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Determinants of Manufacturing Firms' Research and Development Investments in Kenya

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KIPPRA in Brief

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Abstract

Research and Development (R&D) investment underpins firm innovation and productivity, providing opportunities for low- and middle-income countries to converge to high income countries. Recognizing these developmental roles, national, regional and global policies call for measures to promote R&D investment by private sector firms as part of the broader development agenda. The private sector is the key channel for growth of R&D investment, with the government expected to provide incentives and institutional support. Although manufacturing is a focal policy agenda for Kenya, its declining productivity and contribution to Gross Domestic Product (GDP) is a key policy concern. With only 24 per cent of the Kenyan manufacturing firms reporting to undertake R&D investment (World Bank Enterprise Survey, 2018), and the aggregate R&D investment for the country estimated at 0.8 per cent of GDP, falling below the one per cent target set by the African Union Agenda 2063 and 2 per cent target set by the Kenyan government, research on the subject is imperative. The purpose of this study is to provide insights on institutional context and analyze the effects of firm-specific and business environment factors on R&D investment decisions and intensity by Kenyan manufacturing firms. Review of experiences from other countries was used to shed light on institutional gaps for promoting R&D investment in Kenya. Using the World Bank Enterprise Surveys for 2013 and 2018, this study investigates the effects of a range of firm-level, sector-level and business environment factors, including access to credit, informal sector competition, sub-sectoral technological classification and firm size on manufacturing firms R&D investment decisions and intensity. Panel Probit (for R&D investment decision) and two-part model (for R&D intensity) regression models are employed to analyze the effects of the variables of interest on manufacturing firms R&D investment decision and intensity, respectively. The findings reveal the importance of a gradual shift to the role of private sector through institutional support, coordination and incentives for R&D investment. Support for the private sector is essential particularly for start-ups and smaller enterprises, owing to resource constraints to undertake R&D investments. The regression results reveal that access to credit, low threats from informal sector competition, exports market participation, larger firm size, and firms in high technology sub-sectors increase the probabilities of undertaking R&D investment decisions. The firms in the textile and apparel, and leather sub-sectors, which are priorities under the "Big Four" agenda, show lower probabilities of undertaking R&D investment. Informal sector competition and larger firm size lower R&D investment intensity, which together on other firm characteristics signal the importance of policy support for Micro and Small Enterprises (MSEs). The results generally suggest the importance of institutional framework, firm and sector-specific variables and business environment in promoting R&D investments. The study recommends policies on institutional framework and easing of business environment constraints related to access to finance, export promotion, and lessening constraints imposed by competition from informal sector firms.

Abbreviations and Acronyms

AU	African Union
BERD	Business Expenditure on Research and Development
CIP	Competitiveness Industrial Performance
EAC	East African Community
GERD	Gross Expenditure on Research and Development
GLM	Generalized Linear Model
GoK	Government of Kenya
IDB	Industrial Development Bank
KeNIA	Kenya National Innovation Agency
KIRDI	Kenya Industrial Research and Development Institute
KNBS	Kenya National Bureau of Statistics
Ksh.	Kenya Shilling
LRM	Linear Regression Model
MSEs	Micro and Small Enterprises
MSMEs	Micro, Small and Medium Enterprises
MTP	Medium-Term Plan
NACOSTI	National Commission for Science, Technology and Innovation
NRF	National Research Fund
OECD	Organization for Economic Co-operation and Development
R&D	Research & Development
SDGs	Sustainable Development Goals
SMEs	Small and Medium Enterprises
STI	Science, Technology and Innovation
UNECA	United Nations Economic Commission for Africa
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organization
WIPO	World Intellectual Property Organization

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1. Introduction

1.1 Background of the Study

Research and Development (R&D) investment in the manufacturing sector has positive benefits at the firm level and the overall economy. At the firm level, it enhances innovation and ability to exploit external knowledge through learning and assimilation, thus contributing to improved productivity (Cohen and Levinthal, 1989; O'Mahony and Vecchi, 2009; Lee, 2013). At the overall economy level, it accelerates growth of low and middle income countries and therefore convergence with high income economies (Lee, 2013). An increase in R&D to GDP ratio by 1 per cent is estimated to contribute to GDP growth of up to 2.2 per cent (Sokolov-Mladenović, Cvetanović and Mladenović, 2016). Policy efforts to promote private sector R&D investment has increased in recent years owing to this importance in terms of linkages to innovation, productivity and the catch-up process for low and middle income economies. Global, regional and national policies including the Sustainable Development Goals (SDGs) (United Nations, 2015), the East African Community (EAC) Industrialization Policy 2012-2032 and the Kenya Vision 2030 (Government of Kenya, 2007) all call for measures to improve R&D investments to support innovation in the manufacturing sector.

The overall levels of R&D investments including those from the private sector, public sector and institutions of higher learning, however, are low in Africa. Globally, R&D intensity as measured by the ratio of overall R&D investments to the national Gross Domestic Product (GDP) average 2.2 per cent compared to Africa at 0.5 per cent (UNECA, 2018). The ratio is estimated at 0.8 per cent for Kenya[1] (UNESCO, 2016; Sachs et al., 2019), of which over 40 per cent is financed from abroad (UNESCO, 2016). Newly industrialized countries demonstrate relatively higher levels of R&D to GDP ratio compared to Kenya - Republic of Korea 4.2 per cent, Singapore 2.2 per cent and Malaysia 1.3 per cent (UNESCO, 2016). The R&D investments in these countries are largely accounted for by the private sector and are financed domestically.

Different manufacturing sub-sectors have varying degrees of demand for R&D investments (Galindo-Rueda and Verger, 2016). The classifications of manufacturing on the basis of technological intensity is anchored on this feature. Detailed technological intensity classification of manufacturing sub-sectors is elaborated in Appendix 1. The ranking of countries on the basis of manufacturing technological intensity – that is R&D content in the sector's Gross Domestic Product (GDP), is used by the Organization for Economic Cooperation and Development (OECD) and the United Nations Industrial Development Organization (UNIDO) as a measure of deepening industrialization. The Industrial Development Report 2020 shows that the share of medium and high technology manufacturing in overall manufacturing GDP for Kenya is only 15 per cent, unfavourably comparing with aspirator economies including Republic of Korea (63%), Malaysia (44%), India (43%), China (41%), Thailand (41%), South Africa (24%), Nigeria (33%) and Egypt at 18% (UNIDO, 2019).

1 These statistics refer to Gross Expenditure on R&D (GERD), which is elaborated in later sub-section of this paper.

While the manufacturing sector is central to Kenya's development agenda as articulated in the Kenya Vision 2030, it is characterized by low growth rates and declining productivity. The sector is also a priority under the "Big Four" agenda of the Third Medium-Term Plan (MTP) of the Kenya Vision 2030. The performance of the sector is, however, below expectations as evidenced by low annual growth rates averaging 3 per cent compared to the 10 per cent envisaged in the Kenya Vision 2030. Because of the low growth rates, the sector's contribution to GDP declined from 9.4 per cent in 2015 to 7.5 per cent in 2019, contrasting the government's medium-term target of 15 per cent set to be achieved by 2022 (KNBS, 2020). Besides low growth rates, productivity of the sector is also declining (de Vries, Timmer and de Vries, 2015). These undesirable features of the sector call for measures to accelerate R&D investments.

The R&D investment include creative and systematic activities for increasing the stock of knowledge and creating new application of existing knowledge (OECD, 2015). An activity is considered R&D if it is novel, systematic, creative, uncertain and leads to outcomes that are transferable or reproducible as elaborated in Appendix 2. R&D broadly covers three activities: basic research, applied research and experimental development (OECD, 2015). *Basic research*[2] is theoretical in nature and is intended to develop new knowledge *without specific application or use in view*. Examples include testing of hypothesis or theories and the results are generally shared on scientific platforms such as journals. Basic research is commonly undertaken in institutions of higher learning and government research institutions, although it can sometimes be undertaken by private sector businesses, but having no specific use in view (OECD, 2015). In contrast, *applied research* is undertaken to generate new knowledge intended for some specific practical usage that can be protected by intellectual property rights. *Experimental development* is an amalgam of practical experiences and knowledge generated from research to create additional knowledge for improving present products or processes, or for generating completely new products or processes. It involves testing of generic knowledge in developing new products or processes, or improving existing products or processes before commercialization (Hall, 2008; OECD, 2015).

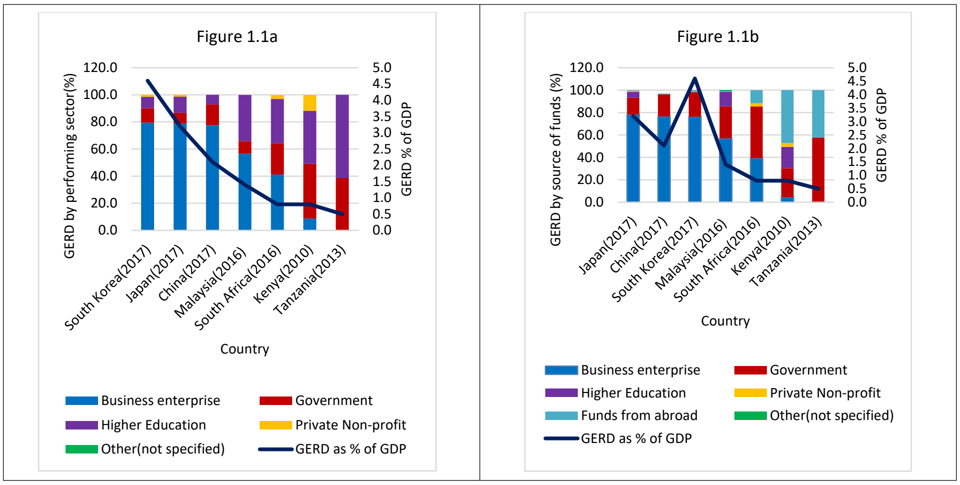
Four institutional sectors are usually involved in R&D investment. These include government, higher education, business enterprises, and private non-profit (OECD, 2015). The combined activities of the four institutional sectors constitute Gross Expenditure on R&D (GERD). The focus of this paper is on the Business Enterprises Expenditure on R&D (BERD) within the manufacturing sector. In this study, R&D encompasses expenditures undertaken by manufacturing firms to generate knowledge for creating *new* or *improved* products or processes (Hall, 2008).

The GERD for Kenya, estimated at about 0.8 per cent of GDP (Cornel University, INSEAD, WIPO, 2019) lags the target of one per cent in the African Union (AU) Agenda 2063. Figure 1.1 shows comparative GERD composition in terms of performing sector (i.e. sector undertaking it) and source of financing for selected countries. Three insights can be drawn from Figure 1.1. First, overall

2 This is different from "pure basic research" which is intended solely for advancement of knowledge without expectations of applications for social or economic benefits in the industry.

GERD intensity is generally high for high income countries (Figure 1.1a). Second, GERD for high income countries is mainly accounted for by BERD and financed by businesses, unlike developing economies such as Kenya and Tanzania that are accounted for largely by government and higher education sectors (Figure 1.1b). Third, BERD in high income countries is largely financed domestically in contrast with low income countries that are financed from abroad. This means that domestically owned enterprises are likely to lag in terms of innovation and productivity improvements that can result from R&D investments. As will be illustrated in section 2 of this paper, countries such as Malaysia and South Korea have historically developed policies to incentivise private sector involvement in R&D investments.

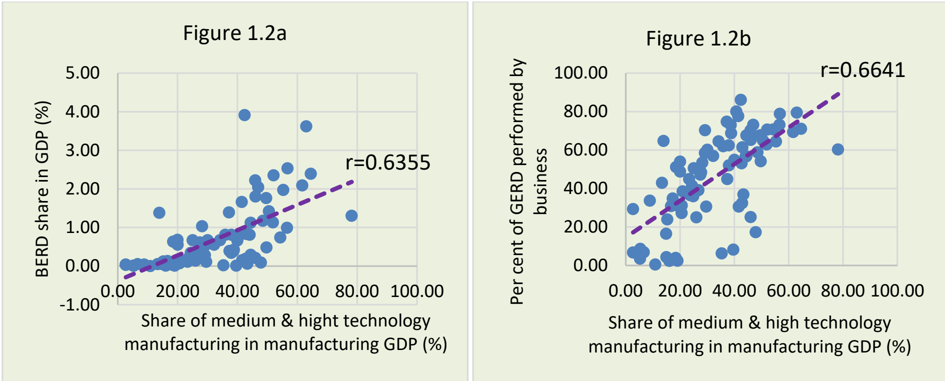
Figure 1.1: GERD by performing sector (Figure 1.1a) and by source of Funds (Figure 1.1b)



Data Source: UNESCO Institute for Statistics (2019); Years indicated are the latest available.

Cross country evidence shows positive association between the share of medium and high technology manufacturing sub-sectors in manufacturing GDP and levels of GERD in GDP (Figure 1.2). This therefore suggests difficulties for developing countries dominated by low technology manufacturing sectors (Appenidx 1) to achieve higher shares of GERD in GDP that can serve as an avenue for economic catch-up (Lee, 2013).

Figure 1.2: BERD share in GDP vs manufacturing technology intensity



Data Source: UNESCO Institute for Statistics (2019; UNIDO (2019)

Conceptually, R&D is an input to the innovation process (Hall, 2008; Jung and Kwak, 2018). Innovation refers to introduction of new or improved products, improvements in production processes, organizational structure and marketing strategies (Dabla-Norris, Kersting and Verdier, 2012). The focus of this study is on R&D investment decision and R&D intensity among the Kenyan manufacturing firms. While the concepts of R&D investment decision and R&D intensity are related, they are distinct. The R&D decision is a binary outcome on whether a firm undertakes an investment or not, while R&D intensity relates to the magnitude of expenditures on such investments (Becker, 2015). Separate analyses of R&D investment decision and R&D investment intensity are important since the two aspects can be affected by different mechanisms and the resultant impacts on innovation and firm performance may also vary. It is possible there exists firm-level or business environment related constraints to undertake R&D investment decision. Once a firm overcomes such constraints (i.e. entry decision constraint), the magnitude of the investment may still vary depending on firm internal capabilities and business environment factors. Firm capabilities refers to the internal resources such as skills base, experience and learning, which tend to be a source of competitive advantages (Teece, Pisano and Shuen, 1997).

Low R&D investments among private sector firms in developing countries remains a significant policy concern. There are increasing policy interests that the weak investment may be explained not only by internal capabilities of firms and industry-level constraints and opportunities, but also by business environment factors. Business environment embodies policy, regulatory and physical infrastructure that supports or impedes operations of the firms (World Bank, 2004; Newman et al., 2016). Much is, however, yet to be explored in terms of which business environment related variables affect R&D investment decision and intensity by manufacturing firms. Unlike prior studies on manufacturing firms R&D investment (Cirera, 2014), this study provides some added value. First, it uses panel survey data for R&D investment decisions, which was lacking in prior studies in Kenya. Panel data analysis has some added advantages such as ability to control for unobserved individual-level and time-related characteristics (Hsiao, 2014). Second, it considers new variables, notably competition from informal sector firms, R&D-intensity technological classification, firm size, participation in export markets and an objective measure of access to loan or a line of credit.[3] The objective measure of access to credit refers to whether a firm has received loan or had an active line of credit, unlike subjective measure that is based on perceptions; for instance to what extent firms perceive access to loan is a challenge. The subjective measures are more prone to measurement errors. Research on implications of competitions from informal firms is increasingly getting policy attention (Pérez et al., 2018) given that formal manufacturing firms in developing countries cite it as a significant constraint to their operations (World Bank, 2014a).

1.2 Statement of the Problem

The Kenya Vision 2030 seeks to transform the economy into an upper middle-income knowledge-based industrialized status by the year 2030. While the Government has in the medium-term set a target of increasing the share of manufacturing in GDP to 15 per cent by 2022 as articulated in the "Big Four" agenda and the Third MTP of the Kenya Vision 2030, the sector's contribution has declined from 11.8 per cent in 2011 to 7.5 per cent in 2019 (KNBS, 2016; 2020). The declining share in GDP reflects slow growth rates experienced by manufacturing relative to the overall economy, perhaps suggesting productivity related challenges faced by the sector. This is evident from the Competitiveness Industrial Performance (CIP) Index published as part of UNIDO's biannual Industrial Development Report. According to the Industrial Development Report 2020, Kenya's capacity to produce and export manufacturing products was ranked at position 128 while the overall CIP ranking[4] was 112 out of 150 economies (UNIDO, 2019).

Countries that have successfully industrialised are characterised by higher performance in manufacturing R&D investments that is largely accounted for by private sector. Moreover, middle-income countries with weak R&D investments experience 'middle-income trap' (Lee, Keun, 2013) in that they stagnate in terms of transition to high income status. Recognising such realities, the Kenya Vision 2030, African Union Agenda 2063, and the Sustainable Development Goals (SDGs) call for improved R&D investments in the manufacturing sector to promote innovation and competitiveness. Despite these policy aspirations, only 24 per cent of the Kenyan manufacturing firms report to undertake R&D investments (World Bank, 2019a). The low levels of R&D investments if left unaddressed may perpetuate persistent undesirable outcomes such as low innovation outcomes and weak competitiveness that culminates into low contribution of the sector to the economy. The SDG 9 identifies the share of R&D investment in GDP as a key development indicator. As will be evident from subsequent sections of this study,

3 Line of credit is a credit facility granted by financial institutions, allowing the client to access funds up to some limit. Interest is paid only on the amount borrowed. Thus, it provides some flexibility to the client. For ease, in this study we use the term 'access to credit' to reflect access to loan or line of credit.

4 CIP index covers three competitive parameters for manufacturing sector: Technological deepening and upgrading; capacity to produce and export manufactured products; and world impact in terms of influence of the individual countries regarding manufacturing.

countries that have a large share of the overall R&D investment in GDP (i.e. GERD) are those that are driven by private sector R&D anchored on the manufacturing sector. While Kenya has set a minimum target of two per cent for the share of overall R&D investment in GDP (Government of Kenya, 2012), which is double the one per cent target set by the AU Agenda 2063 (AU, 2014), the status is estimated at only 0.8 per cent (UNESCO Institute for Statistics, 2019). There are, however, gaps in evidence of institutional, firm-level and business environment factors that may be constraining R&D investments by the manufacturing firms in the country. This study therefore reviews R&D institutional framework drawing on comparative perspectives, and employ micro-level datasets to analyse factors constraining R&D investments among Kenyan manufacturing firms.

1.3 Objectives of the Study

The overall objective of the study is to review R&D investments institutional framework and analyse the effects of firm-specific and business environment factors on R&D investment by Kenyan manufacturing firms. Specifically, the study analyses the effects of firm-specific and business environment factors on formal manufacturing firms R&D investments decision and intensity in Kenya, focusing on effects of:

(i) Access to formal credit;

(ii) Competition from informal firms;

(iii) Sub-sector technological differences; and

(iv) Firm size.

1.4 Justification of the Study

A central goal of the Kenya Vision 2030 is to transform the economy into an upper middle-income status through a diversified and competitive manufacturing sector. These aspirations are further reflected in the government's medium-term priorities to boost development of the sector as one of the four pillars[5] of the "Big Four" agenda with a goal of increasing its share in GDP to 15 per cent by 2022. These aspirations, however, come against persistent decline in the sector productivity (Cirera, 2014; de Vries, Timmer and de Vries, 2015) and contribution to GDP (KNBS, 2016; 2020). Enhanced investments in R&D serve as a key channel for development of the manufacturing sector. The Kenya Vision 2030, the Sessional Paper No. 9 of 2012 on the National Industrialization Policy Framework for Kenya 2012-2030 (Government of Kenya, 2012) and the Sustainable Development Goals (SDGs) all recognize the role of R&D investment in the manufacturing sector's innovation and competitiveness. There is, however, limited evidence to guide policy decisions regarding the institutional framework and firm-level and business environment constraints that may hinder R&D investments by manufacturing firms in the country. The findings and recommendations of this

5 The other three pillars are food security, access to affordable and descent housing, and universal healthcare.

paper are expected to be beneficial to policy actors, with interests in the sector including the National Treasury and Planning; the Ministry of Industrialization, Trade and Enterprise Development; county governments, National Commission for Science, Technology and Innovation (NACOSTI); Kenya Industrial Research and Development Institute (KIRDI); the Vision 2030 Delivery Secretariat; the Kenya Association of Manufacturers (KAM), and development partners.

