# SMEs respond to climate change: Evidence from developing countries

**Abstract**: *Given the concerns stemming from climate change, it is important to investigate whether SMEs could become innovative (and thereby invest in technologies mitigating climate change) because of heightened climate change risk. This study explores the impact of climate change on SMEs' innovation from a resource-based view (RBV) standpoint. Using the generalized method of moments (GMM) estimation of panel data for 443 SMEs from 14 developing countries during the period 2007–2016, we found that climate change has a significant positive impact on SMEs' innovation performance. In economic terms, climate change of one standard deviation variation resulted in a 6.6% increase in innovation investment. Interesting results emerged when the sample was divided into firms with high and low growth, high and low profit, and high and low slack resources, and industries with high and low vulnerability. The results show that SMEs' innovation response to climate change may vary substantially across firms and industries. In high-growth, high-slack-resources firms, and in highly profitable and non-vulnerable industries, SMEs' innovation responds positively to climate change. Our study contributes to the SME and climate change literature by being the first to examine the impact of climate change on SMEs' innovation. Managerial and policy implications are discussed.*

*Key Words: Climate change, SMEs, Innovation, Developing countries*

## 1. Introduction

Small and medium enterprises (SMEs) are considered drivers of economic growth, local employment, and diversity (Mendy et al., 2020). SMEs tend to have greater creativity and hence produce the majority of new products entering the markets (Bower and Christensen, 1995; Amini, 2004; Rosenbusch et al., 2011; Bodlaj et al., 2020; Edeh et al., 2020). Barrow (1993) stated that SMEs developed over 60% of all innovations in the 20th century. On the other hand, it has been claimed that SMEs could be responsible for significant greenhouse gas emissions (e.g. Schaefer et al., 2011; Oliveira and Jabbour, 2017). In a related study, Crick et al. (2018) pointed out that this sector is more vulnerable than other sectors to the impacts of climate change. SMEs have less ability than other firms to deal with climate change as they

often suffer from a lack of resources, liquidity, and skilled labour; weak management skills; and low technical capacity (Wedawatta et al., 2010; Hampel-Milagrosa et al., 2015; Fernández-Olmos and Ramírez-Alesón, 2017; Crick et al., 2018). Through innovation, a firm can ensure the efficient use of limited resources and combat vulnerability to climate change (Trifilova et al., 2013; Su and Moaniba, 2017; Abdelzaher et al., 2020). Similarly, it is commonly believed that vulnerability boosts firms' innovation and creativity. However, the existing literature has failed to examine how SMEs can be supported to deal with climate risk and build climate resilience. The incompleteness of our existing knowledge of this phenomenon indicates a need to give small businesses the knowledge and confidence required to accelerate their response and adapt their policies to climate change.

The ability of firms to deal with the heterogeneous and uncertain impacts of climate change is mainly influenced by innovation capacity (Pinkse and Kolk, 2010; Zilberman et al., 2018). In a relevant study, Marcus (1988) pointed out that innovation may arise when an external threat or opportunity occurs. Thus, it is expected that SMEs are more likely to be innovative if they face threats and opportunities caused by climate change. Innovation helps firms build capacity and adapt to a changing environment as research and technology are essential to define adaptation solutions (Smit and Skinner, 2002; Adger et al., 2008). Zilberman et al. (2018) pointed out that innovation investment produces new procedures and institutions that can help to mitigate climate risks. Moreover, through innovation capabilities, firms can invent technologies that help reduce emissions (Pinkse and Kolk, 2010). Therefore, change and innovation are inextricably tied together. Knowing the relationship between climate change and innovation allows SME managers to develop strategies. These strategic options and decisions will provide them with better adaptation plans. In addition, this will empower SME managers to survive and even thrive in the face of a changing environment and, ultimately,

support the sustainable development of their countries. Therefore, it is interesting to examine the impact of climate change on SMEs' innovation.

The climate is changing, and it is changing more quickly than scientists originally expected (Tollefson, 2022). Although climate change has a significant impact worldwide, this issue is even more critical for developing countries (Micale et al., 2018). These countries are more affected by changing climate conditions as a result of many factors, including their low physical and financial capacity and inadequate government support for social safety nets (Parry et al., 2001; UNDP, 2007; Ward and Shively, 2012). Compared with developed countries, in developing nations there is often relatively weak infrastructure to protect transportation, communication, and health against climate extremes (Ward and Shively 2012). Bhur et al. (2018) found evidence that climate change has increased the cost of capital in these affected countries. They argued that the credit ratings of these countries have deteriorated due to increased climate risks that increase the cost of domestic and international capital, resulting in higher interest payments. Besides the above external institutional challenges, SMEs from developing countries in particular face difficulties internally. Internal challenges are inherent in the lack of financial and organisational resources devoted to climate change, limited capacity for innovation in face of climate change, and lack of access to cleaner technologies (Oliveira and Jabbour, 2017). Despite the challenges that SMEs from developing countries face, we have limited understanding of how SMEs in developing countries respond to climate change impacts (Oliveira and Jabbour, 2017). The aim of this study is to close the gap in the literature by generating new knowledge about SMEs' innovation behaviour in response to climate change. In addition, our research responds to the call by Mitchell et al. (2020) to examine the environmental performance and sustainability of SMEs from developing countries.

The study makes five contributions. First, we examined the impact of climate change on SMEs' innovation in 443 firms from 14 developing countries. To the best of the authors' knowledge,

this is the first study to examine the impact of climate change on SMEs' innovation in developing countries. By doing this, the study provides significant insights into the importance of innovation investment in responding to climate shocks in developing countries. Second, we observed that SMEs' innovation response to climate change may vary substantially across firms and industries, and thus we enriched our understanding of SMEs' innovation behaviour. We found that SMEs with high growth, more slack resources, and greater earnings are more innovative in response to climate change, given that such SMEs have more resources. Further, non-vulnerable SMEs invest more in innovation in response to climate change, as these firms can afford to do so more than vulnerable ones, whose circumstances make it difficult for them to invest in risky, innovative ideas. Third, we applied the resource-based view (RBV) to understand the impacts of climate change. The RBV posits that obtaining strategic assets, including innovation, product differentiation, and patent-protected technologies, promotes technological learning, facilitates the development of skills and competencies, and thus increases firm value. This study enabled us to examine the effects of climate change and SMEs' innovation from an RBV perspective. Fourth, we used an advanced econometric technique that takes into account the persistence of innovation performance. In particular, we used panel data methodology, which allowed us to incorporate a firm's unobserved heterogeneity. In a recent study, Crick et al. (2018) emphasised the use of panel data analysis to firm up the evidence base. Finally, we provided evidence that may help SME managers proactively invest in innovation activities and respond better to a changing environment.

