UNIVERSITY OF CAPE COAST

# CLIMATE VULNERABILITY, TECHNOLOGICAL INNOVATION AND PERFORMANCE OF LISTED AGRO-BASED FIRMS IN SELECTED SUB-SAHARAN AFRICAN COUNTRIES

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BY

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Thesis submitted to the Department of Economic Studies of the School of Economics, College of Humanities and Legal Studies, University of Cape Coast, in partial fulfilment of the requirements for the award of Master of Philosophy Degree in Economics

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## DECLARATION

### Candidate's Declaration

I hereby declare that this thesis is the result of my own original work and that no part of it has been published or presented for another degree in this university or elsewhere.

Signature……. Date……

Candidate's Name: Al-Jafar Suleiman Baidoo

### Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Signature……. Date……

Principal Supervisor's Name: Prof James Atta Peprah

Signature……. Date……

Co-Supervisor's Name: Dr. Benedict Afful

## ABSTRACT

The relationship between climate vulnerability and technological innovation in influencing the performance of agro-based firms in SSA has not been extensively studied. The objective of this study is to address this research gap by examining how climate vulnerability and technological innovation interact with each other to impact the performance of listed agro-based firms in selected countries in sub-Saharan Africa. Specifically, the study investigates the effect of climate vulnerability and technological innovation on firm performance as well as the moderating role of technological innovation in reducing the adverse impact of climate vulnerability on performance of agro-based firms. Return on equity is employed as an indicator for the dependent variable of financial performance. The study employs the system generalised method of moments to investigate the effect of climate vulnerability and technological innovation on performance of agro-based firms in seven SSA countries. The findings indicate that climate vulnerability has a negative effect on the performance of firms while technological innovation has a positive impact on firm performance and can effectively mitigate the adverse effect of climate vulnerability. It is therefore recommended that Government agencies in charge of environmental protection and sustainability should work closely with non-governmental organizations as well as the private sector to develop programs and policies that support the adoption of innovative technologies that can help firms mitigate the impact of climate vulnerability and improve their performance.

**KEY WORDS**

Agro-based firms

Climate vulnerability

Firm performance

Sub-Saharan Africa

Technological innovation

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## DEDICATION

To my elder brother and mentor Kofi Sadick Baidoo (Esq).

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| | |
|---|---|
| AR(2) | Arellano Bond Test |
| CFR | Cash Flow Ratio |
| CPQS | Closing Percent Quoted Spread |
| GDP | Gross Domestic Product |
| GMM | Generalised Method of Moment |
| GSE | Ghana Stock Exchange |
| NASDAQ | National Association of Securities Dealers Automated Quotations |
| NYSE | New York Stock Exchange |
| SSA | Sub-Saharan Africa |
| RBV | Resource Based View |
| ROA | Return On Asset |
| ROE | Return On Equity |
| ROS | Return On Sales |
| R&D | Research And Development |
| IPCC | Intergovernmental Panel on Climate Change |
| UNFCCC | United Nations Framework Convention on Climate Change |
| VUL | Climate Vulnerability |
| WDI | World Development Indicators |

# CHAPTER ONE

# INTRODUCTION

The chapter provides background for the study, focusing on key aspects such as climate vulnerability, firm performance, and technological innovation. It also emphasises the problem statement, research purpose, hypotheses or objectives of the study, how significant the research will be to both academia and policy making, delimitation and limitations of the research, as well as how the research is being organised.

## Background of the Study

The agro processing industry is essential in feeding the growing global population and is also a significant contributor to the world's economy. However, the industry is facing numerous challenges, including climate change effects which are exacerbating the existing vulnerabilities in the industry (Smith et al., 2014). The agricultural sector is being impacted by climate change due to altered precipitation, temperature variations, increase in the degree of severe and frequent weather events, soil degradation and water scarcity (Smith et al., 2014), which directly affects the performance of firms in the agro-processing industry. The agricultural sector contributes significantly to global emissions of greenhouse gases and is extremely vulnerable to the effects of climate change (IPCC, 2014). As a result, agro-based firms must acclimatise to the changing climate to maintain their performance and competitiveness in the global market (Nelson et al., 2009). Climate vulnerability has been noted as a significant challenge that has the potential to adversely affect the performance of these firms (Smith, 2020).

The Sustainable Development Goals (SDGs) and Africa's Agenda 2063 provide crucial frameworks that resonate with the aims of this research. SDG 9, emphasizing "Industry, Innovation, and Infrastructure," underscores the importance of fostering resilient infrastructures and sustainable industrialization. The integration of technological advancements in agriculture is pivotal for the resilience and growth of agro-based firms, especially in the face of climate-related adversities. Additionally, SDG 13, focusing on "Climate Action," highlights the imperative for global collective efforts to combat climate change and its far-reaching consequences. The synergy between climate vulnerability and technological innovation exemplifies the need for innovative strategies that simultaneously enhance climate resilience and advance economic prosperity.

Adoption of innovative technologies has been seen as a key solution in addressing this challenge and improving the resilience of these firms (Johnson, 2019). Building resiliency for adaptation in the presence of climate vulnerability in the agriculture sector is a major technique for addressing the problems caused by climate change. Although, adaptability varies greatly across geographic areas, nations, and cultural classes, and it changes over periods, the much more vulnerable regions include those that have a limited potential for adaptation and are specifically subjected to the dangers of climate change (Abbass, Qasim, Song, Murshed, Mahmood, & Younis, 2022). Countries that are less endowed with resources have low levels of technology, inadequate information, lack of technical know-how, poor infrastructure, and inadequate availability of resources have little capacity for adaptation and are extremely vulnerable.

Reducing vulnerability, especially for the most vulnerable nations, regions, and socioeconomic groups requires enhancing technological innovation. Even though there are significant regional differences in vulnerability, it is acknowledged that technological innovation will be key in reducing the impact of climate vulnerability. As a result, technological innovation has become increasingly important for agro-based firms (Lundvall, 1992). Technology and innovation adoption can help agro-based firms to improve their productivity, reduce costs, and enhance the quality of their products (Lundvall, 1992). Moreover, technological innovation can also help agro-based firms to address some of the challenges posed by climate change, such as increasing water scarcity and intensity of extreme weather (Smith et al., 2014). Due to this, agro-based firms that are able to embrace technological innovation are more capable of sustaining competition in the world market (Lundvall, 1992).

The performance of agro-based firms is impacted by a complex set of factors, which include technological innovation, climate change, and other internal and external factors (Damanpour, 1991). The link that exists between technological innovation and firm performance is particularly relevant for agro-based firms, as implementing new technologies and innovations can significantly affect these firms' performance (Damanpour, 1991). Despite the numerous adverse effects of climate on firm performance, along with the significance of technological innovation (Cevik & Miryugin, 2022; Kling,et al. 2021; Giang, et al. 2021), there has only been limited studies investigating the link (Lundvall, 1992).

Aligned with the Sustainable Development Goals (SDGs), particularly Goal 9 ("Industry, Innovation, and Infrastructure") and Goal 13 ("Climate Action"), this study delves into the intricate relationship between climate vulnerability, technological innovation, and the performance of agro-based firms, addressing pressing challenges within Africa's agricultural sector.

**Statement of the Problem**

The impact of climate change and technological innovation has become crucial for agro-based firms and the larger agricultural industry. Extreme weather events and other climate-related risks, which are increasingly common due to climate change, exerts negative consequences on the financial performance of agro-based firms. In contrast, technological innovation has the prospect of significantly enhancing the performance of such firms by reducing the impact of climate vulnerability, increasing productivity, and improving competitiveness. However, despite the potential impact of these factors, the interaction among climate vulnerability, technological innovation, and the performance of agro-based firms is not well understood.

This link between these variables happen to be complex and multi-faceted, and thus requires further investigation to comprehend. While technological innovation has been shown to increase efficiency and productivity, they also have the potential to increase a firm's vulnerability to the adverse effects of climate change (Smith, 2020). Brynjolfsson and McAfee (2011) argue that technological innovation has been shown to increase efficiency and productivity in a variety of industries, including agriculture.

The authors note that the deployment of new technologies, such as precision agriculture, can lead to increased efficiency in resource use, improved product quality, and reduced production costs. In addition, the authors suggest that technological innovation can drive economic growth by enabling firms to produce more with fewer inputs and improve their competitiveness in global markets. In contrast, Adger et al. (2005) argue that climate vulnerability can limit the adoption and effective implementation of innovative technologies, as well as other adaptation strategies, in vulnerable economies and sectors, such as the agricultural sector. The authors argue that adaptation to climate change requires a comprehensive and integrated mechanism that takes into account social, economic, as well as the ecological context of the affected communities and sectors. This includes assessing the capability of the economies and sectors to adopt and incorporate new technologies, as well as the potential social and environmental impacts of these technologies. To date, there hasn't been much study done on how these factors interact.

There is therefore the need for further research to comprehend the relationship existing between climate vulnerability, technological innovation, and the financial performance of agro-based firms and inform effective policy making. The study therefore seeks to examine the interrelationship between climate vulnerability, technological innovation, and the performance of agro-based firms in selected Sub-Saharan African countries.

## Purpose of the Study

The goal of the study is to evaluate the interrelationship between climate vulnerability, technological innovation and performance of listed agro-based firms.

## Research Objectives

The objectives of the study are:

1. Examine the effect of climate vulnerability on the performance of listed agro-based firms in SSA.
2. Evaluate how technological innovation affect the performance of of listed agro-based firms in SSA
3. Determine the moderating role of technological innovation on the relationship between climate vulnerability and performance of listed agro-based firms in SSA.

## Research Hypotheses

The research empirically tests the following hypothesis based on the primary objective of the research stated above.

1. $H_0$: climate vulnerability has no significant effect on the firm performance of listed agro-based firms within the sub-Saharan African region.

   $H_1$: climate vulnerability has a significant effect on the performance of listed agro-based firms within the sub-Saharan African region.

2. $H_0$: technological innovation does not significantly affect the performance of listed agro-based firms in sub-Saharan Africa.

$H_1$: technological innovation significantly affects the performance of listed firm agro-based firms in sub-Saharan Africa.

3. $H_0$: technological innovation does not moderate the effect of climate vulnerability on the performance of listed agro-based firms in the selected countries.

   $H_1$: technological innovation does moderate the effect of climate vulnerability on the performance of listed agro-based firms in the selected countries.

**Significance of the Study**

How relevant technology innovation as a mitigating factor to the effect of changing climatic circumstances cannot be understated; this offers the rationale for us to research technological innovation's actual contribution to reducing the consequences of climate vulnerability in SSA. This adds to the volume of empirical studies as it not only corroborates the importance of technological innovation to economic growth demonstrated by previous research works. However, it also established that technological innovation is a tool that may be used in reaction to inherent climate vulnerability effects. The work establishes foundation for future research studies on the relationship between financial performance of firms, climate vulnerability, and technological innovation.

The research's findings are important to policymakers since they offer policy guidance as well as recommendations when dealing with the impact of climatic conditions.

Again, for policy purposes, it emphasises the significance of investing in technological innovation if indeed the government wants to strengthen its agricultural sector.

**Delimitations of the Study**

This study looks at how climate vulnerability affects firm performance and how technological innovation mitigates this effect from 2007 to 2017 in selected SSA countries. As a result of available data during the period of study, six of the 48 sub-Saharan African countries were considered for the research.

**Limitations of the Study**

The study's primary flaw is the absence of data for some sub-Saharan African economies. The gap in data also restricted the use of other estimation techniques, like panel ARDL, for robust authentication. The study limits itself to the growth of agro-based firms as literature has shown that the impact of climatic changes in SSA is enormous in the field of agriculture. Regardless of these shortcomings, the study's findings and conclusions are reliable and consistent.

**Organisation of the Study**

The remaining portions of the study is structured as follows; Chapter Two reviews the literature on climate vulnerability, technological innovation, and firm performance from both a theoretical and an empirical perspective. The research approach that was employed for the analysis is detailed in Chapter Three. Chapter Four presents the findings and related discussions, with the conclusion being considered in light of the literature. The main conclusions, recommendations, and opportunities for additional research are outlined in Chapter Five.

# CHAPTER TWO

# LITERATURE REVIEW

## Introduction

This chapter provides a review of theoretical literature and empirical literature in relation to climate vulnerability, firm performance and technological innovation. The relevant theories for the research work were chosen after reviewing theoretical literatures on firm performance and technological innovation theories. The study analysed the literature on firm performance and technological innovation, firm performance and climatic vulnerability, and then worked on firm performance and macro environment in the empirical phase of the literature review. Finally, studies on firm characteristic factors and firm performance were also covered in this chapter.

## Resource Based View

The RBV postulates a relationship between an organisation's internal resources and its financial performance (Özdemir, & Denizel, 2007)). Strategic management establishes the framework of the resource-based perspective of firm performance. RBV contends that a firm's resources can be used to achieve a sustainable market edge if they meet a set of fundamental requirements (Bharadwaj et al., 1993; Hunt, 1999). It shows that the identification and management of crucial internal resources has an impact on a firm's capacity to create and maintain a competitive edge and improve performance (Sund, Bogers, Villarroel, & Foss 2016). The fundamental tenet of RBV is that firms differ by virtue of the vital resources and skills they dominate and possess.

According to Barney (1991), resource heterogeneity is a result of the interplay between resource immobility and inefficiencies in the resource market. Another advancement is the theory put forth by Wernerfelt and Montgomery (1988) that each organisation may be regarded as unique collection of both material and immaterial resources and skills. Without a doubt, resources form the basis of RBV analysis. Meaning the competitive advantage of firms will depend on how well their suite of resources and competencies fit into a certain industry environment. Consistent comparative edge is essentially the goal of resource selection, accumulation, as well as deployment and is centered on the assumption that an organisation's resources are heterogeneous. RBV as a strategy has developed in the actual world for several factors, including the velocity of change in terms of product innovation coupled with new technology, the change in customer needs and desires, and most importantly, the lack of adequate tools for forming organisational strategy in a setting that is becoming more dynamic. Even though organisations are under more pressure to respond quickly and effectively since time management is frequently viewed as a means of gaining a competitive edge, the rate of change is advancing at an ever-increasing velocity.

Barney (1991) posits that an organization can maintain a competitive advantage over time through the ownership of resources and capabilities that are valuable, rare, difficult to imitate, and not easily replaced.

