The relationship between sovereign credit rating changes and firm risk☆

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ABSTRACT

Sovereign credit ratings, extensively studied for their influence on macroeconomics and country risk, have been less explored in the context of their impact on individual firms. This research delves into the effects of sovereign credit rating changes on firm risk. Our findings suggest that an upgrade in sovereign credit ratings decreases firm risk, while a downgrade amplifies it. Furthermore, the magnitude of a country's rating shift positively correlates with changes in firm risk. We also discern a contagion effect between trade-dependent countries: an elevated rating in one country diminishes the firm risk in its trading partner, and vice versa. When categorizing our data into developed and developing markets, we observe that firm risk in developed markets reacts more acutely to rating upgrades. Conversely, rating downgrades, whether domestic or in trade-associated countries, intensify firm risk in developing markets. A robustness check, which evaluates sovereign credit rating fluctuations outside of financial crises, corroborates our core findings.

1. Introduction

In recent years, sovereign risk has garnered significant attention as an indicator of international financial market dynamics. Sovereign credit ratings provide lenders with an indicator to assess the willingness and capacity of countries' central governments to honor their sovereign debt. Moreover, these ratings serve as a tool to gauge country risk. Reinhart [1] emphasizes that sovereign credit ratings play a crucial role in predicting sovereign crises, profoundly influencing the positioning of rated countries within international capital markets. Additionally, a body of literature, including Gande and Parsley [2], suggests that sovereign bonds have implications for security prices, potentially serving as a reference to determine the value of corporate bonds or other financial instruments. These bonds also encapsulate various risks, such as default and the borrowing country's liquidity risk.

Events like the 2009 downgrade of Greece by credit rating agencies such as S&P, Moody's, and Fitch highlight the significant implications of sovereign rating shifts. Such events have spillover effects, as observed in the Eurozone countries of Portugal, Italy,

Ireland, and Spain, collectively termed PIIGS by rating agencies. These cascading consequences can hamper regional economic growth, as Chee et al. [3] point out. They argue that sovereign credit rating dynamics can reshape global financial landscapes and economic growth trajectories in affected countries.

Changes in sovereign ratings can alter a country's perceived risk. A downgrade, for instance, can induce a 'flight-to-quality' trend, with investors pivoting from high-risk to more stable markets. Conversely, sovereign rating enhancements can stimulate investment momentum [4–6]. While scholars like Bernal et al. [7] and Berger et al.[8] , have explored the macroeconomic implications of sovereign credit rating shifts, a gap exists regarding their impact on individual firms within affected countries. Drawing from Ross [9] and Jo and Na [10], risks for firms can be categorized into systematic (market-wide) and unsystematic (firm-specific) risks. The former affects all assets, while the latter can be more judiciously dispersed. Wang et al. [11] highlight the inverse correlation between corporate investment and economic policy uncertainty, further illuminating how shifts in sovereign ratings exacerbate policy volatility.

The concept of financial contagion posits that economic shocks to one country can trigger downturns in others, especially when systemic risks arise due to significant disturbances affecting multiple countries [12]. Such contagion effects become evident when interdependent markets are disrupted, as detailed by Kalbaska and Gatkowski [13]. In essence, shifts in sovereign credit ratings can trigger broad financial repercussions.

Existing research has offered insights into sovereign risks and credit ratings [14–28]. However, their impact on individual firms hasn't been as deeply examined. Borensztein et al. [29] explore the relationship between sovereign and corporate ratings, while Sahibzada et al. [30] investigate how sovereign ratings influence systematic risk. Drawing inspiration from these explorations, our study seeks to advance this dialogue. We undertake a rigorous examination of how shifts in sovereign credit ratings—both upgrades and downgrades—affect firm risk across diverse national contexts. Furthermore, whether and to what extent does a change in sovereign credit rating in one country have on the firm risk of its trading partners? How does firm risk in developed markets respond to sovereign credit rating upgrades and downgrades in comparison to developing markets? Lastly, do the observed relationships between sovereign credit rating shifts and firm risk remain consistent outside of financial crises periods?

To tackle these research questions, our study adopts a granular approach, examining the consequences of sovereign credit rating shifts on individual firms. Utilizing an extensive dataset spanning 1990 to 2017, we have amassed information on firms from 68 countries, paired with their corresponding sovereign credit ratings from S&P. These data form a robust panel dataset. Our analytical framework evaluates firm risk through three pivotal facets of firms: stock returns, total factor productivity, and return on assets, employing the standard deviation of such measures. Armed with the specificity of regression analysis, especially the fixed effects specification suited for our panel data, our research aims to uncoverthe intricate relationship between sovereign ratings and firm risks. Our findings underscore the counteractive effects of sovereign credit rating shifts on firm risk and emphasize the contagion effect, particularly prominent among countries with deep-seated trade connections. Through this detailed investigation, we aspire to fortify the academic narrative, delivering insights essential for policymakers, investors, and corporate stakeholders.

The subsequent sections of this paper are structured as follows: Section 2 provides a brief literature review. Section 3 details our data and methodological approaches, particularly regression specifications. Section 4 presents the measurements of variables, illustrates our empirical results, explores the contagion effect, and offers analysis outcomes based on comparing the impact of sovereign credit rating shifts during financial crises versus stable periods. Finally, Section 5 concludes the paper, discussing the study's limitations and suggesting directions for future research.

2. Literature review

2.1. The determinants of firm risk

Firm risk, a multifaceted construct, is influenced by a variety of financial determinants. When firms struggle with elevated risk, they become more susceptible to credit and bankruptcy risk. Indeed, firm risk serves as an indicator to gauge a company's capability to meet its debt obligations.

Various factors shape firm risk. Prior studies posit an inverse relationship between firm size and such risk [10,31,32]. The rationale is that larger firms, endowed with abundant resources, are better cushioned against financial adversities. Such firms' likelihood of bankruptcy diminishes.

On the other hand, financial leverage characterizes the strategy by which firms modify equity capital using liabilities, effectively adjusting their debt ratio. When the returns on investment outpace the debt costs, elevating financial leverage can enhance the returns to equity shareholders. If this balance is reversed, firms face financial distress, unfortunately. A surge in a company's leverage thus tends to escalate its risk exposure, a finding corroborated by several scholars [32–34].

The Return on Assets (ROA) measure captures the efficiency with which a firm deploys its capital and borrowed funds to generate profits. Empirical investigations illustrate a negative correlation between ROA and both firm-specific and systemic risk [10,31,35]. Particularly, Tran [33] articulates that firms, when presented with an abundance of investment avenues, are inclined to embrace higher risk profiles to optimize the potential rewards, inevitably courting greater risk.

Additionally, the sales growth rate, derived by contrasting current sales against previous figures in percentage, doubles as an indicator of a company's prospects. A bolstered growth rate generally forecasts an improved outlook, mitigating firm risk. This inverse correlation between sales growth and firm risk has been validated in the literature [10,31,33].

The dividend payout ratio's association with firm risk has also been explored, with some evidence suggesting its negative relationship [35]. Hutchinson et al. [36] find that firms with suboptimal dividend disbursements are often of elevated risk. In contrast,

other empirical studies show that a generous dividend distribution strategy, while placating shareholders, can stifle a firm's reinvestment potential, signaling a lack of investor confidence in the firm's long-term trajectory. The dividend payout ratio is thus positively correlated with firm risk.

In a study conducted by Panta [32], it was observed that there is a direct relationship between capital expenditure and firm risk. Capital expenditure refers to a firm's investment in long-term assets such as land and equipment. Firms typically make such investments intending to diminish operational costs in the long run, thereby enhancing their marginal benefits. The ultimate objective is to ensure that these investments yield profitable returns. Thus, capital expenditure signals firm risk.

Asset tangibility, encompassing liquid assets such as cash, commodities, and real estate, provides a pivotal insight into a firm's external financing potential. Dietrich [37] notes that tangible assets serve as a yardstick for external financiers during financial difficulties, offering them a semblance of assurance given the liquidation value of such assets. In essence, a firm's asset tangibility reflects its debt repayment acumen. Furthermore, information asymmetry between managers and shareholders is prevalent in corporate finance. Such asymmetries can exacerbate costs, as managers might exploit opportunities to benefit existing shareholders at the expense of new entrants by deploying precarious debt instruments. Myers and Majluf [38], thus, argue that firms uphold a financial "slack," defined as a surplus of liquid assets and borrowing capacity beyond operational and debt service requirements. Synthesizing these insights suggests that while higher asset tangibility usually tempers firm risk, an excessive financial slack, characterized by the issuance of risky debt, could inflate it. Therefore, firms should retain adequate financial slack or asset tangibility to attenuate their risk.

These factors, as mentioned above, serve as the linchpin influencing firm risk. Elevated firm risk can diminish the capacity to service debt, exposing firms to credit and bankruptcy risks.

2.2. The influence of sovereign credit rating

The essence of credit ratings lies in their ability to quantify the credit default risk of a given entity. Credit rating agencies, including S&P, Moody's, and Fitch Ratings, perform these assessments.

Chen et al. [39] suggest that positive rating revisions are associated with higher capital inflows and reduced sovereign bond yield spreads, thereby bolstering the economic performance of the upgraded countries. Conversely, negative revisions correlate with a steeper cost of foreign financing, increased capital outflows, and expanded sovereign bond yield spreads, making foreign investors more cautious about investing in the affected country. Kräussl [40] posits that shifts in the sovereign ratings of "ground-zero" countries exert a more pronounced impact on emerging economies' financial markets than developed markets. Flores [41] identifies four primary effects of sovereign credit rating changes: (1) shifts in domestic ratings and outlook significantly influence sovereign spreads and stock prices, with stock prices being more responsive; (2) a foreign rating change can have effects on the domestic financial market, a phenomenon termed "contagion"; (3) substantial rating changes exert a more potent influence on financial markets, overshadowing minor ones; and (4) financial markets can often anticipate sovereign credit rating shifts.

Sovereign credit rating changes have an impact both domestically and internationally. Changes in foreign ratings can influence domestic markets, affecting indicators like sovereign spreads, stock prices, and capital flows. Several empirical studies demonstrate the substantial contagion effect in credit default swaps (CDS) and stock markets. For instance, Ismailescu and Kazemi [42] categorize credit rating events into positive and negative groups and find that positive events exert a more pronounced impact on CDS markets and spill over into other emerging nations at a pace surpassing that of negative counterparts. Furthermore, the magnitude of contagion from positive rating declarations overshadows that resulting from negative ones. Huang et al. [43] show that downgrade events cast a larger shadow on abnormal CDS markets than mere negative outlooks. Still, such adverse shocks have a more considerable spillover effect than their positive counterparts.

Regarding stock markets, a robust correlation exists between event and non-event countries, potentially amplifying the credit contagion effect. Examining the CDS market, it is evident that some non-event nations, typically characterized by subpar economic performance and governance standards, are more susceptible to credit contagion. Whether the markets in question are CDS or stock, geographical proximity—either being in the same region or sharing borders—tends to witness a stronger contagion impact.

These prior studies demonstrate that changes in a country's sovereign credit rating can significantly influence both its CDS and stock markets, as well as those of its neighbors. Such changes can catalyze a contagion effect, influencing various economic indicators like capital flow, sovereign spreads, stock prices, and overall economic performance.

2.3. Risk and sovereign credit rating

Sovereign credit rating revisions, irrespective of whether they arise domestically or internationally, are intertwined with shifts in country risk and capital flows, thereby introducing heightened levels of risk and uncertainty.

Chen et al. [6] argue that such sovereign credit rating alterations affect private investment. Specifically, an upgrade positively correlates with a marked uptick in private investment growth. Furthermore, fluctuations in sovereign credit ratings also indirectly sway a country's cost of capital and net present values.

Beirne and Fratzscher [44] investigate the contagion effect, or what is informally termed a "wake-up call," triggered by revisions in sovereign credit ratings. Financial markets exhibited heightened sensitivity to such events, especially during financial crises. This is primarily attributed to a country's risk profile being inextricably linked to its underlying economic fundamentals, such as trade and economic integration. For instance, a rating downgrade can cause a decline in the economic performance of the affected country, which can subsequently ripple through to countries with economic or trade ties to it.

Furthermore, Kalotychou et al. [45] find that the contagion effects due to sovereign credit rating shifts predominantly manifest

intra-regionally in the aftermath of the global financial crisis. This contagion amplifies global sovereign credit risk levels and negatively impacts sovereign spreads, whether intra-regional or global. However, an intriguing observation in their study is that international systemic sovereign credit risk exposure remains resistant primarily to such contagion. This observation suggests that when financial market participants perceive a deterioration in sovereign credits, they attribute it to regional challenges.

The above shows a tangible causal relationship between sovereign credit ratings and firm risk. We posit that fluctuations in sovereign credit ratings have influence over firm risk and propose the following two hypotheses.

Hypothesis 1.   Sovereign credit rating upgrade (downgrade) will decrease (increase) firm risk.

Hypothesis 2.   Sovereign credit rating upgrade (downgrade) of a trade-dependent country will decrease (increase) firm risk; hence the contagion effect exists.

