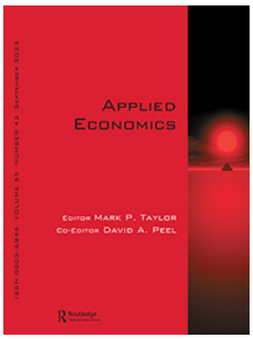

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The effect of firm-level uncertainty on R&D investment and corporate risk-taking of firms in BRICS countries: a simultaneous approach

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ABSTRACT

This study examines the effect of firm-level uncertainty on R&D investment and corporate risk-taking. The current study uses unbalanced panel data of nonfinancial listed firms in BRICS countries (i.e. Brazil, Russia, India, China, and South Africa) for the period 2009–2020, totalling 24,564 observations. We applied a robust two-step generalized method of moments (GMM) to estimate the model and control for endogeneity issues. The findings show that firm-level uncertainty significantly influences R&D investment and corporate risk-taking in BRICS countries. The panel vector autoregression (PVAR) provides more robust results and confirms the significant impact of firm-level uncertainty on R&D investment and corporate risk-taking. The result indicates that firm-level uncertainty has a significant negative effect on R&D investment but a significant positive impact on corporate risk-taking. This study offers important implications for managers, policy-makers, and investors in emerging markets where the relationship has remained ambiguous and applies both theories to analytically investigate the impact of uncertainty on R&D investment and corporate risk-taking of firms in BRICS countries.

KEYWORDS

BRICS; firm-level uncertainty; R&D investment; risk-taking

JEL CLASSIFICATION

D21; D81; G30; O32

I. Introduction

Classical economic theory has largely assumed that the investment-uncertainty nexus is linear, i.e. predicting a negative or positive relationship. However, several strands of literature have provided conflicting evidence supporting this theoretical view. Four reasons are specified in the literature through which uncertainty can influence corporate investment: first, the decision maker's attitude towards risk (Nakamura 1999; Bo and Sterken 2007); second, the options value of irreversible investment (Dixit and Pindyck 1994); third, financial constraints (Minton and Schrand 1999); fourth, production technology and product market competitiveness (Caballero 1991). One crucial factor that has been repeatedly ignored is the investment decisions and the manager's attitude to risk under uncertainty. Studies reveal that uncertainty can significantly influence R&D investment (Jung and Kwak 2018; Wang, Chen, and Huang 2014). On the one hand, proponents of strategic growth option theory argue that R&D investment is positively linked to uncertainty. This school of thought perceives that highly competitive firms trail a pre-emptive strategy under high uncertainty conditions (Van Vo and Le 2017; Ross, Fisch, and Varga 2018). On the other hand, the real option theory predicts a negative association, meaning that continuous investment in R&D cannot be achieved due to the limited capital to fund R&D activities. Hence, financial constraints drive corporate firms to cut investment when faced with high uncertainty.

Real option theory asserts that when uncertainty about an investment outcome exists, a firm has the impetus to acquire relevant information and delay the investment to make a better decision (McDonald and Siegel 1986; Dixit and Pindyck 1994). Meanwhile, increased uncertainty prevents investment because it significantly raises managerial flexibility. Few empirical studies support the assumptions of real options theory on the link between uncertainty and investments. Folta and O'Brien (2004) document that corporate investment decisions are influenced by a trade-off between two options in investment opportunities. Studies argue that small firms are particularly susceptible to uncertainty than big firms because they have limited

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external financing access. However, small firms have fewer bureaucratic constraints and tend to handle R&D activities effectively and efficiently. While corporate investment is vital in combatting global challenges such as climate change and the financial crisis, recent economic challenges may have altered the link between uncertainty and R&D investment. Hence, understanding the connection between firm-level uncertainty and R&D investment is new in emerging economies. Prior studies have yet to establish the link between firm-level uncertainty and corporate risk-taking.

According to literature, extended economic expansion may adversely affect stability – meaning that a rare occurrence such as a cash-flow deficit can trigger firm instability. As such, uncertainty remains a critical determinant of corporate risk-taking (Minsky, 1970). Few theoretical studies supported these arguments. Aghion et al. (2010) posit that when economic conditions are unstable and the capital markets are imperfect, firms allocate long-term investments capital to short-term investments during uncertain periods. Therefore, analysing the influence of firm-level uncertainty might assist investors in assessing the implication of corporate risk-taking for firm growth and stability. Managers' risk choices influence corporate decisions that significantly impact a firm's overall performance, growth, and long-term survival (Shapira, 1995). Since most long-term decisions contain a risk, investigating the risk-taking behaviours of managers provides investors with insights into corporate strategies and investment decisions (Boubakri, Mansi, and Saffar 2013). The empirical literature has focused mainly on advanced economies (primarily the US and European economies) until now. Unlike other studies, this study focuses on emerging economies by examining the nexus between firm-level uncertainty, R&D investment, and corporate risk-taking.

This study focuses on BRICS countries. They are all emerging economies under which several policies are likely to influence corporate behaviour strongly. The GDP of BRICS accelerated up to 25%, and the five countries accounted for 41.4% of the world's population in 2016 as against 9% of global GDP at the end of 2001 (Moudud-Ul-Huq 2020). The vital role and contribution of the BRICS are significant to the world economy in terms of population (40%), GDP (25% nominal and US$ 16.039 trillion), land coverage (30%), world trade (18%), and global forex (US$ 4 trillion) (Iqbal 2022). The rapid recovery of the BRICS economies, financial liberalization, and their relatively stable economic environment raise some interest in these economies (Moudud-Ul-Huq 2020). Second, firms in BRICS countries are essentially funding their resources in R&D to bolster technological integration and economic development through sectoral cooperation in many areas, namely – science and technology, trade promotion and facilitation, energy, and innovation (Iqbal 2022). Emerging markets have enormous future potential for vast political and economic development that foster investment in R&D due to massive knowledge-based technologies, global competition, a shift in customer demand, and strategic international cooperation. There is still a significant gap in the literature in that there is no empirical study on BRICS corporate firms despite their increasingly important role and rising status in the world financial marketplace.

The study examines the effects of firm-level uncertainty on R&D investment and corporate risk-taking in the BRICS countries. The study uses the two-step system GMM model and panel vector autoregression model. It contributes to the literature by providing managers and policymakers with a unique insight into how firms respond to uncertainty. The remainder of the paper is structured as follows. Section 2 reviews the literature. Section 3 explains the data and method. Section 4 discusses the results, and the conclusion ends the study.