2. Policy Review

The institutional framework is discussed through review of policies and literature related to R&D investments in Kenya and selected aspirator countries, including South Korea, Malaysia and South Africa. The reviews are focused on policy design features, including aspects relating to tax incentives, policy targets in terms of R&D share in GDP, institutional coordination in promoting private sector R&D investment, and any special support to Micro and Small Enterprises (MSEs). The selection of the three countries reviewed is on the basis that despite being contemporaries with Kenya in the 1960s, they have made significant milestones in manufacturing sector development. The progress these countries have made is strongly linked to policy reforms around R&D investments and innovation ecosystem in general (Koh, 2010; Yean and Heng, 2011). The review sought to provide insights on R&D investments in terms of policy framework, institutional support, incentives and related performance indicators.

2.1 Review of R&D Institutional Framework

This section reviews the R&D institutional framework relevant to Kenya and draws lessons from South Korea, Malaysia and South Africa. The three countries reviewed have made significant policy initiatives to promote business R&D investments and have a relatively high share of medium and high technology manufacturing compared to Kenya despite being contemporaries at independence. The R&D institutional framework is largely embedded within innovation system. As noted earlier, this is due the fact that R&D investment is an input to innovation. The R&D institutional framework embodies interactions and management of R&D interrelated actors that include public and private sector institutions, R&D inputs and outputs (OECD, 1997).

2.1.1 National institutional framework

Kenya's development agenda is partly anchored on the global and regional development commitments. The country anchors its development agenda within the regional and global commitments through medium-term policies such as the Kenya Vision 2030 MTPs, and review of long-term policies. The Sustainable Development Goals (SDGs), particularly SDG 9 of the United Nations underscores the importance of innovation and sustainable industrialization through enhanced technological capabilities of industrial sectors. As part of this global policy agenda, two R&D indicators have been prioritized for monitoring: R&D investment as a share of GDP, and number of R&D researchers per million population (United Nations, 2018). According to the Global SDG Indicators Database, Kenya's R&D investment as a share of GDP is 0.8 per cent while R&D researchers per million population is about 225 (United Nations, 2019). At the continental level, the African Union Agenda 2063 envisages member countries will increase budgetary expenditure on R&D investments to at least 1 per cent of GDP in efforts to accelerate innovation, productivity and economic growth (AU, 2014). At the East African

Community (EAC) level, the East African Community Industrialization Policy 2012-2032 aims to strengthen R&D, innovation, and technological capabilities of the regional manufacturing sector (EAC, 2012). The specific priorities in the EAC Industrialization Policy include building technological research capabilities of universities and technological centres; infrastructure for collaborative R&D and innovation; budgetary allocation for industrial research; and mechanisms for collecting and disseminating R&D results and innovation. The status in Kenya against the targets in these regional and global policies suggests the need to hasten policy initiatives towards boosting R&D investments as part of the interventions to realize innovation and technological advancement in the manufacturing sector.

a) Policy overview

The R&D investment institutional framework in Kenya is anchored on the agenda of promoting Science, Technology and Innovation (STI) with the aim of realizing a knowledge-based industrialized economy. The principal policy guiding this developmental aspiration is the Kenya Vision 2030, which underscores economic transformation through accelerated STI in priority sectors of the economy, such as manufacturing. The Kenya Vision 2030 is implemented through five-year Medium-Term Plans (MTPs). The First MTP 2008-2012 acknowledged low levels of R&D and weak incentives framework for its promotion (Government of Kenya, 2008). Such concerns are warranted given that newly industrialized countries such as Malaysia and South Korea have institutionalized R&D investment incentives, such as establishing R&D research institutions and providing fiscal incentives to promote R&D investments to deepen the manufacturing base and expand exports (Koh, 2010; Yean and Heng, 2011). Appendix 3 provides synthesis of R&D incentives offered by selected countries – South Korea, Malaysia, and South Africa. While South Korea and Malaysia were contemporaries with Kenya in terms of share of manufacturing contribution to GDP in the 1960s, the two countries have made great strides in industrialization agenda, partly as a result of policy initiatives to promote R&D. Due to policy facilitative roles, the private sector accounts for a significant share of R&D investments in the three countries compared to Kenya.

As part of the institutional reforms, the Second MTP 2013-2017 prioritized the transformation of the Kenya Industrial Research and Development Institute (KIRDI) to undertake industrial research, technology and innovation and dissemination of the resultant findings (Government of Kenya, 2013). KIRDI's support activities focus on Micro, Small and Medium Enterprises (MSMEs) along three thematic areas that include product development, business incubation services and common manufacturing facilities. The transformation of KIRDI has also been prioritized under the Third MTP 2018-2022, with plans to enact the KIRDI Bill 2017[6] (Government of Kenya, 2018a).

6 The STI Act, 2013 repealed the Science and Technology Act, Cap. 250, which originally established KIRDI. KIRDI Bill 2017 is, however, yet to be finalized and enacted as at the time of this study.

The medium-term policy priorities of the Kenyan government for 2018-2022 are reflected in the "Big Four" agenda anchored within the Third MTP with a focus on manufacturing, food and nutrition security, universal health coverage and provision of affordable housing. Under the manufacturing pillar, the policy seeks to increase the sector's contribution to GDP to 15 per cent by 2022. Prioritization of the labour-intensive manufacturing sub-sectors, including agro-processing, textiles and apparel, leather processing, construction materials and opportunities in the blue economy is envisaged to drive employment growth (Government of Kenya, 2018a). The blue economy entails sustainable use of ocean and coastal resources, including fisheries, tourism, aquaculture, offshore renewable energy, marine biotechnology, seabed extractive activities and maritime transport (World Bank and United Nations Department of Economic and Social Affairs, 2017). The Sessional Paper No. 9 on National Industrialization Policy Framework for Kenya 2012-2030 recognizes the role of R&D investments in product development, technology adoption and industrial growth. The priorities in this industrialization policy include human capacity development to support R&D; building a framework for strategic alliances between universities, R&D institutions and the private sector; and mobilization of resources through public-private partnerships and establishment of a Ksh 10 billion industrial fund for long-term financing of manufacturing enterprises (Government of Kenya, 2012). As of 2020, the Industrialization Fund is, however, yet to be operationalized.

The Kenya Investment Policy 2019 (Government of Kenya, 2019a) provides the framework for guiding domestic and foreign investments in the country. Though not explicit on R&D investments, this policy identifies the types of investment incentives (fiscal, non-fiscal, performance-based, discretionary/non-discretionary, and hybrid incentives) and the criteria for granting them. It requires that the granting of investment incentives should consider the potential for technology transfer, employment creation and sustainable development, defined timeframe and be relevant to the priority sectors.

b) Policy implementation tools: Support institutions and legal framework

The Ministry of Industrialization, Trade and Enterprise Development, and the Ministry of Education provide significant roles in R&D investments largely through policy formulation and implementation on the innovation ecosystem. The two ministries implement the policies through various state corporations that have mandates relevant to research, innovation, incubation and financing of enterprises from STI perspectives. The legal frameworks provide for the establishment of the state corporations and their mandates. Moreover, legislations relevant to investment incentives are reviewed.

The Ministry of Industrialization, Trade and Enterprise Development through the State Department for Industrialization undertakes integration of industrial information and research and the coordination of the development of industrial policies and programmes. There are four state corporations under this Ministry, with activities relevant to R&D investments and financing of manufacturing firms: Industrial and Commercial Development Corporation (ICDC), Industrial Development Bank (IDB) Capital, Kenya Industrial Research and Development Institute (KIRDI), and Kenya Industrial Property Institute (KIPI).

The Industrial and Commercial Development Corporation (ICDC) established in 1954 focuses on financing industrial projects that have the potential for employment and wealth creation. Between 2015 and 2019, ICDC supported 28 industrial projects with cumulative financing of Ksh 2.7 billion (KNBS, 2020). The Industrial Development Bank (IDB) Capital, a development finance institution established in 1973, extends long-term financing and working capital to help in establishment, expansion and modernization of small, medium and large-scale industrial enterprises engaged in value addition activities. Between 2015 and 2019, IDB Capital supported 27 industrial projects, advancing a cumulative credit of Ksh 1.5 billion mainly to start-ups in food processing, textiles activities, processing of beauty products, and steel mills (KNBS, 2020). While these development finance institutions are generally mandated to meet financing needs of manufacturing firms, the legal framework establishing them is not explicit on R&D investment financing. This poses challenges in financing R&D investment given its unique features such as uncertainty of outcomes, information asymmetry and appropriability of returns.

KIRDI, which was established in 1979 and currently operates under the STI Act of 2013, plays a relatively more explicit role in manufacturing R&D investments. KIRDI is mandated to undertake industrial research, technology and innovation and dissemination of the resulting findings. The operations of KIRDI are, however, curtailed by some challenges including limited financial resources, use of obsolete equipment, inadequate technical skills in some areas, and inadequacies of policies in areas such as sharing of proceeds of commercialized patents (KIRDI, 2019). During the second MTP 2013-2018, KIRDI generated 96.7 per cent of its cumulative Ksh 7.3 billion revenue from government allocation. The remaining 3.3 per cent of the revenue was generated from Appropriation-in-Aid (A-in-A), donor and collaborative projects. About 50 per cent of the expenditure is on administration and other recurrent expenditure, compared to development expenditure at 48 per cent and research, technology and innovation at 2.6 per cent. According to the Medium-Term Expenditure Report (Government of Kenya, 2019b), during the 2018/19 financial year, KIRDI developed five industrial technologies, transferred two industrial technologies to MSMEs, upgraded 20 MSMEs products to international standards, and supported 584 MSMEs through technology incubation and common manufacturing facilities (Government of Kenya, 2019b). This review shows that despite its key role in promoting industrial research, only a small proportion of KIRDI's budget is spent on research, technology and innovation.

Innovation, which is an output from R&D investment, is subject to a significant uncertainty regarding appropriation of returns in an environment characterized by weak protection of intellectual property rights. The Kenya Industrial Property Institute (KIPI), initially established in 1990 as Kenya Industrial Property Office (KIPO), currently operates under the Industrial Property Act of 2001 and the Trademarks Act, Cap 506 with a mandate to promote inventive and innovative activities and promote acquisition of technology through regulation and registration of trademarks, patents, industrial designs, technovations and utility models (KIPI, 2018). KIPI, however, faces some challenges in delivering on its mandates owing to inadequate financial and human resources, low public awareness on its operations, and centralization of its services in Nairobi (KIPI, 2018).

The Ministry of Education has a vital role in integrating STI into the national development process. It contributes to this agenda through two strategic goals; promotion of innovation, research and technology in learning institutions and the industry; and promotion of linkages between the industry and learning institutions (Government of Kenya, 2018b). It implements relevant policies through various state corporations, including the National Commission for Science, Technology and Innovation (NACOSTI), the Kenya National Innovation Agency (KeNIA) and the National Research Fund (NRF). The Science, Technology and Innovation Act No. 28 of 2013 (henceforth the STI Act) is aimed at making progress towards the policy aspirations on knowledge-based economy and guides the operations of the relevant state corporations under the Ministry of Education. A key object of the STI Act is to link fragmented players that lack a strong coordinating agency (Cirera, 2014).

Section 3 of the STI Act establishes NACOSTI, with a key mandate for regulation and assurance of quality in the STI sector and advise the government on related matters (Government of Kenya, 2012). Other key mandates of NACOSTI is to lead inter-agency consultations on innovation, including KeNIA and NRF. In achieving this mandate, NACOSTI undertakes activities such as issuance of research licenses, registration of research institutions, organizing of STI fora and issuance of STI advisories (Government of Kenya, 2018b).

KeNIA is established under Section 28 of the STI Act to institutionalize the linkages between the relevant actors, including universities, private sector, government and research institutions. It is further mandated to identify strategic fields of innovations and provide incubation for innovative ideas. During the year 2019/2020 to 2021/2022, the agency planned to annually commercialize 15 innovations (Government of Kenya, 2018b). In supporting knowledge and innovation management and development and commercialization, KeNIA is planned to achieve the targets outlined in Table 2.1.

Table 2.1: KeNIA's contributions to STI and projected resource requirements

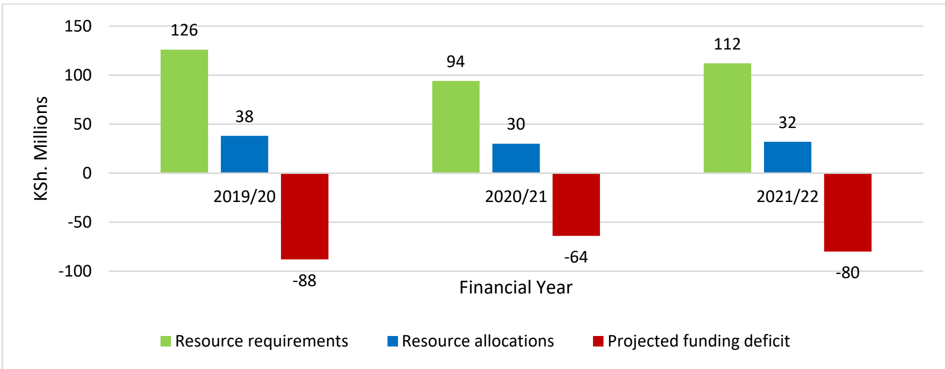
	Financial year				
	Actual	Target			
	2017/18	2018/19	2019/20	2020/21	2021/22
Contributions to STI					
No. of national innovation survey	-	-	1	-	-
No. of award schemes in STI	8	8	8	8	8

No. of commercialized innovation	12	15	15	15	15
No. of innovation platforms and facilities	-	-	3	3	3
Establish an innovation database (% completed)	-	-	50	60	80
No. of innovation promotion and awareness platforms	3	3	3	3	3

Source: Government of Kenya (2018b), Education sector medium-term expenditure framework 2019/20-2021/22; (-) means no target was set

Resource constraints remain a key hindrance to the operations of KeNIA as illustrated in Figure 2.1. In the medium-term, there will be a persistent deficit in its funding requirements, and this might curtail its role in promoting institutional linkages in the country's STI ecosystem. The education sector medium-term expenditure framework corroborates this evidence, pointing out budgetary constraint and the weak link between academia and the industry in enhancing the innovation ecosystem (Government of Kenya, 2018b).

Figure 2.1: KeNIA's budgetary resource requirements and projected allocations

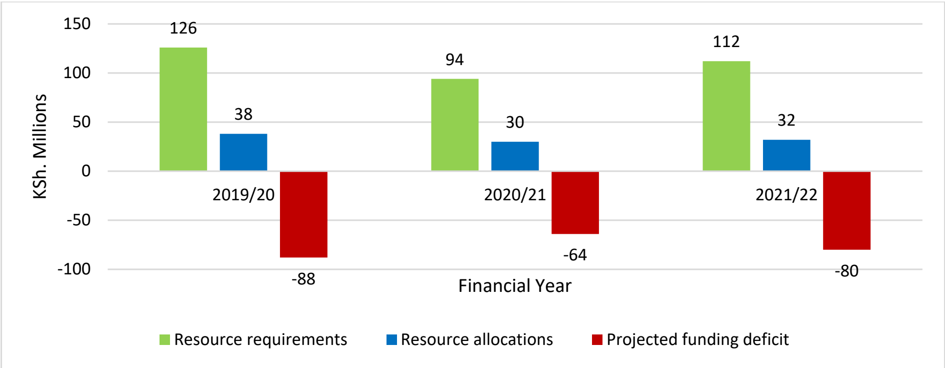


Data Source: Government of Kenya (2018b), Education sector medium-term expenditure framework 2019/20-2021/22

The NRF is established under Section 32 of the STI Act, and it is envisaged to be annually funded by allocations from the National Treasury equivalent to 2 per cent of GDP in line with this legal framework. It is mandated to mobilize and channel resources for research and STI, including through supporting the cooperation and dissemination of relevant research findings. It commenced its operations in 2016/17 with Ksh 3.384 billion (88.7% from the government and 11.3% from donors) (Government of Kenya, 2018c). This financial allocation translated to about 0.04 per cent of GDP in 2017, much below the 2 per cent target. The amount was largely used for research-related activities at 59.7 per cent (multidisciplinary and multi-institutional research 26.2%; infrastructure support programmes 23.6%; postgraduate studies 7.0%; bilateral collaborative matching grants 1.7%; dissemination of research findings through workshops and conferences 0.8%;

and innovations 0.4%), with the remaining 40.3 per cent used for activities such as innovation surveys, and development purposes. In the medium-term, NRF funding requirements and projected allocations are provided in Figure 2.2. The trend shows widening funding gap in the medium-term.

Figure 2.2: NRF's budgetary requirements resource and projected allocations



Source: Government of Kenya (2018b), Education sector medium-term expenditure framework 2019/20-2021/22

Regarding incentives, the R&D institutional support in Kenya is at an embryonic stage, given that policy tools such as tax credit for R&D investment are deficient (Cirera, 2014). While the country has multiple legislations to promote domestic and foreign investments, including the Foreign Investments Protection Act, 1964; the Export Processing Zones Act, 1990; the Investment Promotion Act, 2004; and the Special Economic Zones Act, 2015; these lack clarity on incentives for promoting private sector investments in R&D. The Income Act, 1973 under the Second Schedule provides for various investment incentives, including expenditure on construction of an industrial building, deductions related to capital expenditure on agricultural land, and wear and tear deductions of machinery. To promote STI, this Act provides that expenditure on scientific research, contributions to an approved scientific research association related to the business, or contributions to institutions such as a university, research institutes or a college for undertaking a scientific research related to the business are tax deductible.

In summary, this section on the review of the institutional framework reveals that despite consolidation agenda envisaged in the STI Act, there are multiple institutions that have roles in promoting firm-level R&D investments. Effective coordination and collaboration among these institutions is essential in creating synergy towards promotion of R&D investment. There are some persistent challenges that impede development of the STI sector. First, there is a weak industry-academia linkage that weakens the synergies envisaged in the STI Act. Second, funding constraints limit the potential of the various institutions in delivering on their mandates. Third, there are gaps regarding fiscal incentives targeted at R&D investments, especially those relating to high value manufacturing sub-sectors. The analysis in Appendix 3 makes this last point clear in relation to experiences from review of other countries.

2.2 Lessons from Review of other Countries' R&D Policies and Institutional Support

Table 2.2 shows comparative R&D-related performance indicators sourced from the Global Competitiveness Index (GCI) Report 2019 published by the World Economic Forum, and the Industrial Development Report 2020 published by UNIDO. GCI index focuses on long-term determinants of productivity and economic growth, including innovation and firm capability. The Industrial Development Report provides rankings of Competitive Industrial Performance (CIP) Index that considers an economy's capacity to produce and export manufacturing products, technological intensity of manufactured products, and manufacturing impact of a country in the global economy in terms of value added and exports. The two rankings, thus reflect productivity and competitiveness of manufacturing sectors across the countries. The three countries relatively perform better compared to Kenya on the selected performance indicators.

Table 2.2: Comparative industrial competitiveness and R&D investment performance indicators

a)	b) Overall GCI ranking	c) R&D Per Cent of GDP	d) Global Competitiveness Index (GCI) Rankings on R&D-relevant indictors (Countries are ranked out of 141 economies; rank 1 is the best)						e) Industrial Development Performance (No. of countries: 150)	
			R & D	Property rights	Innovation capability	Skills of workforce	Financial systems depth & stability	Entrepreneurship culture	Medium & high technology manufacturing in total manufacturing (Per cent)	Technological deepening & upgrading ranking
Kenya	95	0.8	62	70	78	43	78	32	15.0	106
South Africa	60	0.8	44	67	46	101	19	39	24.4	53
Malaysia	27	1.3	39	14	30	8	15	4	44.1	14
South Korea	13	4.2	4	26	6	27	18	55	63.0	1

Source: columns (b)-(d) Global Competitiveness Report 2019 (World Economic Forum, 2019); column (e) Industrial Development Report 2020 (UNIDO, 2019)

The review of the selected countries, as detailed in Appendix 3, and which perhaps explains the performance indicators in Table 2.2, reveals the following policy lessons for Kenya:

(i) In early stages, public research institutions and universities play a more dominant role through direct government support. There is then a gradual shift towards the role of private sector in R&D investments, achieved through incentives and other facilitative roles such as synergy among private sector enterprises, research institutions and universities.