The remainder of this paper is organised as follows. In the next section, we present a review of existing literature from an RBV standpoint, and the hypothesis development. Section three introduces the research methodology and discusses the research settings. Section four presents the findings of the study. Finally, section five presents the conclusion and implications.

## 2. Theory and hypothesis development

The RBV posits that firms use resources to gain a competitive advantage (Barney, 1991). According to Asif et al. (2021) and Prasanna et al. (2019), it is important for SMEs to implement practices of knowledge exploitation and knowledge exploration to get insights and information from knowledge resources and gain valuable opportunities in the current dynamic and competitive markets, especially in the context of developing countries. Using a sample of 100 SMEs in Pakistan, Asif et al. (2021) found a positive relationship between knowledge exploitation and knowledge exploration and the performance of SMEs, providing support for the RBV. Festa et al. (2020) stated that with the development of globalisation, firms tend to enter new markets to maintain and expand competitive advantage and thus increase performance. The authors examined Italian SMEs and indicated that SMEs need to seek international markets and identify and exploit their distinctive competitive advantages to succeed. Festa et al. (2019) suggested that crowdfunding is an innovative form of financial support to enable firms, especially SMEs, to engage in sustainability. Hart (1995) extended the RBV regarding firms' proactive environmental strategy. Marin et al. (2015) conducted research on green innovation in SMEs from the EU and identified lack of technical capabilities, market barriers, and knowledge barriers as the main obstacles to green innovation. Fahad et al. (2022) argued that awareness of environmental concerns had put pressure on SMEs in emerging economies to adopt green innovation. Fahad et al. (2022) further identified six main types of obstacles for Pakistani SMEs seeking to adopt green innovation: technical, information, market, economic, political, and managerial. They found that technical barriers are among the main obstacles, and in this category a lack of R&D capacity poses the most significant barrier to implementing green innovation. This finding emphasises the importance of knowledge exploitation and knowledge exploration.

Business plays a significant part in slowing down environmental damage and climate change (Sullivan and Gouldson, 2017; Murray, 2018; Laurent et al., 2019). It is pointed out that large companies' environmentally damaging activities have attracted many concerns, while less attention has been paid to SMEs' environmental management and sustainability issues (Mitchell et al., 2020). Mitchell et al. (2020) further argued that SMEs account for 99% of all business in the context of the EU. It is therefore vital to look at the environmental performance and sustainability of SMEs. Straka et al. (2021) examined SMEs' innovation and economic performance in the context of Thailand, Hungary, and Slovakia. They found that green internal integration and green customer integration significantly impact both the technological performance and the economic performance of SMEs in these three countries. Mafini and Loury-Okoumba (2018) and Straka et al. (2021) suggested that it is imperative for SMEs to engage in green innovation throughout product life cycles and across entire supply chains.

Environmental changes prompt firms to continually build superior knowledge for their own competitive advantage (Chen and Lin, 2004; Williams and Schaefer, 2013). Peloza (2009, p.1526) stated that environmentally active firms are expected to "*enjoy several potential revenue-generating benefits: (a) reducing their exposure to potential carbon costs, (b) opening up new markets, (c) developing competencies that provide a competitive advantage, and (d) creating new revenue streams from excess credits*". It has been identified that SMEs' motivations for engaging in pro-environmental behaviour are compliance, competitiveness, and value-driven ecological and social concern (Mitchell et al., 2020; Williams and Schaefer, 2013). Thus, "*focus on sustainability through eco-innovation is an appropriate approach for SMEs*" (Mitchell et al., 2020, p.159).

In the face of the challenges of climate change, green innovation is regarded as a leading strategy to create a sustainable society. Green innovations include environmental technologies

as well as practices, processes, services, and systems to minimise damage to the environment (Schiederig et al., 2012; Eryigit and Ozcüre, 2015; Jo et al., 2015; Nylund et al., 2021). Aragón-Correa (1998) and Aragón-Correa and Sharma (2003) argued that environmentally proactive firms tend to invest more in R&D to generate environmental capabilities and minimise negative impacts on the environment. In related literature, Su and Moaniba (2017) concluded that innovation activities minimise the effects of climate change. Innovation activities help firms lower costs, improve efficiency, promote adaptation strategies, and enhance organisational resilience to climate change (Smit and Skinner, 2002; Adger et al., 2008; Su and Moaniba, 2017; Zilberman et al., 2018). Asif et al. (2021) pointed out that it is essential to understand that sustainability contributes to innovation-based products and services, and SMEs' sustainability-oriented performance can lead to superior overall performance. Nguyen and Vu (2022) examined the relationship between corporate environmental responsibility and innovation adopted by Vietnamese SMEs and found that corporate environmental responsibility engagement is significantly positively associated with process innovation, labour productivity, and financial performance, which lends support to Asif et al.'s (2021) findings. Syafri et al. (2021) investigated the impact of green innovation and workplace green behaviour on the green performance of Indonesian SMEs. They concluded that green innovation is significantly positively associated with firms' green performance. Syafri et al.'s (2021) study provides further evidence that green innovations by SMEs help them to improve overall performance. Le and Ikram (2022) examined the impact of sustainability innovation on firm performance by Vietnamese SMEs. Using a sample of 435 firms and a well-structured questionnaires, Le and Ikram (2022) found that sustainability innovation is positively associated with financial, environmental, and operational environmental performance for SMEs in Vietnam. Similar results were reported by Bacinello et al. (2019) in the context of

Brazil, Qiu et al. (2020) in the context of China's manufacturing industry, and Suat et al. (2019) in the context of Malaysian manufacturing firms.