II. Literature review

Theoretical studies have found various channels through which uncertainty affects a firm's investment behaviour. Yet, several studies forecast distinct signs of the nexus between uncertainty and investment. The seminal work of Pindyck (1988) attributes the uncertainty-investment nexus to the irreversibility of investment expenditures. Studies perceived that when investment expenditures are firm or industry-specific, they constitute sunk costs. It is also possible that investments that are neither firm nor industry-specific are partially

irreversible. Pindyck (1988) emphasizes capacity choice, marginal investment decision, and firm expansion. The irreversible investment, unknown cost, and future demand environment offer an investment opportunity with two options: first, to pursue the investment opportunity, and second, to kill the option, which can be invested productively at a later date. In addition, there are extensive arguments that financial constraints and the risk-averse attitude of firms are other channels through which the uncertainty-investment nexus can be explained. Some studies, such as Zeira (1990) and Nakamura (1999), suggest that the risk-averse behaviour of firms is one of the crucial causes of the negative relation between uncertainty and investment decisions of corporate firms.

Real option theory argues that there is a possibility of deferring investment where uncertainty in investment, the irreversibility of investment costs, and investment decision-makers' discretion exist (McDonald and Siegel 1986; Dixit and Pindyck 1994). The deferral option generates value when the investment cost is irreversible. Deferring investment opportunity increases uncertainty, enabling investors to invest in a more favourable future investment. Therefore, as soon as a firm has made an investment decision, this option is no longer available. Thus, uncertainty impedes investment by increasing the investment's opportunity cost. Few empirical studies have confirmed the prediction of real option theory on the association between uncertainty and investment (Bulan 2005; Koetse, Groot, and Florax 2009). This study, in contrast, contributes to existing research by investigating the applicability of strategic growth option theory and real options theory in emerging markets. Our focus on BRICS countries is based on their growing role at the national and international levels. The BRICS countries have influenced the global economy with pertinent national economic performance and high potential through their regulation, sectoral production structure, and economic and governmental policies. This study provides a simple comparison between emerging economies in an entirely different context. The investment-uncertainty nexus remains ambiguous. Studies argue that financial options and investment valuation under uncertainty are tied to real options theory from the theoretical point of view.

Some empirical studies have confirmed a positive association between uncertainty and investment. For instance, Van Vo and Le (2017) revealed that uncertainty increases the R&D spending of firms when measured as an idiosyncratic error in stock returns. The study asserts that the pre-emptive strategy under market competition is the primary force that drives the positive association between uncertainty and R&D investment, using panel data analysis from 1985 to 2013. The strategic growth options value is a growing determinant of market uncertainty for a few reasons. When the level of uncertainty is extreme, and future markets are anticipated to collapse, early investment bolsters a firm's competitive advantage in maximizing the available market opportunities compared to other market competitors. In contrast, the inability of the market to grow as expected even when uncertainty is resolved means that the firm can regulate its exposure to the market's adverse risk by giving up investment in growth opportunities. Rashid, Nasimi, and Nasimi (2021) examine uncertainty – investment relationship and the role of firm size in Pakistan. Their findings revealed that the strength of the influence of uncertainty on investment considerably varies across uncertainty types. Unlike firm-specific uncertainty, macroeconomic and political uncertainties have more unfavourable effects on investment.

Ahmadi, Manera, and Sadeghzadeh (2019) recently investigated the impact of uncertainty on US oil and gas firms' investment using a new approach. The study revealed that the effects of uncertainty mainly depend on the sources of uncertainty. Precisely, they showed that oil supply and demand shocks do not have any significant influence on investment. In contrast, the uncertainty associated with global consumption is significantly and negatively related to investment. Khan et al. (2020) found that uncertainties (fsu, mu, and epu) negatively influence R&D investment. This negative relationship is more prominent for firms operating in competitive industries, using a sample of Chinese listed firms. Rashid and Saeed (2017) examined the role of uncertainty in the corporate investment decisions of Pakistani firms from 1998–2013 by analysing the role of firm-specific and macroeconomic uncertainty in the firm investment model. They found that both uncertainties significantly reduce

investment. However, the effects of macroeconomic uncertainty are relatively more pronounced. Gulen and Ion (2015) find a negative impact of aggregate uncertainty about future policy and regulations on firm capital investments. They also find that the effects of policy uncertainty on investment are higher for firms more dependent on government spending and with higher investment irreversibility.

The relation between uncertainty and corporate risk-taking is comparatively limited in emerging markets. Relevant literature has argued that uncertainty might affect the risk-taking behaviours among firms. Tran (2019) shows that economic policy uncertainty and corporate risk-taking are negatively related across 18 countries. The findings reveal that corporate managers engage in less risk-taking when faced with a higher level of policy uncertainty. The study highlighted two possible channels whereby uncertainty might influence corporate risk-taking. First, uncertainty raises external financing costs (Gilchrist, Sim, and Zakrajšek 2014; Brogaard and Detzel 2015), thereby increasing the volatility of future cash flows and the severity of adverse selection between investors and managers (Zhang et al. 2015). Corporate managers are reluctant to generate external funds and bear the risk when facing an increasing external financing cost (Boubakri, Mansi, and Saffar 2013). Second, uncertainty increases managerial conservatism. Managers prefer investment projects with little or no volatile cash flow to reduce the risk of losing jobs or disrupting their investment interests (Gormley and Matsa 2016). Studies revealed that a higher uncertainty environment persuades corporate managers to underinvest (Panousi and Papanikolaou 2012; Bloom 2009). Hence, firms take on lesser risk when confronted with a significant level of uncertainty to sustain financial stability.

III. Methodology

Data and variables

The study aims to analyse the impacts of firm-level uncertainty on R&D investment and the corporate risk-taking of the selected firm. This study uses corporate firms' sample data for the period (2009 to 2020) in BRICS countries. The study period was chosen based on data availability, and only the firms with complete information were selected to construct dynamic panel data during the sample period. This study uses R&D investment and corporate risk-taking as the dependent variable, while the predictor variable is firm-level uncertainty. The firm-specific data were retrieved from the Eikon database and the macroeconomic data from the World Development Indicator database. The dataset includes 24,564 observations across 2047 corporate firms in BRICS countries.

