Research and Development Investment, Technology Adoption and Financial Sustainability of Listed Manufacturing Firms in Kenya

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ABSTRACT

This research will explore the connection between R&D investment, the adoption of technology and financial sustainability among publicly listed manufacturing companies in Kenya. The objective of this study is to analyze R&D factors such as intensity, spending, personnel and collaborative initiatives impact on financial sustainability and to evaluate the moderating impact of technology adoption on the sustainability of firms. Resources-based view theory will anchor the research, quantitative research and longitudinal design will be utilized, relying on secondary panel data derived from the audited financial statements and sustainability reports of nine manufacturing firms listed on NSE for the period 2016 to 2025. Financial sustainability of the firms will be assessed using the Altman Z-Score model. The data analysis will be conducted using SPSS and Stata, incorporating both descriptive and inferential statistical methods, including panel regression analysis and diagnostic evaluations for normality, multicollinearity, autocorrelation, and heteroscedasticity regression analysis. The anticipated results are expected to yield empirical insights into how R&D investment and technology adoption contribute to the financial sustainability of manufacturing firms thereby guiding corporate strategies, industrial policies, and future academic inquiries in the realm of innovation-driven economic growth.

LIST OF ABREVIATIONS

EU-EPA	:	European Union Economic Partnership Agreement
EVA	:	Economic value added
GICS	:	Global Industry Classification Standard
IATR	:	Industrial and Allied Technologies Research
R&D	:	Research and Development
ROA	:	Return on assets
ROE	:	Return on equity
TICAD	:	Tokyo International Conference on African Development
KAM	:	Kenya Association of Manufactures
TICAD 9	:	Ninth Tokyo International Conference on African Development
KIRDI	:	Kenya Industrial Research and Development Institute
IATR	:	Industrial and Allied Technologies Research

Operational Definitions of Terms

R&D intensity: R&D intensity refers to the proportion of a firm's financial resources devoted to research and development activities relative to its total sales or revenue. It reflects the firm's commitment to innovation and technological advancement (OECD, 2015; Hall, 2020). In the study, it will be measured as R&D Intensity (RDI) = R&D Expenditure /Total Sales times 100. A higher R&D intensity indicates greater investment in innovation relative to firm size.

R&D expenditure: R&D expenditure represents the total amount of financial resources allocated to research and development activities, including costs of materials, prototypes, testing, and innovation-related processes (UNESCO, 2022; Hsu et al., 2021). It serves as a direct measure of a firm's innovation input. The total R&D expenditure will be obtained from firms' annual financial reports and expressed in Kenya Shillings (KES). To ensure comparability across firms and years, the value will be standardized using natural logarithmic transformation (ln RDE).

R&D personnel and human capital: R&D personnel and human capital refer to the number and quality of employees directly involved in research, product design, and process improvement. This reflects the firm's capacity to generate and absorb new knowledge (Becker, 1993; Mairesse & Mohnen, 2015). In the current study, it will be measured as R&D Personnel Ratio (RDP) = Number of R&D Staff/Total Employees times 100. Where data is unavailable, disclosures on training, innovation teams, or R&D-related human resource investments will be used as proxies.

Collaborative R&D partnerships: Collaborative R&D partnerships denote formal or informal cooperative arrangements between firms and external entities such as universities, research institutions, or other firms to jointly develop innovations or technologies (OECD, 2018; Cassiman & Veugelers, 2002). In the study, it will be measured by using a partnership index, computed from firm disclosures in annual and sustainability reports. The index will reflect the number and type of active R&D collaborations per year, coded as: 0 = No collaboration, 1 = One active collaboration, 2 = Two or more collaborations. A higher index indicates a greater degree of collaborative engagement.

Technology adoption: Technology adoption refers to the extent to which a firm integrates new technologies into its production, logistics, or management processes. It reflects the firm's adaptability to technological change (Rogers, 2003; Aboelmaged, 2021). In the study, A Technology Adoption Index (TAI) will be developed based on firm disclosures on digitalization, automation, information systems, and green technologies. The index will be rated on a 5-point scale: 1 = Very low adoption, 5 = Very high adoption. This index will be standardized for inclusion in the regression model.

Financial sustainability: Financial sustainability is the ability of a firm to maintain long-term financial viability and avoid distress while supporting ongoing operations and innovation activities (Altman, 1968; Almansour, 2022). Financial sustainability will be measured using the Altman Z-Score, which integrates profitability, liquidity, leverage, and activity ratios. A Z-score> 2.99 indicates financial stability; 1.81–2.99 suggests a grey zone, and < 1.81 signals financial distress.

Chapter One

INTRODUCTION

Background of the Study

Financial sustainability in manufacturing is related to the ability of a company to effectively manage its financial resources to ensure long-term sustainability, competitiveness and profitability. This includes the creation of sufficient revenues to cover the costs of operations, investment towards innovation, and the ability to be resilient against financial and market-related disruptions (Nguyen et al, 2023).

The UN, in its System of National Accounts (2008 SNA) defines R&D as: creative work done in a systematic

way to augment the stock of knowledge and application of that stock of knowledge to the development of new applications. (National Science Foundation, 2025). Research and Development (R&D) are important towards bolstering the financial sustainability of a given firm through innovation, enhancement of competitive edge, and value creation in the long-term.

R&D Intensity Mostly it is measured as the ratio of the R&D spending by a company to its total revenue or sales. In the view of resource based view (RBV), R&D intensity represents internal resource that can create and sustained competitive advantage, hence lead to increased financial sustainability in the long run (Barney, 1991). An increased R&D intensity implies that a company is committed to innovation strategically and this may result in the creation of new products, identification of market opportunities and enhanced efficiencies in the operations of the company. Companies that are highly concentrated on the R&D are more likely to outsmart their rivals by product differentiation and market growth as a result of innovation.

R&D Expenditure refers to the amount of funds that a business uses in conducting research and development projects and includes basic research, applied research as well as experimental development (OECD, 2005). R&D investments enable companies to develop capabilities that they can use to counteract external challenges, harness new opportunities, and broaden their products and services thus acting as a financial cushion in the event of market downfalls (Coad and Rao, 2008). This strategic flexibility is an ingredient towards greater long-term sustainability.

R&D Personnel and Human Capital refer to the human resource of research and development activity that comprises researchers, scientists, and engineers as well as technical people. According to the human capital theory, the productivity and the innovation outcomes of firms are increased by investing in the skills and knowledge of the employees (Becker, 1993). Regarding R&D functions, the knowledge of staff members is crucial in terms of generating new ideas, developing innovative products, and improving processes that eventually have an impact on the performance of the firms and financial sustainability. Research indicates that companies with greater access to skilled R&D staff have more patents, new products and process innovations, which are associated with increase in revenues and competitiveness in the market (Cohen and Levinthal, 1990; Hall and Lerner, 2010).

Collaborative R&D Partnerships involve formal or informal relationships between organizations and companies with external organizations, including universities, research institutions, suppliers, customers or even competitors, where partners collectively participate in research and development activities (Powell, Koput, and Smith-Doerr, 1996). The open innovation theory (Chesbrough, 2003), underscores the importance of external cooperation in speeding up the innovation process through the application of external knowledge and sharing of risks. It enables companies to access complementary resources and skills, reduce expenses, and improve innovation outcomes, which could then contribute to generating financial sustainability. A study published on Emerging Markets Finance and Trade in 2023 has examined more than 1,300 publicly listed Chinese companies between 2007 and 2016. The results demonstrated that the inter-firm collaborative R&D is positively related to the technological innovation performance and market competitiveness and negatively to the profitability metrics.

One study of manufacturing companies established that the moderating effect of technology on the relationship between R&D intensity and financial performance is positive, that is, the higher the technology adoption, the greater the positive impact that R&D would have on financial sustainability (Gupta and Govindarajan, 2022).

Research and development, and sustainability of Manufacturing firms, Global Perspective

The R&D intensity in the emerging markets has a high positive influence on the performance of the manufacturing firms in South Korea and China. Besides, this influence is greater in South Korea compared to China. Moreover, the impact of R&D investment on the performance of Chinese manufacturing firms with respect to that of South Korea has a positive time-lag effect only (Xu and Sim, 2018). The estimates made by the Congressional Budget Office (CBO) indicate that in 2021 the manufacturing industry contributed 12 percent of the U.S. greenhouse gas emissions. Approximately, 75 percent of those emissions were as a result of fuel combustion to produce heat and the other was by-products of industrial processes which convert materials

to products. The manufacturing emissions are expected to rise by 17 percent in the period between 2024 and 2050. CBO assumes that the increase in the activity of the industries emitting high numbers of emissions will cause the growth of the overall emission in the manufacturing sector (Phillip I. Swagel, 2024). The future volumes of the emissions are based on the future economic growth, the oil and gas supply and the technological variants. Alterations in economic growth impact on emissions through altering output in terms of

manufacturing and alterations in oil and gas supplies impact on emissions given the fact that oil and gas are also significant inputs in manufacturing. Technological changes such as the greater use of electrification, carbon capture, and hydrogen fuel can lower direct emissions in the manufacturing sector in the long run, though at the cost of indirect emissions in other sectors, such as the electric power sector (Phillip I. Swagels, 2024). R&D investment in Indonesia was found to be positively and significantly correlated to eco-efficiency and firm value which implies that R&D investment is relevant to enhance eco-efficiency and firm value. The period between 1991 and 2015, the results were established that the degree of negative environmental ratings was correlated with the sustainable practices of the U.S. corporations. Moreover, the intensity of the environmental interests becomes weaker as the firm invests in research and development with time. These imply that larger companies will tend to report higher degree of environmental issues since they experiment with the idea of sustainability. Such companies will also tend to lower the undesirable environmental scores over the years, and achieve economies of scale through sustainable production (Kabongo, 2019). According to Soltanisehat et al. (2019), the innovation of the modern competitive world is primarily based on Research and Development (R&D) and the overflowing technologies, which, in turn, can be identified as a significant source of economic growth. Research activities are another area that can be invested by firms whose technological levels are varying with very high levels like the high technology industries to enhance their productivity. In the drug and chemical industries, as far as medicine is concerned, R&D investments most significantly affect the productivity growth (Soltanisehat et al., 2019)

Research and development, and sustainability of manufacturing firms,

Regional Perspective

Empirical evidence about listed manufacturing companies in Sub-Saharan Africa demonstrates that sustainability practices affect financial performance in a positive and significant way. Scholars have shown that social, environmental, and economic disclosures, corporate philanthropy, and environmental responsibility practices can help firms to improve their financial alternatives such as return on assets (ROA), the ratio of return on equity (ROE), and economic value added (EVA). The practices enhance reputation, customer loyalty and long-term value creation achieved through conformance to the expectation of stakeholders and better risk management.

The intensity of research and development is low in the African economies with an average of 0.5 per cent as opposed to the rest of the world of 2.2 per cent (Shibia, `2022). This gap highlights the importance of analyzing the aspects that may be used to increase innovation and sustainable activities in the industrial sector of the region (Shibia, 2022). Besides, manufacturing, which was traditionally labour-intensive, has developed into a complex field that is informed by the technological processes that are information-based and involves the need to understand how the advanced manufacturing technologies are affecting the sustainability of operations (Nyori, 2015). The existing trend in the modern world where people pay more attention to the environmental situation implies that manufacturing companies, which cause the largest amount of waste and emissions, should also strive to develop strategies of sustainable operations (Sarfraz et al., 2022) (Yvaz, 2024).