Another factor hindering environmental performance is that of contradictory views, as managers may consider environmental issues either as threats or as opportunities (Sharma, 2000). Although it is costly for SMEs to tackle the threat of climate change, when SMEs possess limited resources, doing so provides them with a substantial opportunity, and they are able to seize the opportunity in a multiplicity of ways (VividEconomy, 2006; Chege and Wang, 2021; Gannon et al., 2021). Green (2015) stated that the economic benefit of tackling climate change is greater than its costs. Moreover, SMEs' responses to climate change might be different from those of firms of other types. Generally, SMEs tend to have greater creativity and more flexibility and speed, and thus their process of adapting their operations (including structure, strategy, and resources) is different from that of other firms (Bower and Christensen, 1995; Anderson and Boocock, 2002; Rosenbusch et al., 2011). Both threats and opportunities from environmental changes influence firms to invest in innovation activities (Child, 1972; Marcus, 1988; Fan et al., 2020). In a related study, Huang et al. (2014) stated that engaging in fewer innovation activities may drive SMEs towards bankruptcy risk. As a result, SMEs invest in innovation activities to increase their sales, growth, and organisational adaptability and resilience, and their survival of environmental shocks (Smit and Skinner, 2002; Adger et al., 2008; García-Manjón and Romero-Merino, 2012; Su and Moaniba, 2017). Stakeholders also tend to take a positive view of SMEs engaged in eco-innovation (Ooi et al., 2020). Moreover, Rosenbusch et al. (2011) pointed out that SMEs can benefit greatly from innovation because they have more dynamic capability than larger firms.

Therefore, following the RBV, this paper proposes the following hypothesis:

*H1: Response to climate change positively impacts SMEs' innovation.*

## 3. Methodology

### 3.1 Data

Worldscope, World Bank (World Development Indicators), and Notre Dame Global Adaptation Institute (ND-GAIN) databases were the sources of data for the sample firms. Firm-level data were collected from Worldscope, while climate change risk data were collected from ND-GAIN. Recent studies such as Dogru et al. (2019) also used the ND-GAIN database. Country-level data was collected from World Development Indicators. We applied several sample selection criteria to construct our dataset. First, we chose the sample SME firms from 152 developing countries based on the IMF list (2018). Second, we defined SMEs as firms that employ fewer than 500 employees in a given year, following Saridakis et al. (2019). We excluded from the dataset firms that did not have a value for the number of employees. Third, for a country to be included in the sample, it had to have at least five firms to avoid possible estimation bias. These firms had to have at least five years of consecutive data between 2007 and 2016 to control for short panel bias (see Flannery and Hankins, 2013). We selected this period to close the latest data gap. Fourth, financial firms were excluded due to their different corporate structure and strategy. Based on these criteria, our final sample was composed of an unbalanced panel of 443 firms from 14 countries (see Table 1). These unbalanced panel data were able to control for the survivorship bias problem.

**Table-1: Sample country[1]**

| Country | Frequency | Percentage |
|---|---|---|
| Bulgaria | 13 | 2.93 |
| China | 70 | 15.80 |
| India | 161 | 36.34 |
| Jordan | 5 | 1.13 |
| Malaysia | 10 | 2.26 |
| Nigeria | 7 | 1.58 |
| Pakistan | 7 | 1.58 |

[1] To mitigate the potential for bias from the dominant country, we ran a separate regression without India. We obtained similar results to the main regression. The results will be provided on request.

| | | |
|---|---|---|
| Peru | 5 | 1.13 |
| Philippines | 16 | 3.61 |
| Poland | 48 | 10.84 |
| South Africa | 6 | 1.35 |
| Sri Lanka | 28 | 6.32 |
| Turkey | 54 | 12.19 |
| Vietnam | 13 | 2.93 |
| Total | 443 | 100 |

*Source*: Author's calculation

Table 2 shows the definitions of the variables. The dependent variable is innovation. Researchers have used different approaches to measure innovation. Previous studies such as Grilliches et al. (1987) and Lu and Wang (2018) used number of patents to measure innovation. However, Kafouros et al. (2008) stated that the outcomes of R&D investment are not always successful and successful outcomes are not always patentable. To avoid such criticism, innovation is measured as a log of R&D expenditure, following Alam et al. (2019a). We also used R&D intensity and R&D dummy to measure innovation for robustness tests. The key independent variable is climate change, which refers to a firm's degree of vulnerability in relation to agriculture, population, food, water, health, ecosystem, human habitat, infrastructure, etc., as a result of climate change, following Dogru et al. (2019). Several control variables were used: firm size, debt ratio, cash flow, Tobin's q, tangibility, and GDP growth. In the literature, these variables have been found to have significant impact on firms' innovation (Himmelberg and Petersen, 1994; Lu and Wang, 2018; Alam et al. 2019a, 2019b; Fan et al., 2020). Innovation performance may vary not only over time but also across industries. Therefore, industry dummy and year-specific dummy were used to capture industry and time effects.

**Table-2: Definitions of variables**

| Variables | Measurement | Sources |
|---|---|---|
| Innovation | Log of R&D expenditure | Worldscope |
| Climate change | Measured as vulnerabilities of agriculture, population, food, water, health, ecosystem, human habitat, infrastructure, etc., from climate change | ND-GAIN |
| Firm size | Log of market capitalisation | Worldscope |
| Debt ratio | Total debt / Total assets | Worldscope |
| Cash flow | (Net income + depreciation + R&D) / Total assets | Worldscope |
| Tobin's q | (Total assets + market value of equity - book value of equity) / Total assets | Worldscope |
| Tangibility | Property, plants, and equipment / Total assets | Worldscope |
| GDP growth | Annual gross domestic product growth | World Bank (WDI) |
| Industry dummy | An industry dummy that is equal to 1 if the firm is in a vulnerable industry and 0 otherwise | Worldscope |

Table 3 provides the summary statistics of our sample firms. The statistics show that the average innovation is 0.47, indicating the firms' considerable investment in R&D activities. The fairly large range, from 0 to 3.62, and a standard deviation of 0.99 suggest considerable variability in innovation across firms and over time. Climate change has a mean of 0.44 and a range of 0.32 to 0.52. This implies that firms have experienced changing climate conditions. The average size is 4.52. Its debt ratio, cash flow, Tobin's q, tangibility, and GDP growth average are 0.20, 0.07, 2.04, 0.32, and 6.12, respectively. All variables are winsorised at the 1% and 99% levels to restrict the influence of outliers.