Uncertainty and R&D investment

Numerous empirical studies have found it difficult to discuss a whole operational definition of uncertainty. Most existing studies have proxied uncertainty using marginal revenues (Pindyck and Solimano 1993), stock prices (Khan et al. 2020), cash flow (Ozkan and Ozkan 2004), and sales (Rashid and Saeed 2017). Hence, following the literature (Rashid and Saeed 2017; Rashid, Nasimi, and Nasimi 2021), we estimate the asset returns volatility by estimating the following AR(1) model in equation (1) by controlling for the firm f_1 and time-specific effects f_t.

$$\boldsymbol{FSV_{it}} = f_1 + f_t + y\boldsymbol{FSV_{it-1}} + \varepsilon_t \qquad (1)$$

Where is the firm-specific variable (asset returns) of a firm, and ε_t is the error term. For measuring time-varying volatility, we obtain one-period-ahead residuals (ε_t) from (1) and use them to construct the recursive variance using a one-year window. Specifically, for the year 2009, we compute the variance over 2009 and 2008. Likewise, for the year 2010, the residuals in 2010, 2009 and 2008, and so on are used. The proxy is robust as it measures time-varying volatility and considers the uncertainty associated with firm-specific factors since firms are expected to confront variations while taking any financial and economic decision simultaneously. Furthermore, the study proxy R&D investment by measuring the ratio of R&D expenditures to total assets of firm i at the end of year t (Van Vo and Le 2017; Cherkasova and Kurlyanova 2019).

Corporate risk-taking

Some studies argued that firms that conduct riskier operations incur more volatile returns on capital, and based on variability in corporate earnings, they establish a measure for risk-taking (Li et al. 2013; Tran 2019). Hence, we gauge corporate risk-taking using the country-adjusted standard deviation of return on assets over the research period 2009–2020. We calculate the deviation of the firm's EBITDA/total assets from the country average in year t and then compute the standard deviation of this measure for each firm in the study period. The country adjustment is necessary to eliminate country-level effects and create a clean proxy for risk-taking (John, Litov, and Yeung; Li et al. 2013; Tran 2019).

The study controls for other variables that may affect the nexus between firm-level uncertainty, R&D investment, and risk-taking. The leverage is proxy by equity divided by total assets, while the operating expenses ratio is used to measure the efficiency of firms. The firm size is measured using the natural log of total assets. We use the GDP growth rate to control the impact of macroeconomic factors that affect the stability of a firm (Islam et al. 2020). The Consumer Price Index (CPI) measures inflation, and the return on assets is calculated by dividing net income by the total assets. Also, we estimate the debt ratio by debt to the firm's total assets, while the interest rate is proxied by the interest rate spread. Asset tangibility (TAN) is measured as net property, plant, and equipment divided by total assets. The cash and short-term investments scaled by total assets capture the firm's cash holdings. At the same time, Herfindahl-Hirschman Index is measured as the sum of the square of the market square of an individual firm (Islam et al. 2020; Yao et al., 2018; Djalilov & Piesse, 2016).

$$\boldsymbol{HHI} = \sum_{i=1}^{n} \left(\frac{Assets_{it}}{Assets_{nt}} \right)^2 \tag{2}$$

where $Assets_{it}$ represents the assets of an individual firm, and $Assets_{nt}$ represents the assets of all firms.

IV. Model specification

This study uses the two-step system GMM model to address the possible problems of endogeneity bias and the unobserved specific effects in our model (Blundell and Bond 1998). This study used a GMM approach for several reasons. First, the system GMM estimator offers consistent and efficient predictions, less bias, and more precision, suitable for studies with very little time observation and a persistent time series process. Second, GMM estimations control for lagged values of the dependent variable (David et al. 2006) and address heteroscedasticity and auto-correlation problems. Heteroscedasticity may arise because different countries in the sample have other characteristics; thus, the residuals are unlikely to be constant across observations. Third, several empirical studies have confirmed that within a single framework, GMM is more robust than several estimations, such as OLS, 2SLS, and IV. Hence, to ensure the validity of the instruments, we test the reliability and consistency of the GMM estimation. The Hansen test for the validity of over-identifying instruments and the Arellano-Bond (AR) test were used to verify the validity and robustness of the instruments in the model. The time dummies were also included in the model to eliminate the time-related shocks from the error term (Roodman 2006). The study's sample is based on the corporate firms covering the period (2009–2020) in BRICS countries.

The generalized models for this study are given below:

$$R\&D_{i,t} = \beta_0 + \beta_1 R\&D_{i,t-1} + \beta_2 FLU_{i,t} + \beta_3 Control\ variables_{i,t} + \varepsilon_{i,t} \tag{3}$$

$$RT_{i,t} = \beta_0 + \beta_1 RT_{i,t-1} + \beta_2 FLU_{i,t} + \beta_3 Control\ variables_{i,t} + \varepsilon_{i,t} \tag{4}$$

Where the subscript i denotes firm, and t denotes time. $FLU_{i,t}$ represents the firm-level uncertainty variable; and $R\&D_{i,t}$ represents (R&D) investment; $RT_{i,t}$ denotes the corporate risk-taking variable; $Controlvariables_{i,t}$ defines controlled variables; $\varepsilon_{i,t}$ represents the error term

Descriptive statistics

Table 1 presents descriptive statistics for the variables. Firm-level uncertainty has a mean of 6.018 and a deviation of 2.713 (for Brazil). Russia has

Table 1. Summary of descriptive statistics by country, 2009–2020.

	Brazil		Russia		India		China		South Africa	
Var	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
FLU	6.018	2.713	5.983	2.672	6.148	2.792	5.927	2.5978	6.1470	2.8166
R&D	.3216	.5758	.0333	.1446	.7312	3.899	.7118	3.1099	1.8124	3.2401
RT	.1327	.0734	.1759	.1048	.1477	.0911	.1963	.3893	.1562	.0864
DR	.3363	.1660	.2747	.1972	.2673	.1993	.2157	.1593	.2296	.1597
LEV	.4085	.1764	.5180	.2520	.4947	.2172	.5514	.2195	.4986	.1788
EFF	.5824	.5109	1.1049	1.2009	.9978	.7605	.6785	7.8986	1.1426	.9664
ROA	.0950	.0628	.1008	.0860	.1087	.0860	.0758	.5398	.1315	.0934
HHI	.0021	.0065	.0026	.0982	.0015	.0295	.0046	.00523	.0034	.0772
CH	.1223	.1261	.0987	.1544	.3621	.2300	.1992	.1549	.1099	.1149
TAN	.3655	1.8608	.2956	1.218	.8920	.9371	.2468	.2053	.1154	.6271
SIZE	.2247	.0156	.2235	.0179	.2285	.0191	.2239	.0148	.2088	.0251
INFL	5.527	1.870	6.964	3.518	7.185	2.990	2.2989	1.3733	5.1766	1.1198
INT	30.848	5.6943	4.5665	1.1835	9.924	.8986	2.9275	.0936	3.213	.1502
GDP	.0808	.3192	.0707	.3387	.5610	.4253	.7386	.2003	.06932	.2643