Research and development, and sustainability of Manufacturing firms, Local Perspective

The access to external finance, reduced competition in the informal sector, presence in the exports market, larger firm size, and firms operating in high technology subsectors can positively affect the manufacturing firms in Kenya to make decision on Research and Development (R&D) investments (Shibia, 2023). The KIRDI directorate of Industrial and Allied Technologies Research (IATR) is mandated by the Kenya Industrial Research and Development Institute Act, 2022, to create and execute industrial R&D projects, inform national policy of R&D, track dominant trends in industrial technology, and make research results available to

policymakers and industry (KIRDI, 2022). Policy Research, Manufacturing and Industrialization Directorate, under the Ministry of Investments, Trade and Industry takes a role in industrial policy, incorporating research in the policy-making process, commercialization of innovation, and frameworks related to R&D, aimed to increase industrialization. Tax incentives like capital allowance and investment deductions in Kenya served a significant role in enhancing the financial performance as it minimized the cost of capital incurred by the firms, enhancing productivity in the firms and stimulated innovation and competition. It is an indirect relationship, but it relates government policy to better financial results and indicates that R&D assistance through tax leverages plays a positive role.

Moderating Effect of Technology

Technology Adoption refers to the process by which companies introduce and incorporate the new technologies in their processes to increase efficiency and potential to innovate (Rogers, 2003). One moderator that may be able to reduce or increase the effects of R&D on financial sustainability is technology adoption. The diffusion of innovations theory (Rogers, 2003) is a theory that suggests that those companies that successfully implement new technologies will be in a better position to exploit their research and development activities and begin to innovate, commercialize and improve their operations faster.

According to resource-based perspective (RBV), the use of technology supplements the internal resource in terms of R&D, and it allows firms to more effectively turn investment in R&D into financial payoffs (Barney, 1991). The use of technology enhances the firm to use the output of R&D effectively to reduce time-to-market and the costs that would increase financial returns of R&D (Chong et al., 2016). Through technology adoption, the risk related to R&D can be minimized by offering means to better manage projects, analyze data, and simulate it to improve the rates of R&D project success (Kaiser et al., 2020).

Listed Manufacturing Firms in Kenya

The listed manufacturing companies in Nairobi stock exchange are A.Baumann & Co Ltd (BAUM), B.O.C Kenya Ltd (BOC), British American Tobacco Kenya Ltd (BAT) Carbacid Investments Ltd (CARB), East African Breweries Ltd (EABL), Eveready East Africa Ltd (EVRD), Kenya Orchards Ltd (ORCH), Mumias Sugar Co. Ltd (MSC) and Unga Group Ltd (UNGA)

Statement of the Problem

The manufacturing industry is known to be a key driver of sustainable economic growth, structural change and industrial competitiveness especially in emerging economies (World Bank, 2020). Manufacturing companies listed in the NSE are important to the economy of Kenya as the industry contributes to 15.9 percent of the total employment in the nation in 2024 and is among the highest employers in the country (KNBS, 2025). Manufacturing industry in Kenya is economically significant but has suffered financial instability where many companies such as Eveready East Africa Ltd, Mumias Sugar Company and ARM Cement Ltd have recorded losses, liquidity issues, and difficulties in repayment of debts (KNBS, 2025). The manufacturing contribution has continued to decline at a steady rate of 12% in 2012 to about 7.2% in 2024. (GOK, 2024). The Kenyan governmental programmes intends to increase the GDP portion of manufacturing to 15 per cent by the year 2027 (KNBS, 2025). To have financial sustainability in the manufacturing sector, R&D undertakings and adoption of technology will be of paramount importance.

The research on the firm performance in Kenya and other developing economies place much emphasis on short-term financial performance, non-listed companies and only on a single aspect of performance such as capital structure, corporate governance, and company size (Griliches, 1998; Aghion and Howitt, 2009). The studies on R&D investment and adoption of technology tend to study them separately without considering their interactive outcomes on financial sustainability where's this study will study the impact of R&D investment, technology adoption on financial sustainability of manufacturing firms in Kenya.

Longitudinal data on the manufacturing companies that are listed on the NSE are limited even though they are important industrially. The resource-based view and endogenous growth theory propose that innovation and

competitive advantage can be driven by R&D and technology adoption (Schumpeter, 1934; Barney, 1991; Romer, 1990), though research in developed countries demonstrated that they add value, efficiency, and resilience to firms (Hall et al., 2010; Brynjolfsson and Hitt, 2000; OECD, 2018). However, this remains uncertain whether such impacts are applicable in the emerging markets, hence the rationale behind this research to hone down on the impact of R&D investment and technology adoption on the financial sustainability of the listed manufacturing companies in Kenya.

Research Objectives

General Objective

The primary aim of this research is to assess the investment in research and development, the technology adoption and the relationship on financial sustainability of publicly listed manufacturing companies in Kenya.

Specific Objectives

This study will be guided by the following specific objectives;

i. To analyze the effect of R&D intensity on the financial sustainability of listed manufacturing firms in Kenya.

ii. To assess the impact of R&D expenditure on the financial sustainability of listed manufacturing firms in Kenya.

iii. To investigate the influence of R&D personnel and human capital on the financial sustainability of listed manufacturing firms in Kenya.

iv. To assess how collaborative R&D partnerships contribute to the financial sustainability of listed manufacturing firms in Kenya.

v. To explore the moderating effect of technology adoption on the relationship between Research & Development and financial sustainability of listed manufacturing firms in Kenya.

Research Hypotheses

H01: R&D intensity has no significant effect on the financial sustainability of listed manufacturing firms in Kenya.

H02: R&D expenditure has no significant effect on the financial sustainability of listed manufacturing firms in Kenya.

H03: The quality and quantity of R&D personnel and human capital have no significant effect on the financial sustainability of listed manufacturing firms in Kenya.

H04: Collaborative R&D partnerships have no significant effect on the financial sustainability of listed manufacturing firms in Kenya.

H05: Technology adoption has no moderating effect on the relationship between Research & Development and financial sustainability of listed manufacturing firms in Kenya

CONCEPTUAL FRAMEWORK

As indicated in the Figure below, the independent variable of the study will be Research and Development investment, the moderating variable is Technology

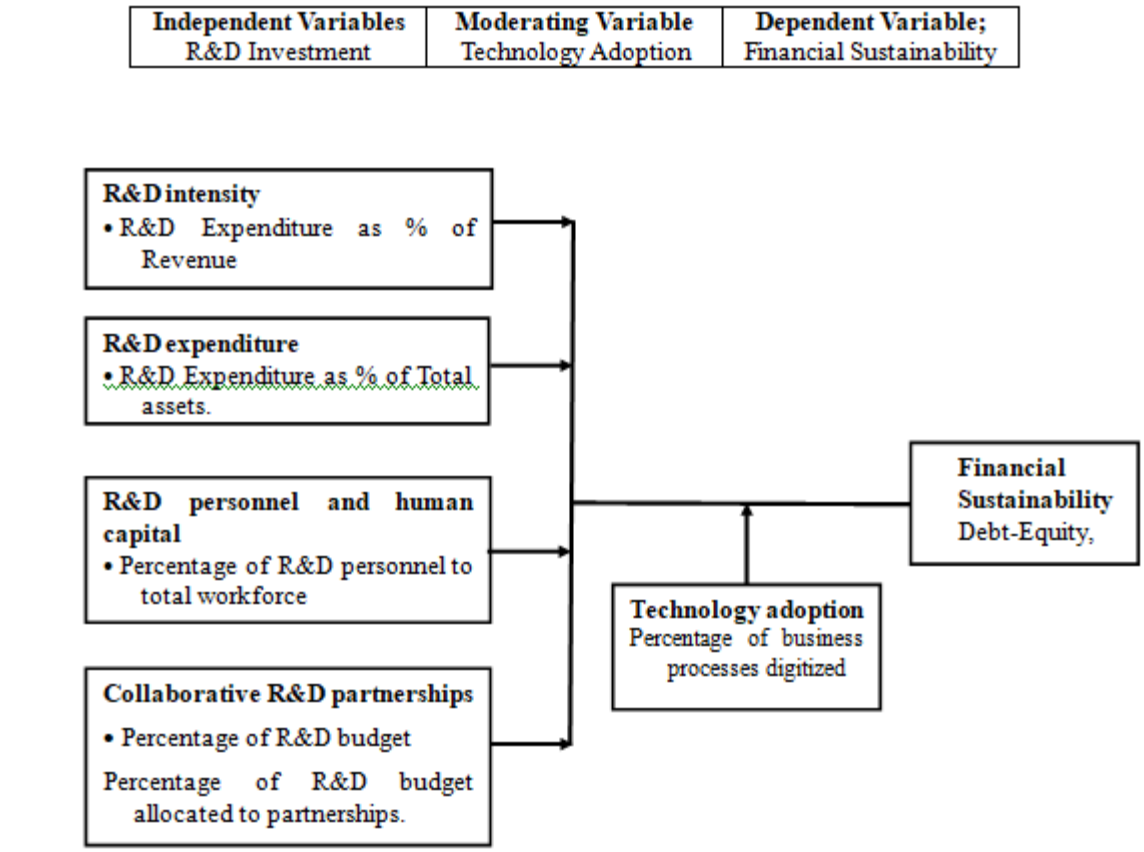

Figure 1.1: Conceptual framework

Source: Researcher (2026)

1.6 Significance of the Study

The study is of significant value in a number of ways. To begin with, it addresses a major gap in the extant literature on the role of Research and Development (R&D) in the financial sustainability of publicly traded manufacturing firms in Kenya. Through the analysis of the impact of R&D intensity, this study will provide empirical evidence of how investments concerning the firm size or revenue determine impact financial sustainability, Second, R&D spending will result in long-term financial stability in developing countries such as Kenya where a company face budget constraints, Thirdly, the study focuses on the role of R&D staff and human resources, Skilled labor force and intellectual resources in promoting sustainable innovation is emphasized. The understanding of this connection will guide the policy formulation in the areas of education, workforce improvement and innovation management. In addition, the paper explores the purpose of joint R & D activities such as collaborations with higher learning institutions, research institutions and other companies in strategic decision-making concerning the partnerships enhancing competitiveness and financial health. Finally, the research will improve understanding of the moderating role of technology adoption by delving into how digital transformation and technological preparedness can contribute to or disrupt the effectiveness of R&D investments.

This study will benefit a wide range of stakeholders such as business executives, investors, policymakers and scholars by enabling them gain practical information to enhance growth R&D investment and financial sustainability in the manufacturing sector in Kenya.

Scope and Delimitations of the Study

Research and development (R&D) investment and the long-term financial sustainabilty of Kenya's publicly listed manufacturing firms are the subjects of this article. Specifically, the study delves into many aspects of R&D investment and how it affects financial sustainability (R&D intensity, expenditure, human capital, and

collaborative networks of R&D activity). Furthermore, the study evaluates how technology adoption mediates the relationship between financial sustainability results and R&D activities. The research is limited to manufacturing firms that are listed in Nairobi Securities Exchange (NSE). The companies used were selected because they had an established reporting structure, financial information was available and due to their contribution towards the industrial and economic development of Kenya. The period of the research and the information to be used will be based on the latest decade between 2016 and 2025 financial years depending on whether the information is available and reliable.

There might be a number of serious limitations to this study. To begin with, it only focuses on publicly traded manufacturing firms thus excluding non-listed or informal sector manufacturing organizations, which have different research and development and financial profiles. Secondly, the study is restricted to companies that are located in Kenya and hence the findings might not be easily applicable to companies in other countries or economic conditions. Thirdly, the study directly aims at financial sustainability as the dependent variable, as opposed to including more general or alternative measures of firm performance including market share, innovation rate, or environmental sustainability. More so, the research not only fails to explore the moderating variable of technology adoption as an independent variable, it also fails to consider the other potential moderators or mediators such as organizational culture, competition in the industry, or a regulatory environment. Lastly, constraint in data can affect accessibility and exhaustivity of data on R&D inputs whenever companies cannot offer in-depth public reporting on their R&D practices. To reduce this problem, the study will use the latest and publicly available audited financial and operational records.