These assets, which include a firm's management abilities, operational procedures, and the knowledge and expertise it controls, can be viewed as collections of both intangible and tangible assets. The resources offer the organisation the ability to develop and put into action initiatives that increase its efficacy and efficiency. A resource is deemed essential if it satisfies certain requirements, including being valuable, non-replaceable, unique or specific, and inimitable to improve firm performance (Barney, 1991; Crook, Ketchen Jr, Combs and Todd, 2008; Turber, Brocke Vom, and Gassmann, 2015).

Value:

Aristotle was one of the pioneering philosophers to conceive the idea of value. Aristotle believed that an object's value stemmed from its ability to either be used or transacted. Classical views concentrated on the factors that influence demand in explaining the value of an object. According to these views, the satisfaction derived from an item as well as how scarce the item determines the value of the item rather than any inherent quality.

Rumelt (1984) argued that the context in which the resources are being used influenced their worth. In line with Rumelt (1984), Barney (2001) also postulated that resources have a value depending on the unique market setting in which they are used and that resource worth may fluctuate based on the prevailing market. Therefore, the most crucial consideration is that there exists no resource that in itself is valuable, rare, or sustainable; instead, they are context-dependent (Collis, 1994).

This means that as organisations co-evolve, the precise economic benefit that a firm derives from a resource will eventually become ionised as to be impossible to distinguish from other contributions. In a world that is constantly evolving, entities that are not optimal now might turn out to be useful in the future.

Rareness:

The term "resource rareness" describes how scarce a resource is thought to be in factor markets. Rare skills are those that can only be acquired occasionally, such as patented items or some competent human resources which creates a significant capacity in an organisation. In other words, it describes how closely resources are integrated into the economic climate to take advantage of opportunities and minimise risks. it is impossible to have a competitive edge or a sustainable competitive advantage when there are numerous competing firms that all have access to significant firm-specific resources (Barney 1991). The RBV explains the possibility of gaining a competitive advantage by combining rarity and value (Barney, 1991)

A deeper degree of study may lead to the conclusion that rarity is pervasive. To some degree, every firm has something distinctive in the industry. The concern is not whether or how numerous firms have the resource, instead if combining the resources which by definition is rare can provide value. This issue is related to the operationalization of the rarity principle. Barney (2001) defined rarity as "less than the number of firms required to produce perfect competition dynamics in an industry".

Imperfectly imitable:

This relates to the idea that competitors find it difficult to implement resources. Due to the resources' inimitable nature, rivals are unable to acquire or copy them, or they can only do so at a large cost premium (Hansson, 2015). Simply put, this indicates that it is extremely difficult for rivals to adapt. Since these resources are first acquired, maintained, and enhanced during the project implementation phase to build connectivity with other resources, the advantage received from inimitability is therefore consistently seen in competencies across time.

Imitability is a core part of the resource-based perspective of the firm. On the condition that firms can create, refine, and produce the same resources as others that already has them and can do so for an insignificant price, that firm cannot have a significant competitive advantage (Barney, 1996).

Non-substitutable:

This is a measure of how much it is difficult for rivals to produce resources that are comparable. Imitative behavior can become problematic or even destructive in highly unpredictable circumstances. Imitation do occur for wide range of causes with significantly diverse outcomes, and in relatively specific circumstances, it can minimise risk for a certain organisation and defuse rivalry (Lieberman & Asaba, 2002).

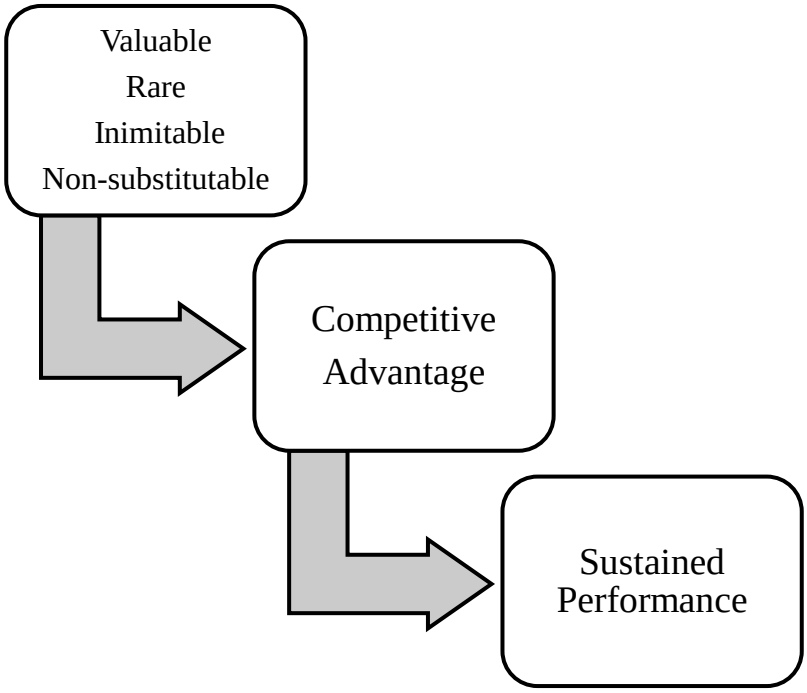


**Figure 1: Resource Based View**

Source: Barney (1991)

The RBV has faced criticism from researchers more recently. They contend that "rare" resources do not always give the company a competitive edge. This is true regardless of whether the resource in question can produce economic rents due to its relative scarcity. Net cash flows, also known as economic rents, are the costs of the services produced by resources. Economic rent in this point is the cost of a good or service relative to a company's resource (rare or not). For instance, greater firm performance above that of the competition cannot be achieved solely by the identification and holding of a strategic asset (Wilden & Gudergan, 2015). To take advantage of the situations a business faces, resources must also be managed properly (Lonial & Carter, 2015). According to RBV, businesses look for strategic resources that can help them grow and maximise their worth.

The RBV viewpoint of firm performance has been criticised lately for having some shortcomings. Even though RBV has received significant results for encouraging competitive advantage, it has certain drawbacks. Firstly, there is concern that the RBV, by ignoring the cost of acquiring and accumulating these resources, may exaggerate the profitability of organisations that exploit these resources. Consequently, the RBV is unable to explain why organisations choose to fund such a valuable asset over another form of assistance (Hitt, Xu, & Carnes, 2016; Tabares, Alvarez, &Urbano, 2015). Research works on how to sustain important resources over the foreseeable future have frequently been conducted without considering their economic value. Another issue with RVB is that there is no clear level of evaluation. The resource analysis levels are infused in the majority of RBV literature. Mosakowski and McKelvey (1997) and Priem and Butler (2001a), regarding the endogenous principle of resource value, assert that it is unclear how we could point in time whether a resource is useful or eccentric. Additionally, the RBV's theoretical implications has drawn criticism (Foss & Knudsen, 2003; Priem & Butler, 2001).

Moreover, Aragon-Correa and Sharma (2003) disputed the RBV's use of the firm as an isolated looped system. They assert that the study of independent elements has typically been excluded from literature works on RBV and that the RVB's strengths are inherent to the firm's resource interaction. Kraaijenbrink, Spender, and Groen (2010) raised two further criticisms of RBV in addition to its limited view of competitive advantage: the ideas of value and resource was also criticised.

**Environmental Determinism**

Environmental determinism is a theoretical viewpoint that holds that organisations' ability to adapt to their environment is limited. It provides an entirely different perspective than enactment on why certain organisations succeed while others fail. Organizations are seen similarly to animals in biological theories by environmental determinism. Animals and organisations both have very limited capacity for environmental adaptation. Therefore, regardless of how smart and perceptive managers are, changes in the external environment can destroy organisations, just as harsh environmental changes led to the extinction of dinosaurs. Goll, Johnson, and Rasheed (2008) state that the environment is a primary factor that helps explain strategic behaviour.

With a relatively short history of a little over a century and deeply ingrained culturally pertinent mythologies, beliefs, and philosophies, environmental determinism has made a significant contribution to philosophical school of thought. Environmental determinism is the idea that all human behaviour is determined by the natural environment. According to environmental determinism, human behaviour is determined by the environment's natural conditions, which can be understood as a result of how humans interact with it (Lewthwaite 1966). According to determinism, only physical factors, particularly the climate, have an impact on how people think and act.

This viewpoint emphasises that "the character of people is seen in the light of the physical environment they inhabit," emphasising how humans adapt to their surroundings (Singh, 2007).

This phrase was used in several studies in reference to how the environment affects people. Determinism is a theory that looks at one or more identifiable factors that enables a comprehensive explanation and forecast of societal or personal characteristics (Singh, 2007). Doyle (2011) defines determinism as a theory or a doctrine based on the idea that natural phenomena, social phenomena, or psychological phenomena are causally determined by earlier occurrences or by natural laws. There are prerequisites for everything that occurs, without which nothing else would be possible. Every event is believed to have a cause and to be entirely dependent upon and controlled by the environment. The fundamental defence of the theory of environmental determinism is that physical geography, particularly the climate influences people's psychological outlooks (Andrew et al., 2003). In view of that, it is clear revie that the environment has an impact on a variety of elements of human life, such as resources, behaviours, culture, politics, health, and socioeconomic factors. These essentially highlight how the physical environment impact on variety of human activities, keeping in mind that the source of our ecotourism is primarily the environment.

Environmental determinism's main argument is that an area's physical characteristics, like climate, have a significant effect on its inhabitants' psychological outlook. The population is then influenced by these different points of view, which helps to define the general preferences and actions of a society. For instance, it was claimed that regions in the tropics have been less developed than those at higher latitudes as the year-round warmth made it easier for residents to survive and they did not have to work as hard to do so.

The theory contends that developments in human culture and societal growth are determined by the environment, especially by its physical elements like climate and landforms. Environmental determinists believe only geographical, climatic, and ecological elements can adequately account for human cultures and behaviors.

According to organisational determinism, environmental factors choose organisational actions that are most appropriate for the environment. The organisation responds in accordance with the needs, demands, and roles that the environment plays within the business. There are two organisational analysis perspectives relevant to this situation: institutional analysis and natural selection. Hannan and Freedman (1977), Aldrich and Pfeffer (1976), and Mckelvey (1982).

This behaviour was compared to institutional isomorphism by DiMaggio and Powel (1983). They promoted three distinct institutional isomorphisms: the coercive isomorphism, which relates to the both formal and informal pressures applied by one organisation to another that is dependent. The legal system and contextual expectations of society are mentioned as sources of pressure. The second is the mimetic isomorphism, which develops as a result of managers' propensity to adopt successful practises implemented in other organisations in response to environmental uncertainty and requirements. The third type is professional isomorphism, which results from the workforce's ongoing professionalisation, particularly among managers. Homogeneity in organisational requirements is caused by the sharing of rules and work procedures that are derived from professional specialisation.

The natural selection model for organisations is criticised by Hall (1984), who contends that it ignores the strategic decisions made by the organisation in assuming that alterations in the external environment ascertain firm's capacity to survive in the atmosphere in which it operates. The focus here is on institutional perspective, which describes a non-rational process of conformity pressures in which internal and external forces drive organisations to seek out similar behaviours and become similar to one another.

## Empirical Review

### Firm performance & climate vulnerability

Cevik and Miryugin (2022) used non-financial firms from 24 developing countries between 1997 and 2019 to conduct an empirical investigation into the effect of climate change vulnerability on firm performance. The empirical findings demonstrated that businesses operating in climate-vulnerable nations are less productive and efficient than businesses in less climate-vulnerable nations. According to the study, decision-makers should increase institutional and economic robustness to better withstand economic activity shocks and lessen the fiscal burden of climate disorders.

Giang et al. (2021) analysed the relationship between firms' financial performance and climate change risk using a regression model. in Vietnam from 2015 to 2019. The outcome of the study indicate that climate change has an adverse effect on the performance of organizations. Based on that, the study recommends that decision-makers concentrate on implementing measures and reforms that enhance the resilience of organizations to climate change.

Acemoglu et. al (2016) examined the impact of climate change on economic growth and found that increased temperatures can reduce the productivity of firms in the agricultural, construction, and manufacturing sectors. They also observed that the negative impact is more severe in developing countries.

**Firm performance and technological innovation**

Auci et al. (2021) used time series data to conduct a study on Europe from 2007 to 2017 to determine whether and how much climate variability affects firm performance through adaptation innovations. Using panel endogenous switching regression model, the empirical findings demonstrated that climate change adaptation technologies improve business performance, particularly for companies in the aquaculture and fishing industries in northern European nations. The study made the recommendation that, overcoming the challenge of climate change through the advancement of new technical expertise improves economic performance hence member states should be urged to significantly boost their investment in developing and implementing adaptation measures.

Handriani (2020) found that innovational performance is positively correlated with firm value after examining the effect of innovational performance on determining the value of manufacturing firms in Indonesia. Multiple regression models were employed on a group of 300 manufacturing firms that were listed on the Indonesia Stock Exchange. The research suggested that managers of publicly traded companies should grow their businesses and invest in financially and physically innovative assets.

In 2019, Lapple and Thornein looked into how Irish Diary Farm's economic sustainability was impacted by innovation. A random selection of 342 Irish dairy farms was examined using a generalised propensity score methodology. According to the empirical data, innovation boosts sustainable growth, but not linearly.

Usman et al. (2017) assessed how R&D investment in G-7 countries affected performance of the firm and firm value. In an effort to evaluate the relationship that exist between R&D and performance, the study combined firm- and country-level data and used the HLM regression analysis technique and a robust standard error. The findings imply that investments in R&D made the same year have a direct relationship with firm value but a deleterious impact on firm performance. However, R&D investment with a one-year lag has a significant direct relation with firm performance and value, while R&D investment with a two-year lag has no impact on either.

Tuan et al (2016) studied how innovation affects the performance of supporting industries in Hanoi, Vietnam. Primary data was gathered by the researchers using a questionnaire survey. The research concentrated on businesses that are operates in the motorcycle, automobile, electronics, and mechanics-related industries. The findings show that innovation activities and firm performance are closely related. According to the study's findings, organisations in the supporting industry should put a lot of emphasis on process, marketing, and organisational innovation activities to improve performance.