FLU = firm-level uncertainty. R&D = research and development. RT = risk-taking. DR = debt ratio. LEV = leverage. EFF = total operating expenses to total asset ratio. ROA = return on assets. HHI = Henchman-Herfindahl Index. SIZE = firm size. GDP = GDP growth. CH = cash holding. TAN = tangibility. INFL = inflation. INT = interest rate.

a mean of 5.983 and a standard deviation of 2.6. India has higher uncertainty at the firm level, with a mean of 6.148 compared to other BRICS countries. Whereas in China, it is 5.927, and South Africa, it is 6.147, with a standard deviation of 2.8166 from the mean. The results show that some countries have more R&D investment than others. For example, Indian firms have a higher mean value of 0.7312 than the average R&D investment of 0.7118 Chinese firms. Regarding risk-taking, China has a more robust risk-taking behaviour with a mean value of 0.1963, while Brazil has the lowest average corporate risk-taking of 0.1327. The debt ratio has a huge mean value of 0.3363 with a deviation of 0.1660 for Brazilian firms, while Russia has the lowest average deb t ratio of 0.1973 among the BRICS countries. The average leverage ratio is 0.4085 for Brazil, while Russian firms have a mean leverage value of 0.5180. For India, the leverage ratio has a mean of 0.4947, while the mean value is 0.5514, with a standard deviation of 0.2195 in China. This implies that China has a higher leverage ratio among the BRICS countries. South Africa has an average leverage ratio of 0.4986, with a standard deviation of 0.1788.

The average efficiency ratio is 0.5824 at Brazilian firms, whereas the average efficiency ratio has a mean of 1.1049, *ceteris paribus*, at Russian firms. The average efficiency ratio is 0.7605 in Indian firms, while the mean value is 0.6785 in China. For South Africa, the efficiency has a mean value of 1.142. Furthermore, South Africa has the highest average return on assets of 0.1315, while China has the lowest mean value of 0.0758 during the study period. Regarding Herfindahl-Hirschman Index (i.e. market competition), China has the strongest competitive environment with a mean value of 0.0046, while India has the lowest average value of 0.0015. The HHI has a mean value of 0.0021 (*for Brazil*), 0.0026 (*for Russia*), and 0.0034 (*for South Africa*). The cash holding has a mean value of 0.1223 for Brazil, 0.0987 (*for Russia*), 0.3621 (*for India*), 0.1992 (*for China*), and 0.1099 (*for South Africa*). For Brazil, asset tangibility has an average value of 0.3655, with a standard deviation of 1.8608. The mean value of tangibility is 0.2956 (*for Russia*), 0.8920 (*for India*), 0.2468 (*for China*), and 0.1154 (*for South Africa*). The firm size varies among emerging countries, such as Brazil, Russia, India, China, and South Africa (BRICS). The size of the firm grew at an average value of $22.5, whereas the inflation rate had a mean of 4.5%. The interest rate had a mean of 6.9%, while the average GDP growth rate was 5.8% for the study period.

V. Discussion of GMM models

Table 2 reports the estimated results of two-step system GMM estimations. In the model, the lag of the measures of R&D investment is treated as endogenous in equation (3). In contrast, the lag of the measure of risk-taking is treated as endogenous in

Table 2. Result of R&D investment Sys-GMM model by country.

	Brazil Model 1		Russia Model 2		India Model 3		China Model 4		South Africa Model 5	
Var.	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat
L.R&D	0.404	3.80***	0.682	9.55***	0.740	21.38***	0.801	27.62***	0.830	14.90***
FLU	−0.173	−1.72*	0.437	1.78*	−0.058	−2.00**	0.036	2.24**	0.058	4.55***
DR	−0.549	−0.38	−0.152	−0.25	0.218	2.47**	−0.067	−2.48***	0.313	1.65*
LEV	1.809	1.10	0.219	0.26	−0.007	−0.09	−0.249	−1.82*	−0.022	−0.20
EFF	−1.326	−1.31	0.031	0.15	−0.178	−1.73*	−0.013	−0.39	−0.026	−0.63
ROA	−0.975	−0.51	−1.036	−1.25	1.029	5.94***	0.156	0.30	−0.087	−2.06**
HHI	1.152	3.01***	1.032	2.11**	−0.049	−0.30	0.355	1.89*	0.022	2.23**
SIZE	−8.884	−2.88***	−8.945	−2.01**	46.286	1.33	−14.319	−1.70*	−0.568	−2.37**
TAN	0.111	2.75***	−0.005	−0.12	−0.002	−0.20	−0.085	−3.25***	−0.411	−2.18**
CH	0.007	1.18	0.244	1.98**	0.295	2.92***	0.644	3.80***	2.357	2.55***
GDP	0.022	0.54	0.197	2.03**	0.313	2.38**	−0.055	−2.40**	0.013	1.51
_cons	−238.21	−2.93***	−229.49	−2.08**	−11.521	−4.76***	−39.619	−1.89*	−3.204	−3.13***
AR(1)	−3.50 (0.002)		4.17 (0.023)		−2.410 (0.020)		−3.51 (0.028)		−3.58 (0.002)	
AR(2)	−0.184 (0.387)		−1.250 (0.211)		2.631 (0.216)		−0.888 (0.374)		0.27 (0.785)	
Hansen Test	37.724 (0.2522)		59.854 (0.372)		55.292 (0.321)		93.15 (0.245)		72.76 (0.732)	
Country effect	Yes		Yes		Yes		Yes		Yes	
Year effect	Yes		Yes		Yes		Yes		Yes	
F Test	7608.27 (0.000)		9732.60 (0.000)		6117.30 (0.000)		6362.23 (0.000)		8201.01 (0.000)	
No. of Instruments	92		104		104		86		95	
Observations	1,284		1,320		8,616		12,432		912	

FLU = firm-level uncertainty. *RT* = risk-taking. DR = debt ratio. LEV = leverage. EFF = total operating expenses to total asset ratio. ROA = return on assets. *HHI* = Henchman-Herfindahl Index. *SIZE* = total asset of firms. GDP = GDP growth. *CH* = cash holding. TAN = asset tangibility. *Notes*: Significant at *** 1%, ** 5%, * 10%. The figures in the bracket represent the *p-value*.

equation (4) and all other variables as exogenous. In all models, the lag of (R&D) investment is uniquely significant, and the instruments' validity is tested using the Sargan and Hansen J test of over-identifying restrictions. The results validate that the models are well specified.