CHAPTER TWO

LITERATURE REVIEW

Introduction

This chapter is presents, in-depth exploration of the theoretical frameworks that link the independent variables to the dependent variable. it reviews the empirical research conducted to explore the correlation between Research and development investment, technology adoption, and financial sustainability. Finally, the results from these empirical studies are analyzed to uncover existing knowledge gaps.

Theoretical Review

This segment provides an analysis of the relevant theories which support the relation of investment in research and development, technological adoption and financial sustainability. These theories will be used to explain the relations studied in this paper. They are discussed holistically in this section with special focus on the Resource-Based View (RBV) theory and Technology-Organization-Environment (TOE) theory, and the Stakeholder Theory.

Resources-Based View (RBV) theory

The research is based on the theory of Resource-Based View (RBV), which suggests a theoretical framework through which the resources available internally within an organization, including R&D, will be used to enhance sustainable competitive advantage and high financial sustainability. The Resource-Based View (RBV) theory is a strategic model, as presented by Barney (1991) that can be used to explain how companies develop a sustainable competitive advantage by successfully obtaining and utilizing valuable, rare, inimitable, and non-substitutable resources and capabilities. The unique internal resources form the foundation of the high level performance and financial sustainability in the long term as described by RBV as applied in the case of publicly listed manufacturing companies in Kenya, RBV can be used especially because of the fast changing manufacturing environment characterized by technological innovation, globalization and escalating competition (Wang and Ahmed, 2007). Innovative capabilities of a firm are dependent on strategic resources such as R&D intensity, expenditure and human capital (Subramaniam and Youndt, 2005). Companies that put more resources in R&D create unique products, enhance the operations along with cost-effectiveness, which are all associated with the positive relationship on the financial sustainability (Grimpe and Sofka, 2009).

The strategic partnerships in research and development enable the firm to share knowledge and complementary in terms of resources, which increase innovation capabilities and market position (Kafouros, Buckley, Sharp, and Wang, 2015). Such alliances help companies tap into external knowledge, minimize risks in innovation and speed up the process of product development, which further strengthens their resource base. As technologies like automation, IoT, and advanced analytics emerge. The adoption of technologies becomes a key organizational capability that is complementary to R&D activities (Tortorella, Giglio, and Miorando, 2021). The adoption of technology helps companies to incorporate innovations efficiently in the manufacturing processes and enhance agility and responsiveness to the needs of the market (Kagermann, Wahlster, and Helbig, 2013). The integration increases the relationship of the R&D investments on financial sustainability.

RBV gives a detailed theoretical framework through which the internal resources in R&D, aided by the adoption of technology, on the financial sustainability of Kenyan manufacturing enterprises.

The Technology–Organization–Environment (TOE) Framework

Technology-Organization-Environment (TOE) framework proposed by Tornatzky and Fleischer (1990) offers a detailed conceptual tool through which technological innovation adoption in firms can be viewed. It assumes that a firm preparedness and ability to adopt and implement new technologies are influenced by three interrelations, namely, technological, organizational, and environmental contexts. Given the presence of sustainability issues and innovation in the centre of competitiveness and regulatory compliance of listed manufacturing firms in Kenya, the TOE framework is very relevant in the context of analyzing the relationships of investment in R&D and uptake of technology in order to improve environmental sustainability.

Technological context is devoted to both internal and external technologies of the firm and its strategic direction. It takes into consideration characteristics of availability, compatibility, relative advantage, and complexity of technology. In the manufacturing industries of emerging economies such as Kenya, companies tend to be hit by issues of accessibility and cost of the technologies such as energy saving machinery or pollution control systems. Nevertheless, the companies that invest heavily in research and development (R&D) are usually in a better position to recognise, obtain or even invent suitable technologies that can enhance their financial sustainability.

The firm context entails internal firm attributes, such as size, structure, human and financial resource, innovation orientation, and managerial commitment. In this regard, R&D investment is a key competency that demonstrates the desire of the firm to innovate and its readiness to meet new technological and sustainability pressures.

In the same vein, a recent study of FDI and firm performance in the manufacturing industry by Ndirangu (2023) in the Kenyan context has identified that organizational readiness, particularly the availability of skilled workers and internal R&D departments, were significant factors that could help a firm embrace new technologies and financial sustainability standards that came with foreign relations.

The environment context means the external pressure and environment which influence the technology decisions of a firm. As an example, Awino et al. (2025) emphasize the idea that although the Kenyan government and development partners are encouraging green transitions in industries such as textiles, the success of these actions is confined to regulatory ambiguity, the inability to enforce them, and the absence of coordinated policy incentives. However, there are external forces by investors, NGOs and global supply chains that are mounting pressure on firms to implement sustainability-enhancing technologies. Simultaneously, as shown by Addai, Yufenyuy, and Kifem (2024), access to green finance and digital infrastructure, or both aspects of the environmental context, contribute significantly to the adoption of the sustainable practices, even in the traditionally low-tech fields, in Sub-Saharan Africa.

Collectively, all these insights depict the usefulness of the TOE framework in this study. The technological situation is used to understand the impact of R&D investment on the awareness and evaluation of sustainability technologies of a firm. The organizational environment shows the manner in which the conditions that make the successful adoption of such technologies are internal capabilities, culture, and resources. The

environmental context explains the institutional and market forces that put pressure or incentive firms to innovate in the direction of sustainability. The holistic approach to the analysis of the interaction of external requirements and internal preparedness of listed manufacturing companies in Kenya through the application of the TOE framework is possible.

Criticism of Theories

The criticisms of the above theories are discussed below.

Criticism of Theories the Resource-Based View (RBV) theory

Contemporary scholarship questions its relevance in a highly dynamic and institutionally complex environment. The fact that it possesses a fixed concept of competitive advantage is one of the primary criticisms of RBV. Traditional RBV insists on the fact that firm specific resources/capability such as R&D investment or human resource competencies may result in sustainable competitive advantage because they are valuable, scarce, imitable and inimitable. However, as time progressed, more and more objections have been leveled that the methodology fails to describe how the firms renew and re-structure capabilities in response to technological turbulence and market changes (Huang and Zhou, 2025;Ghobakhloo, 2020). In Kenyan manufacturing, where external shocks, such as the change in cost of inputs, changes in policy incentives, and industry disruption are commonplace, having valuable resources might not be sufficient to maintain the financial sustainability; firms have to change and reallocate said resources over time, and in this regard, RBV alone cannot be of much help.

The other significant limitation is that RBV might be tautologous and imprecise. Since the value of resources can be frequently justified by the results of performance, scholars caution against circular arguments: resources become valuable when firms display high performance. A recent literature review of RBV notes that empirical applications have difficulty in defining and measuring VRIN criteria in a consistent manner and weaken predictive power (Mailani et al., 2024). This is a feasible challenge to Kenya where macroeconomic conditions can affect financial performance and sustainability indices, which are beyond the control of firms.

RBV is also inclined to the underestimation of the role of institutional and environmental contingencies. Even though the theory puts emphasis on the heterogeneity of internal resources, mounting details on open-access sustainability literature demonstrate that the efficacy of R&D and innovation skills is profoundly conditional by the supporting environmental framework, access to credit, regulatory harmony, and digital infrastructure (Bindeeba et al. 2025). The returns to internal resources are often low in Kenyan manufacturer operations because of policy ambiguity, weak enforcement and infrastructure gaps. The RBV can exaggerate the importance of internal capabilities without directly incorporating these institutional pressures.

Moreover, modern-day innovation is more and more undertaken in inter-organizational networks and ecosystems as opposed to individual firm demarcations. According to open innovation research, the competitive advantage, in most cases, is a result of knowledge sharing, collaborative alliances, and external partnerships, particularly in cases where a firm incorporates digital and sustainability capabilities (Huang & Zhou, 2025). This networked view is implicitly present in RBV, which is traditionally based on firm-owned resources, and it may be less relevant to situations where ecosystem processes are important in determining the results of innovation.

Another criticism is related to the narrow scope of sustainability outcomes, which RBV has. The idea of financial sustainability in manufacturing is not separable on the basis of the environment and social foundations of performance. According to recent literature in sustainable business models, internal resources have to be supplemented by the governing structures, stakeholder involvement, and regulatory alignment to achieve long-term sustainable value creation (John Akwetey Boafo, Efua Odurah Maclean, 2025). On the one hand, RBV, with its firm-centric emphasis, might, therefore, down play the role of external legitimacy and multi-actor governance in determining sustainable competitive advantage.

Lastly, the idea that valuable resources cannot be easily copied becomes poorly argued in the wake of the

increased accessibility of digital technologies and data-driven capabilities to the rest of the world. The ability of firms to leverage and integrate technologies and not own them is becoming an important factor in gaining competitive advantage. This fashion also paves way to the other supportive theories including dynamic capabilities which highlight the flexible utilization of resources so as to attain sustained performance (Bindeeba et al., 2025). Reflectively, as long as RBV still provides a background perspective of examining the role of internal R&D resources in determining financial sustainability, it lacks the explanatory adequacy to the complex sustainability-based innovation activities in Kenyan based manufacturing companies because of its hermetically sealed assumptions, ambiguous tautology, institutional integration drawbacks, and lack of ecosystem focus.

Criticism of the Technology–Organization–Environment (TOE) Framework

Systematic review of TOE literature shows that the framework can provide a global view of the way technological, organizational, and environmental factors can affect adoption, nevertheless, it is commonly unable to offer dynamic explanatory ability, especially to explain longitudinal relationships and post-adoption outcomes (Prakash, 2025). This criticism emphasizes that the categories of TOE are generally a description of factors at a specific time but fails to fully describe how these factors change and recycle into the strategy of the firm over time, a weakness when analysing processes as complex as sustainability-based innovation.

Moreover, recent empirical studies indicate that TOE constructs may differ dramatically in their salience and impact in different contexts creating the question of construct validity and generalization. As an illustration, studies that considered ICT adoption by Malaysian SMEs observed that although relative advantage and top management support always allowed adoption, regulatory support and environmental pressures had contradicting or unstable impacts on adoption in the context of overall institutional and crisis situations, including the COVID-19 pandemic(Chiew & Cheah, 2025). The implication of these results is that the conventional TOE dimensions might not be able to within-the-contextual peculiarities or changes over time in the external pressures that define innovation paths.

Moreover, there is a growing body of literature on the adoption of technology in environmental oriented settings which requires longer frameworks than the original TOE taxonomy. The new Technology-Organization-External-Sustainability (TOES) model, was created specifically due to the perceived incompetence of the conventional TOE set-up when it comes to capturing sustainability-specific drivers and outcomes in Industry implementation initiatives(Satyro et al., 2024). This extension indicates the general intellectual acceptance that sustainability considerations can intersect or alter each of the TOE areas instead of operating as a by-product dimension.

This is also highlighted in other recent research that suggests that the categories used by TOE can be misleading in time to view important moderating and human-centric influences in technology adoption. As an illustration, the adoption of AI in organizations has been found to be associated with the potential incompetence of the traditional TOE framework in explaining workforce competencies, ethical implications, and the cognitive processes of adjusting to advanced technologies, leading to the suggestion of new constructs like human-centered extensions of TOE (Donmez et al., 2025).

Lastly, practical applications of the TOE framework occasionally depict feasible obstacles that are not given much focus in the initial model, including expensive implementation, insufficient technical knowledge, and low awareness to adopting firms; these challenges have been found to be major constraints in the researches of SMEs in new economies (Aina, 2025). These results imply that TOE can be a misleading predictor of actual adoption decisions stemming from resource limits and capacity binding that occur in the real world particularly in the context of the unequal distribution of infrastructure and institutional support. Nonetheless, in conclusion, this recent research literature recommends that although TOE continues to be an effective starting point to the analysis of technology adoption, its heuristic classes need contextualization and theoretical elaboration, in particular, when deployed in the context of sustainability-oriented innovation and institutional contexts that are complex.