3. Data and methodology

3.1. Data

To understand how shifts in a country's sovereign credit rating influence firm risk, we embarked on a comprehensive data collection process. Ratings data were procured from the Standard & Poor's (S&P) database, from which we obtained sovereign credit rating details for all available countries. Complementing this, stock return information and market values of publicly listed firms within these countries were amassed from Datastream. Recognizing the insights financial statements can offer, we further incorporated firm data from the Worldscope database. Here, we extracted key metrics pivotal for the derivation of empirical variables, for instance, ROA and the dividend payout ratio. Moreover, Worldscope was instrumental in furnishing figures on production output, labor, and capital inputs, cornerstones for calculating total factor productivity (TFP). Import and export data were extracted from UN Comtrade to paint a comprehensive picture of trade dynamics, facilitating a deeper dive into between-country trade dependencies. Notably, our dataset spans annual information for each firm and sovereign credit rating information for each country from 1990 through 2017.

Because of the vast heterogeneity across industries and their respective operational norms, a careful classification of firms is indispensable. We categorized firms using the Standard Industrial Classification (SIC) system, ensuring alignment with their core business activities. We must mention our conscious choice to exclude firms under SIC codes 6000–6999 and 4900–4999, representing the financial and utility sectors. This exclusion rationale is rooted in the distinct regulatory environment and unique operational characteristics these sectors exhibit, markedly setting them apart.

Furthermore, in our commitment to data integrity, firms with incomplete data were excluded, as were those in the top and bottom one percentiles across all variables to mitigate outlier influence. Through these rigorous criteria, our final dataset emerges, spotlighting 68 countries, encompassing 20,333 firms, and yielding 184,048 firm-year observations.

3.2. Methodology

3.2.1. Empirical models

Our dataset takes the form of panel data, encompassing observations across multiple firms over distinct time intervals. Within this framework, we not only amass or deduce a range of metrics tied to these firms but also continuously monitor the shifts in sovereign credit ratings of the countries where these firms are based. Given this unique dataset configuration, our analytical approach adopts various panel data regressions. Specifically, we focus on the fixed-effects model to probe the potential repercussions of sovereign credit rating changes on firm risk. The rationale behind employing the fixed-effects model lies in its adeptness at isolating the unobserved yet intrinsic characteristics peculiar to either countries or industries. For instance, the nuances of a country's political system might subtly influence the operational modalities of its resident firms, just as industry-specific norms might engender distinctiveness among firms predominantly engaged in that sector. Our regression specification thus has the form:

$$
\begin{aligned}
RISK_{ijt} = \alpha &+ \beta_1 UG_{ijt-1} + \beta_2 DG_{ijt-1} + \beta_3 SIZE_{ijt-1} + \beta_4 LEV_{ijt-1} + \beta_5 ROA_{ijt-1} \\
&+ \beta_6 SG_{ijt-1} + \beta_7 MB_{ijt-1} + \beta_8 RD_{ijt-1} + \beta_9 DIV_{ijt-1} + \beta_{10} CF_{ijt-1} \\
&+ \beta_{11} CapExp_{ijt-1} + \beta_{12} FA_{ijt-1} + \beta_{13} FS_{ijt-1} + \beta_{14} VIX_{ijt-1} \\
&+ Industry\ dummies + Country\ dummies + Year\ dummies + \varepsilon_{ijt}
\end{aligned} \tag{1}
$$

Here, i, j, and t denote the firm, country, and year. Thus, $RISK_{ijt}$ represents the risk of firm i situated in country j in year t, acting as the dependent variable. UG_{ijt-1} is the dummy variable of the sovereign credit rating upgrades, taking the value of one if the sovereign credit rating is adjusted upwards for firm i in country j in year t-1 and the value of zero otherwise. Comparably, DG_{ijt-1} is the dummy variable of downgrades in year t-1.

Determinants of firm risk delineated previously are incorporated into our model, namely firm size (*SIZE*), debt ratio (*LEV*), return on assets (*ROA*), sales growth rate (*SG*), market-to-book ratio (*MB*), research and development ratio (*RD*), dividend payout ratio (*DIV*), cash flow (*CF*), capital expenditure expense ratio (*CapExp*), tangibility (*FA*), financial slack (*FS*) and volatility (*VIX*). We include *Country, Industry,* and *Year dummies* to capture the idiosyncratic effects of each country, industry, and year. To account for heteroskedasticity and autocorrelation, we adjust the standard errors employing the correction proposed by Newey and West [46].

Sovereign credit rating adjustments, encompassing both upgrades and downgrades, entail not only directional shifts but also score

variations. This additional information on scores can be incorporated into our regression analysis, leading to the formulation of the regression model as depicted below in Eq. (2).

$$RISK_{ijt} = \alpha + \beta_1 UGN_{ijt-1} + \beta_2 DGN_{ijt-1} + \beta_3 SIZE_{ijt-1} + \beta_4 LEV_{ijt-1} + \beta_5 ROA_{ijt-1}$$
$$+ \beta_6 SG_{ijt-1} + \beta_7 MB_{ijt-1} + \beta_8 RD_{ijt-1} + \beta_9 DIV_{ijt-1} + \beta_{10} CF_{ijt-1}$$
$$+ \beta_{11} CapExp_{ijt-1} + \beta_{12} FA_{ijt-1} + \beta_{13} FS_{ijt-1} + \beta_{14} VIX_{ijt-1}$$
$$+ Industry\ dummies + Country\ dummies + Year\ dummies + \varepsilon_{ijt} \tag{2}$$

The upgrade and downgrade dummies, UG_{ijt-1} and DG_{ijt-1}, in Eq. (1) are here substituted by UGN_{ijt-1} and DGN_{ijt-1}, where UGN_{ijt-1} represents the change in the sovereign credit rating score for year t-1 there is a favorable rating event; otherwise, it is zero. Conversely, DGN_{ijt-} captures the absolute change of the sovereign credit rating score for year t-1 in the event of a negative rating adjustment and is set to zero in its absence.

3.2.2. Measurement of firm risk

In this study, it is crucial to illusrtrate the computation specifics employed to measure our dependent variable: firm risk. Although numerous metrics, such as standard deviation proposed by Markowitz [47], Sharpe Ratio formulated by Sharpe [48], and beta suggested by Lintner [49], exist to quantify risk, many cater specifically to individual investments or portfolios. To aptly capture corporate risk in the context of our research, we gravitate toward the most widely accepted method: standard deviation. This measure assesses the spread of outcomes around their expected values. Our adoption of this approach is in line with Faccio et al. [50], Jiang et al. [51], Tran [33], and Vural-Yavaş [34]. These scholars advocate the use of standard deviation, focusing on three key firm attributes: daily stock returns, total factor productivity, and return on assets to ascertain risk. Each of these attributes illuminates a distinct dimension of any firm.

3.2.2.1. Annualized standard deviation of daily stock returns.
One primary approach to measuring firm risk is analyzing daily stock returns [52,53]. These returns represent the market's frequent evaluations of a company's value and anticipated future performance. The computation is defined in Eq. (3) below:

$$RISK\_RETURN_t = \frac{(STDR_{t+1} + STDR_{t+2} + STDR_{t+3} + STDR_{t+4} + STDR_{t+5})}{5} \tag{3}$$

Here $STDR$ represents the annualized standard deviation of stock returns while t denotes the specific year in question. Firm risk in year t, $RISK\_RETURN_t$, is then derived by averaging these yearly standard deviations over a subsequent five-year period.

3.2.2.2. Standard deviation of total factor productivity.
Another metric to assess firm risk is TFP. Fluctuations in TFP often signal shifts in a company's operational efficiency. A pronounced standard deviation in TFP suggests variability in the firm's operational consistency, representing a potential operational risk [54]. To calculate a firm's TFP, we adopt the commonly used Cobb–Douglas production function expressed below:

$$Y_{ijt} = A_{ijt} \times L_{ijt}^{\lambda_L} \times C_{ijt}^{\lambda_C} \tag{4}$$

Again, i, j, and t correspond to the firm, country, and year, respectively; Y signifies the firm's output, while L and C designate its labor and capital inputs. The terms λ_L and λ_C capture the marginal product of labor and capital. The coefficient A constitutes the firm's TFP, which elucidates the segment of a firm's output not attributable directly to the input factors of production. The natural logarithmic transformation of the relationship presented in Eq. (4) produces the equation below.

$$y_{ijt} = a_{ijt} + \lambda_L l_{ijt} + \lambda_C c_{ijt} \tag{5}$$

Building on the methodology proposed by Field and Mkrtchyan [55], we obtain TFP as a residual from the regression outlined in Eq. (5). This derivation is achieved by incorporating firm, year, and country dummies within a fixed-effects panel data regression specification. The variable, a_{ijt}, reflects TFP. Firm risk is calculated through the standard deviation of TFP, derived over a five-year interval as illustrated in Eq. (6).

$$RISK\_TFP_{ijt} = \sqrt{\frac{\sum_{s=1}^{5} \left(a_{ijt+s} - \overline{a_{ijt}}\right)^2}{5-1}} \tag{6}$$

3.2.2.3. Annualized standard deviation of return on assets.
Additionally, Return on Assets (ROA) indicates not merely a firm's operational efficiency but also a gauge of its financial health. By examining ROA fluctuations, one can gain insights into inherent operational risks. Essentially, ROA quantifies a company's capacity to profit from its assets. Over time, a pronounced standard deviation in ROA indicates erratic profitability patterns, indicating heightened business risk [56–58]. We thus employ an approach wherein the standard deviation of ROA is derived from each firm's returns on assets over a five-year interval, as described in Eq. (7) below:

$$RISK\_ROA_{ijt} = \sqrt{\frac{\sum_{s=1}^{5}\left(ROA_{ijt+s} - \overline{ROA_{ijt}}\right)^2}{5-1}}$$ (7)

3.2.3. Measurement of sovereign credit rating

Drawing from the works of Afonso et al. [59], Chen et al. [6], Chee et al.[3], and Chen et al. [39], we treat country sovereign credit rating upgrades *(UG)* and downgrades *(DG)* as dummy variables. When the credit rating experiences a shift within a given year, the value of this dummy variable is set to one; otherwise, it remains zero. Moreover, guided by the methodology proposed by Chen et al. [39], we utilize the sovereign credit rating score, aligning with the ranking grade ascribed by S&P sovereign rating (see Appendix 1). A positive rating event in a year is recorded through the increased change in the country's credit rating score *(UGN)*, whereas an adverse rating event is logged through the "absolute value" of the decreased change *(DGN)*. In instances where the country's sovereign credit rating remains unchanged, the change in the rating score is designated as zero.

3.2.4. Measurement of control variables

Drawing from a rich body of literature, including works by Flores [41], Jo and Na [10], Luo et al. [31], Vural-Yavaş [34], Panta [32], and Liu et al. [60], our regression models employ several control variables. In addition to the key variable, rating change, they encompass firm size *(SIZE)* - which is the natural logarithm of market value as expounded by Vural-Yavaş [34], leverage *(LEV)* - the total debt to total assets ratio [33], return on assets *(ROA)* - the net income to total assets ratio [35], sales growth rate *(SG)* - computed as the change ratio in net sales from the preceding year [10], and the market-to-book ratio *(MB)* - a measure of the market value of equity relative to its book value [10].

Expanding our control variable list, we also reference works by Borde [35], Hutchinson et al. [36], Wang [61], and Tran [33]. Consequently, our regression includes the research and development ratio *(RD)*, dividend payout ratio *(DIV)*, cash flow *(CF)*, capital expenditure expense ratio *(CapExp)*, financial slack *(FS)*, and tangibility *(FA)*. *RD* is derived as the R&D expenses to total assets ratio [10]. *DIV* is the dividend to post-tax and interest profit ratio [36]. *CapExp* is the capital expenditure expenses ratio to total sales [10], while *FS* is the ratio of cash and short-term investments to total assets. *FA* is represented by the plant, property, and equipment to total assets ratio [34]. Lastly, we denote VIX, a measure derived from the implied volatilities of a range of S&P 500 index options to quantify the market's anticipated volatility. This incorporates calls and puts and offers a forward-looking perspective [41]. Table 1 provides a summary of these variables.

Table 1
Definitions of research variables.

Variable	Definition
RISK_RETURN	Standard deviation is averaged after the sum of the annualized standard deviation of daily stock returns for the next five years.
RISK_ROA	Standard deviation is computed using the returns on assets of each firm for the next five years.
RISK_TFP	Standard deviation of total factor productivity
UG	A dummy variable, one representing the sovereign credit rating upgrade in the year, and zero otherwise
DG	A dummy variable, one representing the sovereign credit rating downgrade in the year, and zero otherwise
UGN	The change score of sovereign credit rating in the year of the positive rating event, and zero otherwise
DGN	The absolute change score of sovereign credit rating in the year of the negative rating event, and zero otherwise
UG_DEP	A dummy variable, one representing the sovereign credit rating upgrade between trade-dependent countries in the year, and zero otherwise.
DG_DEP	A dummy variable, one representing the sovereign credit rating downgrade between trade-dependent countries in the year, and zero otherwise.
UGN_DEP	The country credit rating score changes that occur between trade-dependent countries at time *t*-1 of the positive rating event and zero otherwise.
DGN_DEP	The absolute country credit rating score changes that occur between trade-dependent countries at time *t*-1 of the negative rating event and zero otherwise.
Size	Natural logarithm of market value
Leverage	Total debt/Total assets
ROA	Net income/Total assets
Sales Growth (*SG*)	The growth of net sales
Market-to-Book ratio (*MB*)	Market capitalization/Book values
Research and Development (*RD*)	R&D expense/Total assets
Dividend payout ratio (*DIV*)	Dividend per share/Earning per share
Capital expenditure expense ratio (*CapExp*)	Capital expenditure expense/Total sales
Tangibility (*FA*)	Plant, property, and equipment/Total assets
Financial Slack (*FS*)	Cash and short-term investments/Total assets
VIX	The implied volatilities of a range of S&P 500 index options.