Additionally, to eliminate the problem of increasing the finite-sample bias in the coefficient and standard error estimates in the model, the collapse option was used to prevent an over-fit model and to confirm that the number of instruments in all models is less than the number of firms used (Roodman, 2009; Kripfganz 2020). The Arellano-Bond test (AR2) confirms that the model does not have a higher-order serial correlation. Hence, the outcome of the post-estimation tests confirms the model is fit for empirical analysis. We also controlled for several other factors that may affect R&D investments. We include the debt ratio, leverage, efficiency, profitability, Herfindahl-Hirschman Index, firm size, asset tangibility, cash holding, and GDP growth rate in the empirical model. Prior studies have also used such variables in the uncertainty-investment relationship (Rashid and Saeed 2017; Gao, Li, and Huang 2017; Van Vo and Le 2017; Jung and Kwak 2018; Khan et al. 2020; Rashid, Nasimi, and Nasimi 2021).

We use the uncertainty indicator in model (1) with other variables to analyse the effect of firm-level uncertainty on (R&D) investment. The result revealed that the lag term is positively significant at 1%. The results indicate that the main explanatory variable (firm-level uncertainty) negatively and significantly affects R&D investment. The implication is that an increase in FLU leads to a reduction in the R&D investment of firms in Brazil, signifying a potential decrease in firm innovation and outputs. Proponents of real option theory argued that under uncertainty, there is a possibility of deferring investment due to the decision maker's discretion and irreversible investment costs. This claim suggests that as soon as an investment decision is made by a firm, real option no longer exist. Hence, uncertainty increases the opportunity cost of investment, thereby impeding investments. The study is consistent with the prediction of real option theory on the association between uncertainty and investment (Bulan 2005; Koetse, Groot, and Florax

2009; Czarnitzki & Toole, 2013; Wang, Wei, and Song 2017) and contrary to the strategic growth option theory (Van Vo and Le (2017). Therefore, the argument that uncertainty reduces investment holds in the context of Brazilian firms.

The debt ratio, leverage, efficiency, and return on assets have no significant effect on R&D investment. However, the market power (Henchman-Herfindahl Index) significantly and positively impacts R&D investment at 1%. This implies that an increase in competition enhances an investment in Brazilian firms. The firm size has a significant negative effect on investment, suggesting that growth in firm size leads to a decrease in investment and vice-versa. This is contrary to the study (Czarnitzki & Toole, 2011). Tangibility has a significant positive impact on investment, which suggest that an increase in asset tangibility improves (R&D) investments among firms in Brazil. The cash holding and GDP growth rate have no significant effect.

In model (2), the findings reveal that firm-level uncertainty has a significant and positive effect on R&D investment at 10%. This indicates that increased uncertainty at the firm level enhances R&D investment among firms in Russia. The reason is more likely that firms would want to earn more and benefit from an innovative market during uncertainty by funding investments in R&D. Advocates of strategic growth option theory perceives that highly competitive firms trail a proactive strategy under high uncertainty conditions (Lai & Huong, 2017; Ross, Fisch, and Varga 2018). Further, early investment strengthens a firm's competitive advantage in maximizing available market opportunities compared to other market competitors when there is a high level of uncertainty. This is consistent with (Van Vo and Le 2017), who confirms a positive association between uncertainty and investment. The prediction of strategic growth option theory is confirmed at Russian firms. The debt ratio, leverage, efficiency, and return on assets have no significant influence on investment. Market competition has a significant positive impact on firms' R&D investment in Russia. This suggests that increased competition leads to an increase in investment. The firm size has a significant and negative effect on R&D investment, while the cash-holding and GDP growth rate both significantly and positively impact investment. The implication is that economic growth help bolsters investments. However, the asset tangibility has no significant effect.

In model (3), the firm-level uncertainty (FLU) has a significant and negative effect on R&D investment at Indian firms. This suggests that increased FLU leads to a decrease in the R&D investment of firms. This is consistent with the traditional real option theory view that predicts a negative association. The plausible reason is that continuous investment in R&D cannot be achieved under increasing firm-level uncertainty due to limited funds to finance R&D activities. The implication is that corporate firms delay investment decisions due to the unavailability of funds to finance innovative activities when facing uncertainty. The result is consistent with the findings of (Leahy & Whited, 1996; Bulan 2005; Koetse, Groot, and Florax 2009). The debt ratio has a positive and significant impact on R&D investment, suggesting that an increase in debt ratio leads to improvement in investment. On the contrary, efficiency has a significant negative effect on R&D investment. This further shows that increased efficiency reduces firms' investment, thereby limiting the high rate of return. The return on assets, interest rate, and GDP growth rate all significantly and positively affect R&D investment. The implication is that increased return on assets, cash holding, and GDP growth enhance investment at Russian firms. Leverage, market power, firm size, and asset tangibility have no significant association.

The result for China firms in model (4) indicates that firm-level uncertainty has a significant and positive effect on R&D investment. This show that an increase in FLU leads to improvement in the R&D activities of Chinese firms. Some relevant studies argued that uncertainty allows firms to effectively identify external and collective knowledge about markets and customers and technology-facilitated through increased R&D activities (Vuong, Peters, and Roberts 2015). R&D investment allows firms to efficiently absorb new knowledge (Berchicci, de Jong, and Freel 2016), improving the capacity to acquire, integrate, and relate new knowledge to commercial ends. The finding supports the strategic growth option theory. The debt ratio and leverage have a significant negative impact on the R&D activities of Chinese

firms, suggesting that a reduction in debt ratio and negative leverage improves the R&D investments of firms. This implies that corporate managers take a lesser risk to improve R&D investment. The findings are consistent with (Jin et al., 2018; Van Vo and Le 2017). Similarly, the firm size, tangibility, and GDP growth rate negatively and significantly affect R&D investment at Chinese firms. This implies that increased firm size, tangibility, and GDP growth lead to a decrease in R&D investment. This is contrary to the study conducted by (Czarnitzki & Toole, 2011). Cash holding has a positive and significant impact on R&D investment, while efficiency and return on asset both have an insignificant association with R&D investment.