In 2016, Ferreira and Ferreira researched on the short- and long-term effects of internationalization and R&D intensity on firms 'performance for listed companies on the US stock exchange between 1990 and 2013. Results from their work indicates that the level of R&D intensity is favorably correlated with firm value and negatively correlated with operating performance.

Beld (2014) looked at how R&D spending affected performance of manufacturing and non-manufacturing firms in the Netherlands. The research utilised multivariate regression analysis to assess its hypothesis. The findings demonstrated that investments in R&D have a favorable impact on the financial performance of a firms.

**Firm performance and macroeconomic conditions**

Issah and Antwi (2017) examined how macroeconomic factors affected firm performance in the UK with multiple regression analysis being performed on the data. The total number of macroeconomic variables evaluated was reduced to 59 using multiple regression analysis. The lagged ROA, adjusted unemployment rate, benchmarked unit labour costs, real GDP, and exchange rate were all statistically significant factors that contributed to the overall sample model's adjusted $R^2$ value of 0.91.

Owolabi (2017) explored the relationship between macroeconomic variables and financial performance of Nigerian firms. The study used economic variables such as government spending, inflation, interest rates, and exchange rates, and sampled 31 listed manufacturing firms from 2010 to 2014. The study found that the impact of government spending, inflation, interest rates, and exchange rates on EPS and ROA was insignificant.

However, for Tobin's Q, all the variables had a significant effect, but only the interest rate had a significant impact on ROE.

Mwangi and Wekesa (2017) analysed the economic performance of Kenyan firms using a descriptive research methodology, 74 employees of Kenya Airways' Finance Department made up the study sample. The interest rate and taxation were the study's economic determinants, and efficiency and growth were its dependent variables. To test their theories, they used the multiple regression method. It was found that the economy had a major effect on performance.

Rao (2016) also conducted a study which investigated the relationship between macroeconomic variables and financial performance of five firms operating in the energy and petroleum sector listed in the Nairobi Stock Exchange. The study was conducted over a period of 11 years, from 2004 to 2015. The findings indicated that there was a significant negative impact of interest rates and oil prices on the financial performance of these firms. However, the study did not observe any significant impact of inflation rate, exchange rate, or GDP growth on their financial performance.

Otambo (2016) carried out research to find how macroeconomic factors affect the performance of banks in Kenya. The study utilised quarterly data on inflation rates, currency rates, GDP, and interest rates from 2006 to 2015, while financial performance was measured using ROA as a proxy. The study’s ountcome indicated that exchange rates and interest rates have a negative effect profitability of banks, while GDP has a positive impact.

Likewise, the inflation rate did not appear to have a significant effect on bank performance.

A study conducted by Fareed, Ali, Shahzad, Nazir, and Ullah (2016) investigated the variables affecting profitability of 16 companies in Pakistan's power and energy sectors. The study used panel data from 2001 to 2012. The results of the study, using a random effects regression model, showed that growth had a significant direct relationship with profitability of the companies.

**Firm performance and firm characteristics**

Dioha et al. (2018) carried out research on Nigeria to examine how company traits affect profitability. There were 18 consumer goods companies that were publicly traded from 2011 to 2016 used in the sample. The study used firm age, size, sales growth, liquidity, and leverage as proxies for firm characteristics, and used ROS as a proxy for profitability. The data was analysed using multiple regression analysis. The study's findings showed that the profitability of the companies was adversely impacted by size, sales growth, and leverage of the firms. However, age and liquidity had little or no impact on profitability.

Lasisi et al. (2017) conducted an assessment of the profitability of agricultural firms that were listed on the Nigeria Stock Exchange. The sample consisted of four firms that were listed between 2008 and 2016. The study used leverage, liquidity, revenue growth, and operational expense effectiveness as independent factors, and used multiple regression analysis on the panel data.

The findings showed that operational expense efficiency and leverage had a negligible effect on profitability. However, both liquidity and sales growth had a positive and significant impact on profitability.

Mohammed and Usman (2016) conducted a study in Nigeria to investigate how corporate traits affect share prices. The study used a sample of five publicly listed pharmaceutical companies over a period of ten years (2004-2013), and employed multiple regression analysis for data analysis. The results of the study indicated that growth, size, and leverage had a significant and positive impact on profitability.

Rani and Zergaw (2017) carried out research to examine the impact of macroeconomic, bank-specific, and industry-specific factors on the profitability of commercial banks in Ethiopia. The study used ROE and net interest margin as indicators for profitability, and utilised secondary data from 2005 to 2015. Multiple regression analysis was used to test the hypotheses. The findings indicated that net interest margin strongly influenced capital adequacy and earnings, while management effectiveness, earnings, and liquidity ratios significantly impacted capital adequacy and earnings. The sector-specific variable of industry growth rate had a statistically significant effect on net interest margin. Although ROE and net interest margin exhibited a direct relationship with all macroeconomic factors (inflation, GDP, tax rate, and exchange rate), these effects were not statistically significant.

Ghareli and Mohammadi (2016) investigated the financial reporting quality of Iranian companies, examining the impact of macroeconomic factors and firm characteristics. The study considered macroeconomic factors such as GDP, inflation, interest rates, and exchange rates, while working capital, enterprise size, and financial leverage were among the firm-specific variables. The sample included 91 companies listed on the Tehran Stock Exchange between 2005 and 2013. Multiple linear regression and the Spearman correlation test were used to analyse the data. The results revealed that exchange rates, interest rates, and financial leverage had a significant negative impact on GDP. However, the negative impact of inflation and the size of the business were not statistically significant, although they were not entirely insignificant.

Owoputi et al. (2014) carried out research to find the impact of macroeconomic, sector-specific, and bank-specific factors on the profitability of banks in Nigeria. The study revealed that inflation rate had a significant impact on both ROA and ROE, while interest rate was significant for ROA and NIM. The real GDP showed little increase. In terms of bank-specific factors, size was found to be a crucial determinant for profitability measures such as ROA, ROE, and NIM.

Mirza and Javed (2013) conducted a study on the financial performance of Pakistani businesses using both macro and micro factors. The study's sample included 60 businesses listed on the Karachi Stock Exchange between 2007 and 2011.

The findings indicated that per capita income had a direct and significant link with the performance of businesses, whereas inflation had a significant but inverse relationship. In terms of firm characteristics, the study found that the debt-to-equity ratio had a significant and positive relationship with macroeconomic conditions, while the debt to total assets had a substantial and negative relationship. Firm size had a significant and direct impact on business performance, while liquidity (current ratio) had a significantly negative impact.

Chandrapala and Knápková (2013) conducted a study in the Czech Republic to evaluate the effect of firm-specific characteristics on financial performance. The study used data from the Albertina database and included a sample of 974 firms from 2005 to 2008. Pooled and panel designs were employed for the evaluation. The outcome depicted that increasing revenues and size had a significant positive effect on ROA. However, inventory and the debt-to-income ratio had a material negative impact on ROA.

Bhutta and Hasan (2013) investigated the impact of macroeconomic and firm-specific factors on the profitability of food industry firms listed on the Karachi Stock Exchange in Pakistan between 2002 and 2006. The study analysed firm-specific variables such as debt to equity, tangibility, growth, and size, and the macroeconomic factor of food inflation. The findings revealed that profitability and size had a significant adverse effect, while tangibility, growth, and food inflation had a weaker negative relationship.

A study on the relationship between financial performance and firm attributes of Kenyan life insurance companies was conducted by Kaguri (2013). It utilised data from 17 life insurance companies in Kenya from 2008 to 2012, and examined the impact of variables such as size, diversification, leverage, liquidity, age, premium growth, and claim experience on financial performance. Regression analysis was used in the data analysis to identify the statistical significance of each variable.

**Research Gaps**

Current studies have a flaw in the conceptual and logical link between technological innovation and strong firm performance. Many studies rely on intuitive relationships that may not be universally applicable. For example, some studies refute the assertion that the more a company is fit with its surroundings, the higher its rent capacity (Sarta et al., 2021; Kijkasiwat & Phuensane, 2020; Ferreira & Ferreira 2016). This is because rents once established, may be stolen by others. To avoid this trap, some studies identify mechanisms such as economies of scope resulting from structural alignment or the interaction between buyers and suppliers that create rent (Sarta et al., 2021; Giang, et al., 2021). Clarity is essential to avoid assumptions that the survival or performance of an organization that has undergone technological innovation indicates "fit" or "well-adaptedness". Hence the need to carry out this research.

Also, after reviewing previous studies on the topic, it was observed that there have only been few studies that have explored the relationship between climate vulnerability and performance of firms in the agro-processing industry. In fact, only two studies were identified that have investigated this relationship (Cevik & Miryugin, 2022 and Giang et al., 2021). These studies had a contradictory view on the effect of climate on financial performance. There is therefore the need for this research for further clarification.

**Chapter Summary**

The chapter aimed to provide a comprehensive review of both theoretical and empirical literature on climate vulnerability, technological innovation, and firm performance. The resource-based view of firm performance was selected from the theoretical models of firm performance as it provides a clear understanding of how the resources available to firms influence their performance (Davis & DeWitt, 2021). Environmental determinism was also reviewed to explain how the external environment of the firm also dictates its performance (Lewthwaite 1966). Additionally, the chapter identified research gaps in the empirical literature, including the limited research linking climate vulnerability to firm performance, issues with the measurement of climate vulnerability and technological innovation, representativeness of samples used, and methodological weaknesses in some studies such as the work of Giang, et al. (2021).

# CHAPTER THREE

# RESEARCH METHODS

## Introduction

This chapter's objective is to demonstrate the research methods appropriate for conducting the research. The methodology and analytical tools employed in this investigation are discussed in the chapter. In particular, the chapter provides a detailed explanation of the empirical model description of the link that exist between climate vulnerability, technological innovation and firm performance in SSA, as well as the definition, measurement, and justification of variables in the model, data source and type, and estimating procedures.

## Research Approach

The premise for this research is the positivist theory. According to the philosophical school of positivism only "factual" inferences drawn from observation, such as estimation techniques, is reliable. This approach is used in this study to give the findings subjectivity, reliability, and replicability for additional empirical testing and verification.

## Research Design

Considering the goals of the study, a quantitative research paradigm is employed to collect the necessary data. Hopkins (2008) states that the quantitative research paradigm employs numerical measures and aids in quantifying variables to ascertain their correlations and the effects that one variable has on another. Using structured research methodology and quantitative data, it is possible to test the existence of cause-and-effect correlations (Gill & Johnson, 2010).

This study's primary objective is to use quantitative data to investigate the interrelationship between climate vulnerability, firm performance and technological innovation of agro-based firms in SSA. The study used descriptive and statistical regression results to determine this relationship. Therefore, the longitudinal research approach is used in the research, which is a quantitative approach to research design.

**Data and Data Source**

The research population is the listed agro-based firms on the various Stock Exchanges (Ghana Stock Exchange (GSE), Nigeria Stock Exchange, Mauritius Stock Exchange, Zimbabwe Stock Exchange, Tanzanian stock exchange and the Nairobi Stock Exchange). It made use of data from the listed agro-based firms on these Stock Exchanges over eleven (11) years spanning from 2007 to 2017. The year span is as a result of data availability on technological innovation in Africa. As at the time this work was being carried out, technological innovation data on WDI for African countries used in the study was up to 2017. The financial statements were retrieved from African Financials as well as the firms' websites. These listed agro-based firms include:

**Table 1: Summary of selected Listed Firms by countries**

| Country | Selected firms |
|---|---|
| Kenya | Limuru Tea, Sasini Limited, Unga Group Limited, Williamson Tea Kenya Plc, British American Tobacco Kenya Limited, Kapchorua Tea Company Limited, East Africa Breweries, Kakuzi Limited, Mumias Sugar Company Limited |
| Tanzania | East African Breweries, Tanzania Breweries Limited, Tatepa Limited, Tanzania Cigarette |
| Zambia | Zambia Sugar, Zambia Breweries, National Breweries, Zambeef Products Plc, British American Tobacco Zambia Limited |
| Nigeria | Presco Plc, Dangote Sugar Refineries Plc, Guinness Nigeria, Livestock Feed Limited, Nigerian Breweries, Flour Mills Nigeria Plc, Okomu Palm Oil, Nestle Nigeria, International Breweries |
| Ghana | Guinness Ghana, Pbc Limited, Benso Oil, Cocoa Processing Company, Hords Limited |
| Mauritius | Quality Beverages, The Union Sugar Estates Company, Mauritius Chemical & Fertilizer Industry Limited, Constance La Gaiete, Omnicane Limited, Terra Mauricia Ltd |
| Total | 38 |

**Source: Author's construct**

**Model Specification**

The empirical baseline model is specified in accordance with empirical literature. It follows the work of Dodoo, Donkor and Appiah (2021).

The model is specified as follows

$$Y_{iJt} = \alpha + \delta Y_{iJ,t-1} + \beta_1 VUL_{ijt} + \beta_2 R\&D_{it} + \beta_2 X_{iJt} + \varepsilon_t \quad (1)$$

$$FP_{ijt} = \alpha + \delta FP_{iJ,t-1} + \beta_1 VUL_{ijt} + \beta_2 X_{iJt} + \eta_i + \mu_t + \varepsilon_{it} \quad i = 1, 2, 3, \dots, 6; \; t = 1, 2, \dots, 11 \quad (2)$$

Y represents firm performance which in this research is being proxied as ROE. α is the intercept, VUL represents climate vulnerability, R&D is technological innovation, and X represents a set of control variables which include firm size, liquidity, nature of the firm, inflation, regulatory quality, age of technology adoption and GDP growth. The unobserved effect that is country-specific is represented by $\eta_i$ and $\mu_t$ is a dummy for time-specific effects. The error term which is idiosyncratic is being denoted by $\varepsilon_{it}$ where country is indicated by the subscripts *i* and *t* denote country. The subscript *j* in the equation represents the individual firms. *t-1* is the lag of firm performance which is also being used as an independent variable as the performance of a firm in year *t* is seen to correlate with the performance in year *t-1*.

The model is then modified to fit the research objectives.