(ii) There are deliberate efforts to provide incentives that encourage start-ups and smaller enterprises undertake R&D investments largely owing to resource constraints faced by this segment of the enterprises.

(iii) Use of industrial clusters (e.g. *innopolis* in South Korea) for focused support and peer learning.

(iv) Incentives are used to gradually diversify manufacturing into medium and high technology sub-sectors. As illustrated in Appendix 1, these include manufacture of chemicals, pharmaceutical products, electronics, electrical equipment and machinery.

(v) Sustained efforts to generate rich data through surveys on R&D investments. The surveys are guided by international standards, particularly OECD's Frascati Manual. The systematic collection of data guides policy interventions besides providing opportunities for international comparisons.

(vi) The ecosystem for promoting R&D investments by private sector is anchored on commercialization strategies. These are achieved, for instance, through accelerated uptake of locally generated R&D innovative products and intellectual property rights protection in an integrated way.

3. Literature Review

3.1 Theoretical Literature

The theoretical insights are anchored on key features of R&D investments in relation to firm behaviour. These features include the investment-nature of R&D as it is expected to generate a stream of feature benefits, uncertain outcomes, and market failures associated with non-rivalry of outputs from R&D (i.e. knowledge and partly innovation) and information asymmetry between the firm and potential financiers (Bloch, 2005; Hall, 2008; OECD, 2015). The implications of these features may generally vary with firm characteristics and the institutional contexts in which the firm operates. For instance, smaller firms are generally characterized by limited internal resources and higher information asymmetry and, therefore, face higher constraints to undertake R&D investments. The theoretical literature in relation to the objectives of this study and variables considered are synthesized into four complementary thematic areas: structure of the industry and firm characteristics; public policies and institutional factors; and learning behaviour of firms.

3.1.1 Neoclassical theory of firm investment

The neoclassical theory of optimal capital accumulation (Jorgenson, 1963; Jorgenson and Siebert, 1968) postulate that a profit maximizing firm would undertake R&D investment up to the point where expected marginal benefits equate the marginal cost (Li and Hall, 2020). Thus, an underpinning argument is that R&D investments result from differences in desired capital stock and the actual capital stock. This strand of theory anchors on cost of accessing and utilizing capital and expected marginal returns from future revenue streams. The cost of capital and marginal returns depends on firm-specific, sectoral, and business environment factors. For instance, some of the channels through which these factors impact on cost of capital are related to adjustment costs, information gaps between the firm and providers of finance, and uncertainty of realizing returns on investments. The neoclassical theory of firm investment serves as the foundation for other theories (elaborated below) – industry structure and firm characteristics, public policies and institutional factors, and learning by doing, which can influence either cost of capital or expected marginal returns on capital investments.

3.1.2 Industry structure and firm characteristics

The theories on structure of the industry and firm size can be viewed from the Schumpeterian hypothesis perspectives. The Schumpeterian hypothesis (Schumpeter, 1942) postulates that larger firms in concentrated markets have higher incentives to invest in R&D due to larger resource base and lower risks of adverse impacts for undertaking activities with uncertain outcomes. In reference to ‘creative destruction’, a term he coined, Schumpeter argued that innovation (which is an outcome of R&D) is a source of market power in which firms compete to gain larger market share. The term 'creative destruction' points to the cycle whereby an industry evolves from competitive to monopolistic tendency, and back to competitive as firms contest for profits and market share. Furthermore, larger firms are hypothesized to more likely benefit from economies of scope resulting from the portfolio of products. The Schumpeterian hypothesis culminates into two theoretical insights; that is, knowledge investment activities increase with market concentration; and more than proportionately with firm size (Schumpeter, 1942). An emerging issue in literature is the role of competition from informal firms on the behaviour of formal firms. Early economic view was that formal firms and informal firms are segregated and operate in a dual economy (Lewis, 1954). According to this view, the informal sector is a residual for absorbing entrepreneurs who cannot fit in the formal sector. However, more recent alternative argument of parasitic view suggests that formal and informal firms compete in the same market, with the latter eroding the market share of the former due to advantages of operating outside regulatory and taxation framework (Farrell, 2004). The operations of informal firms are therefore postulated to supress growth of formal firms, consequently creating disincentives for investments.

The second strand of theories under this thematic area relates to the resource-based view of the firm (Penrose, 1959; Wernerfelt, 1984; Barney, 1991), which postulate the importance of the bundle of tangible and intangible internal resources in shaping the firm's competitive advantages. The proponents of this theory argue that internal resources such as managerial capabilities are critical in exploiting external opportunities. Internal resources tend to increase with firm size, and this feature has three implications for R&D investments behaviour of firms. First, larger firms can use internal resources such as cash flows for financing R&D, including hiring of technical personnel. Second, larger firm size can ease access to external finance due to abundance of tangible assets and lower information asymmetry as viewed by potential financiers. With increased information asymmetry, the cost of external finance is expected to increase particularly for smaller firms. One problem with financing R&D is that firms have more advantageous information than the financiers, especially given that the former may not wish to disclose full information for strategic reasons (Bloch, 2005). Such situations pose difficulties for lenders to glean low-risk projects from highly-risk projects (Stiglitz and Weiss, 1981). Third, returns to R&D increase with existence of complementary factors such as mix of appropriate skills and technology, be it at firm-level or aggregate level (Cohen and Levin, 1989; Goñi and Maloney, 2017).

3.1.3 Public policies and institutional factors

The second thematic theoretical literature relates to the role of public policies and institutional factors, considering the uncertainties of R&D outcomes and risks in appropriating the benefits resulting from R&D investments. The early work in this strand of literature has foundations in externalities and market failures of R&D outcomes in form of innovation, thus calling for incentives and institutional support to attract private sector firms (Nelson, 1959; Arrow, 1962). The proponents of these theories argue that because outputs from R&D investment can be imitated at lower costs than the original costs, lower private benefits relative to social benefits lead firms to undertake less-than optimal investments. These arguments call for public policy instruments such as subsidies, tax credit and financing (Martin, 2016) to encourage private sector firms to undertake R&D investments. Public policies are postulated to promote R&D investments through two other channels (Schot and Steinmueller, 2018), first by deepening investments in knowledge and R&D infrastructure as part of the wider STI policy. From practical perspectives, this is targeted at alleviating R&D entry costs for firms owing to opportunities to leverage on existing platforms. Second, public policies help build linkages and interactions among the actors involved in R&D investments within the innovation ecosystem, thus promoting learning. The linkage building is suggested to yield benefits at the sectoral, national and regional levels.

Other aspects of public policies relate to more broader investment environment, owing to irreversibility of R&D investments. The real options theory (Myers, 1977; McGrath, 1997) is anchored on irreversibility of investments and asserts that when a firm is faced with uncertainty, it is motivated to delay the investment decision in expectation of gathering more information to mitigate costly decisions. Uncertainties can emanate from macroeconomic conditions and government policies. Costly decisions can be articulated in terms of yielding unfavourable outcomes. Uncertainty increases the opportunity cost of making investments in the prevailing conditions and is, therefore, associated with depressed R&D activities due to postponement tendencies of firms. In the presence of uncertainty and costly (irreversible) R&D investments, the deferral decision in favour of a more conducive future investment environment characterized by relatively more complete information or stable condition creates benefits for the firm.

3.1.4 Learning behaviour of firms

The third strand of theories relate to learning behaviour of firms. The 'learning-by-doing' theoretical literature (Spence, 1981) argues that, over time, firms learn to be more efficient in activities they do through practice and interactions with customers and other firms. The 'learning by exporting' theory argues that participation in international trade creates exposure to the knowledge base present in other economies (Grossman, 1991; Yeoh, 2004). Firms' participation in the export market is also viewed to have other advantages such as stiff competition and international customer demands that create incentives for the firms to device strategies to remain competitive (Love and Ganotakis, 2013) and scale effects by spreading R&D investments over large output as a result of targeting larger market (Aw, Roberts and Xu, 2008). The extent to which learning occurs is, however, theorized to be dependent on absorptive capacity of the firm (Cohen and Levin, 1989), which argues that the stock of firm internal capabilities, including R&D, enhances the ease of knowledge assimilation. More importantly, it outlines the dual role of R&D: direct contribution to firm innovation, and superior absorptive capacity of external knowledge.

In summary, theoretical literature on the nature and determinants of firm-level R&D is varied, ranging from public-good nature of R&D, real options approach reflecting investment under uncertainty, internal resource capabilities, and learning from participation in the export markets.

3.2 Empirical Literature

Conceptually, extant empirical literature can be grouped into four thematic areas (Becker and Pain, 2008): public policies and institutional factors; macroeconomic factors; business environment factors; and firm and industry-specific characteristics. This section provides thematic review of empirical literature based on this conceptual perspective.

3.2.1 Public policies and institutional factors

Motivated by early theoretical views suggesting that R&D faces public good problem (Nelson, 1959; Arrow, 1962), empirical evidence suggests that private rate of return is lower than the social rate of return, which suggests challenges faced by firms to fully appropriate the returns on investments (Griliches, 1998; Appelt et al., 2016). This means that the spillover of the generated knowledge to other firms results to private sector under-investment in R&D than level that is socially optimal. The second challenge faced by private sector firms that calls for policy and institutional support relates to constraints to secure external finance for R&D investment, particularly among start-ups and small enterprises (Appelt et al., 2016). Such findings have motivated use of policy tools and institutional support to accelerate R&D investments by private firms. A survey of literature reveals that policy tools such as subsidies and tax credits can be used to successfully incentivize private firms' R&D investments (Becker, 2013). The impact analyses of such policy tools are, however, possible either in cross-country setting or in situations where some firms are eligible for the public incentives while others are not. Both fiscal incentives such as R&D tax credit (Hall and Van Reenen, 2000; Bloom, Griffith and van Reenen, 2002) and public subsidies (Carboni, 2011) are shown to increase private investment in R&D. Regarding fiscal incentives, cross-country analysis indicates that a 10 per cent cut in cost of R&D leads about 10 per cent increase in R&D intensity in the long run (Dabla-Norris, Kersting, and Verdier, 2012). Beyond fiscal incentives, the institutional support used includes collaborative R&D, which facilitates working together of private firms, universities and public research institutions (Becker, 2013; Jung and Mah, 2013; Appelt et al., 2016).

Some strands of literature on public policies and institutional factors relate to spillover effects of knowledge for driving R&D investments. The spillover effects empirical literature is rooted in agglomeration economies, absorptive capacity and technology diffusion. The key factors related to spillover effects include cooperation with research institutions, rich human capital, association with research joint ventures and geographical proximity to the institutions of higher education (Becker, 2013). Enhanced accessibility to university R&D has indeed been shown to accelerate industrial R&D investment (Jaffe, 1989; Karlsson and Andersson, 2009). Literature further distinguishes between interactive relationships on one hand, usually characterized by collaborations and mutual learning, such as in collaborative R&D projects, and non-interactive relationships usually characterized by copying and imitations by one party (Glückler, 2013; Roper et al., 2016).

3.2.2 Macroeconomic factors

The central theme related to macroeconomic factors include import pressures and the transmission of uncertainty triggered through volatility of macroeconomic variables (Carruth, Dickerson and Henley, 2000; Becker and Hall, 2009). High levels of imports decline in real long-term interest rates, and GDP growth are associated with a rise in R&D investments (Becker and Pain, 2008). These findings suggest that increased import intensifies competition in the domestic market, perhaps pushing firms to invest in R&D as a defensive strategy, while the association between GDP growth and R&D investments can be indicative of some cyclicality and the motivation for firms to tap into growth opportunities. The effects of real exchange rate on R&D, however, remains inconclusive, with some findings suggesting a positive relationship (Chen, 2017) and others negative relationship (Becker and Pain, 2008). It is shown that the effects of real exchange rate on R&D investments by firms vary by levels of development and the associated import-intensive and export-intensive nature of countries in which they operate (Alfaro et al., 2019).

3.2.3 Business environment factors

Access to external finance is a key impediment to R&D investments. As elaborated in Section 2.2.4 of this study, unique firm characteristics such as size tend to create amplified barriers for some segments of enterprises that, for instance, tend to be micro and small. The R&D investment financing challenges largely emanate from key market features of R&D that include non-rivalry in usage of R&D output (i.e. knowledge) that erodes the extent to which returns can be appropriated; high risk premium demanded by financiers owing to uncertainty of outcome and information asymmetry as firm owners and managers tend to possess superior information; and the difficulties associated in collateralizing R&D output (Hall and Lerner, 2010). Access to finance is a key obstacle to growth of firms in Sub-Saharan Africa (Fowowe, 2017) largely due to under-developed nature of the financial markets (Allen, Otchere and Senbet, 2011). Investments for knowledge creation are particularly constrained due to the novel features of R&D investment outlined in this section.

Another key business-environment related factor, that is increasingly becoming a policy concern is the competition faced by formal firms from the informal sector. The World Bank Enterprise Survey reveals that 42 per cent of manufacturing firms in Kenya report that competition from informal firms poses major constraints to their operations, which is higher than Sub-Saharan Africa at 41 per cent and the average for all countries at 29 per cent (World Bank, 2019a). Informal firms operate outside government regulatory and taxation purview as they are neither registered nor licensed. They are therefore not subject to regulatory and compliance costs, including licensing, taxation and standards (Pérez et al., 2018). Informal firms thus gain advantage over formal firms that are subjected to these costs. These disadvantages for formal firms relative to informal firms can create uncertainties for appropriation of returns on R&D investments, creating negative incentives for such investments.

There are also institutional-related business environment factors that can potentially have implications for private sector firms' operations. These include intellectual property rights (Pérez et al., 2018), political environment and enforcement of the rule of law (La Porta et al., 1998; Shibia and Barako, 2017; Barasa et al., 2017). In Kenya, manufacturing firms cite political instability as the third major obstacle to their operations, after access to finance and practices of informal sector (World Bank, 2019a), which may perhaps induce risk premium for investments.

3.2.4 Firm and industry-specific characteristics

Research on firm-specific characteristics reveal that availability of internal financial resources and firm size positively influence firms' R&D investment decisions (Cohen, 1995; Bloch, 2005; Becker and Pain, 2008; Baumann and Kritikos, 2016). While these findings may corroborate the view that financial resources in excess of those required for current operations are needed to support R&D investment, there are contrasting findings that decline in profitability creates incentives for firms to invest in R&D to remain competitive and viable (Hundley, Jacobson and Park, 1996). Firms may prefer to use internal finances for R&D as opposed to borrowing for a number of reasons such as tendency to conceal technological plans from external parties for concerns over leaking such information to competitors (Teece, 1980) and information asymmetry between the firm and the lenders that tend to increase costs of external finance (Myers and Majluf, 1984; Hall and Lerner, 2010; Jung and Kwak, 2018).

For firm size, plausible explanations emerging from literature relate to ability of larger firms to raise capital in imperfect markets and the advantages derived from scale economies in R&D investment, and higher returns to R&D resulting from voluminous turnover over which to spread costs of investments (Cohen and Levin, 1989). The opposing arguments, however, suggest that efficiency in R&D investment diminishes with larger firm size as a result of loss of managerial control (Cohen and Levin, 1989). While smaller firms tend to demonstrate lower probability of undertaking R&D, they tend to have higher R&D intensity (Baumann and Kritikos, 2016). The plausible explanation for this finding is that smaller firms may face entry barriers to undertake R&D (i.e. threshold), but once they overcome such constraints, they tend to outperform larger firms. Additionally, firms undertaking R&D investments for the first time tend to have larger financial outlays than existing and repeat-R&D firms (Peters et al., 2017), suggesting that smaller firms that undertake R&D may face higher costs.

Over time, a firm undergoes different growth phases, and this is expected to affect its investment behaviour along the life cycle. Older firms are shown to invest more in R&D to compensate for the obsolescence of their growth-phase advantages (Cuervo-Cazurra and Un, 2010). Age impacts on R&D through learning effects by allowing more mature firms to leverage on previous experiences, accumulated resources and capabilities (Cuervo-Cazurra and Un, 2010; Fan and Wang, 2019). Other studies have, however, established that the relationship between R&D investments and age of the firm is bell-shaped (Cirera, 2014; Fan and Wang, 2019), meaning that R&D investment is higher among younger firms compared to older firms. The intuition supporting this strand of literature is that younger firms need to invest more in knowledge activities for innovation and survival (Fan and Wang, 2019) and the dynamics of age-linked structural inertia (Le Mens, Hannan, and Pólos, 2015), which argues that older firms face relatively higher difficulties adapting to changes compared to younger firms. The literature on age thus reveals possibly two opposing age-related effects on R&D investments. On one hand there is the learning effects through accumulation of experiences, resources and capabilities that have positive influence, but on the other hand, there is the age-linked structural inertia that imposes negative influence. There are indications that the learning effects have a dominant role when firms are young while the age-related structural inertia is expected to have a dominant effect as firms grow older (Fan and Wang, 2019).

Firm ownership affects investments through corporate governance mechanisms and resource pooling channels. Because managers may tend to be focused on short-term performance of the firm compared to owners who usually have long-term growth interest, corporate governance issues in form of agency problem can arise if there exists separation of ownership and management (Block, 2012). In such cases, because of the uncertain nature of outcomes of R&D investments, there can be cases of excessive risk taking or other instances less-than optimal risk taking by managers acting on behalf of the owners. It is also possible that managers can have superior information on the likelihood of success than owners of the firm. Ownership structure can also relate to concentration in form of family and ownership. Overall higher share of family ownership is associated with lower R&D investment intensity (Block, 2012; Chrisman and Patel, 2012). As time horizons for family interest in the business lengthen, however, investments in R&D tend to rise (Chrisman and Patel, 2012), perhaps suggesting trans-generational goals. Novel features in family ownership include strength of entrepreneurial orientation (e.g. going-concern time horizon, innovativeness and risk appetite) and dynamics of internal family conflicts (Block, 2012). A key advantage of family ownership is, however, the minimization of agency costs as the wedge between the interests of the management and owners narrows and tend to advance long-term performance of the firm to sustain inter-generational ownership (Block, 2012; Chrisman and Patel, 2012).

Internal knowledge resources, commonly measured in form of average years of education, or proportion of skilled personnel is also an important factor positively affecting firm R&D investment (Becker & Pain, 2008; Cuervo-Cazurra & Un, 2010). The skills within firms enhances learning and capacity to successfully transform knowledge inputs to outputs in inform of innovation (Cirera, 2014). Indeed, returns on R&D investments in countries with weak human capital tend to be lower compared to those to those with advanced human capital (Goñi & Maloney, 2017). Higher returns can therefore serve as an incentive to private sector firms' investment in R&D.

Sub-sector heterogeneity also serves a crucial role in R&D investments. Different sub-sectors are subject to varying levels of learning effects and the need to keep abreast with technological and competitive pressures (Pavitt, 1984; Jung and Mah, 2013; Galindo-Rueda and Verger, 2016). Furthermore, firms in different sub-sectors rely on diverse sources of productivity growth such as R&D investments, human capital and investments in capital assets to different extents depending on the levels of economic development (Goedhuys, Janz and Mohnen, 2014).

The empirical literature further suggests the role of competition in firms' R&D investment behaviour. The competitive forces literature draws its support from the Schumpeterian hypothesis of the industry structure (Schumpeter, 1942). The empirical findings relate to competition resulting from the local structure of the industry, and participation in the export markets. Competition in the product market has been shown to have two distinctive effects depending on whether the firm is incumbent or entrant (Becker, 2013; 2015). For the incumbent firm with market power, elevated competition erodes returns on R&D, thus creating negative incentives to invest (Becker, 2013). Investment in R&D can, however, be used as a defensive tool for protecting the incumbent firm's market share (Becker, 2013). The trade-off between the two responses can largely depend on the extent to which the incumbent firm can safeguard its market share. Some studies demonstrate non-linear inverted U-shaped relationship between competition and R&D investment (Aghion et al., 2005). The inverted U-shape relationship implies that at low-level competition, innovation-increasing effects of competition is dominant, while the Schumpeterian effect dominates as competition intensifies (Becker, 2013). For exporting firms, a measure of competition or market concentration is only a partial picture of the reality due to the expanded market (Aghion et al., 2005). Acknowledging that firms learn from exporting, there is added advantage of elevated competition in the international markets, foreign consumer demand and exposure to richer technology which gives incentives to firms to invest in R&D to remain competitive (Aw et al., 2007; Girma, Görg and Hanley, 2008; Becker, 2013).

