

Innovation Capabilities in West African firms



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Declaration

I **Betty-Ann Ananeh-Frempong** declare that this dissertation is my own work, except where acknowledged in the text. I further declare that this thesis has not been submitted for a degree in this or any other university.

Signature

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I would like to extend my gratitude to the African Economic Research Consortium (AERC) without whom I may not have decided to enrol into a PhD program in the first place. Their financial and intellectual support has made it possible for me to become a PhD candidate.

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Abstract

This thesis examines the factors that influence innovation by West African firms. It also seeks to determine the relationship between the different types of innovation. In addition, a case study is used to complement the quantitative chapters. It sets out to provide an in-depth understanding of how backward linkage firms in the Ghanaian gold mining sector develop innovation capability through knowledge transfer and how this is influenced by government policy on procurement and local content.

There was little data on innovation outcomes and innovative capability activity of firms in the West African region until the World Bank Enterprise Survey conducted investment climate assessment surveys that included questions about innovation in firms in the region beginning in 2014. This has provided the opportunity to conduct research on the determinants of innovation outcomes in the region. The case study provides insights into issues not covered in the innovation surveys that influence innovation outcomes such as transfer of knowledge within an industry and government policy aimed at an industry.

Chapter two uses innovation data for ten West African countries to ascertain how innovative activities influence the probability of innovating. The innovation activities used in this chapter are R&D investment, investment in training programmes for employees, the purchase of assets and equipment, and making an export sale. Product and process innovation are the dependent variables. The chapter uses two recursive bivariate probit models to ascertain correlation between product and process innovation. The estimation results show that for both recursive bivariate probit models, firms that engage in one innovation outcome have an increased probability by over 90% of engaging in the other innovation outcome. Thus, the recursive bivariate probit results show that product innovation influences process innovation and vice versa. The marginal effects show that of the innovation activities, R&D investment had the largest marginal effect on the probability that a firm would engage in product and process innovation for both models. The results also show that investment in training programmes for employees increased the probability of innovating in product and process innovation in the first model and in product innovation in the second model. Investment in assets and equipment increased the probability that a firm will engage in process innovation in the first model and in both product and process innovation in the second model. Making an export sale increased the probability that a firm will engage in process innovation in the first model and in product innovation in the second model.

Chapter three uses innovation data for Ghana and Nigeria because it includes data on marketing and organisational innovation. The objective of chapter three is to investigate how product, process, marketing, and organisational innovation are related to each other. This chapter also assesses the influence of innovation activities on all the innovation outcomes. A multivariate probit model with the four types of innovation as the outcome variables and innovation activities such as R&D, worker training, export, and purchase of assets and equipment included as regressors is used for this chapter. The regression results show that three innovation activities namely R&D, worker training and purchase of assets and equipment increase the probability that firms will engage in all the four types of innovation. Export however is not statistically significant for product and process innovation although it increases the probability that firms will engage in marketing and organisational innovation. The results of the off-diagonal elements of the correlation matrix show that there is correlation between the error terms of the innovation outcomes. This means that the innovation outcomes are positively associated and dependent on each other. The values of the covariance matrix show that there is a stronger correlation between the error terms for product and process innovation. Similarly, the error term for marketing innovation is most strongly correlated to that for organisational innovation. Thus, the regression results show that there is a relationship between all four types of innovation.

The case study is to assess how the local content policy has encouraged local participation in the backward linkage firms to the gold mining industry in Ghana. It assesses the prevalence of innovation in these firms. It also assesses the development of innovation capability through the transfer of knowledge from multinational corporations to local supply firms. This was done by interviewing the management of six firms that supply goods and services to the mining companies. These firms are all affiliate members of the Ghana Chamber of Mines. The chapter shows that government policy to promote the local participation of backward linkage firms by increasing Ghanaian content has been able to substantially increase Ghanaian participation in the supply of mining inputs to the mining firms. The management of the firms believed that the policy has also encouraged knowledge transfer between local firms and multinational corporations. Yet, it can be deduced from the supply firms interviewed that there is not much innovation in these firms. The present policy direction encourages the importation of mining inputs over local manufacturing and value-addition. The firms interviewed that import finished goods expressed an interest in adding value through the establishment of assembly and or manufacturing plants if supported by the government.

Dedication

I dedicate this thesis to the loving memory of my grandparents, Thomas Appiah-Kusi and Mercy Akua Afriyie. Your resilience in life is still with me.

List of Acronyms

AUDA - African Union Development Agency

CIS - Community Innovation Survey

CSIR - Council for Scientific and Industrial Research

ECOWAS - Economic Community of West African States

ERP - Economic Recovery Program

ES - Enterprise Survey

FDI - Foreign Direct Investment

GDMC - Ghana Design and Manufacturing Centre

GDP - Gross Domestic Product

GERT - Green Energy Reduction Technology

GNI - Gross National Income

GSS - Ghana Statistical Service

ISIC - International Standard Industrial Classification

ISSER- Institute of Statistical Social and Economic Research

IT - Information Technology

MESTI - Ministry of Environment Science Technology and Innovation

MIIF- Minerals Income Investment Fund

MNE - Multi-national Enterprises

MSME - Micro, Small and Medium Enterprise

NEIP - National Entrepreneurship Innovation Programme

NEPAD - New Partnership for Africa's Development

NRIC - National Research and Innovation Council

NRIF - National Research and Innovation Fund

OECD - Organisation for Economic Co-operation and Development

PACSTI - Presidential Advisory Council for Science Technology and Innovation

R&D - Research and Development

SME - Small and Medium Enterprises

STEPRI- Science and Technology Policy Research Institute

STI - Science Technology and Innovation

UIS - UNESCO Institute for Statistics

UNESCO - United Nations Educational Scientific and Cultural Organisation

UNIDO - United Nations Industrial Organisation

UEOMA- West African Economic and Monetary Union

WAMZ- West African Monetary Zone

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Chapter 1: Introduction

1.1 Introduction

This thesis investigates the factors that influence the probability of West African firms to innovate. The thesis also ascertains the relationship between the different types of innovation. A case study is used to complement the quantitative chapters by providing an in-depth understanding of how firms develop innovation capability through knowledge transfer in backward linkage firms in the Ghanaian gold mining sector given government policy on procurement and local content.

In the 2019 Global Competitiveness Report, sub-Saharan Africa had the lowest score of 29.4 out of 100 in innovation capability while Europe and North America had the highest score of 58.1 (World Economic Forum, 2019). This difference in innovation capability reflects the inability of firms in developing economies to invest in knowledge acquisition activities such as research and development (R&D), licensed or patented inventions, and sophisticated machinery. Firms in sub-Saharan Africa often lack access to low interest loans and as such cannot make the needed investment in human capital and product development that is necessary for knowledge absorption and the development of innovation capability (Cirera & Maloney, 2017).

Furthermore, Egbetokun et al. (2016), show that infrastructure investment and development in developing countries outside Africa exceed that of African countries with similar income levels. Yet the innovation data collected by the World Bank Enterprise Survey (WBES) shows that firms in sub-Saharan Africa engage in innovation output. This suggests that there may be other means of knowledge acquisition and hence innovation activity that may not be captured in the Global Competitiveness Report. This makes the study of innovation in Africa unique.

This is a thesis that seeks to contribute to the literature on innovation in firms, by examining the innovation capabilities of firms found in the World Bank innovation survey for the West African region. The thesis examines the factors that influence the probability of innovating given firm and industry activities in West African countries. It also analyses the relationship between the different types of innovation. The thesis includes a case study that analyses how the mining policy and Science Technology and Innovation (STI) policy have developed backward linkages in the goldmining industry in Ghana and whether these firms have

developed innovation capabilities through local manufacturing and supply chains. Thus, this thesis uses econometric analysis and a qualitative case study to assess the innovation capabilities of West African firms in select countries.

The thesis consists of three chapters that examine the innovation capability of West African firms.

- The second chapter entitled *Determinants of Innovation in West African Firms* focuses on innovation indicator data collected for ten West African countries by the World Bank Enterprise Survey to elaborate on the factors that determine innovation. The chapter identifies the factors that increase the probability that a West African firm will engage in innovation. The chapter is the first step in assessing the variables that determine innovation in West African firms.
- The third chapter is entitled *Innovation Capabilities of firms in Ghana and Nigeria*. The objective of this chapter is to investigate the relationship between the four types of innovation namely, product innovation, process innovation, marketing innovation and organisational innovation. This chapter assesses the influence of innovation activities on all the different types of innovation.
- The fourth chapter is a case study entitled *Innovation and Backward Linkages in the Goldmining Industry in Ghana*. This case study assesses government policy aimed at enhancing local participation in the backward linkage firms to the gold mining industry in Ghana. It includes interviews of the management of backward linkage firms on how these firms develop innovation capability and innovate given government policy on procurement and local content. The case study provides better insight into how the internal and external structures of a firm constrain or facilitate its ability to learn and build productive capacity (Egbetokun, 2015).

1.1.1 Problem Statement

The thesis addresses the scarcity of information on innovation in West African firms. The thesis is a study of the development of innovation capability in industry. Thus, it provides information for innovation policy and contributes to the innovation literature and discourse.

Natural resources have been converted into capital and has led to the development and growth of economies (Broughel & Thierer, 2019). Many developing countries have an abundance of

natural resources that are used in the production process of manufacturing firms. Yet developing countries have not been able to develop their economies even though their natural resources are being extracted. This extraction is usually undertaken by multi-national enterprises (MNEs) (Ferguson, 2005).

According to Fagerberg et al. (2005), developed economies applied technological expertise and institutional and organisational capacity to the extraction of natural resources. This led to the growth of linkage firms that developed the capacity to innovate. This developed innovation capability was transferred to other sectors of the economy that use the extracted natural resource as an input in their production process. Output from these other sectors of the economy were then used by the linkage firms and the extractive industry. This led to increased productivity and economic growth. This cycle of development has not been replicated in developing economies. This may be due to the high costs associated with developing innovation capabilities (Egbetokun et al., 2016). For developing economies to make the most of their natural resource exploitation, their firms will do well to invest in building innovation capability as this will enhance their capacity to imitate firms in developed economies in innovation and development.

It is important that decision makers know the factors that contribute to innovation in the production of goods and provision of services in firms. This will enhance the development and productivity of the firms. There has been an increase in literature on innovation and the development of innovation capability in firms in developing economies in the last two decades. Lema et al. (2021), contend that from 2000 to 2019, innovation literature on developing economies has grown at an average rate of 21% annually. Yet most of the literature is on upper-middle income countries. Their data showed that whereas 6,501 papers were published on innovation in upper-middle income countries over the two decades under study, 1,767 papers were published on innovation in middle to lower-middle income countries. For Low-income countries 390 papers were published over that time. Furthermore, the literature on low-middle income and low-income countries focused on a small number of countries. Those in Africa were Ethiopia, Kenya and Nigeria. This issue is also observed by Jauhiainen and Mugabe (2024), who look at innovation research on Africa from 2015 to 2021. They find that South Africa, Kenya, Ghana, Nigeria and Tanzania are the countries that are most discussed in the

innovation literature covering this period. Thus, there is limited African perspective in international publications on innovation.

The nature of African economies makes it necessary for there to be innovation research from innovation data collected in African firms. Kaplinsky and Kraemer-Mbula (2022), show that on average 74.5% of employment in the non-agricultural sector in sub-Saharan Africa is informal with West Africa having the highest proportion of 81.5%. This is because there is a low barrier of entry and exit for firm owners and workers in the informal sector. These informal firms are set up as a matter of survival for the owners and workers hence innovation is crucial for the survival of these firms. These informal firms cater mainly to consumers who cannot either afford or access goods and services provided in the formal sector. Thus, product and process innovation is incremental and necessary for the informal firms to provide goods and services to their less resourced consumers (Kaplinsky & Kraemer-Mbula, 2022).

Although there are innovation literature that tout the ability of the global value chain to foster the development of innovation capability and innovation in firms in developing countries including Africa (Jegade & Muchie (2024); Delera et al. (2022); Avenyo et al. (2022); Mazzi et al. (2024)), Kaplinsky and Kraemer-Mbula (2022) caution against the over-reliance on the global value chain for the development of innovation capability by African firms. They are doubtful most African firms are going to develop innovative capability through the global value chain in the way that Asian countries have been able to since western countries like the United States of America are adopting protectionist policies while China continues to dominate in global trade. The authors suggest that the increase in the share of intra-regional trade from 27% in 2000 to 42% in 2019 indicate an opportunity for regional value chains to move developing economies from the export of unprocessed raw materials to the export of final products. The development of such manufacturing industries could provide more opportunity for the development of innovation capabilities through trade.

A look at the trends and structure of Africa's position in the global value chain by Ahmad (2022) shows that over the period 2009-2018, lower income economies in Africa's participation in the global value chain was close to zero. Meanwhile, the average global value chain participation of African economies that are upper middle income and higher was more than thrice that of lower middle-income economies in Africa over the same period. Thus, an economy needs to have national innovation capabilities such as strong linkages in the national

innovation systems to be able to participate sustainably in the global value chain. Ahmad (2022) suggests that firms in Africa build linkages within local value chains as a pre-condition to enter global value chains. This is because strengthening local value chain development in a country can significantly improve its innovation capabilities.

The countries that make up the West African economic block known as the Economic Community of West African States (ECOWAS), are all developing countries in sub-Saharan Africa, whose economies rely heavily on the export of commodities such as crude oil, minerals, and agricultural commodities. This sub-region of Africa has 30% of the continent's population and 28% of its GDP (ECOWAS, 2016). It includes the most populous and largest economy in Africa, Nigeria; hence the region's economic growth is affected by changes in Nigeria's economic growth. For instance, in the year 2016, Nigeria went through a recession which was brought on mainly by a fall in the world price of crude oil. This led to the real GDP growth of the ECOWAS region declining by 0.2% (ECOWAS, 2016).

Thus, it is necessary for studies on the factors that influence innovation to focus on this region with its unique characteristics. This region has an abundance of natural resources but has not been able to leverage the extraction of its natural resources to develop local firms and their economies at large. Firms in West Africa are small and are unable to access low interest credit to invest in R&D or sophisticated machinery. They are also not connected to the national system of innovation in their countries and hence do not benefit from research output from universities and research institutions related to their industry (AUDA-NEPAD, 2014). An understanding of the factors that influence innovation activity in this region of Africa could help in the development of policy that can enhance the development of innovation capabilities and enable resource extraction to lead to innovative linkage firms and a transfer of knowledge, expertise and enhancement of innovative capacity in the larger economy.

Patents and investment in Research and Development (R&D) are two of the indicators that have often been used to show the probability of innovating as well as the intensity of innovation in an economy. R&D investment and patents are examples of indicators often used in developed economies. Yet the available data for developing countries show a low investment in R&D. The data also shows that patenting occurs in very few developing countries. This is demonstrated in the Global Competitiveness Report (2019). For instance, Canada's patent applications per million of the population is 105.8 and the R&D expenditure as a percentage

of GDP is 1.5% while patent applications per million for Côte D'Ivoire is 0.01 and R&D expenditure as a percentage of GDP is not available (World Economic Forum, 2019). However, this does not mean that developing economies do not innovate or that innovation cannot take place without patents or R&D. Firms in West Africa may develop innovation capabilities through means other than R&D, collaboration with research institutions or participation in the global value chain. This makes the study of innovation capability in West African firms unique because it sheds light on the different ways in which firms can develop innovation capability.

Daronco et al. (2023) recognize that the framework for innovation capabilities is inconsistent and varies from generic elements to particular resources and practices. The authors have thus identified five main perspectives of innovation capability through a systemic literature review. The perspectives of innovation capabilities are namely a knowledge-based view, a resource-based view, dynamic capabilities, strategic management and practice-based view. The knowledge-based view of innovation capability investigates how firms acquire and disseminate knowledge as well as how knowledge resources influence a firm's ability to generate and adopt innovation. Goedhuys (2007) names R&D, worker skills and training, investment in new equipment and telecommunication and linkages and collaboration with other firms and industries as sources of learning that a firm can engage in to develop innovation capability. Thus factors that can influence a firm's innovation output and capability include the quality or level of skills of managers and employees, a firm's network and interaction with other firms and organisations, and factors specific to the region, country or industry (Egbetokun et al., 2016). This means that for decision makers to enact policies that will enhance innovation activity and develop innovation capabilities in firms in their countries, they must have access to a wide range of innovation studies that cover the many factors that influence innovation activity.

Data collected on innovation in African countries such as the World Bank Enterprise Surveys (WBES) and the UNIDO database show that there is innovation in African firms. This data also shows that although most African firms do not invest in formal R&D many African firms engage in innovation. Kraemer-Mbula et al. (2019), provide evidence that the way that African firms organise their work activity enables them to develop innovation capability. Thus, they posit that African firms develop innovation capabilities and thus innovate through employee adaptability and their ability to learn on the job as well as their creativity in solving problems

they face on the job. Avenyo et al. (2022) using WBES data show that participation in the global value chain (GVC) could stimulate product and process innovation through division of labour, variety of inputs, competition and learning and technology transfer. The authors find that GVC firms that have quality standards through the acquisition of international quality certification and engage in foreign collaborations generate innovation. Goedhuys et al. (2013) discuss technological capabilities as the ability to make effective use of existing knowledge to assimilate, use, master, adapt or change existing technologies and to develop new products and processes. The authors use R&D, innovation and productivity as proxies for technological capabilities. Goedhuys et al. (2013) note that the acquisition and use of new machinery and equipment is the most important route for technological learning in developing economies. Thus, firms must have workers with technical skills who can use the new machinery, equipment and technologies.

This thesis employs WBES innovation data to provide us with a general view of the nature of innovations and the factors that best encourage innovation in West African firms. However, the innovation data available offers limited insights into issues such as the effectiveness of government policy to encourage innovation or the transfer of knowledge within an industry. We therefore use a case study of the technological transfer of knowledge in backward linkage firms given government policy on procurement and local content to complement the quantitative chapters.

1.1.2 Main Objectives

- a) To ascertain the factors that influence the probability of selected West African firms to innovate using the WBES innovation data.
- b) To determine the relationship between product, process, marketing, and organisational innovation as well as assess the influence of innovation activity on each of the different types of innovation.
- c) To use a case study to complement the quantitative chapters by analysing how knowledge transfer occurs in backward linkage firms in the Ghanaian gold mining sector given government policy on procurement and local content.

1.1.3 Research Questions

1. What are the factors that determine innovation in West African Firms?

2. What is the relationship between the different types of innovation in firms in Ghana and Nigeria?

3. How do backward linkage firms in the goldmining industry acquire knowledge and build innovation capabilities given government policy?

1.14 Data Sources

- i. Innovation data from World Bank Enterprise Surveys for ten West African countries.
- ii. Innovation data from World Bank Enterprise Surveys for Ghana and Nigeria.
- iii. Interviews with management personnel in backward linkage firms in Ghana's gold mining industry and other stakeholders, the minerals and mining policy and the National Science Technology and Innovation (STI) policy.

1.2 Motivation

Innovation literature on West Africa as a region is scanty. There are few studies that cover the innovation activity in firms in this region because uniform data on the innovation capability of firms in most West African countries had been lacking until the World Bank Enterprise Surveys included innovation indication information. There is now some data on the firms in the region regarding their innovation capability and activity.

Most of the firms in the West African region like in most developing economies, are small, informal and lack access to term financing and face high borrowing costs (Kaplinsky & Kraemer-Mbula (2022); Cirera & Maloney (2017)). This makes it difficult to invest in R&D or have access to new markets. Yet it is necessary for these firms to build innovation capability to increase the diversity and intensity of localised innovation and complement imported technology (Bell, 2009). For firms in this region to develop innovation capability and absorptive capacity, it is important for government policy and institutions to coordinate this development of absorptive capacity through innovation capability building. Government policy can encourage investment in innovation capacity building as well as direct demand for innovation output.

Innovation policy for West African countries such as Ghana and Nigeria over the years has been vague by not having specific timelines within which to meet specific goals (National

Science, Technology and Innovation (STI) Policy, (2012); Draft-National-STI-Policy-Document-10-July-2017, (2017)). Thus, it has not yielded much in the way of developing the innovation capability of firms in these countries.

Ghana scored 32.9 out of 100 on its innovation capability while Nigeria scored 32.2 out of 100 according to The Global Competitiveness Report (2019). In this report, R&D expenditure as a percentage of GDP for Ghana is 0.4% while for Nigeria it is unavailable. Furthermore, patent application per million for Ghana is 0.02 while for Nigeria it is 0.01. Thus, going by innovation capability that relies on the technological advancement of a country such as R&D expenditure and patent applications, Ghana and Nigeria are behind developed economies such as Germany who's score of 86.8 out of 100 is the highest score for innovation capability in The Global Competitiveness Report (2019).

Germany's R&D expenditure as a percentage of GDP is 2.9% while patent applications per million is 292.1. Yet when it comes to innovation activities like diversity of the workforce, Ghana's score is 60.7, Nigeria scores 57.4 and Germany scores 71.5 out of 100. These scores are closer than the R&D expenditure and patent applications. This indicates that firms in Ghana and Nigeria lacking financial resources to invest in R&D may be developing innovation capability that relies more on worker interactions and learning internally from the diversity of colleagues as discussed by Kraemer-Mbula et al. (2019). It is important to investigate the nature of innovation and how firms in West Africa develop innovation capability to better inform government policy of the areas that the firms need help with. An investigation into firms' innovation capabilities such as R&D investments, worker training and acquisition of machinery and equipment can help policy makers draft policy directed at the needs of the various industries in developing economies.

1.2.1 Innovation Research Literature

Firms in developing economies tend to be further from the technological frontier than their developed economy counterparts. Hence changes to existing products tend to be those that are simple and less costly to implement (Fu et al., 2018). This means that innovation in developing economies is more likely to be imitative and incremental in nature, and more likely to be new to firms rather than new to the market or new to the world. Thus, it is necessary to explore factors that could influence innovation in a firm aside from R&D and patents which are associated with firms at the forefront of the technological frontier.

Academia on innovation has not as yet provided a comprehensive innovation measurement framework (Dziallas & Blind, 2019). Thus, different researchers have found customised measurement frameworks for different industries and different sectors of the economy. This makes it difficult to compare innovation results (or apply results) from firms in one region of the world to firms in another part of the world.

The Bogotá Manual is an attempt to tailor innovation surveys to developing economies. This is an adaptation of the Oslo Manual by some South American countries. It was developed to adapt innovation survey to the Latin American context (Crespi & Peirano, 2007). The aim of this manual was to widen the focus of technological innovation by including technological effort or innovating activity of firms. Thus, concepts such as absorption capabilities and organisational innovation were included in assessing the technological effort of a firm (Crespi & Peirano, 2007).

According to Crespi and Peirano(2007), the manual introduced the principle that the ability of a firm to absorb the technological skill and knowledge available to it depends on the firm's technological capabilities. Thus, the dynamics of technological innovation includes a diversity of inputs such as investment in the training of the workforce, the purchase of new equipment, investment in telecommunication and linkages and collaboration with other firms. This revision of the Oslo Manual came because of data collected from Community Innovation Surveys conducted in some Latin American countries using the Oslo Manual in the 1990s (Crespi & Peirano, 2007).

There is a need for improved innovation measurement in academia as well as in business. A better understanding of the innovation process and the indicator discourse will emerge if innovation indicator data and research results come from all parts of the world. Jauhiainen and Mugabe (2024), posit that there is a need for scholarly knowledge and research-based insights into innovations and innovation processes within the African context. They argue that building and maintaining an ever-evolving database, and accessible information would be valuable to both researchers and policy makers across the African continent. Kaplinsky and Kraemer-Mbula (2022), also recommend that developing economies embark on a large-scale data collection to capture the extent, character and drivers of innovation activities in the informal sector. This will help policy makers understand the dynamics of informality and how the informal economy reacts to specific policy approaches targeted at both formal and informal

actors. Thus, innovation indicator research will better reflect the dynamics of the factors of innovation if the data is representative of the different environments from which innovation can be observed. This will lead to a focus on how to enhance these factors to improve the development of innovation capability of firms in different stages of growth in different regions of the world.

Innovation surveys are useful in explaining the determinants of innovation, the role of innovation in firm performance as well as the characteristics of innovative firms (OECD, 2010). The Oslo Manual has provided a harmonised framework with coherent concepts and tools for undertaking comparable large-scale innovation surveys (OECD, 2010). This thesis uses the World Bank Enterprise Survey with innovation data fashioned after the Oslo Manual, to explore the intensity and diversity of innovation and innovation capability in West African firms. The innovation survey is an innovation indicator while the factors that influence the probability of innovating are the more specific firm activities into which the innovation indicator can be categorized (Dziallas & Blind, 2019).

The innovation research available on developing economies highlight the different ways in which traditional industries in developing countries build innovation capability. For instance, Egbetokun (2015), analyses the relationship between interactive learning and capabilities in Nigerian manufacturing firms. The paper uses innovation data from a survey of 170 Nigerian manufacturing firms implemented at the end of 2007. The survey included firms with at least 10 employees and reported on innovation activity that took place between 2003 and 2006. The results of the research show that informal interactions with agents such as customers and suppliers are as important to firms' development of skill and technological capacity as formal interactions with industry associations and universities.

In 2015, Kraemer-Mbula et al. (2019), gathered innovation data from 296 interviews of micro and small enterprises (MSEs) in four African countries, namely, Nigeria, South Africa, Tanzania and Uganda. The survey was collected on firms with one to forty-nine employees. The data was on innovation, work organisation and capability building. Seven sectors were selected for this study. Agro-processing was the only sector that was studied in all four countries. Clothing and Textiles was selected for Nigeria and South Africa while Metalworkers were selected for Tanzania and Uganda. Firms in ICT were selected from Nigeria, Recycling firms were selected in South Africa, Repair and Maintenance Service firms were selected in

Tanzania and Furniture Making firms were selected in Uganda. Two questionnaires were used to collect the data. One was for employers, and the other was for the employees. Owners or employers answered questions about business relations between suppliers and clients, extent to which MSEs benefit from knowledge exchange with businesses in the same local market as well as questions about linkages to formal support services and access to credit. Employees answered questions within the firm. This included the extent to which they engage in learning and problem-solving or on-going exchange of ideas and knowledge with other employees or with clients and suppliers they interact with. Sampling relied on a combination of local knowledge, support from intermediary organisations and snowball techniques. Thus, the selection of firms was not random.

According to Delera et al. (2022), the United Nations Industrial Development Organization (UNIDO) has a novel database on the adoption of production technologies by manufacturing firms. The database collected in 2019, provides information on different generations of technologies at a highly disaggregated level in three developing and emerging economies, namely, Ghana, Vietnam and Thailand. There are 658 firms surveyed across the three countries. The UNIDO survey is tailored for the analysis of firms' current and expected patterns of technology adoption. It covers a wider range of firm-level indicators such as innovation inputs and outputs, skills, location of production, trade and environmental sustainability. The survey collected data on firms with at least 20 employees operating in selected geographical locations and industrial sectors identified according to their strategic importance for a country's industrial sector.

Thus, there are different innovation surveys that cover individual West African countries, include African countries from different regions of the continent or include some West African countries with countries outside of Africa. These studies provide useful insights into firms in some West African countries, but they cannot be compared to each other because of the different objectives and survey methods of these different surveys. The WBES's innovation data is more streamlined hence it is easier to compare firm capabilities across countries. There is also potential to collect panel data which will allow for the analysis of innovation capability dynamics overtime and provide robust instrumental variables for the problem of endogeneity inherent in innovation data.

A good innovation indicator according to the Organisation for Economic Co-operation and Development (OECD) (2010), will guide policy makers to evaluate the efficiency or effectiveness of their policy and expenditure. It will aid in the assessment of the contribution of innovation to achieve social and economic objectives. It also lends credibility to public intervention in building innovative capability by enhancing public accountability. Innovation indicators must be identified based on their policy relevance, analytical soundness, statistical quality and whether they can be measured over time with prospects for improvement (OECD, 2010). This highlights the importance of this thesis in the innovation discourse of West African firms because it uses uniformly collected data across the countries. Thus, we can compare the factors that influence the probability of firms to innovate as well as how a sector of the economy acquires innovation capabilities across the countries. This will enhance our understanding of the dynamics of innovation in West African firms.

1.2.2 Theoretical Framework

Economic growth comes about through an increase in output and this increase in output can come about through an increase in inputs or from using the same inputs in a different way (Rosenberg, 2004). This new way of setting up the production function to increase output using the same inputs in a new way is what Schumpeter (1939) referred to as innovation. Innovation is important for long-term economic growth because there are limited resources and inputs thus in the long run to increase output, firms will have to innovate (Broughel & Thierer, 2019).

Innovation has the potential to increase output, employment and add value to existing output as well as create better goods and services. Innovation was formally considered to be part of a three-stage process with invention being the first stage followed by innovation. The last stage was diffusion or adoption of the innovation by the target market (Bell, 2009). This means that an innovation had to have high levels of technological novelty and result in a major change in an aspect of society or the economy. This perspective made it difficult for developing economies to be considered in discussions about innovation as very few inventions are patented in developing economies to begin with. Even so, this is not just a developing economy problem as innovation can occur without invention. It is noted by Lanjouw and Schankerman (2004), that research productivity measured by the ratio of patents to R&D has declined in industry over the years, but firms are still innovating.

Freeman & Perez (1988), propose a taxonomy of innovations where innovation comes with different levels of technological advancement and socio-economic influence. The first group of innovation is labelled incremental innovations. These types of innovations exist in all industry or service sectors. They are not dependent on R&D activity but come from inventions and improvements suggested by the workers engaged in the production process or from responding to customer feedback. They improve the efficiency in use of all factors of production. They are associated with the scaling up of plant and equipment and quality improvements to products and services.

The second group of innovations they called radical innovations. Radical innovations occur because of deliberate R&D activity in enterprises and or in university and government research institutions. They often involve a combination of product, process and organisational innovation. Over a period of decades, radical innovations are expected to bring about structural change. The third set of innovations are labelled Changes of Technology System. These are innovations that have far reaching changes in technology affecting several branches of the economy as well as giving rise to entirely new sectors. They arise from a combination of radical and incremental innovations together with organisational and managerial innovations affecting more than one or a few firms. The final group of innovations lead to changes to the techno-economic paradigm, that is, these are technological revolutions. These changes come with many clusters of radical and incremental innovation and may eventually embody several new technology systems. A vital characteristic of this type of technological change is that it has pervasive effects throughout the economy. This taxonomy of the technological nature of innovations show that incremental innovation is necessary in all the different sets of technological change.

For a firm to innovate it must have innovation capability. Innovation capability encompasses a firm's ability to imagine, develop and implement innovations in the goods and services it produces as well as its production process (Bell, 2009). According to the UNESCO Institute for Statistics (2017), innovation activities are all scientific, technological, organisational, financial and commercial steps which actually lead or are intended to lead to the implementation of innovations. Hence, innovation activities are themselves innovative. Thus, innovation activities include R&D; acquisition of machinery, equipment and software; acquisition of other external knowledge; worker training; and market introduction of

innovations. Therefore, innovation activities lead to innovation capability and innovation outcomes are also innovation activities.

The absorptive capacity of a firm depends on the basic skills of its employees, the shared language of the workers in the firm and the source of information as well as knowledge of the scientific or technological development in the firm's industry. This is the transfer of technology to workers in a firm (Cohen & Levinthal, 1990). The absorptive capacity of a firm is important because it enables a firm to use external information to develop innovation capability. Thus, prior knowledge aids a firm to recognize the value of new information, and this information can then be used to develop innovation capability. Hence technological transfer of information to workers develops the absorptive capacity of the workers. The development of absorptive capacity also develops innovation capability. Innovation capability leads to innovation outcomes.

Thus innovation capability seems to have a nebulous definition and this has been observed by certain authors such as Moreira et al. (2024), and Daronco et al. (2023). In a detailed analysis of 103 English language articles on innovation capability written from 2001 to 2022 and sourced from Scopus and Web of Science databases, Moreira et al. (2024), identify four main dimensions of innovation capabilities. The first group comprises of learning, R&D, manufacturing, marketing and organisational strategy and resource exploitation capabilities. The second group is participatory leadership culture, ideation and organization structures, work climate and well-being, development of know-how, regeneration, external knowledge and communication. The third group consists of innovation outcomes. The fourth dimension is the ability of a firm to sense market opportunities and customer needs and the capability of a firm to develop innovation outcomes by adapting to changing market conditions through continuous learning, and experimentation.

Moreira et al. (2024), observe from the literature that there are two main theoretical approaches to the discussion of innovation capability and these are the resource-based view and the dynamic capabilities of a firm. In the resource-based view a firm's valuable resources play a crucial role in determining its competitive advantage. The dynamic capabilities perspective is that to attain new forms of competitive advantage, firms need to continually renew their capabilities. Daronco et al. (2023), perform a comprehensive systematic literature review of 186 papers sourced from Web of Science and Scopus databases. These papers were published

between 1978 and 2018. The authors in this paper propose that there are two main theoretical approaches to innovation capability which are a firm's propensity for innovation and a firm's ability to act or apply its intention and potential to innovate. They for their part identify five main perspectives of innovation capability in the literature. These are the knowledge-based view, resource-based view, dynamic capabilities, strategic management and practice-based view.

These systematic literature review of innovation capability agree that the more existing knowledge a firm has the less the amount of knowledge required for a firm to convert new information into innovative capability (Cohen & Levinthal, 1990). Innovation activities such as R&D, worker training, use of patented or unpatented invention and acquisition of equipment are how a firm improves its absorptive capacity and in turn builds on its innovation capabilities. A firm is expected to increase the level of absorptive capacity when employees increase their prior knowledge hence the need to train workers which transfers technological knowledge. Innovation capabilities increase firms' absorptive capacity. An increase in absorptive capacity increases the ability of a firm to recognise information useful for the development of innovative outcomes. Thus, innovation capabilities generate innovation outcomes and facilitate learning (Cohen & Levinthal, 1990).

It is costly to come by new information as firms must invest in research and engage in other innovation activities to realise knowledge that is relevant for developing innovation output. Existing knowledge has a public good quality in that it is difficult to exclude others from absorbing it and the use of existing knowledge by one firm does not impede its use by other firms. This is why government policy and regulation are important to encourage private firms to develop innovation capabilities and hence innovation output.

Arrow (1962), theorises that there is an incentive to invest in an invention if the inventor can demand royalties from the firms that utilize this invention. Hence government policy can be used to mitigate the private cost of investment in novel technologies or ideas that are useful to an industry. Bell (2009), argues that government policy can be used to direct innovative firms to engage in environmentally sustainable methods of production and output. Institutional structures within a country are important in the development of firms' innovation capability. Government policy can serve to either encourage private investment in innovation or discourage it (Nee et al., 2010). Government intervention can help a firm gain access to a wider

market. This access can advance innovative capacity by improving the process of knowledge accumulation and organisational learning (Kafouros et al., 2008).

Empirical evidence of the effectiveness of government intervention in how firms develop innovation capability has shown that rather than crowd out private investments in R&D as had been suspected, government support has rather served to stimulate private R&D investments especially in small firms (Hunermund et al., 2019). Government institutions will be better situated to coordinate collaborations between private firms and research institutions and universities. Such collaborations are expected to reduce the cost of innovation research. They also signal the quality of innovation output and can attract private investment. Government coordination in these collaborations can engender trust among the various groups and dissipate fears of free riding by members of the collaboration.

1.2.3 Objective of the Structure of the Thesis

The three main chapters in this thesis seek to provide information on the interactions between innovation activities and innovation output in West African firms. This is based on the theoretical assumption that innovation activities build innovation capability that lead to innovation outcomes. They examine the influence of innovation activities on innovation outcomes in ten West African countries in the first main chapter and the correlation of the types of innovation outcomes in the second main chapter. The third main chapter is a case study of how backward linkage firms in the goldmining industry of Ghana acquire knowledge and build innovation capabilities given government policy on procurement and local content. This is based on the theoretical assumption that government policy can be used to mitigate the private cost of investment in novel technologies or ideas that are useful to an industry.

This introductory chapter concludes with an analysis of the West African economies to be studied in this thesis. The chapter is followed by the first quantitative chapter of the thesis. It determines the probability that a firm would innovate by using variables that influence innovation as regressors. The objective is to determine the factors that increase the probability that a firm will innovate. The second quantitative chapter examines simultaneity in the different types of innovation in firms in Ghana and Nigeria. This chapter shows how the different types of innovation relate to each other and are influenced by innovation activities. The qualitative chapter is a case study that critically analyses the role of government policy in the enhancement of the innovation capability of backward linkage firms to the mining sector in Ghana.

It is important to note that a case study can only cover an industry and so may not have outcomes that can be generalized (Fagerberg et. al, 2005). Econometric analyses of innovation often rely on data obtained from periodic surveys while case studies provide a rich source of evidence on the details of the transfer and absorption process (Hoekman & Javorcik, 2006). The case study is to enhance the econometric research of the previous chapters. This is because econometric research and case studies on technological transfer and innovation are complementary. The two quantitative chapters provide us with a general outlook of the nature of innovation and the characteristics that best encourage innovation in the West African context. However, it will be difficult to use the cross-sectional innovation data available to obtain deeper insights into issues not covered in the innovation surveys that influence innovation outcomes such as transfer of knowledge within an industry and government policy aimed at an industry. This case study of firms in a specific industry is important when analysing the ability of an economy to build the competence that is needed to lead firms to innovate.