EMPIRICAL REVIEW

This part is a thorough review and assessment of the available empirical work, which defines major gaps that are present in it. The emphasis is made on the analysis of empirical studies associated with different types of R&D investments, especially on R&D intensity, R&D expenditure, R&D Personnel and human capital, Collaborations, R&D partnerships, adoption of technological innovations and financial sustainability. The review is based on a research of a great variety of industries, countries, and organization backgrounds, which gives it an extensive perspective of the impact of R&D and adoption of technologies on financial performance. The following discussion then highlights what has been learned in the past on the relationship between investments in innovations and financial sustainability of firms, especially when it comes to publicly traded manufacturing companies.

Relationship of Research and development intensity on the financial sustainability of firms

Shamsuddin et al. (2021) carried out a research study that attempted to investigate how the R&D intensity influences financial performance of the actively listed companies in Malaysia. The study has relied on a sample of 45 active Malaysian listed companies between the year 2017 and 2019. This study applied linear regression in order to evaluate the correlation between the intensity of R&D and the financial performance. The findings revealed that the correlation between the levels of R&D and the financial performance of firms is crucial across the Malaysian firms. The earlier researches failed to cover a representative sample of Malaysian companies because they only included 45 active Malaysian listed companies that are involved in R&D. This research will focus on manufacturing companies that are listed in the NSE as they are equally engaged in research and development undertakings. The research will attempt to explore the relationship of the R&D intensity and the financial sustainability of manufacturing firms in Kenya.

Ozcan and Cakir (2025) maintain that the incidences of natural calamities such as fire, droughts, floods, and tornadoes have significantly risen. The researchers also suggest that the developments have brought a corresponding increase in the propensity of adopting sustainability activities. It is agreeable that firms spend a lot of resources on research and development (R&D) in order to fund such projects. The earlier research that was carried out in Turkey aimed to determine the mediating part of R&D activities in linking corporate sustainability practices to the financial performance. Corporate sustainability and financial data on 23 companies listed on the Borsa Istanbul were analyzed in the form of a panel data with the subject of analysis in the monitoring period between 2014 and 2020. The results showed that corporate sustainability practices negatively affect the financial performance; however, it turns to be positive when R&D initiatives are involved. This research project seeks to examine relationships between R&D operations, combined with the adoption of technology on financial sustainability of manufacturing companies listed at the NSE in Kenya, which is a developing country.

The panel data that will be used in this study will be that of the relatively recent years between the years of 2016 and 2025 when major improvements have been made in the field of artificial intelligence.

Ghazal et al. (2024) also argue that research and development (R&D) is a major source of innovation, which enhances performance, in its turn. Based on an array of R&D intensity measures and stock market returns as a measure of company success, the authors examined the aggregate and industry-level connections between R&D intensity and firm performance in the developing market of India. The sample was constituted of one thousand and ninety-seven businesses out of six most active industries in terms of R&D expenditure. The stock market success of the R&D-oriented companies using the Fama-French method of forming portfolios in the EW and VW returns was evaluated. The intensity of research and development (R&D) was positively related to the stock returns. The sample collected a monthly gain of 1.43 ($t = 4.22$) when the long-short model was realized in companies which had a high R&D intensity. Broadly speaking, the results indicated that the undervalued firms are those with a strong focus on research and development, which gives an opportunity to investors to get returns over and above the average. Such effects differ across sectors and systems of returns (equal and value-weighted). Both the measures of R&D growth and the measures of R&D capital made no recognizable difference to the stock returns. Considering the control variables of the market company size and age, the study has shown that the relationship was strong. The study used two sub-periods, 2000-2007 and

2008-2019 and the findings were in agreement with the entire sample. The above study was conducted in order to fill the existing gap in the empirical literature of the relationship between R&D intensity and stock returns in Indian developing market. This research changes the emphasis of the long-term financial viability as the dependent variable. The six large-scale sectors that were examined in the past survey were chemicals, computer and software services, pharmaceuticals, electrical, textiles and transportation that included 1,097 enterprises. The aim of the research was to find industry specific heterogeneity. This study will consist of several companies that belong to various industries.

Al-Shaikh and Hagen (2023) examined the effects of R&D expenditure on the bottom lines of Jordanian enterprises. The metrics used to evaluate the R&D spending were the number of researchers and the ratio of investment per sales. Financial ratios were applied in order to measure the financial performance. The sample was 45 stock exchange listed industrial enterprises at the Amman Stock Exchange. It took seven years and only 21 businesses were taken into the sample. The outcome of the examination showed that the level of spend on research and development is extremely low as compared to the global standards. The study also did not have any statistically significant correlation between the R&D spending and the overall success of the business. This research has been likened to that under discussion, though; the above research was carried out in the developing economy which is different. Nevertheless, one of the differences was that this research sample length would be ten years as opposed to seven years in the previous study. Moreover, this study will include the financial sustainability as the dependent variable, whereas the financial performance was used in the previous study.

Impact of Research and development expenditure on the financial sustainability of firms

In an American study by Sulimany (2022), the influence of R&D expenditure on the sustainability of the firms that belong to the Standard and Poor 500 index was evaluated. Between 2015 and 2022 it adopted a fixed effects technique based on panel data of 231 companies. The generalised method of moments framework was expanded to increase the evidence base. The results support the signalling hypothesis which assumes that a bottom line of a company or ability to create new value can be increased by expenditures on R&D which also improves reputation of the company and facilitates its acquisition of a competitive advantage. Companies which invest in research and development can be a long-term success, which is the given conclusion. The focus of this study will be based on general manufacturing organisations instead of researching on the companies that constitute the NSE 20 share index. In addition, it would even target firms with a steady listing in the NSE between 2015 and 2024 fiscal years. The current research will show data of a growing financial market, Kenya, which, similarly to the former one, will be analysed with the generalised method of moments.

According to Radenovic et al. (2023), intangible assets are the key performance indicators in the current competitive corporate environment. In calculating the profitability of a firm, one would take into consideration the research and development (R&D) activities, the investment made in the research and development activities and the electronics of the research and development investments. This research was carried out with the aim of studying the connection between profitability of creative firms and three performance indicators connected to research and development (R&D): R&D expenditure, R&D intensity and return on R&D capital. With the statistical tools such as correlation, regression, and cluster analysis, the previous study statistically determined the correlation between the core R&D performance indicators and the ROA of the most innovative and the largest R&D investors in the world. The data of the present study was based on 24 R&D-intensive businesses that operated in the period between 2013 and 2021. The results of the regression analysis carried out on the identified clusters show that all the three indicators of the activity of R&D activity have a significant and positive influence on ROA in enterprises with high activity of R&D activity. Firms that have high index of R&D intensity (RDII) are more apt to be influenced more by the various indicators of R&D activities as indicated in the above research. Nevertheless, earlier research was unable to address a full analysis because it reviewed only 24 out of 50 major spenders on R&D in the world. This research will adopt a regional perspective since it will focus on manufacturing firms that are listed in the Kenyan stock market. The secondary panel data to be used in this research will be audited financial statements of manufacturing enterprises between the years 2016 and 2025.

Wu et al. (2025) state that businesses that are specialised and creative are driven by innovation. The findings of the empirical study showed that the connection between corporate R&D expenditure and performance were studied using panel data on 577 new, refined, and specialised firms between 2018 and 2023. The uniqueness, polishing and creativity of small and medium-sized business enterprises could be highly enhanced through investing in research and development (R&D) to improve their performance in innovation. The addition of endogeneity and conducting a set of stringent tests does not change the results. The existing research has employed regression analysis and panel data of Chinese small firms; the research will also adopt the same research method, but financial sustainability will be the dependent variable. This study will target the listed manufacturing firms in Kenya as opposed to the very small firms in China, which the previous one targeted.

Guo et al. (2018) analysed the data on the research and development spending by Chinese publicly-traded manufacturing companies. The study was done to ascertain, among various forms of organisations, the long-term effects of their spending on R&D. The authors found out that when compared to the organisations that have an approach of cost leadership, organisations who invest in R&D and apply a product differentiation strategy perform better in the long run. The correlation between expenditure on research and development and performance, however, has an inverted U-shape when organisations that follow cost leadership approach are taken into consideration. It is also important to note that such an inverted U-shaped relationship existed only in non-state-owned firms, which is quite interesting. Previously researches have concentrated on the manufacturing firms in China and have applied the ordinary least squares (OLS) regression to test the hypothesis. The future performance was determined by ROA and ROE, and R&D expenditure was determined as a ratio of R&D expenditures to operating income. The current research is a literal replica of the previous one, although there are a few major exceptions; the former used data collected during eight years (2009-2016), whereas the latter will use data collected during five years (2016-2025) thereof.

Influence of research and development personnel on the financial sustainability of firms

Al-Shaikh and Hagen (2023) conducted research on the effect of R&D expenditure on the performance of the Jordan companies in the case of the Amman Securities Exchange of Jordan. The two indicators that were used to measure the R&D spending were the number of researchers employed and the percentage of revenue allocated to the R&D. Financial success was measured using a number of financial ratios. In terms of 7 years, just 21 out of 45 industrial enterprises registered in the Amman Stock Exchange were actually involved in the research. As per the results, the amount of investment in the sphere of R&D is significantly less than that observed globally. The studies also show no significant correlation between the monetary success of the companies and the amount of money that was spent on research and development. Though earlier research was carried out in an Asian environment that was characterized by a competitive environment, this will be carried out in Kenya which has a very different topography and climatic condition. The study provides some conclusions and recommendations on the findings. The article will utilize the panel data of the audited financial statements of 2016 to 2025 to narrow down to the businesses listed in the stock exchange. It will address all the eligible firms. Multiple linear regression will also be the analytical tool to be used in the present study.

The research by Biswas (2022) took place in India to determine how manufacturing organisations could reduce the impacts of external shocks such as the COVID-19 epidemic on their stock market and accounting performance through investment in research and development. After analyzing a sample of publicly traded manufacturing firms, the researchers found out that over the same time period, pre-pandemic, investment in research and development provided greater benefits in terms of negative cumulative abnormal returns to shareholders in companies who had participated in research and development than that of firms who did not participate in research and development. It appears that based on the findings, research and development investments are beneficial in eliminating the value loss of shareholders during period of severe crisis. Also, the researchers found that manufacturing enterprises that had previously made investments in research and development in the pre-pandemic period had higher returns to sales and total income growth in the pandemic quarter than those that did not, based on a difference-in-difference fixed effects model. When the financials are in order of a company, it implies that its research and development activities are making it cope with the storms that might face it. The same manufacturing industry used in the earlier study will be involved in this study, however, the analysis will be in Kenya, rather than in India. The records of the study conducted earlier

were considered prior to the COVID-19 outbreak and following the pandemic. As opposed to surveying the entire Kenyan manufacturing firms, the proposed research would involve the use of secondary data on a panel of years 2016-2025 based on the audited financial statements of manufacturing businesses to be listed on the NSE.

In an attempt to understand the relationship between human capital characteristics and manufacturing firms in Colombia and the relationship between innovation and manufacturing firm, Carvache-Franco et al. (2022) conducted a study. The study was a quantitative, non-experimental, cross-sectional study that was based on the data obtained through a survey carried across the entire country in Colombia with a focus on innovative activity. It adopted bivariate probit regression. The process and product innovation is related to research and development personnel, and the level of education of the employees is related to product innovation. Because the capability of the R&D workers to find new uses of knowledge or to innovate with the existing knowledge is one of the crucial predictors of product and process innovation, the theorising implies that product and process innovation are a major predictor variable that determines the skills, abilities, and experience of the workers. It was also observed that the human capital of these firms is improved through the acculturation of education that consequently results in the innovation of products. Conversely, organizations that have not invested much in training appear to have employees whose talents do not lead to creativity. In the previous studies, personnel and product innovation were considered as equal to the process innovation. Rather than profit, financial sustainability and multiple regression will be used in this study. The previous research adopted a quantitative, non-experimental, cross-sectional design and involved all the Colombian manufacturing firms employing 10 or more workers and a production value of COP 506 million or more.