4. Methodology

4.1 Conceptual Framework

The underpinning economic intuition of this study is that R&D is an investment activity, given that it is expected to yield future benefits in form of innovations and productivity. Unlike other investments in physical assets, there are some peculiarities characterizing R&D investments, such as high levels of information asymmetry between the investing firm and lenders, uncertainty of materializing outputs and difficulties in appropriation of returns (Hall and Lerner, 2010; Becker, 2015). The insights on these challenges are anchored on early propositions that knowledge and innovations that are outputs from R&D investments can be easily imitated at lower costs relative to the original investment (Nelson, 1959; Arrow, 1962; Hall and Lerner, 2010). Moreover, the challenges of information asymmetry between the R&D-investing firm and lenders of financial capital results from the fact that firm managers possess superior information on the likely outcome of the investments than external parties (Hall, 2008). These issues imply that R&D investment face some additional adjustment costs relative to physical capital investments.

The behaviour of firms' R&D investment behaviour is a two-step process. First, the firm decides on its optimal stock of R&D investment (R&D), and then determine whether to initiate the investment decision; and secondly it decides on the rate at which it bridges the deficit between current and the desired level of R&D investment, thereby determining the intensity of investment. The decision to undertake any R&D investment depends on existence of any fixed 'entry' costs such as establishment of R&D units/department, procurement of supporting infrastructure, and resourcing of skilled technical personnel (Máñez et al., 2009). Because these entry costs are largely sunk in nature, profit-maximizing firms need to make a choice on whether to make the ('entry') decision of R&D investment. The sunk nature of these costs implies that the R&D-undertaking firm can neither use such investment for alternative uses nor trade it in the market. If the expected returns net of sunk and other start-up costs is positive, this would incentivize the firm to undertake R&D investment (i.e. have a positive R&D investment).

Within the second step, based on the neoclassical theory of optimal capital accumulation (Jorgenson, 1963; Jorgenson and Siebert, 1968), a profit maximizing firm would undertake R&D investment up to the point where expected marginal benefits equate the marginal cost (Li and Hall, 2020). The marginal benefit in this case would be the Marginal Product of R&D investment $MPK_{(r\&d)}$, while the marginal cost would be the user cost of capital (ρ) comprising of foregone interest earnings, economic depreciation, R&D capital price appreciation or depreciation (capital gain/loss), and marginal adjustment costs (Hall and Van Reenen, 2000; Hall and Lerner, 2010). The arbitrage equation for a profit maximizing firm faced with investing available funds in R&D or return-earning opportunity would be:

$$r.p_k = MPK_{(r\&d)} + \Delta p_k \qquad 4.1$$

where r is the opportunity cost of investing in R&D; and Δp_k reflects change in price of R&D (i.e. capital appreciation or depreciation: $\Delta p_k = R\&D_{(t+1)} - R\&D_t$). Through normalizing the price of initial R&D capital $R\&D_t = 1$, equation 4.1 can be rearranged as: $MPK_{(r\&d)} = r - \Delta p_k/p_k$; which considering elements of economic depreciation (δ) and Marginal Adjustment Costs (MAC), the right-hand-side of equation 4.1 can be expanded as:

$$MPK_{(r\&d)} = \rho = r + \delta - \Delta p_k/p_k + MAC \qquad 4.2$$

The user cost of capital (ρ), constitute the overall cost of R&D programme or project implementation in form of r, δ, $\Delta p_k/p_k$ and MAC, and this would facilitate comparison of benefits and costs on a flow basis. The model described here underscores the relevance of various factors in explaining firms R&D investment, notably investors required rate of return, economic depreciation (i.e. obsolescence in an R&D context), and marginal cost of adjusting R&D investments. The factors that affect costs of doing business through business environment variables would increase ρ, implying $MPK_{(r\&d)}$ needs to be much higher for the associated investment to be profitable and attractive to the firm. The economic depreciation/ obsolescence (δ) reflects the industry-level technological change and is affected by factors such as imitation, learning, competition, and market structure. MAC reflects adjustment costs such as those related to acquisition of necessary skills/ personnel, supporting equipment and finance that can be associated with the two-step processes involved in R&D investment. Firm-level factors such as ownership and managerial experience play a role both through required return and marginal adjustment costs. For instance, different firm ownership type can be associated with different risk-return profile, while resource pooling through joint ownership and managerial experience and years of the firm's operations in the sector can affect quality and ease of decisions, which influence marginal adjustment costs. Firm-level variable such as firm size can also affect resource availability and flexibility of decisions, which can affect marginal adjustment costs. These economic basis of uncertainty and information asymmetry offer the intuitions for conjecturing the linkages between R&D investment and a host of firm-specific and business environment factors such as firm size, sub-sectoral characteristics, ownership characteristics, competition and access to external finance. It is well acknowledged that the investment behaviour and performance of a firm is not only determined by its unique internal capabilities and industry characteristics, but also by business environment that embodies policy, regulatory and physical ecosystem in which it operates (World Bank, 2004; Dollar, Hallward-Driemeier, and Mengistae, 2005; Newman et al., 2016). The transmission channels of these factors occur through r, δ, $\Delta p_k/p_k$ and MAC.

4.2 Analysis Approach and Econometric Model

The objective of the study is addressed through descriptive and regression analysis using the World Bank Enterprise Surveys for Kenya. While understanding decision of a firm to undertake R&D is important, it is also vital to understand the factors affecting magnitude of such investments because the productivity impact will eventually depend on the intensity with which it is undertaken. The nature of the dependent variables has implications for the kind of regression analysis, and consequently the econometric models used.

4.2.1 R&D investment decision

First, the analysis focuses on the determinants of the decision to undertake R&D investment. Such binary decisions can be analysed by either Logit or Probit model. While results from the two econometric models yield similar results, in practice Probit is favoured because of its assumption of the normality of the error distribution that makes it convenient to address specification problems (Wooldridge, 2016). For the choice model, the analysis in this study, therefore, employs the Probit model, which is estimated using the maximum likelihood method. The maximum likelihood method selects parameters such that it maximizes the likelihood function by finding the most probable value for a given set of data. The motivation of the panel Probit Model is provided in Appendix 4.

The explanatory variables included in the analyses are based on the theoretical and empirical literature reviewed in earlier sections of this study. The following econometric model is estimated for the R&D investment decision.

$$R\&Ddec_{it} = \beta_0 + \beta_1\, credit_{it} + \beta_2\, informalcomp_{it} + \beta_3\, fsize\_employ_{it} + \beta_4\, fsize\_lnsales_{it} + \beta_5\, fsize\_lnsalessq_{it} + \beta_6\, lnexport_{it} + \beta_7\, lnforeign_{it} + \beta_8\, lnproductdivers_{it} + \beta_9\, judicial_{it} + \beta_{10}\, lnfirmage_{it} + \beta_{11}\, lnfirmagesq_{it} + \beta_{12}\, legal_{it} + \beta_{13}\, political_{it} + \beta_{14}\, tax + \beta_{15}\, subsector_i + u_{it} \quad 4.3$$

The variables used in the model, their descriptions and measurement are provided in Table 4.1. The dependent variable reflects the manufacturing firms' investments decision in R&D and related activities (*R&Ddec*) over a three-year period preceding the survey year. In this case, it reflects whether the firms reported to have undertaken R&D investment and/or reported to have provided formal training or gave time to employees for development or introduction of new products or processes. Thus, if a firm has undertaken either R&D investment, or provided training opportunities or time to develop new ideas, the response variable is coded 1, 0 otherwise. The inclusion of R&D-related activities such as the firms' decision to train or give time to employees for development of new products or processes is in line with previous studies in developing-country contexts (Cirera, 2014). This approach is also helpful in situations where few firms report to undertake R&D investment, as in the case of data used for this study. The choice of the covariates follows the Schumpeterian literature on factors determining knowledge investment activities, which include firm-level, sector and market level variables.

The firm-level variables include employment-related firm size (*firmsize*), export markets participation (*lnexport*), proportion of foreign ownership (*lnforeign*), product diversification (*lnproductdivers*), age of the firm (*lnfirmage*) and its squared term (*lnfirmagesq*), legal status, i.e. form of registration of the firm (*legal*), annual sales (*lnsales*) and its squared term (*lnsalessq*). Firm size is measured both by number of employment and sales to consider the production technology used. Some manufacturing firms are labour-intensive than others, while others can have large output and relatively fewer employees. Firm size can be an important factor especially given that smaller firms can be more risk-averse due to uncertainties involved in R&D outcome as they may suffer severely in case the investment fails to come to fruition. This means the required rate of return would be higher as they are likely to face higher costs of finance and disproportionately higher adjustment costs. This argument would be in line with evidence suggesting that firm performance in developing countries greatly varies by firm size and this has important implications on decisions such as investment behaviour (Ndiaye et al., 2018). Besides firm size, sub-sectoral heterogeneity can also affect R&D investment through channels such technological opportunities owing to the growth phase of the sector and ability to appropriate returns due to structure of the secto, such as competition levels and ease of imitability of knowledge and innovation generated through R&D (Ortega-Argilés, Piva and Vivarelli, 2015), which play a role through δ and $\Delta p/p$. The export market participation is hypothesized to have effects on R&D investment through three possible avenues: first, through learning from demand of foreign consumers R&D-investing firms can be more forward-looking in terms of technology development that is less prone to obsolesce on one hand, and face higher marginal adjustment costs to meet international demands on the other hand. Depending on the technology progress of the sub-sector, exposure to more competitive environment might also affect the rate of obsolescence and relative R&D price changes. Product diversification has implications for firms' decisions in terms of the extent to which managers can assume risk, and therefore resource commitments for R&D investments. Ownership features may also have strategic implications for firms through mechanisms such as resource pooling, flexibility of decision-making, agency costs in case of separation of ownership and management, risk attitude and ownership horizon. The uncertain nature of R&D investment payoff particularly makes implications of these factors vital in light of objectives and preferences of owners (Lee and O'Neill, 2003; Fan and Wang, 2019). Previous research reveals that R&D investment intensity varies with diversification strategies of firms due to reasons such as economies of scope (Baysinger and Hoskisson, 1989).

The quadratic terms for firm-level variables (log of firm age squared and log of sales squared) are included on the right-hand side of the Probit regression due to possible effects on R&D investment decision as was evident from the review of literature. The quadratic terms in regression are usually used to capture increasing or decreasing marginal effects of explanatory variables on the dependent variable (Wooldridge, 2016). Regarding age of the firm, younger firms are observed to intensify investment in knowledge activities for innovation and survival (Fan and Wang, 2019), but with time they face the dynamics of age-linked structural inertia (Le Mens, Hannan and Pólos, 2015), which basically suggests that older firms face relatively higher costs of adjustments and adaptation to changes. An alternative view is that older firms have the advantage of learning effects gained through accumulation of experiences, resources and capabilities that have positive influence. Pulling together these two alternative views, the R&D investment-firm age relationship is expected to exhibit a U-shaped relationship, with younger and much older firms demonstrating higher propensity to engage in undertaking the investment decision. This is because the learning effects is expected to have a dominant role when firms are younger while the age-related structural inertia has a dominant effect as firms grow older (Fan and Wang, 2019), but this negative pressure can diminish as learning resource accumulation benefits sets in beyond some level. Regarding sales as a measure of firm size, the non-linear term is added to take into account the possibility of increasing R&D investment initially owing to economies of scale in form of voluminous turnover over which to spread costs of investments (Cohen and Levin, 1989), but which eventually diminishes owing to dampened marginal productivity and loss of managerial efficiency resulting from increased bureaucratic control (Cohen and Levin, 1989). Thus, it is anticipated R&D investments initially increase with firm size but diminishes beyond some level.

The sub-sector variables are represented by the technological classifications based on UNIDO classification of R&D intensities (*subsector*), while market level variables are accounted for by access to external finance (*credit*), competition emanating from practices of informal sector operators (*informalcomp*), perceptions on the fairness and impartiality of the courts (*judicial*), managerial perceptions regarding political environment and its stability (*political*), and the perceptions regarding taxation as an obstacle (*tax*). The variable on sub-sector technological classification is required to control for variations in technological demands - some sub-sectors are relatively R&D intensive than others due to extensive research required to innovate, and nature of the market, such as openness to domestic and international competition. The market level variables are generally related to the business environment aspects, with transmission mechanisms through costs of doing business, predictability of appropriating returns on R&D investments, and uncertainty of realizing or appropriating returns. Finance is an input to R&D investment. Availability and lower costs of finance is therefore expected to positively impact on the decision and magnitude of R&D investments. The information asymmetry between the firm and potential suppliers of finance can impede access to finance particularly for smaller firms. The specific channels include higher costs of finance as lenders may demand a premium for information asymmetry and uncertainties of outcomes and appropriability of returns. Regarding competition from informal sector firms, the intuition is that formal firms undertaking R&D investments face higher statutory compliance costs and difficulties in appropriability of returns on R&D investments. Further, in a dual market where formal and informal firms compete for the same consumers, formal firms may be dissuaded by ease of imitations, especially in an environment characterized by weak intellectual property protection, as is commonly the case in developing countries (Pérez et al., 2018). Formal firms facing competition from informal firms are therefore expected to suppress their efforts for R&D investments. The institutional quality (reflected here by managerial perceptions on fairness and impartiality of courts, and political stability) can serve to provide firms some degree of assurance on matters such as intellectual property rights. How firms perceive the quality of institutions, say in terms of fairness of the court systems, can therefore be important in the firms' R&D investment behaviour.

Table 4.1: Variables and their measurement[7]

Variable label	Variable Description	Variable measurement level
Dependent Variables		
R&Ddec (R&D investment decision for panel regression)	Whether the firm reported to have invested in R&D investment; and/or reported to have provided formal training or gave time to employees for development or introduction of new products or processes: 1=Invested in R&D 0=Did not invest in R&D	Nominal
R&D_inten (R&D investment intensity for cross section regression)	Previous year's R&D expenditures divided by the firms' annual sales	Ratio
Covariates		
credit	Whether the firm reported to have a line of credit or loan from a financial institution at the time of the survey: 1=Has a line of credit or loan 0=Don't have a line of credit or loan	Nominal
informalcomp	Whether the firm reported it competes against unregistered (informal) enterprises: 1=Competes against informal enterprises 0=Don't compete against informal enterprises	Nominal
fsize_employ	Firm size by employment: - 1=Micro enterprises (1-9 employees); 2=Small enterprises (10-49 employees); 3=Medium and large enterprises (≥50 employees)	Nominal
fsize_lnsales[a]	Firm size as measured by natural log of annual sales	Ratio
fsize_lnsalessq[a]	Firm size as measured by natural log of annual sales squared	Ratio
lnexport	Natural log of % of the firm's export in its total sales	Ratio
lnforeign	Natural log of % of firm's foreign ownership	Ratio
lnproductdivers	Natural log of % of the firm's main product in its total sales	Ratio
judicial	Firm's perception on fairness & impartiality of courts: 1=Agree courts are fair and impartial 0=Disagree courts are fair and impartial	Nominal
lnfirmage	Natural log of the firm age. Firm age is calculated as the number of years since its establishment.	Ratio
lnfirmagesq	Natural log of the firm age squared.	Ratio
legal	Registration form of the firm: 1=Sole proprietorship; 2=Partnership; 3=Company)	Nominal

7 Taking logs for the continuous variables was necessary to rescale the values, minimize the variances and mitigate against outliers

political	Perceptions on whether political instability is an obstacle to the performance of the establishment: 1=Political instability is an obstacle 0=Political instability is not an obstacle	Nominal
tax	Perception of whether taxation (tax rates) in the country an obstacle to business operations: 1=Taxation is an obstacle 0=Taxation is not an obstacle	Nominal
skilled[b]	If access to industrial skill is an obstacle to operations of the firm: 1=Access to industrial skills is an obstacle 0=Access to industrial skills is not an obstacle	Nominal
lnfamilyown[b]	Natural log of % of family ownership	Ratio
lnfamilyownsq	Natural log of % of family ownership squared	Ratio
subsector	Firms' technological intensity based on UNIDO classification. See Appendix 1 for detailed on classifications. 1=Medium-high and high technology; 2=Medium-Low technology; 3=Low technology)	Nominal

Source: Author's compilations; "a" means the covariate applies only to the panel Probit model, "b" the covariate applies only to the cross-section R&D intensity for the two-part model.

4.2.2 R&D investment intensity

In the second model, regarding analysis of R&D intensity , the dependent variable is the amount of R&D expenditures scaled by sales. As noted earlier, the analysis for R&D intensity uses cross section data for the 2018 World Enterprise Survey for Kenya since the 2013 wave of the survey did not capture this variable. In previous studies, the data is scaled for firm size, say in terms of R&D per employee (Griffith et al., Huergo, 2006) or R&D as a ratio of sales (Helfat, 1997; Jung and Kwak, 2018). The scaling in this study is achieved by dividing R&D investment by annual sales. Sales better reflect the size of the firm due to differences in production technology used (i.e. mix of factors of production). Given that a significant proportion of the sampled firms do not undertake R&D investment, Cragg's Two Part Model (Cragg, 1971) is used considering data on the dependent variable piles-up at a point, in this case zero.

The advantage of the two-part model is that it allows for different mechanisms to determine the R&D investment decision and R&D intensity (Wooldridge, 2010; Belotti et al., Deb, 2015). An alternative econometric model, as used in previous literature, is the use of Tobit model (Cohen, Levin and Mowery, 1987; Helfat, 1997; Cuervo-Cazurra and Un, 2010), which has the limitation of assuming the same mechanisms affecting the participation and intensity decisions. The Tobit model assumes that the partial effects of a covariate on $P(y>0|x)$ and $E(y|x)$ have the same statistical sign, and that the relative effects of two continuous covariates, say x_k and x_m on $P(y>0|x)$ and $E(y|x)$ remains constant and equal to β_k/β_m, which may not hold and are considered too restrictive. The other alternative, the Linear Regression Model (LRM), if applied to cases where data is concentrated at some points would yield biased and inconsistent estimates of the regression coefficients (Maddala, 1983; Wooldridge, 2016). As an alternative to the whole sample, some studies restrict the analysis only to the R&D active firms (Galende and *de la* Fuente, 2003) and apply LRM. This approach is, however, associated with sample selection and, therefore, biased parameters (Raffo, Lhuillery and Miotti, 2008). The motivation of the cross-section two-part Model is provided in Appendix 4. The following econometric model is estimated for the R&D investment intensity.

$$R\&D\_inten_i = \alpha_0 + \alpha_1\, credit_i + \alpha_2\, informalcomp_i + \alpha_3 fsize\_employ_i + \alpha_4 lnexport_i + \alpha_5\, lnforeign_i + \alpha_6\, lnproductdivers_i + \alpha_7 judicial_i + \alpha_8\, lnfirmage_i + \alpha_9\, lnfirmagesq_i + \alpha_{10}\, legal_i + \alpha_{11}\, political_i + \beta_{12}\, tax + \alpha_{13}\, skilled_i + \beta_{14}\, lnfamilyown_i + \beta_{15} familyownsq_i + \alpha_{16}\, subsector_i + \varepsilon_i \quad 4.4$$

The differences between equation 4.3 and equation 4.4 regarding the explanatory variables is the addition of the variables *'skilled'* to account for lack of skilled manpower to technological upgrading and *'familyown'* for proportion of family ownership and its square term *'lnfamilyownsq'*. These variables have been established in literature to influence R&D investments but were captured only in the 2018 World Bank Enterprise Survey for Kenya. Family-owned firms face a different agency situation compared to other firms especially in light of information asymmetry around knowledge creation, dual goals of realizing business growth and realizing family needs, and uncertain returns especially in the short-term, making it important to control for family ownership in regression analysis (Block, 2012). A non-linear relationship is expected between family ownership and R&D investment as risk preferences may vary with increasing ownership concentration. While an inverted U-relationship has been observed in some instances owing to family-risk aversion, higher levels of family concentration are expected to have positive impacts on R&D investment intensity in instances characterized by long-term strategic orientations and firm performance that falls below aspirational levels (Chrisman and Patel, 2012). The other difference in equation 4.4 is that since the dependent variable is scaled by sales, it is appropriate to omit *sales* and its squared term *salessq* as part of the explanatory variables. Other explanatory variables in equation 4.4 remain as defined earlier in equation 4.3.