At South African firms, the firm-level uncertainty has a significant positive effect on R&D investments at 1%, which suggests that an increase in FLU leads to an increase in the R&D activities of banks. The plausible reason is that large firms often have access to future investment opportunities because they have the initiative to develop products and offer services that are non-existence in the market. The implication is that innovative firms are more likely to finance R&D activities to gain a competitive advantage during uncertainty to generate enough revenue. The strategic growth option theory corroborates the positive relation between uncertainty and investment. The result contradicts the findings of (Czarnitzki & Toole, 2013; Wang, Wei, and Song 2017), who report a negative relation. Similarly, the debt ratio has a positive and significant impact on R&D investment, suggesting that an increased debt ratio leads to improvement in R&D investments of firms. Return on assets has a significant negative effect, while the market power indicator (HHI) has a significant positive impact on R&D investment. Firm size and inflation rate both have a significant negative influence on R&D investment, suggesting that an increase in firm size and tangibility reduces the investment in R&D at South African firms. Cash holding has a significant and positive impact on R&D investment, implying that increased cash holding leads to improvement in firms' investment. However, leverage, efficiency, and GDP growth rate have no significant impact at South African firms. The empirical findings for the corporate risk-taking (RT) two-step system GMM model by country are indicated in Table 3.

Table 3 indicates that the lag term of corporate risk-taking (RT) is highly significant at 1%. At Brazilian firms, the empirical results reveal that

Table 3. Results of corporate risk-taking GMM model by country.

	Brazil Model 6		Russia Model 7		India Model 8		China Model 9		South Africa Model 10	
Var.	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat
L.RT	0.586	13.41***	0.700	18.89***	0.376	15.75***	0.452	9.39***	0.730	19.38***
FLU	0.160	10.99***	0.009	7.40***	0.308	11.09***	0.533	23.61***	0.019	8.43***
DR	0.062	0.47	0.018	1.39	0.385	5.51***	−0.005	−0.29	0.056	4.03***
LEV	0.080	1.85*	0.127	5.36***	−0.173	−1.35	−0.285	−4.20***	0.073	1.97**
EFF	−0.026	−1.23	−0.006	−0.91	−0.245	−3.05***	−0.339	−4.54***	−0.002	−0.59
ROA	−0.051	−2.44**	−0.049	−1.80*	−0.296	−0.66	0.047	3.74***	−0.042	−3.17***
HHI	0.329	2.41**	−0.020	−0.53	0.700	4.08***	−0.416	−2.62***	0.001	1.28
SIZE	−33.193	−2.54***	0.847	0.47	−33.477	−4.27***	15.653	2.26**	−0.238	−1.40
INFL	1.008	9.89***	0.004	9.42***	−0.006	−2.89***	0.159	9.47***	−0.003	−3.51***
INT	0.971	9.83***	−0.008	−6.07***	0.082	3.97***	−0.869	−5.42***	0.119	6.69***
GDP	0.029	5.70***	0.057	9.67***	−0.103	−3.74	0.092	5.37***	0.008	7.50***
_cons	−2.767	−9.62***	2.130	0.48	−83.458	−4.29	42.006	2.38**	−.390	−3.97***
AR(1)	−1.45 (0.009)		2.069 (0.040)		−3.44 (0.012)		−8.26 (0.017)		−3.18 (0.021)	
AR(2)	−1.02 (0.309)		1.269 (0.204)		−1.534 (0.125)		−4.88 (0.318)		−1.491 (0.251)	
Hansen Test	103.09 (0.163)		96.258 (0.291)		23.21 (0.217)		554.47 (0.221)		73.641 (0.360)	
Country effect	Yes		Yes		Yes		Yes		Yes	
Year effect	Yes		Yes		Yes		Yes		Yes	
F Test	14413.14 (0.000)		17845.52 (0.000)		249475.67 (0.000)		70191.43 (0.000)		594605.03 (0.000)	
No of Instruments	104		104		95		104		86	
Observations	1,284		1,320		8,616		12,432		912	

FLU = firm-level uncertainty. *RT* = risk-taking. DR = debt ratio. LEV = leverage. EFF = total operating expenses to total asset ratio. ROA = return on assets. *HHI* = Henchman-Herfindahl Index. *SIZE* = total asset of firms. GDP. *INFL* = inflation rate. INT = interest rate. *** Significant at 1%, ** at 5%, * at 10%. Figures in the bracket represent the *p-value*.

firm-level uncertainty has a significant and positive impact on corporate risk-taking at a 1% significant level. This suggests that an increase in FLU enhances corporate risk-taking at Brazilian firms. Our study shows that uncertainty increases the likelihood that corporate managers would engage in extreme risk-taking to compensate for operational losses and attain significant economic performance. It is asserted by Aghion et al. (2010) that under uncertainty, corporate managers have the incentive to engage in extreme risk-taking to sustain enterprise value. The study posits that during unstable economic conditions and imperfect capital markets, firms allocate long-term investments capital to short-term investments in uncertain periods. The result is contrary to the argument of (Tran 2019; Wang, Chen, and Huang 2014). Leverage and market power (HHI) both have a significant and positive effect on corporate risk-taking, which suggests that increased leverage and competition enhance the risk-taking of corporate firms. However, profitability ratio (ROA) and firm size have a significant and negative impact on corporate risk-taking. This is consistent with (Li et al. 2013; Boubakri, Mansi, and Saffar 2013). This suggests that an increase in firms' profitability and size reduces corporate managers' risk-taking behaviour. In addition, inflation rate, interest rate, and GDP growth have a positive and significant influence on corporate risk-taking, which suggest that increased inflation and interest rate enhance the risk-taking behaviour of corporate firms. Similarly, positive economic growth increases risk-taking among firms in Brazil. The debt ratio has no significant impact on risk-taking.

The result for Russian firms indicates that firm-level uncertainty (FLU) significantly and positively affects corporate risk-taking at a 1% significant level. This suggests that an increase in uncertainty enhances the risk-taking behaviour of firms. Some studies posit that corporate managers engage in less risk-taking under a high level of uncertainty (Tran 2019; Wang, Chen, and Huang 2014). However, studies also revealed that uncertainty might increase risk-taking behaviour and external financing costs (Gilchrist, Sim, and Zakrajšek 2014; Brogaard and Detzel 2015), thereby increasing the volatility of future cash flows. In addition, leverage has a significant and positive effect on risk-taking, which suggests that increased leverage triggers the corporate risk-taking of firms. Profitability ratio (ROA) and interest rate both negatively and significantly affect corporate risk-taking, implying that an increase in ROA and interest rate reduces risk-taking behaviour at Russian firms. On the contrary, inflation rate and GDP have a significant and positive impact on corporate risk-taking, implying that increased inflation rate and GDP growth encourage risk-taking among firms. Lastly, debt ratio, efficiency, market power, and firm size have no significant impact on risk-taking.