A study by Carvache-Franco et al. (2022) addressed the variables of human capital and its connection with innovation in the manufacturing enterprises in Colombia. This cross-sectional, non-experimental study was based on results of a national survey on innovation efforts in one of the developing countries. A bivariate profit regression model was used to carry out the investigation. The findings showed that there was a correlation between product innovation and employees who had a higher education level and between the R&D staff and process and product innovation. In theory, the findings indicate that the skills, competencies, and experiences of the people working in the R&D are good predictors of product and process innovation. This is attributed to the fact that the ability of R&D employees to identify the new applications of knowledge or to combine known knowledge to develop innovation is an indication of the worth of their efforts. Education is regarded in these companies as the way of developing human capital and competences required to stimulate product development. Nevertheless, the problem with underfunded training is that these skills cannot be used to initiate innovation. The above study developed a relationship between the people, product, and process innovation. The following study will be done by using multiple regression analysis rather than profit, and based on financial sustainability. The former research was a quantitative, non-experimental and cross-sectional study that included all industrial organisations in Colombia that employed 10 or above individuals and produced a value of COP 506 million or above.

Muriithi and Muathe (2023) come to Kenya on their visits. In the contemporary world, firms have to depend on strategic management. Firms have begun relying on them to increase their performance and achieve a competitive advantage in the market. It is important to have the means of adaptation and remaining competitive particularly with the dynamics that are subject to change in the environment. This paper examined the Kenyan manufacturing companies that deal with confectioneries and the influence of the strategic management factors on their success. The propellants are human resource strategy, product diversification, CRM and organisational learning. Because of the necessity of selecting a sample of 124 workers among the target organisations, a descriptive research design was applied in the research. The data collected were subjected to descriptive statistics and multiple regression analysis. The findings suggest that strategic management aspects have a strong influence on the success of candy manufacturing business. The results showed that strategic human capital, product diversification, organisational learning, and customer relationship management have a positive and significant influence on the success of these companies. The effects of organisational learning and strategic human capital were large, whereas the effect of product diversification and customer relationship management was small. Although the previous research was conducted on Kenya candy production sector, the present study will be based on the listed manufacturing firms, which will consist

of businesses across a broad spectrum of industries. The data will consist of a set of secondary data, i.e., audited financial statements of the companies of the 2016-2025 financial years.

Collaborative research and development Partnerships on the financial sustainability of firms

Hindi and Frenkel (2022) study on high-tech companies in Israel has presented a method of evaluating the

sustainability of partnerships by using multivariate regression models. To demonstrate the efficiency of this strategy, the authors examined the impact of strategies of cooperation of high-technology companies on their product development and financial performance. It collected data on 195 high technology companies on their internal research and development spending, their investments in alliances with external organizations as well as the revenues obtained as a result of the consequent product development which was then analyzed through the multivariate regression analysis. The findings showed that those companies which form external collaboration realize a 3.95 times increase in the revenue as opposed to companies which do not. Although the former was performed in a highly advanced technological setting, the present study will be implemented in Kenya, which is a developing country and will replace the dependent variable with financial sustainability instead of concentrating exclusively on the revenues. An evaluation of resilience will be conducted as well as a multiple linear regression model will be used in this study.

Karbowski (2019) studied how cooperative and non-cooperative policies on R&D can influence product innovation and firm performance in Poland. Based on the literature of industrial economics, and the model of optimization, the research took into account R&D rivalry, R&D merging, and complete industry merging approach among the companies in a market with differentiated products and with concurrent price and quality rivalry. The findings showed that R&D cartelization leads to the decrease in the product innovation of a firm in comparison with the R&D competition. However, the R&D competition strategy is not very preferable by profit-maximizing firms. They rather choose between R&D cartelization and the overall industry cartelization approaches, depending on the elasticity of the demand with regard to the R&D investment made by the firm. The social cost of R&D cartelization is the decrease in the product innovation, the social cost of complete industry cartelization is the decrease in the product innovation, as well as the sacrifice of the consumer surplus through the high prices and reduced production of the final product. The previous research was more focused on an oligopoly market structure but in the current study, the research will be based on manufacturing companies in Kenya, a developing economy. Most of the companies that will be considered in this research will not be linked. The regression analysis will be utilized in the current research to investigate the findings.

The study by Kveton and Horak (2024) aimed at studying four regions of the Czech Republic to identify the relationships between horizontal R&D cooperation strategies and vertical supply chain integration strategies adopted by the firm. The authors used the body of literature in the field of evolutionary economic geography and global production networks, which studied the dynamic and combinatorial essence of supply chain integration, R&D collaboration, and the impact on competitiveness in terms of businesses. In theory, researcher proposed that the competitiveness of enterprises depends on the methods of R&D collaboration of their enterprises, and that these strategies differ between modalities of engagement in vertical supply chains. Integration of vertical integration helps in increasing the levels of regional R&D cooperation among companies, as was demonstrated in the previous experiment. Moreover, it was demonstrated that technically advanced and internationally integrated firms do not always have a high level of interconnection within their research and development partnership within regional or national systems of innovation. Conversely, technically competent businesses which do not have a significant or high level of R&D collaboration will on average profit in the long run, but will be poor in the long run. Besides, the degree of loyalty to R&D partnerships which could be the most resilient to economic shocks was high. Similar study already in the past established a positive relationship between medium levels of R&D cooperation and business productivity, which was significant. The present study will adopt the same trend as the one in the past in that it will exam the resilience of businesses in the long-term. Nonetheless, it would also involve other types of cooperation with external cooperation in the manufacturing sector of publicly traded companies in Kenya. This study will employ the same method as the previous one where panel data were used to perform the regression analysis, but in this case, the data will include 2016- 2025 as opposed to 2011- 2019.

Nyiringango (2024) examined the performance of university-integrated hubs in Kenya, and the influence that research partnerships and high-quality education had on them. The study employed the Kenyatta University - Chandaria Centre of Innovation in the study. This study was determined as a descriptive study and qualitative in nature. The theoretical framework of the study incorporated social network theory, resource-based view (RBV) theory, and institutional theory to explain all the factors that are relevant. By applying this paradigm, the researcher could more clearly find out the influence of the social networks, university resources, and institutional structure on the efficacy of university-integrated hubs. The results proved that scientists, universities and business firms had collaborated. These social networks can be attributed to the success of the ihub besides the resources and the institutional structures of the university. Unlike the previous studies which were of more descriptive nature, the current study will involve the use of regression analysis and secondary data, which will comprise of a panel dataset of 2016 to 2025. Although the two studies will be conducted in Kenya, in this one secondary data will be examined and the manner in which companies collaborate with external parties.

Technology adoption and the financial sustainability of firms

Dave et al. (2013) estimated the ability of R&D expenditure to influence the financial sustainability of the IT industry using the context of information technology (IT), using businesses that are listed in the S&P 500 index. The intermediate factors that were considered to bring out the effects of R&D spending included marketing effectiveness, gross margin, and technical performance. This was proxied by return on assets (ROA) so that they examined the influence of these intermediate factors on it. The data shows that the gross margins have the most impact on financial sustainability that is highly dependent on the intensity of the research and development. Research and development improves sales, but the situation is the reverse when it comes to technical performance. Technological performance spreads a few good impacts on long-term financial viability, however. Where other studies were interested in the relationship between technical prowess and long term sustainability of IT companies listed in the S&P 500, this paper will focus on limited to manufacturing companies listed on in Kenya, which is a developing financial market. The study shall use panel data to analyze the past years 2015-2024 through regression analysis because the above fact is not so recent.

Saharti (2025) takes a unique set of panels information with the period of 2020-24 in his work in order to supply empirical information on the impact of innovation and business growth on performance in the G7 countries. In the study, a multitude of innovation proxies such as R&D intensity, R&D-to-assets, and growth rate of R&D was used to analyse two major aspects of company performance; the labour productivity of the company and the assets turnover of the company. The author applied an instrumental variable estimator founded on heteroskedasticity to reduce endogeneity problems, which could have been caused by a reverse causality and omitted variable bias. the study involved the use of financial sustainability. Between 2015 and 2024 a balanced panel was surveyed of 252 publicly traded companies across the G7 economies (Canada, France, Germany, Italy, Japan, UK, and the US). The task of panelizing the entire population of the publicly listed companies in the Kenyan manufacturing sector will be not identical to the last work, which relied on a sample of ten significant industry sectors based on the Global Industry Classification Standard (GICS) where's this study will use data of audited annual report and financial statement of 9 manufacturing firms listed in NSE between the year 2016 to the year 2025.

The primary reason why the modern corporate environment is so fixated on the subject of social media (SM) is the number of new tools and methods in terms of information and communication technology (ICT). There is no information available, though, regarding how Social Media (SM) can assist the SMEs in increasing their financial viability (Rahman et al., 2020). The model by Rahman et al. (2020) was created based on the Technology Organisational and Environmental (TOE) framework. They considered the number of variables that could influence small and medium-sized enterprises (SMEs) in the developing countries that adopt social media (SM), using Pakistan as an example. The study indicated that several variables such as organisational, technical and environmental ones could influence SM adoption among SMEs. The study was founded on a survey of 383 owners and managers of SMEs in Pakistan by survey with questionnaires. In line with the previous studies, findings of the structural equation modelling revealed that SM perceived advantages, SM compatibility, affordability and trust are significant technical factors that affect adoption of SM by SMEs. Similarly, technological competence and the support of the upper management are two organisational variables

that are significant predictors of SM adoption among SMEs. As information intensity, competitive pressure, and customer pressure were all environmental variables that contributed in the encouragement of the use of SM among the SMEs. There was further examination that SM adoption is positively and statistically significantly valuable to the financial sustainability of SMEs. Unlike in the previous study, which concentrated on small and medium-sized enterprises (SMEs) in the developing economy of Pakistan, audited financial statements will be used in this study to assemble a dataset of annual data, between the years 2016 and 2025.

Shwedeh et al. (2022) attempted to learn why SMEs in the hotel and tourist industry, especially, diminished during the global economic crisis of the COVID-19 in their latest research. The study surveyed small and medium-sized enterprise (SME) owners and managers in the UAE tourist sector through online questionnaires as its quantitative research strategy. Structural equation modelling was used to analyse the data. There were a total of 320 questionnaires that were analyzed using the PLS-SEM analysis tool. During economic crises, the findings showed that the reviewed constructs of financial sustainability, SMEs innovativeness and technology use forecast the application of downsizing techniques. Even during this difficult time, SMEs could not improve their level of innovativeness and uptake of technology because they lacked financial sustainability. Unlike the previous study structural equation modelling, it will be based on the regression analysis of a panel dataset that will be collected among Kenyan listed manufacturing enterprises (not SMEs) between 2016 and 2025. Unlike other research studies which used online questionnaires and focused on the tourist industry, the Kenyan manufacturing enterprises that are surveyed in this research define a wide array of sectors.