4.3 Data Sources

For R&D investment decision, the study takes advantage of a panel (longitudinal) data of the World Bank Enterprise Surveys of 2013 and 2018. While the panel is available for three waves of the survey 2007, 2013 and 2018, the analysis is restricted to the most recent two waves (2013 and 2018) since the sample size significantly reduces for the variables considered if the 2007 wave is included. This limitation is due to the methodological changes and survey evolution that limits matching all variables across the three waves (World Bank, 2019b). For R&D investment intensity, due to lack of panel data on the dependent variable, the analysis employs cross sectional analysis using the 2018 World Bank Enterprise Survey data for the manufacturing firms.

The World Bank Enterprise Survey covers formal sector enterprises with 5+ employees in the private sector. It includes enterprises in manufacturing and service sectors. The 2018 survey covered 1,001 firms of which 455 were in the manufacturing sector. The survey mainly covers urban counties that accounts for a large share of the private sector activities. The 2018 survey covered 10 counties: Nairobi, Kiambu, Nakuru, Mombasa, Kirinyaga, Kisumu, Uasin Gishu, Kilifi, Machakos, and Trans Nzoia. The earlier surveys were not based on counties but had regional focus that included Nairobi, Central, Rift Valley, Coast and Nyanza.

5. Findings and Discussions

5.1 Descriptive Results - R&D Investment Decision

Table 5.1 shows summary statistics for various variables used in the analyses. About 59.9 per cent of the sampled firms reported to have undertaken R&D investment activities during the year preceding the survey years in 2013 and 2018. Regarding access to external finance, 58.8 per cent of the firms surveyed indicated they had access to loan or a line of credit while 53.5 per cent indicated they face competition from informal sector enterprises. The value of exports accounts for 23.2 per cent of the firms' sales, on average. Further analysis shows that only about a third of Micro and Small Enterprises (MSEs) report to have participated in export trade, compared to about 70 per cent for medium and larger enterprises. Exporting behaviour is therefore in favour of medium and large enterprises. The share of foreign ownership was also reported to be low at about 10.6 per cent. The share of main products in firms' total sales was significantly high at 89.1 per cent, an indication of product concentration and limited product diversification. Only 48.3 per cent of the firms perceive the court system to be fair and impartial. Regarding R&D intensity technological content with a mean of about 2.5, it means that manufacturing industries in Kenya largely fall in the low-technology sub-sector such as food and beverages, textiles and leather processing (Complete listing is provided in Appendix 1). The implication is that demand for R&D investments in the overall Kenyan manufacturing sector will likely remain low because of the low technological content of these industries. For firm size (as measured by employment) the mean of 2.2 implies that the sampled firms are mostly small-size category. While Kenyan firms are largely micro-level in size, the World Bank Survey targets formal firms with 5+ employees and this perhaps explains why the average in this case reflects dominance of small firms (10-49 employees based on Kenyan definition). Regarding the legal status (i.e. forms of registration)[8], the mean of 2.0 points out that most of the sampled firms are partnerships.

In panel data, both the dependent variable and covariates can vary across observations ('between variations') and over time ('within variations'). The standard deviations in Table 5.1 show that there is more between variations compared to within variations, a suggestion that over the survey cycle, not much changes have been experienced at firm level relative to changes between firms regarding the variables included in the analyses. The minimum and the maximum values for the within variation for the dependent variable (R&D investment decision) as shown in Table 5.1 (i.e. values below 0 and 1, respectively) indicate that, on average, more firms that reported to have undertaken R&D investment during the 2013 survey reported not to have undertaken such investments in the 2018 wave of the survey. This, therefore, means a slowdown in R&D investment activities. This point is further made clear in Figure 5.1. The T-bar in Table 5.1 shows that, on average, the sampled firms performed R&D investment about 1.2 times across the two waves of the survey, thus showing limited continuity in R&D investments across the years.

8 Note that all the sampled firms are formal in the sense that they are registered. Type of registration in this context refers to sole proprietorship, partnership and company (respectively coded 1, 2 and 3).

Table 5.1: Summary statistics for panel data

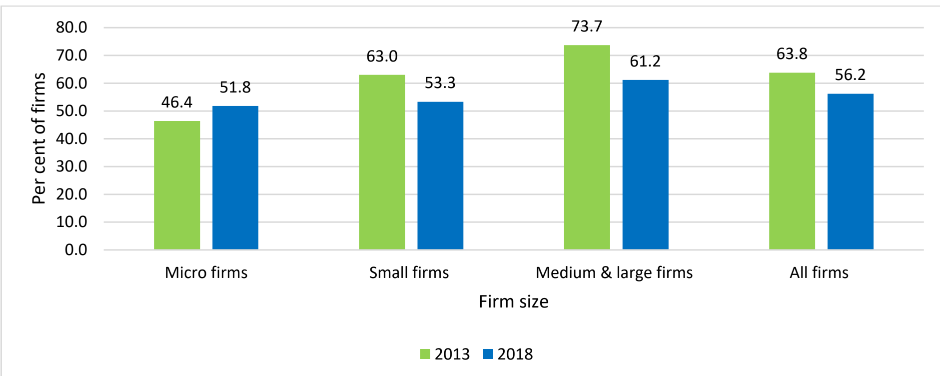
Variable	Variation	Mean	Std dev.	Min	Max	Observations
R&Ddec (R&D investment decision)	Overall	0. 5986	0. 4905	0.0000	1.0000	N =862.0000
	Between	...	0. 4771	0.0000	1.0000	n =735.0000
	Within	...	0. 1598	-0. 0986	0 .7960	T-bar =1.1728
credit (Access to loan/ line of credit)	Overall	0 .5883	0.4924	0.0000	1.0000	N =855.0000
	Between	...	0.4797	0.0000	1.0000	n =729.0000
	Within	...	0.1530	0.0883	1.0883	T-bar =1.1728
informalcomp (Informal sector competition)	Overall	0.5351	0.4991	0.0000	1.0000	N =841.0000
	Between	...	0.4808	0.0000	1.0000	n =721.0000
	Within	...	0.1776	0.0351	1.0351	T-bar =1.1664
fsize_employ (Firm size by employment)	Overall	2.2133	0.7499	1.0000	3.0000	N =858.0000
	Between	...	0.7534	1.0000	3.0000	n =731.0000
	Within	...	0.1323	1.7133	2.7133	T-bar =1.1737
fsize_sales (Annual sales, Ksh M)	Overall	1,890.0	16,900.0	0.1000	425,000.0	N =772.0000
	Between	...	18,100.0	0.1000	425,000.0	n =671.0000
	Within	...	689.0	-6,570.0	10,400.0	T-bar =1.1505
export (Per cent of sales exported)	Overall	23.1542	35.3726	0.0000	100.0000	N =856.0000
	Between	...	34.9536	0.0000	100.0000	n =731.0000
	Within	...	9.6929	-26.8458	73.1542	T-bar =1.1710
foreign (Per cent share of foreign ownership)	Overall	10.5723	27.0158	0.0000	100.0000	N =858.0000
	Between	...	27.0857	0.0000	100.0000	n =730.0000
	Within	...	7.4826	-39.4277	60.5723	T-bar =1.1753
productdivers (Per cent of main product in total sales)	Overall	89.0776	17.1398	20.0000	100.0000	N =864.0000
	Between	...	16.7168	20.0000	100.0000	n =736.0000
	Within	...	5.4075	59.0776	119.0775	T-bar =1.1739
judicial (Courts fair and impartiality)	Overall	0.4825	0.5000	0.0000	1.0000	N =800.0000
	Between	...	0.4806	0.0000	1.0000	n =689.0000
	Within	...	0.1821	-0.0175	0.9825	T-bar =1.1611
firmage (Firm's age, years)	Overall	28.4767	18.9128	0.0000	107.0000	N =860.0000
	Between	...	18.7838	0.0000	107.0000	n =732.0000
	Within	...	1.4872	15.9767	40.9767	T-bar =1.1749
legal (Firm's legal status)	Overall	2.0658	0.7015	1.0000	3.0000	N =851.0000
	Between	...	0.6788	1.0000	3.0000	n =724.0000
	Within	...	0.2401	1.0658	3.0658	T-bar =1.1754
political (Political instability obstacle)	Overall	0.8126	0.3905	0.0000	1.0000	N =859.0000
	Between	...	0.3782	0.0000	1.0000	n =734.0000
	Within	...	0.1428	0.3126	1.3126	T-bar =1.1703
tax (Taxation constraint)	Overall	0.7995	0.4006	0.0000	1.0000	N =858.0000
	Between	...	0.3948	0.0000	1.0000	n =733.0000
	Within	...	0.1301	0.2995	1.2995	T-bar =1.1705

subsector (Subsector based on technology content)	Overall	2.4867	0.8051	1.0000	3.0000	N =865.0000
	Between	...	0.7840	1.0000	3.0000	n =737.0000
	Within	...	0.2083	1.4867	3.4867	T-bar =1.1737

Data Source (World Bank, 2019a); n is the number of observations; N is the total number of individual-time observations; and T-bar is the waves or the average number of time periods a variable is observed, equivalent to N/n.

Except for micro enterprises, a larger share of the sampled firms reported to have undertaken R&D investment activities during the 2013 wave of the survey compared to 2018 (Figure 5.1). The improved performance for micro enterprises is largely driven by reported cases of training to employees for development or introduction of new products or processes, and not the direct R&D investments. The general decline in R&D investment decisions perhaps reflects increasing barriers for R&D investment environment, including difficulties in access to credit due to interest rate capping introduced in 2016. For instance, the proportion of micro and small firms with access to a bank loan or a line of credit marginally declined from 30 per cent in 2013 to 27 per cent in 2018 (World Bank, 2019a). An additional insight from Figure 5.1 is that there is a size phenomenon displayed by manufacturing firms in the decision to undertake R&D investments, and this is observed across both the 2013 and 2018 waves of the survey. With larger size, firms tend to have better human and non-human resources that can serve to support investment in R&D. Further, there are uncertainties related to appropriability of returns on R&D investments, which larger firms can accommodate compared to micro and small firms.

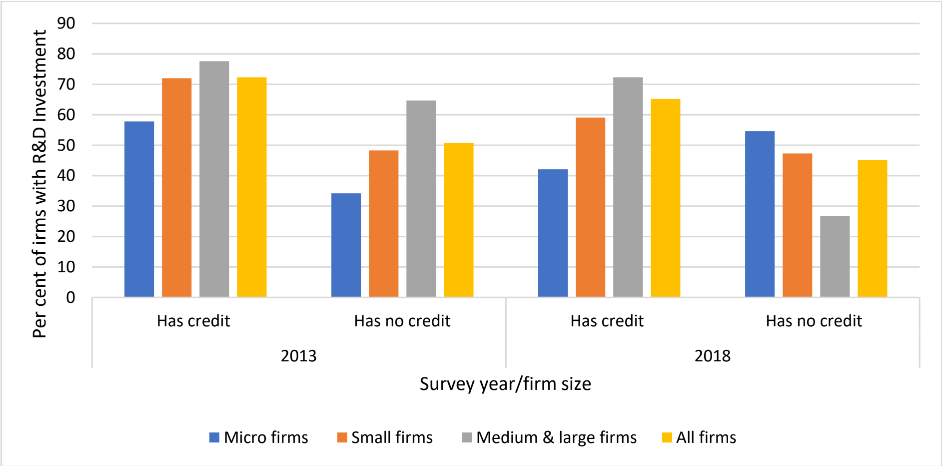
Figure 5.1: Share of manufacturing firms with R&D investment in 2013 and 2018



Data Source: World Bank (2019a)

Firms with access to credit irrespective of the size generally tend to have higher incidence of undertaking R&D investment decision (Figure 5.2). This is an indication that access to credit can be an important input to R&D, perhaps as it complements limited internal financing opportunities.

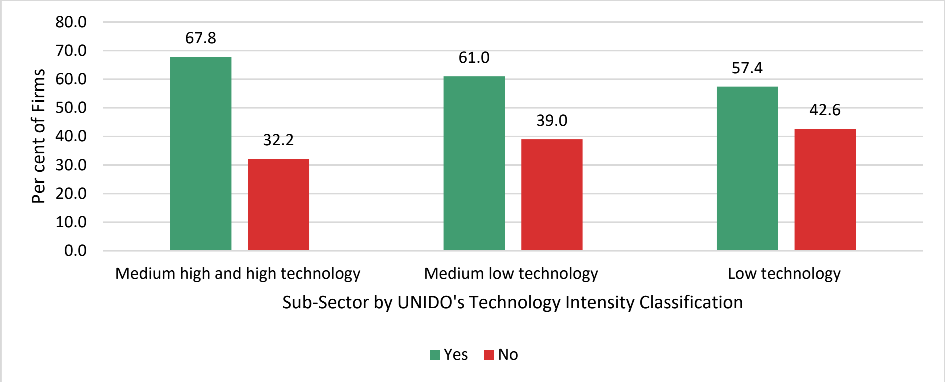
Figure 5.2: Share of manufacturing firms with R&D by access to credit



Data Source: World Bank (2019a)

The SDG 9 calls for diversification into medium and high technology manufacturing sub-sectors among developing countries as a strategy for sustainable industrialization. Figure 5.3 illustrates the share of manufacturing firms with R&D investments, based on UNIDO's classification of technological intensity. On average, among the firms classified as medium high and high technology intensity, 67.8 per cent reported to have undertaken R&D investments, compared to 61.0 per cent for those classified as medium low technology and 57.4 per cent for those classified as low technology. The details on classification of manufacturing sub-sectors by technological intensity are provided in Appendix 1. Evidently, manufacturing priorities in the "Big Four" agenda (agro-processing, textile and leather) of the Kenyan government all fall in the low technology intensity sub-sectors. While these sub-sectors can serve as anchors for job creation due to labour intensity and strong linkages with the agriculture sector, they may not provide much in terms of attracting R&D investments towards achievement of policy targets such as those envisaged in SDG 9. The UNIDO's Industrial Development Report 2020 reveals that the overall share of medium and high-technology manufacturing value added share in total manufacturing GDP for Kenya is only 15 per cent, unfavourably comparing to competitor and aspirator economies such as Egypt (18%), South Africa (24%), China (41%), India (43%), Malaysia (44%), Singapore (78%) and South Korea (63%) (UNIDO, 2019).

Figure 5.3: Proportion of manufacturing firms with R&D by sub-sector technological intensity*



*Data Source: World Bank (2019a); *This is the average for 2013 and 2018 waves of the survey*

The key features of the sampled firms, including R&D investment decisions, technological intensity classification and size are analysed, and the results provided in Table 5.2. The R&D investment varies across the counties that were covered by the survey. Kirinyaga has the highest proportion of firms undertaking R&D investment, followed by Machakos, Murang'a, Kisumu, Nairobi, Uasin Gishu and Mombasa counties. The pattern is perhaps explained by the ecosystem in which the firms operate, such as availability of clusters of similar firms and skills owing to presence of institutions of higher learning in majority of these top-ranking counties.

Table 5.2: County level variations in manufacturing R&D, technology intensity and firm size

County	R&D invested (%)		Firms Distribution by Technology Intensity (%)			Firm Size (%)		
	Yes	No	Low technology	Medium technology	High technology	Micro	Small	Medium & large
Mombasa	53.1000	46.9000	63.7000	14.2000	22.1000	16.1000	47.3000	36.6000
Kilifi	28.6000	71.4000	85.7000	14.3000	0.0000	57.1000	42.9000	0.0000
Machakos	66.7000	33.3000	53.3000	30.0000	16.7000	10.0000	53.3000	36.7000
Kirinyaga	83.3000	16.7000	98.1000	1.9000	0.0000	63.0000	18.5000	18.5000
Kiambu	43.9000	56.1000	82.2000	10.3000	7.5000	11.2000	48.6000	40.2000
Trans Nzoia	50.0000	50.0000	100.0000	0.0000	0.0000	50.0000	40.0000	10.0000
Uasin Gishu	57.7000	42.3000	80.8000	15.4000	3.8000	46.1000	38.5000	15.4000
Nakuru	50.0000	50.0000	78.8000	8.3000	12.9000	25.3000	43.4000	31.3000
Kisumu	66.1000	33.9000	71.4000	5.4000	23.2000	24.1000	33.3000	42.6000
Nairobi	65.9000	34.1000	54.6000	13.9000	31.5000	7.9000	36.3000	55.8000

Nyeri	37.5000	62.5000	100.0000	0.0000	0.0000	56.3000	37.5000	6.2100
Murang'a	66.7000	33.3000	100.0000	0.0000	0.0000	73.3000	26.7000	0.0000

Data Source: World Bank (2019a)

5.2 Regression Results

This section first provides correlation analysis for insights on the strength and direction of association between variables before delving deeper into the regression analysis for causality using panel Probit Model covering the 2013 and 2018 waves of the World Bank Enterprise Surveys. Given that some variables are nominal, it is ideal to use Spearman's rank correlation coefficient, which is a non-parametric test for measuring the direction and strength of association between two variables. Appendix 5 shows the correlation matrix. A few insights can be drawn from the correlation matrix. In terms of association between R&D investment decision and the explanatory variables, there are indications of positive association between R&D decision and access to credit, employment-related firm size, export market participation, and sales. The associations among the explanatory variables are generally low (about 0.30 or less), save for firm size by employment and sales (about +0.64) and the squared terms with their level counterparts. This finding suggests that firm size in terms of employment and sales are positively correlated. Increase in share of sales exported tends to demonstrate a positive association with age of the firm, joint ownership (as opposed to sole proprietorship) and firm size. Firms with higher share of foreign ownership tend to be larger firms.

For purposes of regression analysis, continuous explanatory variables are transformed by taking logarithms for scaling purposes, aimed at reducing the range and make estimates less sensitive to outliers (Wooldridge, 2016). To test for multicollinearity among the explanatory variables, Variance Inflation Factor (VIF) was employed. The individual VIFs, excluding the squared terms, lie between 1.02 and 3.56 with a mean of 1.62. There is, therefore, no sufficient evidence of high multicollinearity among the covariates, given that the VIF values are below the threshold of 10 (Wooldridge, 2016).

5.2.1 R&D investment decision

As evident from literature (Cuervo-Cazurra and Un, 2010), the factors driving R&D investment decision and R&D investment magnitude can vary. The regression results are shown in Table 5.3 (for Probit marginal effects) and Appendix 6 (for Probit coefficients). For non-linear econometric models such as Probit, the focus for interpretations is on the marginal effects, which reflects the relationships between explanatory variables and the actual observed binary outcomes for the dependent variable (1=Yes for R&D, 0=No for R&D in this case). The coefficients in Appendix 6 show that the relationship between explanatory variables and the underlying continuous latent dependent variable is important only as far as understanding the signs and significance of the quadratic terms (i.e. log of firm age squared, and log of sales squared) are concerned. Using the factor-variable notation (#) in Stata, marginal effects for quadratic (exponential) or interaction terms are not generated. This is because the value of the quadratic or interaction term cannot vary exogenous of the values of its constituent terms (Ai and Norton, 2003; Williams, 2012). Thus, it would be inappropriate to estimate a separate marginal effect for the quadratic or interaction term separately by, for example, manually generating these terms and including them in the regression equation as is seen in some applied work. The marginal effects of the quadratic terms are therefore not displayed in Table 5.3. As indicated in Section 4.2 of this study, quadratic terms in regression are used to capture increasing or decreasing effects of explanatory variables on the dependent variable (Wooldridge, 2016). Margins plot (Royston, 2013) are generated for the quadratic terms to demonstrate possibilities of non-linear relationship (e.g. see Figure 5.4a and 5.4b). The margins displayed in the regression tables for continuous variables usually show instantaneous rate of change and tend to confound some important relationships, which can be overcome by using margins plot (Royston, 2013).

The regression results are obtained for two models. In Model 1, the sub-sectors are aggregated based on UNIDO's technological intensity classification. Model 2 discerns the effects of food, textile and apparel, and leather sub-sectors given their emphasis in the "Big Four" agenda and the Kenya Vision 2030. It should be noted that the three sub-sectors (food, textile and leather) are part of low technology sub-sectors as per UNIDO classification. Except for discussions of these sub-sectors in Model 2, the other discussions therefore focus on Model 1. The results show that the factors affecting R&D investment decision include access to credit, competition from practices of informal sector enterprises, firm size as measured by sales, export market participation, age of the firm and sub-sector technological classifications. The marginal effects presented refer to Average Marginal Effects (AMEs), which is preferable to Marginal Effects at Means given the numbers obtained better reflects observations in the data set (Long and Freese, 2014).