**Table-3: Summary statistics**

| | Mean | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|
| Innovation | 0.46529 | 0.98625 | 0.00000 | 3.62097 |
| Climate change | 0.43801 | 0.07430 | 0.32000 | 0.52000 |
| Firm size | 4.52024 | 0.79998 | 2.88705 | 6.24791 |
| Debt ratio | 0.20236 | 0.20693 | 0.00000 | 0.89457 |
| Cash flow | 0.06951 | 0.11041 | -0.35201 | 0.47423 |

| | | | | |
|---|---|---|---|---|
| Tobin's q | 2.04741 | 2.77952 | 0.41407 | 19.02530 |
| Tangibility | 0.32256 | 0.22951 | 0.00270 | 0.92550 |
| GDP growth | 6.11584 | 3.04123 | -4.70000 | 11.11000 |

*Source*: Author's calculation

### 3.2 Model

In order to examine the impact of climate change on SMEs' innovation, the following model was devised:

$$Innovation_{it} = \alpha + \beta(climate\ change)_{it} + \dot{\lambda}(Control)_{it} + d_t + I_i + \varepsilon_{it} \quad (1)$$

where subscript $i$ represents the firm and $t$ represents the year. The dependent variable is innovation, and the main variable of interest is climate change. Control variables that could affect a firm's innovation activities, based on the extant literature, are firm size, debt ratio, cash flow, Tobin's q, tangibility, and GDP growth. $d_t$ is time dummy, which captures the time effect to take into account macroeconomic and cyclical effects. $I_i$ is industry dummy, which controls for the effect of industry as industries are separated into vulnerable and non-vulnerable industries. $\varepsilon_{it}$ is considered a random disturbance term, which is assumed to be $i.i.d$ normal.

### 3.3 Estimation and processing

This study used a two-step system generalized method of moments (GMM) estimation for several reasons. First, the GMM estimation is consistent with panel data, and it is efficient when the number of cross-sections (N equals 443) is higher than the number of time periods (T equals 10) (Alam et al. 2019a; 2019b). Second, endogeneity is a common problem in the innovation literature (Pindado et al., 2015). Omitted variable bias and measurement errors could cause the endogeneity problem (Alam et al., 2019a; 2020). The bilateral causal relationship between dependent and explanatory variables may also create an endogeneity

problem (Su and Moaniba, 2017). In our case, innovation and firm size causality may run in both directions. The GMM approach can control for the endogeneity problem (Pindado et al., 2015). Third, innovation activity is generally an ongoing series; therefore, lagged innovation is also likely to be related to current year innovation. This persistence of firm innovation can be better minimised by GMM estimation (Asongu et al. 2018; Alam et al. 2019a; 2019b). Fourth, Hansen (1982) argued that the GMM approach provides a general platform that considers statistical inference, as it encompasses many estimators of interest to econometrics. In a related study, Worrall (2008) stated that several estimations, such as OLS, 2SLS, and IV, could fit into GMM as a single framework. Fifth, system GMM can control for the inherent biases in the difference GMM (Asongu et al., 2018). Sixth, two-step GMM produces a more efficient estimation than one-step estimation (Alam et al., 2019a; 2020).

## 4. Results and analysis

Table 4 presents the empirical results of the GMM estimation. Lagged value of innovation is significantly different from zero, showing the persistence of innovation investment. The high persistence rate (86%) shows the firm's ability to continue R&D investment projects into subsequent periods. The result follows the smoothing idea and is consistent with the findings of Alam et al. (2019a). Climate change has a significant positive impact on innovation. In economic terms, a one-standard-deviation change in climate change results in a 6.6% (i.e. (0.44 * 0.07) / 0.47)[2] increase in innovation investment. This implies that SMEs tend to invest more in innovative activities to mitigate the negative impacts of climate change. Moreover, investment in innovation will help firms to develop new products, services, and technologies

[2] Calculated as ((0.44∗ 0.07)/0.47) = 0.0655, where 0.44 is the regression coefficient, 0.07 is the standard deviation of climate change, and 0.47 is the mean innovation.

that have lower carbon emissions and greater sustainability. Su and Moaniba (2017) also reached a similar conclusion. Therefore, the results strongly support Hypothesis 1.

The results show that firm size, cash flow, and Tobin's q also influence innovation considerably. Because they have more resources and better access to the financial market, larger firms invest more in innovation activities (Alam et al.2019b), which in turn help firms to better alleviate external environmental shocks such as climate change. With a one-unit increase in firm size, innovation performance increases by 0.09 units. The co-efficient of cash flow is positive and significant, implying that increases in cash flow encourage managers to invest more in innovative activities. Bhagat and Welch (1995) argued that firms that have more significant cash flow engage in more R&D activities and are thus able to avoid external market costs. Results show that firms with higher growth opportunities (Tobin's q) tend to invest more in innovation activities. Growth opportunities help firms explore new ideas and expand knowledge, skills, and abilities for further development, which in turn improve innovation investment.

Debt, tangibility, and GDP growth are found to be fragile determinants and have less impact on SMEs' innovation performance. There is no significant relationship between firm debt and innovation. This is because SMEs become reluctant to borrow external finance for innovative activities as they have limited collateral and unstable cash flow and the potential outcomes are not clear (Brown et al., 2022). Higher tangibility indicates higher fixed assets such as property, plants, and equipment that are used in a company's operations rather than for innovation purposes. The results show that GDP growth and SMEs' innovation investment are uncorrelated. Wang (2010) also reached a similar conclusion. Although sustainable economic growth can bring many benefits to societies and businesses, the volatility in GDP growth may discourage SMEs from investing in risky and uncertain projects such as R&D.

**Table-4: Results**

| | |
|---|---|
| $Innovation_{t-1}$ | 0.85877*** |
| | (0.03354) |
| Climate change | 0.44198** |
| | (0.18071) |
| Firm size | 0.09006** |
| | (0.03008) |
| Debt ratio | 0.06741 |
| | (0.07643) |
| Cash flow | 0.00023* |
| | (0.00013) |
| Tobin's q | 0.01419* |
| | (0.00734) |
| Tangibility | 0.05390 |
| | (0.10766) |
| GDP growth | 0.00080 |
| | (0.00281) |
| Year dummy | Yes |
| Industry dummy | Yes |
| Observations | 2,399 |
| AR(1) | 0.000 |
| AR(2) | 0.205 |
| Hansen | 0.104 |

Standard errors are in parentheses; level of significance at 1%, 5%, and 10%

### 4.1 Additional analysis

Table 5 shows the relationship between climate change and SMEs' innovation based on different groups. The results show that SMEs' innovation response to climate change may vary substantially across firms and industries. Following the RBV, in high growth, high-slack-resources firms, and highly profitable and non-vulnerable industries, SMEs' innovation positively responds to climate change. It is found that high-growth firms respond more positively to climate change than low-growth ones. High growth leads to more savings, which ultimately translates into increased innovation investment. High-slack-resources SMEs respond differently to climate change from low-slack-resources ones. Slack resources enable

firms to be more adaptable to environmental changes and allocate more resources to innovation (Meyer et al., 1990; Nohria and Gulati, 1996). The results suggest that highly profitable firms invest more in innovation in response to climate change. High earnings encourage managers to make more R&D investments and access the competitive advantage of the opportunities created by climate change. It was found that non-vulnerable SMEs experienced more considerable innovation investment than vulnerable ones. Being under threat, vulnerable firms tend to focus on core products and services while avoiding risky investments such as R&D.