To achieve the first objective, using ROE as a proxy for firm performance, the model takes the form

$$ROE_{ijt} = \alpha + \delta ROE_{ij,t-1} + \beta_1 VUL_{ijt} + \beta_2 NAT + \beta_3 LIQ_{ijt} + \beta_4 GDPG_{ijt} + \beta_5 INF_{ijt} + \beta_6 REQ_{ijt} + \beta_7 FSIZE_{ijt} + \varepsilon_t \quad (3)$$

Further, technological innovation is introduced in the absence of climate vulnerability in the second model to analyse the effect of technological innovation on the performance of firms. The strategic adaptation theory of the firm postulates that firm's true strategy may have to be determined from changing patterns of behavior and resource allocation which is a function of time. To capture technology adoption to be consistent with time, the year of adoption is introduced as a control variable in the second and third objectives. Thus, to test for the second objective which is to determine the effect of technological innovation on the performance of listed agro-based firms, the model therefore takes the form;

$$ROE_{it} = \alpha + \delta FP_{i,t-1} + \beta_1 NAT_{it} + \beta_2 LIQ_{it} + \beta_3 GDPG_{it} + \beta_4 INF_{it} + \beta_5 REQ_{it} + \beta_6 FSIZE_{ijt} + \beta_7 AGE_{ijt} + \beta_8 R\&D_{ijt} + \varepsilon_t \quad (4)$$

Where R&D is technological innovation being proxied using expenditure on research and development as a percentage of growth domestic product.

In order to accomplish the final goal, which aims to investigate the moderating role of technological innovation, the research model is specified by equation (5).

$$FP_{ijt} = \alpha + \delta FP_{ij,t-1} + \beta_1 VUL_{ijt} + \beta_2 NAT_{ijt} + \beta_3 LIQ_{ijt} + \beta_4 GDPG_{ijt} + \beta_5 INF_{ijt} + \beta_6 REQ_{ijt} + \beta_7 FSIZE_{ijt} + \beta_8 AGE_{ijt} + \beta_9 R\&D_{ijt} + \beta_{10}(VUL_{ijt} * R\&D_{ijt})\varepsilon_t \quad (5)$$

## Data

For the study, a panel of data covering the years 2007 to 2017 was used. This is composed of 6 sub-Saharan African countries; Kenya (9), Tanzania (4), Zambia (5), Nigeria (9), Ghana (5 fi), and Mauritius (6) giving a total of 38 agro-based firms across the 6 countries within 11 years. The macro level data (INF, GDPG, and REQ) is taken from the Development Index and the Governance Indicators of the World Bank. The micro-level data (ROE, Fsize, and LIQ) are retrieved from the firms' annual financial statements reported on their various stock exchanges which are accessed from African Financials. Climate Vulnerability data is obtained from the Notre-Dam global index. The research is limited to only these 6 countries due to data availability.

## Description of Variables

This section provides a concise overview of the key variables under consideration, offering insight into their definitions and significance within the study's framework.

## Firm Performance

Performance has always been multidimensional, but the best evaluation method to analyse a corporate firm's performance is determined by the type of business being assessed as well as the goals of the evaluation (Kaguri, 2013). Three distinct factors contribute to a firm 's profitability: financial performance, product market returns and stock performance (Richard et al., 2009). Financial performance must be utilised as a gauge for firm performance owing to the nature of the firms studied in this work and the accessibility of data.

Financial performance measures a company's capacity to attain projected financial outlook in comparison to its desired outputs (Mutende et al., 2017). To assess financial performance, financial measures such as return on equity, return on asset, return on capital, return on sales (ROS), and operating margin are frequently utilised (Gilchris, 2013). Ratios provide a more thorough assessment of a performance of the company because they are created using information from its financial statements. As a result, the main focus of the financial performance is on factors that are directly related to the financial report. In contrast to ROE, which measures the effectiveness of equity, ROA measures the performance of the total firm's assets, and ROS measures the efficiency of cost management. Thus, ROE and ROA ratios show how well a company can utilise the capital it has raised through stock and debt, while the ROS ratio measures how well it can control operational expenses.

The frequently employed ratio in the literature to gauge financial performance is ROE. For instance, Marinko and Skare (2015) used ROE to investigate the factors that influence financial performance, and Suseno (2020) used ROA and ROE in measuring financial performance to study the correlation that exist between financial performance, macro and micro economic factors for Indonesian firms dealing in consumable goods. The profitability (financial performance) of agro-based firms in the selected African economies is measured in this study using ROE as it is the most widely used metric for evaluating the performance of firms.

ROE provides a measure of profitability that specifically focuses on the returns generated for the firm's shareholders. Since agro-based firms often have a mix of equity and debt financing, ROE allows for a clearer assessment of the returns generated on the shareholders' invested capital.

The capacity of an organisation to return investment of common stockholders is ascertained by ROE. The ROE, which measures the relationship between net income and average common equity, can be impacted by several economic factors, including changes in net income and equity price fluctuations. Investors assess and compare several companies in a firm using ROE along with other financial parameters. When a company's ROE is high, it suggests that it has pricing power and market dominance, whereas when it is low, it shows that a combination of competitive pressures and subpar operations is hurding the bottom line. Generally, ROEs between 15percent and 20percent are regarded as good, (Skare & Marinko, 2015). As a profitability index, a percentage-based ratio of net income to total equity is used to measure ROE.

$$ROE = \frac{NET\ INCOME}{TOTAL\ EQUITY} \times 100$$

The accounting profit a business has remaining after covering all of its costs is known as net income. It is the difference between generated revenue and total expenses less taxation. The amount that investors invest in a company in exchange for stocks is known as equity. It is a company's remaining value following the liquidation of all of its assets and payment of all of its debts to creditors.

**Climate Vulnerability**

The degree of a system's exposure to climatic risks, along with its sensitivity to climate change and adaptive capacity, define how vulnerable a system is. In simple terms, climate vulnerability refers to the degree of susceptibility of firms to the adverse effect of climate change. Climate vulnerability adversely affects the performance of agro-based firms by increasing their exposure to weather-related risks and uncertainties. It leads to decreased agricultural productivity, disrupted supply chains, and increased production costs due to the need for adaptation measures. Climate vulnerabilities such as extreme weather events, changes in precipitation patterns, and water scarcity can disrupt crop yields, decrease agricultural output, and impact profitability. Additionally, climate vulnerability may also result in market uncertainties, reduced access to financing, and increased volatility, further affecting the overall performance and competitiveness of agro-based firms. There is a large degree of methodological variety in the literature in terms of measurement of vulnerability.

Its conceptualization is mostly based on the IPCC's Third Assessment Report paradigm. It measured climate vulnerability as an index of sensitivity, adaptation and exposure. This method has the advantage of integrating socioeconomic and biophysical factors, which results in a more thorough assessment of vulnerability. It measures the extent to which an economy is exposed to the dangers of climate change. Climate risk has a higher impact on economies that are highly vulnerable to climate change as compared to the less vulnerable economies.

From the socio-economic perspective, climate vulnerability is seen as how responsive an economy is to environmental issues and the extent to which the economy can adapt to lessen the effects of climate change. The Climate vulnerability index by Notre-Dam Global Index is used in this study. Climate vulnerability is an index of exposure, sensitivity, and adaptive capacity. A country with high climate exposure, a high sensitivity coupled with a low adaptive capacity will have a high vulnerability compared to a country with high adaptive capacity, low sensitivity, and low exposure.

**Technological Innovation**

Technology innovation is the complete or partial replacement of an available technology with an innovative one in order to boost productivity, quality of products, and competitiveness of product in the global market. It can either be product innovation or process innovation. While process innovation concentrates on the creation of an entirely new or significantly improved process within an organisation, product innovation involves the introduction of a new or significantly improved product to the market.

Technological innovation positively impacts the performance of agro-based firms by enhancing productivity, efficiency, and sustainability in agricultural practices. It allows for the adoption of advanced machinery, precision farming techniques, and digital solutions that optimise resource utilization and reduce costs. Technological innovations also enable improved crop management, disease prevention, and yield forecasting, leading to higher agricultural output and profitability.

Moreover, innovation in agro-based firms enables the development of value-added products, market diversification, and better supply chain management, enhancing competitiveness and market position. Overall, technological innovation empowers agro-based firms to adapt, thrive, and meet the evolving demands of the industry and consumers.

Technology innovation is driven by the outcomes of rapid technological advancement, new configurations of already-existing technologies, or on the application of extra knowledge that an establishment has acquired. There are a number of channels between the works of literature on firm performance and innovation, and as a result, there are a significant number of research on performance literature that focuses on firms' innovative activities. According to the European Environmental Agency (2019), a major investment in R&D, as well as new strategies is needed to counteract the repercussions of climate vulnerability to alleviate its impact on the performance of the economy as a whole. Innovation is a challenging topic to quantify, due to the fact that studies in the field of innovation is confined to sources like Investment in research and development, personnel and financial capacity, and transitory outputs like trademarks (Hopkins & Siepel, 2013). Due to this, most of the empirical works on financial performance of firms' that uses innovation measures rely on readily available metrics like R&D or patents, or on measures obtained from survey instruments such as Europe's Community Innovation Surveys, such as the share of turnover produced. Following the works of literature, the study used research and development as a proxy for technological innovation.

**Firm Size**

Researchers have not been in agreement on how to measure the size of a firm, but most agree that it is a significant determinant of firm performance. Companies have historically aimed to grow in size to gain an edge over their competitors. Theoretical literature has explored the link between firm size and performance using several firm models, including institutional, organizational, and technology models. But then again, these theories have varying implications for the relationship between firm size and performance. Likewise, previous empirical studies have shown little consensus among scholars on the relationship between size and profitability.

According to theory, economies of scale are responsible for the association between performance and size. Large companies have greater competitive power than small companies in markets where competition is necessary. Due to their larger market share, large businesses have the potential to generate more revenue. Substantial resources also give major firms the opportunity to operate in highly capital-intensive sectors, giving them the chance to do so in less-competitive and perhaps more viable sectors (Alghusin, 2015). However, even as their size grows, many corporations continue to operate poorly year after year. Several proxies in different studies have been used in measuring firm size which includes total sales, total assets, number of employees, and market capitalization. Research works have also shown that the different proxies relate to firm performance differently. In this study, the total asset is used as a measure of firm size due to the performance indicator (ROE) being used.

$$FIRM\ SIZE = LN(TOTAL\ ASSET)$$

**Liquidity**

The firm’s ability to continue operations in the very long run is ascertained by how liquid the firm is. In other words, liquidity is described as a company's potential to strategically manage and focus on maintaining an efficient level of current-asset to liability ratio in order for the firm to have a continual flow of cash to satisfy its short-term obligations and hence continue to exist in the foreseeable future. By liquidity, we are looking at the simplicity with which a business can turn an asset into cash without losing the value of the asset. Firms' activities are embedded with many liabilities, some of which include meeting daily operational expenditures, unforeseen emergencies, contingencies, or accidents.

The firms must therefore be sufficiently liquid to fulfill such obligations effectively and efficiently (Akenga, 2017). Various liquidity ratios, such as the cash ratio, current ratio, quick ratio, and defensive interval ratio, are used by firms to manage their short-term obligations. The ratio between current asset and current liability is being utilised as liquidity in this work.

This has to do with how optimal the firm can manage the current assets and current liability in its operations so as to carry out short-term financial obligations. It is measured as a proportion of current assets to current liability.

$$LIQ = \frac{CURRENT\ ASSET}{CURRENT\ LIABILITY}$$

**Nature of the Firm**

This is created as a dummy to indicate whether a firm exports of its final products or not. Zero indicates the firm is not into the export of its product whiles one is an indication of the firm trading externally. Numerous studies have demonstrated that multinational corporations, which operate in international markets, are relatively large and more efficient than comparable local firms. Firms with a global presence pay wages more than other firms based locally in the same sector. International trade has a positive impact on performance, particularly for businesses from less emerging economies that trade with partners from developed markets. Trading internationally allows firms to expand their markets and gain access to goods and services that otherwise may not have been available domestically. The evidence for the "learning-by-exporting" paradigm is more varied. Results regarding performance gaps between non-exporters and export starters after entrance only point to greater productivity development for exporting firms in most studies.

**Economic Growth**

Stability in the macroeconomic environment stimulates growth in the economy at large and hence affects firms' performance. The study assesses performance of the economy using the GDP's annual percentage growth rate at market rates based on stable local currency. The values are computed using 2015 constant prices stated in US dollars.

**Inflation**

Defined as the persistent rise in the price of goods and services, inflation as a macroeconomic economic variable affects the performance of firms through several channels which may be both direct and indirect. Directly, firms do purchase inputs needed for production and an indirect means includes the firm's interaction with financial institutions. Inflation may slow down the performance of firms through financial intermediaries as it will lead to a high cost of borrowing. Inflation distorts the costs of goods and services in an economy because businesses are unsure of the future prices of their products, high inflation deters investment. Inflation, in the opinion of Fischer (1978), increases the unpredictability of the general price level's future direction. In this study, inflation is measured using the consumer price index. The Laspeyres formula is generally used.

**Age**

Age within the framework of this study is defined as the number of years from the firm’s existence to when technology was being adopted. Even though some people think that the age of the company should be determined by its listing, according to Shumway, 2001, a firm's age is the duration since its incorporation. That is, a firm is created by incorporation and becomes a legal entity. The age of the firm from the year of being founded to when technology was adopted is used by the work to determine the age.

**Table 2: variables used and their expected signs**

| Variable | Variable name | Measurement | Source | Expected sign |
|---|---|---|---|---|
| ROE | Return on Equity | $net\ income/total\ equit$ | Annual Financial Statements | |
| VUL | Vulnerability | Sensitivity, exposure and adaptability | Notre-Dam Global Index | Negative |
| R&D | Technological Innovation | Expenditure on R&D | WDI | Positive |
| REQ | Regulatory Quality | | WGI | Positive/Negative |
| INF | Inflation | Consumer price index | WDI | Positive |
| GDPG | GDP Growth | | WDI | Positive |
| Fsize | Firm Size | Ln total asset | Annual Financial Statements | Positive |
| LIQ | Liquidity | $current\ asset\ /current$ | Annual Financial Statements | Positive/Negative |
| NAT | Nature of the Firm | export or no export | Annual Financial Statements | Positive/Negative |
| AGE | Age of technology adoption | Age of the firm when technology was adopted | Annual Financial Statements | Positive |

Source: Author's construct (2022)

**Estimation Procedure**

To analyse the relationship between climate vulnerability, technological innovation, and the performance of listed agro-based firms, an estimation procedure that is capable of taking care of the endogeneity problem associated with the performance of firms as well as the heterogeneity of country-specific variables is required. In search of the right estimation procedure to be employed, the research made use of panel analysis. Due to the innate characteristics of the endogenous variable (firm performance), it necessitates the use of the dynamic model so as to control the endogeneity issue as current year firm performance may correlate with previous year performance. Thus, the endogeneity issue will be caused by the lag in firm performance that is considered in the model as an explanatory variable.