1.3 Data

The World Bank Enterprise Surveys (WBES) have innovation data for ten of the 15 ECOWAS countries. From 2011-2014, a total of 19 countries were included in the standard Enterprise Survey and surveyed using the Innovation Follow-up Survey. These included 15 African countries and four countries in South Asia. Since then, innovation indicators have been included in the Enterprise Survey (ES) in developing economies. According to the Enterprise Survey's website, World Bank Enterprise Surveys (<http://www.enterprisesurveys.org>), the Enterprise Survey is administered to business owners and top managers of private sector establishments. The manufacturing and services sectors are the primary business sectors of interest. Firms with 100% government or state ownership are not eligible to participate in the survey.

The World Bank Enterprise Surveys has a follow-up survey that re-visits the firms that have already been interviewed in the standard survey. This survey is to provide in-depth information on the determinants of innovation in developing economies to identify projects and advise policies that promote innovation. In addition to collecting data on variables like the innovation survey, the follow-up survey collects additional data on types of innovation depending on the technological intensity of the innovation. Thus, product and process innovation are seen as

technologically intensive while organisational and marketing innovation are the two less technologically intense innovation types that are included in the follow-up questionnaire.

The Enterprise Survey (ES) questions as stated in the questionnaire for product and process innovation for each country used in this thesis is stated in the appendix A1.1. The ES questions for marketing and organisational innovation for Ghana and Nigeria is in the appendix A1.2. The innovation activities that are outlined in this thesis are export, R&D, worker training and the purchase of assets and equipment. R&D investment falls under the resource-based view and export, worker training and the purchase of assets and equipment fall under the dynamic capabilities as outlined by Moreira et al. (2024). On the other hand, R&D, worker training, export and the purchase of assets and equipment fall under the knowledge-based view as outlined by Daronco et al. (2023). According to Daronco et al. (2023), R&D can also fall under the resource-based view. The ES questions for these activities for each country are outlined in the appendix A1.3. The similarities in these questions for the ES for each of these countries justify their combination in the dataset used in this thesis. The first empirical chapter uses innovation data for ten West African countries while the second empirical chapter uses a combination of the main innovation survey for Ghana and Nigeria. Ten West African countries are selected because they were the ones which had WBES innovation data available at the time of this study.

The case study is to complement the quantitative chapters. Six firms affiliated with the Ghana Chamber of Mines were interviewed. Each firm was interviewed once. Three owners and three managers were interviewed in all. The linkage firms interviewed for the case study are in five sections namely, services; capital goods and construction materials; consumables; bulk services and infrastructure and non-core goods (World Bank, 2012). The interview questions were semi-structured in that they were a set of questions designed to guide the interviews. The key themes explored in the interviews were the development of innovation capabilities given government policy aimed at the development of backward linkage firms to the mining industry and the problems faced by the linkage firms as pertains to their access to infrastructure, resources and government enforcement of the requirements of the policy.

The discussion includes quantitative data from reports on the backward linkage firm participation issued by the Chamber of Mines and international civil society organisations as well as reports from local research institutions on government policy and industry. Government

laws and policies are also discussed to assess the effectiveness of the existing STI policy in developing innovation capability in industry. The qualitative data is analysed with the quantitative data to assess the interactions between the mining firms, the backward linkage firms, government institutions and local research institutions.

1.3.1 Innovation Statistics in West African firms

West African countries are varied in terms of income, political stability, and human development. Going by the World Bank country classification for 2021, five of the countries included in this thesis are in the low-income category and the other five are lower middle-income. This is because a Gross National Income (GNI) per capita of \$1,086 or less classifies a country as low-income while a GNI per capita between \$1,086 and \$4,255 classifies a country as lower middle-income. These countries also vary in population sizes with Liberia having the lowest population and Nigeria, the largest population. The population and GNI per capita of the individual countries are in table 1.1 below.

From table 1.1 we see that firms in these countries engage in innovation. The values for product and process innovation are the proportion of firms that engaged in innovation outcomes. From the table we can see that low-income countries engage in product and process innovation at a rate similar to that of lower middle-income countries. More firms engaged in product innovation than in process innovation on average.

Political, tribal, and religious conflicts plague some West African countries. Some of these countries such as Côte D'Ivoire, Liberia and Sierra Leone have been able to achieve relative political stability within the last decade. Côte D'Ivoire had been in a political crisis from 2002 to 2010 but since 2011 the country seems to be enjoying some political stability (African Development Bank Group, 2019). Liberia had a civil war that lasted for 14 years and have had relative political stability since 2003(Catholic Bishop's Conference of Liberia, 2016). Whereas Mali and Niger have recently gone through political coups and have since February 2025 officially left the ECOWAS economic block. Mali has been experiencing instability and conflict since the military coup of 2012 and the occupation of the northern regions by armed groups. Security threats at the borders with Mali, Libya, and Nigeria place Niger's socio-

Table 1.1 GNI per capita and population by country for 2021 and Innovation Outcome

Country	Low- Income	Lower Middle- Income	Population (million)	Product Innovation (%)	Process Innovation (%)
Benin		\$1,350	13	26.2	14.1
Côte D'Ivoire		\$2,420	27.5	36.5	17.7
Ghana		\$2,280	32.8	51.5	51.2
Liberia	\$630		5.2	45	24.5
Mali	\$820		21.9	35.9	32.6
Niger	\$590		25.3	33.6	18
Nigeria		\$2,080	213.4	49.9	49.7
Senegal		\$1,570	16.9	47.6	39.7
Sierra Leone	\$500		8.4	34.2	19.1
Togo	\$960		8.6	36.7	15.3

Source: Author's compilation from World Development Indicators Database, World Bank and <http://www.enterprisesurveys.org>.

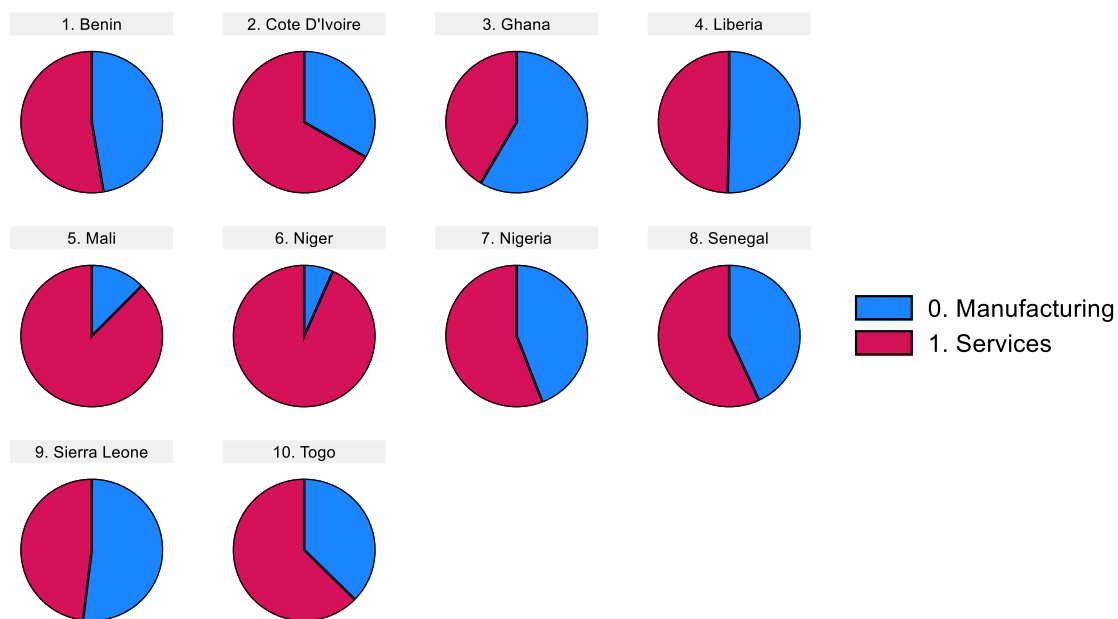
economic stability at risk (Hounsa et al., 2019). The North-South divide in Nigeria has widened in the last decade due to the Boko Haram insurgency and lack of economic development in the northern part of the country (World Bank Group, 2019).

1.4 Economic background for the ten West African countries

The World Bank Enterprise Survey categorizes firms into manufacturing and services. Figure 1.1 below shows the share of each industry type for each country in the dataset. It shows that most of the firms in six countries namely, Niger, Mali, Côte D'Ivoire, Togo, Senegal, and Nigeria are service providers. Thus, most of the firms in the data are in the service industry. This may be because of the high number of retail firms in these countries. Figure 1.2 which follows figure 1.1 below shows the share of innovation output by country in the Enterprise Survey dataset.

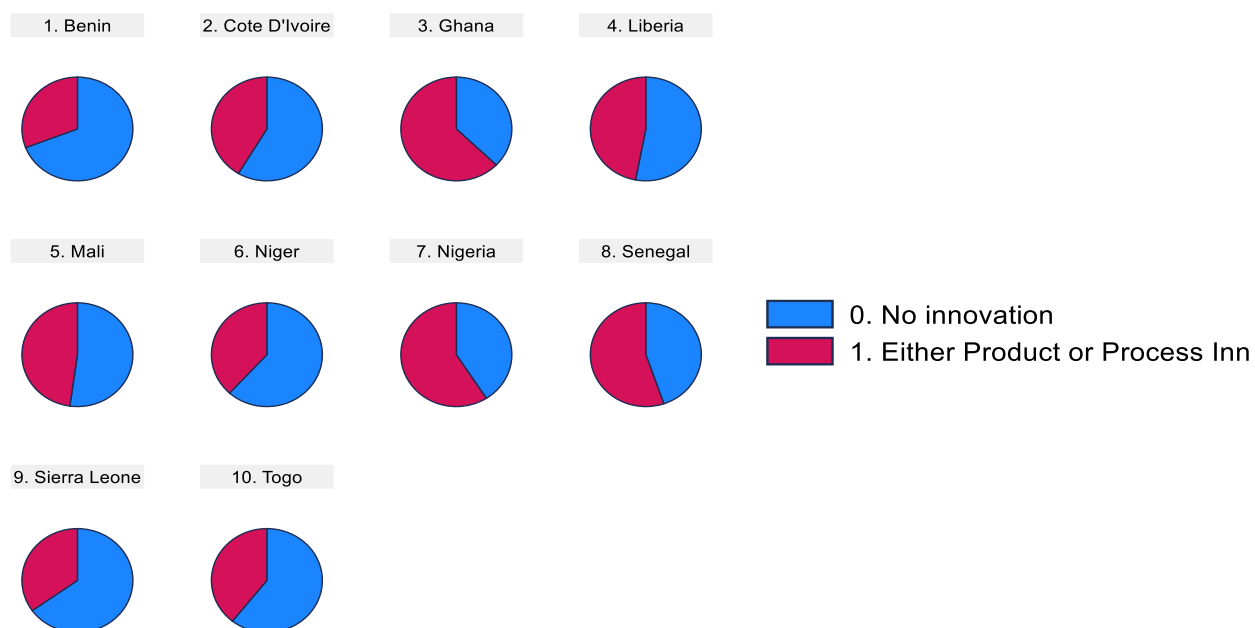
In figure 1.2, we compare the innovation-active firms (i.e. the number of firms that engage in either product or process innovation or both) to the firms that engage in neither innovation activity. It can be observed that more than half of the firms in Ghana, Nigeria and Senegal engage in at least one type of innovation.

Figure 1.1 Share of Industry Type by Country



Graph by Author

Figure 1.2 Share of Innovation by country



Graph by Author

Source: Author using ES data

1.4.1 Economy of the ten West African Countries

Benin's economy is mainly sustained by cross border trade with Nigeria (ECOWAS, 2016). It is a country supported by the agricultural industry. Its major foreign exchange earner is cotton (The World Bank, 2019). Thus, the economy is vulnerable to shocks such as variations in the weather and fluctuations in Nigeria's economy. It can be observed from figure 1.1 that most of the firms in the dataset for Benin provide services while figure 1.2 shows that Benin has the lowest proportion of firms that engage in innovation output. Benin is a lower middle-income country whose economy is dependent on agriculture and trade with Nigeria. Thus, it may explain why the firms in the economy engage more in services than in manufacturing as most of the firms engaged in the service industry are in the retail of imported goods. From table 1.1 we see that nearly twice the firms in Benin that engage in process innovation engage in product innovation. This may be due to the higher costs associated in building innovation capability towards process innovation such as the acquisition of machinery.

Côte D'Ivoire's economic growth averaged eight percent between 2011 and 2018 driven by modern service sectors (mainly communication, banking, and transport) and a construction sector fuelled by an ambitious investment program and rapid urbanization (The World Bank, 2019). Cocoa is its largest foreign exchange earner accounting for more than 70% of the value of the country's exports (Coulibaly & Erbao, 2019). Côte D'Ivoire is the world's largest producer of cocoa with a market share of 40% in 2013 (Coulibaly & Erbao, 2019). Two-thirds of the firms surveyed for Côte D'Ivoire are in the service industry. This is expected as the service sector drives the Ivorian economy. A little over 40% of Ivorian firms surveyed engaged in innovation output. From table 1.1 we see that more than twice the firms that engaged in process innovation, engaged in product innovation. Thus, firms in Côte D'Ivoire may be using the generation of novelty in existing products to remain relevant in a competitive environment thus engaging more in product innovation.

Ghana achieved lower middle-income status in 2011 (World Bank, 2019). Ghana's economy grew at about 8% in 2017 with the growth rate reducing to 6.3% in 2018 and 6.5% in 2019 (Ghana Statistical Service, 2020). Ghana's growth is driven by the mining and oil sectors. Gold accounts for almost half of the value of Ghana's exports and is its highest foreign exchange earner (Ghana Statistical Service, 2020 ;Minerals Commission, 2014). In the survey, Ghana has the highest proportion of manufacturing firms in the dataset. Ghana also has the largest

proportion of firms engaged in innovation output in the survey. Table 1.1 shows that an equal proportion of Ghanaian firms engage in product innovation as process innovation. This may be due to Ghana having a higher proportion of manufacturing firms to service firms in the survey dataset. The Ghanaian economy's growth in recent years has been driven by the mining and oil sectors who have local content policies that has encouraged existing manufacturing firms to supply to the mining firms and oil rigs. For instance since the implementation of the local content policy for the mining industry, 52% of mining inputs sourced in Ghana are supplied by Ghanaian manufacturers and service providers (African Center for Economic Transformation, 2017).

In Liberia, iron ore, gold and rubber together accounted for 90.7% of the value of its exports in 2021 (World Bank Group, 2022). Liberia is nearly split in the middle between manufacturing and service firms in the survey shown in figure 1.1. Similarly, nearly half of firms surveyed engaged in innovation output as can be observed in figure 1.2. From table 1.1 we see that a lot more Liberian firms engaged in product innovation than process innovation. The influence of the mining industry on the Liberian economy may explain why there are nearly an equal number of manufacturing firms in the survey as service firms compared to the other West African economies dominated by agriculture and trade. Liberian firms are likely to be constrained by poor infrastructure and lack funding to invest in formal innovation capability building since it is a low-income country (Egbetokun et al., 2016). Yet the data shows that Liberian firms engage in innovation outcomes.

Mali is a vast, landlocked country with a semi-arid climate. Mali has an undiversified economy that is vulnerable to raw material price fluctuations (World Bank, 2018). Mali's highest foreign exchange earners are gold and cotton which made up 80% of its exports in 2017 (World Bank, 2018). Most of the firms surveyed in Mali are in the service industry. Almost half of the firms surveyed in Mali engaged in innovation output. From table 1.1 we see that firms in Mali engage in process innovation nearly as much as they engage in product innovation. Mali is a low-income country and so most of the firms engage in retail trade that has a lower barrier to entry as far as skill and funding is concerned. Most of the firms in Mali are small with less than 20 employees. These firms have resource restrictions and so engage in innovative activities by producing distinct types of innovation such as product and process innovation to be able to compete in the market (Saunila, 2020).

Niger is a landlocked country with some of the world's largest deposits of uranium, but agriculture makes up nearly 40% of its GDP and employs about 80% of its working population (African Development Bank Group (AfDB), 2018). The Nigerien economy like many West African economies is dependent on the export of raw minerals hence there are very few firms engaged in manufacturing by way of value addition to the commodities exported. This may explain why almost all the firms interviewed in the survey for Niger are in the service industry. Less than 40% of firms in Niger surveyed engaged in innovation output. From table 1.1 we observe that more firms engage in product innovation than in process innovation.

Nigeria's major export is crude oil which makes up over 90% of the value of total exports (World Bank Group, 2019). It is Africa's biggest oil exporter and has the largest natural gas reserves on the continent (International Monetary Fund, 2019). Nigeria is plagued with high regional inequality in terms of income and opportunities (World Bank Group, 2019). This has adversely affected poverty reduction. It can be noted that more than half of the firms surveyed for Nigeria are in the service industry. Nearly 60% of the Nigerian firms surveyed engaged in innovation output. Nigerian firms engaged in product innovation as much as they engaged in process innovation. Nigeria is a net importer of food and consumer products while it exports mainly crude oil in its primary state (Egbetokun, 2015). The innovation outcome of Nigerian firms similar to most firms in lower middle-income economies is low in formal R&D but rather incremental in nature (Egbetokun, 2015).

Senegal's economy is much more diversified. Its exports include agricultural products, gold, and phosphoric acid. Senegal's economy has been growing above 6% since 2014 and is expected to keep growing at that pace especially since the country is set to begin the production of offshore oil and gas between 2022 and 2023 (The World Bank Group, 2020). Over half of firms surveyed for Senegal are in the service industry. More than half of the firms surveyed in Senegal engaged in innovation output. Table 1.1 shows that more firms engaged in product innovation than in process innovation.

The Sierra Leone economy was growing at an average of 7.8% from 2003 after their civil war of about a decade ended when Ebola struck the country in 2014. Coupled with a dip in the price of iron ore, which is their major export commodity, the economy shrank by 21% in 2015 (Kiendrebeogo et al., 2019). The economy seemed to have made a recovery in 2016, growing at 6.4 % only to dip to 5.8% in 2017 following a landslide in Freetown and 3.7% in 2018

(African Development Bank Group, 2019). The ES data for Sierra Leone has more than 50% of firms in the manufacturing sector. A little over a third of firms engaged in innovation output. Table 1.1 shows that more Sierra Leonean firms engage in product innovation than engage in process innovation.

Togo's economic growth between 2011 and 2016 was led by growth in agriculture, commerce, transport and services and construction (The World Bank, 2016). The services sector made up 52% of Togo's GDP in 2023 (World Bank, 2025). Over 60% of the firms surveyed for Togo are in the service industry. Nearly 40% of the firms that were interviewed engaged in innovation output. More than double the firms that engage in process innovation engage in product innovation.

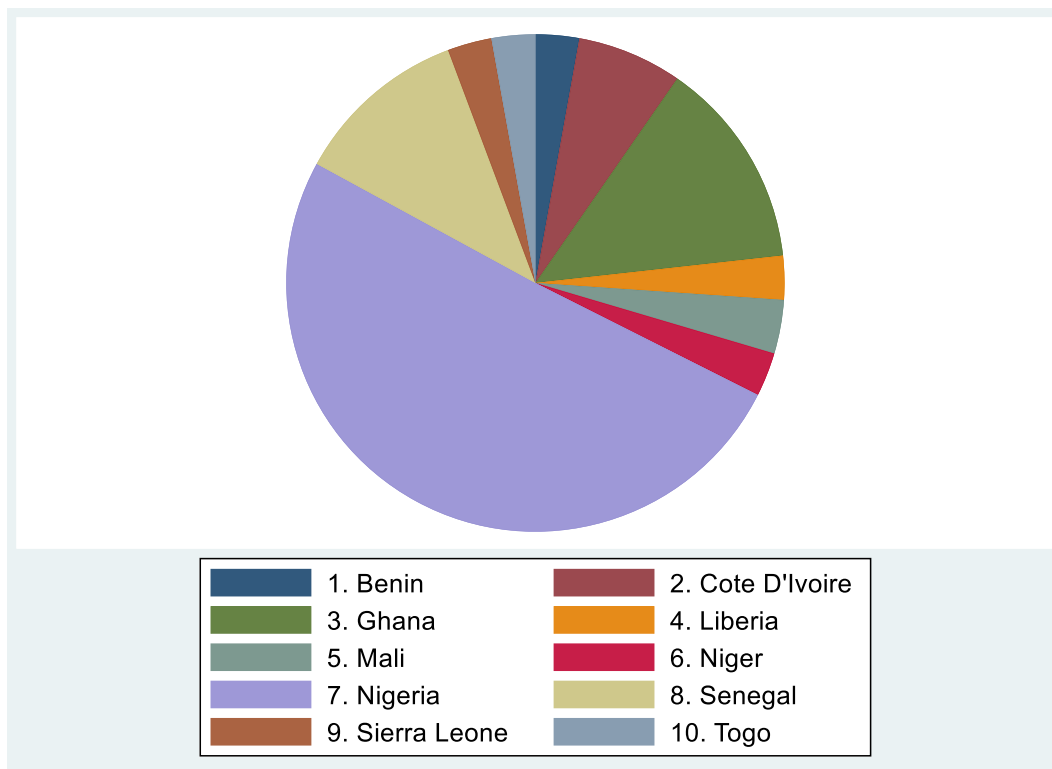
1.4.2 Country statistics in the Enterprise Survey

Figure 1.3 below shows the share of firms for each country in the ES dataset. It can be observed that Nigeria has the largest number of firms in the sample followed by Ghana, Senegal, and Côte D'Ivoire in that order. The other six countries have similar shares of firms. This is because the ES chooses the number of firms to survey in a country based on the size of a country's GNI. According to the ES report (World Bank, 2022) a very small country is a country with a GNI of less than \$20 billion and so 150 firms are sampled.

Benin, Liberia, Niger, Sierra Leone, and Togo neatly fall in this category. Mali is a small country, but its sample size is 185. A small country with a GNI of between \$20 and \$30 billion has 360 firms sampled. Côte D'Ivoire is in this category. A medium sized country has a GNI of between \$30 and \$100 billion. In this category 600 firms are sampled. In this dataset that is Senegal and Ghana. Yet, Ghana's sample is 720 while Senegal's is 601. A large country has a GNI of between \$100 billion and a trillion dollars with a sample of 1000 firms. Nigeria is a large country but its sample is more at 2,676 firms.

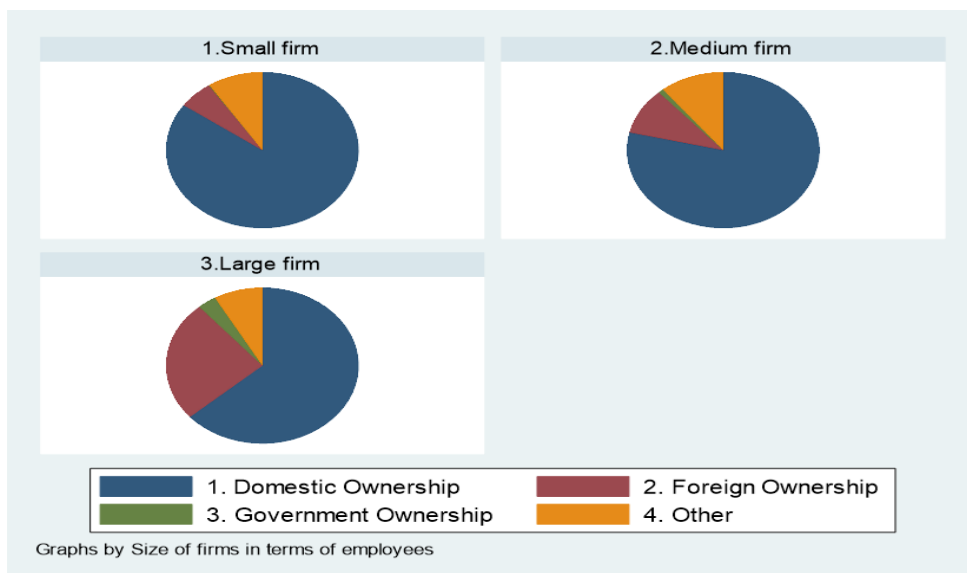
Figure 1.4 below shows the majority ownership of firms in the dataset given firm size. In this dataset, a small firm is a firm with between 5-19 employees. A medium sized firm is one with between 20-99 employees. A large firm is one with 100 or more employees. Figure 1.4 below shows that most small firms are owned by locals while about a quarter of the large sized firms are foreign owned. Although the survey does not include firms with a hundred percent government ownership there are firms that have government as the majority owner.

Figure 1.3 Share of firms by country.



Source: Author using ES data

Figure 1.4 Ownership of firms given firm size.



Source: Author using ES data

Table 1.2 shows firms that engage in both innovation outcomes and in innovation activities. It shows that firms that engage in innovation engage more in the purchase of equipment and worker training than invest in R&D or Export.

Table 1.2 Cross Tabulation of Innovation Capabilities and Innovation Outcome

Innovation capabilities	Product Innovation	Process Innovation
R&D	25% (603)	27% (577)
Training	38% (905)	39% (820)
Asset Purchase	47% (1,082)	49% (1,016)
Export	20% (444)	20% (405)

Source: Author using ES data

1.5 Summary

This thesis uses available innovation data on West African firms to shed more light on the variables that increase the probability of innovating in this region. There is little research on innovation in developing economies compared to developed economies and virtually none on innovation in most West African countries. This research brings more understanding to how innovation activities increase the probability that a firm innovates as well as the relationship between the different types of innovation. Furthermore, this research through a case study explains the need for policy alignment in the extraction industry to encourage innovation in backward linkage firms. In essence, the research suggests that innovation in linkage firms could contribute to the localisation of suppliers to the extractive industry leading to development and growth in the general economy.

This thesis provides important information on the nature of innovation capability and activity in West African firms but more research in the field is still necessary. It is hoped that there would be innovation surveys that cover many years to have data that can show which variables influence innovation overtime and in what capacity. As more innovation surveys are conducted over the years the structure of the taxonomy of innovation capabilities for developing economies will become more standardized.

Theoretically, Daronco et al. (2023), propose four firm-specific determinants of the development of innovation capability. The first is leadership responsible for directing strategic

choices and dedicating resources to innovative activities. The second is organisational structures and systems that encourages innovation efforts and activities. The third consists of norms, beliefs and values that characterize an innovative culture at individual, team and organisational levels. Finally, the strategy to bring all three determinants together that will direct these efforts towards the development of innovation capability overtime.

An examination of some empirical literature provides us with a taxonomy of innovation capabilities for developing economies that this paper can contribute to. For instance Egbetokun (2015), examines the relationship between interactive learning and innovation capabilities of manufacturing firms in Nigeria. The paper found that the most important external sources of knowledge for firm-level capability building are customers, suppliers of machinery and equipment as well as industry associations. The paper notes that formal research and government sources are among the least important sources of knowledge to the firms. Thus market-based linkages increase the probability that a firm will engage in innovation outcomes.

On the other hand, Delera et al. (2022) find that the adoption of industry 4.0 technologies positively relates to firm performance. Industry 4.0 technologies refer to the ultimate result of technological progress in information and communication technologies. The results show that the adoption of advanced digital production technologies is associated with increased productivity of the firm. The paper also showed that firm size, investment in capability building activities such as R&D and worker training, foreign ownership and technological innovation are positively and significantly associated with labour productivity. This paper recognised that very few of the firms surveyed in the developing and emerging economies under the study invested in industry 4.0 technologies.

Kraemer-Mbula et al. (2019) observe that MSEs in Africa lack the financial resources needed to invest in R&D. These firms are not connected to a National System of Innovation such as universities and research institutions hence they do not have access to formal avenues of learning. This means that employers and employees engage in learning by interacting with each other as well as with external stakeholders and industry players such as their suppliers, customers and competitors. Autonomy and interactions are important in learning and capability building. This is how firms in Africa are able to mobilise their employees' skills and individual competencies leading to innovation outcomes (Kraemer-Mbula et al., 2019).

This thesis hopes to contribute to the innovation discourse. The two empirical chapters provide us with a general overview of the nature of innovation and the characteristics that best encourage innovation in the West African context. However, it will be difficult to use the cross-sectional innovation data available to obtain deeper insights into the effectiveness of government policy to encourage innovation. It is important to note that the case study only covers a relatively small number of firms in an industry and so may not have outcomes that can be generalized (Fagerberg et. al, 2005).

Chapter 2: Determinants of Innovation in West African Firms

2.1 Introduction

This chapter investigates the factors that influence innovation by West African firms. The chapter aims to ascertain the factors that influence the probability of selected West African firms to innovate using the World Bank innovation data. The chapter identifies the factors that increase the probability that a West African firm will engage in innovation. Product and process innovation are the dependent variables. Variables that are expected to enhance the development of innovation capability of firms such as expenditure on R&D, worker training, export of output and acquisition of equipment are some of the determinants of innovation in this study.

Innovative capability of a firm enhances its absorptive capacity. The absorptive capacity of a firm depends on the basic skills of its employees, the shared language of the workers in the firm and the source of information as well as knowledge of the scientific or technological development in the firm's industry (Bell, 2009). Thus, prior knowledge aids a firm to recognize the value of new information, and this information can then be used to develop innovative capability. Hence the development of absorptive capacity is also the development of innovative capability. A first step to knowing the innovation capability of firms in a country would be to analyse existing data collected from innovation surveys. This is the objective of this chapter. This chapter seeks to evaluate the factors that influence the probability of firms innovating in West African countries.

The ability of a firm to recognize the value of new, external information, assimilate it and apply it to commercial ends is known as the absorptive capacity of a firm according to Zou et al. (2018). The absorptive capacity of a firm enables it to use external information to develop innovation capability (Cohen & Levinthal, 1990). Innovation capability includes a firm's ability to imagine, develop and implement innovations in the goods and services it produces as well as its production process (Bell, 2009). Firms do not often develop innovative capability on their own. Other factors such as efficient transportation, trade, improved living standards and the level of industrialisation of an economy have been known to lead to the development of innovative capability (Hansen & Ockwell, 2014).

It is important to study the intricacies of innovation in firms in an economy since this would enhance the policy decisions towards improving the competitiveness of industry in a country.

It takes a coordinated national effort for firms in an economy to develop the necessary innovative capabilities that would make them competitive in the international market (Mazzucato, 2013). The innovation activities of a firm are dependent on the firm's links to sources of information, knowledge of available technologies, and human and financial resources (Gault, 2020).

Empirical research on the nature of innovation in developing countries suffers from a scarcity of data on the innovative capability of firms and this is very relevant to those in the West African region. Mairesse & Mohnen (2010b) point to three main innovation indicators: research and development (R&D), patents and innovation surveys. Although R&D is seen as a way of absorbing knowledge, it is still unclear how this knowledge absorption leads to innovation in business (Mairesse & Mohnen, 2010a). Patents do not show whether an invention has been commercialised or how successful that commercialisation has been (Braunerhjelm, 2010). In innovation surveys that follow the Oslo Manual (2005) an innovation has been implemented if it has been either introduced onto the market or used in the production process. Thus, Dziallas and Blind (2019) classify patents and R&D as indirect indicators of innovation. On the other hand, they classify innovations that have been commercialised or implemented as direct indicators of innovation.

Innovation questionnaires following the Oslo Manual such as the World Bank Enterprise Surveys, document the technical features and economic significance of a firm's product or process innovation. This data records innovation that has been implemented and is thus a direct indicator of innovation. Thus, the availability of this data enables us to conduct research into how the factors that enable the development of innovative capability, influence the probability of innovating in developing economies to understand the determinants of innovation.

This chapter is divided into six further sections. Section 2.2 discusses the background which includes discussion of a conceptual framework for absorptive capacity and innovation surveys. It also includes how the innovation ecosystem of some West African countries compares to that of some OECD countries. This is followed by Section 2.3 which discusses the literature which includes literature on the determinants of innovation in developing countries. Section 2.4 is a discussion on the data used. Section 2.5 looks at the empirical approach for this chapter. Section 2.6 discusses the findings of the regression analysis and Section 2.7 concludes the chapter.

2.2 Background

2.2.1 Conceptual Framework of absorptive capacity and innovation surveys

Lichtenthaler and Lichtenthaler (2009), argue that absorptive capacity as discussed by Cohen and Levinthal (1990), focuses on the use of external knowledge by the firm neglecting other important knowledge processes such as internal knowledge generation. Hence, in the development of innovation capability, both internal and external knowledge are required. Lichtenthaler and Lichtenthaler (2009), note that knowledge processes are not sequential but rather there are multiple feedback loops. Internally developed knowledge shows the inventive capacity and transformative capacity of a firm while learning from external sources shows the absorptive capacity of a firm.

Mikhailov and Reichert (2019), performing a systematic literature review of 37 papers on absorptive capacity agree that to promote innovation within a firm, it is not enough to develop absorptive capacity by itself but also a firm's internal conditions such as organisational learning, organisational cultural intelligence and innovative culture are as important as environmental conditions to transform absorptive capacity into innovation output. Mairesse and Mohnen (2010) posit that the different strategies that firms adopt when engaging in innovation activity complement each other. Firms that innovate often implement different strategies simultaneously. They perform R&D, purchase technologies, engage in innovation output, patent, collaborate and so on. Thus innovative capacity comprises the process of transmitting knowledge and converting this knowledge into products and services (Lichtenthaler & Lichtenthaler, 2009).

Mairesse and Mohnen (2010) explain that innovation surveys as an innovation indicator are extensively taken into consideration by economists, statisticians and policy observers to monitor innovation performance as well as explore and analyse the determinants and effects of innovation. They propose an accounting framework to compare innovation performance across regions, industries or countries. They believe a linear approximation of the innovation function around a reference region, industry or country will make it possible to attribute cross-sectional differences in innovation performance to differences in determinants. The authors suggest that it is best for cross-country comparisons to have a core of basic questions asked in the same way with the same definitions in the same order in different countries. The World Bank Enterprise

Surveys' innovation questionnaire satisfies these requirements and thus makes it well suited for this analysis.

2.2.2 Comparative Analysis of Innovation activity

The Global Competitiveness Index (GCI) 4.0 captures the determinants of long-term growth in an economy. In the GCI 4.0 framework, the determinants of long-term growth are an enabling environment, human capital quality, markets, and the innovation ecosystem. Sub-Sahara African countries lag in global competitiveness indicators for innovation activities. According to World Economic Forum (2019), 25 of the 34 economies that fell below a score of 50 were in sub-Saharan Africa. The scale ranges from 0 to 100. Thus, it is important to understand the factors that influence innovation in firms in West African countries. This will provide a focus for policy makers tasked with the development of innovation capability of firms in this region. A better directed policy could enable these firms to improve on their competitiveness in the global market.

In table 2.1 below, the values listed are used to measure the innovation ecosystem. Innovation capability, Research and Development and Multi-stakeholder collaboration are scored on a scale from 0 to 100, where 100 represents the optimal situation. It includes data for six of the ten West African countries discussed in this chapter as well as data for five Organisation for Economic Co-operation and Development (OECD) countries selected from five continents.

Table 2.1 GCI Innovation Indicators

Country	Innovation capability	Research and development	Patent application/million	Multi-stakeholder collaboration
Benin	28.4	19.0	0.0	41.3
Côte D'Ivoire	30.7	20.1	0.2	41.5
Ghana	32.9	21.6	0.3	50.7
Mali	29.0	19.1	0.1	44.1
Nigeria	32.2	23.6	0.1	37.0
Senegal	31.9	23.9	0.3	44.0
Australia	69.5	77.3	76.5	54.5
Chile	42.5	35.8	30.0	44.8
Japan	78.3	100	100	61.6
Mexico	43.6	38.3	19.2	45.3
Portugal	49.7	52.2	48.1	36.8

Source: Author's compilation from GCI framework on innovation ecosystem in The Global Competitiveness Report, 2019.

These are Australia for Oceania, Chile for South America, Japan for Asia, Mexico for North America and Portugal for Europe.

Table 2.1 shows how much lower the standard innovation indicators (i.e. R&D and Patent application) for the West African countries are compared to countries at differing proximity to the technological frontier. The table shows that although Chile and Mexico are further from the technological frontier compared to the other OECD countries, their indicator values are still higher than those of the West African countries.

The innovation indicators in the GCI do not look at factors captured in innovation surveys such as the purchase of equipment, training of the workforce or if firms export a portion of their output. These are the factors that have been shown by empirical research to influence the building of a firm's productive capability in developing countries (Fagerberg et al., 2010). The World Bank Enterprise Surveys (WBES) has innovation data that cover these factors. The innovation questionnaire has a core of basic questions asked in the same way with the same definitions in the same order for the different West African countries in this study. The values for multi-stakeholder collaboration in the GCI framework are closer between the West African countries and the other countries. Portugal has the lowest score of all 11 countries. It shows that collaboration with external partners, suppliers and institutions are important in the development of innovative capability in these West African countries compared to R&D investment and patent application. This makes the WBES innovation data better suited for investigating the determinants of innovation in West African countries.

In table 2.2 below we have the descriptive statistics for three West African countries provided in the African Innovation Outlook II (AUDA-NEPAD, 2014).

Table 2.2 Innovation Rate and Share of innovation expenditure by type of innovation activity.

Country	Innovation Rate	% of Innovation expenditure by type of innovation activity			
		Intramural R&D	Extramural R&D	Acquisition of Machinery	Acquisition of External knowledge
Ghana	72.5	38.2	19.1	18.6	24.1
Nigeria	65	14.8	18.3	62.1	4.8
Senegal	63.1	39.0	15.6	5.5	39.9

Source: Author's compilation from AUDA-NEPAD (2014)

The Innovation rate in the African Innovation Outlook II is calculated as the number of innovation-active firms as a percentage of all firms with responses in the survey. Intramural R&D is R&D performed within a country in a specific reference period. Extramural R&D is R&D sourced from outside a country in a specific reference period. Acquisition of External knowledge is knowledge transferred from collaborations with other firms and customers. The high innovation rate in the countries in table 2.2 despite the relatively low investment in R&D and lack of patenting shows that there are other factors that influence innovation in African firms. For instance, we can see that the sum of the proportion of firms that spent money on the acquisition of machinery and external knowledge exceed the proportion of firms that engaged in intramural R&D expenditure for Ghana and Senegal while the expenditure on acquisition of machinery for Nigeria exceeds that of intramural and extramural R&D combined.