**Table-5: Additional analysis**

Low- vs high-growth SMEs

| | Low growth | High growth |
|---|---|---|
| Climate change | 0.48612 | 0.49715* |
| | (0.32045) | (0.26276) |
| Controls | Yes | Yes |
| Observations | 1,235 | 1,164 |
| AR(1) | 0.002 | 0.000 |
| AR(2) | 0.42 | 0.206 |
| Hansen | 0.929 | 0.107 |

Low- vs high-slack-resources SMEs

| | Low slack resources | High slack resources |
|---|---|---|
| Climate change | 0.77302 | 0.54040* |
| | (0.47426) | (0.30746) |
| Controls | Yes | Yes |
| Observations | 1,175 | 1,224 |
| AR(1) | 0.001 | 0.000 |
| AR(2) | 0.182 | 0.546 |
| Hansen | 0.303 | 0.175 |

Low- vs high-profit SMEs

| | Low profit | High profit |
|---|---|---|
| Climate change | 0.38614 | 0.76492** |
| | (0.36797) | (0.36059) |
| Controls | Yes | Yes |
| Observations | 1,220 | 1,179 |
| AR(1) | 0.017 | 0.000 |
| AR(2) | 0.285 | 0.175 |

| | | |
|---|---|---|
| Hansen | 0.104 | 0.102 |

Vulnerable vs non-vulnerable industries

| | Vulnerable | Non-vulnerable |
|---|---|---|
| Climate change | 0.00723 | 0.71253* |
| | (0.31893) | (0.27387) |
| Controls | Yes | Yes |
| Observations | 682 | 1,707 |
| AR(1) | 0.000 | 0.000 |
| AR(2) | 0.562 | 0.134 |
| Hansen | 0.155 | 0.144 |

Firm growth is measured as changes in sales between year t and t-1. Firms with above-median sales growth are high-growth firms, and those with below-median sales growth are low-growth firms. Slack resources are measured as log of cash and short-term investment at the end of the year. Firms below the median are classified as having low levels of slack resources and the rest are considered to have high levels of slack resources. Firm profitability is measured by return on assets (ROA). Firms with ROA above the median are classified as highly profitable, otherwise as having low profits. Vulnerable firms in vulnerable industries are as defined in Huang et al. (2018). Standard errors are in parentheses; level of significance is at 1%, 5%, and 10%.

### 4.2 Robustness tests

Table 6 shows the robustness checks. We conducted several tests to check the robustness of our results. We used an alternative measure of innovation, R&D intensity (R&D over total assets), as a dependent variable for GMM estimation. As a further robustness check, we used an alternative method, the probit estimation, while taking the innovation dummy (if the value of R&D was positive equal to 1, 0 otherwise) as the dependent variable. The regression results of these robustness tests confirm the principal conclusion that SMEs' response to climate change positively impacts their innovation.

**Table-6: Robustness tests**

| Dependent variable | R&D intensity | R&D dummy |
|---|---|---|
| $Innovation_{t-1}$ | 0.73636*** | |
| | (0.07753) | |
| Climate change | 0.00218* | 1.59976* |

| | | |
|---|---|---|
| | (0.00116) | (0.82526) |
| Firm size | 0.00010 | 0.16837** |
| | (0.00026) | (0.05209) |
| Debt ratio | -0.00002 | -0.10540 |
| | (0.00053) | (0.12474) |
| Cash flow | 0.00001* | 0.00046 |
| | (0.00000) | (0.00042) |
| Tobin's q | 0.00019* | -0.0004 |
| | (0.00010) | (0.00953) |
| Tangibility | -0.00102** | -0.32485** |
| | (0.00050) | (0.13741) |
| GDP growth | -0.00002 | 0.00027 |
| | (0.00002) | (0.00524) |
| Year dummy | Yes | Yes |
| Industry dummy | Yes | Yes |
| Observations | 2399 | 2842 |
| AR(1) | 0.002 | |
| AR(2) | 0.293 | |
| Hansen | 0.134 | |
| Wald | | 0.0004 |

Standard errors are in parentheses; level of significance at 1%,5%, and 10%

## 5. Conclusion and implications

Climate change is a global issue. Meeting this challenge could provide an opportunity to create new sources of growth for SMEs. Developing mitigation strategy and adopting policies to tackle the challenge of climate risk can make SMEs more innovative. Therefore, drawing on the RBV perspective, this paper examined the impact of climate change on SMEs' innovation. Utilising firm-level data from 14 developing countries, we performed a GMM estimation to find out the impact of climate change on SMEs' innovation. The results show that climate change has a significant positive impact on SMEs' innovation. This is because SMEs tend to invest more than firms of other types in innovative activities to mitigate and adapt to climate change. Interesting results emerged when the sample was divided into high- and low-growth, high- and low-slack-resources firms, high- and low-profit firms, and vulnerable and non-

vulnerable industries. The results show that SMEs' response to climate change may vary substantially across firms and industries. High-growth, high-slack-resources, highly profitable, and non-vulnerable SMEs showed a positive innovation response to climate change.