The generalised method of moments devised by Arellano and Bond (1991), Arellano and Bover (1995), Blundell and Bond (1998), and Blundell and Bond (2000) dominate literature when it comes to the selection of a dynamic model for a panel data of such span. The following benefits of generalised methods of moments (GMM) over alternative estimating techniques make them appropriate for this kind of research.

First, there is the issue of endogeneity, which may arise from the dependent variable's correlation with its lag version, which is employed as an explanatory variable, as well as from omitted variable bias, measurement errors, and unobserved variables that are country-specific. This endogeneity issue is being addressed by the generalised methods of moments.

Again, the ordinary least square approach's crucial normality assumption is relaxed, which makes it easier to estimate how different variables will affect one another regardless of whether the error term is normally distributed.

In order to eliminate the constant term as well as the country unobserved heterogeneity effects, the first difference GMM of Arellano and Bond (1991) is employed.

$$FP_{ijt} - FP_{ij,t-1} = (\alpha - \alpha) + \delta(FP_{ij,t-1} - FP_{ij,t-2}) + \beta_2(VUL_{ijt} - VUL_{ijt-1}) + \beta_3(X_{ijt} - X_{ijt-1}) + +(\eta_i - \eta_i) + (\mu_t - \mu_{t-1}) + (\varepsilon_t - \varepsilon_{t-1}) \quad i = 1, 2, 3, \dots, 6;\ t = 1, 2, 3, \dots, 11 \quad \textit{.....(6)}$$

$$FP_{ijt} - FP_{ij,t-1} = \delta(FP_{ij,t-1} - FP_{ij,t-2}) + \beta_2(VUL_{ijt} - VUL_{ijt-1}) + \beta_3(X_{ijt} - X_{ijt-1}) + +(\eta_i - \eta_i) + (\mu_t - \mu_{t-1}) + (\varepsilon_t - \varepsilon_{t-1}) \quad i = 1, 2, 3, \dots, 6;\ t = 1, 2, 3, \dots, 11 \qquad (7)$$

equation (7) can then be re-written as

$$\Delta FP_{ijt} = \delta(\Delta FP_{ij,t-1}) + \beta_1(\Delta VUL_{ijt}) + \beta_3(X_{ijt}) + \Delta\mu_t + \Delta\varepsilon_t \quad i = 1, 2, 3, \dots, 6;\ t = 1, 2, 3, \dots, 11 \qquad (8)$$

The first difference when taken, leads to the problem of endogeneity bias. This is because the new error term ($\varepsilon_{i,t} - \varepsilon_{i,t-1}$) as in equation (8) would correlate with $FP_{ij,t-1} - FP_{ij,t-2}$. The lagged error term ($\varepsilon_{i,t-1}$) will also correlate with the explanatory variables. The difference GMM estimator offers a solution to this problem by allowing the use of lag values of the independent variables as instruments once they meet two presumptions or moment conditions.

These conditions are

1. the error term does show any correlation with the instruments
2. There is weak exogeneity in the explanatory factors.

$$E[FP_{ij,t-s}, (\varepsilon_{i,t} - \varepsilon_{i,t-1})] = 0 \; for \; all \; s \geq 2; \; t = 3, \ldots, 11$$

$$E[X_{ij,t-s}, (\varepsilon_{i,t} - \varepsilon_{i,t-1})] = 0 \; for \; all \; s \geq 2; \; t = 3, \ldots, 11 \quad (9)$$

The estimation method is referred to as difference GMM when the used instruments satisfy the moment conditions. The difference GMM is associated with weak instruments where there is an overtime persistence of the explanatory variable (Blundell & Bond, 1998). To merge a set of differential and level equations Blundell and Bond (2000) argued that together with using the lagged independent variable as an instrument in the difference equation, the level equation should also use lagged difference dependent variables as an instrument.

For efficiency, the system GMM is preferred over the difference GMM. To use the system GMM, the following condition ought to be fulfilled;

$$E\left[\left(FP_{ij,t-s} - FP_{ij,t-s-1}\right)\left(\eta_i + \varepsilon_{i,t-1}\right)\right] = 0 \text{ for all } s = 1; \; t = 3, \ldots, 11$$

$$E\left[\left(X_{ij,t-s} - X_{ij,t-s-1}\right)\left(\eta_i + \varepsilon_{i,t-1}\right)\right] = 0 \text{ for all } s = 1; \; t = 3, \ldots, 11 = 0 \text{ for } s = 1; \; t = 3, \quad (10)$$

Equations 10-12 are estimated using the GMM system.

The GMM estimator to achieve the first objective is;

$$\Delta FP_{ijt} = \delta(\Delta FP_{ij,t-1}) + \beta_1(\Delta VUL_{ijt}) + \beta_2(X_{ijt}) + \Delta\mu_t + \Delta\varepsilon_t \quad i = 1, 2, 3, \ldots, 6; \; t = 1, 2, 3, \ldots, 11 \quad (11)$$

The estimator of the GMM model for the second objective of the study will therefore be:

$$\Delta FP_{ijt} = \delta(\Delta FP_{ij,t-1}) + \beta_1(\Delta VUL_{ijt}) + \beta_2(R\&D_{ijt}) + \beta_3(X_{ijt}) + \Delta\mu_t + \Delta\varepsilon_t \quad i = 1, 2, 3, \dots, 6;\ t = 1, 2, 3, \dots, 11 \qquad (12)$$

Then for the last objective, the GMM model estimator becomes

$$\Delta FP_{ijt} = \delta(\Delta FP_{ij,t-1}) + \beta_1(\Delta VUL_{ijt}) + \beta_2(R\&D_{ijt}) + \beta_3(\Delta VUL_{ijt} * \Delta R\&D_{ijt}) + \beta_5(\Delta X_{ijt}) + \Delta\mu_t + \Delta\varepsilon_t \quad i = 1, 2, 3, \dots, 6;\ t = 1, 2, 3, \dots, 11 \qquad (13)$$

**Model Diagnostic Tests**

Few presumptions about the error term are made by the GMM estimator. In light of this, there are very few post-estimation tests required. after GMM estimation (Wooldridge, 2012). The two GMM post-estimation tests were created by Bond and Blundell in 1998. These tests are the Sargan test for over-identification of restriction and the Arellano and Blundell test for autocorrelation (AR Test). The two requirements that must be met in order to determine the system GMM estimator's reliability and consistency are:

1. the error term cannot be serially correlated;
2. the instruments must be reliable.

**Arellano-Bond test for serial correlation**

The AR Test was conducted to assess the presence of autocorrelation in the first- and second-order. In order to evaluate the hypothesis that the errors in the first difference regression are not serially associated, the AR TEST was used. To ensure the validity of GMM results, the null hypothesis of AR TEST should not be rejected.

This means that the significance level of the AR test result must be high enough to prevent rejection of the null hypothesis. If the AR TEST does not reject the null hypothesis, it suggests that the model's autocorrelation is not problematic. To perform the AR (2) test for serial correlation, the standard covariance matrix of the coefficients was used based on residuals from the estimate. The null hypothesis is that there is no second-order serial correlation among the errors in the first difference.

**Sargan Test for Over-Identification Restrictions**

The second test to evaluate the validity of the GMM estimator is the Sargan test, which checks for the over-identification of restrictions. The validity of the instrument used in the estimation determines the consistency of the GMM estimator's output, according to Arellano and Bond (1991). The null hypothesis of the Sargan test assumes that the instrumented variables are exogenous and have no correlation with the error term. The instruments are considered valid if the null hypothesis cannot be rejected.

To ensure the GMM estimation is efficient, both the AR test and the Sargan test should have insignificant probability values, meaning that the null hypothesis should not be rejected.

## Chapter Summary

In chapter three, the methodological approach used to conduct this study was explained. It displays the data source and sample selection process. The quantitative method of analysis was used in the study. In order to infer the empirical models, the theoretical panel data model was again specified. Climate Vulnerability and Technological Innovation served as the primary interest-generating variable, firm size, liquidity, nature of the firm, economic growth, inflation, and regulatory quality were used as control variables to explain the performance of agro-based firms in SSA.

# CHAPTER FOUR

# RESULTS AND DISCUSSIONS

## Introduction

The main goal of this research was to investigate how climate vulnerability, technological innovation, and firm performance are related. Specifically, the study's goal is to determine how climate vulnerability affects firms' financial performance, the impact of technological innovation on firms' financial performance, and how technological innovation moderates the relationship between climate vulnerability and firms' financial performance. The chapter is divided into two sections, with the first section presenting summary statistics and correlation analyses, and the second section discussing the results of the generalised method of moments (GMM).

## Descriptive statistics

Table 1 provides the summary statistics for the study's variables, allowing us to assess the data's statistical distribution. The descriptive statistics include details on the variables that were used in the study, such as the total observations for each variable, mean, standard deviation, and the range (minimum and maximum values). Table 1 clearly displays these numbers.

**Table 3: Summary statistics**

| Variable | Observation | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Return on Equity (%) | 410 | 0.211 | 0.646 | -8.953 | 3.795 |
| Vulnerability | 418 | 0.503 | 0.042 | 0.411 | .548 |
| Technological Innovation (%) | 418 | 3.235 | 0.47 | 2.091 | 4.117 |
| Regulatory Quality | 418 | -0.206 | 0.558 | -0.919 | 1.127 |
| Firm Size | 410 | 18.639 | 2.243 | 13.487 | 26.752 |
| Liquidity | 404 | 1.702 | 2.088 | -7.589 | 13.011 |
| Nature of the firm | 418 | - | - | 0 | 1 |
| Economic Growth (%) | 418 | 5.227 | 2.468 | -1.617 | 14.047 |
| Inflation (%) | 418 | 9.627 | 4.853 | 0.978 | 26.24 |
| AGE | 418 | 58.342 | 32.280 | 3 | 148 |

Source: Author's construct

The average value of Return on Equity (ROE) used in measuring the performance of firms for the six Sub-Saharan African countries studied from 2007 to 2017 is 0.211 US dollars. The countries utilised for the study had an average variance of 0.646 US dollars, with a range of -8.953 to 3.795 US dollars. This suggests that for every one-dollar worth of total assets of firms in the study, $0.211 was earned as profit after tax of firms in Sub-Saharan. Compared to figure 2 which displays the mean values on country basis, Nigeria, Tanzania and Zambia firms averagely performs better. This can be attributed to the differences in the cost of borrowing.

Within the region, the Climate Vulnerability Index (VUL) ranges from 0.411 to 0. 548, with an average value of 0.503. Within the specified location, the Vulnerability Index deviates from the mean by 0.042. This accounts for why Africa as a continent is deemed to suffer the most from climate risk effects.

The mean value of R&D as a percentage of GDP, a metric used to assess technological innovation, is 3.235, with a regional standard deviation of 0.47. Within the nations chosen from the SSA region, R&D levels range from 2.091 at the lowest level to 4.117 at the highest. This shows that investment in research and development on average has been low in sub-Saharan Africa.

Within the SSA countries considered for the study, regulatory quality (REQ), a control country variable had range value between -0.919 and 1.127. Regulatory Quality recorded a mean value of -0.206 and a region-wide deviation from the mean by 0.558.

Firm Size gives the ability to evaluate the expansion of the firm over time. The overall mean value for firm size for the six SSA countries included in the study is 18.639, with a variance of 2.243. In the SSA countries, the greatest value for firm size is 26.752 and the lowest value is 13.487. It suggests that each firm in the sample has a firm size of at least 13.487.

The average value of the annual percentage increase in Gross Domestic Product (GDP) is 5.227, it falls within a range of 14.047 and -1.617. In the region's chosen countries, the difference from the mean is 2.468.

The region's average Consumer Price Index, which calculates inflation as a percentage of GDP, is 9.627 percent, with a standard deviation of 4.853, and has a maximum value of 26.24 with 0.978 being the least value recorded.

The minimum age recorded for the firms used in the study is 3years whiles a maximum of 148years was recorded. Across the six regions, the average age of the firms used in the study is 58.342 with a deviation of 32.280.

**Return on Equity (ROE) in terms of country groupings**

The Six Sub-Saharan African countries' average Return on Equity trends from 2007 to 2017 is depicted in Figure 1. The country-specific variances in ROE are shown in the bar graph. Tanzania comes in second with an average ROE of 0.4333, while Zambia has the highest average ROE of 0.4345. Following in that order are Nigeria, Kenya, and Ghana, with average ROE values of 0.0947, 0.0593, and 0.3178, respectively. Mauritius has the lowest average value among the selected countries, at 0.0292. The variations as indicated earlier may highly be as a result of the cost of capital in the various economies.