The innovation data collected by WBES includes more West African countries than were studied in the African Innovation Outlook II. It also includes data on a firm's training of workers and export activity as well as expenditure on R&D and acquisition of machinery as well as other firm specific variables. This makes it better suited in the study of determinants of innovation in West African firms. The questionnaire includes follow-up questions where the respondent is asked to go into detail about their innovative product or service and how it compares to other products or services in the local and international market and in the firm. This is not observed in the African Innovation Outlook II data analysis. Thus, the survey recognizes that, for developing economies, the lack of capacity in scientific research and patent development means that firms build absorptive capacity through informal interactions with customers and suppliers (Jensen et al., 2007).

Studies in developed economies on how firms develop their technological capacity have often relied on patents and investments in research and development (R&D). It will be difficult to use these indicators to explain innovation in firms in developing economies. This is because, patents are very scarce in developing economies and are not prevalent in certain industries. In addition, many inventions in developing countries fall short of the requirement for a patent (Cirera & Maloney, 2017). This means that innovation in developing economies will be missed if we only look at patenting and investment in research and development for indications of innovative capacity.

This chapter aims to use innovation data on 10 West African countries to examine the determinants of innovation in the region. The main factors that could lead to innovation output used here are investment in R&D, worker training, purchase of machines and assets for transfer of knowledge by using equipment and export for international transfer of knowledge. Other firm specific variables that are under study include firm size, firm age, manager's years of experience and local or foreign ownership. Product and process innovation are the dependent variables in this chapter.

2.3 Literature review

Firms develop absorptive capacity in many different ways, for instance, Goedhuys (2007), investigates how the various sources of learning lead to successful product innovation in Tanzanian firms. The paper demonstrates that foreign innovative firms have stronger vertical linkages with other foreign firms and invest more in human and physical capital while local firms invest more in R&D and collaborate more with other local firms. Onyeiwu (2011), shows that the absorptive capacity of a country is a significant indicator for variations in the growth performance of African countries. The various factors that impact knowledge transfer are discussed below.

2.3.1 Worker Training and R&D as means of Knowledge Transfer

Worker training is a factor that is expected to positively influence innovation through the development of absorptive capacity. Firms use employee training to encourage them to develop new ideas and enhance their creativity (Børing, 2017). Innovation training focuses workers towards the company's goal in innovation investment and equips them with innovation capabilities and skills (Michaelis & Markham, 2017).

2.3.2 Trade as a Means of Knowledge Transfer

According to Hoekman and Javorcik (2006), a firm's productivity is mainly determined by the firm's ability to absorb technology. The major means of technological transfer is through trade, foreign direct investment, purchasing new or used equipment, licensing agreements and hiring consultants (Hoekman & Javorcik, 2006). Almeida and Fernandes (2008), examine international technological transfers using firm level data across 43 developing economies and find that trade is an important channel of technological transfer. Exports are a way for firms to

accumulate experience and knowledge about foreign markets. When a firm participates in the export market it can lead to learning and enhance innovation capabilities (Golovko & Valentini, 2011). Firms can extract knowledge, enhance their innovative capabilities and sharpen their competitive advantage through exports (Ayllón & Radicic, 2019). Ayllón and Radicic (2019) confirm that there is a simultaneous positive impact of export activity on product innovation.

2.3.3 Firm size as an indicator of innovation activity

Firm size is another factor aside from R&D that can influence the innovation output of a firm. Theoretically, large firms are expected to innovate more because they can fund R&D, can take advantage of economies of scale, and have higher skilled workforce. On the other hand, small firms can quickly take decisions on investment in innovation capabilities and are highly motivated to innovate to stay in business (Rogers, 2004). Empirical research results are mixed on this issue. Bianchini et al. (2018), find that R&D productivity and patent quality reduce with an increase in firm size while Cucculelli (2018), show in their results that product innovation is more prevalent among small and medium sized firms than larger firms.

On the other hand, Rogers (2004) and Ayllón and Radicic (2019) suggest that larger firms report more product innovation. Fang et al. (2021), demonstrate that there are nonlinear effects of firm size on innovation. Their empirical results demonstrate that the probability of a firm engaging in product innovation increases with size up to a point after which the share of new products in total sales tends to fall slightly with a further increase in firm size. Fang et al. (2021), argue that firms switch from product innovation to process innovation as they increase in size. This is because process innovation leads to a reduction in production costs while it is uncertain that a product innovation will be profitable enough to offset the cost in R&D investment and loss of revenue from older products the new product might replace. There is also the cost of acquiring the materials to make a new product that must be considered.

2.3.4 Firm age as an indicator of innovation activity

In the same way that larger firms are expected to have easier access to funds and have higher skilled workers, older firms are also expected to benefit from organisational capabilities such as more experienced workers. Thus, older firms are theoretically expected to be better positioned to engage in innovation activity. Yet, just as in the case of firm size, older firms are observed to not be flexible and so lack the needed flexibility in decision making that is necessary for engaging in innovation activity. Balasubramanian and Lee (2008), present

empirical results that show that the technical quality of innovation falls with an increase in firm age. In this paper, the authors use data on patents in the National Bureau of Economic Research (NBER) dataset in combination with time series data of publicly listed firms in the United States found in the COMPUSTAT dataset. Balasubramanian and Lee (2008), show proof that the older a firm is the less the firm benefits from the cost-effectiveness of learning by doing. The research also showed that older firms are slow to make radical changes and strategize towards innovation activity making them more expensive to run.

Cucculelli (2018), takes a different approach to the question of firm age. The empirical results in this paper show that young firms have a high probability of innovating which declines constantly in the post-entry period and increases again after 15 years. Firms between 35 and 60 years experience a decline in innovation but firms between the ages of 20 and 35 are either as innovative as new entrants or better. Thus, by categorizing the firm age, Cucculelli (2018), shows that the relationship between firm age and innovation is positive in some categories and negative in others. On the other hand, Bianchini et al. (2018), investigate the relationship between corporate governance (CG) and innovation for firms of different ages. The results show that CG has a significant and negative effect on the patenting strategy of young firms. Ayllón and Radicic (2019), show that older firms are more likely to engage in product innovation.

2.3.5 Patents as indicator of innovation activity

A patent is used as a less than perfect proxy for new-to-world innovations since the true rate of technological innovation cannot be observed (Furman et al., 2002). Thus, in Romer's knowledge production function, idea generation is derived from existing knowledge and human capital (Guan & Chen, 2010). Thus, patents and the educational level of management and the training of employees are used to represent the knowledge stock of a firm (Guan & Chen, 2010). It is important to note that not all inventions are patented. This may be because of the high cost of obtaining and enforcing patents. Thus, patents can give a misleading impression of the true output of the research process. Thus, Lanjouw and Schankerman (2004) suggest it is better to use R&D inputs and innovation inputs such as investment in employee training and acquisition of equipment instead of patents.

2.3.6 Empirical Research on Determinants of Innovation in African Economies

Avenyo et al. (2022) in their working paper examine the relationship between global value chain (GVC) participation and firm innovative capabilities in Africa using innovation data from the World Bank Enterprise Surveys (WBES). Global value chain participation is indicated in this paper by firms that simultaneously export, import and have internationally recognized quality certification. Their results show that firms in Africa that engage in GVC activities have a higher likelihood of introducing an innovative product onto the market. This paper shows that GVC participation could stimulate product and process innovation through division of labour, greater variety of inputs, competition, learning and technology transfer. The paper used bivariate probit models to check the robustness of the probit model to address endogeneity arising from reverse causality between the innovation output and GVC participation.

Ayalew et al. (2020), use WBES data for 28 African countries to investigate the effect of firm characteristics, openness and resource-based determinants on innovation. Openness as used in this study refers to export intensity, competition and foreign ownership. Resource-based determinants here refer to a firm's access to credit, R&D expenditure, employee training and the gender of the top manager. The results show that firm size, openness and resource-based determinants influence a firm's probability to innovate. This study also employs a recursive structural form to check the robustness of the probit model used because the probit model does not adequately address the endogeneity issues present in innovation studies.

Nyeadi and Adjasi (2020), investigate the impact of foreign direct investment (FDI) on host firm's innovation in Nigeria and South Africa using the WBES dataset. The study results show that FDI has a positive influence on firm innovation in Nigeria but has no influence on firm innovation in South Africa. The regression results showed that FDI has contributed positively to the innovation ability of Nigerian firms both through product and process innovation. This impact is through the transfer of knowledge, technology transfer and the injection of capital into host firms. On the other hand, FDI had no significant impact on product and process innovation in South African host firms. To control for endogeneity in the model, they employ two instrumental variable estimation techniques. These are two-stage least squares and limited information maximum likelihood estimation. As instruments for product innovation two variables were combined, i.e., international quality certificate and foreign technology license. For process innovation, usage of email, possession of website and having audited financial

statements were combined. It is noteworthy that although the instrumental variables adopted in Nyeadi and Adjasi (2020)'s paper correlate with the endogenous variables and not the error term, they are arbitrary and do not have economic justification. The WBES dataset used in these papers are cross-sectional making the use of probit models and instrumental variables less robust.

To build upon these papers, this chapter is looking at the determinants of innovation in ten West African countries. The countries are included as dummies in the regression to examine their influence on innovation output. This chapter uses the recursive bivariate probit because there is likely to be simultaneity between the innovation outcomes and the innovation activities selected for this chapter. A recursive bivariate probit allows for the estimation of a binary dependent variable with endogenous explanatory variables (Marra & Radice, 2011). The Recursive Bivariate Probit (RBP) model controls for the simultaneity of product and process innovation as well (Filippini et al., 2018).

2.4 Data

The World Bank Enterprise Surveys data will be used to answer the research questions empirically. It has innovation data for 10 of the 15 ECOWAS countries as at the time of writing this chapter. These countries were included in the standard Enterprise Survey and surveyed using the Innovation Follow-up Survey. The innovation datasets are not nationally representative as the survey is stratified by industry, establishment size and region according to the implementation documents (World Bank, 2022). The Enterprise Survey is administered in person to business owners and top managers of private sector establishments. Sometimes the survey respondent calls company accountants and human resource managers into the interview to answer questions in the sales and labour sections of the survey. Typically, 1200-1800 interviews are conducted in larger economies, 600 interviews are conducted in medium-sized economies, and for small economies, 360 interviews take place. For very small economies, 150 interviews are conducted (World Bank, 2022).

The manufacturing and services sectors are the primary business sectors of interest. Firms with 100% government or state ownership are not eligible to participate in the survey (World Bank, 2022). Median weights are used for all indicators published on the Enterprise Surveys website.

Many of the indicators computed from the survey are proportions, such as percentage of firms that engage in X activity or chose Y action (World Bank, 2022). Business environment and performance indicators are created by computing weighted averages of businesses' responses to questions in the Enterprise Survey using sampling weights. Median weights refer to entries that meet strict eligibility and adjusted more freely to include entries from fax machines, answering machines and refusals to the screener since they indicate that those establishments exist (World Bank, 2022). Firms with less than five employees are not included in the data.

The ES innovation data is collected using the Oslo Manual format. The Oslo Manual uses a statistical sampling method to identify a sample population of innovative firms. This provides the basis for a population estimate of the propensity to innovate (Gault, 2020). The Oslo Manual is a manual for collecting, reporting, and using innovation data of firms where a product innovation has been introduced into the market or a process innovation is being used in a firm. The Manual does not place restrictions on the type of innovation to be measured or on its outcomes (Gault, 2020).

The sampling of the West African countries is shown in table 2.3 below.

Table 2.3 Countries and firm representation

West African Countries	Frequency	Percent
1. Benin	150	2.8
2. Côte D'Ivoire	361	6.8
3. Ghana	720	13.6
4. Liberia	151	2.9
5. Mali	185	3.5
6. Niger	151	2.9
7. Nigeria	2,676	50.5
8. Senegal	601	11.3
9. Sierra Leone	152	2.9
10. Togo	150	2.8
Total	5,297	100.00

Source: World Bank Enterprise Surveys, <http://www.enterprisesurveys.org>

The Enterprise Survey's (ES) definition of the innovation indicators for the different countries are listed in the appendix A1.1 and the definitions for the innovation activities and export are in appendix A1.3. The survey defines an innovation as a new or significantly improved product or process to the enterprise that brings it to the market or uses it in the production process. This innovation should have been introduced over the last 3 years. Thus,

Table 2.4 Definitions and Descriptive Statistics of Variables

<i>Variable</i>	<i>Description</i>	<i>Obs</i>	<i>Mean</i>	<i>Std. dev.</i>	<i>Frequency Missing</i>
<i>Innovation</i>	Firm has engaged in either innovation output	5,297	0.54	0.50	2,852 0
<i>Product Innovation</i>	New or significantly improved products	5,218	0.46	0.50	2,415 79
<i>Process Innovation</i>	New or significantly improved processes	5,217	0.41	0.50	2,163 80
<i>RnD</i>	Firm invested in R&D	5,194	0.16	0.36	809 103
<i>Training</i>	Firm conducted training for the employees	5,168	0.29	0.45	1,505 129
<i>Assetpurchase</i>	Firm purchased new equipment for production	5,021	0.37	0.48	1,875 276
<i>Certification</i>	Internationally recognised quality certification	5,005	0.90	0.28	455 292
<i>Export</i>	export sale made	4,897	0.16	0.37	779 400
<i>Ownership</i>	Firms that have more than 50%;				
	1. Domestic ownership	4,780	0.81	0.89	3,890 517
	2. Foreign ownership	4,780	0.09	0.89	425 517
	3. Government ownership	4,780	0.01	0.89	29 517
	4. Other	4,780	0.09	0.89	436 517
<i>Firm age</i>	Age of firm	4,989	0.94	12.64	4,989 308
<i>Manager Experience</i>	Manager's years of experience	5,043	0.95	10.11	5,043 254
<i>Firm Size</i>	Variable for number of employees				
	1. Small firm: A firm with 5-19 employees	4,731	0.60	0.68	2,867 566
	2. Medium firm: A firm with 20-99 employees	4,731	0.29	0.68	1,362 566
	3. Large firm: A firm with more than 99	4,731	0.11	0.68	502 566
<i>Industry (Services)</i>	Whether firm is manufacturing or services	5,297	0.57	0.50	3,002 0

the innovation variables are product and process innovation. The variable Innovation is a variable created from the two main variables in the ES, that is, product innovation and process innovation. This variable will be used to determine the innovation rate. The innovation rate is the number of innovative-active firms as a percentage of the total number of firms surveyed.

From the definitions and descriptive statistics in table 2.4 above, the innovation rate is 54%. Thus, more than half of the firms engaged in at least one innovation output. From this table, we notice that only about a sixth of the firms surveyed invested in R&D. Meanwhile, 37% of firms surveyed invested in an asset or equipment. We also see that firms owned by locals far exceed those owned by foreign companies or nationals. Almost 60% of the firms surveyed are in the service industry. The dependent variables and some control variables have missing values. This can be due to the inclusion of firms that refused to respond to the screener or did not have a response for those questions. The unknown responses are also treated as missing in the dataset. Nigeria has most of these unknown responses especially for firm ownership. Firm size has the largest number of missing data because of some firm size specification issues for Ghana and Nigeria. In the case of Ghana apart from unknown information, some firms were combined as medium and large. In the case of Nigeria firms with less than 5 employees were included and so the researcher labelled them as missing since the survey is expected to cover only firms with 5 employees or more. Senegal also had missing information for firm size.

2.5 Methodology

The Enterprise Surveys collects innovation data as a binary outcome within a period of three years. In Appendix A1.1 the question for product innovation is stated as follows; *During the last three years, has this establishment introduced new or significantly improved products or services?* The question for process innovation is stated in a similar manner for all the countries. Most of the explanatory variables cover the year within which the data was collected except for R&D investment for Ghana and Nigeria. In Appendix A1.3, the question for R&D investment for Ghana and Nigeria is stated as follows; *During the last three years, did this establishment spend on formal research and development activities, either in-house or contracted with other companies?* Thus, the presence of these confounding variables could lead to simultaneity as well as selection bias in binary explanatory variables and this leads to endogeneity of the explanatory variables (Marra & Radice, 2011). A recursive bivariate probit

allows for the estimation of a binary dependent variable with endogenous explanatory variables (Marra & Radice, 2011). The probit model is chosen over the logit because of the extensions to the model that allow it to be run as a bivariate probit, and later a multivariate probit. The probit models assume multivariate normality, which is defensible in the context of innovation models. Hahn and Soyer (2005) empirically examine the relationship between link function selection and model fit of probit and logit in multivariate binary response models and find that the probit link is better at enhancing model fit in multivariate binary response models.

Harris and Moffat (2011), argue that there is a simultaneous influence between R&D, export, and innovation outcome. This is because firms often engage in R&D and innovation to customise goods for a foreign market. Firms also receive information from their foreign customers that could lead to R&D and innovation. Thus, R&D and export as explanatory variables are expected to be endogenous in a regression with innovation as the dependent variable. Hence, R&D and Export will be tested for correlation with innovation outcomes later in this chapter.

According to Filippini et al. (2018), when modelling two jointly determined binary choices, researchers often use either the Bivariate Probit (BP) model or the Recursive Bivariate Probit (RBP) model. This econometric estimator controls for the simultaneity of product and process innovation since the data does not show the order of these innovation outputs. Filippini et al. (2018), explain that the ρ in a BP model captures the correlation between the error terms of the two dependent variables but does not reflect the correlation between the two dependent variables. They posit that a lack of significance for the ρ in a bivariate probit does not necessarily mean that there is no correlation between the dependent variables and so a recursive bivariate probit that uses one dependent variable as a regressor in the equation of the other dependent variable is used instead. In the absence of a recursive structure the RBP collapses to the BP. Thus, the RBP is a system of two probit equations that allows the error terms to be correlated, and the binary dependent choice in one equation to be an endogenous regressor in the other equation (Filippini et al., 2018).

With the possibility of endogeneity between the regressors and the dependent variable, there have been some solutions provided in the literature. Heckman (1978), developed a class of econometric models for simultaneous equation systems with dummy endogenous variables and proved that full rank of the regressor matrix alone is a sufficient condition for the identification

of a general class of simultaneous equation models with endogenous dummy variables. In reviewing the argument by Maddala (1983) that the parameters are not identified because of the lack of variation in the data, Wilde (2000), shows this lack of variation rises because of the restriction placed on one of the probabilities where one dependent variable is the regressor in the other simultaneous equation. Wilde (2000), proves that in a BP model where the dependent variable is not an exogenous regressor in the other dependent variable's equation, the specification of an endogenous dummy regressor enlarges the number of parameters without enlarging the variation in the data. Hence, for the standard case with varying exogenous regressors, the full rank of the regressor matrix is sufficient for the identification of the parameters.

Li et al. (2019), review the usefulness of the RBP model given Wilde's proof and the debate regarding its ability to have endogenous dummy regressors. They conclude that so long as both equations of the RBP model contain an exogenous regressor with a continuous distribution¹ then full rank of the matrix regressors alone is sufficient for identification even in the absence of equation specific instruments. This clarifies the extreme case for the notion of identification by functional form. Thus, to decide whether there is a correlation between the dependent variables and not just their error terms a RBP model will be utilized in this chapter. The RBP equation is used where only one of the dependent variables is an exogenous variable in the other equation and so two RBP equations will be specified. This is because Wilde (2000), was able to prove that because in this case, one equation differs structurally from the other equation in the model, the classical identification problem of endogeneity no longer exists. This is expressed as follows;

$$\begin{aligned} y_{1i}^* &= \beta_1' x_{1i} + u_{1i} \\ y_{2i}^* &= \delta_{21} y_{1i} + \beta_2' x_{2i} + u_{2i} \end{aligned} \quad (1)$$

$$y_{1i} = \begin{cases} 1 & \text{if } y_{1i}^* > 0 \\ 0 & \text{otherwise} \end{cases} \quad y_{2i} = \begin{cases} 1 & \text{if } y_{2i}^* > 0 \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

From (1) we see a recursive linear simultaneous equation system where y_{1i}^* and y_{2i}^* are latent variables for which only the dichotomous variables y_{1i} and y_{2i} can be observed. The vectors of exogenous variables are x_{1i} and x_{2i} and they are not necessarily different from each other.

¹ This is the variable `Manager_exp` in this chapter.

The error terms u_{1i} and u_{2i} are assumed joint normal with means zero and $\text{Var}(u_{1i}) = \text{Var}(u_{2i}) = 1$. The variable δ_{21} reflects the correlation between y_1 and y_2 and is zero in a BP. The crucial point for the identification problem in linear simultaneous equations is that a linear combination of equations possibly contains the same variables as an original equation. But for the second equation of model (1) this problem is not given. Multiplying the equations with λ_1 and λ_2 where λ_1 and λ_2 are generic coefficients, thus, adding up leads to:

$$\begin{aligned} \lambda_1 y_{1i}^* + \lambda_2 y_{2i}^* &= \lambda_2 \delta_{21} y_{1i} + \lambda_1 \beta_1' x_{1i} + \lambda_2 \beta_2' x_{2i} + \lambda_2 u_{2i} + \lambda_1 u_{1i} \\ \Leftrightarrow y_{2i}^* &= \delta_{21} y_{1i} - \frac{\lambda_1}{\lambda_2} y_{1i}^* + \frac{\lambda_1}{\lambda_2} \beta_1' x_{1i} + \beta_2' x_{2i} + (u_{2i} + \frac{\lambda_1}{\lambda_2} u_{1i}) \end{aligned} \quad (3)$$

From (3), we see that even if x_{1i} and x_{2i} contain the same exogenous variables as they do in this chapter, (3) differs structurally from the second equation of (1) by the term $\frac{\lambda_1}{\lambda_2} y_{1i}^*$. Thus, the recursive bivariate probit eliminates the classical identification problem.

The two dependent variables are modelled as follows:

$$product_inv = \begin{cases} Y_{1i}^* = X_{1i}' \beta_1 + u_{1i} \\ Y_{1i} = 1 \text{ if } Y_{1i}^* > 0 \\ Y_{1i} = 0 \text{ otherwise} \end{cases} \quad (4)$$

$$process_inv = \begin{cases} Y_{2i}^* = X_{2i}' \beta_2 + u_{2i} \\ Y_{2i} = 1 \text{ if } Y_{2i}^* > 0 \\ Y_{2i} = 0 \text{ otherwise} \end{cases} \quad (5)$$

From equations (4) and (5) above, the index functions Y_1^* and Y_2^* represent the dependent variables for product and process innovation respectively. X_1 and X_2 are the same for both equations because they represent the explanatory variables for both product innovation and process innovation, which are the same for both variables. Here, the u_{1i} and u_{2i} are assumed joint normal with means zero, variances one, and correlation ρ . This model collapses to two separate probit models for Y_1 and Y_2 when the error correlation $\rho = 0$ (Cameron & Trivedi, 2005).

There are four types of observations, $(Y_1 = 0, Y_2 = 0)$; $(Y_1 = 1, Y_2 = 0)$; $(Y_1 = 0, Y_2 = 1)$ and $(Y_1 = 1, Y_2 = 1)$. The corresponding probabilities become;

$$\begin{cases} (Y_1 = 0, Y_2 = 0): \Pr(Y_1 = 0, Y_2 = 0|X) = P_1 = \Phi(-X'_1\beta_1, -X'_2\beta_2, -\rho) \\ (Y_1 = 1, Y_2 = 0): \Pr(Y_1 = 1, Y_2 = 0|X) = P_2 = \Phi(X'_1\beta_1, -X'_2\beta_2, -\rho) \\ (Y_1 = 0, Y_2 = 1): \Pr(Y_1 = 0, Y_2 = 1|X) = P_3 = \Phi(-X'_1\beta_1, X'_2\beta_2, -\rho) \\ (Y_1 = 1, Y_2 = 1): \Pr(Y_1 = 1, Y_2 = 1|X) = P_4 = \Phi(X'_1\beta_1, X'_2\beta_2, \rho) \end{cases} \quad (6)$$

Where Φ and ρ represent the cumulative distributive function (CDF) of the bivariate normal distribution function and the correlation between the error terms (u_1, u_2) respectively. The probit model specifies the conditional probability. It is widely used because it is the natural model if the starting point is a latent normal regression model (Wooldridge, 2012).

In this chapter the recursive bivariate probit regressions will be expressed as follows for RBP1:

Product_inv = Process_inv + RnD + training + AssetPurchase + Export + certification + ownership + Firmage + Manager_exp + Firmsize + Industry + Country

Process_inv = RnD + training + AssetPurchase + Export + certification + ownership + Firmage + Manager_exp + Firmsize + Industry + Country

For RBP2:

Product_inv = RnD + training + AssetPurchase + Export + certification + ownership + Firmage + Manager_exp + Firmsize + Industry + Country

Process_inv = Product_inv + RnD + training + AssetPurchase + Export + certification + ownership + Firmage + Manager_exp + Firmsize + Industry + Country

The variable Manager's years of experience (Manager_exp) is an exogenous regressor with a continuous distribution and hence the RBP regressions above fulfil the condition under which a RBP will be identified even when it contains endogenous binary regressors. Product and process innovation are binary outcomes that cover a duration of three years. All the regressors are within one year except for R&D investment for Ghana and Nigeria that also covers a duration of three years. The selection bias of the regressors makes the regressors endogenous. This makes the RBP a suitable model for this data because so long as both equations of the RBP model contain an exogenous regressor with a continuous distribution (Manager's experience), then full rank of the matrix regressors alone is sufficient for identification even in the absence of equation specific instruments. Table 2.5 below lists the variables under study and their rationale for inclusion as discussed by Daniels (2022).

Table 2.5 Specification of variables in the recursive bivariate probit

Variable	Rationale for inclusion
Product Innovation	Dependent variable
Process Innovation	Dependent variable
R&D Investment	Firm's Resource base. Investment in R&D increases the stock of knowledge of workers in a firm. This knowledge base enhances a firm's ability to absorb external knowledge and innovation capability.
Worker Training	Dynamic Capabilities. Worker training enhances absorptive capacity for external and internal knowledge transfer
Purchase Of Assets and Equipment	External Source of Knowledge. Workers learn to use equipment and machinery. New equipment and machinery could lead to innovation in products and production processes.
Export	International transfer of Knowledge. Exports are a way for firms to accumulate experience and knowledge about foreign markets. Customers in a different environment could provide useful feedback that could lead to innovative changes in a product.
Firm size	Firm specific variable. Larger firms have the skilled labour and funds to invest in research and worker training while small and medium sized firms are incentivized to innovate to stay in business.
Firm age	Firm specific variable. Older firms have more experienced workers and market knowledge while younger firms are more flexible in decision making which is necessary for product and process innovation.
Manager's years of experience	Internal resource of firm. An experienced manager has knowledge of the product and markets that is useful for having a knowledge base to build upon. Less experienced managers may be eager to please and thus incentivized to introduce innovative products and ideas.
Ownership	Local or foreign ownership could impact knowledge transfer. Foreign owned firms have access to knowledge and resources outside of the local market while local firms are best situated to understand the local market better.
Certification	International Collaboration. Internationally recognized certification signals collaboration with other professionals and markets and thus increased knowledge base that enhances absorptive capacity.
Industry	Type of firm. Manufacturing firms serve as the base in this thesis to compare the relative influence of the service firms on innovation compared to manufacturing firms.
Country	Dummy for countries with Benin as base. This is to observe the relative influence of the countries on innovation output.

2.6 Results

2.6.1 Descriptive statistics for Innovation outcome and Innovation activities.

In this section, we evaluate the prevalence of innovation activity in firms in West Africa. Table 2.6 below shows the distribution of innovation activity across the countries. Innovation activity is whether a firm engaged in either product or process innovation. The table shows that more than half of the firms surveyed engaged in innovation activity. Overall, Benin has the least innovation activity and hence the least innovation rate while Ghana has the highest innovation activity and rate. More firms engaged in product innovation than process innovation. Firms in Ghana, Nigeria and Senegal engaged above average in innovation activity. Less than 20% of firms in Benin, Togo, Côte D'Ivoire, Niger and Sierra Leone engaged in process innovation.

Table 2.6 Share of firms engaging in Innovation Activity by Country.

Country	Innovation rate	Product innovation	Process Innovation
1. Benin	31% (46)	26% (39)	14% (21)
2. Côte D'Ivoire	42% (151)	37% (131)	18% (62)
3. Ghana	63% (452)	51% (369)	51% (367)
4. Liberia	47% (71)	45% (68)	25% (37)
5. Mali	48% (88)	36% (66)	33% (60)
6. Niger	38% (57)	34% (50)	18% (27)
7. Nigeria	58% (1,543)	50% (1,301)	50% (1,299)
8. Senegal	55% (332)	48% (284)	40% (238)
9. Sierra Leone	35% (53)	34% (52)	19% (29)
10. Togo	39% (59)	37% (55)	15% (23)
Total	54% (2,852)	46% (2,415)	41% (2,163)

Note: Number of firms in parentheses

Table 2.7 shows the share of firms engaged in innovation activities. These are activities that enhance the absorptive capacity of firms. The export of a portion of output, investment in R&D, worker training and the purchase of assets and equipment are expected to lead to the transfer of knowledge from foreign collaborators, researchers and learning through the use of production equipment and worker training.

Table 2.7 Share of firms engaged in Innovation Capabilities by Country.

Country	Export	R&D	AssetPurchase	Training
1. Benin	15% (22)	13% (19)	32% (48)	19% (29)
2. Côte D'Ivoire	12% (43)	10% (36)	31% (106)	43% (153)
3. Ghana	9% (66)	22% (159)	51% (365)	40% (285)
4. Liberia	7% (10)	11% (16)	56% (84)	26% (39)
5. Mali	21% (38)	14% (26)	48% (87)	20% (35)
6. Niger	10% (15)	11% (16)	45% (68)	26% (39)
7. Nigeria	21% (476)	17% (451)	34% (81)	29% (754)
8. Senegal	9% (54)	7% (43)	22% (130)	14% (82)
9. Sierra Leone	3% (5)	11% (17)	62% (94)	28% (42)
10. Togo	34% (50)	17% (26)	48% (72)	31% (47)
Total	16% (779)	16% (809)	37% (1,875)	29% (1,505)

Note: Number of firms in parentheses

Table 2.7 shows that more firms purchase assets and equipment and train workers than export or invest in R&D. Here, less than 10% of firms in Ghana, Liberia, Senegal, and Sierra Leone export some of their output. Firms in Senegal invest the least in R&D, purchase of assets and equipment and worker training yet the innovation rate of Senegal is 55% and this is above the regional average. This further shows that there are other factors that lead to innovation output besides the innovation capabilities listed in the dataset.

2.6.2 Empirical results for the Recursive Bivariate Probit estimation 1 (RBP1)

The RBP estimation results in Table 2.8 below shows the marginal effects for joint probabilities and unitary probabilities. This is the RBP estimation where process innovation is a dependent variable and a regressor while product innovation is only a dependent variable. The Wald χ^2 shows that the point estimates are jointly statistically significant, hence, the regression model is fitted to the data. The correlation coefficient ρ is also significantly different from zero at the 10% level. Thus, there is correlation between the error terms of product and process innovation. The sign of the ρ does not necessarily mean that there is a negative correlation between the error terms in a recursive bivariate probit estimation. This is because according to Filippini et al. (2018) p.105, the sign of the correlation coefficient in a RBP cannot be interpreted as it is

in the BP. This is because the correlation coefficient in the RBP captures the correlation between the error terms and the correlation between the dependent variables which is subsumed into the parameter associated with the endogenous variable. Hence the sign of the correlation coefficient does not necessarily reflect the direction of the correlation between the dependent variables as is the case in a BP.

Process innovation leads to product innovation at a statistical significance of 1%. We see that Export and AssetPurchase are statistically significant for process innovation but not for product innovation. R&D, and training are statistically significant innovation activities that influence both product and process innovation in the firms. Ghana, Mali, Nigeria, and Senegal were also statistically significant for process innovation while Liberia was significant for product innovation. The joint probabilities of a firm having both product and process innovation or neither product nor process innovation were found to be statistically significant in all the innovation capability regressors (R&D, Training, AssetPurchase and Export). Firms that engage in process innovation increase by 92% the probability of engaging in product innovation. This means that firms are more likely to engage in product innovation when they engage in process innovation.

Thus, there is a dependent relationship between product and process innovation. A unit increase in investment in R&D increases a firm's probability of engaging in product innovation by nearly 12%. A unit increase in investment in R&D also increases probability of engaging in process innovation by about 27% and product and process innovation simultaneously by almost 15%. Training workers will increase the probability of engaging in product innovation by nearly 7%. Training workers will increase the probability of engaging in process innovation by about 13%. Training workers increases the probability of a firm engaging in product and process innovation simultaneously by about 7%.

A unit increase in purchasing assets and equipment will increase the probability of a firm engaging in process innovation by 18%. A unit increase in export of a portion of a firm's output increases the probability that it will engage in process innovation by 8%. While a firm that has an internationally recognised quality certification has an increased probability of engaging in product innovation by 6.5%. Firms in the service industry are about 4% more likely to engage product innovation than manufacturing firms. Firms in Liberia are 14% more likely to engage

Table 2.8 Marginal effects for RBP1 model

Variables	P (y ₁ =0, y ₂ =0)	Std. Error	P (y ₁ =1)	Std. Error	P (y ₂ =1)	Std. Error	P (y ₁ =1, y ₂ =1)	Std. Error
Process_inv	-0.600***	0.0917	0.917***	0.0978			0.317***	0.0126
RnD	-0.246***	0.0252	0.119**	0.0489	0.273***	0.0273	0.146***	0.0317
Training	-0.123***	0.0181	0.068**	0.0294	0.127***	0.021	0.072***	0.0176
AssetPurchase	-0.128***	0.0177	0.025	0.0312	0.181***	0.0189	0.078***	0.0194
Export	-0.049**	0.0229	-0.001	0.0313	0.081***	0.0283	0.031**	0.0149
Certification	-0.020	0.0276	0.065*	0.0386	-0.037	0.0349	0.008	0.0157
Foreign Ownership	-0.052**	0.0254	0.039	0.0365	0.048	0.0357	0.034*	0.0194
Government Ownership	0.119	0.1611	-0.057	0.1786	-0.113	0.1449	-0.051	0.0474
Other	-0.010	0.0256	0.075**	0.0339	-0.068**	0.0298	-0.003	0.0142
Firmage	-0.0001	0.0007	0.00003	0.0010	0.0002	0.0009	0.00007	0.0004
Manager's experience	0.001	0.0008	-0.00008	0.0011	-0.0009	0.0011	-0.0004	0.0005
Medium firm	-0.0001	0.0166	-0.006	(0.0219)	0.007	0.0207	0.0004	0.0097
Large firm	0.047	0.029	-0.032	0.0344	-0.039	0.0329	-0.024*	0.0144
Industry = Service	0.001	0.0152	0.038*	0.0200	-0.041	0.0182	-0.003	0.0088
Côte D'Ivoire	-0.059	0.0530	0.063	0.0622	0.006	0.0388	0.009	0.0119
Ghana	-0.150***	0.0488	-0.066	0.0648	0.298***	0.0393	0.082***	0.0269
Liberia	-0.162***	0.0565	0.144**	0.0683	0.066	0.0473	0.048**	0.0223
Mali	0.0003	0.0626	-0.098	0.0747	0.112**	0.050	0.015	0.0156
Niger	-0.032	0.0630	0.034	0.0738	0.003	0.0459	0.005	0.0132
Nigeria	-0.197***	0.0482	-0.103	0.0682	0.409***	0.0353	0.109***	0.0322
Senegal	-0.222***	0.0485	0.028	0.0696	0.331***	0.0413	0.138***	0.0342
Sierra Leone	-0.053	0.0600	0.052	0.0668	0.010	0.0425	0.009	0.0133
Togo	-0.070	0.0595	0.108	0.0689	-0.038	0.0397	-0.0004	0.0117
ρ				-0.4885*				0.213
Observations				3,536				
Log-likelihood				-3719.848				
Wald χ^2 (df)				1815.43***(45)				
Wald Test on joint significance				3.61148*(1)				

Notes: The base variable for the ownership of firms is Domestic ownership. The base variable for firm size is Small Firm while the base variable for Country is Benin. The standard errors are robust. ***, **, and * denote 1%, 5% and 10% statistical significance respectively.

in product innovation than firms in Benin. Firms in Ghana are about 30% more likely to engage in process innovation than firms in Benin. Firms in Mali are about 11% more likely to engage in process innovation than firms in Benin. Firms in Nigeria are about 41% more likely to engage in process innovation than firms in Benin. While firms in Senegal are about 33% more likely to engage in process innovation than firms in Benin.

The coefficient of the process innovation as an explanatory variable shows the relationship between product and process innovation is positive. The Wald Test on joint significance of the correlation coefficient ρ is significant and shows that we can reject the null hypothesis that there is no correlation between the error terms of product and process innovation.

2.6.3 Empirical results for the Recursive Bivariate probit estimation 2 (RBP2)

The results of the RBP2 model in Table 2.9 below, evaluates product innovation as both a dependent and a regressor while process innovation is only a dependent variable in this model. The RBP estimation results below shows the marginal effects for joint probabilities and unitary probabilities. It has a Wald χ^2 that is statistically significant at the 1% level and shows that the point estimates are jointly statistically significant, hence, the regression model is fitted to the data. The correlation coefficient ρ is also significantly different from zero at the 1% level. This shows that the error terms of product and process innovation are correlated in this model as well. The Wald Test on joint significance of the correlation coefficient ρ is significant and shows that we can reject the null hypothesis that there is no correlation between the error terms of product and process outcomes. Table 2.9 has the results of the marginal effects for the second model.