This study has made theoretical contributions to extend the application of the RBV to the relationship between responses to climate change and innovation performance. This study used a sample of 443 SMEs from 14 developing countries to conduct comprehensive research on the impact of climate change on the innovation performance of SMEs from developing countries from the perspectives of knowledge exploitation and knowledge exploration. This study provides further evidence that if SMEs respond to climate change with knowledge exploitation and exploration it can improve their innovation performance. Beyond that, the contribution of this study is significant in practical terms as SMEs, especially those from developing markets, tend to receive less attention for their green innovation and environmental protections compared with multinationals from developed countries. As the results indicate, SMEs tend to experience technological, environmental, and reputational benefits from their responses to climate change. This implication may interest both managers and policymakers engaged in addressing environmental protection issues: these findings on the positive impact of SMEs' responses to climate change on their innovation performance have some managerial and policy implications. This study will help SME managers to better understand how to engage with innovation activities to tackle environmental issues in general and climate change in particular. SME managers can gain competitive advantages from the new business opportunities that may arise from responding to climate change by investing in innovative activities. Therefore, the findings of the study encourage SME managers to invest more in innovation activities and increase organisational resilience to environmental changes. Regarding policy, without a holistic response to the impacts of climate change, small firms face

a wide range of problems such as challenges to growth and survival. Policymakers and international organisations could encourage SMEs' to engage in innovation activities to increase mitigation and adaptation to tackle climate change and ensure sustainable development. To this end, our key finding – that climate change has a significant impact on SMEs' innovation – is an important contribution to SME research.

Although we used GMM analysis, it is not without limitations. It does not address the endogeneity arising from time-variant omitted variables (Abbasi et al., 2021). Hence, we suggest that future researchers conduct qualitative analysis through interviews and surveys to corroborate our findings. Moreover, we did not consider how the culture and institutional quality of a country could affect the relationship between climate change and SMEs' innovation. This may be a fruitful area of research as, for example, certain cultures may attach limited importance to climate change, and some countries' institutions may be more conducive to efforts to address climate change.

**References**


Abbasi, K., Alam, A., Du, M. A., Huynh, T. L. D. 2021. FinTech, SME efficiency and national culture: evidence from OECD countries. Tech. Fore. Soc. Cha., vol. 163, 120454

Abdelzaher D. M., Martynov A., Abdel Zaher A. M. 2020. Vulnerability to climate change: Are innovative countries in a better position?, Res. Intern. Bus. Fin., vol. 51, pp. 1-16

Adger, W. N. et al. 2008. Are there social limits to adaptation to climate change?, Clim. Chan., vol. 93, pp.335-354

Alam A., Uddin M. M., Yazdifar H. 2019a. Financing behavior of R&D investment in the emerging markets: The role of alliance and financial system, R&D Man., vol. 49, Issue 1, pp. 21-32

Alam A., Uddin M. M., Yazdifar H. 2019b. Institutional determinants of R&D investment: Evidence from emerging markets', Tech. Fore. Soc. Cha.**,** vol. 138, pp. 34-44

Alam A., Uddin, M. M., Yazdifar H., Shafique S., Lartey T. 2020. R&D investment, firm performance and moderating role of system and safeguard: Evidence from emerging markets' J. Bus. Res., vol.106, pp.94-105

Amini, A. 2004. The distributional role of small business in development, Int. J. Sma. Econ., vol. 31, pp.33-46

Anderson, V., Boocock, G. 2002. Small firms and internationalisation: Learning to manage and managing to learn, Hum. Res. Man. J., vol. 12, pp. 5-24.

Aragón-Correa, J. A. 1998. Strategic proactivity and firm approach to the natural environment, Aca. Man. J., vol. 41, pp. 556-567.

Aragón-Correa, J. A., Sharma, S. 2003. A contingent resource-based view of proactive corporate environmental strategy, Aca. Man. Rev., vol. 28, pp. 71-88.

Asif, M.U., Asad, M., Kashif, M., Abrar ul Haq, M. 2021. Knowledge exploitation and knowledge exploration for sustainable performance of SMEs, proceedings of the 3rd int. Sust. Resi. Conf.: Clim. Cha., pp. 29-34.

Asongu, S. A., Roux, S. L., Biekpe, N. 2018. Enhancing ICT for environmental sustainability in sub-saharan Africa', Tec. For. Soc. Cha., vol.127, pp. 209-216

Bacinello, E., Tontini, G. Alberton, A. 2019. Influence of maturity on corporate social responsibility and sustainable innovation in business performance, Cor. Soc. Res. Env. Man., vol. 27(2), pp. 749-759.

Barney J. B. 1991. Firm resources and sustained competitive advantage, J. Man., vol.17, pp.99-120

Barrow, C. 1993. The essence of small business. Pren. Hal., London

Bhagat, S., Welch, I. 1995. Corporate research and development investments: International comparisons, J. Acc. Econ., vol. 19, pp. 443-470

Bhur, B., Donovan, C., Kling, G., Lo. Y., Murinde, V., Pullin, N. Volz, U. 2018. Climate change and the cost of capital in developing countries. Imperial College Business School and SOAS, Uni. of London Report

Bodlaj, M., Kadic-Maglajlic, S., Vida, I. 2020. Disentangling the impact of different innovation types, financial constraints and geographic diversification on SMEs' export growth. J. Bus. Res., vol. 108, pp. 466-475.

Bower, J. L., Christensen, C. M. 1995. Disruptive technologies: Catching the wave, Har. Bus. Rev., vol.73, pp.43-54

Brown, R., Liñares-Zegarra, J. M., Wilson, J. O. 2022. Innovation and borrower discouragement in SMEs. Sma. Bus. Econ., 1-29.

Fahad, S., Alnori, F., Su, F., Deng, J. 2022. Adoption of green innovation practices in SMEs sector: evidence from an emerging economy, Econ. Res., pp. 1-16,

Festa, G., Metallo, G., Cuomo, M.T., Situm, M. 2019. Crowdfunding in wine business as financing opportunity for smaller wineries, Int. J. Glob. Sma. Bus., vol. 10, pp. 278-292

Chege, S. M., Wang, D. 2020. The influence of technology innovation on SME performance through environmental sustainability practices in Kenya. Tech. Soc. Vol. 60, 101210

Chen C.-J., Lin, B.-W., 2004. The effects of environment, knowledge attribute, organizational climate, and firm characteristics on knowledge sourcing decisions, R&D Man., vol.34, pp.137-146

Child J. 1972. Organization structure, environment and performance: The role of strategic choice, Sociol., vol.6, pp.1-22

Crick, F., Eskander, A. M. S. U., Fankhauser, S., Diop, M. 2018. How do African SMEs respond to climate risks? Evidence from Kenya and Senegal, Wor. Devel., vol.108, pp.157-168

Dogru, T., Marchio, E. A., Bulut, U., Suess, C. 2019. Climate Change: Vulnerability and resilience of tourism and the entire economy, Tou. Man., vol.72, pp.292-305

Edeh, J. N., Obodoechi, D. N., Ramos-Hidalgo, E. 2020. Effects of innovation strategies on export performance: New empirical evidence from developing market firms. Tec. For. Soc. Cha., vol. 158, 120167

Eryigit, N., Ozcüre, G. 2015. Eco-Innovation as modern era strategy of companies in developing countries: comparison between Turkey and European Union. Pro. Soc. Beh. Sci., vol. 195, pp. 1216–1225.