Table 2

Sample distribution, UG, DG, UGN, and DGN by country We use the S&P sovereign credit rating history data to obtain each country's UG, DG, UGN, and DGN, and the sum of each to obtain our observations. *UG* is a dummy variable to know whether the country's sovereign credit rating was upgraded in the year, 1 represents credit rating upgraded, and zero otherwise; *DG* is a dummy variable to know whether the country's sovereign credit rating was downgraded in the year, 1 represents credit rating downgraded, and zero otherwise. *UGN* is the score of sovereign credit rating in year t-1 of the positive rating event and zero otherwise; *DGN* is the absolute change score of sovereign credit rating in year t-1 of the negative rating event, and zero otherwise. The percentage of countries' firms is the number of firms in each country divided by the sum of all firm numbers. The percentage of firms' years is the number of firm-years of each country divided by the sum of all firm-year numbers.

Country	Number of firms	Percentage	Number of firm-years	Percentage	Frequency of UG	Frequency of DG	UGN	DGN
United Arab Emirates	17	0.08%	102	0.06%	0	0	0	0
Argentina	27	0.13%	345	0.19%	4	4	10	14
Australia	769	3.78%	5198	2.82%	2	0	2	0
Austria	43	0.21%	531	0.29%	0	1	0	2
Belgium	66	0.32%	872	0.47%	0	1	0	2
Bangladesh	22	0.11%	66	0.04%	0	0	0	0
Bulgaria	96	0.47%	351	0.19%	1	1	1	2
Brazil	196	0.96%	1796	0.98%	8	2	9	4
Canada	489	2.40%	3789	2.06%	1	1	1	1
Switzerland	167	0.82%	2636	1.43%	0	0	0	0
Chile	99	0.49%	1146	0.62%	5	0	5	0
China	1941	9.55%	9294	5.05%	6	1	8	1
Colombia	25	0.12%	179	0.10%	2	2	2	3
Cyprus	33	0.16%	202	0.11%	1	3	1	14.5
Germany	486	2.39%	5454	2.96%	0	0	0	0
Denmark	90	0.44%	1329	0.72%	2	0	2	0
Egypt	51	0.25%	305	0.17%	0	3	0	8
Spain	107	0.53%	1287	0.70%	2	4	2	12
Estonia	10	0.05%	51	0.03%	3	1	4	2
Finland	103	0.51%	1403	0.76%	3	2	3	3
France	462	2.27%	5736	3.12%	0	1	0	2
United Kingdom	648	3.19%	7545	4.10%	0	0	0	0
Greece	176	0.87%	1452	0.79%	4	4	8	17.5
Croatia	55	0.27%	283	0.15%	0	2	0	3
Hungary	17	0.08%	133	0.07%	3	4	5	7
Indonesia	284	1.40%	2409	1.31%	6	3	10	11.5
India	974	4.79%	6095	3.31%	2	1	2	1
Ireland	16	0.08%	147	0.08%	3	3	3	8.5
Iceland	8	0.04%	61	0.03%	1	2	1	7
Italy	179	0.88%	2036	1.11%	0	5	0	8
Jordan	83	0.41%	425	0.23%	0	0	0	0
Japan	2928	14.40%	37,163	20.19%	1	3	1	6
Kenya	25	0.12%	142	0.08%	1	1	1	2
Korea	1436	7.06%	11,663	6.34%	7	1	11	10.5
Kuwait	49	0.24%	268	0.15%	2	0	2	0
Sri Lanka	146	0.72%	898	0.49%	1	1	1	1
Lithuania	18	0.09%	100	0.05%	3	2	4	4
Latvia	10	0.05%	61	0.03%	2	3	4	7.5
Morocco	17	0.08%	66	0.04%	2	0	2	0
Mexico	101	0.50%	1242	0.67%	4	2	5	2
Malta	10	0.05%	51	0.03%	0	1	0	2
Malaysia	654	3.22%	6824	3.71%	5	2	5	7
Namibia	10	0.05%	54	0.03%	0	0	0	0
Nigeria	41	0.20%	92	0.05%	1	1	1	1
Netherlands	71	0.35%	1139	0.62%	0	0	0	0
Norway	108	0.53%	1042	0.57%	0	0	0	0
New Zealand	39	0.19%	341	0.19%	2	2	2	2
Oman	52	0.26%	262	0.14%	2	0	2	0
Pakistan	119	0.59%	1058	0.57%	3	1	3	7
Peru	107	0.53%	986	0.54%	4	1	4	1
Philippines	126	0.62%	1214	0.66%	4	2	6	2
Poland	311	1.53%	1641	0.89%	4	0	6	0
Portugal	42	0.21%	593	0.32%	3	5	3	12
Romania	61	0.30%	262	0.14%	0	1	0	2
Russia	133	0.65%	503	0.27%	6	2	14	5
Saudi Arabia	40	0.20%	187	0.10%	2	0	2	0
Singapore	455	2.24%	4257	2.31%	2	0	2	0
Serbia	37	0.18%	84	0.05%	0	0	0	0
Slovenia	23	0.11%	122	0.07%	3	2	4	4
Sweden	279	1.37%	2704	1.47%	1	1	1	1
Thailand	604	2.97%	5810	3.16%	3	2	4	6
Tunisia	18	0.09%	89	0.05%	0	2	0	3

Table 2 (*continued*)

Country	Number of firms	Percentage	Number of firm-years	Percentage	Frequency of UG	Frequency of DG	UGN	DGN
Turkey	223	1.10%	1879	1.02%	4	3	7	9
Ukraine	23	0.11%	79	0.04%	1	3	3	8
United States	3951	19.43%	36,200	19.67%	0	1	0	2
Venezuela, RB	11	0.05%	128	0.07%	5	5	7	10
Vietnam	138	0.68%	454	0.25%	0	1	0	2
South Africa	178	0.88%	1732	0.94%	4	1	5	2
SUM	20,333	100.00%	184,048	100.00%	141	103	191	255

Table 3

Effect of UG, DG, UGN, and DGN on firm risk measured through the annualized standard deviation of daily stock returns We use the annualized standard deviation of daily stock returns to obtain each sample firm's RISK 1 (dependent variable). *UG*, *DG*, *UGN*, and *DGN* are obtained from S&P sovereign credit rating history data. *UG* is a dummy variable to know whether the country's sovereign credit rating was upgraded in the year, 1 represents credit rating upgraded, and zero otherwise; *DG* is a dummy variable to know whether the country's sovereign credit rating was downgraded in the year, 1 represents credit rating downgraded, and zero otherwise. *UGN* is the score of sovereign credit rating in year t-1 of the positive rating event and zero otherwise; *DGN* is the absolute change score of sovereign credit rating in year t-1 of the negative rating event, and zero otherwise. Among the control variables, firm size (*SIZE_MV*) is the natural logarithm of market value; the debt ratio (*LEV*) is the total debt to total assets; return on assets (*ROA*) is the net income to total assets; the sales growth ratio (*Sales_growth*) is the ratio change in net sales in the previous year; the market-to-book ratio (*MB*) is the proportion of a firm's market capitalization to its book value; the research and development (*RD*) is the ratio of R&D expenses to total assets; the dividend payout ratio (*DIV*) is the ratio of dividend payments to profit after interest and tax; the capital expenditure expense ratio (*CapExp*) is the ratio of capital expenditure divided by total sales; tangibility (*FA*) is the value of plant, property, and equipment over total assets; financial slack (*FS*) is cash and short-term investments divided by total assets; and the implied volatilities of a range of S&P 500 index options are used to calculate VIX (*VIX*). Control variables include dummies for country, industry, and year. The SIC code and the industry classification of Fama and French [62] are used to classify industry dummy variables. ***, **, and * represent 1%, 5%, and 10% significance levels.

	(1)	(2)	(3)	(4)
Intercept	6.8048*	6.8019*	6.4794	6.4889
	(0.0624)	(0.0624)	(0.1059)	(0.1025)
UG	−0.0809**		−0.0809**	
	(0.0150)		(0.0150)	
DG	0.0468**		0.0468**	
	(0.0256)		(0.0206)	
UGN		−0.0389**		−0.0389**
		(0.0109)		(0.0109)
DGN		0.0411***		0.0411***
		(0.0068)		(0.0068)
SIZE_MV	−0.3040***	−0.3042***	−0.3040***	−0.3042***
	(0.0047)	(0.0047)	(0.0047)	(0.0047)
LEV	0.9169**	0.9135**	0.9169**	0.9135**
	(0.0371)	(0.0371)	(0.0371)	(0.0371)
ROA	−1.4602	−1.4613	−1.4602	−1.4613
	(0.2397)	(0.2399)	(0.2397)	(0.2399)
Sales_growth	−0.0597**	−0.0514**	−0.0597**	−0.0514**
	(0.0348)	(0.0350)	(0.0348)	(0.0350)
MB	0.1353***	0.1355***	0.1353***	0.1355***
	(0.0072)	(0.0072)	(0.0072)	(0.0072)
RD	2.7171	2.7196	2.7171	2.7196
	(0.2445)	(0.2447)	(0.2445)	(0.2447)
DIV	−11.3176	−11.3066	−11.3176	−11.3066
	(0.5313)	(0.5318)	(0.5313)	(0.5318)
CapExp	1.1352	1.1261	1.1352	1.1261
	(0.1544)	(0.1544)	(0.1544)	(0.1544)
FA	−0.5863**	−0.5847**	−0.5863**	−0.5847**
	(0.0441)	(0.0441)	(0.0441)	(0.0441)
FS	0.2004**	0.2007**	0.2004**	0.2007**
	(0.0485)	(0.0485)	(0.0485)	(0.0485)
VIX			0.0181***	0.0174***
			(0.0043)	(0.0040)
Country dummies	Included	Included	Included	Included
Industry dummies	Included	Included	Included	Included
Year dummies	Included	Included	Included	Included
Adj.R²	0.4312	0.4314	0.4312	0.4314
F-value	648.00***	648.34***	648.00***	648.34***
Number of Countries	68	68	68	68
Observations	184,048	184,048	184,048	184,048

4. Empirical results

4.1. Sample description

Table 2 delineates the distribution of countries in our sample, incorporating the count of sovereign credit rating upgrades and downgrades for each country and the corresponding number of firms. It also reveals the rating scores corresponding to these changes. Notably, a *UGN* value of zero signifies a year without any positive changes in credit ratings. In contrast, a non-zero *UGN* indicates a positive shift in the credit rating. Conversely, *DGN*, given its absolute value nature, marks a year with a negative credit rating change and is zero in its absence. In the dataset, Japan and the United States emerge prominently, accounting for 20.19% and 19.67% of the sample based on the number of firm-years. From 1990 to 2017, the 68 countries in the sample collectively underwent 141 sovereign credit rating upgrades and 103 downgrades. Among these, Brazil has the most upgrades (frequency of *UG*), numbering eight. For

Table 4

Effect of UG, DG, UGN, and DGN on firm risk measured through the annualized standard deviation of return on assets We use the annualized standard deviation of return on assets to obtain each sample firm's RISK 2 (dependent variable). *UG, DG, UGN,* and *DGN* are obtained from S&P sovereign credit rating history data. *UG* is a dummy variable to know whether the country's sovereign credit rating was upgraded in the year, 1 represents credit rating upgraded, and zero otherwise; *DG* is a dummy variable to know whether the country's sovereign credit rating was downgraded in the year, 1 represents credit rating downgraded, and zero otherwise. *UGN* is the score of sovereign credit rating in year *t*-1 of the positive rating event and zero otherwise; *DGN* is the absolute change score of sovereign credit rating in year *t*-1 of the negative rating event, and zero otherwise. Among the control variables, firm size (*SIZE_MV*) is the natural logarithm of market value; the debt ratio (*LEV*) is the total debt to total assets; return on assets (*ROA*) is the net income to total assets; the sales growth ratio (*Sales_growth*) is the ratio change in net sales in the previous year; the market-to-book ratio (*MB*) is the proportion of a firm's market capitalization to its book value; the research and development (*RD*) is the ratio of R&D expenses to total assets; the dividend payout ratio (*DIV*) is the ratio of dividend payments to profit after interest and tax; the capital expenditure expense ratio (*CapExp*) is the ratio of capital expenditure divided by total sales; tangibility (*FA*) is the value of plant, property, and equipment over total assets; financial slack (*FS*) is cash and short-term investments divided by total assets; and the implied volatilities of a range of S&P 500 index options are used to calculate VIX (*VIX*). Control variables include dummies for country, industry, and year. The SIC code and the industry classification of Fama and French [62] are used to classify industry dummy variables. ***, **, and * represent 1%, 5%, and 10% significance levels.