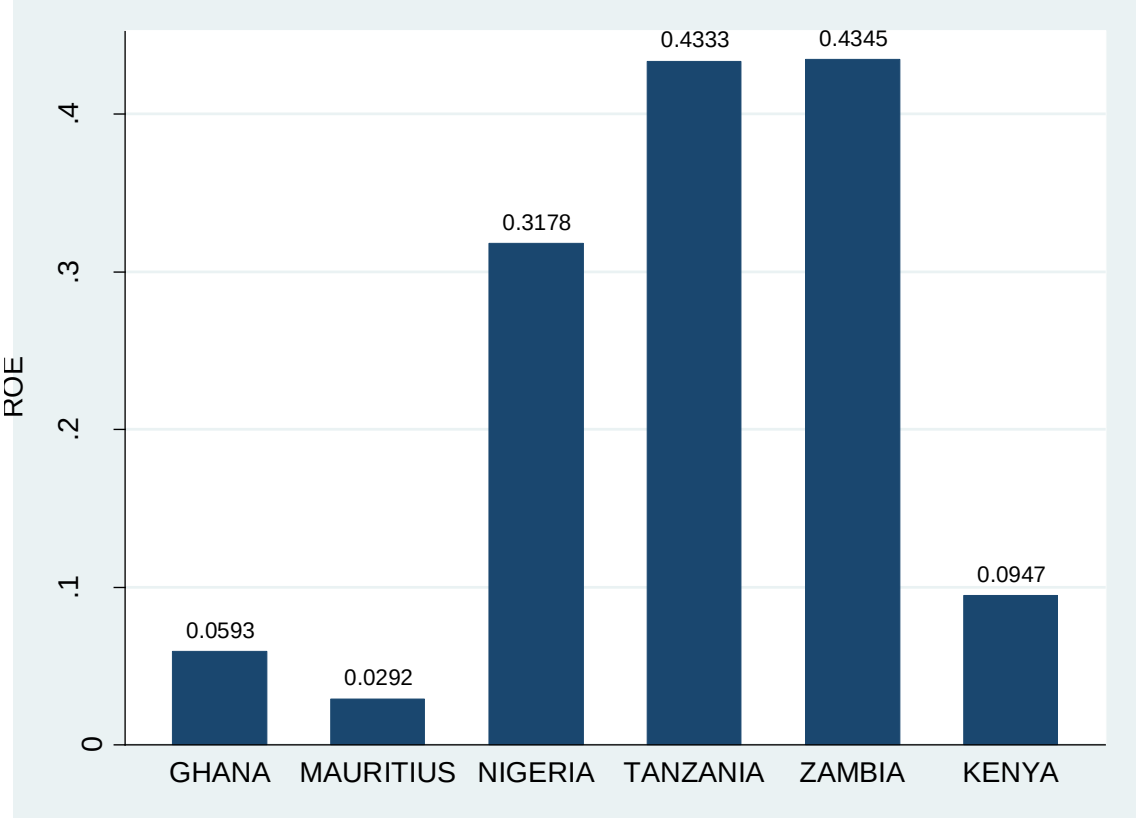


**Figure 2: Return on Equity (ROE) by country basis**

Source: Author's construct (2022)

**Climate Vulnerability in terms of country groupings**

On the basis of climate vulnerability, out of the six studied countries, the country which will be hit hardest by climate disturbances is Mauritius. This is followed by Ghana, Nigeria, Tanzania, and Zambia in that order. Kenya is the least in terms of vulnerability to climate changes

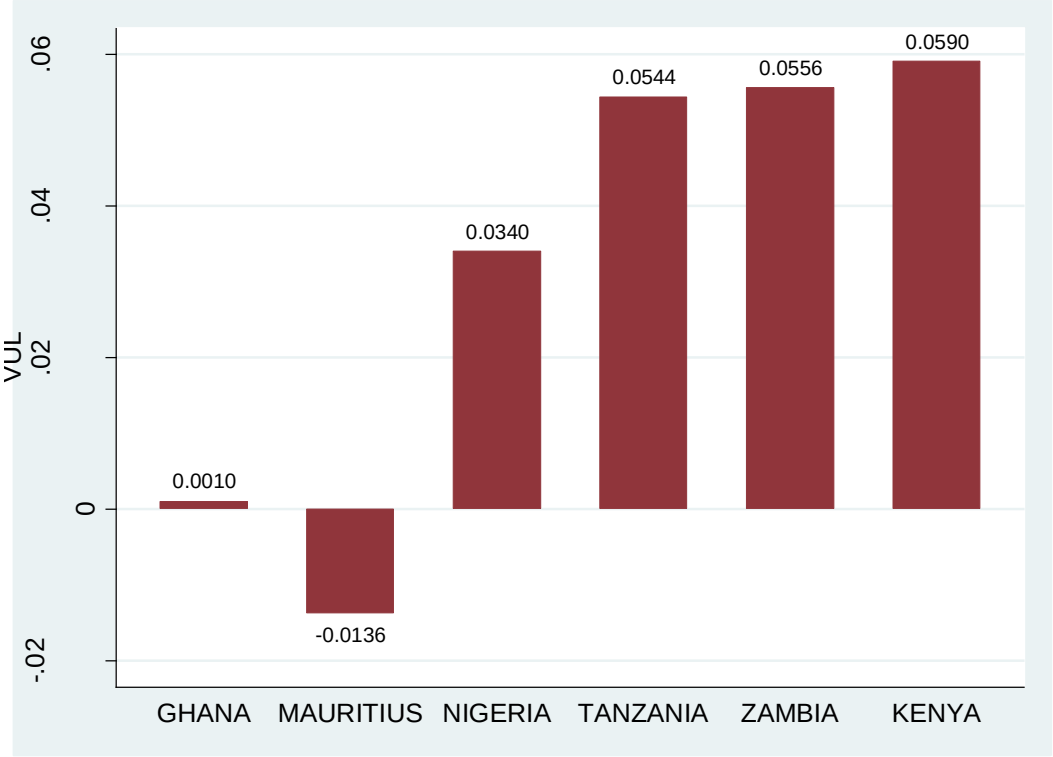


**Figure 3: Climate Vulnerability by country**

Source: Author's construct (2022)

**Country-specific research and development**

The trend in research and development (R&D) for the six countries under consideration is shown in Figure 4. Kenya, Mauritius, and Nigeria are performing better in R&D than Tanzania, Zambia, and Ghana. Ghana has the lowest R&D spending as a percentage of GDP among the analysed countries whereas Kenya records the highest value for R&D expenditure over the study period. This account for Kenya's lead in the agro-processing industry in SSA. The high expenditure on R&D increases market participation, cost management benefits, advancements in marketing abilities and trend-matching of firms in the industry.

It also reduces costs through more efficient production processes or more efficient products thereby making Kenyan firms in the industry more competitive.

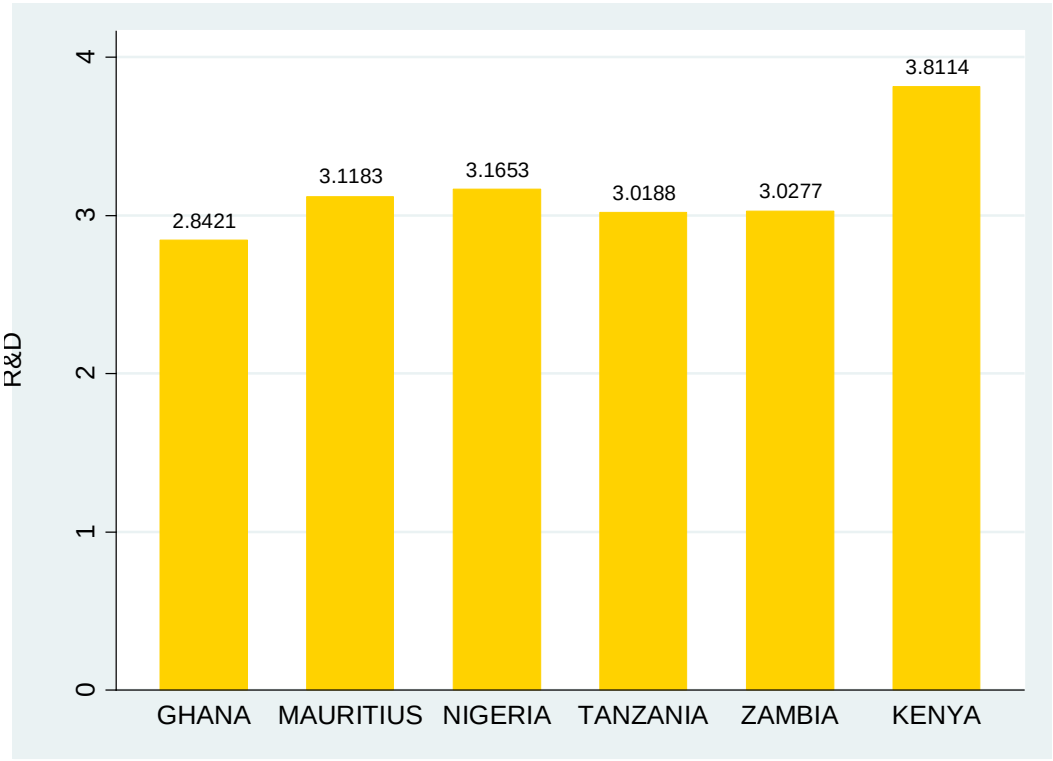


**Figure 4: Country-specific research and development**

Source: Author's construct (2022)

**Climate Vulnerability and investment in Country-specific research and development**

When the six nations are compared, Mauritius is the most vulnerable to climate change from 2007 to 2017, followed by Ghana, Nigeria, Zambia, Tanzania, and Kenya. Figure 5 shows that countries that tend to invest more in research and development are less vulnerable to climate change.

Kenya is a prime example of this, as it has the largest R&D spending per capita and thus the lowest vulnerability to climate change.

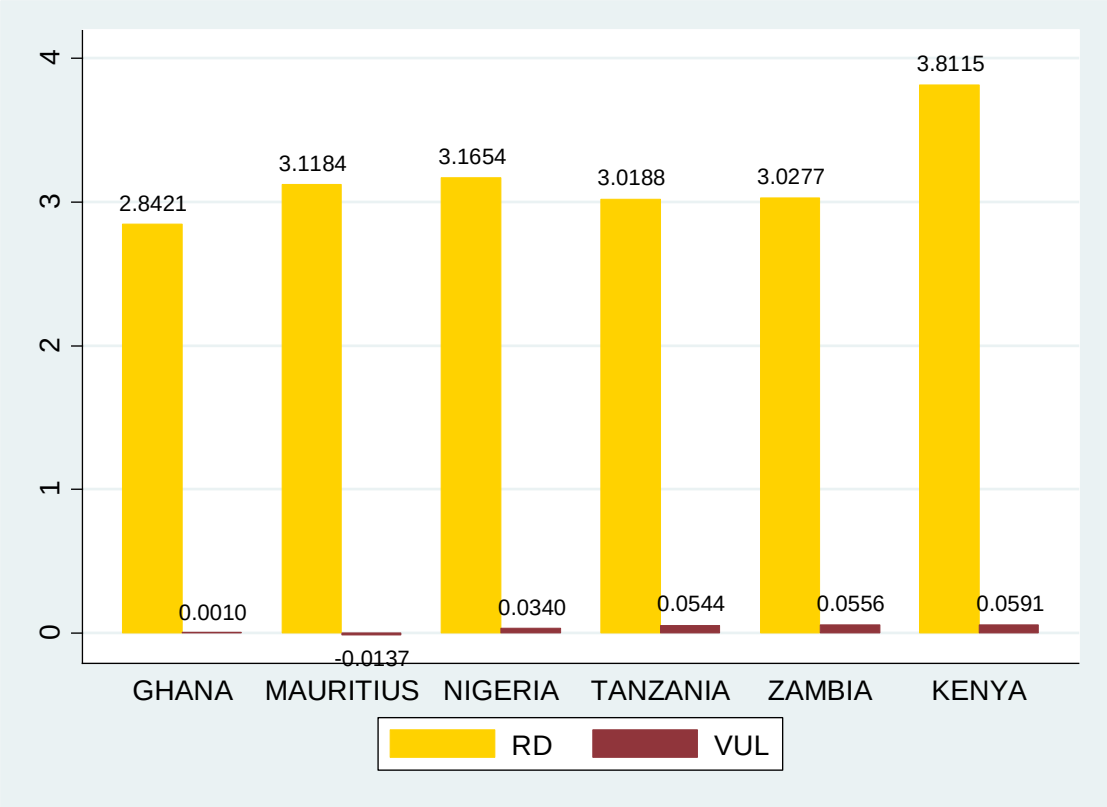


**Figure 5: Climate Vulnerability and investment in Country-specific research and development**

Source: Author's construct (2022)

**Correlation Analysis**

The association between the study's variables is displayed in Table 1. The correlation matrix aids in determining whether or not there is multicollinearity between the variables. The correlation between ROE and its log, vulnerability, firm size, nature2 (when a firm exports), yearly growth in the Gross Domestic Product, and inflation is positive and significant, as demonstrated in Table 1.

This illustrates that a rise in each of the variables has a favorable impact on the performance of firms. ROE is negative and significantly relates to regulatory quality, character, and R&D as a percentage of GDP, Regulatory Quality, and nature1 (when the firm does not export). Although not significant, there is a inverse link between ROE and liquidity. The correlation table's outcome depicts that there is no multicollinearity between ROE and the study's variables.

**Table 4: Pairwise Correlation Coefficient matrix**

**Pairwise correlations**

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| (1) ROE | | | | | | | | | |
| (2) VUL | 0.254* | 1.000 | | | | | | | |
| (3) R&D | -0.089* | 0.246* | 1.000 | | | | | | |
| (4) REQ | -0.252* | -0.766* | -0.059* | 1.000 | | | | | |
| (5) Fsize | 0.062* | 0.108* | -0.254* | -0.217* | 1.000 | | | | |
| (6) LIQ | -0.016 | 0.117* | 0.250* | 0.024 | -0.159* | 1.000 | | | |
| (7) nature | 0.192* | 0.429* | 0.200* | -0.218* | -0.119* | 0.232* | 1.000 | | |
| (8) GDPGann | 0.078* | 0.142* | -0.116* | -0.085* | -0.057* | -0.019 | 0.055* | 1.000 | |
| (9) INF | 0.078* | 0.306* | -0.115* | -0.416* | 0.011 | -0.022 | 0.108* | -0.172* | 1.000 |

Source: Author's construct (2022)

**Table 5: Regression of climate vulnerability (VUL) On Firm Performance (ROE)**

| ROE | Coef. | Std. Err. | P>t |
|---|---|---|---|
| L.ROE | 0.238*** | 0.019 | 0.000 |
| Vulnerability | -1.975** | 0.984 | 0.045 |
| Regulatory Quality | -0.092 | 0.078 | 0.239 |
| Firm Size | 0.030** | 0.014 | 0.033 |
| Liquidity | -0.002 | 0.003 | 0.526 |
| Nature of the firm | 0.491*** | 0.11 | 0.000 |
| Economic Growth | 0.020*** | 0.006 | 0.000 |
| Inflation | -0.009*** | 0.003 | 0.003 |
| Time Dummy | YES | | |
| Prob > F | 0.000 | | |
| AR (1) | 0.056 | | |
| AR (2) | 0.320 | | |
| Sargan test for overid. | 0.3120 | | |
| No of Obs. | 368 | | |
| No of groups | 38 | | |
| No of instruments | 34 | | |

Note; $^{*}p< 0.1$, $^{**}p< 0.05$, $^{***}p< 0.01$ indicates significance at 10percent, 5percent and 1percent respectively. Stata's xtdpdsys command was used to perform the estimation.