Fan D., Rao-Nicholson, R., Su, Yi. 2020. When tough get going: Performance of R&D in the adverse economic condition, Lon. Ran. Plan., vol. 53(3), 101867

Fernández-Olmos, M., Ramírez-Alesón, M. 2017. How internal and external factors influence the dynamics of SME technology collaboration networks over time, Tech., vol. 64, pp. 16-27.

Festa, G., Rossi, M., Kolte, A., Situm, M. 2020. Territory-based knowledge management in international marketing processes - the case of "Made in Italy" SMEs", Euro. Bus. Rev., Vol. 32 No. 3, pp. 425-442.

Mitchell, S., O'Dowd, P., Dimache, A. 2020. Manufacturing SMEs doing it for themselves: developing, testing and piloting an online sustainability and eco-innovation toolkit for SMEs, Int. J. Sust. Engin., Vol. 13 No. 3, pp. 159-170.

Nguyen, V. H., Vu, N. H. 2022. Corporate environmental responsibility and innovation: empirical evidence from Vietnam, Int. J. Eme. Mark., (Forthcoming)

Nylund, P.A., Brema, A., Agarwal, N. 2021. Enabling technologies mitigating climate change: The role of dominant designs in environmental innovation ecosystems, Tech., 102271.

Straka, M., Oláh, J., Kassakorn, N. 2021. Impact of green supply chain integration on SMEs technological and economic performance, Glo. J. Ent. Man., vol. 2, pp. 12-30.

Syafri, W., Prabowo, H., Nur, S.A., Muafi, M. 2021. The impact of workplace green behavior and green innovation on green performance of SMEs: A case study in Indonesia, J, Asi. Fin., Econ. Bus., vol. 8, pp. 365-374.

Le, T. T., Ikram, M. 2022. Do sustainability innovation and firm competitiveness help improve firm performance? Evidence from the SME sector in Vietnam, Sus. Prod. Con., vol. 29, pp. 588-599.

Flannery, M. J., Hankins, K. W. 2013. Estimating dynamic panel models in corporate finance'. J. Cor. Fin., vol. 19, pp. 1-19.

Gannon, K. E., Crick, F., Atela, J., Conway, D. 2021. What role for multi-stakeholder partnerships in adaptation to climate change? Experiences from private sector adaptation in Kenya. Clim. Ris. Man. 32.

García-Manjón, J. V., Romero-Merino, M. E. 2012. Research, development, and firm growth. Empirical evidence from European top R&D spending firms, Res. Pol., vol. 41, pp. 1084–1092.

Green, F. 2015. Nationally self-interested climate change mitigation: a unified conceptual framework', Centre for Climate Change Economics and Policy, Wor. Pap. No 224, pp. 1-44.

Grilliches, Z, Pakes, A., Hall, B. 1987. The value of patents as indicators of inventive activity. In: Dasgupta, P., Stoneman, P. (Eds), Econ. Pol. Tec. Perf. Cambridge Uni. Pres., Cambridge, PP.97-124

Hampel-Milagrosa, A., Loewe, M., Reeg, C., 2015. The entrepreneur makes a difference: Evidence on MSE upgrading factors from Egypt, India and the Philippines, Wor. Dev., vol. 66, pp.118-130

Hansen, L. P., 1982. Large sample properties of generalized method of moments estimators, Econom., vol. 50, pp. 1029-1054

Hart, S. L. 1995. A natural-resource-based view of the firm, Aca. Man. Rev, vol. 20, pp. 986-1014

Himmelberg, C. P., Petersen, B. C., 1994. R&D and internal finance: A panel study of small firms in high tech industries, Rev. Econ. Stat., vol. 76, pp. 38-51

Huang H. H., Kerstein, J., Wang, C., 2018. The impact of climate risk on firm performance and financing choices: An international comparison, J. Int. Bus. Stud., vol.49, pp. 633-656

Huang J, Tang P, Jiang Z. 2014. R&D investment, risk and income of agricultural enterprises under the preferential tax policy: An empirical test based on China's agricultural listing corporation. J. Agr. Tec. Econ., vol. l, pp. 120-128.

Jo, J., Roh, T.W., Kim, S.H., Youn, Y., Pinto, I.S., Han, K.J., Jang, E.K., 2015. Eco innovation for sustainability: evidence from 49 countries in Asia and Europe. Sus., vol. 7 , pp. 16820–16835.

Kafouros, M., Buckley, P. J., Sharp, J. A., Wang, C., 2008. The role of internationalization in explaining innovation performance, Tech., vol.28, pp.63-74

Laurent, A., C. Molin, M. Owsianiak, P. Fantke, W. Dewulf, C. Herrmann, S. Kara, Hauschild M., 2019. The role of life cycle engineering (LCE) in meeting the sustainable development goals report from a consultation of LCE experts. J. Clean. Prod. Vol. 203, pp. 378–382.

Lu, J., Wang, W., 2018. Managerial conservatism, board independence and corporate innovation', J. Cor. Fin., vol. 48, pp.1-16

Mafini, C., Loury-Okoumba, W. V., 2018. Extending green supply chain management activities to manufacturing small and medium enterprises in a developing economy. Sou. Afr. J. Econ. Man. Sci., vol. 21, pp. 1-12.

Marcus, A. A., 1988. Responses to externally induced innovation: Their effects on organization performance, Str. Man. J., vol.9, pp.387-402

Marin, G., Marzucchi, A., Zoboli, R. 2015. SMEs and barriers to eco-innovation in the EU: exploring different firm profiles. J. Evol. Eco., vol. 25, pp. 671–705.

Mendy, J., Rahman, M., Bal, P. M. 2020. Using the "best-fit" approach to investigate the effects of politico-economic and social barriers on SMEs' internationalization in an emerging country context: Implications and future directions. Thun. Int. Bus. Rev., Vol. 62, pp.199-211.