Firms with a line of credit or loan from a financial institution have 13.4 percentage point higher probability of undertaking R&D investment compared to firms without a loan or line of credit. Firms that report to face competition from practices of informal sector enterprises have 7.5 percentage point lower probability of undertaking R&D investments, compared to those who reported they do not face competition from informal sector enterprises. It is likely that competition from the informal sector increases uncertainty of appropriating returns on R&D investments, for example through reduced economies of scale. In terms of firm size as measured by sales, there is a 2.3 percentage point higher probability of undertaking R&D investment for a marginal increase in the log of sales. There is, however, a non-linear association; the margins plot in Figure 5.4b relates to the effects of log of sales on predicted probability to engage in R&D investment. The effects initially increase for a substantial range of log of sales, peaks and falls thereafter. This implies that as firm size increases, there could be inefficiencies in managerial effectiveness due to bureaucratic decisions, or firms turn to other strategies to remain competitive. The initial positive effects of firm size on R&D investment decision can be explained by advantages of internal resource capability, and ability to bear uncertainties involved in R&D investments. Furthermore, larger firms can benefit from economies of scale because of spreading R&D investment costs over larger outputs (Cohen and Levin, 1989). These findings suggest that advantages of firm-size effects may be dominated by inefficiencies in managerial control beyond some level. The firm size effects based on employment size is insignificant after controlling for size based on sales.

In terms of sub-sectoral technological differences, firms in the low technology sub-sectors have about 11.5 percentage point lower probability of undertaking R&D investments compared to firms in the medium-high and high technology sub-sectors. While these results are unsurprising, it is a concern for developing countries where low technology sub-sectors account for a large share of manufacturing GDP (UNIDO, 2019), and particularly for economies such as Kenya that have put special focus on sub-sectors such as agro-processing, textile and leather that fall in low technology sub-sector. An important policy implication is that for countries that have large shares of low technology sub-sectors, it might be harder to reach industrialization targets such as those envisaged in the SDG 9 through private sector initiatives. Weak R&D investments in developing countries make it much harder for them to catch up with developed economies (Lee, 2013; Goñi and Maloney, 2017). The marginal effects in Table 5.3 suggest that firms in textile and garments, and leather sub-sectors have 15.1 percentage points and 28.4 percentage points lower probability, respectively, of undertaking R&D investment compared to firms in the medium-high and high technology sub-sector. Besides the technological content characteristics, the lower probabilities of decisions to invest in R&D among the firms in textile and garments, and leather sub-sectors can be due to intense competition from substitutes such as second-hand imports and imports from low cost economies. This view is consistent with the extant literature suggesting that influx of imports dissuades investment in R&D (Becker and Pain, 2008).

The results suggest strong positive effects of export market participation on the manufacturing firms' R&D investment decision. For a marginal increase in the log of share of exports, the probability of undertaking R&D investment increases by 3.8 percentage points. The positive effects of exporting behaviour on the decision to undertake R&D investment can be due to learning by exporting hypothesis (Grossman, 1991) and exposure to international consumer demands and more intensive international competition forces (Aw, Roberts and Winston, 2007; Girma, Görg and Hanley, 2008). As was revealed by descriptive statistics (Table 5.1), only 23.2 per cent of the value of sales of the sampled manufacturing firms are exported, on average, an indication of limited opportunities for R&D investment transmission channel of 'learning by exporting'. Some of the factors that have been identified to constrain Kenyan firms' exports relate to high costs of production and non-tariff barriers, such as technical regulations and conformity assessments that impose cumbersome procedures and high transaction costs (International Trade Centre, 2014; Were, 2016).

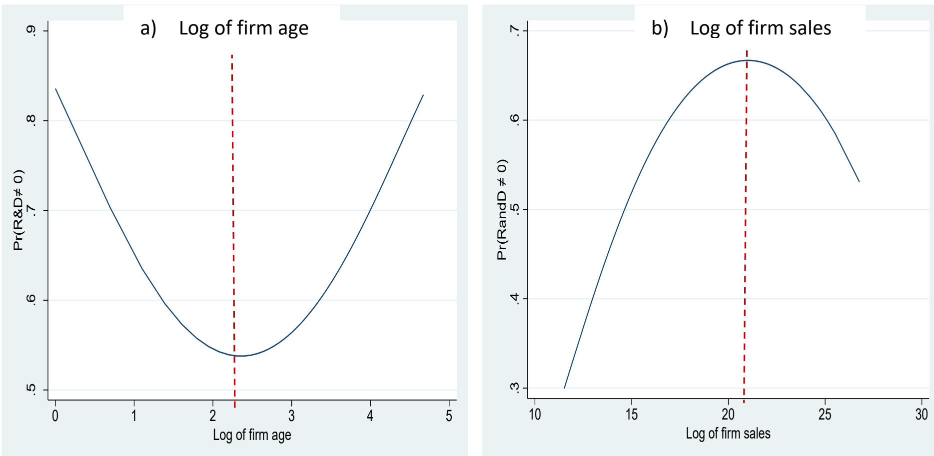
Table 5.3: Panel probit marginal effects

Variables		Model 1	Model 2
credit: Has access to a line of credit or loan		0.1340*** (0.0385)	0.1300*** (0.0383)
informalcomp: Competes against informal enterprises		-0.0748** (0.0351)	-0.0718** (0.0351)
fsize_employ: Firm size by employment	Small enterprises	0.0206 (0.0556)	0.0331 (0.0570)
	Medium and large enterprises	-0.0261 (0.0655)	-0.0020 (0.0679)
fsize_lnsales: Natural log of annual sales		0.0233** (0.0105)	0.0218** (0.0105)
lnexport: Natural log of % of the firm's exports it its total sales		0.0383*** (0.0104)	0.0379*** (0.0106)
lnforeign: Natural log of % of firm's foreign ownership		-0.0030 (0.0123)	-0.0015 (0.0122)
lnproductdivers: Natural log of % of firm's main product in its total sales (product diversification)		-0.0876 (0.0697)	-0.0919 (0.0691)
judicial: Agree courts are fair and impartial		-0.0015 (0.0345)	-0.0033 (0.0345)
lnfirmage: Natural log of firm age		0.0844*** (0.0281)	0.0816*** (0.0281)
legal: Registration form of the firm	Partnership	-0.0386 (0.0512)	-0.0429 (0.0509)
	Company	0.0317 (0.0557)	0.0202 (0.0566)
political: Political instability is an obstacle		0.0480 (0.0484)	0.0520 (0.0488)
tax: Taxation is an obstacle		-0.0172 (0.0448)	-0.0213 (0.0448)
subsector: Firms technological intensity based on UNIDO classification	Medium technology	-0.0842 (0.0691)	-0.0827 (0.0689)
	Low technology	-0.1150** (0.0466)	-0.125** (0.0605)
	Food		-0.0794 (0.0521)
	Textile and garments		-0.1510** (0.0670)
	Leather		-0.2840** (0.1270)
Observations		666	666

*Data Source: World Bank (2019a); Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0*

Controlling for other factors included in the model, age of the firm initially tends to have negative effects on the decision to undertake R&D, but the effects turns out to be positive as the age grows larger as shown by the Probit coefficients of the squared term of log age (Appendix 6). This finding is confirmed by the margins plot for log of firm age shown in Figure 5.4a, showing that the predicted probability of the decision to undertake R&D investment initially decreases with increase in average age of the firm up to about log age 2.3 years (about 9.8 years in level), beyond which the margins steadily increase. Potential explanations for these findings can be linked to innovation opportunities at much younger age and resource accumulation and learning by doing (which increases efficiency of R&D) with more years of operations (Coad, Segarra and Teruel, 2016).

Figure 5.4: Margins plot of log of firm age (panel a) and log of firm sales (panel b)



Data Source: World Bank (2019a)

5.2.2 R&D investment intensity

This section presents results of the two-part model, using R&D investment as a proportion of annual sales. The descriptive statistics are provided in Table 5.4. The R&D intensity (R&D expenditures divided by the firms' annual sales) is low at about Ksh 0.01 per sales. The relatively larger standard deviation reflects larger dispersion in R&D efforts across the firms. About 55.0 per cent of the sampled firms reported to have access to loan or a line of credit. Majority of the firms are in low technology intensity activities, with 53.8 per cent indicating they face competition from activities of informal sector enterprises. In terms of firm size, majority of the sampled firms are MSEs. The share of firms' sales exported is about 21.4 per cent on average, while the share of foreign ownership is 12.2 per cent, on average. The average share of family ownership is high at 67.7 per cent. A large proportion of the sampled manufacturing firms reported high incidences of perceived business environment constraints to their operations: Political instability (82.6%), taxation (81.8%) and constraints in availability of relevant industrial skills (65.3%). The correlation among the explanatory variables (Appendix 5b) is low, save for those with squared terms, which is expected.

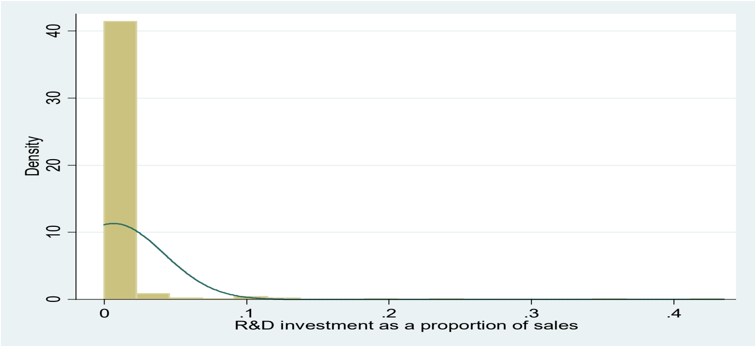
Table 5.4: Descriptive statistics for R&D investment intensity variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
R&D_inten (R&D investment intensity)	402	0.0065	0.0351	0.0000	0.4348
credit (Access to loan/line of credit)	451	0.5499	0.4981	0.0000	1.0000
subsector (Subsector based on technology content)	455	2.5077	0.7736	1.0000	3.0000
informalcomp (Informal sector competition)	446	0.5381	0.4991	0.0000	1.0000
fsize_employ (Firm size by employment)	455	2.2220	0.7400	1.0000	3.0000
export (Per cent of sales exported)	454	21.4251	34.9983	0.0000	100.0000
foreign (Per cent share of foreign ownership)	453	12.1832	29.4013	0.0000	100.0000
productdivers (Per cent of main product in total sales)	455	89.4747	16.9299	20.0000	100.0000
judicial (Courts fair and impartiality)	429	0.4732	.4999	0.0000	1.0000
firmage (Firm's age, years)	454	26.3282	18.6597	0.0000	103.0000
legal (Firm's legal status)	455	2.1165	0.7006	1.0000	3.0000
political (Political instability obstacle)	453	0.8256	0.3799	0.0000	1.0000
tax (Taxation constraint)	450	0.8178	0.3865	0.0000	1.0000
skilled (Skills constraint)	447	0.6532	0.4765	0.0000	1.0000
familyownsq (Proportion of family ownership)	445	67.6562	40.9629	0.0000	100.0000

Data Source: World Bank (2019a)

The R&D investment intensity is highly skewed. Skewness (measure of symmetry) and kurtosis (deviation of tails of a distribution compared to that of normal distribution) provide measures of divergence of a distribution from normality. Ideally, the value in the normal distribution for skewness and kurtosis are 0 and 3, respectively (Daniels and Minot, 2020). The values of skewness and kurtosis for the R&D investment intensity are 8.7 and 89.6, respectively, indicating R&D intensity is not normally distributed. The positive value of skewness (8.7) suggests the R&D investment distribution is skewed to the right, while the value of 89.6 for kurtosis shows relatively thicker tails and more outliers compared to a normal distribution. The skewness and kurtosis are significantly different from those of a normal distribution at 5 per cent significance level. The graphical distributions of dependent variable are shown in Figures 5.5a-5.5c. Figure 5.5a shows the distributions of R&D investment as a proportion of sales for all the sampled manufacturing firms (i.e., the visual illustration corroborates the skewness and kurtosis statistics of deviations from normality).

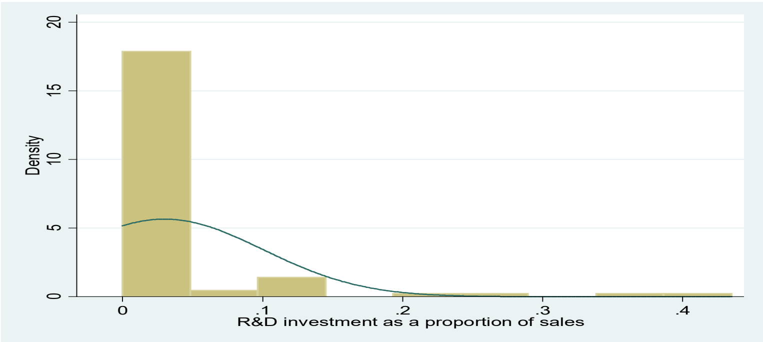
Figure 5.5a: Distribution of R&D as a fraction of sales for R&D≥0



Data Source: World Bank (2019a)

Figure 5.5b shows the distribution of R&D investment as a fraction of sales for firms with positive R&D. The distribution is still skewed with large concentrations near zero. It shows that among the sub-sample of firms that undertake R&D investments, majority undertake only marginal investments relative to sales (i.e. few firms have a large R&D investment intensity compared to majority).

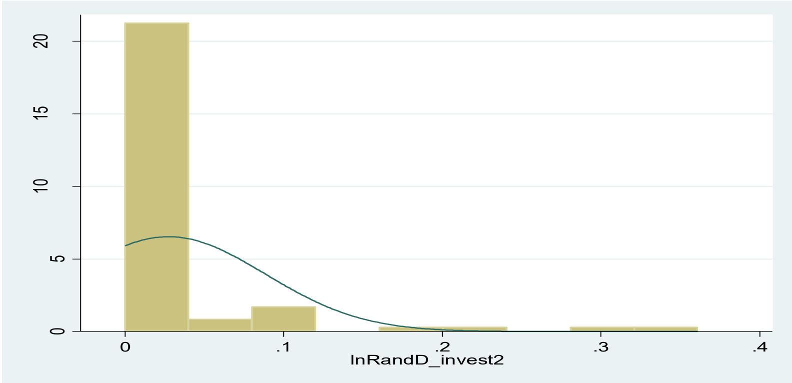
Figure 5.5b: Distribution of R&D investment as a fraction of sales for R&D>0



Data Source: World Bank (2019a)

Taking logarithm of a variable helps to narrow its range and in case of a dependent variable helps in achieving the classical linear model assumptions such as normally distributed error, compared to level forms (Wooldridge, 2016). The distribution of the log transformation of the dependent variable is shown in Figure 5.5c. The log transformation achieves little in normalization of the distribution of R&D investment intensity variable.

Figure 5.5c: Log of distribution of R&D as a fraction of sales for R&D>0



Data Source: World Bank (2019a)

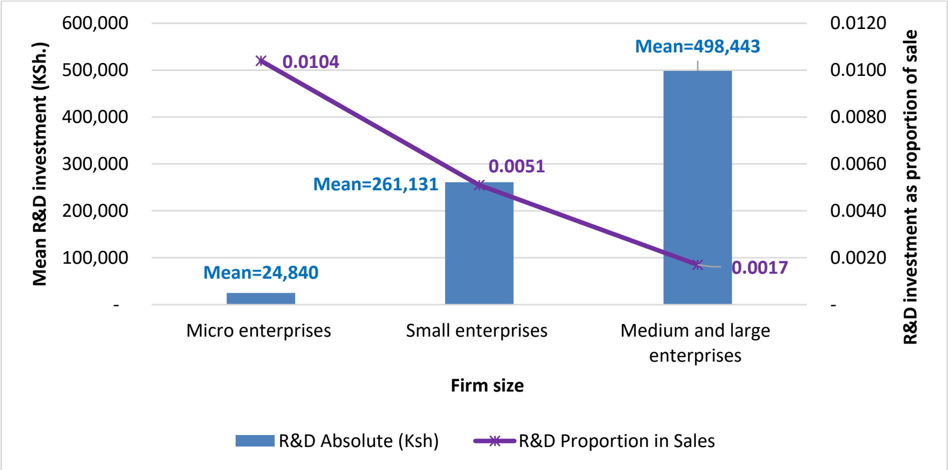
The results in Figures 5.5a-5.5c have implications for the choice of the specifications for the second part of the two-part model, in which either Ordinary Linear Regression or the Generalized Linear Model (*GLM*) is used. The use of *GLM* as opposed to the ordinary linear regression has some advantages for highly skewed data. Compared to linear regression, *GLM* offers some advantages, including a range of functional forms to obtain the expected value of the outcome variable as a function of a linear index of covariates; accommodation of skewness; and explicit modelling of heteroskedasticity, in which variance is not constant across the observations (Deb and Norton, 2018). Distributions with mass at zero, such as the one observed in R&D intensity variable, is usually characterized by heteroskedasticity, hence the use of *GLM* is more appropriate.

The two-part model provides results for R&D investment decision and R&D intensity. Table 5.5 presents the regression results of the two-part model. The first part (participation decision) employed Probit model and the second part *GLM*. Besides the covariates included in the panel Probit, two additional covariates are considered in this section: Challenges relating to lack of skilled manpower for technological upgrading; and proportion of family ownership. These two variables are not available for the panel data because they were covered only in the 2018 wave of the World Bank Enterprise Survey for Kenya. These two variables have been shown to be important factors determining R&D investment (Sciascia et al., 2015; Choi et al., 2015) and their exclusion in the analysis of a cross sectional data can result to variable omission bias, particularly for a cross-sectional data as in this case.

The results for the R&D intensity, which is the main focus of this section, show that informal sector competition, employment-based firm size, and legal status (registration type) of the firm are the factors determining R&D investment intensity among the surveyed manufacturing firms. Firms that reported they face competition from informal sector enterprises have about Ksh 1.2 lower R&D investment per annual sales, compared to those that reported they do not compete against informal sector enterprises conditional on spending any amount. While competition within the formal sector alone can have positive benefits, competition emanating from practices of informal sector enterprises can pose negative investment incentives to formal enterprises due to cost differences such as regulation, and taxes faced by firms in the formal sector (González and Lamanna, 2007; Pérez et al., 2018). It is also noteworthy that the economy is dualistic in nature, with markets for formal and informal firms for a particular industry not being segmented. The fact that formal and informal firms operate in the same market raises the uncertainty of appropriating returns on R&D investments, perhaps lowering the incentives to commit significant investments. The findings underscore the importance of transitioning informal enterprises to the formal sector, not only for the benefits of formalizing firms but also for boosting investments among other formal firms. Research on the informal sector in Kenya show that while 53 per cent of the informal firms report willingness to formalize, their aspirations are dampened by high compliance costs related to operating formally; such as taxes, costly registration process, compliance with regulatory procedures and perceived lack of clear benefits for registration (World Bank, 2016b). The impediments to formalization of firms, therefore, include a range of factors that present explicit and implicit costs, partly depending on literacy levels of entrepreneurs. While 84 per cent of the informal firms managed by entrepreneurs with primary or no formal education indicate costly procedures (time, fees, and paper work required for registering), only 52 per cent of those with secondary, technical and university education raised it as a constraint (World Bank, 2016b). These findings from literature suggest that there are challenges in accessing information on registration process or comprehending available information.

The results show that small, and medium and large firms tend to have less R&D investment intensity compared to micro firms. These results remain robust even when R&D investment is considered in absolute terms and sales considered as a control to scale for revenue related size effects. Small firms, and medium and large firms, spend about Ksh 2.65 and Ksh 2.08 on R&D per annual sales less than micro firms, respectively, conditional on spending any amount. Visual comparisons of R&D investment intensity in absolute terms and as a proportion of sales (Figure 5.6) show that while small and medium and large firms have larger absolute R&D investment on average, micro firms are more R&D intensive as measured by the ratio of R&D to sales. These results suggest that if constraints facing micro firms' investment decision are addressed (i.e. 'R&D entry barriers'), they can serve as a seedbed for R&D investments, which can promote innovation and industrial competitiveness. These findings are also informative for policy design on incentives for R&D investment based on firm size. The findings that larger firms are less R&D intensive than small firms are in congruence with previous studies (Cohen and Levin, 1989; Akcigit, 2009; Baumann and Kritikos, 2016). The plausible explanations relate to diminishing efficiency in R&D investment as costs of managerial control increases with firm size, and possibility of entry barriers for smaller firms that, once overcome, enhances the magnitude of the investments.