Source: Author's construct (2022)

The baseline empirical finding demonstrates that most of the parameters estimated of the firm and country-level control variables have the predicted signs and are also statistically significant. With regards to the primary variables, after adjusting for macroeconomic and microeconomic factors that impact financial performance, it was found that climate vulnerability is statistically significant.

This occurs at a 5 percent alpha level and exerts an economically valuable effect on firm performance with an estimated coefficient of -1.975. This posits that a unit decline in the vulnerability index of a country; thus, increasing the rate of climate vulnerability of a country is associated with a decline of 1.975unit points in firm performance in the short run holding all other factors constant. It supports the work of Cevik and Miryugin (2022) that nonfinancial firms conducting business in countries that are more vulnerable to climate change tend to have trouble obtaining debt financing, even at higher interest rates, while being less profitable and productive compared to firms in countries that are less susceptible to climate change's effects.

In addition, model 1 indicates that the Regulatory Quality of the country in the short run insignificantly affects the firm’s financial position. The implication is that, when all other factors are held constant, the effectiveness of the country's regulations is not related to the overall performance of the firms. The coefficient value of -.092 and a probability value of 0.239 highlights that there exists a negative and insignificant relationship between Regulatory Quality and the performance of firms in the country. The negative coefficient can be clarified with the assertion that Regulatory Control compels firms to implement clean technology which is often relatively expensive and therefore makes firms adamant about adopting, which results in bad performance.

The study supports the findings of Wang et al. (2021), but it runs counter to Leira's (2019) assertion that in emerging economies, firm performance has an inverse relationship with the quality of the regulatory environment. Therefore, there is a positive correlation between regulatory quality and corporate performance.

The assessment of the firm characteristics reveals that firm size has a positive effect and is statistically significant in predicting the performance of the firm. At a 5percent alpha level, a significant positive link between firm size and performance is demonstrated by a coefficient value of 0.03 and a probability value of 0.033. The implies that size of the firm has a short-term positive impact on the financial performance of agro-based firms using ROE as a measure of company performance. According to Cormier and Magan (2014), a manufacturing firm's output capacity is positively impacted by the size of the firm. This argues that increasing a manufacturing company's size while holding all other factors constant will result in an increase in performance.

With easier access to the capital market, large corporations can more easily find sources of funding for their operations. This will boost investor confidence, which could improve investor sentiment and ultimately enhance firm performance. Contrary to the results of Velnampy and Niresh (2014) and Becker-Blease et al. (2010), the research's findings, suggest that direct relationship exist between firm size and performance of agro-based firms in sub-Saharan Africa. This is consistent with those of Mule et al. (2015), and Pervan et al. (2012).

The results also differ marginally from the findings of Meiryani et al. (2020), who came to the conclusion that the Firm Size Variable had no significant and favorable impact on ROA (Return-on-Asset) with a 95percent level of confidence.

Moreover, the regression analysis investigates the relationship between firm performance and liquidity of the firms. The coefficient and probability value for liquidity were -0.002 and 0.56, respectively. The conclusion suggests that, in the short run, there is a negligible negative relationship between liquidity and the performance of agro-based firms. This finding further suggests that all other things being equal, a firm's financial prospects in terms of performance as measured by ROE will decline the easier it is for a firm to use its present asset to fulfill its short-term liabilities. As a result, the performance of the firms will decline as their degree of liquidity increases. The results vary considerably from those of Chia et al. (2020), who came to the same conclusion using Closing Percent Quoted Spread (CPQS) as a proxy for liquidity and found that liquidity has a negative association but had a significant impact on firms' profitability in the Malaysian stock market.

In addition, the performance of a firm and its nature are significantly correlated. at a 1 percent alpha level. The nature of the firm, which was being proxied as a dummy and defined as whether the firm is into export or not shows a strong and positive correlation with the firm's financial performance in the short run. The outcome reveals firms that are into export perform better in terms of performance being measured by ROE as compared to firms that do not export.

This can be explained in the sense that exportation exposes firms to the international market wherein they can easily seek assistance in terms of finance and technological know-how. This also makes the products of the firms more competitive in the local market as they produce to meet the standard of the international market.

With a coefficient value of 0.02 and a probability value of 0.000 economic growth was statistically significant at the 1percent alpha level. This shows that for every 1-unit point improvement in the economy's overall performance, ROE, the measure of firm performance, will rise by 0.02 unit while holding all other variables equal. This supports the works of Putra et al. (2021), and Otambo (2016), which suggested that economic growth (GDP) has a significant and direct effect on firm performance. However, despite being significant, the findings of Al-Homaidi et al. (2021) showed an adverse relationship between economic growth and financial performance of listed commercial banks on the Bombay Stock Exchange in India.

The study's short-term results indicate that inflation has an adverse effect on firm performance, with a negative coefficient of 0.009 and statistical significance at 1%. This means that a 1% increase in inflation results in a 0.9% decline in firm performance. According to Mankiw (2014), changes in sales volume, cost levels, and the relationship between prices and costs are the channels through which inflation affects performance. During inflation, pricing strategy becomes especially critical because businesses typically use cost as a benchmark to set prices. Regardless of whether prices are set based on the original cost or current replacement cost, the level of financial performance varies.

The findings of this study support the work of Rezina, Ashraf, and Khan (2020), who concluded that inflation has an indirect yet significant impact on corporate performance. The results suggest that inflation cannot be ignored as it significantly affects firm performance. However, these findings contradict those of Pervan et al. (2019), who argue that inflation has a financially beneficial and statistically significant effect on firm performance.

**Table 6: Regression of Technological Innovation (R&D) On Firm Performance (ROE)**

| **ROE** | **Coef.** | **Robust Std. Err.** | **P>t** |
|---|---|---|---|
| L.ROE | 0.147*** | 0.026 | 0.000 |
| Technological Innovation (R&D) | 0.227*** | 0.047 | 0.000 |
| Regulatory Quality | -0.529*** | 0.103 | 0.000 |
| Firm Size | 0.004 | 0.013 | 0.738 |
| Liquidity | -0.005 | 0.003 | 0.116 |
| Nature of the firm | 0.638*** | 0.221 | 0.004 |
| Age | 0.012*** | 0.002 | 0.000 |
| Economic Growth | 0.035*** | 0.007 | 0.000 |
| Inflation | -0.011*** | 0.002 | 0.000 |
| Time Dummy | YES | | |
| Prob > F | 0.000 | | |
| AR (1) | 0.0733 | | |
| AR (2) | 0.4168 | | |
| Sargan test for overid. | 0.5014 | | |
| No of Obs. | 368 | | |
| No of groups | 38 | | |

| | |
|---|---|
| No of instruments | 34 |

Note; $^{*}p< 0.1$, $^{**}p< 0.05$, $^{***}p< 0.01$ indicates significance at 10percent, 5percent and 1percent respectively. Stata's xtdpdsys command was used to perform the estimation.

Source: Author's construct (2022)

The primary variable in this objective, technological innovation (R&D), demonstrated a positive association with firm performance and was statistically significant at a 1 percent alpha level with a probability value of 0.000. This suggests that raising R&D spending will improve the performance of an organisation while keeping all other variables constant. According to the findings, a unit rise in R&D expenditure will result in a 0.313unit growth in ROE. The result is not different from the findings of Vanderpal (2015) who looked into the impact of R&D expenses on corporate financial performance. He demonstrated those R&D expenditures had a favorable effect on future earnings, market capitalization, productivity growth, and the operating performance of firms. Ehie and Olibe (2010) also examined the impact of R&D spending on US manufacturing and services sector business performance between 1990 and 2007 and discovered a positive relationship between them. In contrast to Kitching et al. (2013), the study's findings revealed that regulation has a detrimental effect on the performance of agro-based firms. Holding all other variables constant, a unit rise in regulation results in a 0.405 unit drop in company performance over the short term. This effect is statistically significant at an alpha level of 1percent when technical innovation is present.

With a statistically insignificance level, the estimated firm size variable coefficient shows a positive effect, indicating that firm size has a direct relationship with firm performance as measured by ROE. It implies that large firms are efficient in generating returns on their equity as compared small ones in the short run. This result indicates that bigger businesses use their negotiation power to lower the cost of their inputs, increasing their profitability. This conclusion may also suggest that larger corporations are better at adapting to macroeconomic shocks, which could improve their profitability in comparison to smaller firms. The report by Asimakopoulos et al. (2009) further elaborates that large organisations have a stronger cost advantage when negotiating input prices compared to small organisations, leading to superior performance.

Based on the study's conclusion, liquidity has no significant impact on the performance of agro-based firms. The analysis depicts a probability value of 0.116, indicating that the current assets to current liability ratio of listed agro-based firms has an insignificant effect on their ROE. This finding contradicts the conclusion of a study conducted by Lasisi et al. (2017) in Nigeria, which found that leverage has a significant negative impact on ROE while liquidity has a significant positive impact in the agricultural sector.

The nature of the firm again showed significant and direct relationship with firm performance. At a 1 percent degree of significance, the switch of a firm from producing solely for the local market to exporting its finished goods will increase the performance of the firm by 0.638 units compared to a firm that does not export holding all other factors constant in the short run.

The study also reveals that the sample countries' annual GDP growth has a considerable impact on their organisational performance. The proposition is that a rise in the economic performance of a country is directly associated with the performance of firms in the country. GDP growth and the effectiveness of the firm are significantly and positively correlated, as shown by the probability value of 0.000 and a coefficient value of 0.035. This suggest that a firm's exposure to stronger state-level economic growth is beneficial to the firm's performance, both in the context of expansion as well as earnings. According to Cho and Pattern (2007), a company's performance is reflected in its sales volume. The assumption is that economic expansion, which is connected to greater sales volume, will lead to improved performance.

According to the inflation coefficient of -0.011, a unit change in inflation will, in the short run, result in a 0.011 decline in firm performance. The outcome meets the criteria for statistical significance at the 1percent level. Increasing inflation is unfavorable for the performance of the company, as seen by the negative influence it has on firms performance. The outcome confirms Egbunike and Okerekeoti's findings from their analysis of factors that influence financial performance of some manufacturing firms listed on the Nigerian stock exchange in 2018. Inflation was found to be significant and inversely correlates with performance of firms.

**Table 7: Regression of Technological Innovation (R&D) and Climate Vulnerability (VUL) On Firm Performance (ROE)**

| Variables | Coef. | Robust Std. Err. | P>t |
|---|---|---|---|
| L.ROE | 0.122*** | 0.0226 | 0.000 |
| Vulnerability | 12.744*** | 3.244 | 0.000 |
| Technological Innovation (R&D) | 2.189*** | 4.28 | 0.000 |
| VUL*TIN | -4.001*** | 1.017 | 0.000 |
| Regulatory Quality | -0.466*** | 0.092 | 0.000 |
| Firm Size | 0.001 | 0.013 | 0.935 |
| Liquidity | -0.006* | 0.003 | 0.053 |
| Nature of the firm | 0.62*** | 0.219 | 0.005 |
| Age | 0.017*** | 0.002 | 0.000 |
| Economic Growth | 0.034*** | 0.006 | 0.000 |
| Inflation | -0.006*** | 0.002 | 0.008 |
| Time Dummy | YES | | |
| Prob > F | 0.000 | | |
| AR (1) | 0.0730 | | |
| AR (2) | 0.4365 | | |
| Sargan test for overid. | 0.5404 | | |
| No of Obs. | 368 | | |
| No of groups | 38 | | |
| No of instruments | 36 | | |

Note; $^{*}p< 0.1$, $^{**}p< 0.05$, $^{***}p< 0.01$ indicates significance at 10percent, 5percent and 1percent respectively. Stata's xtdpdsys command was used to perform the estimation.

Source: Author's construct (2022)

The regression analysis examines the effect of climate vulnerability and technological innovation on the performance of firms. Climate vulnerability had a positive coefficient and a probability value of 0.000 signaling a direct correlation between climate vulnerability and firms' performance. The result implies that vulnerability and performance of agro-based firms have a short-run, significant relationship. That is, at an alpha level of 1percent, the effect of climate vulnerability on the performance of agro-based firms is statistically significant. In line with Reboredo and Ugolini (2022) who concluded that businesses with minimal transition risk exposures outperform their competitors financially. They did this by utilising a firm-level carbon risk score which measures how vulnerable a firm's value is to the transition to a low-carbon economic system.

The study also looked at how technological innovation affects financial performance of firms, and the result indicates that agro-based firms' financial performance is significantly improved by spending funds on research and development. The correlation coefficient between R&D spending and firm performance was 2.189, and the probability value was 0.000, indicating a strong statistical significance. This finding suggests that for agro-based firms, increasing investment in R&D can lead to a significant improvement in their performance, even when other factors are held constant. The result confirms the findings of Auci and Coromaldi (2021), concluding that firms perform better when using climate change adaptation technology, particularly those in the aquaculture and fishery subsectors in northern European nations.

According to the discussed regression results, the research rejects the second hypothesis, claiming that R&D has no impact on how well publicly traded agro-based firms perform, and comes to the conclusion that R&D significantly affects firms' performance (ROE). Additionally, it supports the research of Ghaffar and Khan (2014), who from 2007 to 2012 also looked at how R&D affected the financial performance of pharmaceutical firms listed on Pakistan Stock Exchange. R&D spending and business performance were found to be strongly and positively correlated. The findings of this study are in disagreement with those of Vithessonthi and Racela's (2016) study, which examined the effects of internationalisation and the level of R&D activity on the short- and long-term financial performance of firms. Their study considered various factors such as firm size and asset ratio and used data from NASDAQ and NYSE firms in the US between 1990 and 2013. They found that the intensity of research and development negatively affects the operating performance of firms.

The study now looks at how technological innovation influences the relationship between firm performance and climate vulnerability in the Sub-Saharan African region. This analysis took technological innovation into account when evaluating how climate vulnerability will affect firm performance.