Meyer, A., Brooks, G., Goes, J. 1990. Environmental jots and industry revolutions: Organizational responses to discontinuous changes, Str. Man. J., vol.11, pp.93-110

Micale, V., Tonkonogy, B., Mazza, F., 2018. Understanding and increasing finance for climate adaptation in developing countries, Clim. Pol. Init .paper.

Mitchell, S., O'Dowd, P., Dimache, A. 2020. Manufacturing SMEs doing it for themselves: Developing, testing and piloting an online sustainability and eco-innovation toolkit for SMEs. Int. J. Sust. Eng. Vol. 13, pp. 159-170.

Murray, T. 2018. IPCC report reveals urgent need for CEOs to act on climate. Forbes. Washington, DC, 09 October. Accessed March 30th, 2022. https://www.forbes.com/sites/edfenergyexchange/2018/10/09/ipcc-report-reveals-urgent-need-for-ceos-to-act-on-climate/#68a8bc143333

Nohria, N., Gulati R., 1996. Is slack good or bad for innovation, Aca. Man. J., vol. 39, pp.1245-1264

Oliveira, J. A. P. de., Jabbour, C. J. C., 2017. Environmental management, climate change, CSR, and governance in clusters of small firms in developing countries: Toward an integrated analytical framework', Bus. Soc., vol. 56, pp. 130-151

Ooi, S. K., Ooi, C. A., Memon, K. R. 2020. The role of CSR oriented organisational culture in eco-innovation practices. Wor. Rev. Ent. Man. Sust. Dev. Vol.16, pp. 538-556.

Parry, M. Arnell, N., McMichael, T., Nicholls, R., Martens, P., Kovats S., et al. 2001. Millions at risk: Defining critical climate change threats and targets, Glo. Env. Cha., vol.11, pp.181-183

Peloza, J. 2009. The challenge of measuring financial impacts from investments in corporate social performance. J. Man., vol. 35, pp. 1518-1541.

Pindado, J., Queiroz, V. d., Torre, C. d. l. 2015. How do country-level governance characteristics impact the relationship between R&D and firm value, R&D Man., vol.45, pp.515-526

Pinkse, J., Kolk, A., 2010. Challenges and tradeoff in corporate innovation for climate change, Bus. Str. Env., vol. 19, pp.261-272

Prasanna, R., Jayasundara, J., Gamage, S. K. N., Ekanayake, E., Rajapakshe, P. Abeyrathne, G., 2019. Sustainability of SMEs in the competition: A systemic review on technological challenges and SME performance, J. Ope. Inn., vol. 5, pp. 1-18.

Qiu, L., Jie, X., Wang, Y., Zhao, M., 2020. Green product innovation, green dynamic capability, and competitive advantage: evidence from Chinese manufacturing enterprises. Cor. Soc. Resp. Env. Man., vol. 27, pp. 146-165.

Rosenbusch, N., Brinckmann, J., Bausch, A., 2011. Is innovation always beneficial? A meta-analysis of the relationship between innovation and performance in SMEs, J. Bus. Vent., vol.26, pp. 441-457

Saridakis, G., Idris, B., Hansen, J. M., Dana, L. P., 2019. SMEs' internationalisation: When does innovation matter?, J. Bus. Res., vol. 96, pp. 250-263.

Schaefer, A., Williams, S. Blundel, R. 2011. SMEs construction of climate change risks: The role of networks and value. In: SMEs: Moving towards sustainable development, Int. Conf., 20-22 Oct, 2011, Montreal, Canada

Schiederig, T., Tietze, F., Herstatt, C. 2012. Green innovation in technology and innovation management – an exploratory literature review. R&D Man., vol. 42, pp. 180–192.

Sharma S. 2000. Managerial interpretations and organization context as prediction of corporate choice of environmental strategy, Aca. Man. J., vol. 43, pp.681-697

Smit, B., Skinner, M. W. 2002. Adaptation options in agriculture to climate change: A typology, Mit. Ada. Str. Glob. Cha., vol.7, pp.85-114

Su, H.-N., Moaniba, I. M. 2017. Does innovation respond to climate change? Empirical evidence from patents and greenhouse gas emissions, Tec. For. Soc. Cha. vol. 122, pp. 49-62

Suat, L.A., San, O.T. 2019. Corporate environmental management: eco-efficiency and economics benefit is among manufacturers certified with EMS14001 in Malaysia, Int. J. Rec. Tec. Eng, vol. 7(6), pp. 873-886.

Sullivan, R., Gouldson, A. 2017. The Governance of corporate responses to climate change: An international comparison. Bus. Str. Env., vol. 26 (4), pp. 413–425.

Tollefson J. 2022. Climate change hitting the planet faster than scientists originally thought, Nat., 28th February, available at https://www.nature.com/articles/d41586-022-00585-7 (Accessed on 21st August, 2022)

Trifilova, A., Bessant, J., Jia, F., Gosling, J. 2013. Sustainability-driven innovation and the climate savers' program: Experience of international companies in China, Cor. Gov., vol., 13, pp. 599-612

United Nations Development Programme. 2007. Human Development Report 2007-08, N. Y. : Palgrive-Macmillan

Vivid Economy. 2006. The business opportunities for SMEs in tackling the causes of climate change, Bus. Rep., pp.1-30

Wang, E.C., 2010. Determinants of R&D investment: The extreme-bounds analysis approach applied to 26 OECD countries, Res. Pol., vol. 39, pp. 103-116.

Ward, P., Shively, G. 2012. Vulnerability, income growth and climate change, Wor. Dev., vol.40, pp. 916-927

Wedawatta, G., Ingirige, B., Amaratunga, D. 2010. Building up resilience of construction sector SMEs and their supply chains to extreme weather events, Int. J. Str. Pro. Man., vol.14, pp.362-375

Williams S., Schaefer, A. 2013. Small and medium-sized enterprises and sustainability: Managers' values and engagement with environmental and climate change issues, Bus. Str. Env., vol, 22, pp.173-186

Worrall, J. L. 2008. The effects of local law enforcement block grants on serious crime, Crim. Pub. Pol.,vol. 7, pp. 325-350.

Zilberman, D., Lipper, L., McCarthy, N., Gordon, B. 2018. Innovation in response to climate change, Cli. Sma. Agri., vol.52, pp.49-74.