Research Gaps

The review of the available empirical research data indicates that the majority of studies considering the impact of research and development (R&D) and technology-related variables on the firm performance have been significantly dedicated to the financial performance, profitability, or innovation output, but not the more general concept of financial sustainability. Past studies in different setting such as Malaysia (Shamsuddin et al., 2021), Turkey (Ozcan and Cakir, 2025), India (Ghazal et al., 2024), Jordan (Al-Shaikh and Hagen, 2023), the United States (Sulimany, 2022) prove that the levels of R&D intensity and expenditure improve the performance and competitiveness of firms. But these were mostly restricted to developed and emerging economies, small or industry-specific samples, and older periods that do not represent the current AI explosion and digital transformation. In addition, previous research has hardly incorporated the multidimensional facets of R&D, i.e., R&D staff, human resources, collaborative alliances and technology uptake, into one analytical framework despite their simultaneous impact on the financial resilience. The limited literature that has taken into consideration human capital (Biswas, 2022; Carvache-Franco et al., 2022) or collaboration (Hindi and Frenkel, 2022; Kveton and Horak, 2024) primarily looked at the outcome of innovation and productivity, but the relationship between it and financial sustainability has not been studied extensively. On the same note, research on technology adoption (Dave et al., 2013; Rahman et al., 2020; Saharti, 2025) has been focused on developed economies or on SMEs sectors and has frequently been based on perceptual or survey information instead of audited financial data. Taken together, these restrictions indicate the absence of empirical data of developing economies, specifically Kenya, where the digitalization of industries and technological investments is changing swiftly. There is thus a research gap at substantive level on the impact of R&D intensity, R&D spending, R&D human resource, collaborative R&D ventures and technology adoption on the financial Sustainability of manufacturing firms. This study will fill this gap by using secondary panel data between the years 2016 and 2025 on manufacturing companies listed in the Nairobi Securities Exchange (NSE) using the powerful econometric models and gives context-based information on how technological and innovation drivers influence the financial sustainability of firms in a developing market environment.

The analysis of the empirical studies creates a necessity to create the empirical evidence of the impact of research and development (R&D) and technology-related aspects on financial sustainability of the firms operating in the developing economies, namely Kenya. Although there is an extensive body of literature relating R&D, innovation, and adoption of technology to firm performance in developed markets, there is still a lack of research based on African manufacturing companies that are subject to unique structural, financial and technological constraints. The manufacturing industry is one of the major pillars of the national economic development agenda in Kenya that has undergone an important digital transformation and R&D investment over the past years. But there is minimal knowledge on how these investments can make it to be long-term

financially sustainable as opposed to short-term profitable. On the foregoing, the researcher will conduct the current study titled as Research and development investment, technology adoption and sustainability: a study of listed manufacturing firms in Kenya.

Chapter Three

RESEARCH AND METHODOLOGY

Introduction

This chapter describes the research methodology adopted in the study. It explains the research paradigm, research design, target population, sample size, sampling procedures, research instruments, reliability and validity of the instruments, data collection procedures, data analysis, and ethical considerations.

Research Paradigm

The philosophy that will be used in this study is positivism which holds the position that knowledge is derived after making objective and measurable observations on various activities. Regarding the idea of positivism, the physical world and social world are independent of human perception (Park et al., 2023). In the study, the researcher will employ quantitative methods of analysis and use of statistics to test the hypotheses of the relationship between investment in Research and Development, technology-adoption, and financial sustainability of publicly listed manufacturing companies in Kenya. This will involve application of regression and correlation analysis to identify the trends in the data collected. Through its focus on the phenomena, which can be observed, the study aims at providing empirical evidence and objective information on the effects of Research and Development investment and technology adoption on financial sustainability of Kenya publicly listed manufacturing companies.

Research Design

The study will utilize correlational research designed, which is suitable in exploring the nature and interconnection between the variables without manipulation of the environment. According to Creswell and Creswell (2018), such design is most appropriate in cases when the researcher wants to explain the direction and the strength of the relationships between variables, and not just present its characteristics. This research approach is applicable in business and financial studies where the variables of the R&D investment, the level of technology adoption within companies and the financial sustainability data to identify patterns, establish cause and effect relationships to assess the hypothetical relationships and infer possible causal relationships.

In this research, the correlational approach will be used by gathering of numerical data that can be statistically tested to revealed tendencies, patterns and relationships, hence allowing the use of numerical data available in the financial statements and sustainability reports. This will enable the objective measure and study of the relationship between independent variables (R&D investment), Moderating variable (technology adoption) and a dependent one (Financial sustainability). Moreover, the quantitative method enhances the extrapolation of the results in the target population of publicly listed manufacturing companies in Kenya.

3.4. Target Population

The target population for this research consists of all manufacturing firms that are publicly listed in Kenya. These entities are registered within the manufacturing sector and are traded on the Nairobi Securities Exchange (NSE). The rationale for selecting the listed manufacturing firms lies in their legal obligation to publish audited financial statements and sustainability reports, which ensures the availability of reliable secondary data for analysis. Furthermore, listed firms typically engage more extensively in formal research and development (R&D) initiatives, technology-oriented production methods, and sustainability reporting than their smaller or unlisted counterparts.

As reported in the Nairobi Securities Exchange (NSE) Market Report (2025), there are currently nine (9) manufacturing and allied firms listed on the exchange. This group constitutes the entire population for the study. The decision to concentrate on this population is driven by the study's aim to investigate the impact of R&D investment and technology adoption on sustainability performance within the manufacturing sector of Kenya, utilizing firms that offer consistent and verifiable disclosures. Each listed manufacturing firm serves as

a unique unit of analysis. Panel data will be gathered from the audited financial statements of these firms for the years 2016 to 2026 on an annual basis, resulting in a total of 90 units of observation. The relatively limited size of the population permits the study to either employ a census approach, incorporating all nine firms in the analysis, or to utilize a purposive sampling strategy should data accessibility issues arise. This approach facilitates thorough coverage of the sector while ensuring analytical rigor.

Description of the Sample Size and Sampling Procedures

The target population for this research will consist of all manufacturing and related firms listed on the Nairobi Securities Exchange (NSE). As of 2025, there are nine (9) firms actively trading in this sector. Due to the relatively limited size of the population, the study will implement a census approach, incorporating all eight firms into the analysis. According to Mugenda and Mugenda (2019), a census is suitable when the population is small and accessible, as it mitigates sampling error and facilitates comprehensive data coverage. The research will exclusively utilize quantitative secondary data sourced from the audited financial statements and sustainability disclosures of the firms for the period spanning 2016 to 2025. These reports are publicly accessible via the Nairobi Securities Exchange website, individual company websites, and the repositories of the Capital Markets Authority (CMA). The employment of audited financial data will bolster the objectivity, accuracy, and reliability of the study's findings. Each firm will serve as a distinct unit of analysis, with data being extracted for pertinent financial indicators related to research and development investment, technology adoption, and financial sustainability. Since all nine firms will be included, there will be no necessity for additional sampling procedures. However, should complete data for any firm be unavailable, the study will implement a census-with-replacement strategy, whereby data from the remaining firms with complete information will be analyzed, ensuring the representativeness of the findings. The census design will allow the study to achieve a thorough overview of trends and relationships among R&D investment, technology adoption, and sustainability performance within Kenya’s listed manufacturing sector during the specified study period.

Description of Research Instruments

The data extraction sheet will be the primary instrument of the research because it will be used to collect the quantitative secondary data in form of financial statements and financial sustainability reports of the publicly listed manufacturing companies in Kenya. This data extraction sheet will be designed in such a manner that ensures that a systematically and uniform information is gathered on the variables of interest of the study in all firms and throughout the study periods (2016/2025). The tool will be characterized by clear variables and measuring indicators that match the exact goals of the research. All of the variables will be measured by using measurable financial or quantitative variables found in the reports of the firms.

Pre testing of the data extraction sheet will be done with the reports of a firm not part of the main sample. This is done to ensure that the variables are clearly defined, measurable and applicable across firms. Any form of ambiguities or inconsistencies identified in the pretest will be corrected prior to the process of actual data collection starting. This is a structured and standardized instrument that will enable the researcher to obtain reliable and similar quantitative data in all the identified manufacturing companies to facilitate effective statistical analysis of the relationships identified in the objectives of the study.

Validity and Reliability of Research Instruments

To ensure the credibility and integrity of results of a study, it is necessary to ensure the validity and reliability of the research instruments. Given that this study will use secondary quantitative data that will be obtained through audited financial statements and sustainability reports, the data extraction sheet will be designed and

tested with high care to ensure that the data collected will be accurate, consistent, and objective in the research process (Saunders, Lewis, and Thornhill, 2019).

Validity of the Research Instrument

Validity refers to the extent to which a tool is capable of measuring what it is supposed to measure (Creswell and Creswell, 2018). In order to ensure the validity, a comprehensive content and construct validation shall be used on the data extraction sheet. First, the variables and indicators, which will be included in the data extraction sheet, will be developed in reference to the existing literature on research and development (R&D), technology adoption, and financial sustainability. Previous empirical studies and international accounting standards will be used to operationalize the variables of R&D intensity, R&D expenditure, and financial sustainability so that conceptual integrity is achieved.

After that, the data extraction sheet will be checked by the academic experts and supervisors to ensure that it covers all the aspects of the study objectives comprehensively. The responses obtained through such professional reviews will be used to improve and match the tool to the study design. Finally, a pilot extraction exercise will be carried out based on the data of a listed manufacturing company that would not be included into the main analysis. The pretest will aid in verifying the level of clarity of the variables and the possibility of the collection of data that is consistent and possible to obtain through the corresponding financial and sustainability reports. The required changes will then be effected prior to the actual data mining.

Reliability of the Research Instrument

Reliability is based on the degree to which an instrument provides similar results whenever repeated measurements are taken in a similar condition (Saunders, Lewis, and Thornhill, 2019). The data extraction sheet will be reliable through a series of measures. The data extraction practice will first be uniformed to the extent that all firms and years (2016/2025) will be using the same definition, formulas, and sources to extract data which will be standard. Data checking protocols will then be introduced, and some of them consist of double-entry, cross-checking of numbers among financial statements, and correcting any differences between the official NSE and CMA filings. Since the research will use audited financial statements then reliability of the information will be also intrinsic to the professional and legal requirements of these reports preparation. In addition to this, the data will be extracted and then internal consistency will be checked using Microsoft Excel or SPSS to identify and correct any error in coding or entry rate before the analysis. The research will ensure that the instrument of the research produces valid, reliable, and reproducible results that are suitable to undergo rigorous quantitative analysis through these strategies.

Description of Data Collection Procedures

The study will follow a systematic procedure to ensure the orderly, ethical, and accurate collection of secondary data from publicly listed manufacturing and allied firms in Kenya.

First, the researcher will obtain an official research authorization letter from the Catholic University of Eastern Africa (CUEA) confirming that the study is being conducted for academic purposes. This will be followed by an application for a research permit from the National Commission for Science, Technology and Innovation (NACOSTI), which is a mandatory requirement for conducting research in Kenya (NACOSTI, 2019). Upon receiving the necessary approvals, the researcher will proceed with the collection of secondary data from publicly available and verifiable sources.

The study will utilize quantitative secondary data obtained from the audited annual financial statements and sustainability reports of the nine (9) manufacturing and allied companies listed and actively trading on the Nairobi Securities Exchange (NSE). The data collection process will be guided by the objectives of the study and the variables specified in the data extraction sheet to ensure consistency and comparability across firms and years of analysis. According to Saunders, Lewis, and Thornhill (2019), clearly defined data collection procedures enhance the credibility, reliability, and replicability of research findings.

Thereafter, the researcher will identify and obtain relevant company reports from authoritative sources, including the Nairobi Securities Exchange (NSE) website, the Capital Markets Authority (CMA) online repository, and the official websites of the respective companies. Where necessary, the researcher will contact the investor relations departments of the selected firms to obtain additional reports or sustainability disclosures that may not be readily accessible through public platforms. This approach is consistent with the recommendations of Creswell and Creswell (2018), who emphasize the importance of obtaining secondary data from legitimate and verifiable sources to enhance data validity.

The study will focus on a ten-year period covering 2016 to 2025 to facilitate the analysis of long-term trends and patterns. Data will be collected annually for each firm on research and development (R&D) intensity, R&D expenditure, R&D personnel, collaborative R&D partnerships, technology adoption, and financial sustainability. Financial sustainability will be measured using the Altman Z-Score model, which is widely recognized as an objective indicator of a firm's ability to maintain financial stability and avoid financial distress over time (Altman, 1968; Mwangi & Muturi, 2020). The model combines key dimensions of financial performance, including profitability, liquidity, leverage, solvency, and operational efficiency, thereby providing a comprehensive assessment of long-term financial sustainability (Sandada & Mangwende, 2022). Recent studies have continued to affirm the predictive accuracy and applicability of the Altman Z-Score model in both developed and emerging markets (Otuya & Kariuki, 2022; Agyapong et al., 2023; Kumar & Dutta, 2024).