In the second model the coefficient of product innovation is statistically significant at the 1% level. The innovation capability variables (R&D, Training, AssetPurchase and Export) are all statistically significant for product innovation but only AssetPurchase is statistically significant for process innovation as well at the 10% level of significance. Here, Ghana, Nigeria and Senegal are statistically significant for both product and process innovation with Liberia and Mali having statistical significance in product and process innovation respectively.

Table 2.9 Marginal effects for RBP2 model

Variables	P (y ₁ =0, y ₂ =0)	Std. Error	P (y ₁ =1)	Std. Error	P (y ₂ =1)	Std. Error	P (y ₁ =1, y ₂ =1)	Std. Error
Product_inv	-0.735***	0.0826			0.986***	0.0304	0.252***	0.0568
RnD	-0.225***	0.0228	0.300***	0.0279	-0.005	0.0317	0.070***	0.0228
Training	-0.103***	0.0168	0.147***	0.0208	-0.012	0.0226	0.032***	0.0114
AssetPurchase	-0.141***	0.0155	0.150***	0.0192	0.036*	0.0231	0.045***	0.0157
Export	-0.070***	0.0228	0.059**	0.0278	0.034	0.0281	0.023**	0.010
Certification	0.036	0.0292	0.015	0.0352	-0.064*	0.0362	-0.013	0.0095
Foreign Ownership	-0.035	0.0249	0.064*	0.0340	-0.016	0.0343	0.013	0.0114
Government Ownership	0.087	0.1467	-0.128	0.1385	0.022	0.1611	-0.020	0.0231
Other	0.055**	0.0271	0.011	0.0315	-0.082***	0.0294	-0.015**	0.0073
Firmage	-0.0002	0.0007	0.0003	0.0009	0.0002	0.0010	0.00007	0.0002
Manager's experience	0.001	0.0009	-0.001	0.0011	-0.0004	0.0011	-0.0003	0.0003
Medium firm	-0.010	0.0164	0.005	0.0204	0.008	0.0207	0.004	0.0058
Large firm	0.026	0.0279	-0.049	0.0324	0.016	0.0317	-0.007	0.0080
Industry = Service	0.032**	0.0148	0.001	0.0181	-0.044**	0.0186	-0.011*	0.0065
Côte D'Ivoire	-0.024	0.0552	0.053	0.0508	-0.029	0.0571	0.0004	0.0014
Ghana	-0.313***	0.0504	0.191***	0.0472	0.172***	0.0579	0.049***	0.0221
Liberia	-0.111*	0.0611	0.168***	0.0596	-0.055	0.0593	0.003	0.0039
Mali	-0.146**	0.0648	0.026	0.0580	0.128**	0.0711	0.007	0.0081
Niger	-0.013	0.0649	0.028	0.0602	-0.015	0.0678	0.0002	0.0015
Nigeria	-0.377***	0.0482	0.237***	0.0440	0.237***	0.0576	0.097***	0.0284
Senegal	-0.330***	0.0502	0.280***	0.0484	0.104*	0.0597	0.054	0.0252
Sierra Leone	-0.016	0.0616	0.048	0.0558	-0.032	0.0582	0.0002	0.0013
Togo	0.044	0.0611	0.042	0.0576	-0.087	0.0600	-0.001	0.0015
ρ				-0.834***				(0.0912)
Observations				3,536				
Log pseudolikelihood				-3722.5615				
Wald χ^2 (df)				3604.15***(45)				
Wald Test on joint significance				16.0549***(1)				

Notes: The base variable for the ownership of firms is Domestic ownership. The base variable for firm size is Small Firm while the base variable for Country is Benin. The standard errors are in parentheses and robust. ***, **, and * denote 1%, 5% and 10% statistical significance respectively.

Firms that engage in product innovation increase by 98% the probability of engaging in process innovation. A unit increase in R&D investment of a firm increase their probability of engaging in product innovation by 30%. Firms that train their workers increase the probability of engaging in product innovation by nearly 15%. A unit increase in the purchase of assets and equipment increase the probability of engaging in product innovation by 15% and the probability of engaging in process innovation increases by 3.6%. A unit increase in the purchase of assets and equipment will increase the probability of engaging in product and process innovation simultaneously by 4.5%. A unit increase in export will increase the probability of engaging in product innovation by 6%.

Firms in the service industry are about 4% less likely to engage in process innovation than manufacturing firms. Firms in Ghana are 19% more likely to engage in product innovation and 17% more likely to engage in process innovation than firms in Benin. Firms in Ghana are about 5% more likely to engage in product and process innovation simultaneously than firms in Benin. Firms in Liberia are about 17% more likely to engage in product innovation than firms in Benin. Firms in Mali are about 13% more likely to engage in process innovation than firms in Benin. Firms in Nigeria are about 24% more likely to engage in both product and process innovation than firms in Benin. Firms in Nigeria are about 10% more likely to engage in product and process innovation simultaneously than firms in Benin. Firms in Senegal are 28% more likely to engage in product innovation and 10% more likely to engage in process innovation than firms in Benin.

From the RBP1 in table 2.8, we see that a unit increase in export in the year in which the survey was taken increased the probability of process innovation and in RBP2 it increased the probability of product innovation. Exporting output is an indication that a firm is in contact with other firms in other parts of the world and is likely to benefit from an exchange of knowledge and skill through this interaction. According to Michie et al.(2002), countries that specialize in innovation tend to realize larger gains from openness while a reduction in innovation reduces gains from trade. Firms that export output are participating in the global value chain. This participation could stimulate product and process innovation through division of labour, greater variety of inputs, competition, learning and technology transfer (Avenyo et al., 2022).

Investment in assets and equipment is significant for process innovation in RBP1 and for product and process innovation in RBP2. Thus, West African firms seem to absorb knowledge and develop skills through the acquisition of machinery and equipment. The results also show that firm investment in training programmes for their employees increased the probability of innovating in both product and process innovation in RBP1 while it increased the probability of innovating in product innovation in RBP2. Training programmes boost the ability of workers to use newly acquired equipment and thus enhance their ability to make new or significantly improved products or production processes.

While firms in the service industry are more likely to engage in product innovation than firms in the manufacturing industry in RBP1, in RBP2, firms in the service industry are less likely to engage in process innovation compared to manufacturing firms. It may seem that firms in the service industry engage more in product innovation than in process innovation compared to manufacturing firms because it is harder to capture process innovation for service firms than it is to capture process innovation for manufacturing firms (Ettlie & Rosenthal, 2011).

For both RBP1 and RBP2 models, Ghana, Liberia, Mali, Nigeria, and Senegal are statistically significant. Ghana, Nigeria, and Senegal are lower middle-income countries while Liberia and Mali are low-income countries. These countries are at different levels of economic development, political stability, and population size. Hence, innovation takes place in all types of economies at all income levels.

There is not much statistical significance in other variables such as manager's experience, firm size, firm age, or type of firm ownership in both models. This may not necessarily mean that these variables do not influence the innovation outcomes as the dataset is cross sectional. The innovation outcomes are introduced over the last three years from the period the data was collected while some of the explanatory variables concern the period in which the data was collected except for R&D investment for Ghana and Nigeria. The R&D investment for Ghana and Nigeria covers a period of three years. This creates specification issues and could lead to heterogeneity and omitted variable bias in the estimation results. Thus, the lack of statistical significance may be an indication that these variables did not influence an innovation outcome that occurred up to three years prior.

Firms in Nigeria make up half of the firms in the sample thus it is possible that the Nigerian firms may be swaying the results. To investigate this, the two models were run without Nigeria as a regressor. The marginal effects of the RBP without Nigeria are in appendix A2.1 for the RBP2 model where product innovation is a regressor. The ρ is not statistically significant from zero for the RBP1 model where process innovation is a regressor. The results in appendix A2.1 do not differ much from the main model in the thesis hence Nigeria does not have much sway on the explanatory variables that are statistically significant in the model.

The ten West African countries can be divided into two monetary zones. There is the West African Monetary Zone (WAMZ) which includes Ghana, Nigeria and Sierra Leone. In this thesis we include Liberia because Harvey and Cushing (2015) show that the WAMZ countries do not have common sources of shock and respond differently to common supply, demand and monetary shocks. The WAMZ is not a common currency area. Thus, the formation of the WAMZ has not had much impact on the economies of the member countries. On the other hand, the West African Economic and Monetary Union (UEMOA) is a common currency area and includes all the six francophone countries in this study, namely, Benin, Côte D'Ivoire, Mali, Niger, Senegal and Togo. Yet according to the IMF Country Report (2011), the member countries of UEMOA lack proper coordination of fiscal and monetary policies and have weak public financial management. Two recursive bivariate probit models were run grouping the West African countries into the two monetary zones. The results showed that the correlation coefficient ρ is not significantly different from zero. Hence in the absence of a recursive structure the RBP collapses to the BP (Filippini et al., 2018). These results are in appendix A2.5 and A2.6.

2.6.4 Testing Endogeneity of R&D and Exports

Innovation literature often asserts that R&D and Exports may be endogenous to product and process innovation (Harris & Moffat, 2011). The data employed in this chapter is cross-sectional and so the usual remedy of using the previous year's version of the endogenous variables cannot be applied here. We can however test for the endogeneity that may exist between R&D and Export and innovation in this dataset. A chain of recursive bivariate probit estimation has been used to show the relationship between product innovation, process innovation, R&D and Export. Mullahy (2016), shows that a multivariate probit estimation could increase computation time and poses some numerical constraints which were

experienced with this dataset. Mullahy (2016), thus, demonstrates that a series of bivariate probit regressions will be faster in computational time and will produce consistent estimates of all the parameters in a multivariate probit. The bivariate probit also provides marginal effects for the parameter estimates for additional information about the parameters.

In the first case a recursive bivariate probit showing the relationship between product innovation and R&D was run as follows:

- a.
$$\text{Product_inv} = \text{RnD} + \text{training} + \text{AssetPurchase} + \text{Export} + \text{certification} + \text{ownership} + \text{Firmage} + \text{Manager_exp} + \text{Firmsize} + \text{Industry} + \text{Country}$$
$$\text{RnD} = \text{training} + \text{AssetPurchase} + \text{Export} + \text{certification} + \text{ownership} + \text{Firmage} + \text{Manager_exp} + \text{Firmsize} + \text{Industry} + \text{Country}$$
- b.
$$\text{Product_inv} = \text{training} + \text{AssetPurchase} + \text{Export} + \text{certification} + \text{ownership} + \text{Firmage} + \text{Manager_exp} + \text{Firmsize} + \text{Industry} + \text{Country}$$
$$\text{RnD} = \text{Product_inv} + \text{training} + \text{AssetPurchase} + \text{Export} + \text{certification} + \text{ownership} + \text{Firmage} + \text{Manager_exp} + \text{Firmsize} + \text{Industry} + \text{Country}$$

The correlation coefficient ρ for equation (a) is not statistically significant from zero but the correlation coefficient (ρ) for equation (b) is statistically significant from zero indicating that product innovation leads to R&D investment, but the reverse may not necessarily be true. The regression for model (a) has been placed in the appendix A2.2.

The RBP model (b) estimation results displayed in table 2.10 below show the unitary marginal effects for outcomes, product innovation and R&D. The Wald χ^2 shows that the point estimates are jointly statistically significant thus the regression model is fitted to the data. From the table, we can observe that the correlation coefficient rho (ρ) is negative and significant at the 5% level. The Wald Test on joint significance of the correlation coefficient ρ is significant and shows that we can reject the null hypothesis that there is no correlation between the error terms of product innovation and R&D.

Table 2.10 Marginal effects for RBP(b) model

Variables	Product_inv	Std. error	R&D	Std. error
Product_inv			0.339***	0.1062
Training	0.190***	0.0202	0.067***	0.0213
AssetPurchase	0.171***	0.0185	0.009	0.0197
Export	0.074***	0.0278	0.039**	0.0172
Certification	0.053	0.0341	0.032	0.0192
Foreign Ownership	0.043	0.0338	-0.060***	0.0178
Government Ownership	-0.113	0.1524	0.064	0.0936
Other	0.015	0.0306	-0.002	0.0203
Firmage	0.001	0.0009	0.001*	0.0005
Manager's experience	-0.001	0.0010	-0.001	0.0007
Medium firm	0.003	0.0203	0.008	0.0130
Large firm	-0.034	0.0326	0.073***	0.0250
Industry = Service	-0.013	0.0180	-0.026**	0.0117
Côte D'Ivoire	0.039	0.0496	-0.070*	0.0421
Ghana	0.178***	0.0459	-0.036	0.0422
Liberia	0.151**	0.0593	-0.070	0.0484
Mali	0.016	0.0565	0.014	0.0521
Niger	0.026	0.0584	-0.017	0.0533
Nigeria	0.224***	0.0426	-0.068	0.0430
Senegal	0.249***	0.0475	-0.125***	0.0454
Sierra Leone	0.001	0.0564	-0.048	0.0493
Togo	0.040	0.0565	0.011	0.0514
ρ	-0.613**	0.2116		
Observations	3,545			
Log pseudolikelihood	-3467.6702			
Wald χ^2 (df)	1119.09*** (43)			
Wald Test on joint significance	4.43259** (1)			

Notes: The base variable for the ownership of firms is Domestic ownership. The base variable for firm size is Small Firm while the base variable for Country is Benin. The standard errors are robust. ***, **, and * denote 1%, 5% and 10% statistical significance respectively.

From the marginal effects results above, it can be observed that firms that engage in product innovation have a 34% increase in the probability that they will invest in R&D. Firms that train their workers increase the probability that they will engage in product innovation by 19% and a unit increase in R&D investment increases the probability of engaging in product innovation by about 7%. A unit increase in the purchase of assets and equipment have an increased probability of 17% of engaging in product innovation. A unit increase in export of output increases by 7% the probability of engaging in product innovation by 4% the probability of investing in R&D. Firms with mainly Foreign Ownership are 6% less likely to invest in R&D compared to firms with mainly Domestic Ownership. Large firms are about 7% more likely to invest in R&D. Firms in the service sector are less likely to invest in R&D compared to firms in the manufacturing sector of industry. Côte D'Ivoire and Senegal are less likely to invest in R&D than Benin.

A recursive bivariate probit regression for product innovation and export in a similar fashion as for R&D and product innovation stated above, were run with the rho in both instances not statistically significant. This may indicate that there is no correlation between product innovation and Export. The regression results for this are in the appendices A2.3 and A2.4.

When it came to the relationship between process innovation and R&D, it was possible to run one recursive bivariate model to test the correlation between the variables although the Wald χ^2 is missing. The model is expressed below as:

$$\begin{aligned} \text{c. } \text{Process_inv} &= \text{RnD} + \text{training} + \text{AssetPurchase} + \text{Export} + \text{certification} + \text{ownership} + \\ &\quad \text{Firmage} + \text{Manager_exp} + \text{Firmsize} + \text{Industry} + \text{Country} \\ \text{RnD} &= \text{Process_inv} + \text{training} + \text{AssetPurchase} + \text{Export} + \text{certification} + \text{ownership} + \\ &\quad \text{Firmage} + \text{Manager_exp} + \text{Firmsize} + \text{Industry} + \text{Country} \end{aligned}$$

The unitary marginal effects for outcomes, process innovation and R&D are indicated in table 2.11. In the regression for model (c), the correlation coefficient rho is negative but statistically significant at the 1% level of significance. The rho in a RBP includes the correlation between the error terms of each equation as well as the correlation between the dependent variables. Thus, the sign of the rho cannot be interpreted in the same way as is done in a BP model. The Wald Test on joint significance of the correlation coefficient ρ is significant and shows that we can reject the null hypothesis that there is no correlation between the error terms of process innovation and R&D.

From the marginal effects we can observe that if a firm engages in process innovation it increases the probability of investing in R&D by 60%. A unit increase in investment in R&D increases the probability of engaging in process innovation by 86%. A unit increase in the purchase of assets and equipment increases the probability of engaging in process innovation by 10%. A unit increase in the purchase of assets and equipment reduces the probability of investing in R&D by 5%. Firms with an internationally recognized quality certification are about 8% less likely to engage in process innovation and more than 5% more likely to invest in R&D. Firms with majority Foreign Ownership are about 8% more likely to engage in process innovation than firms with majority Domestic Ownership. Yet firms with majority Foreign Ownership are about 4% less likely to invest in R&D compared to firms with majority Domestic Ownership. Here also Large firms are about 6% more likely to invest in R&D and

Table 2.11 Marginal Effects for RBP (c) model

Variables	Process_inv	Std. error	R&D	Std. error
Process_inv			0.598***	0.019
RnD	0.865***	0.0280		
Training	-0.002	0.0204	0.016	0.0145
AssetPurchase	0.104***	0.0184	-0.055***	0.0140
Export	0.015	0.0284	0.003	0.0196
Certification	-0.077**	0.0338	0.055**	0.0231
Foreign Ownership	0.077**	0.0320	-0.044**	0.0184
Government Ownership	-0.101	0.1263	0.040	0.0925
Other	-0.053*	0.0274	0.038*	0.0216
Firmage	-0.001	0.0008	0.001	0.0006
Manager's experience	0.000	0.0010	-0.000	0.0007
Medium firm	0.004	0.0190	-0.003	0.0127
Large firm	-0.064**	0.0299	0.055**	0.0242
Industry = Service	-0.016	0.0169	0.003	0.0118
Côte D'Ivoire	0.036	0.0452	-0.048	0.0616
Ghana	0.253***	0.0428	-0.148***	0.0545
Liberia	0.084	0.0538	-0.025	0.0741
Mali	0.108*	0.0551	-0.045	0.0710
Niger	0.014	0.0532	-0.008	0.0756
Nigeria	0.354***	0.0398	-0.204***	0.0530
Senegal	0.315***	0.0439	-0.193***	0.0540
Sierra Leone	0.039	0.0513	0.001	0.0722
Togo	-0.024	0.0492	0.095	0.0730
ρ	-1***	3.70e-12		
Observations	3,543			
Log pseudolikelihood	-2598.4941			
Wald χ^2 (df)				
Wald Test on joint significance	16.1393*** (1)			

Notes: The base variable for the ownership of firms is Domestic ownership. The base variable for firm size is Small Firm while the base variable for Country is Benin. The standard errors are robust. ***, **, and * denote 1%, 5% and 10% statistical significance respectively.

about 6% less likely to engage in process innovation compared to Small firms. Firms in Ghana, Nigeria, and Senegal are less likely to invest in R&D compared to firms in Benin.

For process innovation and export, there was a statistically significant correlation between export and process innovation as it was with process innovation and R&D. The model is outlined below.

$$\text{d. Process_inv} = \text{Export} + \text{RnD} + \text{training} + \text{AssetPurchase} + \text{certification} + \text{ownership} + \text{Firmage} + \text{Manager_exp} + \text{Firmsize} + \text{Industry} + \text{Country}$$

$$\text{Export} = \text{Process_inv} + \text{RnD} + \text{training} + \text{AssetPurchase} + \text{certification} + \text{ownership} + \text{Firmage} + \text{Manager_exp} + \text{Firmsize} + \text{Industry} + \text{Country}$$

The unitary marginal effects for process innovation and Export outcomes in model (d) above are expressed in table 2.12 below. The correlation coefficient ρ is negative but statistically significant at the 1% level of significance. The Wald Test on joint significance of the correlation coefficient ρ is significant and shows that we can reject the null hypothesis that there is no correlation between the error terms of process innovation and Export.

From table 2.12, we can observe that firms that engage in process innovation have an increased probability by 48% of exporting their output. A unit increase in the export of output increases the probability that a firm will engage in process innovation by 72%. A unit increase in investment in R&D increases the probability that a firm will engage in process innovation by 17% and there is about an 8% decrease in the probability that a firm will engage in export of their output. Firms that train their workers have an 8% increase in the probability that they will engage in process innovation and a 3.5% decrease in the probability that they will export their output. A unit increase in the purchase of assets and equipment increases the probability that a firm will engage in process innovation by nearly 13% but there is a 5% decrease in the probability that they will engage in export of their output.

Firms with an internationally recognized quality certification are about 12% less likely to engage in process innovation and 8% more likely to export some of their output. Firms with majority Foreign Ownership are 6% less likely to engage in process innovation and 10% more likely to export some of their output compared to firms with majority Domestic Ownership. Large firms are 9% less likely to engage in process innovation and 9% more likely to export some of their output. Firms in Ghana, Liberia, Nigeria, Senegal, and Sierra Leone are less likely to export a portion of their output compared to firms in Benin. Firms in Togo are more likely to export a portion of their output compared to firms in Benin.

The RBP models testing endogeneity of R&D and Export in innovation outcomes show that there is correlation between the error terms of product innovation and R&D and between process innovation and R&D and Export. There is also a dependent relationship between product innovation and R&D, process innovation and R&D and process innovation and export. Thus, in this data set, process innovation is correlated with R&D and Export while product innovation is correlated with R&D but not export. This is a cross-sectional dataset, and it would be interesting to investigate this correlation further in a panel dataset.

Table 2.12 Marginal Effects for RBP (d) model

Variables	Process	Std. error	Export	Std. error
Process_inv			0.482***	0.0190
Export	0.721***	0.0226		
RnD	0.170***	0.0277	-0.077***	0.0196
Training	0.080***	0.0201	-0.035***	0.0136
AssetPurchase	0.127***	0.0179	-0.050***	0.0133
Certification	-0.117***	0.0347	0.081***	0.0233
Foreign Ownership	-0.063**	0.0305	0.108***	0.0261
Government Ownership	-0.119	0.1099	0.070	0.0947
Other	-0.135***	0.0263	0.127***	0.0249
Firmage	0.000	0.0008	-0.000	0.0006
Manager_exp	-0.001	0.0010	0.001	0.0007
Medium firm	-0.004	0.0196	0.005	0.0143
Large firm	-0.093***	0.0301	0.090***	0.026
Industry = Service	-0.014	0.0167	-0.009	0.0115
Côte D'Ivoire	0.013	0.0449	-0.052	0.0546
Ghana	0.314***	0.0435	-0.176***	0.0488
Liberia	0.097*	0.0545	-0.150**	0.0613
Mali	0.086*	0.0497	-0.004	0.0576
Niger	-0.005	0.0523	-0.017	0.0693
Nigeria	0.331***	0.0400	-0.136***	0.0480
Senegal	0.30***	0.0442	-0.163***	0.0493
Sierra Leone	0.017	0.0500	-0.205***	0.0563
Togo	-0.084*	0.0458	0.218***	0.0657
ρ	-1***	3.47e-13		
Observations	3,543			
Log pseudolikelihood	-2712.7851			
Wald χ^2 (df)				
Wald Test on joint significance	22.4289*** (1)			

Notes: The base variable for the ownership of firms is Domestic ownership. The base variable for firm size is Small Firm while the base variable for Country is Benin. The standard errors are robust. ***, **, and * denote 1%, 5% and 10% statistical significance respectively.

2.7 Conclusion

This chapter focuses on innovation data that has been collected for West African countries by the World Bank Enterprise Survey to elaborate on the factors that bring about innovation. The dependent variables product and process innovation due to the innovation questions for each country in the survey questionnaire could have taken place within the previous three years the data was collected while most of the explanatory variables took place within the year the survey was taken. This makes it impossible to identify the sequencing of the activities, whether sequential or simultaneous. Therefore, the RBP approach is the most relevant estimator because we could account for the endogeneity directly in the estimation process.

The marginal effects show that for both recursive bivariate probit models, firms that engage in one innovation output have an over 90% increase in the probability of engaging in the other

innovation output. The statistical significance of the correlation matrix in both main models show that there is dependence between product and process innovation and correlation between their error terms. This means that we cannot rule out the simultaneity and endogeneity of the innovation outcomes. The design of the questionnaire suggests simultaneity of the innovation outcomes, and the regression results of the RBP confirms this and shows endogeneity between the innovation outcomes. This is an important contribution to innovation literature because researchers using the World Bank Enterprise Surveys innovation data can consider the simultaneity and endogeneity between innovation outcomes in their research.

The results of the regression showed that firms that engage in export are more likely to engage in innovation outcomes as they can extract knowledge, enhance their innovative capabilities and sharpen their competitive advantage through exports (Ayllón & Radicic, 2019). This provides an incentive for governments to encourage firms that export their output with subsidies for their research as well as encourage value addition in the export sector since most of the economies under study rely heavily on the export of commodities such as crude oil, minerals, and agricultural commodities. Ghana for instance provides exemption from the payment of income tax on profits for 10 years for firms that export at least 70% of annual production of goods and services.

Investment in assets and equipment is significant for innovation output in this study. Worker training also increases the probability that a firm will engage in innovation outcomes. Workers can increase their knowledge base using equipment and machinery acquired at the firm. Most of the firms in the study are small and are unable to access low interest credit to invest in R&D or acquire sophisticated machinery hence governments can encourage collaborations with research institutions and more advanced private businesses (Multinational or local) and small firms where workers can be trained on the use of new machinery and equipment within an industry.

In this chapter, investment in R&D in the regression results showed the largest marginal effect on innovation output even though more firms engaged in worker training and purchased assets and equipment than engaged in R&D investment. The chapter has also shown a dependent relationship between innovation and R&D and Export. It has shown that firms that engage in innovation activity are more likely to invest in R&D and export and vice versa. Thus, there is

a simultaneous and endogenous relationship between R&D and product and process innovation and between export and process innovation.

The developing countries under review have structural and socio-political issues that impede their ability to develop technological and innovation capability. Yet the firms in the data have an innovation rate of 54%. Investment in R&D also had the largest marginal effect in both main RBP models. Hence there is innovation even in these circumstances. An investment in human capital coupled with government encouragement of private investment in R&D and other innovation activity could help stimulate the firms to build innovation capacity.

This empirical analysis provides a glimpse of the factors that determine innovation activity in West African countries. The simultaneous influence between innovation activities such as R&D and export and innovation output could mean that the linear specification of the regressors in the bivariate probit models could obscure the influence of the regressors in non-linear form (Marra et al., 2013). There is an opportunity for further innovation research that explores the influence of non-linear forms of innovation activity on innovation output.

The innovation survey must be collected over a longer period or longitudinally over multiple time points to better assess the effects of innovation activities on innovation outcome in this region. New survey questions could include in-depth questions such as firm access to government subsidies or tax breaks for R&D and access to funding for worker training. This will help in assessing the effectiveness of government policy in building innovation capability of firms.

Chapter 3: Innovation Capabilities of Firms in Ghana and Nigeria

3.1 Introduction

The objective of this chapter is to investigate the relationship between the four types of innovation namely, product, process, marketing, and organisational innovation. This is enabled by the fact that the World Bank Enterprise Surveys (WBES) has additional innovation data that includes marketing and organisational innovation for Ghana and Nigeria. This chapter also assesses the influence of innovation activities on the different types of innovation.

Innovation comes about when we make new things or make existing things better (Bell, 2009). A firm's ability to innovate is enhanced by the firm's ability to absorb available knowledge in the industry. Innovation capabilities as a term is defined by Hansen and Ockwell (2014) to denote the resources that firms need to create new products or to implement more substantial changes in products and production process organisation. In other words, innovation capability refers to the capacity needed to imagine, develop and implement innovation in the goods and services produced in an economy as well as innovation in how to produce these goods and services (Bell, 2009).

According to the UNESCO Institute for Statistics (2017), there are four types of innovation. These are product, process, marketing, and organisational innovation. Most of the literature on innovation for developing countries cover product and process innovation and this may be because the innovation data for the Enterprise Surveys often leave out questions on marketing and organisational innovation as is the case for the data for eight of the ten West African countries covered in chapter 2 of this thesis. This means that there is little research on the relationship between all four types of innovation.

Organisational and marketing innovation first appear in the third edition of the Oslo Manual (Cirera & Maloney, 2017). The manual classifies them as non-technological innovation. The Oslo Manual defines product innovation as the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. Process innovation is defined as the implementation of a new or significantly improved production or delivery method. Organisational innovation as defined by the Oslo Manual is the implementation of a

new organisational method in the firm's business practises, workplace organisation or external relations. Marketing innovation is the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing.

Product and process innovation are believed to be the outcome of more technological innovation capabilities such as R&D, worker training, use of a patented or unpatented invention and purchase of assets and equipment. On the other hand, marketing and organisational innovation come about by using the existing human resource and organisational capital (Cirera & Maloney, 2017). Thus, the experience of management is the innovation capability that is expected to influence the less technological innovations. However, Rahman and Kavida (2018), found that technological innovation capabilities lead to all four types of innovation outcomes. Also, according to Mairesse and Mohnen (2010b), the four types of innovation often occur simultaneously in a firm. Hence, this chapter seeks to investigate the relationship between all four types of innovation by running a multivariate probit with the product, process, marketing, and organisational innovation as the outcome variables with innovation capability indicators such as R&D, worker training, export, and asset purchase included in the regressors.

Ghana and Nigeria are the two countries chosen for this chapter because these countries have data on organisational and marketing innovation. This is absent in the innovation data of the other West African countries. Ghana and Nigeria are developing economies and so most of the firms produce traditional goods such as textiles and food. Hence technological innovation is more likely to take place in low technology labour intensive firms (Pavitt, 1984). This chapter investigates how all four types of innovation are related to each other. This is to add to our understanding of the relationship between the different types of innovation. The results are expected to underscore the interactions between the different types of innovation and the innovation activities that influence the innovation outcomes of firms in Ghana and Nigeria. Thus, this chapter will assess the influence of innovation activities on all the innovation outcomes.

The participation of firms in developing economies in R&D and patented or unpatented invention is low compared to the participation of firms in developed economies (Cirera & Maloney, 2017). This may lead to a lower absorption capacity of firms in developing economies. A look at the summary report of the 2015 innovation data collected by the

UNESCO Institute for Statistics (2017), shows that internal R&D is the predominant innovation activity of firms in developed countries while acquisition of machinery, equipment and software is the main innovation activity performed by firms in developing countries. However, manufacturing firms in developed economies also engage in innovation activity through means other than R&D. For instance, Huang et al. (2007), noted that in the third European Community Innovation Survey, more than half of the innovative firms did not conduct intramural or extramural R&D but rather acquired knowledge through the purchase of advanced machinery, patents and licenses and worker training.

It is thus important to research the activities that firms in developing countries such as Ghana and Nigeria engage in to acquire innovation capability. Relying on R&D data alone may exclude innovation activity in sectors that are not technologically intensive but make up the bulk of firms in developing economies (Lopez-Rodriguez & Martinez-Lopez, 2017). It will also better direct government policy towards the areas in the economy that can be improved to enhance the acquisition of knowledge in the economy. This will enhance the ability of local industry to adapt the knowledge from technologically advanced economies and improve upon it to create their own technologies.

The chapter has been arranged in the following order. The next section will contain background information on the economies of Ghana and Nigeria and their national commitments towards enhancing the innovation capacity of firms. The literature review will follow in section 3.3, and this will be followed by a discussion of the data to be analysed in the chapter. The way the different industry sectors engage with innovation activities will be discussed and analysed in section 3.5, and the multivariate probit regression for all innovation output will follow in Section 3.6. Section 3.7 concludes this chapter.

3.2 Background

Ghana and Nigeria are the two countries selected for this chapter. This is because apart from the fact that they are the two West African countries that have marketing and organisational innovation data for the World Bank Enterprise innovation survey, the two countries have similarities in the composition of their economies. This section is a discussion of the economies of Ghana and Nigeria and their governments' efforts in enhancing innovation and education.

3.2.1 Composition of Economies

The Gross National Income (GNI) per capita is very similar with Ghana's being \$2,280 and Nigeria's being \$2,080 (World Development Indicators Database, World Bank(2021)). There are similarities in the distribution of the major sectors' contribution to GDP of the economies of Ghana and Nigeria. For both countries, the services sector is the largest sector of the economy. In Nigeria, the services sector contributes 53% of GDP. This is followed by the agricultural sector which contributes a quarter of GDP leaving industry to contribute 22% of GDP (World Bank Group, 2019). In Ghana, the services sector contributes about 47% of GDP followed by industry which contributes about 34% and agriculture which contributes about 19% (Ghana Statistical Service, 2020). For both countries, the commodity sector employs less than 1% of the labour force. The largest employer in Nigeria is agriculture which employs half of the labour force (World Bank Group, 2019). In Ghana, the services sector is the largest employer at about 46% (Ghana Statistical Service, 2022).

These countries have developing economies where agriculture and the services sectors are more dominant than industry. It is thus expected that most firms are small, informal and have difficulty accessing credit to invest in R&D or possess patents. These firms are more likely to develop innovation capabilities through worker training and interactions, feedback from customers and the acquisition of machinery and equipment. Firms in these countries could benefit from government policy that invests in research institutions and supports interactions between these research institutions and relevant firms in the country. There has been attempts by each country to develop a national science, technology and innovation policy that is further discussed in the next section.

3.2.2 Government STI Policy, Investment in R&D and R&D Output

Ghana and Nigeria each have a national Science Technology and Innovation (STI) policy. The Nigerian STI policy was composed in 2012 and revised in 2016. It was put together to harmonise Science and Technology policy with other socio-economic policies. The aim of this combination was to create a National Systems of Innovation where the national STI policy aligned with the socio-economic policies of Nigeria (National Science, Technology and Innovation (STI) Policy, 2012). This is because the government of Nigeria identified innovation as a global tool for sustainable development. In the same vein, the government of

Ghana drafted a national policy on STI in 2017. A cursory look at the STI policies of both countries shows that the objectives for developing the technological capabilities of industry at the national level are broad without specific objectives and timelines as to how the government seeks to enhance the development of innovative capacity in all sectors of their economy.

For instance, in Nigeria, their STI policy spoke of establishing a National Research and Innovation Fund (NRIF) and a National Research and Innovation Council (NRIC) was inaugurated in 2016 to oversee the implementation of the policy. The NRIC must be backed by legislation and so the National Assembly of Nigeria passed the NRIC bill in 2019 and again in 2023, but the president is yet to sign it into law. On the other hand, in Ghana, the apex body set up to oversee the implementation of the STI policy is the Presidential Advisory Council for Science Technology and Innovation (PACSTI). The council was inaugurated in 2019, but the 2020 budget did not mention a fund for the apex body but rather provided funding for the president's executive projects on STI development (Government of Ghana, 2019). Lack of funding is cited in Ghana's STI policy as the main impediment to the implementation of previous STI policies.

Egbetokun et al. (2010), discuss the low-level of industry-academic relations in terms of R&D. they argue that this is due to issues such as communication gap, bureaucracy, inadequate research personnel, infrastructure and facilities and the difference between industry and university culture regarding R&D activities. The paper found that because there are weak linkages between local actors and high cooperation with foreign technical partners, Nigerian engineering and agro-allied firms depend on foreign firms for technological/technical development in improving or modifying existing products and processes. The research pointed out that since 75% or more of research projects arise from within research institutions, research is not demand-driven and hence it makes it difficult for the industrial sector to adopt the research output. There is thus the need for government policy to facilitate and support the development of linkages between local research institutions and firms that enhance knowledge generation, innovation, education and technological entrepreneurship.

The Council for Scientific and Industrial Research (CSIR) is Ghana's foremost public science and technology research institution (CSIR, 2022). According to the CSIR Strategic Plan for 2023 to 2027, the CSIR generates and applies innovative technologies and efficiently and effectively exploits science and technology for socio-economic development in agriculture,

industry, environment and some aspects of public health and social sciences. The activities of the CSIR are guided by the United Nations' Sustainable Development Goals (SDGs) and the African Union's long-term Agenda 2063. The CSIR has a Technology Development and Transfer Centre that leads the commercialisation and technology transfer of technologies and innovations from the CSIR research institutes to the private sector. In the outlined problems and issues that could have impacted the performance of the CSIR in industry and the Ghanaian society at large, the CSIR noted that historically, government has not been committed adequately to science and technology driven socio-economic development. They also noted that government has not accepted full responsibility for funding STI research in public research institutions.

Investment in R&D as a percentage of GDP in both Ghana and Nigeria is below the 1% minimum target agreed upon by African countries at the New Partnership for Africa's Development (NEPAD) conference in 2007 (AUDA-NEPAD, 2014). There is very little information on R&D expenditure as a proportion of GDP for both Ghana and Nigeria. The latest data available for Ghana is 0.08% in 2014 (AUDA-NEPAD, 2019) and for Nigeria it is 0.13% in 2007 according to UNESCO Institute for Statistics (UIS) (UNESCO, 2017). This is reflected in the Global Competitiveness report, where Ghana ranks 92nd out of 141 countries on Research and Development while Nigeria ranks 78th (World Economic Forum, 2019). A breakdown of this ranking shows that Ghana ranks 83rd on the number of scientific publications published between 2016 and 2018. Nigeria ranks 67th in this area. On patent applications per million population submitted between 2013 and 2015, Ghana ranks 120th while Nigeria ranks 124th. The research institutions prominence index used in this report, measures the prominence and standing of private and public research institutions for 2019. It comprises of private and public universities, governmental agencies, corporate entities, and health institutes. Ghana ranks 81st on this index while Nigeria ranks 50th (World Economic Forum, 2019).