	(1)	(2)	(3)	(4)
Intercept	0.1735***	0.1734***	0.1733***	0.1723***
	(0.0035)	(0.0035)	(0.0062)	(0.0059)
UG	−0.0023***		−0.0023***	
	(0.0087)		(0.0009)	
DG	0.0025***		0.0025***	
	(0.0011)		(0.0011)	
UGN		−0.0016***		−0.0016***
		(0.0006)		(0.0006)
DGN		0.0013***		0.0013***
		(0.0005)		(0.0005)
SIZE_MV	−0.0083***	−0.0083***	−0.0083***	−0.0083***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
LEV	0.0091***	0.0090***	0.0091***	0.0090***
	(0.0023)	(0.0023)	(0.0023)	(0.0023)
ROA	−0.1034**	−0.1035**	−0.1034**	−0.1035**
	(0.0192)	(0.0193)	(0.0192)	(0.0193)
Sales_growth	−0.0025***	−0.0022***	−0.0025***	−0.0022***
	(0.0024)	(0.0024)	(0.0024)	(0.0024)
MB	0.0079***	0.0079***	0.0079***	0.0079***
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
RD	0.2338**	0.2338**	0.2338**	0.2338**
	(0.0180)	(0.0180)	(0.0180)	(0.0180)
DIV	−0.3006**	−0.3001**	−0.3006**	−0.3001**
	(0.0368)	(0.0369)	(0.0368)	(0.0369)
CapExp	0.0434***	0.0434***	0.0434***	0.0430***
	(0.0091)	(0.0091)	(0.0091)	(0.0091)
FA	−0.0292***	−0.0291***	−0.0292***	−0.0291***
	(0.0023)	(0.0023)	(0.0023)	(0.0023)
FS	0.0112***	0.0113***	0.0112***	0.0113***
	(0.0031)	(0.0031)	(0.0031)	(0.0031)
VIX			0.0000***	0.0001***
			(0.0003)	(0.0002)
Country dummies	Included	Included	Included	Included
Industry dummies	Included	Included	Included	Included
Year dummies	Included	Included	Included	Included
Adj.R^2	0.3122	0.3123	0.3122	0.3123
F-value	388.93***	389.03***	388.93***	389.03***
Number of Countries	68	68	68	68
Observations	184,048	184,048	184,048	184,048

downgrades (frequency of *DG*), Italy, Portugal, and Venezuela share the spotlight, each with five instances. Cumulatively, the score for upgrades reached 191 points, whereas downgrades totaled 255 points. Significantly, Russia experienced the most substantial positive score changes (*UGN*), registering 14, whereas Greece led in terms of negative score variations (*DGN*), with a decrement of 17.5.

4.2. The impact of sovereign credit rating on firm risk

4.2.1. Daily stock return

Table 3 displays the regression results between *RISK_RETURN* and other pertinent variables. The regression specifications delineated in Columns 1–4 all exhibit the expected signs for the coefficients on *UG*, *DG*, *UGN*, and *DGN*. These coefficients are all significant at a 5% level. Columns 1 and 3 investigate the effects of *UG* and *DG* on firm risk. Notably, both produce a significant negative coefficient of −0.0809 for *UG*. This finding suggests that upgrading a country's credit rating correlates with reducing firm risk, thus

Table 5

Effect of UG, DG, UGN, and DGN on firm risk measured through the standard deviation of total factor productivity We use the standard deviation of total factor productivity to obtain each sample firm's RISK 3 (dependent variable). UG, DG, UGN, and DGN are obtained from S&P sovereign credit rating history data. UG is a dummy variable to know whether the country's sovereign credit rating was upgraded in the year, 1 represents credit rating upgraded, and zero otherwise; DG is a dummy variable to know whether the country's sovereign credit rating was downgraded in the year, 1 represents credit rating downgraded, and zero otherwise. UGN is the score of sovereign credit rating in year t-1 of the positive rating event and zero otherwise; DGN is the absolute change score of sovereign credit rating in year t-1 of the negative rating event, and zero otherwise. Among the control variables, firm size (SIZE_MV) is the natural logarithm of market value; the debt ratio (LEV) is the total debt to total assets; return on assets (ROA) is the net income to total assets; the sales growth ratio (Sales_growth) is the ratio change in net sales in the previous year; the market-to-book ratio (MB) is the proportion of a firm's market capitalization to its book value; the research and development (RD) is the ratio of R&D expenses to total assets; the dividend payout ratio (DIV) is the ratio of dividend payments to profit after interest and tax; the capital expenditure expense ratio (CapExp) is the ratio of capital expenditure divided by total sales; tangibility (FA) is the value of plant, property, and equipment over total assets; financial slack (FS) is cash and short-term investments divided by total assets; and the implied volatilities of a range of S&P 500 index options are used to calculate VIX (VIX). Control variables include dummies for country, industry, and year. The SIC code and the industry classification of Fama and French [62] are used to classify industry dummy variables. ***, **, and * represent 1%, 5%, and 10% significance levels.

	(1)	(2)	(3)	(4)
Intercept	0.3140***	0.3138***	0.3082**	0.3013**
	(0.0083)	(0.0083)	(0.0172)	(0.0164)
UG	−0.0154***		−0.0154***	
	(0.0020)		(0.0020)	
DG	0.0067***		0.0067***	
	(0.0031)		(0.0031)	
UGN		−0.0122***		−0.0122***
		(0.0014)		(0.0014)
DGN		0.0023***		0.0023***
		(0.0010)		(0.0010)
SIZE_MV	−0.0127***	−0.0127***	−0.0127***	−0.0127***
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
LEV	0.0108***	0.0109***	0.0108***	0.0109***
	(0.0053)	(0.0053)	(0.0053)	(0.0053)
ROA	−0.1521**	−0.1522**	−0.1521**	−0.1522**
	(0.0236)	(0.0236)	(0.0236)	(0.0236)
Sales_growth	0.0010***	0.0016***	0.0010***	0.0016***
	(0.0057)	(0.0058)	(0.0057)	(0.0058)
MB	0.0104***	0.0104***	0.0104***	0.0104***
	(0.0010)	(0.0010)	(0.0010)	(0.0010)
RD	0.2974**	0.2971**	0.2974**	0.2971**
	(0.0347)	(0.0347)	(0.0347)	(0.0347)
DIV	−0.5323*	−0.5310*	−0.5323*	−0.5310*
	(0.0625)	(0.0625)	(0.0625)	(0.0625)
CapExp	0.0480**	0.0464**	0.0480**	0.0464**
	(0.0253)	(0.0253)	(0.0253)	(0.0253)
FA	−0.0077***	−0.0073***	−0.0077***	−0.0073***
	(0.0066)	(0.0067)	(0.0066)	(0.0067)
FS	0.1345***	0.1348***	0.1345***	0.1348***
	(0.0085)	(0.0085)	(0.0085)	(0.0085)
VIX			0.0003***	0.0007***
			(0.0007)	(0.0007)
Country dummies	Included	Included	Included	Included
Industry dummies	Included	Included	Included	Included
Year dummies	Included	Included	Included	Included
Adj.R^2	0.2089	0.2089	0.2089	0.2089
F-value	225.74***	225.77***	225.74***	225.77***
Number of Countries	68	68	68	68
Observations	184,048	184,048	184,048	184,048

supporting Hypothesis 1. Conversely, a downgrade (*DG*) is associated with increased firm risk.

Columns 2 and 4 assess the implications of changes in *UGN* and *DGN* on firm risk. The results indicate that a rise in the rating score leads to a decline in firm risk. However, a decrease in the rating score is concomitant with an uptick in firm risk.

Furthermore, *SIZE_MV*, *Sales_growth*, and *FA* negatively correlate with firm risk. This suggests that larger firms with significant net sales growth and higher tangibility tend to have reduced risk levels. Conversely, *LEV*, *MB*, and *FS* positively correlate with firm risk. Specifically, increasing company leverage (*LEV*) results in greater firm risk. Similarly, rises in the market-to-book ratio (*MB*) and the financial slack ratio (*FS*) are associated with heightened firm risk.

4.2.2. Return on assets

In Table 4, our empirical exploration focuses on firm risk, which is gauged through the annualized standard deviation of the return on assets. The results indicate that the estimated coefficients of *UG*, *DG*, *UGN*, and *DGN* are all statistically significant at the 1% level across the four regression specifications. Specifically, *UG* and *UGN* display a negative association with firm risk, evidenced by regression coefficients of -0.0023 and -0.0016, respectively. In contrast, *DG* and *DGN* produce positive coefficients of 0.0025 and 0.0013, suggesting that a downgrade in a country's credit rating or an increase in its downgrade rating score is linked to an uptick in firm risk. Conversely, an upgrade or a rise in the upgrade rating score signals a potential decrease in firm risk. These observations further corroborate Hypothesis 1.

While Table 3 offers particular insights, Table 4 highlights the significance of variables like *ROA*, *RD*, *DIV*, and *CapExp*. There is a noticeable negative correlation between contemporary *ROA* and firm risk, hinting that companies with a higher *ROA* typically encounter lower risks. On the other hand, the research and development ratio (*RD*) positively correlates with firm risk, suggesting that companies with higher *RD* ratios may face increased risks. Similarly, the capital expenditure ratio (*CapExp*) is positively associated with firm risk, hinting that higher capital expenditures might be linked with greater risks. Conversely, the dividend payout ratio (*DIV*) presents a negative correlation, indicating that when firms disburse larger dividends, raising the dividend payout ratio, they may witness a simultaneous dip in risk.

4.2.3. Total factor productivity

Table 5 presents empirical findings using the total factor productivity standard deviation as a proxy for firm risk. These results align with those derived from prior regression specifications. In both Columns 1 and 3, the regression coefficient for *UG* consistently stands at -0.0154, significant at the 1% level. This suggests that a country's credit rating upgrade is inversely correlated with firm risk. As the country receives an upgrade, domestic firms will likely experience reduced risk levels. Conversely, *DG* exhibits a positive association with firm risk, as evidenced by a coefficient of 0.0067, significant at the 1% level, implying that a downgrade announcement by credit rating agencies can heighten firm risk, further substantiating Hypothesis 1.

Columns 2 and 4 explore the influence of shifts in rating scores on firm risk. With a coefficient of -0.0122, *UGN* significantly and negatively affects firm risk, suggesting that an increase in a country's rating score corresponds to a decrease in firm risk. In contrast, *DGN*, with its positive coefficient, underscores that an increase in the country's downgrade rating score amplifies firm risk, significant once again at the 1% level.

4.3. Contagion effects

To explore the potential contagion effect arising from changes in sovereign credit ratings, we modify the regression specification initially laid out in Eq. (1). The updated equation is shown in Eq. (8):

$$
\begin{aligned}
RISK_{ijt} = {} & \alpha + \beta_1 UG\_DEP_{irt-1} + \beta_2 DG\_DEP_{irt-1} + \beta_3 SIZE_{ijt-1} + \beta_4 LEV_{ijt-1} \\
& + \beta_5 ROA_{ijt-1} + \beta_6 SG_{ijt-1} + \beta_7 MB_{ijt-1} + \beta_8 RD_{ijt-1} + \beta_9 DIV_{ijt-1} \\
& + \beta_{10} CF_{ijt-1} + \beta_{11} CAPX_{ijt-1} + \beta_{12} FA_{ijt-1} + \beta_{13} FS_{ijt-1} + \beta_{14} VIX_{ijt-1} \\
& + Industry\ dummies + Country\ dummies + Year\ dummies + \varepsilon_{ijt}
\end{aligned}
\tag{8}
$$

In the revised specification denoted by Eq. (8), *UG_DEP*$_{irt\text{-}1}$ represents the sovereign credit rating upgrade of country r in the preceding year t-1, where r is distinct from j and country r shares significant trade dependent with country j. The variable r represents a country with a high trade dependence with country j. Analogously, *DG_DEP*$_{irt\text{-}1}$ denotes the sovereign credit rating downgrade in country r for the same year t-1 with the same distinction $r \neq j$.

To probe the influence of shifts in the rating scores of trade partners on the risk exposure of domestic firms, we refine the regression model delineated in Eq. (2). The updated equation is presented as Eq. (9):

$$
\begin{aligned}
RISK_{ijt} = {} & \alpha + \beta_1 UGN\_DEP_{irt-1} + \beta_2 DGN\_DEP_{irt-1} + \beta_3 SIZE_{ijt-1} + \beta_4 LEV_{ijt-1} \\
& + \beta_5 ROA_{ijt-1} + \beta_6 SG_{ijt-1} + \beta_7 MB_{ijt-1} + \beta_8 RD_{ijt-1} + \beta_9 DIV_{ijt-1} + \beta_{10} CF_{ijt-1} \\
& + \beta_{11} CAPX_{ijt-1} + \beta_{12} FA_{ijt-1} + \beta_{13} FS_{ijt-1} + \beta_{14} VIX_{ijt-1} \\
& + Industry\ dummies + Country\ dummies + Year\ dummies + \varepsilon_{ijt}
\end{aligned}
\tag{9}
$$

In this specification, *UGN_DEP*$_{irt\text{-}1}$ represents the score variation in the sovereign credit rating upgrade for country r in the previous year t-1, stipulating that r is not equivalent to j and that a pronounced trade dependency exists between countries r and j. Similarly,

$DGN\_DEP_{irt\text{-}1}$ signifies the score alteration in the sovereign credit rating downgrade of country r during the same preceding year t-1. When no change in a country's credit rating score occurs at t-1, variables related to rating score adjustments are designated the value of zero.