Figure 5.6: Comparative R&D investment intensities by firm size



Data Source: World Bank (2019a)

Table 5.5: Two-part model regression results

Variables		Model 1		Model 2	
		Probit Coefficients (R&D decision)	glm Coefficients (R&D Intensity)	Probit Coefficients (R&D decision)	glm Coefficients (R&D Intensity)
credit: Has access to a line of credit or loan		0.4050** (0.1920)	0.7850 (0.6290)	0.4110** (0.1940)	0.6700 (0.6760)
informalcomp: Competes against informal enterprises		-0.0079 (0.1690)	-1.1910** (0.5110)	-0.0346 (0.1710)	-0.9880 (0.6280)
fsize_employ: Firm size by employment	Small enterprises	0.2730 (0.2630)	-2.6450*** (0.8640)	0.2770 (0.2670)	-2.4760** (0.9780)
	Medium and large enterprises	0.3090 (0.2820)	-2.0810** (1.0350)	0.3280 (0.2850)	-2.0610* (1.0760)
lnexport: Natural log of % of the firm's exports it its total sales		0.0798 (0.0519)	0.0906 (0.1750)	0.0739 (0.0524)	0.1300 (0.1860)
lnforeign: Natural log of % of firm's foreign ownership		0.0713 (0.0547)	-0.1370 (0.1820)	0.0645 (0.0550)	-0.1280 (0.1870)
lnproductdivers: Natural log of % of firm's main product in its total sales (Product diversification)		-0.5450* (0.3070)	0.9650 (0.7090)	-0.5860* (0.3120)	0.9170 (0.7210)
judicial: Agree courts are fair and impartial		0.0224 (0.1660)	0.8430 (0.5160)	0.0260 (0.1670)	0.7360 (0.5920)
lnfirmage: Natural log of firm age		-1.0400** (0.4150)	-0.7360 (1.1380)	-1.006** (0.4250)	-1.1120 (1.5150)
lnfirmagesq: Natural log of firm age squared		0.1720** (0.0790)	-0.0360 (0.2280)	0.1660** (0.0807)	0.0587 (0.2970)

legal: Registration form of the firm	Partnership	-0.1110 (0.2510)	1.5330* (0.8360)	-0.1140 (0.2530)	1.2630 (0.9680)
	Company	0.3190 (0.2720)	2.3940*** (0.7730)	0.3160 (0.2790)	2.1930** (0.8620)
political: Political instability is an obstacle		-0.1240 (0.2220)	0.3680 (0.6390)	-0.1210 (0.2230)	0.1320 (0.7900)
tax: Taxation is an obstacle		-0.0066 (0.2220)	0.3750 (0.7160)	-0.0204 (0.2240)	0.4810 (0.8050)
skilled: Access to industrial skill is an obstacle		0.0904 (0.1800)	-0.9660 (0.6170)	0.1070 (0.1820)	-0.9430 (0.6740)
lnfamilyown: Natural log of % of family ownership		-1.0740*** (0.3350)	0.3890 (0.8270)	-1.0670*** (0.3360)	0.4630 (0.8970)
lnfamilyownsq: Natural log of % of family ownership squared		0.2210*** (0.0713)	-0.0084 (0.1800)	0.2210*** (0.0715)	-0.0299 (0.1950)
subsector: Firms technological intensity based on UNIDO classification	Medium technology	-0.3230 (0.2900)	-0.3410 (0.8090)	-0.3220 (0.2900)	-0.4010 (0.8290)
	Low technology	-0.5200** (0.2140)	-0.6680 (0.6190)	-0.7070** (0.2740)	-0.2350 (0.9550)
	Food			-0.4680* (0.2500)	-0.8360 (0.7010)
	Textile and garments			-0.4020 (0.2990)	-0.5820 (0.9090)
	Leather			-0.1260 (0.6240)	-1.2490 (1.8270)
Constant		3.1080** (1.5700)	-6.5010* (3.6980)	3.2340** (1.5810)	-5.8820 (3.9680)
Observations		351	351	351	351

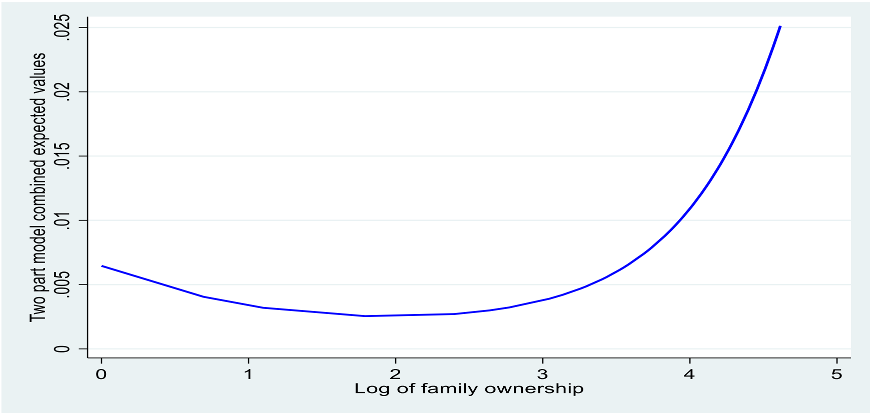
Data Source: (World Bank, 2019a)

*Standard errors in parentheses   *** p<0.01, ** p<0.05, * p<0.1*

The firm's legal status (registration type) also statistically affects R&D intensity. Compared to firms registered as sole proprietors, firms registered as partnerships and those registered as companies spend more, on average, by about Ksh 1.50 and Ksh 2.40 on R&D investment per annual sales conditional on spending any amount. The findings, anchored on resource-based view of the firm (Penrose, 1959; Wernerfelt, 1984) can be due to human and non-human resource pooling benefits associated with partnerships and companies relative to sole proprietors. This argument is in line with findings that complementary resources such as skills and capital augment R&D investment due to enhanced returns (Goñi and Maloney, 2017).

The first part (participation decision) is influenced by access to a line of credit or loan, age of the firm, and sub-sector technological intensity - all showing identical results similar to those obtained from the panel regression on R&D investment decision. A variable that has been included in this section (not available for the earlier section using panel data for R&D decision) is the proportion of family ownership, which requires further elaboration here regarding the decision to undertake R&D investment. The coefficients for the share of family ownership is statistically significant (but not for intensity decision), initially negative but turns out to be positive at much higher levels of family ownership. Figure 5.7 provides visual illustration of these dynamics, jointly considering the R&D decision and intensity. While the long-held view is that family-owned firms may generally invest less on R&D to minimize losses to family wealth, this position has been challenged in situations where family ownership is associated with long-term strategic orientation. When family ownership interest is long-term with trans-generational family control, R&D investments can be intensified as a tool for minimising below-expectations performance of the business (Chrisman and Patel, 2012).

Figure 5.7: Combined expected value of log of share of family ownership



Data Source: World Bank (2019a)

6. Conclusion and Recommendations

6.1 Conclusion

Firm-level investment in R&D is of immense policy interest owing to its role in innovation and productivity. Enhanced R&D investment by Kenyan manufacturing firms is particularly important in supporting the reversal of the sector's declining productivity as evident from its contribution to GDP. The Kenya Vision 2030 seeks to transform the economy into a middle-income industrialised country by the year 2030. In line with this long-term development plan, the government has set a policy target of increasing the share of manufacturing in GDP to 15 per cent by 2022. In contrast the sector's contribution to GDP has declined by about two percentage points from 9.4 per cent in 2015 to 7.5 per cent in 2019.

Acknowledging the role of R&D investment in innovation and productivity growth of firms, both SDGs and the African Union Agenda 2063 have set targets towards increasing the share of R&D investments in GDP. Despite these policy recognitions, only a quarter of the manufacturing firms in Kenya report to undertake R&D investments. This study sought to review the institutional framework and establish determinants of R&D investment decisions and intensity among the Kenyan manufacturing firms, focusing on the effects of firm and industry specific characteristics (firm size, sub-sectoral technological classification and export markets participation) and business environment-related variables including access to finance and informal sector competition. The review of policies and literature were used to gain insights on institutional framework, particularly regarding lessons learnt from aspirator countries such as South Africa, Malaysia and South Korea. The analysis of firm and industry-specific factors affecting the decision and intensity of R&D investments utilized the World Bank Enterprise Surveys undertaken in 2013 and 2018. The findings are three-fold.

Regarding institutional framework, evidence suggests a more direct role of the government during early stages of deepening R&D investments, but with a gradual shift to the role of private sector through institutional support, coordination and incentives. Support for the private sector is essential, particularly for start-ups and smaller enterprises owing to their resource constraints to independently undertake R&D investments. Industrial clusters are also used to promote peer learning and more focused institutional support for R&D investments. Promoting R&D investments is espoused within the larger innovation ecosystem, particularly in terms of commercialization strategies including support for uptake of locally generated R&D innovative products and intellectual property rights protection in an integrated way. Frequent and comprehensive surveys on R&D investments is essential to monitor performance and guide policy interventions. The countries reviewed largely follow international standards, particularly the OECD's Frascati Manual, and this proves vital for international comparisons in the context of progress towards achieving the SDGs' targets.

The regression results reveal that access to credit, export markets participation, larger firm size as measured by sales volume, firms in medium-high and high technological sub-sectors increases probabilities *R&D investment decisions*. Additionally, competition from informal sector enterprises lowers R&D investment decisions. The share of family ownership reveals non-linear effects: initially an increase in family ownership has negative effects, but the effects turn positive beyond some level perhaps for long-term strategic orientations. Firm age has a U-shaped relationship with R&D investment decision; younger firms and older firms tend to have more R&D decisions than moderately aged firms. Firm size (as measured by sales volume) has positive effects that eventually diminishes. The two findings (firm age and size effects) together signal the importance of unlocking constraints faced by MSEs. The firms in the textile and apparel, and leather sub-sectors, which have been prioritized in the "Big Four" agenda generally fall in the low technology intensity sub-sectors and tend to have lower probability of undertaking R&D investment. Larger firms and firms that report they compete against informal firms are found to have lower *R&D investment intensity*. Firms competing against informal firms perhaps face disproportionately higher uncertainties in appropriating returns on investment given that informal firms may not be subject to some of the statutory obligations such as taxation and regulatory compliance costs. The findings that smaller firms are less likely to undertake R&D decision, but when they do, they have relatively higher intensity may suggest existence of size-related R&D entry barriers and therefore calls for policy design related to firm size. The regression results also reveal that firms incorporated as sole proprietors have less R&D investment intensity compared to those incorporated as partnerships and companies, which may indicate the importance of resource pooling that benefits firms.

6.2 Recommendations

6.2.1 Policy Recommendations

Based on the foregoing analysis and the conclusions derived from an amalgam of evidence from review of selected countries and in-depth analysis of primary data, the following recommendations are suggested.

i) Institutional support

A robust institutional support and a holistic ecosystem on innovation is key to promoting R&D investments by manufacturing firms. Kenya is at an infancy stage in terms of R&D investment by the private sector and incentive mechanisms. There is therefore a need for more policy support to promote uptake of R&D investment by private sector manufacturing firms. The country already has the institutional framework in terms of STI Act, 2013 that provide roles for NACOSTI, KeNIA and NRF. The review of performance of these institutions, however, show weak impacts on R&D investments by private sector firms. This is partly due to limited funding and weak industry-academia-research institutional linkages. Additionally, KIRDI which also operates under the STI Act, 2013 with key mandates of promoting industrial research, technology, innovation and dissemination of the resulting findings faces some challenges including limited financial resources, use of obsolete equipment, inadequate technical skills in some areas, and inadequacies of policies in areas such as sharing of proceeds of commercialized patents. Unlike other institutions, the STI Act does not clearly stipulate the roles of KIRDI. The STI Act, 2013 repealed the Science and Technology Act, Cap. 250, which originally established KIRDI. KIRDI Bill 2017 is, however, yet to be enacted as at the time of writing this paper. This institutional challenge partly impedes the role of KIRDI in promoting industrial R&D investments. In contrast to investment in physical assets, Kenya has weak incentive mechanisms for R&D investments. For the reviewed countries including South Korea, Malaysia and South Africa R&D incentives are clearly defined around three policy goals: Promotion of R&D investments; promotion of technology transfer and promotion of venture capital formation with special focus on start-ups and MSEs. Considering these issues, the following recommendations are suggested to strengthen institutional support:

a) The industry-academia-research linkages be enhanced through existing institutions, particularly KeNIA, NRF, KIRDI and KIPI. This can be achieved through joint R&D and technology centres of excellence (as in the case of South Korea) that can then generate spin-offs; and provide opportunities for engagement in terms of knowledge sharing. The cross-cutting nature of this recommendation require the relevant national government ministries to take a lead in its actualization. The Ministry of Industrialization, Trade and Enterprise Development; and the Ministry of Education can champion this initiative.

b) Provide clearly defined incentives for promoting R&D investments. To be effective, the incentives should be tailored to different segments of private sector firms, for instance start-ups and MSEs. These can include fiscal incentives and measures to promote commercialization of R&D-generated products to create demand. The fiscal incentives can be addressed through review of the Income Tax Act, which can then be actualized through development of appropriate regulations to clearly define eligibility criteria, among other issues. An aspect of the demand measures can include public procurement measures for such products and taxation measures for a defined time period.

c) Establish measures including policy prioritization and budgetary allocations to support regular and systematic surveys on R&D investments. Monitoring of R&D investment is an integral part of SDG 9.5 and, therefore, regular surveys are required to track the indicators. For the countries reviewed in this study, sector-disaggregated R&D investment data is available on annual basis. The OECD's Frascati Manual provide a comprehensive guideline on R&D statistics. In addition the UNESCO Institute for Statistics has developed a Guide to Conducting an R&D Survey. For countries starting to measure Research and Experimental Development (UNESCO Institute for Statistics, 2014) that provides detailed operational guidelines. Institutions with key responsibilities for actualizing this recommendation include the Ministry of Education; the Ministry of Industrialization, Trade and Enterprise Development; KeNIA; NRF; and KNBS.

ii) Financing of R&D Investments

As discussed in this study, R&D investment faces unique challenges of information asymmetry (between firm owners/managers and financial institutions) and uncertainty of outcomes (successes). These issues are particularly severe for start-ups and MSEs. Policies to support financing of R&D investments, therefore, need to seek ways of mitigating these constraints. Some firms may further not wish to fully disclose information on R&D investments for strategic reasons. In these regards, the following recommendations are suggested:

a) Enhance IPR framework and protection of intellectual property through collaborations between innovation support institutions and financial institutions. This can also include frameworks for valuation of IPR and creation of database, as in the case of Malaysia, that is reviewed in this study. KIPI can play a lead role in implementation of this recommendation in partnership with financial institutions and the relevant private sector associations such as Kenya Bankers Association, KEPSA and KAM.

b) Provide insurance to lenders through credit guarantee schemes for R&D-related activities. This can leverage on the National Credit Guarantee Scheme operationalised under the Public Finance Management (Credit Guarantee Scheme) Regulations, 2020. The National Treasury and Planning can play a lead role regarding this recommendation. Development partners can support funding of the credit guarantee scheme and capacity building activities.

c) Enhance commercialization and market support for R&D-generated products. Support mechanisms can be offered through public procurement measures that provide market opportunities for the resultant products. This initiative can be actualized through public procurement regulations.

d) Operationalization of the industrialization fund envisaged in the National Industrialization Policy. Once the Fund is operationalized, it is imperative to develop regulations that support lending to firms undertaking R&D, especially the MSEs.

iii) Formalisation of informal firms

The analysis shows that formal firms competing against informal firms demonstrate low R&D investment decisions and intensity. It is therefore imperative to design policy measures to enhance initiatives to encourage formalization of informal enterprises to mitigate such adverse effects. Research reveals the informal firms' willingness to formalize once they are supported through improved business environment related to costs of registration and access to credit, electricity, water and worksites (World Bank, 2016a). Policies to foster formalization of informal firms should therefore be an integral part of the wider improvements in business environment. These policy suggestions are in line with the ILO's recommendations on awareness creation on advantages of formalization, and use of incentives including enhanced skills, access to business services, technology, market, infrastructure, markets and reduced registration and compliance costs (ILO, 2015). Formalization should be recognized as a multidimensional process including licensing, registration and compliance with statutory provisions such as labour laws, taxation and social security. The key policy actors for actualization of this recommendation include the county governments and all concerned National government institutions whose mandates and operations touch on activities elaborated here.

iv) Exports promotion

An important element of export markets participation is that firms gain exposure to international markets that can then incentivize them to undertake R&D investment through 'learning by doing', international competitive pressure and demands of international consumers. As shown in the analysis, fewer manufacturing MSEs (about a third) export their products, compared to 70 per cent of medium and large manufacturing firms. Given that majority of the manufacturing firms are MSEs, policy support towards exports can, therefore, consider size-based interventions. These can include more targeted measures to encourage MSEs use platforms such as the Kenya Trade Portal hosted by the State Department for Trade. The portal provides information on market access requirements and allow suppliers to post their products on the platform for view by international and local buyers.

v) Diversification into medium and high technology manufacturing sub-sectors

Different manufacturing sub-sectors have different levels of demand for R&D investments. Although medium and high technology manufacturing are generally less labour intensive, it has higher productivity and provides opportunities for spill-over effects of knowledge. This study has shown that low technology manufacturing accounts for 85 per cent of the overall manufacturing GDP in Kenya, yet it is characterized by low demand for R&D investment compared to medium and high technology manufacturing. Diversification into medium and high technology manufacturing requires policy support to attract Foreign Direct Investment (FDI) in high technology manufacturing, competitive industrial clustering and development of the requisite skills (Yean, 2015; Weiss, 2015). FDI works well if incentives are linked to performance criteria such as technology transfer to local enterprises and investment in high technology sub-sectors. This was the practice in economies such as Malaysia and Singapore. The Kenya Investment Policy, 2019 outlines some important criteria for awarding investment incentives, which can be emulated in the context of R&D investments. These include aligning the incentives to targeted priority sectors that generate benefits such as employment, skills development and technology transfer. Operationalization of these policy provisions are therefore imperative as a strategy for diversification into medium and high technology manufacturing. The initiatives can include developing frameworks and regulations for investment incentives for technology and skills transfer. The National Treasury and Planning, Ministry of Industrialization and Enterprise Development, and KenInvest are strategically placed to provide leading roles in implementing mechanisms for operationalizing the investment policy.

6.2.2 Areas for future research

To provide more insights on R&D investments by manufacturing firms, the following areas for further research are recommended:

a) The evolution of questions across different waves of the World Bank Enterprise Surveys limited matching of some variables to create a longer panel data set. Future surveys by the World Bank and other institutions should seek to address this limitation in efforts to support building of rich panel datasets.

b) Future empirical research can consider cross-country analysis such as within the EAC region to understand implications of institutional contexts that proves to be a challenge to address in a study based within a single country.

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Appendices

Appendix 1: Classification of manufacturing activities by technological intensity

Internal Standard Industrial Classification Rev. 4	Descriptions
Medium-high and high technology	
20	Chemicals and chemical products
21	Basic pharmaceutical products and pharmaceutical preparations
26	Computer, electronics and optical products
27	Electrical equipment
28	Machinery and equipment
29	Trailers, semi-trailers and motor vehicles
30	Other transport equipment
Medium-low technology	
19	Coke and refined petroleum products
22	Rubbers and plastic products
23	Other non-metallic mineral products
24	Basic metals
25	Fabricated metal products, except machinery and equipment
32	Other manufacturing except medical and dental instruments
33	Repair and installation of machinery and equipment
Low technology	
10	Food products
11	Beverages
12	Tobacco products
13	Textile
14	Wearing apparel
15	Leather and related products
16	Wood and wood products including cork
17	Paper and paper products
18	Printing and reproduction of recorded media
31	Furniture
32	Other manufacturing

Source: UNIDO (2019)

Appendix 2: Key features of R&D activities

Feature	Descriptions
Novel	The activity creates new findings relative to existing knowledge (embodied in products and processes) in the industry.
Creative	The activity generates new concepts or ideas used to enhance existing knowledge.
Uncertain	The end of the activity is uncertain regarding parameters such as time, cost and outcomes.
Systematic	The activity is intentional with clearly documented processes and outcome.
Transferrable/ reproducible	The outcome of the activity can be used to transfer knowledge for use by others in the industry; and allow for others to reproduce the results.