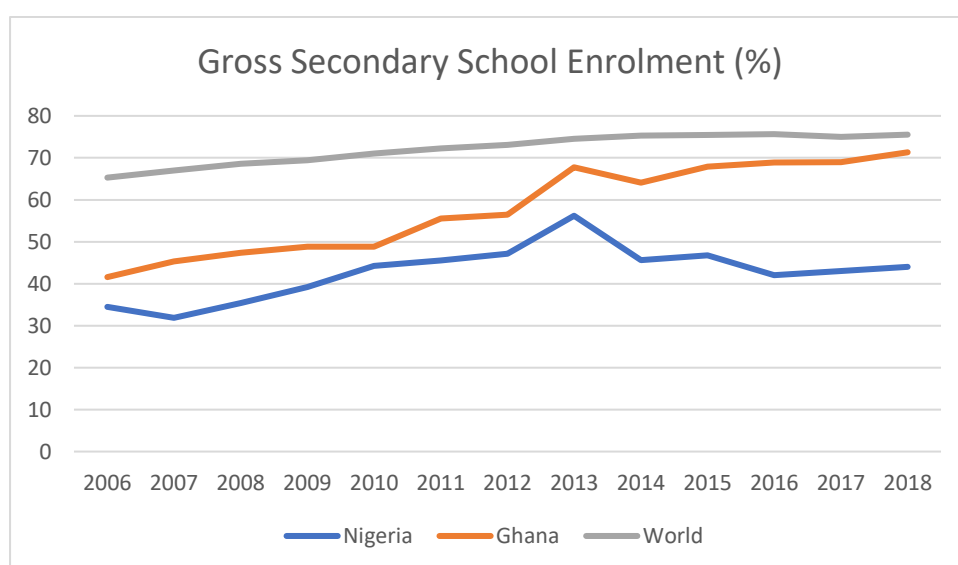
3.2.3 Education

Education has been identified as another key indicator that enables technological absorption between technologically advanced economies and developing economies as it is key to the development of human capital (Bell (1984); Lall (1992); Romijn (1997); Lundvall (2007), Mkandawire (2007). Figure 3.1 shows the gross secondary school enrolment for Ghana, Nigeria and the world. The gross secondary school enrolment refers to the number of students

enrolled in secondary education regardless of age as a percentage of the population of secondary school age children.

In the case of Ghana and Nigeria, we see from the graph in Figure 3.1 that the gross secondary school enrolment is below the world average of 75.6% according to the 2018 data from the UIS. The available data for Nigeria goes up to 2018. Ghana's gross secondary school enrolment has been growing much more steadily than Nigeria's and by 2018 it was close to the world average at 71.3%. Ghana's policy of free secondary education which began in September 2017 may have contributed to the increase in gross secondary school enrolment as the rate was 69% in 2017 and as of 2020, Ghana's gross secondary school enrolment rate (78%) has surpassed the world average of 77% (World Bank Open Data, 2023).

Figure 3.1 Gross Secondary School Enrolment from 2006-2018



Source: Author's compilation from UNESCO Institute for Statistics (UIS) Bulk Data Download Service (uis.unesco.org). Accessed September 9, 2020.

Figure 3.1 shows that Nigeria's secondary enrolments were increasing until 2014. This is the beginning of a fall in world prices of crude oil that led to a terms of trade shock triggering a recession in 2016 (World Bank Group (2019); International Monetary Fund (2019)). It was also the peak of insurgency in the North-East region of Nigeria where religious militants with

an ideology against western education kidnapped more than 200 girls in a secondary school (Isokpan & Durojaye, 2016). The gross secondary school enrolment in Nigeria dropped from 56.2% in 2013 to 45.6% in 2014. It went down to 42% in 2016 and increased to 44% in 2018.

When it comes to tertiary education enrolment, Nigeria's last recorded gross tertiary enrolment was in 2018 at 12% while Ghana's gross tertiary enrolment for 2020 was 19% (World Bank Open Data, 2023). The world average for 2020 was more than double that of Ghana's at 40%. Investment in education as a proportion of GDP has only one entry for Nigeria in 2013 which is 0.5% of GDP. In 2018, Ghana's investment in education was about 4% of GDP. The world average was 4.2% in that same year (UIS, 2022).

The Global Trade and Innovation Policy Alliance (2019) report suggests that education and training fosters knowledge creation while industry consumes this knowledge and turns it into innovation output. The report points to the fact that America's investment in research and investment in innovation in industry through funds like the Small Business Innovation Programme and legislative policy such as the Bayh-Dole Act has led to America being the only country in their report that reported achieving effective technology transfer and commercialisation of new discoveries from universities, research institutions and national laboratories to the private sector of industry. Thus, investment in education and research paired with policy that protects Intellectual Property can encourage technology transfer and innovation from academia to industry.

There are similarities in the economic make-up of Ghana and Nigeria. Both countries earn foreign exchange mainly from their extractive industries. The services sector is the major contributor to the GDP of both countries. The commodities sub-sector of industry for both countries make-up a similar proportion of their respective GDPs. Both countries have innovation policies but lack consistent investment and follow through. Secondary education for Nigeria has been affected by both commodity issues that have affected the economy and socio-political conflicts. Hence the development of innovation capabilities and innovation in firms can be influenced by issues outside the firm or country. Yet the governments of Ghana and Nigeria could encourage knowledge transfer from academia to industry by investing in academia and establishing policy that streamlines this transfer of knowledge and protects Intellectual Property.

3.3 Literature Review

The literature review is made up of three sections. The first section discusses the different types of innovation output, their interconnectedness, and how innovation output can lead to more innovations. The second section discusses the importance of innovation in industry and the different stages in the life cycle of industry where each innovative type is developed. The third section looks at the nature of innovation in developing countries and the direction of innovation research in developing countries.

3.3.1 Types of Innovation

According to Karlsson and Tavassoli (2016), product innovation is the introduction of a good or service that is significantly improved regarding its characteristics or intended purpose. Process innovation is the implementation of a new or significantly improved production or delivery method. According to Purchase and Volery (2020), marketing innovation is the implementation of new marketing practices involving significant changes in design, distribution, promotion or pricing of a product or a service. Birkinshaw et al. (2008), define organisational innovation as the generation and implementation of a management practice, process, structure, or technique that is new to the firm and is intended to further the organisational objectives of the firm.

The definitions of the different types of innovation show a connection between them. Product innovation relates to changes in its characteristics whereas marketing innovation involves changes in the product design. Process innovation relates to improvement in the delivery method while organisational innovation means an improvement in the structure or technique of the practice of management. This connection between the different types of innovation is observed by researchers such as Purchase and Volery (2020), who posit that a new product development needs marketing innovation to market it to consumers while marketing innovation can increase the consumer base of an existing product and lead to product innovation as a result of consumer feedback from increased demand. D'Attoma and Ieva (2020), agree with this and posit that marketing innovation can increase the demand for innovative products and thus encourage product innovation. Aksoy (2017), theorises that marketing and organisational innovation creates a culture of innovation that drives product and process innovation. This is because organisational innovation for instance often comes from the firm leadership. Thus,

innovation led by the firm leadership encourages employees to share their knowledge and skills with their colleagues and this knowledge absorption can lead to innovation output.

In empirical research, Azar and Ciabuschi (2017), use data from 218 Swedish export firms to explore the relationship between organisational and technological innovations (product and process innovation) and firm export performance. The results show that organisational innovation enhances export performance both directly and indirectly by sustaining technological innovation. Karlsson and Tavassoli (2016), use a long panel of Community Innovation Surveys in Sweden over a 10-year period (2002-2012) to trace the preferred innovation strategy of firms in the dataset. They found that six innovation strategies account for 70% of the firms' chosen strategies. That is either they introduced each innovation type separately or introduced both product and process innovation together or introduced all four types of innovation to the market at the same time.

3.3.2 Importance of innovation in industry

According to Tavassoli and Karlsson (2015), the competitiveness of firms depends on their innovative capacity over time. Firms that generate knowledge can use their existing stock of knowledge to develop knowledge at a lower cost compared to their competitors even as they also develop their innovative capacity. Thus, firms that invest in the generation of knowledge can exploit the dynamic economies of scale of developing innovative capacity (Tavassoli & Karlsson, 2015). Similarly, innovation is important for the growth of firms as it helps firms to attract customers, retain existing customers and strengthens ties with supply and distribution networks (Chandra & Neelankavil, 2008). Tavassoli and Karlsson (2015) argue that the generation of knowledge is important for both technological and non-technological innovations. This is because all types of innovation have a measure of novelty that can only happen through the creation of knowledge.

Innovation research initially was biased in favour of technological innovation but in 2005, the third edition of the OECD's Oslo Manual expanded the nature of firms surveyed to include firms in the service sector. Marketing and organisational innovation were also added to the types of innovations surveyed. The Europe-wide Community Innovation Surveys (CIS) adopted these changes made in the Oslo Manual (Meissner et al., 2017). Thus, since 2013, the Enterprise Surveys (ES) have included innovation indicators that reflect the different factors that lead to innovation success (Meissner et al., 2017).

The different types of innovation are observed at different stages of the life cycle of a firm and are complementary in ensuring the success of the innovative products on the market. Tavassoli (2015) posits that new knowledge and technology increase the propensity of a firm to engage in product and process innovation. A firm is more likely to engage in technological innovation at the initial stage of the life cycle of a product before it is brought to the market (Tavassoli, 2015). Tavassoli (2015) also argues that a firm that has an established product is more likely to export its output. Thus, these firms are more likely to engage in marketing and organisational innovation compared to product and process innovation.

3.3.3 Innovation research in developing countries.

Coccia (2006), outlines the different ways innovation can come about and the effect of innovation on the firm, market, economy or even the world. Coccia (2006), labels innovation that comes about through deliberate R&D as radical innovations. These innovations are unevenly distributed over sectors and over time. They often lead to the growth of new markets or large reductions in production costs and an increase in product quality. Over time, a radical innovation could have dramatic effects in an economy if it leads to the rise of entire industries and services. Coccia (2006), discusses new technological systems that are innovations that are technically and economically inter-related. These innovations lead to the development of other industries and innovations. Then there are technological revolutions which are far reaching and pervasive, affecting many branches of the economy as well as creating new sectors. Coccia (2006), presents incremental innovation as a more common form of innovation that comes about not through formal R&D but through inventions and improvements suggested by workers directly engaged in the innovation process. It can also come about through user reviews and suggestions. Incremental innovation often goes unnoticed and unrecorded, but the effects are apparent over time.

Zanello et al. (2016), agree that innovation can either be groundbreaking or imitative and incremental. Their literature review of innovation research papers covering developing economies explain that firms in developing countries upgrade their technological capacities by imitating or importing existing technologies. They also make adjustments to existing products and production processes to suit the needs of customers and operate with available resources. This is because groundbreaking innovation often comes about through high sunk costs of establishing R&D facilities, highly skilled workers, and the risk of not profiting from

developing an innovative idea. Thus, firms in developing countries usually acquire knowledge in ways that do not appear in the questionnaires of statistical surveys on innovation. Zanello et al. (2016), observed that innovation studies are a consolidated research area in developed countries but have not received as much attention in developing countries. They suggest that this may be due to the initial view that innovation occurs at the end of development rather than as a means to development. There is thus the need for innovation studies to be more inclusive of innovation that takes place in developing countries.

Lema et al. (2021), examine how the literature on innovation in developing economies has evolved in the social science disciplines from 2000 to 2019. They find that while the literature output has increased at an annual rate of 21% most of the literature is on developing economies that are upper middle-income countries. Furthermore, the literature on low middle income countries is focused on a small number of countries. Jauhiainen and Mugabe (2024), observe this as well and argue that as a result there is limited African perspective in international publications on innovation. They suggest that we build and maintain an evolving database and accessible information on innovation research on African countries as this would be valuable to both researchers and policy makers across the African continent.

Kaplinsky and Kraemer-Mbula (2022), indicate that innovation research for Africa will benefit from a focus on the informal sector. They show that nearly 75% of non-agricultural employment in sub-Saharan Africa is in the informal sector. For Western Africa, this figure is 81.5%. On the other hand, Delera et al. (2022), empirically develop a framework for analysing the factors that enhance the adoption of advanced digital production technologies associated with Industry 4.0 in developing economies. Their results show that the adoption of advanced digital production technologies leads to an increase in productivity. Factors such as firm size, investment in innovation capabilities, foreign ownership and technological innovation were also shown to be positively and significantly associated with labour productivity in their paper.

Egbetokun et al. (2016), discuss innovation surveys carried out in 11 African countries. The data shows the share of firms that engaged in product, process, marketing and organisational innovation. The data showed that a large proportion of firms in these countries engaged in innovation output regardless of the level of development of the economy. Thus, they suggest that at the firm level, innovation may not depend on the current level of economic development of the economy as was previously believed.

Abereijo et al.(2007), assess the ability and competencies of manufacturing SMEs to innovate in Nigeria. They posit that innovation capability of a firm is developed through innovation activities such as R&D, innovation output and worker training. In the study, there are two sources of developing innovation capability. These are internal sources and external sources. Internal sources include initial work experience of the manager, professional qualification of the workforce, internal R&D, worker training and the acquisition of technological licences. External sources include networking with private sector agents and institutions, geographical proximity to networking opportunities and the nature and extent of institutional support received from government and other organisations. The study showed that internal sources of developing innovation capability such as R&D investment, worker training, attaining higher academic degrees and education in science and engineering as well as previous experience of the founder or manager had a significant influence in the development of innovation capability. Here also, external sources of developing innovation capability such networking with local firms and multinationals as well as universities and research institutes had significant influence on the development of innovation capability. Similarly, Saunila (2020), present the results of a systematic review of innovation capability literature on small businesses. The author looked at 39 English-language peer-reviewed articles with empirical evidence over the period 2009-2018. The review found that determinants of innovation capability could also include the determinants of innovation types that is internal sources such as prior work experience, education of management and workers and external sources such as suppliers and customer feedback.

Medase and Barasa (2019), use the 2012 Nigeria Innovation Survey data collected over the period 2008-2010 to investigate how specialised capabilities such as absorptive capability and marketing capabilities influence innovation commercialisation in manufacturing and service firms in Nigeria. Marketing capabilities measure new product marketing and marketing innovation. The results in the paper show that absorptive capacity as measured by openness and formal training facilitates the assimilation and use of external knowledge and this enhances innovation performance. Openness in this paper is measured as the percentage of the degree of importance firms attach to the different sources of information for innovation activities or that have led to the successful completion of existing innovation projects within each firm. This measure reflects the intensity with which firms draw on different sources of information. The

paper finds that formal training for new product development enhances innovation capability and stimulates both inter-organisational learning and intra-organisational learning. The research shows that marketing capabilities significantly account for innovation performance in Nigeria. This is because marketing capabilities are essential for differentiating products from competitors and for connecting firms with customers.

Conducting multi case qualitative research to understand innovation capability building in fresh fruit processing in Ghana, Osei-Amponsah (2022), argues that learning mechanisms differ with agro-enterprise size. The findings show that knowledge acquisition in the micro to small enterprises occurs through learning-by-doing and informal mechanisms that require context-specific interventions. Thus, there is no formal science-based internal learning in micro to small firms. In these firms, technical knowledge is acquired through internet searches, training on standard operating practises, workshops, machinery and equipment acquisition and customer feedback. Large enterprises on the other hand place importance on new product development and quality assurance. They have R&D units that are staffed with workers who have specialised skills and scientific expertise.

An analysis of innovation capability building in Kenya's agro-biotech is conducted by Kingiri (2022). The case study demonstrates that R&D capabilities, technical development and biosafety have been built up simultaneously over two decades. This has facilitated testing and adoption of new traits that have opened new opportunities for expansion of government agendas such as food security. Building innovation capabilities has encouraged private and public sector investment in biotechnology research, commercialisation and industrialisation. Over more than two decades many scientists have been trained in biotechnology countrywide with a significant number actively engaged in Genetic Engineering (GE) work. Yet there are infrastructural and human capacity issues as well as prolonged approval decisions on GE research applications. These problems are due to inadequate government support for biotech research and the political economy of biotech innovation. The co-evolution of biotechnology R&D and biosafety regime development has resulted in a functional biosafety framework. Thus, Kenya has made progress in building the requisite capacities and this has led to the commercial release of the Bt. Cotton application. This shows that when local and international research institutions, private sector, government institutions and knowledge think tanks work in an integrated way, they are able to develop significant regulatory and policy capacity.

The different ways in which firms develop innovation capability can influence the type of innovation output a firm engages in. The different innovation output can also influence each other. This chapter looks at the relationship between innovation output in firms in Ghana and Nigeria. In this chapter we will evaluate whether there is simultaneity between the outcome variables. This is a useful indication of the probability to innovate since not all firms that innovate engage in innovation activities such as R&D, worker training, use of patented or unpatented invention and acquisition of equipment. Thus, this chapter seeks to ascertain the innovation capabilities that influence innovation output and investigate the influence each of the four types of innovation output has on the others. This is to help in understanding the innovation activities that influence innovation indicators and the simultaneity of these indicators in firms in Ghana and Nigeria.

3.4 Data

The World Bank Enterprise Surveys (ES) for Ghana and Nigeria includes questions for marketing and organisational innovation (World Bank Enterprise Surveys, <http://www.enterprisesurveys.org>). The main innovation survey for the two countries has the questions for organisational and marketing innovation in questions H.5 and H.6 respectively. The questions are stated in appendix A1.2. There are no such questions for the other eight West African countries covered in this thesis.

Product and process innovation are indicated as technologically intensive while organisational and marketing innovation are the two less technologically intense innovation types according to the Oslo Manual (UNESCO (2017); Cirera & Maloney (2017)). It is noteworthy that the manufacturing and services sectors are the primary business sectors of interest. Firms with 100% government or state ownership are not eligible to participate in the survey (World Bank, 2022).

Table 3.1 has definitions and descriptive statistics of the variables in the dataset used for this chapter. From this table, we notice that about half of the firms surveyed engaged in product, process, and marketing innovation. Nearly 40% of the firms surveyed engaged in organisational innovation. A little over a sixth of the firms surveyed invested in R&D and exported a portion of their output. Meanwhile, 38% of firms surveyed invested in an asset or

Table 3.1 Definitions and Descriptive Statistics of Variables

<i>Variable</i>	<i>Description</i>	<i>Obs</i>	<i>Mean</i>	<i>Std. dev.</i>	<i>Frequency</i>	<i>Missing</i>
<i>Product Innovation</i>	New or significantly improved products	3,327	0.5	0.5	1,670	69
<i>Process Innovation</i>	New or significantly improved processes	3,330	0.5	0.5	1,666	66
<i>Organisational Innovation</i>	New or significantly improved organisation	3,335	0.39	0.49	1,315	61
<i>Marketing Innovation</i>	New or significantly improved marketing	3,339	0.51	0.5	1,690	57
<i>RnD</i>	Firm invested in R&D	3,313	0.18	0.39	610	83
<i>Training</i>	Firm conducted training for the employees	3,288	0.32	0.46	1,039	108
<i>Assetpurchase</i>	Firm purchased new equipment for production	3,147	0.38	0.48	1,186	249
<i>Certification</i>	Internationally recognised quality certification	3,171	0.1	0.3	311	225
<i>Export</i>	export sale made	3,017	0.18	0.38	542	379
<i>Ownership</i>	Firms that have more than 50%;					
	1. Domestic ownership	2,950	0.83	0.42	2,460	446
	2. Foreign ownership	2,950	0.05	0.2	152	446
	3. Government ownership	2,950	0.01	0.08	21	446
	4. Other	2,950	0.11	0.29	317	446
<i>Firm age</i>	Age of firm	3,137	16.57	12.4	3,137	259
<i>Manager Experience</i>	Manager' s years of experience	3,209	13.49	9.25	3,209	187
<i>Firm Size</i>	Variable for number of employees					
	1. Small firm: A firm with 5-19 employees	2,945	0.63	0.49	1,857	451
	2. Medium firm: A firm with 20-99 employees	2,945	0.28	0.42	829	451
	3. Large firm: A firm with more than 99	2,945	0.09	0.26	259	451
<i>Country</i>	Ghana	3,396	0.21	0.41	720	0
	Nigeria	3,396	0.79	0.41	2,676	0

equipment. While 32% of firms trained their workers. Nigerian firms in the survey number 2,676 while Ghanaian firms are 720.

The dependent variables and some control variables have missing values. This can be due to the inclusion of firms that refused to respond to the screener. The unknown responses are also treated as missing in the dataset. Nigeria has most of these unknown responses especially for firm ownership. Firm size has the largest number of missing data because of some firm size specification issues. In the case of Ghana there were some unknown information. Some firms were also labelled as both medium and large. In the case of Nigeria firms with less than 5 employees were included and so the researcher labelled them as missing since the survey is expected to cover only firms with 5 employees or more. The unknown responses are treated as missing in the dataset. Nigeria has most of these unknown responses.

3.5 Methodology

3.5.1 Research questions

The main question this chapter seeks to answer is how the different types of innovation output relate to each other given a common set of determinants. This is to include innovation output as an indicator for innovation along with innovation activities. Thus, this chapter investigates the determinants of the four types of innovation: product, process, marketing and organisational.

It is expected that firms that engage in product and process innovation are firms that invest in developing innovation capabilities such as R&D, worker training and the purchase of assets and equipment while firms that engage in organisational and marketing innovation are more likely to be influenced by export and managerial experience (Cirera & Maloney (2017); Azar & Ciabuschi (2017); Tavassoli (2015)). The chapter investigates the influence each innovation output has on the other as well as the influence of innovation activity on innovation output.

3.5.2 Probit Models

This chapter is using a multivariate system of probit models as the main estimator because the four outcome variables; product, process, marketing, and organisational innovation are binary outcomes. This means that certain assumptions of the classical linear regression model will be violated by the nature of the outcome variables. In the questionnaire the question for each innovation states that the innovation output took place during the last three years to the period

of the survey. Most of the regressors took place within the survey year except for R&D which also took place during the last three years. Thus, the error terms of the innovation outcomes are not expected to be independent since the innovation output could have taken place simultaneously or one could have caused the other leading to endogeneity. This situation could also lead to heteroscedasticity and autocorrelation. This will make OLS estimates and the use of standard statistical tests such as the t-ratios incorrect. The probit model is the most appropriate for this data set because it restricts the value of the predictor variable to be between 0 and 1 and is effective in minimizing heteroscedasticity when appropriate corrections are made (Adekoya et al., 2002).

It is possible that firms consider different types of innovation at the same time. In chapter 2, we observed from the results of the recursive bivariate probit models that product and process innovations are dependent on each other, and their error terms are correlated. In this chapter we include marketing and organisational innovation to product and process innovation to determine the relationship between all four types of innovation. A multivariate probit (MVP) is an appropriate model to determine whether there is a relationship between all four innovation types.

In this chapter, we apply multivariate probit modelling to explore the possibility of simultaneity between product, process, marketing, and organisational innovation. We also use the multivariate probit to determine correlations between the innovation activities namely R&D, worker training, and equipment and asset purchase. This is to establish possible correlation between the innovation output and innovation activity as suggested by the literature (González et al. (2016); Harris & Moffat (2011)).

The multivariate probit model is typically specified as;

$$y_{ij}^* = x_i \beta_j + u_{ij} \quad (1)$$

$$y_{ij} = 1 (y_{ij}^* > 0) \text{ and } y_{ij} = 0 \text{ otherwise} \quad (2)$$

$$\mathbf{u}_i = [u_{i1}, \dots, u_{iM}] \sim MVN(\mathbf{0}, \mathbf{R}) \text{ or } \mathbf{y}_i^* = [y_{i1}^*, \dots, y_{iM}^*] \sim MVN(\mathbf{x}_i \mathbf{B}, \mathbf{R}) \quad (3)$$

Where $i = 1, \dots, N$ indexes firm observations while $j = 1, \dots, M$ denotes variables. The x_i is a K-vector of exogenous covariates, while y_i^* is a collection of responses on all j variables. Hence y_{ij} is a binary response on the ith observation unit and jth variable (Chib & Greenberg, 1998).

The u_{ij} are assumed to be independent and identically distributed (iid) across i but correlated across j for any i (Mullahy, 2016). MVN stands for the multivariate normal distribution. R is a correlation matrix where the diagonal elements are 1 and the off-diagonal elements ρ_{pq} where $\{\rho_{pq}\} \in \{1, \dots, M\}, p \neq q$. The x variables have the standard full rank conditions and each $|\rho_{pq}| < 1$. Then $B = [\beta_1, \dots, \beta_M]$ and R will be identified and estimable with sufficient sample variation in the x variables.

The specification of the multivariate probit model for the full set of innovation determinants can then be denoted as follows:

$$\text{Product_inv} = \text{RnD} + \text{training} + \text{AssetPurchase} + \text{Export} + \text{certification} + \text{ownership} + \text{Firmage} + \text{Manager_exp} + \text{Firmsize} + \text{Sector} + \text{Country}$$

$$\text{Process_inv} = \text{RnD} + \text{training} + \text{AssetPurchase} + \text{Export} + \text{certification} + \text{ownership} + \text{Firmage} + \text{Manager_exp} + \text{Firmsize} + \text{Sector} + \text{Country}$$

$$\text{Marketing_inv} = \text{RnD} + \text{training} + \text{AssetPurchase} + \text{Export} + \text{certification} + \text{ownership} + \text{Firmage} + \text{Manager_exp} + \text{Firmsize} + \text{Sector} + \text{Country}$$

$$\text{Organisational_inv} = \text{RnD} + \text{training} + \text{AssetPurchase} + \text{Export} + \text{certification} + \text{ownership} + \text{Firmage} + \text{Manager_exp} + \text{Firmsize} + \text{Sector} + \text{Country} \quad (4)$$

Each of the equations have the same set of explanatory variables. According to Cappellari and Jenkins (2003), the most popular simulation method for evaluating multivariate normal distribution functions is the Geweke–Hajivassiliou–Keane (GHK) smooth recursive conditioning simulator. Cappellari and Jenkins explain that the GHK simulator derives values for the truncated univariate standard normal variates by taking random draws from upper-truncated standard normal distributions with truncation points and then recursively computes a multivariate probability value (Cappellari & Jenkins, 2003). The GHK simulator's simulated probabilities are unbiased. They are bounded within the (0,1) interval, and the simulator is a continuous and differentiable function of the model's parameters (Cappellari & Jenkins, 2003). The GHK simulator is also more efficient in terms of the variance of the estimators of probabilities than other simulators such as the acceptance–rejection or Stern simulators (Cappellari & Jenkins, 2003).

Cappellari and Jenkins (2003), posit that the simulated maximum likelihood (SML) estimator is consistent as the number of draws and the number of observations tend to infinity. Thus, the desirable properties of the SML estimator are asymptotic, as they are for all maximum likelihood estimators. Hence it is expected that, the sample size required to reduce the finite sample bias to some acceptable level will increase with the number of equations. The mvprobit program in STATA fits multivariate probit models using the method of SML (Cappellari & Jenkins, 2003). Hence, using this program to run the multivariate probit specified above, it is expected that the simulated probabilities are unbiased and the variance of the estimators of the probabilities are efficient.

3.6 Results

The results are presented in two sections. In the first section we analyse the descriptive statistics, and this is followed by a discussion of the regression results. The multivariate probit will be used to determine the correlation between the types of innovation and R&D, worker training and the purchase of assets and equipment because there could be endogeneity between these innovation activities and the types of innovation.

3.6.1 Analysis of the descriptive statistics for the different sectors of Industry

Table 3.3 below shows the various industries sampled in the dataset. The items under the industry sampling sector are named to show that some industries have been merged but have one label. The firms that have been merged are as follows; Food and Beverages which include hotels and restaurants. Garments include textile firms and leather firms. Furniture includes wood firms. Publishing includes paper firms. Plastics and Chemicals include non-metallic mineral products and recycling. Fabricated Metal Products include basic metals. Machinery and Equipment include electronics and precision instruments. Transport Services include services of motor vehicles.

From table 3.2 below, we can see that a significant number of firms interviewed engage in wholesale and retail activities. This is not surprising as retail trade demands little capital investment or skill hence it is a means of earning an income that is available to most people in developing economies. Thus, in the dataset, 566 firms are engaged in retail trade across both countries. Firms that engage in Fabricated Metal Products and Plastics and Chemicals which include non-metallic mineral products have substantial representation in the dataset. This may

be because the manufacturing industry of both countries is dominated by the extractive sector of industry. Machinery and Equipment firms and IT firms make up about 1% of the firms in the sample. These firms are expected to have workers that are highly skilled in modern technology and may require more investment in R&D compared to firms in the Food and Beverages sector for instance. Developing countries like Ghana and Nigeria often have limited resources and access to modern technologies. This may explain why they make up such a small proportion of firms in the dataset. The heavy use of machinery and equipment in Construction could also explain the small proportion of Construction firms.

Table 3.2 Industry Sampling for all firms

Industry Sampling Sector	Ghana	Nigeria	Frequency	Percent
Food & Beverages	111	521	632	19
Garments	35	239	274	8
Furniture	55	248	303	9
Publishing	65	171	236	7
Plastics & Chemicals	77	264	341	10
Fabricated Metal Products	80	194	274	8
Machinery & Equipment	8	37	45	1
Construction	35	52	87	4
Wholesale & Retail	172	604	776	22
Transport Services	75	304	379	11
IT	7	42	49	1
Total	720	2,676	3,396	100.00

Source: World Bank Enterprise Surveys, <http://www.enterprisesurveys.org>

Table 3.3 below shows the type of innovation that each industry engages in. It can be observed that about half of the firms engaged in all the types of innovation except organisational innovation that had less than 40% of firms engaged. We see that 75% of firms in IT Services engaged in product innovation followed by 61% of firms in Garments. About 61% of firms in the Garments sector engaged in process innovation. Thus, more than 60% of firms in the Garments sector engaged in both product and process innovation. Similarly, 55% of the firms in the Food and Beverages sector engaged in both product and process innovation. Fabricated Metal Products also has a similar percentage of firms engaged in product and process

innovation at 48% and 47% respectively. Transport Services had the lowest proportion of firms engaged in product, process, and marketing innovation at 42% each. For marketing innovation, the IT sector engaged the most with 60% of IT firms engaging in marketing innovation. Only two sectors, Construction and IT had more than half of their firms engaged in organisational innovation at 55% and 54% respectively. Furniture, Publishing and Plastics and Chemicals are the three sectors where a higher proportion engaged in process innovation than in product innovation.

Table 3.3 Industry Sampling Sector and Innovation type

Industry Sampling Sector	Innovation type (Number of firms in parentheses)			
	<u>Product</u>	<u>Process</u>	<u>Marketing</u>	<u>Organisation</u>
Food & Beverages	55% (337)	55% (340)	57% (356)	46% (282)
Garments	61% (163)	61% (165)	50% (135)	38% (101)
Furniture	47% (141)	53% (160)	51% (151)	35% (105)
Publishing	53% (119)	58% (131)	46% (104)	40% (90)
Plastics & Chemicals	48% (161)	52% (174)	53% (178)	46% (155)
Fabricated Metal Products	48% (131)	47% (130)	48% (132)	35% (95)
Machinery & Equipment	53% (23)	43% (18)	45% (20)	34% (15)
Construction	53% (46)	49% (43)	54% (47)	55% (48)
Wholesale & Retail	47% (357)	42% (321)	49% (382)	33% (253)
Transport Services	42% (156)	42% (158)	42% (156)	39% (145)
IT	75% (36)	54% (26)	60% (29)	54% (26)
Average	50% (1,670)	50% (1,666)	51% (1,690)	39% (1,315)

Wholesale and Retail firms are expected to handle finished goods hence innovation is expected to be geared towards marketing and organisational innovation. More Wholesale and Retail firms engaged in marketing innovation than in any other innovation although more of these firms engaged in product and process innovation than in organisational innovation.

In table 3.4 below, we can observe that all the different sectors engage in innovation activity to some degree. In general, in table 3.4, 38% of firms engaged in the purchase of assets and

equipment while 32% invested in worker training and 18% invested in R&D and export. More than a quarter of firms in sectors such as Machinery & Equipment, Construction, Plastics and Chemicals and IT Services invested in R&D. Construction and IT Services had the highest proportion of firms that acquired assets and equipment at 59% and 45% respectively. Similarly, 48% of IT firms provided training for their workers while 46% of Construction firms provided their workers with training. Plastics and Chemicals which includes non-metallic mineral products and Recycling firms, engaged the most in export with 24% of firms in this sector exporting some of their output.

Table 3.4 Industry Sampling Sector with Innovation Activity

Industry Sector	Innovation activity (Number of firms in parentheses)			
	<u>RnD</u>	<u>AssetPurchase</u>	<u>Training</u>	<u>Export</u>
Food & Beverages	18% (111)	38% (217)	34% (208)	19% (108)
Garments	19% (51)	39% (105)	30% (80)	16% (39)
Furniture	14% (41)	36% (99)	24% (70)	22% (60)
Publishing	20% (45)	42% (88)	33% (75)	13% (27)
Plastics & Chemicals	30% (101)	43% (136)	32% (104)	24% (70)
Fabricated Metal Products	17% (47)	41% (107)	31% (81)	13% (31)
Machinery & Equipment	30% (13)	41% (16)	28% (12)	14% (5)
Construction	26% (22)	59% (47)	46% (39)	15% (13)
Wholesale & Retail	15% (110)	30% (219)	27% (203)	18% (124)
Transport Services	15% (57)	38% (133)	39% (144)	17% (57)
IT	26% (12)	45% (19)	48% (23)	20% (8)
Average	18% (610)	38% (1,186)	32% (1,039)	18% (542)

This may be because these countries depend on the export of mineral products for foreign exchange. There is also an increase in global demand for recycled products because of growing sensitivity to climate change (Bora et al., 2020). Plastics and Chemicals and Machinery and Equipment also had 30% of the firms in these sectors invest in R&D. This is the highest proportion of firms that invest in R&D in the many sectors of industry. We observe that on average, less than a fifth of firms engage in export.

From table 3.4, we can observe that more than twice the proportion of firms that engage in R&D engage in asset and equipment purchase while nearly double the proportion of firms engage in worker training as engage in R&D. Even the non-traditional firms like IT Services and Machinery & Equipment engage more in AssetPurchase than R&D.

Table 3.5 Multivariate Probit Estimation from equation (4)

Variables	Product	Standard errors	Process	Standard errors	Marketing	Standard errors	Organisational	Standard errors
R&D	0.7729***	0.0736	0.7206***	0.0748	0.9917***	0.0797	0.8620***	0.0719
Training	0.3341***	0.0593	0.3127***	0.0599	0.3272***	0.0612	0.3981***	0.0608
AssetPurchase	0.4682***	0.0549	0.5322***	0.0557	0.4855***	0.0562	0.3511***	0.0563
Export	0.0607	0.0696	0.0190	0.0708	0.2707***	0.0735	0.3011***	0.0721
Certification	0.1091	0.0962	-0.0252	0.0960	0.0196	0.0994	0.0704	0.0992
Foreign Ownership	0.0897	0.1337	0.1516	0.1281	0.0417	0.1412	0.0237	0.1427
Government Ownership	-0.1879	0.5444	-0.2581	0.3978	-0.1808	0.5705	-0.3152	0.3790
Other	0.0085	0.0876	-0.0259	0.0905	0.0906	0.0941	0.0650	0.0920
Firm age	-0.0010	0.0029	-0.0077***	0.0028	-0.0036	0.0028	-0.0044	0.0031
Manager experience	0.0019	0.0033	0.0066*	0.0034	-0.0019	0.0034	0.0021	0.0036
Medium Firm	0.0358	0.0633	0.0360	0.0661	-0.0346	0.0649	0.0809	0.0668
Large Firm	-0.2477**	0.1144	-0.0278	0.1155	-0.2782**	0.1263	-0.1464	0.1236
Food and Beverages	0.1117	0.0835	0.3122***	0.0818	0.1736**	0.0842	0.3222***	0.0846
Garments	0.2951***	0.1053	0.5777***	0.1090	-0.0200	0.1072	0.1773	0.1080
Furniture	-0.0263	0.0980	0.3595***	0.0987	0.0599	0.1037	0.1087	0.1031
Publishing	0.0233	0.1091	0.3064***	0.1142	-0.1962*	0.1106	0.1798	0.1188
Plastics & Chemicals	-0.1410	0.0979	0.1176	0.0998	-0.0600	0.1013	0.2000*	0.1064
Fabricated Metal Products	-0.0385	0.1047	0.1628	0.1037	-0.0237	0.1031	0.0709	0.1070
Machinery & Equipment	-0.1368	0.2513	-0.0683	0.2981	-0.2917	0.2650	-0.2010	0.2754
Construction	-0.1177	0.1684	-0.0077	0.1883	-0.0732	0.1837	0.4899***	0.1823
Transport Services	-0.2603***	0.0990	0.0081	0.0988	-0.1919*	0.0995	0.1771*	0.0964

Variables	Product	Standard Errors	Process	Standard Errors	Marketing	Standard Errors	Organisational	Standard Errors
IT	0.5065	0.2246	0.3490	0.2499	0.0180	0.2440	0.4879**	0.2461
Country (Ghana)	-0.1679**	0.0656	-0.2296***	0.0664	-0.4859***	0.0658	-0.2224***	0.0686
Constant	-0.3615***	0.0737	-0.4875***	0.0740	-0.2087***	0.0755	-0.8439***	0.0777
ρ_{21}				0.7478***				0.0178
ρ_{31}				0.5620***				0.0245
ρ_{41}				0.5426***				0.0264
ρ_{32}				0.6140***				0.0234
ρ_{42}				0.5994***				0.0239
ρ_{43}				0.6682***				0.0226
Observations				2,533				
Log-likelihood				-5176.5763				
Wald χ^2 (df)				793.43*** (92)				
χ^2 (df)				1936.73*** (6)				

Notes: The base variable for the ownership of firms is Domestic ownership. The base variable for firm size is Small firm while the base variable for industry sectors is the Wholesale and Retail sector. The standard errors are robust. ***, **, and * denote 1%, 5% and 10% statistical significance respectively.

3.6.2 Multivariate Probit Results

In this subsection, the results for the multivariate probit regression model outlined in equation four in the methodology are presented in table 3.5 above. The Wald test shows that the point estimates are jointly statistically significant, hence, the regression model is fitted to the data.