In Table 6, we utilize the annualized standard deviation of daily stock returns to measure firm risk to probe the contagion effect of credit ratings among trade-dependent countries. This analysis is based on the regression specification outlined in Eq. (9). We find that an improving credit rating in these countries has a marked negative contagion effect, as evidenced by the coefficient of UG_DEP being -0.0546, suggesting that when a trade-dependent country's credit rating improves, there is a corresponding decrease in firm risk for its trading partners, illustrating the contagion effect. On the other hand, a declining credit rating in these countries results in a positive contagion effect, with the coefficient of DG_DEP being 0.0768, supporting the notion that a deteriorating credit rating in a trade-dependent country can increase firm risk in its trading partners, consistent with Hypothesis 2. Notably, countries interconnected through trade demonstrate this contagion effect and upgrade and downgrade rating scores for trade-dependent countries are statistically significant at the 1% level.

Table 6

Contagion effect of UG, DG, UGN, and DGN on firm risk measured through the annualized standard deviation of daily stock returns We use the annualized standard deviation of daily stock returns to obtain the contagion effect of each sample firm. UG_DEP, DG_DEP, UGN_DEP, and DGN_DEP are obtained from S&P sovereign credit rating history data. UG_DEP is a dummy variable to know whether the country's sovereign credit rating was upgraded at time t-1, 1 represents credit rating upgraded, and zero otherwise; DG_DEP is a dummy variable to know whether the country's sovereign credit rating was downgraded at time t-1, 1 represents credit rating downgraded, and zero otherwise. UGN_DEP is the country credit rating score changes that occur at time t-1 of the positive rating event and zero otherwise; DGN_DEP is the absolute country credit rating score changes that occur at time t-1 of the negative rating event and zero otherwise. Among the control variables, firm size ($SIZE\_MV$) is the natural logarithm of market value; the debt ratio (LEV) is the total debt to total assets; return on assets (ROA) is the net income to total assets; the sales growth ratio ($Sales\_growth$) is the ratio change in net sales in the previous year; the market-to-book ratio (MB) is the proportion of a firm's market capitalization to its book value; the research and development (RD) is the ratio of R&D expenses to total assets; the dividend payout ratio (DIV) is the ratio of dividend payments to profit after interest and tax; the capital expenditure expense ratio ($CapExp$) is the ratio of capital expenditure divided by total sales; tangibility (FA) is the value of plant, property, and equipment over total assets; financial slack (FS) is cash and short-term investments divided by total assets; and the implied volatilities of a range of S&P 500 index options are used to calculate VIX (VIX). Control variables include dummies for country, industry, and year. The SIC code and the industry classification of Fama and French [62] are used to classify industry dummy variables. ***, **, and * represent 1%, 5%, and 10% significance levels.

	(1)	(2)	(3)	(4)
Intercept	7.3475***	7.3470***	6.9101***	6.9091***
	(0.0490)	(0.0490)	(0.0534)	(0.0534)
UG_DEP	−0.0546***		−0.0546***	
	(0.0183)		(0.0183)	
DG_DEP	0.0768***		0.0768***	
	(0.0240)		(0.0240)	
UGN_DEP		−0.0552***		−0.0552***
		(0.0175)		(0.0175)
DGN_DEP		0.0412***		0.0412***
		(0.0125)		(0.0125)
SIZE_MV	−0.3219***	−0.3219***	−0.3219***	−0.3219***
	(0.0038)	(0.0038)	(0.0038)	(0.0038)
LEV	0.6551***	0.6544***	0.6551***	0.6544***
	(0.0252)	(0.0252)	(0.0252)	(0.0252)
ROA	−1.6131***	−1.6131***	−1.6131***	−1.6131***
	(0.1634)	(0.1634)	(0.1634)	(0.1634)
Sales_growth	−0.0220	−0.0219	−0.0220	−0.0219
	(0.0192)	(0.0192)	(0.0192)	(0.0192)
MB	0.1425***	0.1425***	0.1425***	0.1425***
	(0.0064)	(0.0064)	(0.0064)	(0.0064)
DIV	−9.7074***	−9.7077***	−9.7074***	−9.7077***
	(0.3364)	(0.3364)	(0.3364)	(0.3364)
CapExp	0.4498***	0.4498***	0.4498***	0.4498***
	(0.0872)	(0.0872)	(0.0872)	(0.0872)
FA	−0.5929***	−0.5927***	−0.5929***	−0.5927***
	(0.0247)	(0.0247)	(0.0247)	(0.0247)
FS	0.4564***	0.4564***	0.4564***	0.4564***
	(0.0365)	(0.0365)	(0.0365)	(0.0365)
VIX			0.0243***	0.0243***
			(0.0008)	(0.0008)
Country dummies	Included	Included	Included	Included
Year dummies	Included	Included	Included	Included
Industry dummies	Included	Included	Included	Included
Adj.R^2	0.3841	0.3841	0.3841	0.3841
F-value	1305.61***	1305.7***	1305.61***	1305.7***
Number of Countries	68	68	68	68
Observations	184,048	184,048	184,048	184,048

Table 7 delineates the contagion effect through the lens of the annualized standard deviation of return on assets. A salient observation is the negative correlation between trade-dependent countries' rising sovereign credit ratings and the contagion effect. The coefficients of *UG_DEP* and *UGN_DEP* are −0.0028 and −0.0027, respectively, both significant at the 5% level, suggesting that as a country's sovereign credit rating escalates, its trading partners experience a reduction in the spillover effect. Additionally, control variables such as *SIZE_MV*, *ROA*, *DIV*, *FA*, and *VIX* negatively correlate with firm risk. Meanwhile, *LEV*, *MB*, *CapExp*, and *FS* display a positive association.

Table 8 presents the contagion effect, using the total factor productivity standard deviation as a proxy for firm risk. The coefficient of *UG_DEP* is −0.0535, implying that when a trade-dependent country experiences a credit rating uplift, its trading partners observe a mitigated propagation of firm risk. In contrast, the coefficient of *DG_DEP* is 0.0086, suggesting that a credit rating decrement in one trade-linked country can elevate the contagion risk for its counterparts. This observation aligns with Hypothesis 2. Furthermore, the coefficients of *UGN_DEP* and *DGN_DEP*, −0.0505 and 0.0052, respectively, indicate that shifts in credit rating scores in one country can either attenuate or amplify firm risk in its trading allies.

Table 7

Contagion effect of UG, DG, UGN, and DGN on firm risk measured through the annualized standard deviation of return on assets We use the annualized standard deviation of return on assets to obtain the contagion effect of each sample firm. *UG_DEP*, *DG_DEP*, *UGN_DEP*, and *DGN_DEP* are obtained from S&P sovereign credit rating history data. *UG_DEP* is a dummy variable to know whether the country's sovereign credit rating was upgraded at time *t*-1, 1 represents credit rating upgraded, and zero otherwise; *DG_DEP* is a dummy variable to know whether the country's sovereign credit rating was downgraded at time *t*-1, 1 represents credit rating downgraded, and zero otherwise. *UGN_DEP* is the country credit rating score changes that occur at time *t*-1 of the positive rating event and zero otherwise; *DGN_DEP* is the absolute country credit rating score changes that occur at time *t*-1 of the negative rating event and zero otherwise. Among the control variables, firm size (*SIZE_MV*) is the natural logarithm of market value; the debt ratio (*LEV*) is the total debt to total assets; return on assets (*ROA*) is the net income to total assets; the sales growth ratio (*Sales_growth*) is the ratio change in net sales in the previous year; the market-to-book ratio (*MB*) is the proportion of a firm's market capitalization to its book value; the research and development (*RD*) is the ratio of R&D expenses to total assets; the dividend payout ratio (*DIV*) is the ratio of dividend payments to profit after interest and tax; the capital expenditure expense ratio (*CapExp*) is the ratio of capital expenditure divided by total sales; tangibility (*FA*) is the value of plant, property, and equipment over total assets; financial slack (*FS*) is cash and short-term investments divided by total assets; and the implied volatilities of a range of S&P 500 index options are used to calculate VIX (*VIX*). Control variables include dummies for country, industry, and year. The SIC code and the industry classification of Fama and French [62] are used to classify industry dummy variables. ***, **, and * represent 1%, 5%, and 10% significance levels.

	(1)	(2)	(3)	(4)
Intercept	0.1870***	0.1871***	0.1906***	0.1907***
	(0.0031)	(0.0031)	(0.0033)	(0.0033)
UG_DEP	−0.0028**		−0.0028**	
	(0.0012)		(0.0012)	
DG_DEP	−0.0011		−0.0011	
	(0.0015)		(0.0015)	
UGN_DEP		−0.0027**		−0.0027**
		(0.0011)		(0.0011)
DGN_DEP		−0.0008		−0.0008
		(0.0007)		(0.0007)
SIZE_MV	−0.0087***	−0.0087***	−0.0087***	−0.0087***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
LEV	0.0026*	0.0026*	0.0026*	0.0026*
	(0.0014)	(0.0014)	(0.0014)	(0.0014)
ROA	−0.1302***	−0.1302***	−0.1302***	−0.1302***
	(0.0142)	(0.0142)	(0.0142)	(0.0142)
Sales_growth	−0.0009	−0.0009	−0.0009	−0.0009
	(0.0014)	(0.0014)	(0.0014)	(0.0014)
MB	0.0102***	0.0102***	0.0102***	0.0102***
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
DIV	−0.2395***	−0.2395***	−0.2395***	−0.2395***
	(0.0260)	(0.0260)	(0.0260)	(0.0260)
CapExp	0.0230***	0.0230***	0.0230***	0.0230***
	(0.0055)	(0.0055)	(0.0055)	(0.0055)
FA	−0.0286***	−0.0286***	−0.0286***	−0.0286***
	(0.0013)	(0.0013)	(0.0013)	(0.0013)
FS	0.0345***	0.0345***	0.0345***	0.0345***
	(0.0025)	(0.0025)	(0.0025)	(0.0025)
VIX			−0.0002***	−0.0002***
			(0.00004)	(0.00004)
Country dummies	Included	Included	Included	Included
Year dummies	Included	Included	Included	Included
Industry dummies	Included	Included	Included	Included
Adj.R^2	0.2892	0.2892	0.2892	0.2892
F-value	850.29***	850.3***	850.29***	850.3***
Number of Countries	68	68	68	68
Observations	184,048	184,048	184,048	184,048

Table 8

Contagion effect of UG, DG, UGN, and DGN on firm risk measured through the standard deviation of total factor productivity We use the standard deviation of total factor productivity to obtain the contagion effect of each sample firm. *UG_DEP*, *DG_DEP*, *UGN_DEP*, and *DGN_DEP* are obtained from S&P sovereign credit rating history data. *UG_DEP* is a dummy variable to know whether the country's sovereign credit rating was upgraded at time *t*-1, 1 represents credit rating upgraded, and zero otherwise; *DG_DEP* is a dummy variable to know whether the country's sovereign credit rating was downgraded at time *t*-1, 1 represents credit rating downgraded, and zero otherwise. *UGN_DEP* is the country credit rating score changes that occur at time *t*-1 of the positive rating event and zero otherwise; *DGN_DEP* is the absolute country credit rating score changes that occur at time *t*-1 of the negative rating event and zero otherwise. Among the control variables, firm size (*SIZE_MV*) is the natural logarithm of market value; the debt ratio (*LEV*) is the total debt to total assets; return on assets (*ROA*) is the net income to total assets; the sales growth ratio (*Sales_growth*) is the ratio change in net sales in the previous year; the market-to-book ratio (*MB*) is the proportion of a firm's market capitalization to its book value; the research and development (*RD*) is the ratio of R&D expenses to total assets; the dividend payout ratio (*DIV*) is the ratio of dividend payments to profit after interest and tax; the capital expenditure expense ratio (*CapExp*) is the ratio of capital expenditure divided by total sales; tangibility (*FA*) is the value of plant, property, and equipment over total assets; financial slack (*FS*) is cash and short-term investments divided by total assets; and the implied volatilities of a range of S&P 500 index options are used to calculate VIX (*VIX*). Control variables include dummies for country, industry, and year. The SIC code and the industry classification of Fama and French [62] are used to classify industry dummy variables. ***, **, and * represent 1%, 5%, and 10% significance levels.