The collected data will be recorded and organized using a structured data extraction sheet, which will serve as the primary data collection instrument. The data extraction sheet will ensure that all relevant information required for the study is systematically captured and documented (Mugenda & Mugenda, 2019). To enhance data accuracy and completeness, the researcher will cross-check information obtained from different sources, such as comparing figures reported in NSE filings with those contained in company annual reports and sustainability disclosures. Where discrepancies occur, priority will be given to audited figures reported in official annual reports prepared in accordance with established accounting and reporting standards.

The researcher will further review all extracted data for completeness, consistency, and accuracy to minimize transcription and coding errors. As noted by Saunders et al. (2019), data validation and consistency checks are essential in maintaining the credibility of secondary data. Subsequently, the collected data will be entered into Microsoft Excel for initial coding, organization, and cleaning before being exported to Statistical Package for Social Sciences (SPSS) Version 30 and Stata Version 18 for analysis. Any missing values, inconsistencies, or anomalies identified during the data cleaning process will be documented and addressed systematically to ensure that the final dataset is accurate and suitable for statistical analysis. According to Mugenda and Mugenda (2019), proper data preparation and cleaning are critical prerequisites for obtaining valid and reliable quantitative research findings.

Finally, the cleaned dataset will be subjected to descriptive and inferential statistical analyses in accordance with the study objectives. This structured data collection procedure will ensure the integrity, reliability, validity, and suitability of the data for examining the effect of research and development activities on the financial sustainability of publicly listed manufacturing firms in Kenya.

Table 3.3 Operationalization of Variables

Variable	Indicators	Measurement	Empirical evidence
R&D intensity	Ratio of total R&D expenditure to total sales revenue or total assets, indicating the firm's investment intensity in R&D activities.	Ratio (Continuous)	A study by **Kumar & Dutta (2024)** found that R&D intensity positively affects firm stock returns and long-term profitability in emerging markets (*Journal of Risk and Financial Management, 17*(5), 180)
R&D Personnel /	Proportion of employees engaged	Ratio (Continuous)	**Wang & Chen (2020)** found that R&D personnel competence significantly contributes to innovation

Human Capital	in R&D activities, or R&D staff cost as a percentage of total employee costs.		efficiency and sustainable firm growth (*Journal of Cleaner Production, 252*, 119796).
Collaborative R&D partnerships	Number or presence of formal R&D collaborations or joint projects reported annually.	Nominal / Interval	**Lee & Hwang (2022)** showed that R&D collaborations and inter-firm partnerships strengthen innovation performance and competitiveness (*Technovation, 114*, 102479).
Technology Adoption	The level of technology use is measured by proxies such as capital expenditure on new technologies, automation, or digitalization investments.	Ratio (Continuous)	**Ali et al. (2024)** found that technology adoption moderates the relationship between innovation investment and sustainability in SMEs (*Sustainability, 16*(17), 7351). Similarly, **Olapade & Kayode (2023)** demonstrated its moderating role on SME financial performance during crises (*Journal of Innovation and Entrepreneurship, 12*(1), 317).
Financial Sustainability	Altman Z-Score model	Ratio (Continuous)	Corporate Failure Prediction: A Literature Review of Altman Z-Score and Machine Learning Models Within a Technology Adoption Framework (2025): The review found that while ML models often have superior accuracy, the Z-Score model remains valuable due to its **simplicity, interpretability**, and **lower resource requirements**. It remains useful, especially for firms with limited analytical infrastructure
			The Joint Forces of How to Live: Does Intellectual Capital Matter between Innovation and Financial Vulnerability? (2023)

Description of Data Analysis Procedures

The quantitative data on the publicly listed manufacturing companies in Kenya will be analyzed using both the descriptive and inferential methodology based on the quantitative data available on the audited financial reports and sustainability reports that will be available in the period between 2021 and 2025. The statistical package of social sciences (SPSS) and the Stata software will be used to analyze the data because it will simplify the organization, summary and presentation of the data. In the summarization and characterization of data, descriptive statistics will be used. All variables of the study (R&D intensity, R&D expenditure, R&D personnel, collaborative R&D partnerships, technology adoption, and the Altman Z-Score as a financial sustainability indicator) will be proposed to measures of central tendency (mean, median) and dispersion (standard deviation, variance). Information will also be presented using frequencies and percentages on the level of technology adoption and patterns of the same by the firms. The results will be presented in tables, graphs and charts to enhance clarity and interpretation.

The hypotheses of the study will be tested with the help of inferential statistics and detect the relationships between the variables of research and development investment, technology adoption, and financial sustainability. Data will be analysed through panel data regression because the data will cover more than a single firm (cross-sectional) during a number of years (time-series). A multiple regression model will be used to explore how the variables of R&D investment affect the financial sustainability of the publicly listed manufacturing companies. As a dependent variable (a proxy of financial sustainability), the Altman Z-Score will be used, whereas the independent variables will be R&D intensity, R&D expenditure, R&D personnel, and collaborative R&D partnerships. As a moderating variable, the adoption of technology will be considered to have an effect on the relationship between the R&D investment and financial sustainability.

The test of hypotheses will be done based on 5% (a = 0.05) level of significance. The regression coefficients, including the p-values of the coefficients will be used to decide whether the independent variables have a significant impact on the dependent variable. The p-value value of below 0.05 will make a variable significant. The findings are going to be presented in tables, charts, and graphs and their interpretation is going to be based on both the statistical findings and theoretical basis. The research will provide empirical results on the effect of R&D investment and technology adoption on financial sustainability of publicly listed manufacturing firms in Kenya.

3.9.1 Research Equation

Since the study aims to empirically examine the relationship between investment in research and development, adoption of technology and financial sustainability among publicly listed manufacturing firms in Kenya, the panel multiple regression model will be used in the study. The dependent variable will be financial sustainability, which will be measured by using the Altman Z-Score, whereas the independent variables will be the R&D intensity, R&D expenditure, R&D personnel, collaborative R&D partnerships and adoption of technology. The panel data will cover the period between the years 2016 and 2025 and this will help us to analyse both the cross-sectional and time-series variations. This methodological will enhance the strength of the statistical inferences and will be able to explain the unobserved heterogeneity on firm level.

Model Specification

The functional form of the regression models will be as follows:

Direct Effects Model

The modified least squares model will be used to estimate the direct impact of the R&D investment on financial sustainability of the listed manufacturing companies as suggested by Newey and West (1987). The reason why the Modified Least Squares Model is used is that Newey and West Modified Least Squares provides estimates of Heteroscedasticity and Autocorrelation Consistent (HAC) that is used to address the presence of both heteroscedasticity and autocorrelation at the same time (Donald, 1991).

$$Zit=\beta0 + \beta1RDIit + \beta2RDEit + \beta3RDPit + \beta4CRDit + \beta5Tait + \varepsilon it$$

Where:

Zit = The financial sustainability of firm i in year t, as assessed by the Altman Z-Score.

RDIit = Research and Development Intensity, calculated as R&D expenditure divided by total sales.

RDEit = Research and Development Expenditure, representing the total R&D investment in KES.

RDPit = R&D Personnel and Human Capital, defined as the number or ratio of R&D staff to total employees.

CRDit = Collaborative R&D Partnerships, evaluated through the count or a weighted index of joint R&D ventures.

TAit = Technology Adoption Index, indicating the degree to which firms have embraced new production or digital technologies.

$\beta0$ = The constant term (intercept).

$\beta1 \ldots \beta5$ = Coefficients that quantify the strength and direction of the relationships between the independent variables and financial sustainability.

εit = The error term that accounts for unobserved factors.

Moderating Effects Model

To achieve the objective of interrogating the moderation effects of Technology adoption on the relationship between the R&D investment and financial sustainability, the researcher will adopt the Whisman and McClelland (2005) two-step moderation tests.

Step 1: Relationship between dependent (Firm stability) and independent variables

$$Zit=\beta0 + \beta1RDIit + \beta2RDEit + \beta3RDPit + \beta4CRDit + \beta5Tait + \varepsilon it$$

Step 2: The moderating effect of Technology adoption on the relationship between Research and Development, and financial sustainability.

$$Zit=\beta0 + \beta1RDIit + \beta2RDEit + \beta3RDPit + \beta4CRDit + \beta5Tait +(R\&D *Tait) + \varepsilon it$$

Zit = The financial sustainability of firm i in year t, as assessed by the Altman Z-Score.

RDIit = Research and Development Intensity, calculated as R&D expenditure divided by total sales.

RDEit = Research and Development Expenditure, representing the total R&D investment in KES.

RDPit = R&D Personnel and Human Capital, defined as the number or ratio of R&D staff to total employees.

CRDit = Collaborative R&D Partnerships, evaluated through the count or a weighted index of joint R&D ventures.

TAit = Technology Adoption Index, indicating the degree to which firms have embraced new production or digital technologies.

$\beta0$ = The constant term (intercept).

$\beta1 \ldots \beta5$ = Coefficients that quantify the strength and direction of the relationships between the independent variables and financial sustainability.

εit = The error term that accounts for unobserved factors.

Choice of Model: Testing for the Validity of the Fixed Effects Model

Panel data analysis can be approached using three distinct methods:

Pooled Panels: The method presupposes no individual qualities of the people in the measurement sample and no similar impacts of time. Pooled Panels (also known as Pooled OLS (Ordinary Least Squares)) is a method of panel data analysis, which summarizes all observations studied over time periods as though they were in a single cross-section. The poolability F-test will be done in the study to test the joint significance of firm-specific effects. The null hypothesis will be that all the intercepts of firms are equal and this implies that pooled OLS will be used. The alternative hypothesis will be that at least one of the firm intercepts are different, which will show that there is a firm specific heterogeneity and there may be the necessity of a fixed effects model. When F-statistic is significant ($p < 0.05$), the result will be that there are firm-specific effects and the pooled OLS model will be discarded to a fixed effects model. On the contrary, when the F-statistic does not show any significant difference ($p > 0.05$), it will imply that the pooled OLS is suitable to the analysis. This technique works under the conditions that all things or persons in the panel are similar and represent the same population hence not having individual or time-specific features. Such a method makes the assumption that there is uniformity in all the observations in the dataset and no differentiated attributes or impacts that are subject to change over time across entities. It summarizes all the data points to form one sample to be analyzed with all observations accounted to without considering the possibility of some variations in each entity or at some particular time. The Pooled Panels fail to distinguish the individual and time specific effects and

therefore is applicable in a case where such variance is not significant or other wise it is not of much concern. This is an especially effective approach where the form of panel data is not of great importance to the estimated regression coefficients so that average effects can be estimated with ease on the whole population. Scholars tend to use Pooled Panels when the overall aim is to approximate general tendencies or overall influence in a large group of people without observing the subtleties of the individual or temporal variations. It is an easier method of analysis of panel data, and it looks at general relationships, not individual or time effects that might exist within the data set. It is, however, important to mention that the applicability of Pooled Panels depends on whether the assumption that the effect of individual-specific, as well as time-specific effects, is not significant enough to influence the outcomes under investigation. Should the poolability F-test reject pooled OLS, the study will utilize a fixed effects model, the use of which will enable individual firms to possess their own intercept in order to control time-invariant factors, which might affect their financial sustainability, including the managerial practices or organizational culture that are not observed.

To make the choice between the fixed and the random effects model, the study will conduct the Hausman test that will test the null hypothesis that the estimates of the random effects are consistent and efficient. In case Hausman test is significant, the study will come to the conclusion that effects of the firms are correlated with the regressors and will choose the fixed effects model, otherwise, the study will find the random effects specification to be suitable.