Using equation (13) to determine the moderating effect of technological innovation, gives

$$\frac{\Delta \mathrm{FP}_{ijt}}{\Delta \mathrm{VUL}_{ijt}} = \beta_1 + \beta_4 R\&D_{ijt}$$

$$\frac{\Delta \mathrm{FP}_{ijt}}{\Delta \mathrm{VUL}_{ijt}} = \beta_1 + \beta_4 \overline{\overline{R\&D}}$$

$$\frac{\Delta \mathrm{FP}_{ijt}}{\Delta \mathrm{VUL}_{ijt}} = 12.744 + (-4.001)(\overline{\overline{R\&D}})$$

Placing the mean value of technological innovation which is 3.235 from table 3, gives;

$$\frac{\Delta \mathrm{FP}_{ijt}}{\Delta \mathrm{VUL}_{ijt}} = 12.744 + [(-4.001)(3.235)]$$

$$\frac{\Delta \mathrm{FP}_{ijt}}{\Delta \mathrm{VUL}_{ijt}} = 12.744 + (-12.9432)$$

$$\frac{\Delta \mathrm{FP}_{ijt}}{\Delta \mathrm{VUL}_{ijt}} = -0.1992$$

This demonstrates that, on average, increase in climate vulnerability by a unit will lead to 0.1992 unit decline in firm performance due to technological innovation. This suggests that advancements in technology lessen the effect of climate vulnerability on firm performance. This illustrates that, once adopted, technological innovation has a significant effect on firm performance as a factor that affect firm performance on its own and as a variable that negatively influences climate vulnerability to improve the performance of firms.

The model again illustrates the conclusion regarding how the performance of firms is influenced by regulatory quality. Using a 1% level of significance, the regulatory quality had a negative and statistically significant impact on firms' financial performance, as shown by the probability value of 0.000 and a correlation coefficient of -0.466. The law and finance theory advanced by Porta et al. (1998) is at odds with this.

According to Porta et al. (1998), financial development is influenced by the origins of the laws, the regulations themselves, and the effectiveness of how those laws are enforced. Accordingly, Beck et al. (2003) suggested that institutional quality can account for cross-country disparities in financial development. The results also go against the theory put forth by Law and Azman-Saini (2012), who claimed that low-income nations are on the bottom end of the institutional quality spectrum and that raising it will help them advance financially. According to the rating by Krasue (2016), the majority of SSA regions have poor institutional quality, and Aluko and Ajayi (2017) claimed that this is a likely cause of the region's lower levels of banking sector development.

Firm size again had a statistically insignificant negative coefficient. This demonstrates that firm size does not influence how well firms perform. This can also be justified by the assertion that, on average, a percentage rise in the size of a firm results in 0.1 percent fall in firm performance (ROE). The findings contradict Odusanya et al. (2018)'s, Bhatia and Srivastava's (2016), and Mathuva's (2015) findings that company size and firm performance are positively correlated. It also contradicts the Schumpeterian theory, which holds that only big businesses can consider making technological change because they can make "optimal" R&D investments. In other words, small businesses would not be capable of strategically investing in R&D in such a competitive market due to it being too risky. Schumpeter asserts that large organizations have stronger incentive to devote more resources to R&D than smaller organisations because they possess the means to augment technological advancement.

Thus, perceive greater returns from technology adoption than smaller organisations since their share of the market will further act as a deterrent to instantaneous emulation. However, Lazăr (2016) as well as Margaretha and Supartika, (2016) demonstrated a negative correlation between performance and firm size. This is explicable in the context that large businesses are more prone to experience the principal agency problem (managerial and shareholder disagreement), which can reduce profitability because management behavior is less under control. Additionally, larger businesses may exhibit significant diversification, which reduces their efficiency.

Again, between liquidity and financial performance, the result suggest that firms perform worse if they are more liquid. According to the indirect link, an increase in liquidity by 1percent will cause a decline in firm performance of 0.006, which is statistically significant. The results show that listed agro-based firms tend to perform worse when their current liability to asset ratio is higher.

The conclusion elaborates that instead of firms with greater liquidity to benefit from using initiatives that guarantee growth and therefore have enhanced ability to handle variations in highly competitive economies, greater liquidity rather reduces the performance of firms. This suggests when firms find it easier to fulfill their short-term obligations, their performance worsens. The results confirm Delen et al. (2013)'s finding that cash flow ratio (CFR) and firms' financial performance have negative relationship.

The argument made in support of the assertion was that managers who have more resources available for the organisation's operational processes confront the problem of excessive spending, which has an unfavorable impact on profitability of organisations.

Again, the nature of the firm as to whether the firm exports it finished goods or not tends to have statistically positive influence on firms' financial performance. At 1 percent degree of significance, switch of a firm from producing solely for the local market to exporting its finished goods will increase the performance of the firm by 0.62 units compared to local producers holding all other factors constant in the short run.

Age of the firm when technology was adopted had a significantly impacted on how well the firms performed finacially. A rise in the firms age by a year will induce firm performance to rise by 0.017 and statistically significant at 1 percent alpha level. In line with the research results of Egbunike and Okerekeoti (2018) and Hassan and Muniyat (2019), this result once more depicts positive correlation between GDP growth and firm performance in the short run. This does meet the prior expectation of the GDP growth variable's coefficient, which is; a direct relationship exists between ROE and GDP growth. In particular, when all other factors remain equal, a unit increase in GDP growth will enhance ROE by 0.034unit points. In particular, Egbunike and Okerekeoti (2018) observed and concluded that GDP and firm performance are positively associated after looking into macroeconomic determinants of firm performance in Nigeria.

However, Tan and Floros (2012) found in their study; "Bank profitability and inflation: the case of China" that in the short run, bank profitability declines when gross domestic product rises which contradicts the finding of the research.

Results from the research shows that performance of firms is significantly impacted by inflation. This happens through the firms' cost of production, such that if the rate of inflation rises, the cost of production does too, and this has an impact on the firms' worth in terms of financial performance. Although cost increases would be absorbed into production costs, whether they would be passed on to consumers would depend on the types and elasticity of the products and services. The outcome demonstrates that at 1percent alpha level, a rise in inflation by a unit will result in a short-term decrease in ROE by 0.006 and is statistically significant.

**Table 8: Long-Run Interpretation for Significant Variables in model 3**

| **Variables** | **Coef.** | **Std. Err.** | **P>t** |
|---|---|---|---|
| L.ROE | 14.5231*** | 3.5624 | 0.000 |
| VUL | -2.404 | 4.08 | 0.000 |
| R&D | 2.4943*** | 0.5705 | 0.000 |
| VUL*RD | -4.5593*** | 1.1343 | 0.000 |
| REQ | 0 -.5315*** | 0.144 | 0.000 |
| LIQ | - 0.0069** | 0.0034 | 0.046 |
| NAT | 0 .7062*** | 0.2432 | 0.004 |
| GDPG | 0.0387*** | 0 .0076 | 0.000 |
| INF | -0.0074*** | 0.003 | 0.009 |

Note; $^{*}p< 0.1$, $^{**}p< 0.05$, $^{***}p< 0.01$ indicates significance at 10percent, 5percent and 1percent respectively. The stata command nlcom was used for the estimations.

Source: Author's construct (2022)

Table 8 illustrates the long-run effect of significant variables in the regression of technological innovation and climate vulnerability on firm performance (ROE). Climate vulnerability and technological innovation still remain highly significant in the long run. The coefficient of both variables increases in the long run implying that its impacts on performance, in the long run, will be higher as compared to the short run effect. Regulatory Quality remains significant with an increasingly adverse effect on firm performance.

For the firm level characteristics, liquidity and nature of the firm are significant at a 1percent and 5percent alpha level respectively. The marginal impact for all the firm-level variables increases in the long run. Economic Growth and nature of the firm showed a highly significant correlation with firm performance in the long run. At a statistical level of 1percent, the nature of the firm and economic growth exerts an increasing marginal effect on firm performance compared to the short-run effect while maintaining its positive direction.

The study made use of the Arellano-Bond test for autocorrelation AR (2) as well as the Sargan test for over-identifying constraints. For the Arellano-Bond test for serial correlation AR (2), the null hypothesis is that there is no second-order serial correlation, whereas for the Sargan test, the null hypothesis is that the instrumented variables are exogenous and not correlated to the error term. The values of the AR (2) for models 1 through 3 are 0.320, 0.351, and 0.369, respectively, indicating that the researcher was unable to reject the null hypothesis that there is no second-order serial correlation and reached the conclusion that serial correlation has no effect on the models.

The study's attempt to refute the null hypothesis of overidentifying restrictions failed because results of the Sargan over-identification test were 0.3120, 0.2080, and 0.2407, respectively. This indicates that there is no over-identification of restrictions. The results are consistent and reliable, which the researcher can infer from the post-estimations.

**Chapter Summary**

The chapter outlines descriptive statistics and a correlation assessment of the data used, proceeded by the results and a discussion of the main objectives of the research. The first objective was to investigate how climate vulnerability affected firm performance in selected SSA economies. The findings demonstrated that the performance of agro-based businesses in the chosen regions is significantly impacted by climate vulnerability.

To better understand how technological innovation affects the success of agro-based firms in SSA region, the second objective examined this relationship. In light of the findings, it is clear that technical innovation considerably enhances firm performance.

The third goal was to analyse how technological innovation reduces the impact of climate vulnerability on firms' performance in SSA. The result revealed that in the presence of technological innovation, the influence of climatic sensitivity on firm performance is limited and statistically insignificant.

# CHAPTER FIVE

# SUMMARY, CONCLUSIONS, AND RECOMMENDATION

## Introduction

The summary, conclusions, and recommendations are to be presented in this last chapter. The objective is to provide the study's key findings and offer policy suggestions as a solution to create a better and more sustainable economy that is able to adapt to climatic changes. Additionally, the chapter offers recommendations for future research works.

## Summary

The study aimed to investigate whether climate vulnerability affects the financial performance of agro-based firms in selected SSA countries and whether technological innovation has a moderating effect on this relationship. The study also controlled for other factors that could affect firm performance. To analyse the data, the study used the system General Methods of Moments methodology developed by Arellano and Bover (1995) and Blundell and Bond. The dataset was compiled from data from the World Governance Indicators, World Development Indicators and firm-level data obtained from published annual financial statements on various stock exchanges. The study covered a period of 11 years in six SSA countries.

The preliminary findings suggested that, in the short run, climate vulnerability has an inverse relationship with firm performance and was statistically significant.

Regulatory Quality, Liquidity, and Inflation were counterproductive to firm performance, Firm size, Nature of the firm and Economic growth had a favorable effect on financial performance of firms.

According to the study's second objective results, technological innovation had a positive impact on firm performance in the short term, while inflation and regulatory quality had a negative impact, despite being statistically significant. The study found that Regulatory Quality and Inflation had a detrimental effect on the financial performance of the selected agro-based firms in SSA.

The final objective of the research rejected the null hypothesis that technological innovation does not moderate the effect of climate vulnerability on firm performance. Although the impact of climatic vulnerability was found to be weak and insignificant, the study revealed that technological innovation has a significant and direct effect on firms' financial performance.

The outcome of the long-run estimations did not show any deviations in significance compared to the short-run outcome. Firm size, nature of the firm, and economic growth had statistically significant and appreciating effects on firm performance whilst liquidity remained insignificant in both periods. According to both short-run and long-run dynamics, regulatory quality and inflation continue to have an adverse impact on firms' performance and were statistically meaningful in both time frames.

## Conclusions

The primary goal of the study was to assess the interrelationship between climate vulnerability, technological innovation and performance of agro-based firms with focus on the role being played by technological innovation in moderating the effect of climate vulnerability on the performance of listed agro-based firms. The study applied System Generalised Method of Moment estimation for thirty-eight listed agro-based firms across six selected countries in SSA from 2007 to 2017 financial years.

The research used Regulatory Quality, Firm Size, Liquidity, Nature of the Firm, Economic Growth, and Inflation as determinants of firm performance aside the variables of interest (Climate Vulnerability and Technological Innovation). The research findings were backed up by theories and existing works of literature.

The study shows that climate vulnerability has an adverse effect on the financial performance of agro-based firms. It also demonstrated that investment in technological innovation tends to boost the financial performance of agro-based firms by making them adaptive to climatic changes. In the presence of climate vulnerability, the regression result showed a positive and statistical significance association between technological innovation and firms' performance. Thus, higher investment in technological innovation, yields more profit for the firm through production efficiency and increased productivity.

## Recommendations

Climate change has the potential to cause significant disruption and financial consequences. An increasing climate vulnerability presents considerable concerns for Sub-Saharan Africa. Africa benefits from international accords that minimise the causes of future climate change, but the continent also needs to take action to prepare for expected future climate threats. Following are some recommendations that the research makes in light of this:

Promote innovation and technology adoption: Encourage agro-based firms to invest in technological innovation and adopt advanced agricultural technologies to improve productivity, resource efficiency, and adaptive capacity. This can include precision farming techniques, remote sensing, data analytics, and climate forecasting tools. This will reduce the negative impact of climate vulnerability.

According to the study's conclusions, funding for research and development (investment in technological innovation) can minimise the effects of climate change by enhancing the region's ability to adapt, hence the study recommends that priority be given to funds allocated to research and development in annual budget of countries in SSA. The relevant government agencies and non-governmental organizations should provide support for firms to invest in innovative technologies that are capable of mitigating climate vulnerability. They can provide financial incentives, technical assistance, and create awareness on the benefits of investing in innovative technologies that can help companies adapt to the changing climate.

Government agencies in charge of environmental protection and sustainability should work closely with non-governmental organizations and the private sector to develop policies and programs that support the adoption of innovative technologies that can help firms mitigate the impact of climate vulnerability and improve their performance.

**Future Research Direction**

Future studies can examine the specific technological innovations that firms can adopt to mitigate the adverse effect of climate vulnerability on their performance in Sub-Saharan Africa. This research can investigate the types of innovative technologies that are most effective for different sectors and regions in the continent.

The study suggests that future research can benefit from a comparative analysis of the effects of climate vulnerability and technological innovation on firm performance not only in Sub-Saharan Africa but also in other regions of the world. Such a study can provide useful information on how these factors impact firms across different regions and help identify effective strategies to address the challenges of climate vulnerability in the continent.

Lastly, future studies can also consider investigating the potential barriers to the adoption of innovative technologies by firms in Sub-Saharan Africa, including financial, institutional, and cultural factors. This research can provide insights into the specific challenges that firms face when trying to adopt innovative technologies to address the issues of climate vulnerability in the continent.

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