From table 3.5, we observe that Manager's experience is significant and increases the probability that a firm will engage in process innovation only although it was expected to significantly influence marketing and organisational innovation. Firm age is also significant for process innovation. The results show that, the probability that a firm will engage in process innovation as it gets older decreases. Furniture firms are also significant for process innovation. A Furniture firm is likely to engage in process innovation compared to a firm in the Wholesale and Retail sector of industry. Publishing is significant for both process and marketing innovation, but publishing firms are more likely to engage in process innovation while they are less likely to engage in marketing innovation compared to a firm in the Wholesale and Retail sector. Plastics and Chemicals, Construction and IT are significant for only organisational innovation. These firms are more likely to engage in organisational innovation than the Wholesale and Retail firms.

Food and Beverages is significant for process, marketing, and organisational innovation. These firms are more likely to engage in process, marketing and organisational innovation compared to Wholesale and Retail firms. Garments is significant for product, process, and organisational innovation. Transport Services is significant for product, marketing, and organisational innovation. Transport Service firms are less likely to engage in product and marketing innovation and more likely to engage in organisational innovation compared to Wholesale and Retail firms.

The variables that indicate innovation activity such as R&D, asset and equipment purchase, and worker training increase the probability that a firm will engage in innovation outcomes at the 1% level of significance. These innovation activities are statistically significant and positive for the technological innovation outcomes, that is, product and process innovation as well as the non-technological innovation outcomes, that is, marketing innovation and organisational innovation. The variable Export however is not statistically significant for product and process innovation although firms that export some of their output increase the probability of engaging

in marketing and organisational innovation at the 1% level of significance. A firm in Ghana is less likely to engage in any of the innovation outcomes compared to Nigerian firms.

The ρ values refer to the off-diagonal elements of the correlation matrix between the innovation outcomes discussed in the methodology. The positive and 1% level of statistical significance of the ρ values shows interdependence between the different innovation output. The ρ values represent the correlation between the error terms of two outcome variables in the multivariate probit that are denoted by the subscript of the ρ . The correlation between the error terms of the outcome variables if they are statistically significant and not zero denote a dependence between the outcome variables (Filippini et al., 2018). The ρ values are all positive indicating a positive dependence between the outcome variables. Thus, ρ_{21} shows that product and process innovation have the strongest dependence followed by marketing and organisational innovation whose correlation between their error terms is denoted by ρ_{43} . The dependence between product innovation and organisational innovation denoted by ρ_{41} , is the weakest in terms of the magnitude but is still statistically significant.

The questions for the innovation outcomes in the questionnaire suggest that there could be simultaneity between the innovation outcomes. It is impossible to determine if one innovation outcome causes the other or if they happen at the same time. Thus, the multivariate system of equations is the appropriate estimator to investigate the joint conditional distributions of the innovation outcomes. The outcome variables seen as technological, that is, product and process innovation, have the strongest dependence while the non-technological outcome variables marketing and organisational also have a strong and significant dependence. Thus, the entire system of innovation outcomes is a set of co-dependent relationships.

This chapter provides empirical evidence for the innovation theory that the different types of innovation are related to each other. We see from the ρ values that they indicate that the innovation types are not independent of each other. The multivariate probit regression results show that variables such as R&D, asset and equipment purchase, and worker training increase the probability that a firm will engage in all the different innovation outcomes. These variables are innovation activities and so the positive influence on the innovation outcomes are expected.

There are other factors that could influence the probability that a firm will engage in innovation. This chapter does not include all the possible explanatory variables that could lead to

innovation due to limitations in data collection. There are also specification issues where the innovation outcomes are introduced over the last three years while some of the explanatory variables are collected for one year. These issues mean that the estimates could have an omitted variable bias. Yatchew and Griliches (1985), show that for binary choice models, omitted variable bias makes the coefficients of the explanatory variables inconsistent. The resulting heteroscedasticity means the covariance matrix could be inappropriate. The robustness of the standard errors corrects for heteroscedasticity. We use the χ^2 to test for the appropriateness of the covariance matrix for the multivariate probit model in this chapter. The results in table 3.5 above show that we can reject the null hypothesis that the covariance matrix is spurious.

It is difficult to calculate the marginal effects of the variables in a multivariate probit; hence, the predicted values of the dependent variables will provide us with the probability of a firm engaging in each innovation type as well as engaging in all the innovation types simultaneously. This is important to show us the magnitude of the probability of a firm engaging in each innovation outcome as well as the probability of engaging in all the innovation outcomes simultaneously.

As discussed in the methodology section, the multivariate normal distributions used to calculate the joint probabilities are derived by simulation using the GHK simulator, with the seed and number of random draws. Table 3.6 below shows the predictions based on the parameter estimates from the estimated multivariate probit model in table 3.5. It is fitted and use the same number of random draws (and seed) to generate the joint probabilities (Cappellari & Jenkins, 2003).

Table 3.6 shows that the probability of a firm to engage in product innovation given the explanatory variables listed is 5%. For process innovation, it is about 6% and for marketing innovation, it is about 8%. A firm is 29% less likely to engage in organisational innovation given the explanatory variables listed in the regression model. Thus, the regressors increase the probability of a firm engaging in an innovation outcome except for organisational innovation where the regressors together reduce the probability that a firm will engage in organisational innovation.

We see that the predicted marginal success of a firm engaging in any of the four-innovation output are close to the percentage of firms that engaged in the innovation output. For instance,

50% of firms engaged in product innovation as indicated in table 3.3 and in table 3.6, the predicted marginal success probability of product innovation is 51%.

Table 3.6 Predicted values of the multivariate probit

Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
Predictions for fitted index-values (xb)					
Product (xb1)	2,560	0.0515	0.5064	-0.8704	1.8432
Process (xb2)	2,560	0.0572	0.5160	-1.2339	1.6908
Marketing (xb3)	2,560	0.0771	0.5987	-1.0844	2.0397
Organisational(xb4)	2,560	-0.2909	0.5463	-1.3229	1.6245
Predicted marginal success probabilities (pmarg)					
Product (pmarg1)	2,560	0.5123	0.1783	0.1920	0.9674
Process (pmarg2)	2,560	0.5154	0.1827	0.1086	0.9546
Marketing (pmarg3)	2,560	0.5181	0.2008	0.1391	0.9793
Organisational(p marg4)	2,560	0.3924	0.1942	0.0929	0.9479
Joint Predicted Probabilities (pal10 and pal11)					
All Innovation (pal11)	2,560	0.2462	0.1902	0.0173	0.9378
No Innovation (pal10)	2,560	0.2754	0.1576	0.0039	0.6940

From the predicted joint probability of a firm engaging in all four innovation outcomes (pal11), we can observe that nearly a quarter of firms engaged in all four-innovation output. The predicted joint probability also shows that 27% of firms did not engage in any innovation output. This means more than 70% of firms engaged in at least one innovation output.

The coefficients of the control variables Certification, Foreign ownership, Government ownership, Other type of ownership, Medium Firm, Fabricated Metal Products and Machinery and Equipment are not statistically different from zero. This may not necessarily mean that these variables do not influence the innovation outcomes as the dataset is cross sectional. The innovation outcomes are introduced during the last three years from the period the data was collected while some of the explanatory variables concern the period in which the data was collected. These specification issues could lead to heterogeneity and omitted variable bias in the estimation results. Thus, the lack of statistical significance may be an indication that these variables did not influence an innovation outcome that occurred up to three years prior.

In appendix A1.1 and A1.2, the innovation output questions in the questionnaire for Ghana and Nigeria concern innovation output introduced over the last three years. Appendix A1.3 covers ES questionnaire questions for innovation activity. For Export, AssetPurchase and Training, the questionnaire is for the last complete financial year but for R&D, it is R&D spending during the last three years such as it is for the innovation output period. This is usually resolved in econometric literature by using the previous data for the explanatory variable. This dataset has no previous data due to the cross-sectional nature of the dataset. Hence in the next subsection we will run another multivariate probit model to determine the correlation between innovation output and innovation activities.

3.6.3 Correlation between innovation outcomes and innovation activities

In this subsection, we will look at the correlations between the types of innovation and innovation activities. This section is going to investigate this relationship through a multivariate equation where all the types of innovation and the innovation activities are dependent variables. This is because the nature of the questions for innovation outcomes and innovation activities in the survey creates the potential for there to be an endogenous relationship between innovation activities and the four types of innovation. Thus, there will be a multivariate probit model to ascertain correlation between the error terms of innovation output and R&D, worker training and purchase of assets and equipment.

The multivariate probit model to investigate the simultaneous relationship between innovation and R&D, worker training and purchase of assets and equipment is denoted as follows:

$$\text{Product_inv} = \text{Export} + \text{Certification} + \text{Ownership} + \text{Firmage} + \text{Manager_exp} + \text{Firmsize} + \text{Sector} + \text{Country}$$

$$\text{Process_inv} = \text{Export} + \text{Certification} + \text{Ownership} + \text{Firmage} + \text{Manager_exp} + \text{Firmsize} + \text{Sector} + \text{Country}$$

$$\text{Marketing_inv} = \text{Export} + \text{Certification} + \text{Ownership} + \text{Firmage} + \text{Manager_exp} + \text{Firmsize} + \text{Sector} + \text{Country}$$

$$\text{Organisational_inv} = \text{Export} + \text{Certification} + \text{Ownership} + \text{Firmage} + \text{Manager_exp} + \text{Firmsize} + \text{Sector} + \text{Country}$$

$$\text{R\&D} = \text{Export} + \text{Certification} + \text{Ownership} + \text{Firmage} + \text{Manager_exp} + \text{Firmsize} + \text{Sector} + \text{Country}$$

$$\text{Training} = \text{Export} + \text{Certification} + \text{Ownership} + \text{Firmage} + \text{Manager_exp} + \text{Firmsize} + \text{Sector} + \text{Country}$$

$$\text{AssetPurchase} = \text{Export} + \text{Certification} + \text{Ownership} + \text{Firmage} + \text{Manager_exp} + \text{Firmsize} + \text{Sector} + \text{Country} \quad (5)$$

Table 3.7 below shows the estimation results for the multivariate probit regression model outlined in equation five. The coefficient for Export shows that all the innovation and innovation capability outcomes are influenced positively by the export of output. Firms that have an internationally recognised quality certification are likely to engage in product, marketing, and organisational innovation. These firms are also likely to invest in R&D and worker training. Firms with majority Foreign Ownership are less likely to train their workers compared to firms with majority Domestic Ownership. The more experienced a firm's manager, the more likely the firm trains its workers and the less likely the firm purchases assets and equipment. Medium and Large firms are more likely to train their workers and purchase assets and equipment. Large firms are more likely to invest in R&D than small firms.

The ρ values in table 3.7 are all statistically significant. This suggests that there is interdependence between all four types of innovation and the innovation activities. The correlation coefficient is larger between the types of innovation than between innovation activities. It is also larger between the types of innovation than between the types of innovation and innovation activities. The magnitude of the correlation coefficient between innovations is larger in table 3.8 than in table 3.6. This may be because the likely endogenous regressors are included as dependent variables in table 3.8. The correlation between R&D and the innovations is the largest magnitude of the correlation coefficients between innovations and the innovation activities. The χ^2 is statistically significant. This means that the covariance matrix is not spurious.

Table 3.8 Multivariate Probit Estimation from equation (5)

Variable	Product	Process	Marketing	Organisation	R&D	Training	Asset Purchase
Export	0.216*** (0.0658)	0.169** (0.0668)	0.4*** (0.0692)	0.425*** (0.0684)	0.392*** (0.074)	0.312*** (0.0697)	0.265*** (0.0672)
Certification	0.231** (0.0939)	0.101 (0.0934)	0.17* (0.096)	0.219** (0.095)	0.387*** (0.0975)	0.409*** (0.0954)	-0.05 (0.0935)
Foreign Ownership	0.039 (0.1211)	0.082 (0.1221)	-0.021 (0.1265)	-0.051 (0.1306)	-0.155 (0.1402)	-0.23* (0.1275)	0.036 (0.1211)
Government Ownership	-0.070 (0.4714)	-0.082 (0.4353)	0.014 (0.5136)	-0.124 (0.4143)	0.071 (0.5827)	0.386 (0.4161)	0.609 (0.4735)
Other	0.003 (0.0837)	-0.032 (0.0867)	0.068 (0.0904)	0.048 (0.0907)	-0.016 (0.1047)	0.005 (0.0947)	-0.094 (0.0917)
Firm age	0.003 (0.0026)	-0.003 (0.0027)	0.001 (0.0027)	0.000 (0.0028)	.009*** (0.0028)	0.004 (0.0028)	0.009*** (0.0029)
Manager experience	0.000 (0.0031)	0.004 (0.0033)	-0.003 (0.0033)	0.001 (0.0034)	-0.003 (0.0037)	0.009*** (0.0034)	-0.006* (0.0034)
Medium Firm	0.073 (0.0617)	0.07 (0.0625)	-0.008 (0.0629)	0.098 (0.0641)	-0.032 (0.0727)	0.138** (0.065)	0.119* (0.063)
Large Firm	-0.035 (0.1117)	0.159 (0.1142)	-0.04 (0.1173)	0.069 (0.118)	0.353*** (0.1178)	0.495*** (0.1135)	0.28*** (0.1072)
Food and Beverages	0.145* (0.0806)	0.327*** (0.0805)	0.194** (0.0812)	0.322*** (0.0823)	0.056 (0.0957)	0.108 (0.0852)	0.216*** (0.0825)
Garments	0.353*** (0.1032)	0.611*** (0.1049)	0.072 (0.1055)	0.23** (0.1072)	0.246** (0.1193)	0.033 (0.1103)	0.316*** (0.1069)
Furniture	-0.027 (0.0942)	0.336*** (0.0964)	0.063 (0.0968)	0.09 (0.0987)	-0.02 (0.1177)	-0.068 (0.1069)	0.159 (0.0999)
Publishing	0.108 (0.1058)	0.352*** (0.1084)	-0.103 (0.1056)	0.22** (0.1112)	0.138 (0.1211)	0.045 (0.1139)	0.28** (0.1105)

Variable		Product	Process	Marketing	Organisation	R&D	Training	Asset Purchase
Plastics & Chemicals		-0.009 (0.0964)	0.215** (0.0997)	0.061 (0.0992)	0.272*** (0.1023)	0.292*** (0.1114)	-0.067 (0.1049)	0.246** (0.1000)
Fabricated Products	Metal	0.033 (0.1001)	0.219** (0.0997)	0.053 (0.1016)	0.131 (0.104)	0.231* (0.1190)	0.068 (0.1079)	0.275*** (0.1039)
Machinery & Equipment		0.002 (0.2617)	-0.004 (0.2765)	-0.187 (0.293)	-0.113 (0.3071)	0.322 (0.2864)	-0.028 (0.2525)	0.234 (0.2632)
Construction		0.056 (0.1585)	0.178 (0.1728)	0.125 (0.1633)	0.617*** (0.1708)	0.288 (0.1841)	0.384** (0.1668)	0.603*** (0.1625)
Transport Services		-0.189** (0.0921)	0.062 (0.0931)	-0.135 (0.0959)	0.19** (0.0956)	-0.03 (0.1139)	0.177* (0.097)	0.157* (0.0951)
IT		0.724*** (0.2405)	0.568** (0.2434)	0.292 (0.2329)	0.72*** (0.2366)	0.576** (0.2433)	0.698*** (0.241)	0.41** (0.2087)
Country (Ghana)		0.039 (0.0618)	-0.01 (0.0626)	-0.239*** (0.0627)	-0.026 (0.0652)	0.254*** (0.0720)	0.392*** (0.0657)	0.485*** (0.0635)
Constant		-0.157** (0.0696)	-0.257*** (0.0706)	0.006 (0.0711)	-0.598*** (0.0721)	-1.333*** (0.0856)	-1.011*** (0.0755)	-0.737*** (0.0733)
	ρ_{21}	0.7874*** (0.0153)						
	ρ_{31}	0.6321*** (0.0214)						
	ρ_{41}	0.6111*** (0.0232)						
	ρ_{51}	0.4741*** (0.0295)						
	ρ_{61}	0.2924*** (0.0298)						
	ρ_{71}	0.3233*** (0.0277)						
	ρ_{32}	0.6732*** (0.0205)						
	ρ_{42}	0.6589*** (0.0208)						
	ρ_{52}	0.4611*** (0.0306)						
	ρ_{62}	0.2835*** (0.0299)						

ρ_{72}	0.3596*** (0.0275)
ρ_{43}	0.7258*** (0.0192)
ρ_{53}	0.5176*** (0.0278)
ρ_{63}	0.3171*** (0.0293)
ρ_{73}	0.3505*** (0.0274)
ρ_{54}	0.5141*** (0.0289)
ρ_{64}	0.3238*** (0.0293)
ρ_{74}	0.3040*** (0.0280)
ρ_{65}	0.3844*** (0.0298)
ρ_{75}	0.2803*** (0.0308)
ρ_{76}	0.3055*** (0.0290)
Observations	2533
Log pseudolikelihood	-9346.973
χ^2 (df)	3457.54***(21)

Notes: The base variable for the ownership of firms is Domestic ownership. The base variable for firm size is Small firm while the base variable for industry sectors is the Wholesale and Retail sector. The standard errors are in parentheses and are robust. ***, **, and * denote 1%, 5% and 10% statistical significance respectively.

3.7 Conclusion

This chapter showcases the simultaneous relationship between the different types of innovation. The main MVP model shows that the innovation outcomes are positively associated and dependent on each other. The descriptive statistics show that more firms are engaged in innovation than engaged in innovation activities. This suggests that there are firms that did not engage in innovation activity but engaged in innovation. The suggestion of simultaneous relationships between the innovation types in the ES questionnaire makes the MVP the appropriate model to investigate this relationship. The correlation of the error terms of the innovation outcomes suggests that engaging in one type of innovation relates to engaging in another type of innovation. The values of the covariance matrix show that product innovation is most strongly correlated with process innovation. Similarly, marketing innovation is most strongly correlated with organisational innovation. The MVP that investigates the correlation between innovation and innovation activities show a positive and significant correlation between them. The correlation between the innovation activities, namely R&D, Training and AssetPurchase and innovation are not as strong as the correlation between the innovation types.

In this chapter, the main regression results show that the innovation activities namely R&D, worker training and purchase of assets and equipment all increase the probability that a firm will engage in all the types of innovation. The estimation results show the manager's experience has a statistically significant influence for only process innovation in table 3.5. This is different from the expectation that managerial experience is more likely to influence organisational and marketing innovation. Export however was not statistically significant for product and process innovation but statistically significant for marketing and organisational innovation as expected.

The governments of Ghana and Nigeria have made attempts to invest in education, research and innovation. Compared to most developed economies and the minimum target for investment in R&D as a proportion of GDP agreed upon by African countries at the NEPAD conference in 2007, both countries fall short in R&D investment and hence in R&D output such as research papers and patents. There is also very little partnership between industry and research institutions. This could explain why the regression showed that very few innovative firms invest in R&D. Ghana's CSIR has taken steps to rectify this by establishing a unit to

bridge the information transfer gap between industry and research institutions. This unit needs government policy and funding to make it more effective.

Nigeria has socio-political issues that has negatively impacted gross secondary school enrolment for over a decade. Yet from the regression results firms in Nigeria are more likely to engage in innovation output than firms in Ghana. The descriptive statistics shows that most of the innovative firms did not engage in innovation activities. Thus, there are other factors that influence innovation output that are not covered in this thesis or in the ES data. There is thus an opportunity to interrogate other sources of knowledge transfer such as customer feedback and inter-firm collaborations.

This chapter expands on the study of innovation by adding marketing and organisational innovation to the product and process innovations evaluated in the previous chapter. Thus, this chapter includes more innovation indicators and assesses the relationship between all the different types of innovation indicators. The data is cross-sectional and the nature of the innovation question in the questionnaire could explain the lack of significance for some of the explanatory variables. There is an opportunity in future research to collect the innovation data over a longer period to have a better understanding of how the explanatory variables influence the probability to innovate overtime. The results of a panel dataset could be helpful to determine the influence of previous innovation outcomes on future innovation outcomes.

Chapter 4: Case Study of Innovation and Backward Linkages in the Goldmining Industry in Ghana

4.1 Introduction

The aim of this case study is to assess government policy aimed at enhancing local participation in the backward linkage firms in the gold mining industry in Ghana. It includes interviews of the management of backward linkage firms to investigate how these firms develop innovation capability and innovate given government policy on procurement and local content.

This chapter aims to enhance the empirical research of the previous chapters. This is because econometric research on innovation and case studies on technological transfer and innovation are complementary. The two quantitative chapters provide us with a general perspective of the nature of innovation and the characteristics that best encourage innovation in West African firms. However, it will be difficult to use the cross-sectional innovation data available to obtain deeper insights into the effectiveness of government policy to develop firms in an industry and encourage innovation capability building.

Hirschman (2013), argues that the extraction of a primary good can lead to the development of an economy if there are strong production, consumption, and fiscal linkages to that economy. Production linkages include the backward and forward linkages to the primary good sector. Kaplinsky et al. (2012), examine the backward linkage firms that supply to the commodities sector of industry in developing countries. They argue that the extent to which backward linkage firms in developing economies benefit from their interaction with the commodities sector depends on how government policy on local content facilitates this development of backward linkage firms. In their analysis of the relationship between government policy on local content and the development of linkages in the gold mining industry in Ghana, the authors discovered that the Mining Act (2006) was ineffective in preventing mining companies from procuring intermediate goods and services from foreign firms.

The objective of this policy was to enhance local content in the mining sector. Local content according to the Minerals and Mining Act (2006) refers to increasing the proportion of Ghanaians employed by the mines as well as increasing Ghanaian ownership and employment in the supply of mining inputs. The local content policy includes the supply of goods manufactured in Ghana as well as goods imported by Ghanaians. According to Kaplinsky et

al. (2012) the policy was poorly coordinated with the existing trade policy in the economy. For instance, imports by mining companies of a wide range of inputs were exempted from tariffs. This tariff exemption was not extended to local manufacturers of mining equipment for their imported inputs. The result was that mining firms chose to import their inputs rather than source them locally. Hence the local content policy had little impact on the breadth and depth of linkage development.

Initially, pressure for Ghanaian content in linkages to the mining sector came from civil society organisations, media, and mining communities (Bloch & Owusu, 2012). This was heeded by the government. Thus, the government together with stakeholders in the mining sector have been able to draft mining regulations to increase local participation. Authors such as Bloch and Owusu (2012), Owusu-bio et al. (2016), and Smith et al. (2019) discuss the effect of local content policy on the development of backward linkage firms but these analyses stop short of interviewing the management of the backward linkage firms to find out their views on how government policy has enhanced their operations in the mining sector. This chapter includes interviews of the management of six backward linkage firms. These interviews seek to ascertain their views on how effective government policy to enhance their participation in the industry has been. The interviews also investigate whether these firms have been able to collaborate with the multinational corporations (MNCs) that used to supply to the mining firms and whether this collaboration has led to the transfer of technological knowledge.

Research into the effectiveness of government policy to encourage the development of linkages and innovation is necessary to ensure that the extraction industry contributes more to the development of backward linkages and to innovation capabilities in the backward linkage firms. It is important to interview the management of these firms to ascertain how the introduction of the mining policy has influenced their firm's development. The interviews focused on suppliers to the mining firms and how these firms are developing innovation capabilities. This could inform government to develop policies to promote more domestic content as well as tailor innovation policy to suit their needs.

Bell (2009) argues that for a country to have innovative capability, it must develop indigenous scientific capacity. Indigenous scientific capacity can be developed if an economy does not only use ready-made technologies from advanced economies but also adapts, improves, and creates technologies that are used to improve productive capacity. Indigenous scientific

capacity can be better established with government coordination through policy and institutions. These ideas form the foundation for the concept of the National System of Innovation. Lundvall (2007), explains that the National System of Innovation is a theory that places emphasis on knowledge as the most important resource of a country and learning as the most important process. The theory argues that a country's history of knowledge development and absorption explains its level of innovation in industry. The theory posits that the innovation process is an intricate interplay between micro and macro phenomena where macro-structures condition micro dynamics and vice-versa. Thus, there is the need to understand how macro structures such as state institutions and national policy lead to the development of the capacity and skill needed for technological innovation in any given industry.

The African continent has the largest share of the world's reserves of valuable minerals such as gold, diamonds and platinum group minerals yet most of the minerals mined on the continent are exported without any significant value-addition (African Union, 2009). The technological capacity and financial investment may be lacking on the continent for forward linkage firms but there is potential for the development of backward linkage firms to the mining sector. The linkage firms developed around these mines could potentially be invested in by way of training and capacity building to enhance value-addition or manufacturing of inputs supplied to the mining firms.

It is important to note that a case study can only cover an industry and so may not have outcomes that can be generalized (Fagerberg et. al, 2005). Econometric analyses on innovation often rely on data obtained from periodic surveys while case studies provide a rich source of evidence on the details of the transfer and absorption process (Hoekman & Javorcik, 2006). Lundvall (2007), believes that the organisation of an economy and the structure of an industry will influence how technological innovation takes place within a firm. Hence a firm's innovative activity is dependent on the national education system, labour market, financial market, intellectual property rights and competition in the product market. This case study of firms in a specific industry is important when analysing the ability of an economy to build the competence that is needed to lead firms to innovate.

This chapter is thus focusing on linkage firms in the goldmining industry in Ghana. It will first consider the history of gold mining in Ghana and its role in the Ghanaian economy in Section 4.2. It will then look at the literature on linkage development and how government policy in

developed and emerging economies has improved the innovation climate in industry in Section 4.3. Section 4.4 discusses the main objectives of this chapter and the types of firms interviewed. Section 4.5 analyses the interviews by exploring the issues around procurement and how firms are building innovative capacity. Section 4.6 concludes the chapter.

4.2 Background

4.2.1 A brief history of the gold mining industry in Ghana

Gold mining is the most important part of mining and quarrying in Ghana accounting for about 95% of the mining sector. Gold exports are the highest gross foreign exchange earner in Ghana (Minerals Commission (2014); Bank of Ghana (2020)). Gold contributed about 7% of GDP in 2019 (Ghana Statistical Service, 2020). According to Ghana's Minerals Commission, Ghana has been mining gold for a millennium. Centuries before Portuguese sailors reached the shores of West Africa, gold was mined in what became present day Ghana and transported across the Sahara Desert to North Africa (Minerals Commission of Ghana, 2011). It was this gold mining activity that led the Portuguese to name Ghana the Gold Coast. It is estimated that Ghana accounted for 36% of world gold output between 1493 and 1600 (Minerals Commission, 2014).

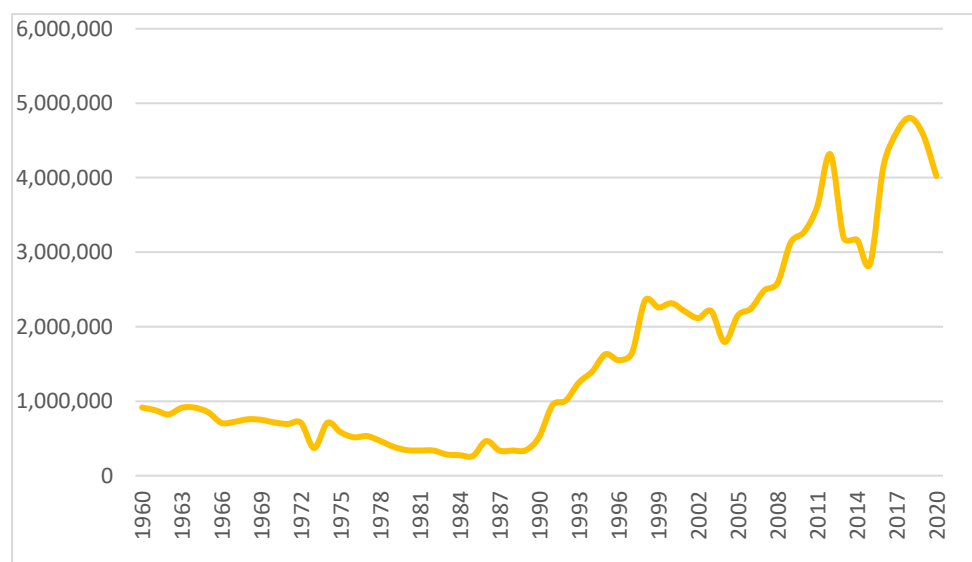
After Ghana attained independence from the British in 1957, the state took ownership of all mineral resources in the country. In the early 1960s the government of Ghana bought out several privately owned gold mines and formed the State Gold Mining Corporation. Ghana went through an economic downturn in the mid-1960s mainly as a result of an over-zealous investment in capital-intensive industry, mismanagement of natural resources, inflationary effects of import restrictions and a fall in the price of cocoa (World Bank (2007); Jedwab & Osei (2012)). The deterioration of the economy coupled with the unstable political climate led to negative growth in 1967, 1972, 1975-1976, 1979, and 1980-1981 (Baah-Boateng et al., 2013).

After 1967, the government of Ghana began to seek foreign direct investment in the mining sector. Yet the Ghanaian economy was characterised by political upheavals, external shocks in the commodity market and poor policy coordination in the mining sector (Minerals Commission (2014); Baah-Boateng et al. (2013)). Thus, gold output fell from 1960 to 1990. Declining from 915,217 ounces in 1960 to approximately 250,000 ounces at its lowest point in

1985²(International Council on Mining & Metals, 2015) Minerals Commission of Ghana (2011)). The trend in gold output from 1960 to 2020 is illustrated in figure 4.1.

We can observe that gold output started to recover after the government of Ghana embarked on the Economic Recovery Programme (ERP) in 1983. This was sponsored by the World Bank and the International Monetary Fund (IMF). As occurred in many African countries at the time, the ERP was a structural adjustment programme which urged government to secure the confidence of foreign investors through institutional and legal framework reform of the economy including the mining sector (Bourgouin, 2011). The economy was liberalised, and government policy was set to attract FDI and led to the privatisation of state owned firms including mines (Baah-Boateng et al., 2013).

Figure 4.1: Gold production in Ghana from 1960-2020



Source: Author's compilation

In 1986, the Minerals and Mining Law was introduced, and the Minerals Commission was established. Mining companies were allowed to keep up to 45% of their business earnings in foreign exchange retention accounts and had improved access to mining inputs through export rehabilitation credits. Small-scale mining of gold and diamonds was also legalised (Ayee et al., 2011).

² The table for figure 4.1 is in the appendix A4.1.

4.2.2 Mining Policy, Backward Linkages and Employment

The Minerals and Mining Law (1986) did not connect mining to other sectors of the economy, nor did it have the macroeconomic objective to develop the economy. There were no provisions in the law for mining investment to promote the development of linkages (Bourgouin, 2011). Presently, there are 14 large scale gold mining companies in Ghana. Twelve of them are foreign owned. Small scale mining is reserved for Ghanaians.

Ghana's contribution to global gold production has increased steadily over the last decade. This has been due in part to an enhancement of the minerals and mining regulations leading to an increase in output by large scale mines and partly due to the increased output of small-scale mining. Total gold production by artisanal and small-scale miners has risen from about 2.2% of the total gold output in 1989 to 40% of Ghana's gold output in 2018 (Minerals Commission (2014);Ghana Chamber of Mines (2019)).

The Mining Act (2006) was expected to enhance local content in the mining sector, but it was ineffective in preventing mining companies from procuring intermediate goods and services from foreign firms. The revised Minerals and Mining Regulations in the Legislative Instrument (L.I.) 2173 and L.I. 2174, were enacted into law in 2012 but enforced in 2014. These regulations provide fiscal incentives to attract foreign investment as well as ensure the employment of local skilled labour in the mines and local content in the sourcing of mining inputs (Nickerson & Geipel, 2018). The regulations provide guidelines on how mining companies and companies that supply to mining firms are to recruit Ghanaian and expatriate workers. They also prescribe punitive measures for firms that flout the provisions of the guidelines.

The mining policy has been revised to promote the localization of linkage firms and the mining sector. This localization in linkage firms aims to increase Ghanaian participation in terms of ownership and management by Ghanaians and employment of Ghanaians in firms that supply to the mines. Thus, the local content policy includes the supply of goods manufactured in Ghana as well as goods imported by Ghanaians.

According to Bloch and Owusu (2012), the enclave thesis that FDI in the extractive sector tends to create its own eco-system with little or no linkages to local producers, importers, and financial and labour markets of the host country no longer holds in Ghana's mining sector. The data on the large-scale mining firms that are members of the Ghana Chamber of mines shows

that in 2020, 85.7% of their expenditure was spent in Ghana. This was an increase over the 2019 figure of 83% (Ghana Chamber of Mines, 2021). These expenditures comprised of fuel and electricity, the local procurement of goods and services, statutory payments to the state, employee remuneration and corporate social investment projects. Large scale mines directly employ 11,899 Ghanaians (Ghana Chamber of Mines, 2020) but the Minerals Commission estimates that there are about a million Ghanaians engaged in small-scale mining (Minerals Commission, 2014).

According to World Bank (2019), Micro, Small and Medium Enterprises (MSMEs) account for 99% of all business establishments in Ghana and 83% of employment in all business establishments. Many of these firms are informal and lack access to term financing and face high borrowing costs. Thus, the small and informal nature of majority of firms in Ghana, make them unable to invest in R&D, build innovative capacity or have access to new markets. This chapter investigates if the mining and innovation policy has enhanced innovation capability in firms that supply to the mining industry.

4.3 Literature Review

The literature review is divided into two sections. The first section discusses literature on the importance of local content in the development of innovation capability in extractive industries and how FDI can help in the transfer of knowledge to local firms. The second section discusses literature on the interactions between backward linkage firms and government policy.

4.3.1 Local content and FDI

According to Geenen (2019), local content in a narrow sense refers to the local procurement of goods and services. The definition of a local supplier is in contention because it can be defined by location, ownership or extent of value added. Geenen (2019), observes that local content is beneficial to both the foreign businesses as well as the local economy as it provides lower costs and social legitimacy to operate. Wilhelm (2023), posits that the aim of local content policies is to facilitate inclusive resource-based development through direct and indirect employment by multinational mining firms as well as create linkages along the mining value chain. Geenen (2019), believes that because the extractive sector is capital intensive and is increasingly moving towards automation and digital mining, there is limited capacity for employment.

Ackah-Baidoo (2020), recognizes this problem and suggests local content policies in sub-Saharan Africa are hindered by deeply rooted partnerships between mining companies and countries where most mining equipment are produced. The author suggests that local content policies in sub-Saharan African countries can be constructed so that local partnerships with foreign manufacturers benefit from the transfer of knowledge that comes about through importing mining equipment and learning how to service them. For example, in Australia, Newmont Corporation is expected to procure its mining equipment from Caterpillar through a Perth-based Caterpillar dealer, Wes Trac. The local importer manages the logistics of the autonomous haul truck delivery and commissioning.

Mining attracts foreign direct investment (FDI). The literature on the relationship between FDI and the development of local linkages in developing economies shows mixed results as far as the effectiveness of FDI to enhance local linkages is concerned. For instance, Javorcik (2004), suggests that knowledge spillover can be expected to be more prominent in backward linkages where the local firms supply intermediate inputs to multinational clients than in forward linkages. Using an unbalanced panel of Lithuanian firms covering the period 1996-2000 from an annual enterprise survey collected by the Lithuanian Statistical Office, Javorcik (2004), shows that the productivity of Lithuanian firms is positively correlated with the extent of potential contracts with multinational customers but not with the presence of multinationals in the same industry or the existence of multinational suppliers of intermediate inputs. The paper also shows that firms with shared domestic and foreign ownership are more likely to transfer knowledge to local suppliers than firms fully owned by foreigners.

4.3.2 Backward Linkages and Government Policy
Amendolagine et al. (2013) investigate the determinants of backward linkages to foreign manufacturing firms in sub-Saharan African countries. They use firm level data collected through the UNIDO Africa Investor Survey (2010) for 19 countries. They conclude that good institutional support for the development of linkages such as a well-functioning institutional setting as well as a good legal system are important in boosting locally owned backward linkage firms that supply to foreign owned manufacturing firms. Amendolagine et al. (2013), find that foreign firms with a local partner have a higher share of backward linkages than firms with no local partnership. Thus, a local content policy has the potential to enhance the spillover effect of a foreign firm operating in the country.

Although many countries in sub-Saharan Africa are endowed with natural resources and minerals, most of these countries are yet to experience the developmental potential of these resources. An effective local content policy can encourage economic diversification and growth in other areas of the economy (Ovadia, 2016). Ovadia (2016) observed that few natural resource endowed countries in sub-Saharan Africa had local content policies or had effectively implemented local content policies prior to 2013.

For instance, the South African government promoted the localisation of wind-turbine component production through local content requirements as part of the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP). Local content here was defined as the costs of the local components and materials used as a percentage of the total construction costs of a given project (Larsen & Hansen, 2022). The focus of the local content requirements was to promote locally manufactured wind-turbine towers, blades, and nacelle components including the input materials required to produce these components such as steel and aluminium. Civil engineering and locally sourced building materials were also accepted. The REIPPPP that began in 2011 was put on hold in 2015 because the national utility company ESKOM refused to sign contracts with project developers (Larsen & Hansen, 2022).

Meanwhile in Zambia, although various governments have drafted local content policies over the years, the implementation has either been delayed or terminated. This reflects structural challenges such as lack of resources, institutional capabilities or political will (Kragelund, 2022). In June 2025, the Zambian Minister of Mines and Minerals development signed two new pieces of mining legislation; The Minerals Regulation Commission Act (2024) and the Geological and Mineral Development Act (2015) published on 13th June 2025 (www.miningfocusafrica.com/2025/07/02). The new mines Act creates a minerals regulation commission. This commission is yet to put forward a bill that will provide the legal framework that will compel mining companies to source goods and services locally (www.lusakatimes.com/2025/09/24/).