Fixed Effects Models

This approach is based on the assumption that people possess distinct, time independent features which cannot be attributed to random drawing. It takes into consideration group or time variation in intercepts. The models hold that some individual characteristics like location-specific factors or in-built skills tend to affect the dependent variable in some ways that do not change with the period of observation. It takes fixed effects of individual entities or groups into the panel. Fixed Effects Models are highly helpful in accommodating the variations in the intercepts between entities, and that is, it is supposed that the slopes (coefficients of independent variables) are constant. The main assumptions of Fixed Effects Models are that there are personal attributes that are fixed, and have not changed over time due to fluctuation. This is especially effective when one wants to examine differences across entities (as is done in learning about the effects of policy changes in particular entities or when learning about individual-specific factors that influence outcomes). In addition, Fixed Effects Models are also skillful at resolving endogeneity problems as well as omitted variable bias in relation to time-invariant factors. These models also increase the strength of the cause-effect conclusions made in response to the analysis of panel data by eliminating any time-invariant individual-specific effects. The Fixed Effects Models are usually used by the researcher as they study the within-group changes over time or when individual-specific effects are essential to the outcomes that the research is examining. In this way, a more refined perspective of how individual characteristics determine the observed results may be obtained and the possible biases of the unobserved heterogeneity in the analysis of panel data are effectively eliminated. Fixed Effects Models are therefore a potent instrument of investigating dynamics in panel data which include rigid individual-specific effects over time.

Random Effects Models

This methodology presupposes that individuals possess non-time-dependent characteristics that are randomly varied which are not correlated with the regressors of the individual. The model is appropriate to make inferences concerning the whole population as opposed to the sample being investigated. The main premise of the Random Effects Models is to assume that individual-specific attributes are random variables that do not have systematic relationships with the explanatory variables used in the model. These models do not ignore the fact that there is individual-specific heterogeneity which is not the main subject of the analysis but also there is still an impact on the observed results. They can be used to estimate the average effects in the sample taking into consideration such random individual-specific effects. Random Effects Models come in especially when the main problem of interest is to estimate the average effect in the whole sample with the additional consideration of an individual-specific level of heterogeneity not explicitly modeled or of central interest. They are also used in cases where individual-specific effects are taken to be random and they are not consistent to patterns that can be ascribed to observed variables. Random Effects Models are usually applied in longitudinal

studies, economic analysis and social science studies to examine time-varying variations and consider the individual-specific effects, which are not observed. The models can be used to give information about general patterns and relationships within panel data that Fixed Effects Models may not identify since they capture random individual-specific heterogeneity. Therefore, Random Effects Models is a versatile and potent instrument of analyzing panel data dynamics in a wide range of research areas.

The type of the model to be selected is determined by the purpose of the analysis and the problems associated with the exogeneity of the explanatory variables. In this analysis, both fixed and random effects model will be taken into account because the pooled regression model assumes that all financial institutions are similar, which is not the case. The pooled regression model will be used to assume that the coefficients including inter-

cepts are the same across all the financial institutions. Conversely, the fixed and random effects models does capture the notion of heterogeneity or individuality of the manufacturing firms by making each firm have its time-invariance intercept value. The study will use the Hausman test to calculate whether the appropriate model to use is the fixed or the random effects.

Model Estimation Technique

The panel regression analysis will be used in the research and integrates an aspect of time series and cross-sectional data. According to the Hausman specification test, the choice to adopt fixed effects or random effects models will be achieved. The diagnostic tests that will be performed before model estimation are as follows to verify the reliability of the regression results:

Assumptions of the Regression Model

Prior to the execution of the regression analysis, a set of diagnostic tests shall be conducted to ensure that the data meet the requirements set by the multiple regression hence coming up with the result attained are credible and devoid of bias. Such tests will include tests of normality, multicollinearity, autocorrelation and heteroscedasticity. The analyses will be performed with use of SPSS and Stata statistical programs.

Normality

Normality test will be conducted to test the normality of the residual values of the regression model. Linear regression has a fundamental assumption of the normality of the residuals since it ensures reliability of hypothesis testing and confidence intervals (Gujarati and Porter, 2020). The KolmogorovSmirnov test and the ShapiroWilk test will be used in order to statistically verify normality. Moreover, the visual analysis of the graphical methods including histograms, QQ plots, and PPF plots of the residuals will be conducted. In case the results show that there is a lack of normality, data transformations (logarithmic/square root transformations) will be applied to the variables that will be in the problem in order to achieve the normal distribution.

Multicollinearity

Multicollinearity is a situation that occurs when one or more independent variables have a great degree of correlation which may cause the regression coefficient to be distorted and reduce the reliability of the model. In order to determine multicollinearity, Variance Inflation Factor (VIF) and Tolerance Values will be computed on each independent variable (Hair et al., 2019). There has been a general rule that indicates that a VIF above 10 or a tolerance of below 0.1 would indicate multicollinearity. In case multicollinearity is found, the variables under consideration will be discussed, and the possible remedies, including turning variables around, dropping redundant predictors, or combining similar pointers will be considered.

Autocorrelation Test

In order to determine the occurrence of correlation amongst the observations in the dataset, the test will be conducted to determine the autocorrelation of the residuals. Autocorrelation compromises the independence assumption of regression models, and thus, inefficient estimates are obtained (Wooldridge, 2020). Durbin

Watson (DW) statistic will be used to establish the existence of autocorrelation in the residuals. In DW the possible values fall in 0-4 range. When the value is close to 2, it is autocorrelated and when the value is consonant by a large amount, positive autocorrelation, and when the value is consonant towards a large amount, negative autocorrelation. Adjustments to the case of autocorrelation will include the application of generalised least squares (GLS) estimator or the application of strong standard error.

Heteroscedasticity Test

Heteroscedasticity denotes the presence of unequal variance in residuals across different observations, which can compromise the efficiency of regression estimates and the integrity of statistical inferences. In order to assess heteroscedasticity, this study will utilize both the Breusch–Pagan (BP) test and the White test (Gujarati & Porter, 2020). Should the results of these tests reveal heteroscedasticity (p-value < 0.05), corrective actions such as the application of heteroscedasticity-consistent standard errors (robust SE) or the transformation of variables will be implemented to achieve variance stabilization.

Ethical Considerations

In this research, the researcher will strictly adhere to the best ethical practices in order to uphold integrity, transparency and professionalism in the entire process of conducting the research. Since the proposed research will take the form of a quantitative study and will be based on secondary data, which will be sourced through audited financial reports, annual reports, and sustainability reports of publicly listed manufacturing firms in Kenya, the ethical aspects to be considered are mainly responsible data usage, institutional endorsement, and academic honesty. The researcher will obtain a written consent of the Catholic University of Eastern Africa (CUEA), National Commission of Science, Technology, and Innovation (NACOSTI), and other relevant authorities, such as the Nairobi Securities Exchange (NSE) when the need arises, before the commencement of data collection. The endorsements will confirm that the research complies with institutional and national ethical standards of research.

The study will adhere to the key ethical principles of integrity, objectivity, transparency, and confidentiality (Pietila, Nurmi, Halkoaho, and Kyngas, 2020). Integrity: The investigator will ensure that there is accuracy, truth, and responsibility in managing, analyzing, and reporting data. The information will be used strictly on academic grounds and will be properly reported without any manipulation and falsification. Objectivity: The analysis will be conducted without any bias, and statistical methods will be used in the analysis to ensure that no bias is applied. The findings will only be analyzed through empirical data of the findings on the data. Transparency:

Any secondary data will be clearly recognized and references to all published materials and reports that will be used in the study will be cited. Confidentiality: Although the data will be collected using publicly available financial reports, firm specific identifiers will be handled with sensitivity. To make sure that the results can not be stolen or misunderstood on the example of specific companies, the analysis will be focused on aggregated or coded data.

All the financial and sustainability information will be obtained with references to credible and publicly accessible sources including annual reports of the company, audited financial statements, and NSE databases. The information will be safely in password-protected computers and cloud systems and only the researcher will have access to it. The backups will be performed on a regular basis to prevent the unauthorized access or data loss. The study will not use any personal or sensitive data on individuals; therefore, the study poses no direct threat to human subjects. The ethical consideration will then be on the protection of confidentiality of corporate data, responsible usage, and protection of proprietary information in case of need.

Academic Plagiarism and Academic Dishonesty. To uphold academic integrity, all the secondary materials will be properly cited and referenced in addition to the APA guidelines of the 7 th Edition. To avoid plagiarism, the researcher will make sure that all the borrowed ideas, data and concepts are credited accordingly. Paper-detecting plagiarism tools will be used to ensure that the research work is original before submitting it. Compliance and Ethical Assurance, The researcher will completely adhere to the research code

of ethics developed by the Catholic University of Eastern Africa and NACOSTI. The research will be used purely in scholarly purposes and will not be disclosed to any other third parties. Empirical findings will be objectively used to draw all conclusions and make sure that the study will advance knowledge, and it will not be against ethical guidelines. With these principles, the study will ensure that ethical behavior is maintained in all the processes involved including data collection and analysis, as well as reporting and sharing of findings.

Declaration

This proposal is my original work and has never been submitted to any University or any other Institution of higher learning for the award of any degree.

Signature……...…Date: ……

MARABA K. HENRY

Registration NO: 1035803

This research proposal has been submitted with our approval as the University Supervisors.

Dr. Dickson Sing'oei, PhD

The Catholic University of Eastern Africa

Signature:……Date: ……

Dr. Alex Kamau, PhD.

The Catholic University of Eastern Africa

Signature:……Date: ……

Dedication

I dedicate this work to my family, who have been a great support throughout the process of writing this Research paper. Catholic University of Eastern Africa (Gaba Campus) and all people of goodwill for their support throughout the study period.

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APPENDIX I: DATA EXTRACTION SHEET

Firm Name……...

Year	2016	1017	2018	2019	2020	2021	2022	2023	2024	2025
FS										
R&D Intensity										
R&D Expenditure										
R&D Personnel										
R&D Collaboration										
TEC Adoption										
X_1										
X_1										
X_1										
X_1										
X_1										
Z-Score										

APPENDIX II: LIST OF MANUFACTURING AND ALLIED FIRMS LISTED AT NSE

SECURITY	TRANDING SYMBOL
1. A.Baumann & Co Ltd	BAUM
2. B.O.C Kenya Ltd	BOC
3. British American Tobacco Kenya Ltd	BAT
4. Carbacid Investments Ltd	CARB
5. East African Breweries Ltd	EABL
6. Eveready East Africa Ltd	EVRD
7. Kenya Orchards Ltd	ORCH
8. Mumias Sugar Co. Ltd	MSC
9. Unga Group Ltd	UNGA

APPENDIX III: TIME PLAN

	2025/2026				
	May/June	July	July/Jan	May	June/July
Topic selection					
Concept paper writing/Defence					
Proposal writing and Defence					
Defense					
Piloting					

Data collection					
Analysis					
Preparation of 1st Draft					
2nd Correction					
Final submission					

APPENDIX IV: RESEARCH BUDGET

ACTIVITIES	ITEMS/PARTICIPANTS	COST (KSHS)
Proposal development	Library search and Travelling expenditure by the researcher, typing, photocopying, and binding of the proposals.	80,000
Designing and developing Research instruments	Typing and Photocopying of research instruments	40,000
Research permit	Transport and accommodation of the researcher	10,000
Research induction and training	Transport of the researcher and research assistants	30,000
Pilot Survey	Transport for researchers and research assistants	25,000
Main field data collection	Travel and subsistence for 30 days Researcher-15000 Research assistants-9000	30,000
Data processing, analysis, and thesis writing	Researcher's subsistence, transport, typing, Photocopying and binding	40,000
Purchases	Flash disk	8,000
	Stationery	3,000
Miscellaneous		8000
Total		**274,000**