1/25
RET	0/049 (0/024)	1/61
CIM	−0/079 (−0/471)	1/23
PCF	−0/201 (−0/223)	1/42
Industry/year effects	Controlled	
R^2	0/032	
F-statistic	11/1	
Durbin-Watson	2/23	

[a]Significance at the 5% level. The coefficient for each variable is reported, and *t*-test values appear in brackets.

company-year data. The analytical approach employs panel data multiple regression, leveraging the "R" software, and introduces three metrics to measure corporate customer concentration: the proportion of significant customer sales, the Herfindahl-Hirschman Index, and a Ranking Index based on substantial customer sales.

The study uses the Ranking Index to reveal a noteworthy inverse relationship between corporate customer concentration (highest concentration) and stock price crash risk. This suggests that companies with a high concentration of significant customers may experience lower stock price crash risk.

Similarly, the results show an inverse association between government customer concentration (Ranking Index) and stock price crash risk. This contradicts findings in Lee et al.'s (2020) study in the USA, suggesting that government customers in Iran may contribute to more stable cash flows for supplier companies.

Institutional investors positively influence the correlation between corporate customer concentration (measured through various indices) and stock price crash risk. This implies that the presence of institutional investors may mitigate the risk associated with the high attention of corporate customers.

Surprisingly, the research demonstrates that institutional ownership does not exert a discernible impact on the relationship between government customer concentration and stock price crash risk. This suggests that institutional investors may not play a significant role in moderating the effects of government customer concentration in the Iranian market. We acknowledge the importance of elaborating on the reasons behind the differences in results between the Iranian and U.S. contexts. The dissimilarity in findings could be attributed to several factors inherent to each country's economic and market conditions.

Firstly, the economic structures of Iran and the USA differ significantly. As a developing nation, Iran may experience unique challenges and opportunities in its capital market that are distinct from the mature and well-established market of the USA. These variations in economic development, regulatory frameworks, and institutional environments could contribute to the observed differences in the relationship between customer concentration and stock price crash risk.

Secondly, cultural and geopolitical factors may play a crucial role in shaping the dynamics of the Iranian market. The influence of government policies, international sanctions, and regional geopolitical tensions might introduce complexities that are not present in the USA's relatively stable and predictable environment. These factors can impact the behaviour of both corporate and government customers, thereby influencing the relationship with stock price crash risk.

Additionally, the nature of customer relationships and business practices can vary between countries. How companies in Iran interact with their major corporate and government customers may be influenced by cultural norms, legal frameworks, and

Table 12 Results of testing the major total concentration using the Sales-based Index and the HHI-.

Variable	Sales-based Index				HHI			
	Estimate	*t*-statistic	Sig.	VIF	Estimate	*t*-statistic	Sig.	VIF
Intercept	−1.477	−1.339	0.181	-	−1.418	−1.229	0.220	-
CCT	0.047	0.253	0.800	1.67	0.074	0.397	0.691	1.47
SIZE	0.126	1.640	0.102	2.19	0.124	1.573	0.116	1.60
ROA	1.668	2.191	0.029	1.39	1.640	2.165	0.031	1.38
LEV	2.276	0.703	0.483	1.76	0.256	0.652	0.514	1.76
DTURNOVER	0.965	0.836	0.404	1.60	0.960	0.829	0.407	1.61
MB	0.064	3.402	0.001	1.18	0.062	3.302	0.001	1.18
SIGMA	−0.531	−0.659	0.511	1.34	−0.649	−0.793	0.428	1.35
RET	−0.249	−0.129	0.898	1.19	0.342	0.169	0.866	1.23
CIM	0.112	0.775	0.439	1.48	0.145	0.953	0.341	1.58
PCF	−0.455	−0.875	0.382	1.19	−0.463	−0.903	0.367	1.23
Industry/year effects		***F*-statistic**		**Durbin-Watson**		***F*-statistic**		**Durbin-Watson**
Controlled		7.12 (0.00)		2.1		7.9 (0.00)		0.11

Table 13 Results of testing the major total concentration using the Ranking Index.

Variable				
	Estimate	*t*-statistic	Sig.	VIF
Intercept	−1.452	−1.305	0.192	-
CCT3	−270	−1.483	0.139	1.11
CCT4	0.301	1.991	0.046	1.11
CCT5	−0.014	−2.189	0.039	1.11
SIZE	0.126	1.6	0.11	1.36
ROA	1.645	2.147	0.032	1.75
LEV	0.23	0.585	0.559	1.6
DTURNOVER	0.737	0.651	0.516	1.18
MB	0.062	3.233	0.001	1.34
SIGMA	−0.7	−0.886	0.376	1.22
RET	0.472	0.245	0.806	1.58
CIM	0.183	1.23	0.219	1.23
PCF	−0.496	−0.943	0.346	1.21
Industry/year effects		*F*-statistic	Durbin-Watson	
Controlled		7.3 (0.00)	2.1	

historical business practices that differ from those in the USA. These contextual nuances could lead to variations in the impact of customer concentration on stock price crash risk.

Discussion and conclusion

Our study significantly advances the understanding of stock price crash risk in the context of customer concentration within a developing nation, Iran. Addressing the gaps in existing research, we introduced three indicators to assess the impact of corporate and government customers on stock price crash risk, providing valuable insights into the dynamics of a developing economy. We aligned our results with this study's research questions and hypotheses.