	(1)	(2)	(3)	(4)
Intercept	0.3824***	0.3822***	0.3929***	0.3926***
	(0.0064)	(0.0064)	(0.0073)	(0.0073)
UG_DEP	−0.0535***		−0.0535***	
	(0.0022)		(0.0022)	
DG_DEP	0.0086**		0.0086**	
	(0.0044)		(0.0044)	
UGN_DEP		−0.0505***		−0.0505***
		(0.0021)		(0.0021)
DGN_DEP		0.0052***		0.0052***
		(0.0020)		(0.0020)
SIZE_MV	−0.0158***	−0.0158***	−0.0158***	−0.0158***
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
LEV	−0.0091**	−0.0092**	−0.0091**	−0.0092**
	(0.0037)	(0.0037)	(0.0037)	(0.0037)
ROA	−0.1660***	−0.1660***	−0.1660***	−0.1660***
	(0.0204)	(0.0204)	(0.0204)	(0.0204)
Sales_growth	−0.0064*	−0.0063*	−0.0064*	−0.0063*
	(0.0035)	(0.0035)	(0.0035)	(0.0035)
MB	0.0159***	0.0159***	0.0159***	0.0159***
	(0.0009)	(0.0009)	(0.0009)	(0.0009)
DIV	−0.6286***	−0.6288***	−0.6286***	−0.6288***
	(0.0437)	(0.0437)	(0.0437)	(0.0437)
CapExp	−0.0193	−0.0191	−0.0193	−0.0191
	(0.0151)	(0.0151)	(0.0151)	(0.0151)
FA	−0.0037	−0.0037	−0.0037	−0.0037
	(0.0039)	(0.0039)	(0.0039)	(0.0039)
FS	0.1437***	0.1437***	0.1437***	0.1437***
	(0.0066)	(0.0066)	(0.0066)	(0.0066)
VIX			−0.0006***	−0.0006***
			(0.0001)	(0.0001)
Country dummies	Included	Included	Included	Included
Year dummies	Included	Included	Included	Included
Industry dummies	Included	Included	Included	Included
Adj.R^2	0.2054	0.2053	0.2054	0.2053
F-value	505.68***	505.46***	505.68***	505.46***
Number of Countries	68	68	68	68
Observations	184,048	184,048	184,048	184,048

4.4. Comparison between developed and developing countries

In studies, such as Neumeyer and Perri [63], Uribe and Yue [64], and Arellano [65], it is posited that emerging markets exhibit greater countercyclical interest and volatility compared to developed markets. Such characteristics make them more susceptible to economic instability and heightened country risk. This leads to the inference that the ramifications of sovereign rating shifts on firm risk could vary between developed and developing markets. To explore this distinction, we segregate our sample data into developed and developing markets, as detailed in Appendix 2, and examine the repercussions of sovereign credit rating and contagion effects on firm risk.

Table 9 reveals the influences of *UG*, *DG*, *UGN*, and *DGN* on the firm risk across both market categories. It is observed that for both developed and developing markets, *UG* and *UGN* significantly reduce firm risk. This implies that an upgrade in a country's rating or an increased rating score results in diminished firm risk. Conversely, *DG* and *DGN* amplify firm risk, suggesting that the firm risk escalates if a country's rating is downgraded or its downgrade rating score rises. Notably, the susceptibility of firm risk in developed markets to

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Table 9

Effects of UG, DG, UGN, and DGN on firm risk across developed and developing economies The economic development status (developed economies versus developing economies) is classified according to the World Bank. We use the annualized standard deviation of daily stock returns, the annualized standard deviation of return on assets, and the standard deviation of total factor productivity to obtain the risk of each sample firm. *UG*, *DG*, *UGN*, and *DGN* are obtained from S&P sovereign credit rating history data. *UG* is a dummy variable to know whether the country's sovereign credit rating was upgraded in the year, 1 represents credit rating upgraded, and zero otherwise; *DG* is a dummy variable to know whether the country's sovereign credit rating was downgraded in the year, 1 represents credit rating downgraded, and zero otherwise. *UGN* is the score of sovereign credit rating in year *t*-1 of the positive rating event and zero otherwise; *DGN* is the absolute change score of sovereign credit rating in year *t*-1 of the negative rating event, and zero otherwise. Among the control variables, firm size (*SIZE_MV*) is the natural logarithm of market value; the debt ratio (*LEV*) is the total debt to total assets; return on assets (*ROA*) is the net income to total assets; the sales growth ratio (*Sales_growth*) is the ratio change in net sales in the previous year; the market-to-book ratio (*MB*) is the proportion of a firm's market capitalization to its book value; the research and development (*RD*) is the ratio of R&D expenses to total assets; the dividend payout ratio (*DIV*) is the ratio of dividend payments to profit after interest and tax; the capital expenditure expense ratio (*CapExp*) is the ratio of capital expenditure divided by total sales; tangibility (*FA*) is the value of plant, property, and equipment over total assets; financial slack (*FS*) is cash and short-term investments divided by total assets; and the implied volatilities of a range of S&P 500 index options are used to calculate VIX (*VIX*). Control variables include dummies for country, industry, and year. The SIC code and the industry classification of Fama and French [62] are used to classify industry dummy variables. ***, **, and * represent 1%, 5%, and 10% significance levels.

	Developed Economies						Developing Economies					
	Annualized standard deviation of daily stock returns		Annualized standard deviation of return on assets		Standard deviation of total factor productivity		Annualized standard deviation of daily stock returns		Annualized standard deviation of return on assets		Standard deviation of total factor productivity	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Intercept	6.6468***	6.6216***	0.1869***	0.1863***	0.3840***	0.3827***	5.3657***	5.3728***	0.1211***	0.1213***	0.3179***	0.3194***
	(0.0585)	(0.0584)	(0.0036)	(0.0036)	(0.0081)	(0.0080)	(0.0684)	(0.0683)	(0.0029)	(0.0029)	(0.0096)	(0.0097)
UG	−0.1484***		−0.0073***		−0.0249***		−0.0622***		−0.0030***		−0.0152***	
	(0.0142)		(0.0008)		(0.0020)		(0.0151)		(0.0006)		(0.0017)	
DG	−0.0184		0.0002		0.0007		0.1982***		0.0030*		0.0195***	
	(0.0158)		(0.0009)		(0.0026)		(0.0343)		(0.0016)		(0.0041)	
UGN		−0.0649***		−0.0049***		−0.0188***		−0.0210**		−0.0023***		−0.0099***
		(0.0120)		(0.0006)		(0.0015)		(0.0107)		(0.0004)		(0.0012)
DGN		0.0281***		0.0005*		0.0006		0.0874***		0.0005		0.0064***
		(0.0055)		(0.0003)		(0.0008)		(0.0131)		(0.0005)		(0.0016)
SIZE_MV	−0.3221***	−0.3222***	−0.0087***	−0.0087***	−0.0157***	−0.0157***	−0.1870***	−0.1874***	−0.0040***	−0.0040***	−0.0090***	−0.0091***
	(0.0043)	(0.0043)	(0.0003)	(0.0003)	(0.0005)	(0.0005)	(0.0038)	(0.0038)	(0.0002)	(0.0002)	(0.0004)	(0.0004)
LEV	0.7250***	0.7223***	−0.0015	−0.0014	0.0005	0.0008	0.6662***	0.6646***	0.0197***	0.0198***	−0.0309***	−0.0308***
	(0.0273)	(0.0273)	(0.0016)	(0.0016)	(0.0043)	(0.0043)	(0.0411)	(0.0411)	(0.0018)	(0.0018)	(0.0048)	(0.0048)
ROA	−1.5593***	−1.5607***	−0.1177***	−0.1178***	−0.1588***	−0.1588***	−2.2316***	−2.2242***	−0.1135***	−0.1134***	−0.1844***	−0.1837***
	(0.2010)	(0.2012)	(0.0161)	(0.0161)	(0.0210)	(0.0210)	(0.1170)	(0.1171)	(0.0068)	(0.0068)	(0.0144)	(0.0144)
Sales_growth	−0.0616***	−0.0552**	0.0001	0.0003	−0.0020	−0.0018	0.0096	0.0137	−0.0060***	−0.0061***	−0.0115***	−0.0115***
	(0.0236)	(0.0237)	(0.0017)	(0.0017)	(0.0042)	(0.0042)	(0.0253)	(0.0253)	(0.0012)	(0.0012)	(0.0040)	(0.0040)
MB	0.1837***	0.1842***	0.0110***	0.0110***	0.0163***	0.0163***	0.0376***	0.0372***	0.0052***	0.0052***	0.0114***	0.0113***
	(0.0080)	(0.0080)	(0.0005)	(0.0005)	(0.0010)	(0.0010)	(0.0047)	(0.0047)	(0.0003)	(0.0003)	(0.0008)	(0.0008)
DIV	−12.1147***	−12.1078***	−0.3543***	−0.3541***	−0.7546***	−0.7541***	−5.4039***	−5.3929***	0.0011	0.0010	−0.2502***	−0.2497***
	(0.4462)	(0.4466)	(0.0328)	(0.0328)	(0.0550)	(0.0550)	(0.2657)	(0.2658)	(0.0112)	(0.0112)	(0.0339)	(0.0339)
CapExp	0.4699***	0.4664***	0.0257***	0.0255***	−0.0081	−0.0091	−0.5079***	−0.5140***	−0.0217***	−0.0217***	−0.0977***	−0.0981***
	(0.1035)	(0.1035)	(0.0063)	(0.0063)	(0.0191)	(0.0191)	(0.1136)	(0.1136)	(0.0052)	(0.0052)	(0.0147)	(0.0147)
FA	−0.7237***	−0.7236***	−0.0347***	−0.0347***	−0.0005	−0.0004	−0.2631***	−0.2620***	−0.0180***	−0.0180***	−0.0066	−0.0065
	(0.0279)	(0.0279)	(0.0015)	(0.0015)	(0.0047)	(0.0047)	(0.0369)	(0.0369)	(0.0017)	(0.0017)	(0.0052)	(0.0052)
FS	0.4136***	0.4141***	0.0281***	0.0281***	0.1427***	0.1430***	0.0201	0.0195	0.0010	0.0010	0.0165*	0.0164*
	(0.0376)	(0.0376)	(0.0024)	(0.0024)	(0.0069)	(0.0069)	(0.0577)	(0.0577)	(0.0029)	(0.0029)	(0.0099)	(0.0099)
VIX	0.0292***	0.0299***	−0.0001***	−0.0001**	−0.0005***	−0.0005***	0.0130***	0.0129***	−0.00004	−0.00004	−0.0005***	−0.0006***
	(0.0009)	(0.0009)	(0.00005)	(0.00005)	(0.0001)	(0.0001)	(0.0013)	(0.0013)	(0.0001)	(0.0001)	(0.0002)	(0.0002)
Country dummies	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Year dummies	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Industry dummies	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Adj.R^2	0.4215	0.4215	0.3010	0.3009	0.2172	0.2171	0.2562	0.2563	0.0957	0.0957	0.1211	0.1208
F-value	1460.09***	1459.65***	852.83***	852.55***	548.03***	547.85***	266.53***	266.61***	84.43***	84.37***	108.81***	108.47***
Number of countries	36	36	36	36	36	36	32	32	32	32	32	32
Observations	137,941	137,941	137,941	137,941	137,941	137,941	46,107	46,107	46,107	46,107	46,107	46,107

Table 10

Contagion effects of UG, DG, UGN, and DGN on firm risk across developed and developing economies The economic development status (developed economies versus developing economies) is classified according to the World Bank. We use the annualized standard deviation of daily stock returns, the annualized standard deviation of return on assets, and the standard deviation of total factor productivity to obtain the contagion effect of each sample firm. *UG*, *DG*, *UGN*, and *DGN* are obtained from S&P sovereign credit rating history data. *UG* is a dummy variable to know whether the country's sovereign credit rating was upgraded in the year, 1 represents credit rating upgraded, and zero otherwise; *DG* is a dummy variable to know whether the country's sovereign credit rating was downgraded in the year, 1 represents credit rating downgraded, and zero otherwise. *UGN* is the score of sovereign credit rating in year *t*-1 of the positive rating event and zero otherwise; *DGN* is the absolute change score of sovereign credit rating in year *t*-1 of the negative rating event and zero otherwise. Among the control variables, firm size (*SIZE_MV*) is the natural logarithm of market value; the debt ratio (*LEV*) is the total debt to total assets; return on assets (*ROA*) is the net income to total assets; the sales growth ratio (*Sales_growth*) is the ratio change in net sales in the previous year; the market-to-book ratio (*MB*) is the proportion of a firm's market capitalization to its book value; the research and development (*RD*) is the ratio of R&D expenses to total assets; the dividend payout ratio (*DIV*) is the ratio of dividend payments to profit after interest and tax; the capital expenditure expense ratio (*CapExp*) is the ratio of capital expenditure divided by total sales; tangibility (*FA*) is the value of plant, property, and equipment over total assets; financial slack (*FS*) is cash and short-term investments divided by total assets; and the implied volatilities of a range of S&P 500 index options are used to calculate VIX (*VIX*). Control variables include dummies for country, industry, and year. The SIC code and the industry classification of Fama and French [62] are used to classify industry dummy variables. ***, **, and * represent 1%, 5%, and 10% significance levels.