Bloch and Owusu (2012), explain how large-scale gold mining in Ghana has moved away from being an enclave industry through government policies such as the Minerals and Mining Act of 2006 (Act 703). Large scale gold mining previously had few linkages to local suppliers of goods and services. Basic services such as laboratory testing, cleaning, security, and catering were outsourced to foreign companies with subsidiaries in Ghana. Mining machinery and

equipment were also purchased from international dealers with sales and service operations in Ghana. Government intervention has created backward linkages that provide mining inputs and services to the mines. These include manufacturers and suppliers who provide intermediate inputs and services for metalworking, engineering, and construction. Other services such as transportation, haulage, catering, and cleaning are also locally sourced. They observe the potential for the government to combine policy with investment to encourage the development of manufacturing firms that supply to the mining companies.

Hansen (2014), reiterates that government intervention is required for the development of sustainable backward linkage firms that supply to foreign firms in the extractive industry. Ovadia (2016) agrees that well implemented local content policies have the potential to lead to structural transformation, industrialisation and diversification that brings about sustainable socio-economic development. Ablo (2015), analyses the effectiveness of the Enterprise Development Centre (EDC) to enhance the productivity and efficiency of Ghanaian firms. The EDC was commissioned by the Petroleum Commission to deepen the capacity of small and medium enterprises (SMEs) that supply to the oil and gas industry. The article also analyses the ability of the EDC to promote the participation of Ghanaian firms in the oil and gas industry. The study finds that the EDC facilitates the interaction between local entrepreneurs, officials of state institutions and foreign oil mining companies. However, only the well-established medium to large-scale Ghanaian enterprises can take advantage of the opportunities provided by the EDC project and expand their operations leaving small businesses unable to gain entry.

Government intervention is more effective in an environment where there is coordination between government institutions in charge of innovation and trade policy, the private sector, consumers, universities and research institutions (Ma et al., 2021). In the empirical research by Gao et al. (2020), a survey of 482 firms in the Zhejiang province of China showed that government support is more effective in enhancing the innovation climate when firms are in a competitive market. In another empirical paper, Deng et al. (2019), investigate the effectiveness of using both R&D subsidies and intellectual property rights protection to enhance the innovation performance of the pharmaceutical industry in China. The results show that the use of both policies together is only effective in the eastern and western regions of China where the firms are more technologically advanced and hence more encouraged to innovate if they are assured of protection from competitors who could copy their R&D output.

Thus, government intervention is more effective if it is tailored to address the needs and organisation of different firms in different industries.

The difficulties faced by Ghana in their industrialization process mirror those of other African countries. According to Moyo (2016), many African countries initiated ambitious industrialization projects after gaining independence from western colonizers but by the 1990s most of these countries became de-industrialised due to unsustainable government policies and poor management. This was compounded by the imposition of structural adjustment policies which required rapid trade and economic liberalization. On the other hand, certain East-Asian countries such as South Korea and China have been using industrialization to bring their countries out of poverty. These countries have become economic miracles in the last half century (Khaled (2007); Song et al. (2017)). The governments in these countries had a hands-on approach in developing a competitive industrial market that was low-skilled and labour-intensive in the early stages of development. They guaranteed property rights and provided investment guarantees to foreign investors while keeping a tight lid on labour unions (Khaled (2007); Song et al. (2017)). These countries then moved on to higher-value-added manufacturing and innovation. They are also becoming world leaders in the service industry.

4.4 Methodology

This chapter is a case study of firms that supply to the gold mining industry in Ghana. It assesses the views of management on the effectiveness of the local content policy. It also interrogates how these firms absorb technology and innovate. To interrogate how the firms absorb technology and innovate, the management of these firms are interviewed. The management of some government and private sector institutions are also interviewed. The case study also examines the STI policy in Ghana to ascertain its efficacy in developing the innovative capacity of industry.

The data to be analysed is obtained from firm interviews and interviews of researchers and heads of government agencies, as well as analysis of government policy and policy papers by civil society organisations and industry support institutions. Thus the subjective interviews are supported by objective data by assessing Ghana's STI policy for developing innovation capability in industry as well as the development of manufacturing capacity for linkage firms

in Ghana (Krippendorff, 2019). The interviews seek to ascertain the development of innovation capability following Kamal Saggi's method of assessing technological absorption (Hoekman & Javorcik, 2006). Linkage development and technological transfer and absorption will be analysed through using interviews with supplier firms to investigate:

- a. How exposure to the superior technology of MNCs in the industry have led firms to update their own production methods.
- b. How physical movement of workers within the industry leads to the transfer of skill and technological know-how.
- c. The two-way relationship between multinationals and linkages.

Thus, from these interviews as well as discussions on the country's STI policy, this chapter seeks to answer the following research questions:

1. How do backward linkages to the gold mining industry develop?
2. How prevalent is innovation in linkage firms?
3. Are these linkages enhancing the output of other sectors?
4. To what extent are the development of backward linkages and technological transfers in linkage firms a function of
 - i. Intrinsic features of the sector
 - ii. Contextual determinants of linkages namely, ownership, infrastructure, capabilities, institutions and the policy environment (Kaplinsky et al., 2012).

Table 4.1 below shows the questions that were asked to ascertain how the nature of the industry and government policy has worked to enable the development of innovation capabilities in the backward linkage firms discussed. The interview questions were semi-structured in that they were a set of questions designed to guide the interviews. The questions for firms engaging in product and process innovation are in appendix A4.3. It was discovered that none of the firms interviewed had introduced an innovative product or process to the market or firm within the previous three years.

Table 4.1 Questions for developing innovation capability in backward linkage firms

Questions on the development of linkages to the mining industry	Questions on the contextual determinants of linkages	Questions on the policy environment
1. What percentage of business comes from the mining industry?	1. What percentage of your establishment is owned privately by Ghanaians?	1. Does this establishment benefit from any government initiative?
2. Has your share of the market in the mining industry grown since you started doing business with them?	2. What percentage of your establishment is owned privately by foreign individuals or firms?	2. Are the roads leading to the mines in good shape?
3. Have the mining firms invested in infrastructure that has enhanced your business with them? If yes how has this enhanced your business?	3. What percentage of your inputs is locally sourced?	3. Do you have reliable sources of energy?
4. Has the government invested in infrastructure that has enhanced your business with the mining firms? If yes how has this enhanced your business?	4. Does the firm use locally manufactured machinery or equipment?	4. How difficult is it to obtain financing for expansion?
5. Which other sectors of the economy does this establishment do business with?	5. Does this establishment use technology licensed from a foreign-owned company?	5. Are there aspects of the local content policy that are constraints on the productivity of this establishment?
6. Have this establishment's association with the mining industry enhanced its business with other sectors of the economy?	6. Does this establishment have an internationally recognised quality certification?	6. Do you have any other problems or concerns about any government policy?
7. Does this establishment supply to mining companies within the West African region apart from Ghana?	7. Is this establishment a member of a formal or informal business association?	

The firms interviewed were selected from the mining supply firms that are affiliate members of the Ghana Chamber of Mines. Emails were sent to 26 firms in all over a three-week period and six firms successfully scheduled meeting times for the interview. One interview was scheduled for each firm. The respondents for all the firms were either managers or owners of the firm. Precisely three owners and three managers were interviewed.

The World Bank (2012) categorises suppliers to the mines into five groups. All the firms interviewed belonged to at least one of the supply categories, namely;

1. **Services:** core services to the gold mining enterprises including exploration and mineral resource assessment services, corporate support services such as legal, regulatory and negotiation services and engineering and construction services.
2. **Capital Goods and Construction Material:** these include machinery for crushing, grinding, crushers, and grinding mills as well as auxiliary equipment for ventilation, pumps, and pipelines.
3. **Consumables:** these include processing inputs, energy and water inputs and replacement parts. There are also companies which produce spare parts and ground-engaging tools.
4. **Bulk Services and Infrastructure:** electricity is mainly provided by the Electricity Company of Ghana. The government of Ghana also provides roads and railways for transportation. It also includes fuel and related petroleum products that are supplied by private firms.
5. **Non-core Goods:** these are firms that provide overalls, protective helmets, lamps, boots, eyewear, fire protection equipment and air quality monitoring devices.

Table 4.2 provides information on the firms that were interviewed. This includes the type of supplier, the goods and services they supply to the mines, the goods and services they provide to the rest of the economy, the type of ownership and whether it is a manufacturing firm or a supply firm. Four out of six firms engaged in consumables and one other supply category. Participants consented to the use of anonymised excerpts for academic publication but did not consent to the public release of full transcripts. Accordingly full transcripts are not included in this chapter.

Table 4.2 Information on Firms Interviewed

Type of Supplier	Goods and Services Supplied to the Mines	Goods and Services Supplied in the Economy	Type of Ownership	Type of firm
Services	Engineering and construction services, mining equipment.	Equipment for construction companies.	Foreign and Ghanaian owned with both foreign and Ghanaian directors.	Importer
Capital Goods and Construction Material	Auxiliary equipment for ventilation.	Oxygen services to hospitals and local industries.	Ghanaian owner and directors.	Importer
Consumables				
1. Firm 1	Replacement parts	Equipment for construction companies.	Foreign and Ghanaian owned with both foreign and Ghanaian directors.	Importer
2. Firm 2	Grinding Media Explosives and quarrying at the mines.	Quarrying for construction companies as they also own drilling machines.	Ghanaian owner and directors.	Supplier of locally manufactured explosives
3. Firm 3	Hydrated Lime	Asphalt mix for road construction	Foreign owners and directors	Manufacturer
4. Firm 4	Explosives and blasting	Quarrying and construction	Foreign owners and foreign directors (divesting to Ghanaians)	Manufacturer
Bulk Services and Infrastructure	General Lubricants and Fuel	General Lubricants and Fuel	Ghanaian owner and directors.	Supplier of locally refined oil
Non-Core Goods	Working gear and welding electrodes.	Oxygen services to hospitals and local industries.	Ghanaian owner and directors.	Importer

Thus, three of the firms are completely Ghanaian owned. Two of the firms are foreign owned manufacturing companies with different degrees of Ghanaian participation. There are two importer firms. One importer firm is jointly owned by Ghanaians and foreigners while the other importer firm is fully Ghanaian owned. The other two firms interviewed supply locally manufactured inputs to the mines. There were also interviews conducted with academic researchers in Institute of Statistical Social and Economic Research (ISSER), Science and Technology Policy Research Institute (STEPRI) and the Head of Research, Innovation and Consultancy at the University of Mines and Technology in Tarkwa. The head of the government agency in charge of trade, industrial and innovation policy at the Ministry of Trade and a representative of the Ghana Chamber of Mines an organisation that represents the interests of mines and suppliers to the mining firms were also interviewed.

The researchers were interviewed to ascertain collaborations between the backward linkage firms and research institutions. The representative of the Chamber of Mines explained how backward linkage firms affiliated with them were supported. This representative was instrumental in securing some of the meetings with the firms. After trying to reach their management with no success, the Chamber was involved to assist in getting their members to agree to an interview. This led to a positive response from the management of three firms. The government official at the trade ministry was interviewed to understand the differences in government policy for input import of firms that produce for the local market and firms that export most of their output.

Reports on the backward linkage firm participation by the Chamber of mines and international civil society organisations as well as reports from local research institutions and government laws and policies were accessed for objective data and further information on interactions between the mining firms, the backward linkage firms, government institutions and local research institutions.

The interview questions were approved by the Commerce Faculty Ethics in Research Committee (see appendix 4.4). There were firm specific questions, questions on the development of linkages, questions on the policy environment and finally questions on innovations the firm had embarked on. The interview questions were adapted to who was being interviewed. The innovation questions were on product and process innovation which are deemed as technological innovation in the literature (Cirera & Maloney, 2017).

An innovation has been implemented if it has been introduced to the market (product innovation) or used with a production process (process innovation). The following do not comprise technological innovations;

- improvements that only make them attractive to the buyer without changing their technological characteristics.
- minor technological changes that do not have the sufficient degree of novelty.
- changes where the novelty is on their aesthetic or subjective quality alone.

It is noteworthy that local content does not have a set definition, but this chapter is using it in the context of the Minerals and Mining Act. Thus, local content refers to increasing the proportion of Ghanaians employed by the mines. It also means the procurement of goods from suppliers with the highest proportion of Ghanaian participation in terms of ownership, management, and employment. Thus, local content in this chapter refers to an increase in Ghanaian participation in terms of ownership and management by Ghanaians and employment of Ghanaians in firms that supply to the mines. Local content here includes Ghanaian participation in locally manufactured goods as well as imported goods. Most of the firms that supply inputs to the mines are in the capital city, Accra, and the industrial and port city, Tema. A few of these firms are in Takoradi and Kumasi which are the cities closest to the mines in Tarkwa and Obuasi respectively. Most of the supply firms also have offices close to the mines.

4.5 Analysis of Interviews

4.5.1 Technological transfer and absorption in linkage firms

An analysis of the interviews with the suppliers shows that supply firms have benefitted from associating with MNCs in the mining sector. There is a very strong link between local supply firms and MNCs that either produce the output the local firms supply or used to supply the output to the gold mines before the products were placed on the procurement list. In the Minerals and Mining Regulations (L.I. 2173), (2012), in sub-regulation (10), it is stated that;

The Commission shall have a local procurement list and specify in the list the goods and services with Ghanaian content which shall be procured in Ghana by the holder of a mineral right, a licence to export or deal in minerals or a person registered to provide mine support services.

Now in sub-regulation (11), it is stated that;

A holder of a mineral right, a licence to export or deal in minerals or a person registered to provide mine support services who fails to comply with sub-regulation (10) is liable to pay to the Commission the full customs import duty in respect of the goods imported and a penalty as provided in the local procurement list.

This list was expected to be reviewed annually. According to the Minerals Commission, the list that began in 2014 with 8 items was revised in 2015 and then in 2018 and recently in 2022. It now contains 41 mining inputs that must be procured from either Ghanaian owned companies or companies with the highest level of Ghanaian participation in terms of ownership, management, and employment. The procurement list is a legal grey zone and could be abused by bureaucrats. It could also entrench local industry interests and lead to inflated prices (Hansen, 2014). The definition of a local-content compliant company as defined by the L.I 2173 is vague, and it leaves room for mining firms to use their discretion. Mining firms pay duty on imported goods and a penalty if they import goods and services on the procurement list. Ghanaian owned supply firms that import goods on the procurement list do not pay any duty on these mining inputs.

Since 2018, general lubricants and fuel have been supplied solely by Ghanaian owned firms with Ghanaian directors and shareholders. This is in line with the National Petroleum Authority's requirement that a Bulk Distributing and Export Company License can only be obtained by a firm with 100% equity interest held by a Ghanaian or Ghanaians (Public Notice, 2015). This began in June 2015 as part of the Strategic National Energy Plan (SNEP I, 2006-2020) to increase local content in the petroleum sector (Energy Commission, 2006). Thus, it has led to an increase in Ghanaian firms that supply petroleum products to the mining firms. Before petroleum products were added to the procurement list, MNCs like Shell and Total had nearly monopolised the market for supplying to mining firms. The firm owner interviewed stated that

“Ghanaian owned companies were only taken seriously by the mostly foreign owned mines if we had expatriates in our technical team. Even so, we had to be substantially cheaper than the MNCs before we would be given contracts.”

The new regulations mean that the MNCs have lost access to this market. It has also led to the movement of qualified personnel from the MNCs to the Ghanaian owned petroleum products supply firms. They have in turn been able to develop their capacity and expertise in supplying to the mining firms. Thus, the firm interviewed has been able to expand into neighbouring countries such as Burkina-Faso and Mali.

In the case of the supply of Grinding Media Explosives (Emulsion), another mining input that is on the procurement list, there are foreign owned firms in Ghana that produce explosives locally but contract a Ghanaian owned company to supply them to the mining firms. Explosives are another mining input that has more Ghanaian owned firms participating in their supply to mining firms because of government's local content policy in the mining sector. Regulation 2, sub-section (1) of the L.I 2173 states;

A mine support service provider, a holder of a mineral right or a licence to export or deal in minerals shall procure goods and services with Ghanaian content to the maximum extent possible and consistent with safety, efficiency, and economy.

Thus, mining firms and MNCs that establish companies that manufacture explosives contract the supply of mining inputs that are on the procurement list to a Ghanaian owned supplier that owns bulk emulsion operation vehicles. Here, the MNC has established an explosives plant where about 40% of the explosives are manufactured onsite using the emulsion process. A Ghanaian owned firm is then contracted to store, manage, and transport the explosives to the mine site. The Ghanaian distributor interviewed also performs quarrying at the mines and for construction companies as they also own drilling machines. This firm interviewed was established in 1994 to partner the explosives manufacturer. Hence, although the manufacturing firm is following the minerals and mining regulations, they had been partnering with a locally owned supply firm for 20 years before the mining regulations were enforced. Their operations have been greatly enhanced by their partnership with the MNC that produces the explosives as the firm interviewed has developed the skill and capacity to perform quarrying in the neighbouring countries of Togo, Burkina-Faso and Benin.

The local content policy has enhanced the use of Ghanaian suppliers of inputs that are not on the procurement list. These suppliers are often working in collaboration with MNCs. These can be firms that acted as local agents of a MNC and supplied to other areas of the economy but

added the mining sector to their portfolio as local content was encouraged compelling the mining companies to source these inputs from Ghanaian owned firms. One such Ghanaian firm supplies on site oxygen services to the mines. The firm owner interviewed here is quoted stating that;

“Our main demand came mostly from hospitals and local industries but our share of the market in mining has grown dramatically since the Minerals and Mining Act was revised in the L.I. 2173.”

Such firms that offer services that are specifically and exclusively related to mining, which the Minerals Commission consider necessary for the effective and sustainable development of the mining industry can import at concessionary rates of customs import duties. They can import duty free such inputs as plant, machinery, equipment, and accessories as provided in the Mining List, that is, items imported specifically and exclusively for mining-related activities. These regulations are laid out in the Minerals and Mining (Support Services) Regulations, 2012 (L. I. 2174).

The local content policy has made backward linkage firms competitive in the market even if the goods they supply are not on the procurement list. This firm that used to supply to hospitals and local business now has 60% of its business in terms of value coming from their supply to the mines. The firm has also expanded into supplying items on the procurement list such as working gear and welding electrodes. The mining companies expected this firm to also offer maintenance services which encouraged the firm to invest in the training of staff to perform maintenance services after installation and this has greatly enhanced their services to hospitals and industry. They have even begun to perform remote monitoring of their installed oxygen generators. The leadership of the firm also made the point that the demand for safety and quality in the delivery of their services by the mining companies has led to higher quality in service delivery. They have also expanded their services to a mine in Guinea and are looking to expand into Burkina-Faso and Mali. This is a Ghanaian supplier that is an authorized dealer of a MNC which supplies them with oxygen generators. This MNC has been instrumental in training the staff of the Ghanaian owned supplier to adhere to safety standards expected by the mining companies. They also trained the staff to perform maintenance services on installed generators. As a result, in the last four years the installation and maintenance of generators has been done by the firm.

There are also certain supply firms that are both foreign and Ghanaian owned but locally registered with Ghanaian participation in terms of management and employment. This qualifies them to supply to the mining firms in line with the local content policy. One such firm interviewed, supplies construction and mining equipment to the mines. This firm is the local dealer of several MNCs. These MNCs have specialised in the production of construction and mining equipment. The local dealer also supplies spare parts to the mines and provides technical services which include maintenance, repairs and machine rebuild programmes. The manager interviewed explained that;

“A machine rebuild means extending the lifespan of equipment to save on the cost of acquiring new equipment.”

They have about 95% of their business focused on the mining sector with the remainder going to construction companies. Their share of the market has also grown since the Minerals Commission began to implement the requirement for local content in the Minerals and Mining Regulations. They use local sub-contractors for rebuilding and lime boring, engineering works and painting of machines. They thus qualify for concessionary duty whereby they only pay 5% in import duties while other suppliers with more foreign content pay 15% in import duties. Thus, the local content policy has largely enhanced their business. But their concessionary duty is limited to imports for the supply to the mining sector. Their imports for the construction sector attract an import duty of 20%. Due to the firm being a local dealer for foreign MNCs, they cannot expand into neighbouring countries as their MNC suppliers also have local dealers in other countries.

There are also foreign owned companies producing mining inputs in Ghana. One such company manufactures lime using calcium oxide and calcium hydroxide. This company is 100% foreign owned but with mostly Ghanaian employees. This firm was set up in 1994 to specifically supply to the mining sector. The company also supplies asphalt mix for road construction, but this is just about 1% of their business. They are targeting the agricultural sector and hope to develop products that enhance soil fertility using locally produced limestone. They are also looking to enter the building and construction sector. They have developed special lime bricks using locally sourced laterite and pozzolana, that is durable and regulates the room temperature. The firm is also developing a water purification and treatment plant for both fresh water and wastewater. The research and development section of this firm is in the parent company outside

of Ghana. The company also supplies to mining firms in Burkina-Faso and Mali. They also supply to Côte D'Ivoire where they offer water treatment services. The manager interviewed stated that;

“We had nearly monopolised the market in Ghana until hydrated lime was included in the procurement list. We now face competition from local firms that import lime products.”

The company is also facing pressure from government to have local equity ownership. Since they are not local content compliant, they face high customs import duty and higher taxes in general making them less competitive.

Another foreign owned manufacturing company that was interviewed manufactures and supplies explosives to the mining sector and also engages in the blasting of rocks before they are sent for grinding. The top management which makes up 1% of their employees are expatriates. They also have a quarrying and construction section of the company. About 70% of their output is for the mining sector while the remaining 30% consists of quarry blasting. The firm controls about 45% of the market share for explosives. They also supply to Côte D'Ivoire, Mali, Burkina-Faso, Mauritania, Guinea, Liberia, and Cameroon. They deliver quarry output to Togo and Benin. The manager interviewed stated that;

“The local content legislation has led to some divestiture to Ghanaian individuals. We also source some of our chemical inputs locally.”

These inputs such as sodium nitrate, sodium acetate, acetate acid and thiourea account for about 20% of their input materials. The manufacturing plant is essentially an assembly plant as the most important input; ammonium nitrate is imported. All the machinery is also imported. Their parent company invests in research and development outside Ghana to produce cheaper and more effective explosives. This company does not have a problem with complying with the local content policy and hence benefits from increasing the Ghanaian content in its ownership and employees. The benefits come in the form of tax breaks and lower import duties.

4.5.2 Problems faced by the supply firms.

From the interviews, we can see that the Ghana government's local content policy in the mining sector has enhanced the business of supply firms with Ghanaian content and increased Ghanaian participation in the mining sector. The development of local backward linkages to the mining sector has also enhanced the capacity of these supply firms to supply to other sectors

of industry. The revised mining regulations in the form of L.I 2173 and L.I 2174 have regulated the supply space in the mining sector and the procurement list is coordinated with the policy on other areas of the economy such as the petroleum and trade sectors. Yet there are certain issues with regulation enforcement and the provision of the necessary infrastructure to enhance the expansion of supplier firms. The government could also facilitate training and development of skill and capacity of locally owned firms in this sector.

In our interview with the senior research officer of the Ghana Chamber of Mines, we discovered that the mining firms that were members of the Chamber had just about 2% of their employees as expatriates. The mining firms however employ just about a fraction of the people employed in mining with small scale mining being the main source of employment in the mining sector (Minerals Commission, 2014). The senior research officer of the Ghana Chamber of Mines explained that;

“This is because the mining firms mainly use sophisticated machinery in the extraction of the ore while small scale mining is more labour intensive.”

There seems to be potential for the development of local manufacturing and supply firms to the small-scale mining companies if they are regulated properly.

Many of the supply firms interviewed admitted to preferring not to engage with small-scale miners as they are poorly regulated and many of them are mining illegally. This problem is being tackled by the government as in May 2020, an L.I. 2404 was introduced to regulate small scale miner's use of earth moving mining equipment. This equipment needs to be registered with the Minerals Commission who will fit it with a tracking device. There is an opportunity for the development of a supply chain with value addition for small scale mining. Small scale miners are expected to get permission for the use of explosives, excavators, and bulldozers. This is because small scale miners usually engage in surface mining that has a more detrimental effect on the environment. There could be regulations to encourage the firms that supply mining equipment to small scale mines to supply value added equipment that are more environmentally friendly.

There were several complaints from the supply firms about the state of roads to the mines. Ghana's road network in general is in a bad state. This led the president to declare 2020 the

year of roads in his state of the nation address to parliament on the 20th of February 2020. A sophisticated rail network would also greatly enhance the delivery of mining equipment.

Despite the increase in the use of Ghanaian suppliers by large scale mining companies, the procurement list lacks clarity such as what constitutes a firm that is strictly incorporated in Ghana. One owner interviewed stated that;

“The list is not backed by law and hence it is not properly enforced. This means that there are grey areas in terms of the procurement list and so the mining firms are still able to import certain equipment on the procurement list without paying any import duty.”

The definition of a local firm in the legislative instruments which is “a firm that contains the highest level of Ghanaian participation” is vague and leaves ample room for mining companies to use their discretion. This could allow MNCs to outcompete Ghanaian owned firms. For instance, MNCs can set up companies that are incorporated in Ghana with a little divestment to Ghanaians and then meet the criteria for local content.

The L.I 2173 and L.I 2174 do not have provisions for value addition. This may be because many of the locally owned firms are yet to develop the capacity and skills needed for value addition. The locally owned supply firms that were interviewed have developed their innovation capacity as it pertains to knowledge transfer from the MNCs they import from or interact with as well as feedback from the mines they supply to. They expressed an interest in developing the capacity to engage in value addition but bemoaned the difficulty in obtaining low interest loans. They intimated that it would be easier for them to engage in value addition and establish manufacturing plants if they were extended similar benefits for engaging in manufacturing as offered to firms declared Free Zone Developers. They were especially hoping for the exemption from the payment of income tax on profits for 10 years that is offered to firms declared as Free Zone Developers. The mining sector does not constitute a priority area in the free zone according to the Ghana Free Zones Authority. For a manufacturing firm to qualify for the incentives provided for the free zone, at least 70% of annual production of goods and services must be exported.

Some firms cited a lack of contract enforcement between local suppliers and the mines. The mining companies sometimes change ownership or management of the mines, and this often leads to a renegotiation of contract terms that can be unfavourable to the Ghanaian supply firm.

Fierce competition among local supply firms means that often the firm that wants to keep their contracts intact in times of changes in management, ownership or changes in the gold price may have to reduce their prices. Unsustainably low pricing could push small Ghanaian owned firms out of the market defeating the purpose of the local content policy.

In the L.I 2173, Regulation 2 sub-section (2), every mining firm must submit a procurement plan to the Mineral Commission for approval. In Regulation 2 sub-section (5), it is stated that,

The procurement plan must include specific support to providers or suppliers as well as other measures to develop the supply of local goods and services, including broadening access to opportunities and technical and financial assistance.

According to the supply firms the stipulation above is not being adhered to by the mines nor being enforced by the Minerals Commission.

Ghanaian owned supply firms lack capacity to produce the goods that they supply compared to MNCs that manufacture these goods. A developed capacity and skill set for the supply firms to engage in value addition and manufacturing of mining inputs will have a spillover effect in the wider Ghanaian economy. For Ghanaian owned supply firms to develop the capacity and skill to begin manufacturing the inputs supplied to the mining firms, the country will have to invest more in science, technology, engineering, and mathematics (STEM) education as well as in technical vocational education training (TVET). This investment must be guided by a skills and capabilities assessment to be able to determine the actual needs of the firms that would want to expand into manufacturing.

4.5.3 Assessment of STI policy for developing innovation capability in industry.

The Ministry of Environment, Science, Technology, and Innovation (MESTI) is the government body in-charge of technological development in industry. It is comprised of agencies such as the Council for Scientific and Industrial Research (CSIR) which is the foremost national science and technology institution in Ghana. The CSIR is mandated to carry out scientific and technological research for national development. The ministry has thus drafted a national policy on science, technology and innovation to create the conditions and enabling environment for innovations to occur (Draft-National-STI-Policy-Document-10-July-2017, 2017). This was expected to cover the period from 2017 to 2020. According to the draft document, an apex STI body to ensure coordination and harmonization of the country's STI

policy and programmes must be established. This apex body: The Presidential Advisory Council for Science, Technology, and Innovation (PACSTI), was established in 2019. This implies that there has not been a coordination and harmonization STI body at the national level for most of the period that this medium-term national STI policy was expected to have been implemented.

The policy also pointed out that Ghana has not made adequate funding available for STI research thus the establishment of an STI fund would be a priority for PACSTI. However, there were no provisions for such a fund in the 2020 budget statement. The budget statement showed that there were plans for STI projects that did fall under programmes to be pursued by the national STI policy to develop innovation in industry, but nothing was said about how to fund these projects. For instance, the yet to be established Ghana Design and Manufacturing Centre (GDMC) is to facilitate the incubation of new technological industries and serve as a resource for national research institutions and private industry. Funding was also provided for the National Entrepreneurship Innovation Programme (NEIP) in the 2020 budget which was set up by the present government to provide additional avenues to self-employment opportunities for Ghanaian youth and support to Micro, Small and Medium Enterprises (MSMEs), but this does not appear to fall under any ministry. Thus, Ghana's STI policy implementation is disjointed with the apex body established to coordinate the many aspects yet to begin work.

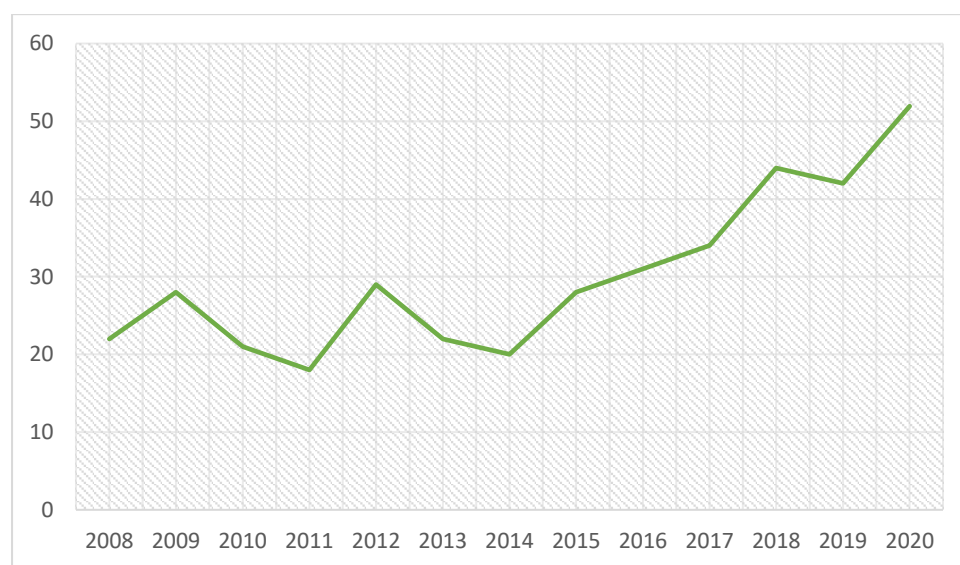
4.5.4 The development of manufacturing capacity for linkage firms

Mining inputs sourced from firms located in Ghana increased from 18% of input purchases (excluding fuel and power) in 2011 to about 51.9% of their input requirements (excluding fuel and power) in 2020 (Ghana Chamber of Mines (2011); Ghana Chamber of Mines (2021)). This increasing trend can be observed in figure 2 below. The table covering the data in figure 2 is in appendix A4.2. Although not all firms are Ghanaian owned, all the firms located in Ghana that supply to the mines have various degrees of Ghanaian content. This is largely because of the implementation of the Minerals and Mining Regulations in 2014. Yet according to the African Center for Economic Transformation (2017), only 52% of mining inputs sourced in Ghana are supplied by Ghanaian manufacturers and service providers.

The Center suspects that the present Minerals and Mining regulations could encourage local manufacturing firms to import supplied inputs as the imports are duty free while the manufactured output attract a value-added tax. Thus, the mining regulations and mineral policy

have enhanced the development of Ghanaian content in supply firms. Yet it has discouraged the manufacturing of inputs to the sector by providing duty free incentives to imports of mining inputs without providing incentives for manufacturing and value-addition.

Figure 4.2: Local purchases of goods and services as a percentage of mineral export receipts from 2008-2020



Source: Author's compilation from reports from the Ghana Chamber of Mines from 2011 to 2020.

The Minerals Commission (2014), shows that the policy had the intention to establish a fund from the revenue accrued from mining for projects that enhanced forward, backward and side-stream linkages needed for the expansion of the Ghanaian economy. In September 2018, the Minerals Income Investment Fund (MIIF) Act, 2018 (Act 978) was passed by parliament (Government of Ghana, 2019). The MIIF was created to hold and manage the mining company equity interests of the Republic, receive mineral royalty revenues due from mining operations, and provide for the management and investment of the assets of the MIIF. A board for the fund was inaugurated in October 2019.

The Minerals and Mining Policy enforced in 2014, does not make any provision for government investment in research and development in the manufacture of mining inputs. The policy is expected to be reviewed every five years, and a review could include incentives for firms that invest in value addition of inputs supplied to the mining firms. The policy review

could also explore the possibilities of allocating funds from the MIIF towards research and development that could support backward linkage firms that seek to add value to the goods they supply to the mining companies. The firms interviewed expressed an interest in adding value through the establishment of assembly and/or manufacturing plants. Local manufacturing in the backward linkage firms could increase employment in the mining industry and hence increase Ghanaian content and the benefits from mining.

4.5.5 Evaluation of the effectiveness of the local content policy and Policy recommendations

Venables and Baldwin (2015), develop a model for evaluating the ability of government trade and local content policy to enhance the ‘width’ and ‘height’ of the industrial base of an economy. The width of the industrial base is the range of inputs produced domestically while the height of the industrial base is the range of final goods produced domestically. They posit that there is a simultaneously positive relationship between the range of final goods produced domestically and the range of inputs produced domestically. That is the range of domestically produced final goods depend positively on the range of domestically produced inputs and vice-versa. Ghana’s local content policy for mining can be evaluated using this model.

From the reports on the local purchases of goods and services by the mines by the Ghana Chamber of Mines and the African Center for Economic Transformation (2017), mining inputs sourced from firms in Ghana increased from 18% in 2011 to 51.9% in 2020. This means that the local content’s penalty for mining firms for not sourcing inputs on the procurement list has been a deterrent. The number of goods and services on the list has also increased from eight in 2014 to 41 in 2022. Yet only 52% of mining inputs sourced in Ghana were produced by Ghanaian manufacturers and service providers.

The interviews with the manufacturing firms includes a company that manufactures lime using calcium oxide and calcium hydroxide that they also produce. This company is 100% foreign owned but with mostly Ghanaian employees. The company was established in 1994 and had nearly monopolised the market in Ghana until hydrated lime was included in the procurement list. Since the company is completely foreign owned, they face high customs import duty for inputs and higher taxes in general. They are also now in competition with locally owned firms that import lime products. On the other hand, another foreign owned manufacturing company that was interviewed manufactures and supplies explosives to the mining sector and engages

in the blasting of rocks before they are sent for grinding. The top management of their employees are expatriates, but the local content legislation has led to some divestiture to Ghanaian individuals and the sourcing of some of their chemical inputs locally. These inputs account for about 20% of their input materials. Hence the manufacturing plant is essentially an assembly plant as the most important input is imported. All the machinery is also imported. Yet because they are more local content compliant, they benefit from tax breaks and lower import duties. Thus, the local content policy has the potential to be used to enhance the width and height of Ghana's industrial base. The policy can be used together with the trade and tax policies to discourage the importation of finished goods that are produced locally while encouraging manufacturing firms that supply to the mines to source their inputs locally.

To increase local content in the petroleum sector after the discovery of offshore oil deposits in Ghana, only Ghanaian owned firms can obtain a Bulk Distribution and Export Company license. The interview with such a company exposed the influence of policy coordination in enhancing the local production and supply of production inputs. Thus, petroleum products are supplied to the mines by firms with 100% equity interest held by Ghanaians. Similar policies could be used to encourage the supply of mining inputs manufactured in Ghana. Thus, industrial policies can be tailored to coordinate local content in different sectors of the economy to increase the demand of domestically produced inputs by the mining firms.

It can be observed from the nature of the supply firms interviewed that there is not much innovation or value-addition happening in backward linkage firms to the goldmining industry in Ghana. The firms interviewed admitted that they were not engaged in any innovative product or service or production process at the time of the interview nor had they introduced any innovative product or service or production process since they began supplying to the mines. Both manufacturing firms interviewed have their research and development section in the parent company outside of Ghana.

There has not been definitive government policy or investment geared towards developing the capacity and skill of manufacturing firms and importers that supply to the mining sector. The present policy direction encourages the import of mining inputs over local manufacturing and value-addition. Meanwhile the linkage firms could develop technological and innovative capacity through value-addition and manufacturing. These backward linkages possess the potential to develop capacity for manufacturing and value addition in the supply of some of the

mining inputs as they can repair and maintain most of the equipment they supply to the mines. They will therefore need support from government by way of incentives and investment in R&D and technical and vocational training to develop the needed human and physical capital. Government incentives such as tax relief and R&D subsidies can encourage manufacturing, value addition and innovation in firms.

Gomm et al. (2000) discuss the generalizability and transferability of findings in a case study. They posit that social phenomenon occurs in specific contexts and hence are the product of multiple causal processes. The number of firms interviewed in this case study are only six and do not represent all the different types of firms that supply to the mining industry in Ghana. Yet this case study has intrinsic value in furthering the knowledge of the implementation of Ghana's local content policy. The case study aids our understanding of how firms that supply to the mines have developed their technological capability through collaborations with MNC that used to supply to the mines before the implementation of this policy and MNC that they import from. This case study also shows how local content policies in different sectors of industry can be coordinated to expand the industrial base of an economy. Hence this case study has sufficient intrinsic relevance to avoid the generalization problem (Gomm et al., 2000).