Source: OECD (2015), Frascati Manual

Appendix 3: R&D investment incentives in South Korea, Malaysia, and South Africa

Policy Review of Selected Countries - Main Features and Incentives
a) Republic of Korea (South Korea)
In early stages (1960s-1970s), the South Korean government played more dominant roles through technology importation, construction of public research complex (i.e. Daedeok Research Complex), establishing research institutes and investments in education and R&D. The Korea Institute of Science and Technology (KIST) commenced operations in 1969 to serve as a centre of excellence for R&D, leveraging technology development of machinery, electronics and other industrial exports. With growth of R&D and deepening of technology, spin-offs emerged from KIST. Other institutions established in the 1970s include the Korea Institute of Chemical Research, and the Korea Institute of Machinery and Materials that supported industries with technology development. Commencing in 1980s, there was a policy shift towards private sector led innovation and technology development, with the government providing facilitative role through incentives and creation of synergy among private sector enterprises, research institutions and universities. The incentives provided were focused around three policy goals: Promotion of technology transfer, promotion of R&D investments and promotion of venture capital formation. The incentives included tax exemptions, reduced import duties on R&D equipment, tax credit for expenditures related to human resource development, special depreciation rates for investments in R&D equipment, special tax benefits for SMEs investing in R&D, income tax exemption for expatriates (e.g. engineers) supporting R&D, and for venture capitals, exclusion of capital gains from taxable income. Commencing 2000, the policy focus has been more on ecosystem for R&D and innovation. The key intervention towards this policy agenda is the establishment of innopolis (i.e. R&D and innovation-focused clusters/cities). Daedeok Research Complex was expanded to Daedeok innopolis in 2005. Each of the innopolis support targeted high-technology manufacturing and are modelled to link R&D, technology commercialization, and industrial production. As of March 2020, there are five innopolis: Innopolis Daedeok (2005); innopolis Daegu (2011); Innopolis Gwangju (2011); Innopolis Busan (2012) and Innopolis Jeonbuk (2015). The legislations related to tax incentives to achieve specific national economic objectives were consolidated in 1999 through enactment of the Special Tax Treatment Control Law (STTCL). The STTCL provides various tax incentives to deepen R&D, including tax credit for technology transfer, research and manpower development, mergers or acquisition of innovative SMEs. The tax credit is graduated based on firm size, with SMEs relatively benefiting more compared to large enterprises. The graduated tax credit is aimed at encouraging new growth sectors and enhancing productivity and competitiveness of the SMEs in the industrial sector. The following issues emerge from review of the case of South Korea: - ◇ Through policy support for R&D investments, South Korea has managed to gradually diversify into high technology manufacturing products: Steel and petrochemical in 1970s; Automobile and shipbuilding in 1980s; Semi-conductor and electronics in 1990s; mobile communication (ICT), IT convergence and software in 2000s. ◇ Available incentives: R&D tax credits, graduated by firm size; tax reduction or exemption on incomes generated from R&D; tax exemptions on incomes of expatriates supporting R&D; collaborations among private firms, research institutions and universities; industrial clusters (innopolis). *Sources consulted: Jung and Mah (2013); Innopolis Foundation (2019; PwC (2019)* **Global Competitiveness Performance 2019 key indicators:** Overall ranking: 13/141; R&D ranking: 4/141; R&D share in GDP: 4.2 per cent; property rights ranking: 26/141; innovation capability rank: 6/141; skills of workforce ranking: 27/141; financial system ranking: 18/141; entrepreneurial culture ranking: 55/181.

Policy Review of Selected Countries - Main Features and Incentives
b) Malaysia

The Malaysian government anchored the significance of business R&D investments in national development policies, commencing in mid 1980s with the launch of the Industrial Master Plan (IMP) 1986. This plan underscored fiscal incentives for exporting and R&D-undertaking firms, thus starting the journal for exports growth and diversification into high-value manufactured products through deliberate policy efforts. The Action Plan for Industrial Technology Development (APITD), launched in 1990 to guide the industrial development further sought to accelerate industrial R&D through enhanced government support in form of grants and soft loans. The Second Industrial Master Plan (IMP2) was launched in 1996, that in addition to fiscal incentives sought to promote R&D through value chain integration and cluster approaches particularly for Small and Medium Enterprises (SMEs). The policy goal was then for SMEs to build their technology capability through value chain integration with multinational large enterprises and peer learning through clustering. These policy initiatives from 1980s were accompanied by establishment of institutions (Office of the Science Advisor, and the Ministry of Science, Technology and Innovation) to coordinate policies on national development based on STI. These institutions were key in implementation of National Science and Technology Policies (first launched in 1986 and reviewed in 2002) that in addition to boosting business R&D sought to promote commercialisation of innovation resulting from R&D activities. The National Policy on Science, Technology and Innovation launched in 2013 currently guides development and promotion of R&D activities in Malaysia. This policy places emphasis on the role of private sector in R&D and underscores the role of the government in seamless coordination across various actors – businesses, universities and public research institutions. The review of Malaysian experiences reveals the following: -

- ◇ Sustained policy efforts to promote R&D investments and commercialisation since 1980s, with precise targets. Before 2013 the government target for R&D share in GDP averaged 1.5 per cent. The current policy targets 2 per cent of GDP, of which 70 per cent is to be accounted for by the private sector.
- ◇ Recognition of the private sector in R&D, which can be encouraged through fiscal incentives, value chain integration and financial support. The share of private sector in R&D peaked in 2006 and has generally remained high.
- ◇ The ecosystem for boosting R&D is anchored on commercialisation strategies. As such the Malaysian government has set a set a target of commercialising and accelerate uptake of locally generated R&D innovative products. Some R&D ecosystem unique initiatives include establishment of R&D shared facilities and mechanisms for intellectual property valuation and database, which are particularly useful for start-ups and SMEs. Other initiatives include capacity building and awareness creation initiatives to inculcate culture of R&D and innovation.
- ◇ Use of a comprehensive approach to promote R&D. Firms undertaking in-house R&D are eligible for investment tax allowance, while companies that provide R&D services are also provided with incentives such as investment tax allowance and exemptions from income tax for specified time frame. The array of incentives includes tax allowance; tax deduction; tax exemptions; financial support; and tax holidays. Further, automatic double deduction for R&D projects is available for SMEs.
- ◇ Regular comprehensive surveys to guide policy decisions. Malaysia has been undertaking national surveys on R&D. Since 1994 eleven national R&D surveys have been undertaken.
- ◇ Enhanced coordination among key actors - industry (businesses), universities and research institutions with clearly articulated roles. For instance, the Malaysian STI policy articulates higher education institutions are expected to supply skilled human resources, generate knowledge through R&D and support commercialisation of research outputs. Public research institutions are expected to undertake applied research, support technology transfer as serve as information service centres. The government trough the Ministry of Science, Innovation and Technology play policy formulation, coordination and incentives design roles.

Sources consulted: Government of Malaysia (2013); OECD (2016); Hamzah (2017); Ernest & Young, (2018)

Policy Review of Selected Countries - Main Features and Incentives
c) South Africa
The government developed White Paper on Science and Technology, 1996 to spur R&D through a holistic approach of national innovation system. The focus then was on building human capacity for private sector, enhanced support through by the government through funding schemes and interactions with public research institutions. The adoption of the National R&D Strategy in 2002 to implement focused aspects of the 1996 White Paper served to catapult the policy efforts in deepening STI in industrial development. A key focus of the strategy is creation of an enabling environment through enhanced coordination (governance) of R&D activities through the Department of Science and Technology and the national system of innovation – functioning institutions/policies and organisations that create synergy. Other aspects of the enabling environment include technology pillar focused on value addition in manufacturing; and human resource development through science, engineering and technology. These initiatives were envisaged to increase share of R&D in GDP to 1 per cent. To reenergise the role of private sector, South Africa first introduced R&D tax incentives in 2006 to stimulate private sector investment in R&D. The incentive is embedded within the Income Tax Act No. 58 of 1962. Firms undertaking R&D across various sectors are allowed to deduct 150 per cent of the R&D spending when computing taxable income. The Department of Science and Technology closely works with the South African Revenue Service and National Treasury in implementing the fiscal incentive. Through its long-term development blueprint, the National Development Plan 2030, the South African Government prioritised partnership with private sector to raise the level of R&D as part of the strategy for global competitiveness. The government set to increase gross expenditure on R&D to 1.5 per cent of GDP, of which two-third was to be generated by the private sector. The White Paper on Science, Technology and Innovation 2019 replaces the 1996 White Paper to align the policy framework to national and global developments. The new policy sets a new higher target for R&D at 1.5 per cent of GDP. The policy recognises that technology absorptive capacity and the magnitude of R&D stock in the economy determines the gains from foreign direct investments and global value chain integration. The policy thus seeks to support capacity of firms in undertaking R&D, particularly among SMEs. Areas of support identified for SMEs include access to finance and infrastructure including equipment, technology commercialisation and related support services. Other SMEs support priorities include linkages with larger firms and improved coordination of institutions supporting SMEs to support R&D in collaboration with the Department of Science and Technology. In summary key features of South Africa to support business R&D include: - ◇ The government annually undertakes a National R&D Survey to measure and gauge the magnitude, composition and growth of R&D, as well as the financing sources. Enhanced R&D intensity is identified is identified as a key strategy to stimulate manufacturing through development of products, innovation and commercialisation. ◇ Keen interests to provide enabling environment for the private sector. The government constituted a Joint Government-Industry Task Team in 2015 on R&D Tax Incentive, drawing membership from relevant government agencies, private sector (R&D performing firms, industry associations and consulting firms), academia and policy research institutions to review constraints to R&D and provide recommendations on appropriate measures. The recommendations of the Task Team are being mainstreamed into R&D policy framework. Key recommendations relate to streamlining of incentives administrative procedures, automation of applications, complexity of information and limited access by micro, small and medium enterprises. ◇ Special support for SMEs to undertake R&D. This is more pronounced particularly in the White Paper on Science, Technology and Innovation 2019. Key provisions include special fiscal incentives for, R&D vouchers for use with R&D-registered service providers, mentorship support and innovation hubs for university spinoffs and SMEs in high technology sectors particularly in terms of intellectual property rights and commercialisation strategies. ◇ Mix of incentives to support R&D generally: These include cash grants; tax deductions; and accelerated depreciation. *Sources consulted: Government of South Africa (1996; 2002; 2012; 2016); Government of South Africa (2018; 2019; OECD (2007; 2017); Ernest & Young (2018); Centre for Science, Technology and Innovation Indicators (2019)*

Source: Author's construct

Appendix 4: Motivation of the econometric models

a) Panel Probit Model: For R&D Investment Decision

In a binary response econometric model such as Probit, the focus is on the response probability of the economic agent's optimization behaviour, which in this case can be expressed as: $P(y=1|x)$
Such that $P(y=1)$ is the probability of the firm undertaking R&D investment given a set of the explanatory variables, $\boldsymbol{x}$. The firms have different unobservable propensities to undertake R&D investment. Consider an underlying latent variable y^*, that reflects the propensity of a firm to undertake R&D investment. Although y^* is not directly observable, a change in its value beyond some threshold level results to the observable y, seen as the R&D investment decision. The latent y^* variable is continuous in nature and is linearly related to the observed explanatory variables, x, by the following structural model in a panel data setting: $y_{it}{}^* = x_{it}\,\beta + u_{it}$

Where i denotes the observation, t time period, β vector of coefficients and u the error term assumed to be normally distributed. The observed binary dependent variable is coded 1 for a positive outcome (occurrence of R&D), and 0 for non-occurrence of R&D investment. The relation between the binary observed y and the continuous latent variable y^* is defined by a measurement as follows (Long & Freese, 2014).:

$y_{it} = \{1$ *if* $y_{it}{}^* > 0$

$\quad 0$ *if* $y_{it}{}^* \leq 0$

For Probit model, it is assumed that u is normally distributed and is exogenous of x. Given that the latent y^* lacks a well define unit of measurement, for interpretations, it is convenient to focus on effects of x_{it} on $P(y=1|x)$. The approach to the partial effects depends on whether x_i is continuous or categorical (Wooldridge, 2016). If x_i is continuous, its partial effect on $p(x) = P(y=1|x)$ is given by the partial derivative $(\partial p(x))/(\partial x_i)$. On the other hand, if x_i, say x_k is categorical, the partial effects of changing x_k from 0 to 1, ceteris paribus, is given by $p(y=1 \mid x, x_k=1) - p(y=1 \mid x, x_k=0)$ which reflects discrete change in probabilities.

a) Cross-Section Two-Part Model: For R&D Investment Intensity and Investment Decision

The two-part model has two components: The participation and intensity parts. The R&D participation decision is modelled using Probit model as follows: The underlying latent variable, $y_i{}^*$ is related to a vector of covariates linearly as: $y_i{}^* = x_i\,\beta + \varepsilon_i$ such that the link between the observed binary variable y and the latent y^* is demonstrated by the measurement equation:

$y_i = \{1$ *if* $y^* > 0$

$\quad 0$ *if* $y^* \leq 0$

The second part for non-limit observations is: $E(y|y=1) = \beta' x + u$ *if* $\beta' x + u > 0$

Appendix 5a: Table of correlation matrix for panel probit

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. R&Ddec	1.0000															
2. credit	0.2146	1.0000														
3. subsector	-0.0836	-0.0693	1.0000													
4. informalcomp	-0.0755	0.0221	-0.0631	1.0000												
5. fsize_employ	0.1388	0.2647	-0.1490	-0.0567	1.0000											
6. lnexport	0.2102	0.1065	0.0163	-0.1440	0.1920	1.0000										
7. lnforeign	0.0464	0.0179	-0.0776	-0.0881	0.1866	0.1547	1.0000									
8. lnproductdivers	-0.0513	-0.1292	0.1479	-0.0674	-0.0872	0.0493	-0.0697	1.0000								
9. judicial	0.0068	-0.0564	0.0331	0.0619	0.0068	-0.0342	0.0274	-0.0440	1.0000							
10. lnfirmage	0.1348	0.0873	0.0292	-0.0631	0.2361	0.2439	0.0018	-0.0239	-0.0569	1.0000						
11. lnfirmagesq	0.1455	0.0838	0.0317	-0.0576	0.2277	0.2454	0.0121	-0.0246	-0.0664	0.9800	1.0000					
12. legal	0.1058	0.0632	0.0233	-0.0545	0.1340	0.2977	0.1819	-0.0370	-0.0209	0.1920	0.1947	1.0000				
13. fsize_lnsales	0.2103	0.2349	-0.1936	-0.1109	0.6487	0.2762	0.2887	-0.0649	-0.0284	0.3036	0.2966	0.2612	1.0000			
14. fsize_lnsalessq	0.2010	0.2254	-0.1932	-0.1046	0.6380	0.2768	0.2994	-0.0676	-0.0229	0.2875	0.2840	0.2494	0.9958	1.0000		
15. political	0.0424	0.0545	-0.0082	-0.0001	0.0300	-0.0695	-0.0825	0.0041	-0.0370	-0.0217	-0.0088	-0.0033	-0.0351	-0.0403	1.0000	
16. tax	-0.0298	0.0075	-0.0181	0.0654	0.0644	0.0016	-0.0044	0.0095	-0.0453	-0.0026	0.0005	0.0175	0.0359	0.0354	0.2081	1.0000

Appendix 5b: Table of correlation matrix for cross section two part model

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. R&Ddec	1.0000																
2. credit	0.0731	1.0000															
3.subsector	0.0043	-0.0801	1.0000														
4. informalcomp	-0.0015	0.0380	-0.0205	1.0000													
5. fsize_employ	-0.0830	0.3969	-0.1280	-0.0742	1.0000												
6. lnexport	-0.0031	0.0804	-0.1280	-0.2227	0.0975	1.0000											
7. lnforeign	-0.0375	0.0673	-0.1132	-0.0366	0.2013	0.1485	1.0000										
8. lnproductdivers	-0.0015	-0.1209	0.1561	-0.1407	-0.0441	0.0904	-0.0549	1.0000									
9. judicial	-0.0026	-0.0678	0.0525	0.0612	0.0139	-0.0963	0.0003	-0.0076	1.0000								
10. lnfirmage	-0.1572	0.0674	0.0094	-0.1173	0.2605	0.2826	0.0024	-0.0235	-0.0872	1.0000							
11. lnfirmagesq	-0.1307	0.0559	0.0269	-0.1162	0.2456	0.2889	0.0095	-0.0142	-0.0924	0.9783	1.0000						
12. legal	0.0326	0.0634	0.0410	-0.0321	0.1327	0.3420	0.1123	0.0474	-0.0494	0.2505	0.2564	1.0000					
13. political	0.0361	0.0995	-0.0531	-0.0045	0.1327	-0.1268	-0.1165	-0.0550	-0.0720	-0.0746	-0.0604	-0.0726	1.0000				
14. tax	0.0534	0.0346	-0.0283	-0.0045	0.0095	-0.0462	0.0153	-0.0408	-0.0551	-0.0556	-0.0545	-0.0028	0.1636	1.0000			
15. skills	-0.0345	0.0599	-0.0504	0.0257	-0.1061	0.0230	-0.1015	-0.0334	-0.1304	-0.0200	-0.0284	0.0251	0.2126	0.1891	1.0000		
16. lnfamilyown	-0.0254	0.1355	-0.1438	0.0257	0.1825	-0.3492	-0.0248	-0.1058	-0.0221	-0.0671	-0.0963	-0.3422	0.0717	0.0304	-0.0176	1.0000	
17. lnfamilyownsq	-0.0188	0.1268	-0.1407	0.0937	0.1520	-0.3552	-0.0588	-0.1026	-0.0326	-0.0642	-0.0934	-0.3607	0.0839	0.0317	0.0127	0.9879	1.0000

Appendix 6: Panel probit coefficients for R&D investment decision

Variables		**Model 1**	**Model 2**
credit: Has access to a line of credit or loan		0.3830*** (0.1090)	0.3730*** (0.1100)
informalcomp: Competes against informal enterprises		-0.2190** (0.1030)	-0.2110** (0.1030)
fsize_employ: Firm size by employment	Small enterprises	0.0617 (0.1660)	0.0987 (0.1690)
	Medium and large enterprises	-0.0769 (0.1950)	-0.0059 (0.2000)
fsize_lnsales: Natural log of annual sales		0.4870* (0.2530)	0.5100** (0.2500)
fsize_lnsalessq: Natural log of annual sales squared		-0.0116* (0.0067)	-0.0123* (0.0067)
lnexport: Natural log of % of the firm's exports it its total sales		0.1130*** (0.0317)	0.1120*** (0.0323)
lnforeign: Natural log of % of firm's foreign ownership		-0.0088 (0.0362)	-0.0043 (0.0362)
lnproductdivers: Natural log of % of firm's main product in its total sales (Product diversification)		-0.2580 (0.2050)	-0.2710 (0.2040)
judicial: Agree courts are fair and impartial		-0.0044 (0.1010)	-0.0098 (0.1020)
lnfirmage: Natural log of firm age		-0.8250** (0.3660)	-0.8270** (0.3730)
lnfirmagesq: Natural log of firm age squared		0.1750*** (0.0655)	0.1740*** (0.0665)
legal: Registration form of the firm	Partnership	-0.1120 (0.1510)	-0.1260 (0.1510)
	Company	0.0948 (0.1650)	0.0609 (0.1690)
political: Political instability is an obstacle		0.1400 (0.1400)	0.1520 (0.1410)
tax: Taxation is an obstacle		-0.0509 (0.1330)	-0.0631 (0.1340)
subsector: Firms technological intensity based on UNIDO classification	Medium technology	-0.2560 (0.2080)	-0.2510 (0.2070)
	Low technology	-0.3450** (0.1450)	-0.3730** (0.1810)
	Food		-0.2410 (0.1610)
	Textile and garments		-0.4470** (0.1980)
	Leather		-0.8190** (0.3660)
Constant		-2.8150 (2.3340)	-2.9350 (2.3120)
Observations		666	666
Number of panel ID		589	589

Data Source: (World Bank, 2019a)

*Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

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