Corporate customer concentration. Contrary to findings in developed countries, our study reveals a substantial negative association between corporate customer concentration, measured by the highest concentration level of the Ranking Index, and stock price crash risk. This contradicts the positive relationship Lee et al. (2020) observed in the USA. The empirical support for our first hypothesis underlines the significance of our novel Ranking Index, indicating that heightened corporate customer concentration, when measured through this index, reduces operational expenses and enhances overall company performance, aligning with prior research (Patatoukas, 2012; Hui et al. 2012).

Government customer concentration. Our study confirms a negative relationship between government customer concentration, assessed through the Ranking Index, and stock price crash risk. This aligns with the stabilising effect that Lee et al. (2020) identified in a developed country context. The second hypothesis substantiates the role of government customers in enhancing supplier companies' cash flows and reducing bankruptcy risk, particularly evident when measured through our innovative Ranking Index.

Institutional investors. The third hypothesis demonstrates that institutional investors influence the relationship between corporate customer concentration and stock price crash risk. Their positive influence, evident across various customer concentration indices, aligns with prior studies emphasising the capacity of institutional investors to mitigate agency issues, enhance managerial oversight, and reduce the likelihood of stock price crashes (Bhattacharya and Graham, 2007; Cornett et al. 2007).

Government customer concentration and institutional investors. Contrary to the expected impact, the fourth hypothesis does not support the moderating effect of institutional ownership on the relationship between government customer concentration and stock price crash risk across the three customer concentration measures. This suggests that institutional shareholders may have a relatively lesser impact on controlling government transactions, highlighting the distinct nature of these interactions.

Broader implications and practical applications. Beyond empirical analysis, our study offers valuable insights into the broader implications of the findings, emphasising the nuanced nature of the customer concentration-stock price crash risk relationship in developing countries. The practical applications underscore the strategic significance of effective risk management, acknowledging the potential amplification or mitigation of business and cash risk associated with significant customer concentration.

Table 14 Results of testing the third and fourth hypotheses, the major total concentration using the Sales-based Index and the HHI.

Variable	Focus criterion: selling to main customers				Focus criterion: selling to main customers			
	Estimate	*t*-statistic	Sig.	VIF	Estimate	*t*-statistic	Sig.	VIF
Intercept	−1.323	−1.142	0.254	-	−1.397	−1.214	0.225	-
CCT	−0.128	−0.491	0.623	1.67	−0.46	−0.185	0.854	1.47
IST	−0.245	−0938	0.349	2.19	−0.149	−0.685	0.494	1.60
CCT*IST	0.297	1.984	0.433	2.12	0.254	2.732	0.046	1.51
SIZE	0.128	1.611	0.108	1.39	0.130	1.656	0.098	1.38
ROA	1.703	2.160	0.031	1.76	1.673	2.131	0.034	1.76
LEV1	0.266	0.701	0.484	1.60	0.258	0.674	0.501	1.61
DTUNOWER	1.043	0.909	0.364	1.18	1.031	0.901	0.368	1.18
MB1	0.063	3.277	0.001	1.34	0.061	3.187	0.002	1.35
SIGMA	−0.552	−0.679	0.497	1.19	−0.660	−0.799	0.425	1.23
RET	−0.265	−0.137	0.891	1.48	0.285	0.140	0.889	1.58
CIM	0.114	0.782	0.435	1.19	0.143	0.935	0.350	1.23
PCF	−0.642	−1.042	0.298	1.35	−0.618	−1.016	0.310	1.34

Industry/year effects	*F*-statistic	Durbin-Watson	*F*-statistic	Durbin-Watson
Controlled	7.12 (0.00)	2.1	7.9 (0.00)	2.09

Table 15 Results of testing the third and fourth hypotheses, the major total concentration using the Ranking Index.

Variable				
	Estimate	*t*-statistic	Sig.	VIF
(Intercept)	−1.275	−1.112	0.267	-
CCT_3	−0.534	−1.698	0.09	1.6
CCT_4	0.263	0.76	0.447	1.6
CCT_5	−0.186	−0.833	0.411	1.6
IST	−0.279	−1.066	0.287	1.99
CCT_3*IST	0.429	1.064	0.288	1.64
CCT_4*IST	0.027	1.993	0.049	1.64
CCT_5*IST	0.295	2.866	0.0387	1.64
Size	0.131	1.641	0.101	1.39
ROA	1.656	2.078	0.038	1.76
LEV	0.204	0.539	0.59	1.61
DTUNOVER	0.842	0.76	0.448	1.18
MB	0.06	3.014	0.003	1.36
SIGMA	−754	−0.952	0.341	1.24
RET	0.502	0.262	0.793	1.58
CIM	0.184	1.229	0.22	1.24
PCF	−0.765	1.19	0.235	1.37

Industry/year effects	*F*-statistic	Durbin-Watson
Controlled	8.3 (0.00)	2.1

Limitations and future research. Acknowledging limitations related to data constraints and the temporal nature of data capture, our study encourages further interdisciplinary research. Future studies could delve into the implications of contextual factors, political dynamics, and economic conditions in shaping the intricate interplay between customer concentration and stock price crash risk, fostering a deeper understanding of economic and social systems through agent-based approaches. Future research could extend our study by incorporating additional variables related to information disclosure practices, corporate governance mechanisms, and communication dynamics between institutional owners and management. By doing so, we aim to provide a more comprehensive analysis of the factors influencing the risk of bad news hoarding and its implications for stock price crash risk.

Data availability

Not available, but access to data can be purchased via the TSE website at: https://mabnadp.com/products/rahavard365.

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Competing interests

The authors declare no competing interests.

Ethical approval

This study used publicly available data and, therefore, needed no ethical approval.

Informed consent

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