In model (8), the result shows that FLU significantly and positively affects corporate risk-taking at Indian firms. This implies that an increase in firm-level uncertainty enhances corporate risk-taking. This is contrary to the findings of (Gormley and Matsa 2016; Amihud & Lev, 1981), who argue that uncertainty increases managerial conservatism. Studies showed that a higher uncertainty environment persuades corporate managers to underinvest (Panousi and Papanikolaou 2012; Bloom 2009). This reveals further that corporate managers would prefer to choose projects with minimal cash flow volatility to reduce the risk of disrupting investment interest. However, our findings display a different orientation in the context of firms in BRICS countries. A debt ratio and market power significantly and positively affect firms' risk-taking. This suggests that increased debt ratio and market power enhances the risk-taking at Indian firms. Contrarily, efficiency, firm size, and inflation rate have a significant negative impact on corporate risk-taking, suggesting that increase in firm size, efficiency and inflation rate reduces the risk-taking behaviour of corporate firms. Lastly, leverage, profitability ratio, and GDP growth rate have no significant association.

In model (9), the empirical result reveals that FLU has a positive and significant impact on corporate risk-taking at Chinese firms, which suggests that increased uncertainty increases the risk-taking behaviour of firms. The findings are contrary to (Tran 2019; Phan et al. 2019), who argued for a negative association. Few theoretical arguments explain that big firms have absorptive capacity and are not vulnerable to uncertainty like small firms with minimal external financing access. Leverage and efficiency both significantly negatively impact

risk-taking, which means that an increase in leverage and efficiency reduces corporate risk-taking and vice-versa. Return on assets and firm size have a significant positive impact on risk-taking, which suggest that increased ROA and firm size enhance corporate risk-taking among firms. The effect of market power (HHI) and interest rates on corporate risk-taking are significant and negative. In contrast, inflation, and GDP growth rates both significantly positively influence corporate risk-taking at Chinese firms. Lastly, the debt ratio has no significant association.

Furthermore, firm-level uncertainty has a significant and positive influence on the corporate risk-taking of South African firms, which suggests that an increase in FLU enhances the risk-taking behaviour of corporate firms. Similarly, debt ratio and leverage have a significant positive impact on risk-taking, implying that an increase in debt ratio and leverage leads to an increase in the corporate risk-taking of firms. Return on assets and the inflation rate have a significant and negative impact on risk-taking, implying that an increase in return on assets and inflation rate reduces corporate risk-taking among firms. On the contrary, interest rate and GDP growth rate have a significant and positive effect on the corporate risk-taking of firms. This suggests that increased interest rates and GDP increase the corporate risk-taking of firms in South Africa.

VI. Robustness checks

The study conducts further estimations using the panel vector autoregression method (PVAR) because it combines both panel VAR and GMM estimation, provides a consistent estimate and captures the cross-sectional dimension of the sample (Abrigo and Love 2015). It is a robust estimate that controls the model's endogeneity problem. The controlled variables were excluded to detect changes in the firm-level uncertainty, R&D investment, and corporate risk-taking nexus. The panel unit root test (ADF test unit-root test) is conducted to effectively identify the stationary and stochastic qualities of the variables along with their order of integration. Fisher-type tests based on augmented dicky-fuller (ADF) were chosen as it allows unbalanced panel data. The results show that the variables – R&D investment, corporate risk-taking, and firm-level uncertainty are stationary at level. The result for the unit root test is presented in Table 4. We also conduct a Pedroni test for cointegration. All the test statistics reject the null hypothesis of no cointegration in favour of the alternative hypothesis that R&D investment, risk-taking, and firm-level uncertainty are cointegrated in all panels with a panel-specific cointegrating vector (see Table 5). Furthermore, we conduct the eigenvalue stability and likelihood-based criteria to ensure the panel VAR model's stability (Andrews and Lu 2001). Figure 1 revealed that the stability condition for the panel VAR is satisfied, which implies that the moduli are strictly less than one and the eigenvalue is well within the unit circle.

VII. Panel VAR estimation

The PVAR result shows a negative and significant link between R&D investment and firm-level uncertainty at firms in BRICS countries. The findings reveal that both investment and uncertainty significantly affect each other. This finding is

Table 4. Fisher-type unit-root test based on augmented Dickey-Fuller tests.

	P	Z	L*	Pm
FLU	7318.3143***	−43.4596***	−39.8999***	35.6327***
R&D	1.29e+04***	−29.4927***	−55.7885***	97.6873***
RT	6083.8050***	−28.0590***	−25.8315***	21.9898***

All panel unit root tests were performed with intercept and trend.
***indicate significant at 1% level.

Table 5. Pedroni test for cointegration.

	Modified Phillips–Perron t	Phillips–Perron t	Augmented Dickey-Fuller t
R&D, FLU	15.5825***	−9.0811***	1.7261***
RT, FLU	43.6784***	46.6858***	38.7558***

Note: All the test statistics reject the null hypothesis of no cointegration.
***indicate significant at 1% level.

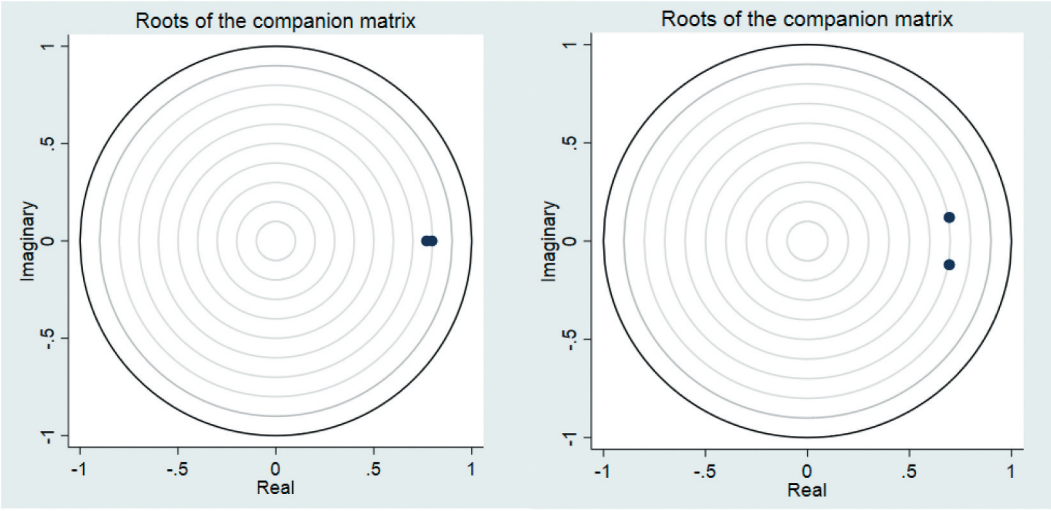

Figure 1. Graph of eigenvalue (R&D - FLU, RT-FLU). Note: The eigenvalue is within the unit circle.