	Developed Economies						Developing Economies					
	Annualized standard deviation of daily stock returns		Annualized standard deviation of return on assets		Standard deviation of total factor productivity		Annualized standard deviation of daily stock returns		Annualized standard deviation of return on assets		Standard deviation of total factor productivity	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Intercept	6.7834***	6.7832***	0.1937***	0.1938***	0.3897***	0.3894***	5.4619***	5.4611***	0.1274***	0.1273***	0.3179***	0.3194***
	(0.0622)	(0.0622)	(0.0039)	(0.0039)	(0.0087)	(0.0087)	(0.0709)	(0.0709)	(0.0033)	(0.0033)	(0.0096)	(0.0097)
UG_DEP	−0.0981***		−0.0037***		−0.0557***		−0.0153		0.0004		−0.0152***	
	(0.0207)		(0.0013)		(0.0026)		(0.0376)		(0.0018)		(0.0017)	
DG_DEP	0.0265		−0.0018		0.0063		0.2724***		0.0037**		0.0195***	
	(0.0308)		(0.0020)		(0.0059)		(0.0373)		(0.0018)		(0.0041)	
UGN_DEP		−0.0944***		−0.0034***		−0.0521***		−0.0203		0.00003		−0.0099***
		(0.0198)		(0.0012)		(0.0025)		(0.0360)		(0.0018)		(0.0012)
DGN_DEP		0.0123		−0.0013		0.0037		0.1370***		0.0017*		0.0064***
		(0.0141)		(0.0008)		(0.0025)		(0.0183)		(0.0009)		(0.0016)
SIZE_MV	−0.3356***	−0.3356***	−0.0093***	−0.0093***	−0.0162***	−0.0162***	−0.1895***	−0.1895***	−0.0044***	−0.0044***	−0.0090***	−0.0091***
	(0.0045)	(0.0045)	(0.0003)	(0.0003)	(0.0005)	(0.0005)	(0.0041)	(0.0041)	(0.0002)	(0.0002)	(0.0004)	(0.0004)
LEV	0.6916***	0.6913***	−0.0049***	−0.0049***	0.0002	0.0001	0.6899***	0.6885***	0.0203***	0.0203***	−0.0309***	−0.0308***
	(0.0302)	(0.0302)	(0.0017)	(0.0017)	(0.0047)	(0.0047)	(0.0417)	(0.0417)	(0.0020)	(0.0020)	(0.0048)	(0.0048)
ROA	−1.5099***	−1.5099***	−0.1200***	−0.1200***	−0.1540***	−0.1540***	−2.1807***	−2.1790***	−0.1240***	−0.1240***	−0.1844***	−0.1837***
	(0.1954)	(0.1954)	(0.0169)	(0.0169)	(0.0211)	(0.0211)	(0.1169)	(0.1169)	(0.0080)	(0.0080)	(0.0144)	(0.0144)
Sales_growth	−0.0748***	−0.0747***	−0.0003	−0.0003	−0.0007	−0.0006	−0.0169	−0.0170	−0.0072***	−0.0072***	−0.0115***	−0.0115***
	(0.0263)	(0.0263)	(0.0018)	(0.0018)	(0.0047)	(0.0047)	(0.0257)	(0.0257)	(0.0014)	(0.0014)	(0.0040)	(0.0040)
MB	0.1799***	0.1799***	0.0113***	0.0113***	0.0153***	0.0153***	0.0322***	0.0323***	0.0057***	0.0057***	0.0114***	0.0113***
	(0.0083)	(0.0083)	(0.0006)	(0.0006)	(0.0011)	(0.0011)	(0.0048)	(0.0048)	(0.0003)	(0.0003)	(0.0008)	(0.0008)
DIV	−11.5863***	−11.5855***	−0.3554***	−0.3554***	−0.7166***	−0.7164***	−5.2920***	−5.2915***	0.0159	0.0159	−0.2502***	−0.2497***
	(0.4500)	(0.4500)	(0.0348)	(0.0348)	(0.0565)	(0.0565)	(0.2654)	(0.2653)	(0.0129)	(0.0129)	(0.0339)	(0.0339)
CapExp	0.4367***	0.4365***	0.0294***	0.0294***	−0.0061	−0.0060	−0.5522***	−0.5520***	−0.0295***	−0.0295***	−0.0977***	−0.0981***
	(0.1219)	(0.1219)	(0.0076)	(0.0076)	(0.0222)	(0.0222)	(0.1158)	(0.1158)	(0.0057)	(0.0057)	(0.0147)	(0.0147)
FA	−0.7536***	−0.7535***	−0.0349***	−0.0349***	0.0030	0.0030	−0.3240***	−0.3237***	−0.0185***	−0.0185***	−0.0066	−0.0065
	(0.0317)	(0.0317)	(0.0017)	(0.0017)	(0.0051)	(0.0051)	(0.0382)	(0.0382)	(0.0019)	(0.0019)	(0.0052)	(0.0052)
FS	0.4275***	0.4274***	0.0300***	0.0300***	0.1534***	0.1534***	0.0177	0.0167	0.0001	0.0001	0.0165*	0.0164*
	(0.0420)	(0.0420)	(0.0027)	(0.0027)	(0.0076)	(0.0076)	(0.0590)	(0.0590)	(0.0034)	(0.0034)	(0.0099)	(0.0099)
VIX	0.0315***	0.0315***	−0.0001*	−0.0001*	−0.0005***	−0.0005***	0.0126***	0.0127***	−0.00001	−0.00001	−0.0005***	−0.0006***
	(0.0010)	(0.0010)	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0013)	(0.0013)	(0.0001)	(0.0001)	(0.0002)	(0.0002)
Country dummies	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Year dummies	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Industry dummies	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Adj.R²	0.4175	0.4175	0.3150	0.3150	0.2176	0.2175	0.264	0.2641	0.0935	0.0935	0.1211	0.1208
F-value	1324.42***	1324.41***	842.73***	842.75***	510.43***	510.08***	266.25***	266.34***	79.01***	79.01***	108.81***	108.47***
Number of countries	36	36	36	36	36	36	32	32	32	32	32	32
Observations	137,941	137,941	137,941	137,941	137,941	137,941	46,107	46,107	46,107	46,107	46,107	46,107

sovereign credit rating upgrades is more pronounced than in developing markets. Specifically, the decline in firm risk in developed markets is more substantial when there's an increase in the upgrade score or an improvement in the sovereign credit rating. On the other hand, the firm risk in developing markets is more acutely sensitive to downgrades. This could allude to the inherent political and economic instabilities in developing markets, implying that the surge in firm risk in these markets surpasses that in developed markets when faced with a sovereign credit rating downgrade or a rising downgrade score.

Table 10 investigates the contagion effect on firm risk across both country cohorts. We discern that *UG_DEP* and *UGN_DEP* have a markedly negative influence on all firm risk variables in developed markets, suggesting that when a trade-dependent country experiences an improvement in its credit rating or its score rises, the reduction in firm risk in developed markets exceeds that in developing markets. Such a finding indicates a more potent contagion effect in developed markets in response to positive credit rating changes. Conversely, *DG_DEP* and *DGN_DEP* exert a pronounced positive impact on firm risk in developing markets, implying that when a trade-dependent country undergoes a decline in its credit rating score or faces a downgrade, the contagion effect is more intense in developing markets than in developed counterparts.

4.5. Non-financial crisis periods

Prior studies underscore that fluctuations in sovereign credit ratings manifest more pronounced effects during financial crises than non-crisis periods [3,66,67]. An examination of Fig. 1 reveals that many countries experienced downgrades in their sovereign credit ratings during the Asian and global financial crises. To ensure the reliability of our findings in previous sections, we scrutinize the repercussions of changes in sovereign credit ratings on firm risk during non-financial crises and assess the consistency of these outcomes with those observed during financial crises.

Table 11 elucidates the influence of *UG*, *DG*, *UGN*, and *DGN* on firm risk in non-financial crises. Specifically, *UG* exerts a significant adverse effect on firm risk with coefficients of −0.0687, −0.0047, and −0.0194, suggesting that an upgrade in a country's sovereign credit rating leads to a decline in firm risk, aligning with Hypothesis 1. Conversely, *DG* positively correlates with firm risk, implying an increase in firm risk following a downgrade in the country's sovereign credit rating. Furthermore, the coefficients for *UGN* stand at −0.0217, −0.0032, and −0.0132, underscoring that a rise in the sovereign credit rating score is associated with reduced firm risk. In contrast, *DGN*'s positive correlation indicates that a heightened frequency of sovereign credit rating downgrades amplifies firm risk.

Table 12 unveils the contagion effect during non-financial crisis periods. It is observed that when trade-dependent countries experience upgrades in their sovereign credit ratings, there's a concomitant reduction in the firm risk of other countries, as evidenced by *UG_DEP* coefficients of −0.0525, −0.0028, and −0.0496. Similarly, *UGN_DEP* showcases a negative correlation with firm risk with coefficients of −0.0536, −0.0026, and −0.0469, suggesting that as trade-dependent countries' sovereign credit rating scores ascend, the firm risk in other nations diminishes. Conversely, both *DG_DEP* and *DGN_DEP* manifest positive correlations with firm risk. Specifically, the coefficients for *DG_DEP* are 0.1196 and 0.0078, implying that sovereign credit rating downgrades in trade-dependent countries escalate firm risk in other countries. With *DGN_DEP* coefficients of 0.0458 and 0.0043 (both significant at the 5% level), it's evident that a declining rating score in trade-dependent countries augments the firm risk in other countries, endorsing Hypothesis 2.

Synthesizing the findings from Tables 11 and 12, it's evident that the outcomes during non-financial crisis periods corroborate prior observations. Notably, Table 12 supports a contagion effect even outside financial crises.

5. Conclusion, limitations, and future research directions

Previous research has scarcely examined the influence of sovereign credit ratings on firm risk. In our study, we delved deep into this nexus, examining a comprehensive dataset of 20,333 firms from 68 countries. We discovered a clear empirical relationship: improved
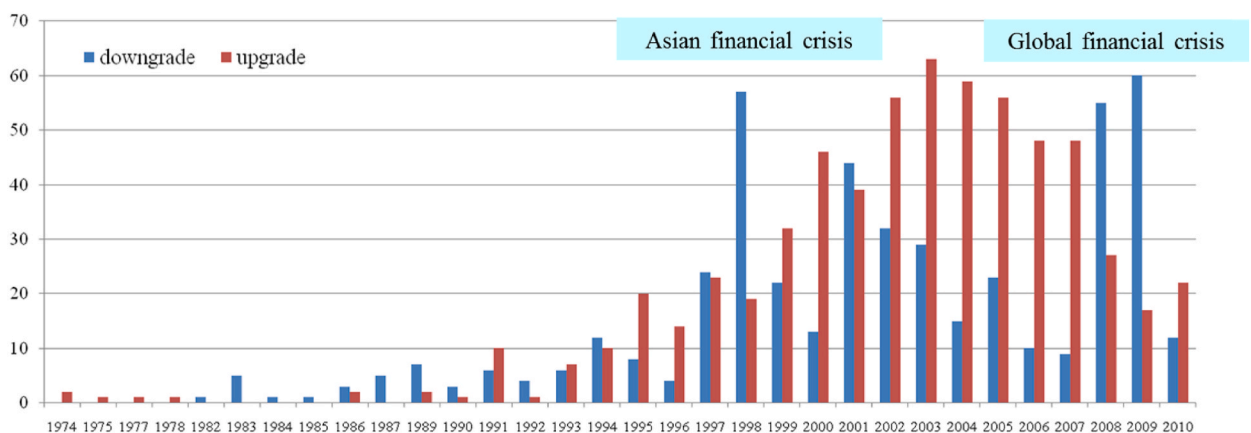

Fig. 1. Financial crisis and sovereign credit rating changes.

Table 11

Effects of UG, DG, UGN, and DGN on firm risk in non-financial crisis periods We use the annualized standard deviation of daily stock returns, the annualized standard deviation of return on assets, and the standard deviation of total factor productivity as three methods to obtain the risk effect of each sample firm during the non-financial crisis period. *UG*, *DG*, *UGN*, and *DGN* are obtained from S&P sovereign credit rating history data. *UG* is a dummy variable to know whether the country's sovereign credit rating was upgraded in the year, 1 represents credit rating upgraded, and zero otherwise; *DG* is a dummy variable to know whether the country's sovereign credit rating was downgraded in the year, 1 represents credit rating downgraded, and zero otherwise. *UGN* is the score of sovereign credit rating in year t-1 of the positive rating event and zero otherwise; *DGN* is the absolute change score of sovereign credit rating in year t-1 of the negative rating event, and zero otherwise. Among the control variables, firm size (*SIZE_MV*) is the natural logarithm of market value; the debt ratio (*LEV*) is the total debt to total assets; return on assets (*ROA*) is the net income to total assets; the sales growth ratio (*Sales_growth*) is the ratio change in net sales in the previous year; the market-to-book ratio (*MB*) is the proportion of a firm's market capitalization to its book value; the research and development (*RD*) is the ratio of R&D expenses to total assets; the dividend payout ratio (*DIV*) is the ratio of dividend payments to profit after interest and tax; the capital expenditure expense ratio (*CapExp*) is the ratio of capital expenditure divided by total sales; tangibility (*FA*) is the value of plant, property, and equipment over total assets; financial slack (*FS*) is cash and short-term investments divided by total assets; and the implied volatilities of a range of S&P 500 index options are used to calculate VIX (*VIX*). Control variables include dummies for country, industry, and year. The SIC code and the industry classification of Fama and French [62] are used to classify industry dummy variables. ***, **, and * represent 1%, 5%, and 10% significance levels.