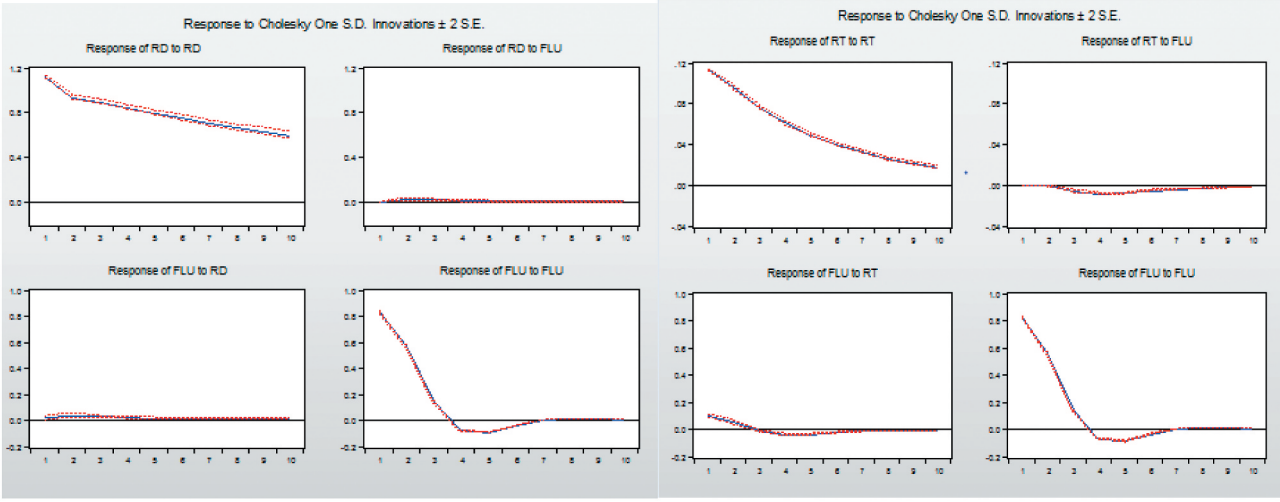

Figure 2. Impulse Response of FLU, RT, and R&D using the PVAR approach.

consistent with (Bulan 2005; Koetse, Groot, and Florax 2009; Czarnitzki & Toole, 2013; Wang, Wei, and Song 2017) and confirms the prediction of the real option theory. There is a positive and significant association between corporate risk-taking and firm-level uncertainty index at firms in BRICS countries. This result confirms our findings when we use the two-step system GMM estimates. (The results are available on request).

Figure 2 depicts the estimated impulse response functions (IRF) using the forecast-error variance decomposition (FEVD) recommended by (Abrigo and Love 2015). The IRF confidence interval was determined using 1000 Monte Carlo draws based on the fitted model. The result shows the response of R&D investment to shocks from firm-level uncertainty and corporate risk-taking (RT) to shocks from firm-level uncertainty. The findings revealed that firm-level uncertainty significantly affects R&D investment and corporate risk-taking at firms in BRICS countries.

VIII. Conclusions and policy issues

This study bridges the literature gap by examining the firm-level uncertainty effect on R&D investment and the corporate risk-taking of firms in BRICS countries. A balanced panel of 2047 firms

in five BRICS countries were used in the study from 2009–2020, tallying 24,564 observations. We use the two-step system GMM estimates to provide a consistent estimation and to address the problem of endogeneity bias in the models. In addition, we also use the PVAR as a robust estimate that is efficient and provides a correct endogenous interaction between the key variables. Our findings are peculiar as we aim to corroborate the predictions of real option theory and strategic growth option theory by showing that firm-level uncertainty influences R&D investment by focusing on key emerging countries.

The findings of the study are unique. First, the study found a negatively significant nexus between firm-level uncertainty and R&D investments at firms in Brazil and India, but a positively significant nexus was found at firms in Russia, China, and South Africa. Our findings support the traditional real option theory and strategic growth option theory. Further results reveal that firm-level uncertainty significantly and positively affects corporate risk-taking at firms in Brazil, Russia, India, China, and South Africa. Our results imply that corporate firms in a highly volatile competitive market are comparatively more likely to engage in excessive risk-taking no matter their level of uncertainty. We find that firm-level uncertainty remains positively related to corporate risk-taking in all models. The panel vector autoregression estimates reveal a significant and negative nexus between firm-level uncertainty and R&D investment, while FLU positively and significantly impacts corporate risk-taking.

Part of the significant contribution of this study is the different implications of uncertainty to corporate investment of firms in BRICS countries. On the one hand, the real option theory clarifies why firms are inclined to reduce investment under increased uncertainty – arguing that firms postpone investment opportunities to reduce losses and await information about the market condition. On the other hand, the strategic growth option theory advocates that firms maximize market opportunities by investing early due to access to market information and resources that provide a competitive advantage. This study offers comprehensive knowledge of the relevance of these theories to firms in BRICS countries.

In addition, this study offers a few important policy implications. First, the significant influence of firm-level uncertainty on R&D investments reinforces the need for policymakers to regulate, control, and manage the key macroeconomic policies harmful to firm stability. By extension, reducing uncertainty will help create a growing investment environment for corporate firms with limited access to external financing. Second, policymakers must identify country-specific policies to help understand firm-specific R&D investment patterns and strategic investment decisions since firms respond to uncertainty in idiosyncratic ways. Finally, it is imperative to recognize that economic stability and institutional settings have become more vital to corporate managers' investment strategy and decisions as most emerging markets move towards a market economy. Hence, this study provides invaluable implications for investors, managers, and policymakers.

Disclosure statement

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