	Annualized standard deviation of daily stock returns		Annualized standard deviation of return on assets		Standard deviation of total factor productivity	
	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	6.5221***	6.5132***	0.1743***	0.1742***	0.3790***	0.3784***
	(0.0538)	(0.0538)	(0.0031)	(0.0031)	(0.0070)	(0.0070)
UG	−0.0687***		−0.0047***		−0.0194***	
	(0.0100)		(0.0005)		(0.0012)	
DG	0.0043		0.0005		0.0088***	
	(0.0141)		(0.0007)		(0.0021)	
UGN		−0.0217***		−0.0032***		−0.0132***
		(0.0078)		(0.0003)		(0.0009)
DGN		0.0248***		0.0002		0.0038***
		(0.0061)		(0.0003)		(0.0008)
SIZE_MV	−0.2984***	−0.2984***	−0.0078***	−0.0078***	−0.0149***	−0.0149***
	(0.0040)	(0.0040)	(0.0002)	(0.0002)	(0.0004)	(0.0004)
LEV	0.6679***	0.6671***	0.0026**	0.0027**	−0.0138***	−0.0138***
	(0.0240)	(0.0240)	(0.0013)	(0.0013)	(0.0035)	(0.0035)
ROA	−1.7281***	−1.7289***	−0.1212***	−0.1212***	−0.1686***	−0.1687***
	(0.2200)	(0.2201)	(0.0160)	(0.0160)	(0.0222)	(0.0222)
Sales_growth	−0.0179	−0.0157	−0.0003	−0.0003	−0.0051	−0.0048
	(0.0213)	(0.0214)	(0.0015)	(0.0015)	(0.0034)	(0.0034)
MB	0.1523***	0.1525***	0.0097***	0.0097***	0.0158***	0.0158***
	(0.0067)	(0.0067)	(0.0004)	(0.0004)	(0.0008)	(0.0008)
DIV	−9.7481***	−9.7360***	−0.2291***	−0.2287***	−0.6382***	−0.6363***
	(0.4014)	(0.4015)	(0.0271)	(0.0271)	(0.0442)	(0.0442)
CapExp	0.3261***	0.3286***	0.0168***	0.0168***	−0.0231*	−0.0233*
	(0.0830)	(0.0830)	(0.0048)	(0.0048)	(0.0139)	(0.0139)
FA	−0.5554***	−0.5563***	−0.0279***	−0.0279***	0.00003	0.0001
	(0.0226)	(0.0226)	(0.0012)	(0.0012)	(0.0036)	(0.0036)
FS	0.4712***	0.4723***	0.0292***	0.0293***	0.1277***	0.1279***
	(0.0338)	(0.0338)	(0.0021)	(0.0021)	(0.0060)	(0.0060)
VIX	0.0238***	0.0240***	−0.0001***	−0.0001***	−0.0005***	−0.0005***
	(0.0007)	(0.0007)	(0.00004)	(0.00004)	(0.0001)	(0.0001)
Country dummies	Included	Included	Included	Included	Included	Included
Year dummies	Included	Included	Included	Included	Included	Included
Industry dummies	Included	Included	Included	Included	Included	Included
Adj.R^2	0.3789	0.3789	0.2691	0.2691	0.2027	0.2026
F-value	1219.68***	1219.56***	734.06***	733.89***	504.74***	504.45***
Number of Countries	68	68	68	68	68	68
Observations	184,048	184,048	184,048	184,048	184,048	184,048

sovereign credit ratings corresponded to reduced firm risk, while downgrades were associated with heightened risk levels. This relationship was further accentuated when considering the contagion effect among nations with trade linkages. When one nation experienced a rating upgrade, its trading partner typically exhibited diminished firm risk; conversely, a downgrade had the opposite effect.

When segmenting our sample by the economic status of countries, intriguing nuances emerged. Firm risks in developed markets were more positively influenced by sovereign credit rating upgrades than those in developing markets. However, the adverse effects of rating downgrades were more pronounced in developing economies.

This research endeavors to bridge a gap in current literature. It not only sheds light on the intricate dynamics between firm risk and sovereign credit ratings but also ventures into uncharted territory, probing contagion effects across heterogeneously linked nations. Our observations underscore that during economic disturbances, sovereign credit ratings, particularly downgrades, exhibit marked

Table 12

Contagion effects of UG, DG, UGN, and DGN on firm risk in non-financial crisis periods. We use the annualized standard deviation of daily stock returns, the annualized standard deviation of return on assets, and the standard deviation of total factor productivity as three methods to obtain the contagion effect of each sample firm during the non-financial crisis period. *UG_DEP*, *DG_DEP*, *UGN_DEP*, and *DGN_DEP* are obtained from S&P sovereign credit rating history data. *UG_DEP* is a dummy variable to know whether the country's sovereign credit rating was upgraded at time *t*-1, 1 represents credit rating upgraded, and zero otherwise; *DG_DEP* is a dummy variable to know whether the country's sovereign credit rating was downgraded at time *t*-1, 1 represents credit rating downgraded, and zero otherwise. *UGN_DEP* is the country credit rating score changes that occur at time *t*-1 of the positive rating event and zero otherwise; *DGN_DEP* is the absolute country credit rating score changes that occur at time *t*-1 of the negative rating event and zero otherwise. Among the control variables, firm size (*SIZE_MV*) is the natural logarithm of market value; the debt ratio (*LEV*) is the total debt to total assets; return on assets (*ROA*) is the net income to total assets; the sales growth ratio (*Sales_growth*) is the ratio change in net sales in the previous year; the market-to-book ratio (*MB*) is the proportion of a firm's market capitalization to its book value; the research and development (*RD*) is the ratio of R&D expenses to total assets; the dividend payout ratio (*DIV*) is the ratio of dividend payments to profit after interest and tax; the capital expenditure expense ratio (*CapExp*) is the ratio of capital expenditure divided by total sales; tangibility (*FA*) is the value of plant, property, and equipment over total assets; financial slack (*FS*) is cash and short-term investments divided by total assets; and the implied volatilities of a range of S&P 500 index options are used to calculate VIX (*VIX*). Control variables include dummies for country, industry, and year. The SIC code and the industry classification of Fama and French [62] are used to classify industry dummy variables. ***, **, and * represent 1%, 5%, and 10% significance levels.

	Annualized standard deviation of daily stock returns		Annualized standard deviation of return on assets		Standard deviation of total factor productivity	
	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	6.6680***	6.6679***	0.1807***	0.1807***	0.3902***	0.3900***
	(0.0565)	(0.0565)	(0.0034)	(0.0034)	(0.0074)	(0.0074)
UG_DEP	−0.0525***		−0.0028**		−0.0496***	
	(0.0181)		(0.0011)		(0.0021)	
DG_DEP	0.1196***		0.00000		0.0078*	
	(0.0241)		(0.0015)		(0.0043)	
UGN_DEP		−0.0536***		−0.0026**		−0.0469***
		(0.0173)		(0.0010)		(0.0021)
DGN_DEP		0.0458***		−0.0005		0.0043**
		(0.0114)		(0.0007)		(0.0019)
SIZE_MV	−0.3088***	−0.3088***	−0.0083***	−0.0083***	−0.0155***	−0.0155***
	(0.0042)	(0.0042)	(0.0003)	(0.0003)	(0.0005)	(0.0005)
LEV	0.6618***	0.6613***	0.0009	0.0009	−0.0142***	−0.0143***
	(0.0257)	(0.0257)	(0.0014)	(0.0014)	(0.0037)	(0.0037)
ROA	−1.6781***	−1.6780***	−0.1241***	−0.1241***	−0.1632***	−0.1632***
	(0.2143)	(0.2143)	(0.0168)	(0.0168)	(0.0223)	(0.0223)
Sales_growth	−0.0269	−0.0268	−0.0011	−0.0011	−0.0057	−0.0056
	(0.0225)	(0.0225)	(0.0016)	(0.0016)	(0.0037)	(0.0037)
MB	0.1480***	0.1481***	0.0101***	0.0101***	0.0158***	0.0158***
	(0.0069)	(0.0069)	(0.0005)	(0.0005)	(0.0009)	(0.0009)
DIV	−9.3462***	−9.3513***	−0.2252***	−0.2253***	−0.6216***	−0.6219***
	(0.3984)	(0.3984)	(0.0287)	(0.0287)	(0.0450)	(0.0450)
CapExp	0.3035***	0.3029***	0.0149***	0.0149***	−0.0307**	−0.0306**
	(0.0922)	(0.0922)	(0.0055)	(0.0055)	(0.0153)	(0.0153)
FA	−0.5838***	−0.5839***	−0.0273***	−0.0273***	−0.0002	−0.0003
	(0.0248)	(0.0248)	(0.0013)	(0.0013)	(0.0039)	(0.0039)
FS	0.4989***	0.4983***	0.0308***	0.0308***	0.1323***	0.1323***
	(0.0371)	(0.0371)	(0.0024)	(0.0024)	(0.0066)	(0.0066)
VIX	0.0244***	0.0243***	−0.0001**	−0.0001**	−0.0006***	−0.0006***
	(0.0008)	(0.0008)	(0.00004)	(0.00004)	(0.0001)	(0.0001)
Country dummies	Included	Included	Included	Included	Included	Included
Year dummies	Included	Included	Included	Included	Included	Included
Industry dummies	Included	Included	Included	Included	Included	Included
Adj.R²	0.3778	0.3778	0.2768	0.2768	0.2003	0.2002
F-value	1133.76***	1133.63***	714.91***	714.91***	467.76***	467.53***
Number of Countries	68	68	68	68	68	68
Observations	184,048	184,048	184,048	184,048	184,048	184,048

volatility.

Endogeneity, a perennial concern in econometrics, poses challenges due to omitted variables, measurement errors, and circular causation. For instance, metrics such as research and development are inherently vulnerable to these issues. Our mitigative strategy incorporated instrumental variables and leveraged the intrinsic strengths of panel data. We integrated dummies for countries, industries, and years, the latter aiming to capture potential macroeconomic fluctuations influencing variables like firm risk and the capital expenditure expense ratio. Despite these measures, our fixed-effects panel regression might still harbor some residual biases.

Several promising avenues for future research come into focus. We envision a deeper exploration of the ramifications of sovereign credit rating changes, coupled with other macroeconomic variables such as economic growth, inflation, and unemployment. These variables might more accurately depict the environment preceding or surrounding sovereign credit rating changes, adding a valuable

dimension to this domain of inquiry.

Author contribution statement

Chong-Chuo Chang: conceived and designed the experiments; performed the experiments; analyzed and interpreted the data; contributed reagents, materials, analysis tools or data; wrote the paper.

Wing-Keung Wong: conceived and designed the experiments; analyzed and interpreted the data; wrote the paper.

Shih-Tse Lo: conceived and designed the experiments; analyzed and interpreted the data; wrote the paper.

Yu-Hsuan Liao: conceived and designed the experiments; performed the experiments; analyzed and interpreted the data; contributed reagents, materials, analysis tools or data; wrote the paper.

Data availability statement

The authors do not have permission to share data.

Additional information

No additional information is available for this paper.

Declarations

The following additional information is required for submission. Please note that this form runs over two pages and failure to respond to these questions/statements will mean your submission will be returned to you. **If you have nothing to declare in any of these categories then this should be stated.**

Please state any sources of funding for your research

Ethical approval

Work on human beings that is submitted to *Medical Engineering & Physics* should comply with the principles laid down in the Declaration of Helsinki; Recommendations guiding physicians in biomedical research involving human subjects. Adopted by the 18th World Medical Assembly, Helsinki, Finland, June 1964, amended by the 29th World Medical Assembly, Tokyo, Japan, October 1975, the 35th World Medical Assembly, Venice, Italy, October 1983, and the 41st World Medical Assembly, Hong Kong, September 1989. You should include information as to whether the work has been approved by the appropriate ethical committees related to the institution(s) in which it was performed and that subjects gave informed consent to the work.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendixes

Appendix 1
Sovereign credit rating's numerical scale

Investment grade		Speculative grade	
Rating	Score	Rating	Score
AAA	21	BB+	11
AA+	20	BB	10
AA	19	BB-	9
AA-	18	B+	8
A+	17	B	7
A	16	B-	6
A-	15	CCC+	5
BBB+	14	CCC	4
BBB	13	CCC-	3
BBB-	12	CC	2

(continued on next page)

Appendix 1 (*continued*)

Investment grade	Speculative grade	
	C	1
	SD, D	0

Source: Chen, S. S., H. Y. Chen, C. C. Chang and S. L. Yang (2016), "The relation between sovereign credit rating revisions and economic growth," *Journal of Banking & Finance*, Vol. 64, p.99.

Appendix 2
Countries with developed and developing markets

Developed Countries		Developing Countries	
United Arab Emirates	Iceland	Argentina	Nigeria
Australia	Italy	Bangladesh	Pakistan
Austria	Japan	Bulgaria	Peru
Belgium	Korea	Brazil	Philippines
Canada	Kuwait	Chile	Romania
Switzerland	Latvia	China	Russia
Cyprus	Malta	Colombia	Serbia
Germany	Netherlands	Egypt	Thailand
Denmark	Norway	Indonesia	Tunisia
Spain	New Zealand	India	Turkey
Estonia	Oman	Jordan	Ukraine
Finland	Poland	Kenya	Venezuela, RB
France	Portugal	Sri Lanka	Vietnam
United Kingdom	Saudi Arabia	Lithuania	South Africa
Greece	Singapore	Morocco	
Croatia	Slovenia	Mexico	
Hungary	Sweden	Malaysia	
Ireland	United States	Namibia	

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