4.6 Conclusion

From the interviews of the management for the backward linkage firms, government policy to promote the localisation of backward linkage firms by increasing Ghanaian content has been successful in increasing Ghanaian participation in the supply of mining inputs to the mining firms. The fears that local content requirements would discourage investment in mining by international mining firms have not materialised. In 2020, nearly 52% of the mineral export revenue went into inputs sourced from suppliers located in Ghana (excluding energy and fuel) compared to 31% in 2015 (Ghana Chamber of Mines (2021); Ghana Chamber of Mines (2016)). In 2020, Ghana was ranked 6th in gold production in the world compared to its 10th position in 2015. The local content policy has also aided in the transfer of technological knowledge and skills such as the installation, maintenance and repair of machinery and equipment the backward linkage firms supply to the mining firms. Thus, the policy has encouraged the participation of Ghanaians in the mining sector through the supply of inputs to the mines. This was the primary objective of the policy.

The policy can however be revised to move from supply of imported goods to investment in technological and innovation capacity to manufacture or add value to some of these imports inhouse. In October 2020 an L.I. 2431 was introduced to promote job creation using local expertise and increase the capability and international competitiveness of local industry in the mining sector. This L.I is to develop local capacities in the mining industry value chain through education, skills and technology transfer as well as institute R&D programmes (Minerals and Mining-Local Content and Local Participation Regulations-2020-LI-2431, 2020). To promote R&D and skill development, the L.I. states that;

The Commission in consultation with the mining industry, universities, research, technical and vocational training institutions develop guidelines for applicable areas of training, research, and skills development.

If this guideline is developed and enforced, then the Minerals Commission could introduce an L.I. that necessitates value-addition to imported goods supplied to the mining firms. Similar incentives as given to free zone firms could facilitate this.

Although governments over the years have included the development of technological and scientific skills and capacity in their medium-term plans, this has often not translated into concrete sustainable action and implementation. A lack of commitment and funding seem to be the underlying factor preventing the implementation of these plans. It is hoped that the establishment of the Minerals Income Investment Fund (MIIF) means that government is much more committed to investment in the mining sector. This fund can be used to encourage local manufacturing and value-addition in inputs used by small scale miners.

Government policy towards developing the science, technology and innovation capability of the Ghanaian economy requires a long-term vision. Mineral wealth is a non-renewable resource. Before we deplete our reserves, we must make the most of this resource (Kaplinsky et al., 2012) . The present mining regulations and mining policy have led to the development of a supply chain with increased Ghanaian content. They have however neglected the development of value-addition and manufacturing in backward linkage firms. This appears to be the next step that government policy must take to deepen the benefits of the mining sector to the local economy.

Chapter 5: Conclusion, synopsis, and policy implications

5.1 Introduction

This dissertation sought to ascertain the probability of engaging in innovation output given innovation activity. It also investigated the relationship between the types of innovation as well as study an industry to determine the knowledge transfer and absorption process considering government policy on local content and innovation. The thesis used Enterprise Survey data on innovation in firms in some West African countries to explore the innovation activity that influences innovation output in this region. The case study of the suppliers to the goldmining industry in Ghana is to enrich our understanding of the dynamics between government policy, industry, and the development of innovation capability.

Developing economies have received limited attention in scholarship about innovation as very few firms invest in R&D and inventions are rarely patented in developing economies. It is noted by Lanjouw and Schankerman (2004), that research productivity measured by the ratio of patents to R&D has declined in industry over the years, but firms are still innovating. This decline may be due to the cost involved in coming up with new information as firms must invest in research and other innovation activities to realise knowledge that is relevant for developing innovation output.

This is why government policy and regulation are important to encourage private firms to develop innovation capabilities and hence innovation output. Empirical evidence of the effectiveness of government intervention in how firms develop innovation capability has shown that rather than crowd out private investments in R&D as had been suspected, government support has rather served to stimulate private R&D investments especially in small firms (Hunermund et al., 2019). Government institutions will be better situated to coordinate collaborations between private firms and research institutions and universities. Such collaborations are expected to reduce the cost of innovation research. These collaborations are likely to attract private investment as they are expected to lead to higher quality innovation output.

This dissertation used suitable econometric methods such as the recursive bivariate probit and multivariate probit to empirically analyse the influence of innovation capabilities on innovation output and the relationship between the types of innovation. The results showed that although most firms did not engage in innovation activity, more than half of the firms engaged in

innovation. The results showed that firms that engaged in innovation activity had an increased probability of engaging in innovation. It also showed that there is a relationship between all the types of innovation. There are dependent relationship and simultaneity between the types of innovation. The case study exposed the areas in which government policy could be directed to enhance the innovation capability building of backward linkage firms in the goldmining industry in Ghana.

There are four other sections in this closing chapter. Section 5.2 discusses the main findings of the thesis. Section 5.3 will look at the policy implications of the thesis findings. Section 5.4 discusses the limitations of this research and Section 5.5 looks at the areas for further research.

5.2 Synthesis of Key Findings

Chapter 2 aimed to determine the prevalence of innovation activity and output in West African firms and the factors that influence the probability of innovating in West African countries. It focused on innovation indicator data that has been collected for West African countries by the World Bank Enterprise Survey to elaborate on the factors that bring about innovation. This survey is streamlined across countries so that the same questions are asked across countries for the innovation output and most of the innovation activities. The chapter discovered that innovation activities, namely R&D investment, export, purchase of assets and equipment and worker training were the main explanatory variables that increase the firm's probability to innovate. From the estimation results, R&D investment had the largest marginal effect on the probability that a firm would engage in product innovation and process innovation. The results also showed that a unit increase in export sale in the year in which the survey was taken increased the probability of engaging in product and process innovation. A unit increase in the purchase of assets and equipment also increased the probability that a firm would engage in innovation output. The results also show that worker training programmes increased the probability of innovating. The marginal effects show that firms that engage in product innovation have an over 90% increase in the probability of engaging in process innovation and vice versa. Thus, there is dependence between product and process innovation and correlation between their error terms. The design of the questionnaire suggested simultaneity of the innovation outcomes, and the regression results confirmed this and showed endogeneity between the innovation outcomes. Investment in R&D and export were found to be endogenous

to innovation as innovation literature suggests. Process innovation is correlated with R&D and export while product innovation is correlated with R&D but not export.

Chapter 3 investigated the relationship between the four types of innovation as well as the innovation activity that influence each type of innovation. The chapter combined innovation survey data collected by the World Bank Enterprise Surveys for Ghana and Nigeria. The multivariate probit was used to determine the relationship between product, process, marketing, and organisational innovations. The correlation between the error terms of the outcome variables showed a dependence between all four types of innovation. The correlation coefficient showed that product and process innovation have the strongest dependence followed by marketing and organisational innovation. Innovation activities such as R&D, purchase of assets and equipment, and worker training increase the probability that a firm will engage in innovation outcomes. These innovation activities increase the probability of a firm engaging in technological innovation outcomes, that is, product and process innovation as well as the non-technological innovation outcomes, that is, marketing innovation and organisational innovation. The variable Export however is not statistically significant for product and process innovation although firms that export some of their output increase the probability of engaging in marketing and organisational innovation. If a firm is a Ghanaian firm, it decreases the probability that the firm will engage in any of the innovation outcomes compared to Nigerian firms. Here also it was discovered that there is correlation between all the types of innovation and R&D investment, worker training and purchase of assets and equipment. The correlation coefficient is larger between the types of innovation than between innovation activities. It is also larger between the types of innovation than between the types of innovation and innovation activities.

The case study assessed government policy aimed at enhancing local participation in the backward linkage firms to the gold mining industry in Ghana. It critically analysed whether government policy has developed innovative capabilities in the backward linkage firms to the gold mining sector. The firms with Ghanaian ownership interviewed confirmed that the local content policy has increased their participation in supplying to the mines. The reports from the Ghana Chamber of Mines showed that the local content policy has increased the value of Ghanaian participation in the goldmining industry through the supply of inputs to the mines. The interviews with the management and owners of the supply firms also showed that there is

knowledge transfer between the Ghanaian owned supply firms and the foreign firms they import from and those that used to supply to the mines before the implementation of the local content policy. The policy, however, has the potential to discourage actual domestic value-addition or manufacturing in the supply of mining inputs. The Minerals and Mining Policy does not make any provision for government investment in research and development in the manufacture of mining inputs. The policy is expected to be reviewed every five years, and it could include incentives for firms that invest in value addition of inputs supplied to the mining firms. The firms interviewed admitted to not having introduced an innovative product or service or production process since they started supplying to the mines. They however expressed an interest in adding value through the establishment of assembly and or manufacturing plants. Local manufacturing in the backward linkage firms could increase employment in the mining industry and hence increase Ghanaian content and the benefits from mining.

There is little research on innovation in most West African countries. This research brings more understanding to the intensity and diversity of innovation and the capacity to innovate as well as how innovation activities increase the probability of a firm to innovate in West Africa. Furthermore, this research through a case study has shown how policy in an industry can encourage the development of innovation capability. It also explains the need for policy alignment in the mining industry to encourage innovation in backward linkage firms. In essence, the research showed that the development of innovation capability in firms leads to innovation output and could contribute to development and growth in the general economy.

5.3 Policy Implications

A common theme in innovation data is that small firms invest the most in R&D and innovate the most. The results of the main regression in chapters two and three shows that there is a negative relationship between innovation output and firm size. Large firms are less likely to engage in innovation compared to small firms. Investment in R&D improves the efficiency and hence productivity of labour while innovation leads to lower cost output and hence higher return to capital. Small firms often lack the capital to invest in R&D and worker training. In general, the regression results show that investment in innovation activities such as R&D, worker training and asset and equipment purchase lead to innovation output. Policy makers in

West Africa will do well to enhance the ability of small firms to invest in R&D or benefit from R&D performed by academia by enhancing collaboration between academic research and the private sector. In this regard, government can also set up worker training programmes and make it easier for firms to import production equipment. There is knowledge transfer when firms are trained on how to use machinery and equipment. The firms that manufacture the machinery and equipment can teach the workers who use them to maintain and repair them further developing the innovative capabilities of the workers and firms. The government can encourage the MNCs that produce these equipment to train the workers that use them through import tariffs that encourage the establishment of a local supply firm and production subsidies.

Ghana and Nigeria have STI policies and so on a national level acknowledge the importance of R&D in innovation. It is important that the governments in West Africa prioritize investment in R&D in research institutions with a focus on industry applications. Their STI policies could also provide incentives for firms to invest in intramural R&D such as tax holidays and subsidies. Their governments could also facilitate collaboration between academia and industry in the development of innovation capabilities. There is opportunity for ECOWAS to establish regional research institutions to enhance collaborations and knowledge transfer across countries in the region. It will help these developing countries share resources and information.

It can be observed from the education statistics that Nigeria and Ghana need to invest more in education to enhance their human capital's technological absorptive capacity. This may lead to a stronger influence of worker training on innovation activity. Lee (2019), argues that when comparing the development of innovation capability between South America and East Asia, human capital development was found to influence the development of innovation capability more than the development of institutions, democracy, and financial liberalization. The governments of West African countries can invest in the innovation capability of industry through human capital development. This could help reduce the youth unemployment plaguing these economies and at the same time increase the efficiency and productivity of industry.

The multivariate probit in chapter 3 showed that in general, the main means of knowledge acquisition are also the main variables that increase the probability that a firm will engage in all the types of innovation. Few firms engaged in innovation activity, but these activities influenced the probability that a firm will engage in innovation. The correlation of the error terms shows that if a firm engages in one type of innovation, it is likely to engage in other types

of innovation. Scholars using the World Bank Enterprise Surveys innovation data can consider the simultaneity and endogeneity between innovation outcomes in their research. The ES questionnaire could include a question for whether a firm engaged in more than one innovation activity at the same time.

The present mining regulations and mining policy has led to the development of a supply chain with increased Ghanaian content. It has however neglected the development of value-addition and manufacturing in backward linkage firms. This seems like the next step that government policy must take to deepen the benefits of the mining sector to the local economy. The policy can be revised to move from supply of imported goods to investment in technological and innovation capacity to manufacture or add value to some of these imports inhouse. It is hoped that setting up the Minerals Income Investment Fund (MIIF) means that government is much more committed to investment in the mining sector. Firms that want to develop local capacity by adding value to inputs supplied to the sector could benefit from this fund if some of it is invested in the development of local skill and capacity for value-addition. This fund can be used to encourage local manufacturing and value-addition in inputs used by small scale miners.

Innovation is important for long-term economic growth because there are limited resources thus in the long run to increase output, firms will have to innovate (Broughel & Thierier, 2019). Innovation capabilities such as R&D, worker training, and acquisition of equipment are some ways in which a firm can improve its absorptive capacity and in turn build on its innovation capabilities. Government policy and regulation can be used to mitigate the private cost of investment in novel technologies or ideas that are useful to an industry. Government policy can be used to encourage firms to invest in building innovation capability and innovate.

5.4 Study Limitations

The empirical analysis provides a glimpse of the factors that determine innovation activity in West African countries. The cross-sectional innovation data available cannot provide information on the effectiveness of government policy to encourage innovation. The innovation survey must be collected over a longer period to better assess the effects of innovation activities on innovation activity in this region. These other surveys could include in- depth questions to tease out information on the resources available to firms for innovative activity such as access to government subsidies or tax breaks for R&D and access to funding for worker training. This

is to include information on government policy directed towards the development of technological and innovative capability in the assessment of the innovation activity of a firm.

If the data is collected over multiple years, then the previous years' values for variables such as R&D and export can be used as instruments to correct for the possibility of endogeneity between these variables and innovation. The follow-up innovation surveys conducted by the World Bank Enterprise Surveys could investigate innovation more deeply by including the expenditure on each innovation output over the last three years. This will provide information on how intentional firms are when they decide to invest in innovation activity. The framework for analysing how firms develop innovation capability can be revised to include unconventional ways by which a firm may come by an innovative idea. This can be done by formulating the questionnaire in such a way as to allow the firm managers to volunteer information on how they develop absorptive capacity.

It is important to note that the case study only covers select firms in an industry and so may not have outcomes that can be generalized (Fagerberg et. al, 2005). The recommendations for government policy here are for the goldmining industry specifically. The development of backward linkages in other sectors of the economy needs to be studied for their specific needs and the influence of government policy may differ in those sectors depending on the goals government has for those industries.

5.5 Areas for Further Research

5.5.1 Data collection

There is an opportunity for the World Bank to collect data on these firms in subsequent years. This will provide data that can be compared to observe changes in innovation capability building and innovation output. A panel can be created from this dataset and the consistency of innovation activity that leads to innovation output can be determined. The innovation survey could include a section for government policy focused on the development of innovation capability building. If the data is collected over a longer period, it could provide a rich source for research on the effectiveness of government policy to increase innovation capability and hence innovation output in West African firms.

5.5.2 Collaboration between industry and academia

The STI policies for both Ghana and Nigeria show that government is interested in facilitating collaboration between firms and research institutions. There could be research into existing collaborations between firms and research institutions to ascertain the issues in such collaborations and advise governments on the best way to facilitate such collaborations. Research into the best way government can facilitate worker training and knowledge transfer between industry and research institutions and academia can improve the efficiency and productivity of industry.

5.5.3 Innovation in linkage firms

The economies of the West African firms in this dissertation depend on the extractive industry. A study of the linkage firms that have developed around the extractive industry in each country will be interesting. There could be research into how the linkage firms develop in each country and how government policy has facilitated or constrained the growth of linkage firms in the most dominant extractive industry in each country. The research could investigate how each industry engages in the transfer of knowledge between multinational corporations and local firms.

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Appendix

Appendix A1.1 ES Questions for Product and Process Innovation for all countries

Country	Product	Process
Benin	H.1. During the last three years, has this establishment introduced new or significantly improved products or services? Pg19	H.5. During the last three years, has this establishment introduced any new or significantly improved process, that is: methods of manufacturing products or offering services; logistics, delivery, or distribution methods for inputs, products, or services; or supporting activities for processes? Pg 20
Côte D'Ivoire	H.1. During the last three years, has this establishment introduced new or significantly improved products or services? Pg 19	H.5. During the last three years, has this establishment introduced any new or significantly improved process, that is: methods of manufacturing products or offering services; logistics, delivery, or distribution methods for inputs, products, or services; or supporting activities for processes? Pg 20
Ghana	H.1. During the last three years, has this establishment introduced new or significantly improved products or services? Pg19	H.3. During the last three years, has this establishment introduced any new or significantly improved methods of manufacturing products or offering services? Pg19
Liberia	H.1. During the last three years, has this establishment introduced new or significantly improved products or services? Pg19	H.5. During the last three years, has this establishment introduced any new or significantly improved process, that is: methods of manufacturing products or offering services; logistics, delivery, or distribution methods for inputs, products, or services; or supporting activities for processes? Pg20
Mali	H.1. During the last three years, has this establishment introduced new or significantly improved products or services? Pg19	H.5. During the last three years, has this establishment introduced any new or significantly improved process, that is:

		methods of manufacturing products or offering services; logistics, delivery, or distribution methods for inputs, products, or services; or supporting activities for processes? Pg20
Niger	H.1. During the last three years, has this establishment introduced new or significantly improved products or services? Pg19	H.5. During the last three years, has this establishment introduced any new or significantly improved process, that is: methods of manufacturing products or offering services; logistics, delivery, or distribution methods for inputs, products, or services; or supporting activities for processes? Pg20
Country	Product	Process
Nigeria	H.1. During the last three years, has this establishment introduced new or significantly improved products or services? Pg19	H.3. During the last three years, has this establishment introduced any new or significantly improved methods of manufacturing products or offering services? Pg19
Senegal	H.1. During the last three years, has this establishment introduced new or significantly improved products or services? Pg19	H.5. During the last three years, has this establishment introduced any new or significantly improved process, that is: methods of manufacturing products or offering services; logistics, delivery, or distribution methods for inputs, products, or services; or supporting activities for processes? Pg20
Sierra Leone	H.1. During the last three years, has this establishment introduced new or significantly improved products or services? Pg19	H.5. During the last three years, has this establishment introduced any new or significantly improved process, that is: methods of manufacturing products or offering services; logistics, delivery, or distribution methods for inputs, products, or services; or supporting activities for processes? Pg20

Togo	H.1. During the last three years, has this establishment introduced new or significantly improved products or services? Pg19	H.5. During the last three years, has this establishment introduced any new or significantly improved process, that is: methods of manufacturing products or offering services; logistics, delivery, or distribution methods for inputs, products, or services; or supporting activities for processes? Pg20
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Appendix A1.2 ES Questions for Marketing and Organisational Innovation for Ghana and Nigeria

Country	Organisational	Marketing
Ghana	H.5. During the last three years, has this establishment introduced any new or significantly improved organisational structures or management practices? Pg20	H.6. During the last three years, has this establishment introduced new or significantly improved marketing methods? Pg20
Nigeria	H.5. During the last three years, has this establishment introduced any new or significantly improved organizational structures or management practices? Pg20	H.6. During the last three years, has this establishment introduced new or significantly improved marketing methods? Pg20

Appendix A1.3 ES Questions for Innovation Activities for all countries

Country	Export	R&D	AssetPurchase	Training
Benin	D.3c. In last complete fiscal year, what percentage of this establishment's sales were: Direct Exports Pg13	H.8. During last fiscal year, did this establishment spend on formal research and development activities, either in-house or contracted with other companies, excluding market research surveys? Pg21	K.4. In fiscal year 2015, did this establishment purchase any new or used fixed assets, such as machinery, vehicles, equipment, land or buildings, including expansion and renovations of existing structures? Pg28	L.10. Over fiscal year 2015, did this establishment have formal training programs for its permanent, full-time employees? Pg45
Côte D'Ivoire	D.3c. Coming back to fiscal year 2015, what percentage of this establishment's sales were: Direct Exports Pg13	H.8. During last fiscal year, did this establishment spend on formal research and development activities, either in-house or contracted with other companies, excluding market research surveys? Pg21	K.4. In fiscal year 2015, did this establishment purchase any new or used fixed assets, such as machinery, vehicles, equipment, land or buildings, including expansion and renovations of existing structures? Pg28	L.10. Over fiscal year 2015, did this establishment have formal training programs for its permanent, full-time employees? Pg45
Ghana	D.3c. In last complete financial year, what percentage of this establishment's sales were: Direct exports Pg12	H.7. During the last three years, did this establishment spend on formal research and development activities, either in-house or contracted with other companies? Pg20	K.4. In last complete financial year, did this establishment purchase any new or used fixed assets, such as machinery, vehicles, equipment, land or buildings? Pg27	L.10. Over last complete financial year, did this establishment have formal training programs for its permanent, full-time employees? Pg41
Liberia	D.3c. Coming back to fiscal year 2015, what percentage of this establishment's sales were:	H.8. During last fiscal year, did this establishment spend on formal research and development activities, either in-house or	K.4. In fiscal year 2015, did this establishment purchase any new or used fixed assets, such as machinery, vehicles, equipment,	L.10. Over fiscal year 2015, did this establishment have formal training programs for

	Direct Exports Pg13	contracted with other companies, excluding market research surveys? Pg21	land or buildings, including expansion and renovations of existing structures? Pg28	its permanent, full-time employees? Pg45
Country	Export	R&D	AssetPurchase	Training
Mali	D.3c. Coming back to fiscal year 2015, what percentage of this establishment's sales were: Direct Exports Pg13	H.8. During last fiscal year, did this establishment spend on formal research and development activities, either in-house or contracted with other companies, excluding market research surveys? Pg21	K.4. In fiscal year 2015, did this establishment purchase any new or used fixed assets, such as machinery, vehicles, equipment, land or buildings, including expansion and renovations of existing structures? Pg28	L.10. Over fiscal year 2015, did this establishment have formal training programs for its permanent, full-time employees? Pg45
Niger	D.3c. Coming back to fiscal year 2015, what percentage of this establishment's sales were: Direct Exports Pg13	H.8. During last fiscal year, did this establishment spend on formal research and development activities, either in-house or contracted with other companies, excluding market research surveys? Pg21	K.4. In fiscal year 2015, did this establishment purchase any new or used fixed assets, such as machinery, vehicles, equipment, land or buildings, including expansion and renovations of existing structures? Pg28	L.10. Over fiscal year 2015, did this establishment have formal training programs for its permanent, full-time employees? Pg45
Nigeria	D.3c. In last complete financial year, what percentage of this establishment's sales were: Direct exports Pg12	H.7. During the last three years, did this establishment spend on formal research and development activities, either in-house or contracted with other companies? Pg20	K.4. In last complete financial year, did this establishment purchase any new or used fixed assets, such as machinery, vehicles, equipment, land or buildings? Pg27	L.10. Over last complete financial year, did this establishment have formal training programs for its permanent, full-time employees? Pg41

Country	Export	R&D	AssetPurchase	Training
Senegal	D.3c. Coming back to fiscal year 2015, what percentage of this establishment's sales were: Direct Exports Pg13	H.8. During last fiscal year, did this establishment spend on formal research and development activities, either in-house or contracted with other companies, excluding market research surveys? Pg21	K.4. In fiscal year 2015, did this establishment purchase any new or used fixed assets, such as machinery, vehicles, equipment, land or buildings, including expansion and renovations of existing structures? Pg28	L.10. Over fiscal year 2015, did this establishment have formal training programs for its permanent, full-time employees? Pg45
Sierra Leone	D.3c. Coming back to fiscal year 2015, what percentage of this establishment's sales were: Direct Exports Pg13	H.8. During last fiscal year, did this establishment spend on formal research and development activities, either in-house or contracted with other companies, excluding market research surveys? Pg21	K.4. In fiscal year 2015, did this establishment purchase any new or used fixed assets, such as machinery, vehicles, equipment, land or buildings, including expansion and renovations of existing structures? Pg28	L.10. Over fiscal year 2015, did this establishment have formal training programs for its permanent, full-time employees? Pg45
Togo	D.3c. Coming back to fiscal year 2015, what percentage of this establishment's sales were: Direct Exports Pg13	H.8. During last fiscal year, did this establishment spend on formal research and development activities, either in-house or contracted with other companies, excluding market research surveys? Pg21	K.4. In fiscal year 2015, did this establishment purchase any new or used fixed assets, such as machinery, vehicles, equipment, land or buildings, including expansion and renovations of existing structures? Pg28	L.10. Over fiscal year 2015, did this establishment have formal training programs for its permanent, full-time employees? Pg45

Appendix A2.1 Marginal Effects for RBP2 model excluding Nigeria.

Variables	Product inv	Std error	Process inv	Std error
Product_inv			0.824***	0.057
RnD	0.286***	0.0365	-0.005	0.0375
Training	0.155***	0.027	-0.002	0.0281
AssetPurchase	0.065 ***	0.0246	0.049**	0.0247
Export	0.113***	0.0415	0.016	0.0392
Certification	-0.027	0.0511	-0.039	0.0466
2.Foreign owned	0.065*	0.035	-0.026	0.0307
3.Government	-0.12	0.1892	0.12*	0.0646
4.Other	0.048	0.0549	-0.171***	0.0353
Firmage	0.002	0.0011	0.001	0.001
Manager_exp	-0.001	0.0013	-0.002	0.0011
2.Medium Firm	0.019	0.0273	-0.008	0.0249
3.Large Firm	-0.048	0.0395	-0.000	0.035
Industry= Service	0.011	0.0247	-0.066***	0.0227
2.Côte D'Ivoire	0.046	0.0495	-0.022	0.0531
3.Ghana	0.214***	0.0463	0.135**	0.0559
4.Liberia	0.19***	0.0584	-0.055	0.0557
5.Mali	0.023	0.0566	0.129*	0.0671
6.Niger	0.038	0.059	-0.011	0.0632
7.Senegal	0.272***	0.0469	0.094	0.0584
8.Sierra Leone	0.081	0.0559	-0.051	0.053
9.Togo	0.048	0.0561	-0.092*	0.0547
ρ	-0.822*** (0.1251)			
Observations	2,060			
Log pseudolikelihood	-2148.9387			
Wald χ^2 (df)	1783.90*** (43)			
Wald Test on joint significance	9.07383***(1)			

Notes: The base variable for the ownership of firms is Domestic ownership. The base variable for firm size is Small Firm while the base variable for Country is Benin. Robust standard errors in parentheses. ***, **, and * denote 1%, 5% and 10% statistical significance respectively.

Appendix A2.2 Recursive Bivariate probit estimation for RBP Model (a)

Variables	Product inv	Std error	RnD	Std error
RnD	1.181***	0.4375		
Training	0.313***	0.0957	0.660***	0.0604
AssetPurchase	0.360***	0.0607	0.330***	0.0584
Export	0.121	0.0792	0.314***	0.0806
Certification	0.037	0.0914	0.255***	0.0975
2.Foreign owned	0.174**	0.0880	-0.300**	0.1187
3.Government	-0.364	0.3721	0.045	0.5099
4.Other	0.032	0.0796	0.010	0.0966
Firmage	0.000160	0.0023	0.00633**	0.0025
Manager_exp	-0.002	0.0027	-0.005	0.0033
2.Medium Firm	0.001	0.0513	0.0390	0.0666
3.Large Firm	-0.157*	0.0869	0.247**	0.1004
Industry= Service	0.007	0.0474	-0.165***	0.0594
2.Côte D'Ivoire	0.197	0.1434	-0.286	0.1834
3.Ghana	0.471***	0.1323	0.115	0.1622
4.Liberia	0.450***	0.1619	-0.101	0.2111
5.Mali	0.044	0.1652	0.060	0.2027
6.Niger	0.096	0.1698	-0.045	0.2161
7.Nigeria	0.609***	0.1247	0.042	0.1523
8.Senegal	0.728***	0.1340	-0.349*	0.1822
9.Sierra Leone	0.108	0.1637	-0.233	0.2105
10.Togo	0.111	0.1625	0.091	0.1962
Constant	-0.959***	0.1337	-1.490***	0.1641
ρ	-0.234 (0.2502)			
Observations	3,545			
Log pseudolikelihood	-3466.1002			
Wald χ^2 (df)	738.16*** (43)			
Wald Test on joint significance	0.813 (1)			

Notes: The base variable for the ownership of firms is Domestic ownership. The base variable for firm size is Small Firm while the base variable for Country is Benin. Robust standard errors in parentheses. ***, **, and * denote 1%, 5% and 10% statistical significance respectively.

Appendix A2.3 RBP estimation comparing Product Innovation and Export 1

Variables	Product inv	Std error	Export	Std error
Export	0.759**	0.3844		
RnD	0.704***	0.0859	0.309***	0.0797
training	0.356***	0.0567	0.171**	0.0672
AssetPurchase	0.364***	0.0519	0.204***	0.0613
certification	-0.003	0.0964	0.400***	0.0958
2.Foreign owned	0.053	0.103	0.689***	0.0937
3.Government	-0.391	0.372	0.182	0.446
4.Other	-0.0487	0.0953	0.557***	0.0870
Firmage	0.001	0.00224	-0.001	0.00285
Manager_exp	-0.00250	0.00260	0.00291	0.00340
2.Medium Firm	-0.004	0.0515	0.0589	0.0673
3.Large Firm	-0.188**	0.0903	0.390***	0.0945
Industry= Service	0.0129	0.0470	-0.167***	0.0603
2.Côte D'Ivoire	0.193	0.142	-0.208	0.170
3.Ghana	0.521***	0.132	-0.535***	0.169
4.Liberia	0.496***	0.164	-0.669***	0.243
5.Mali	0.024	0.165	0.167	0.193
6.Niger	0.092	0.171	-0.009	0.217
7.Nigeria	0.586***	0.126	0.180	0.148
8.Senegal	0.721***	0.134	-0.213	0.164
9.Sierra Leone	0.146	0.164	-0.979***	0.264
10.Togo	0.0116	0.171	0.593***	0.176
Constant	-0.958***	0.133	-1.510***	0.162
ρ	-0.333 (0.2087)			
Observations	3,545			
Log pseudolikelihood	-3383.6419			
Wald χ^2 (df)	841.02*** (43)			
Wald Test on joint significance	2.17829 (1)			

Notes: The base variable for the ownership of firms is Domestic ownership. The base variable for firm size is Small Firm while the base variable for Country is Benin. Robust standard errors in parentheses. ***, **, and * denote 1%, 5% and 10% statistical significance respectively.

Appendix A2.4 RBP model comparing Product Innovation and Export 2

VARIABLES	Product inv	Std error	Export	Std error
Product_inv			0.096	0.800
RnD	0.774***	0.0705	0.288	0.230
AssetPurchase	0.396***	0.0473	0.184	0.131
Training	0.387***	0.0526	0.157	0.131
Certification	0.0826	0.0868	0.400***	0.0985
2.Foreign owned	0.177**	0.0875	0.680***	0.105
3.Government	-0.372	0.409	0.173	0.461
4.Other	0.0554	0.0792	0.561***	0.0875
Firmage	0.000739	0.00223	-0.000795	0.00287
Manager_exp	-0.002	0.00264	0.003	0.00343
2.Medium Firm	0.004	0.0516	0.070	0.0667
3.Large Firm	-0.123	0.0852	0.396***	0.103
Industry = Service	-0.00949	0.0459	-0.163***	0.0607
2.Côte D'Ivoire	0.168	0.144	-0.198	0.176
3.Ghana	0.473***	0.132	-0.537**	0.217
4.Liberia	0.427***	0.163	-0.656**	0.269
5.Mali	0.0532	0.167	0.176	0.194
6.Niger	0.0912	0.171	0.00965	0.219
7.Nigeria	0.621***	0.125	0.166	0.228
8.Senegal	0.712***	0.135	-0.232	0.265
9.Sierra Leone	0.0703	0.163	-0.959***	0.263
10.Togo	0.144	0.164	0.586***	0.182
Constant	-0.926***	0.134	-1.539***	0.215
ρ	0.0159 (0.4837)			
Observations	3,545			
Log pseudolikelihood	-3385.0403			
Wald χ^2 (df)	753.43*** (43)			
Wald Test on joint significance	0.001083 (1)			

Notes: The base variable for the ownership of firms is Domestic ownership. The base variable for firm size is Small Firm while the base variable for Country is Benin. Robust standard errors in parentheses. ***, **, and * denote 1%, 5% and 10% statistical significance respectively.

Appendix A2.5 RBP model 1 comparing WAMZ and UEMOA

Variables	Product inv	Std. error	Process inv	Std. error
Process_inv	0.801***	0.1653		
RnD	0.151***	0.0609	0.259***	0.0262
Training	0.088***	0.0325	0.107***	0.0199
AssetPurchase	0.057*	0.0330	0.127***	0.0179
Export	-0.006	0.0343	0.096***	0.0269
Certification	0.051	0.0390	-0.030	0.0336
Foreign Ownership	0.069**	0.0356	-0.050	0.0321
Government Ownership	-0.092	0.1758	-0.091	0.1316
Other	0.061*	0.0343	-0.043	0.0294
Firmage	-0.000	0.0010	0.001	0.0009
Manager's experience	-0.000	0.0011	-0.002	0.0010
Medium firm	-0.007	0.0222	0.022	0.0203
Large firm	-0.033	0.0347	-0.027	0.0327
Industry = Service	0.025	0.0216	-0.060***	0.0176
MonetaryZone = UEMOA	0.073*	0.0402	-0.216***	0.0200
ρ	-0.276	0.3010		
Observations	3,536			
Log pseudolikelihood	-3864.2814			
Wald χ^2 (df)	1101.61*** (29)			
Wald Test on joint significance	0.759149			

Notes: The base variable for the ownership of firms is Domestic ownership. The base variable for firm size is Small Firm. Robust standard errors in parentheses. ***, **, and * denote 1%, 5% and 10% statistical significance respectively.

Appendix A2.6 RBP model 2 comparing WAMZ and UEMOA

Variables	Product inv	Std. error	Process inv	Std. error
Product_inv			0.413	0.2623
RnD	0.296***	0.0275	0.181***	0.0664
Training	0.141***	0.0203	0.066*	0.0372
AssetPurchase	0.130***	0.0181	0.095***	0.0334
Export	0.062**	0.0273	0.097***	0.0310
Certification	0.019	0.0338	-0.048	0.0382
Foreign Ownership	0.021	0.0327	-0.074**	0.0353
Government Ownership	-0.132	0.1421	-0.048	0.1571
Other	0.019	0.0305	-0.064**	0.0330
Firmage	0.000	0.0009	0.001	0.0010
Manager's experience	-0.001	0.0010	-0.001	0.0011
Medium firm	0.010	0.0202	0.025	0.0221
Large firm	-0.045	0.0329	-0.007	0.0364
Industry = Service	-0.020	0.0177	-0.065***	0.0192
MonetaryZone = UEMOA	-0.083***	0.0198	-0.227***	0.0227
ρ	0.276	0.3685		
Observations	3,536			
Log pseudolikelihood	-3866.2806			
Wald χ^2 (df)	688.91***(29)			
Wald Test on joint significance	0.504141			

Notes: The base variable for the ownership of firms is Domestic ownership. The base variable for firm size is Small Firm. Robust standard errors in parentheses. ***, **, and * denote 1%, 5% and 10% statistical significance respectively.

Year	Gold (Ounces)	Year	Gold (Ounces)
1960	915,317	1990	522,517
1961	878,459	1991	946,269
1962	823,115	1992	1,006,943
1963	911,663	1993	1,251,010
1964	912,592	1994	1,396,887
1965	851,090	1995	1,630,309
1966	708,906	1996	1,550,814
1967	724,134	1997	1,644,622
1968	757,346	1998	2,353,000
1969	750,435	1999	2,257,681
1970	714,442	2000	2,315,000
1971	693,770	2001	2,205,473
1972	710,013	2002	2,115,196
1973	371,711	2003	2,208,154
1974	709,550	2004	1,794,497
1975	583,103	2005	2,149,372
1976	515,654	2006	2,244,680
1977	531,084	2007	2,486,821
1978	465,651	2008	2,585,993
1973	387,730	2009	3,130,328
1980	342,904	2010	3,270,080
1981	338,042	2011	3,614,385
1982	337,754	2012	4,313,190
1983	285,291	2013	3,192,648
1984	275,291	2014	3,167,755
1985	265,795	2015	2,848,574
1986	465,651	2016	4,150,000
1987	337,754	2017	4,610,000
1988	338,042	2018	4,803,257
1989	342,904	2019	4,577,637
		2020	4,022,502

Source: Author's compilation from Minerals Commission (2014) 1960-1983, Minerals Commission of Ghana (2011) 1984-1989, Ghana Chamber of Mines (2015) 1990-2015 Ghana Chamber of Mines report 2016-2020.

Appendix A4.2: Table for figure 4.2

Year	Local Purchases as a percentage of Mineral export receipts
2008	22
2009	28
2010	21
2011	18
2012	29
2013	22
2014	20
2015	28
2016	31
2017	34
2018	44
2019	42
2020	51.93

Source: Author's compilation from Ghana Chamber of Mines report 2011-2020

Questions on Product innovation going by the World Bank Enterprise Survey	Questions on process innovation going by the World Bank Enterprise Survey
1. Has this establishment introduced any innovative product or service to the market since it began supplying to the mining industry?	1. Has this establishment introduced any new or significantly improved method of manufacturing products or providing services since supplying to the mining industry?
2. If yes to above question, describe in detail how the main innovative product or service is different from other similar products or services (or whether the product or service is completely new).	2. Please describe in detail the innovative process and how the innovative process is different from other similar production processes (or is it a completely new process).
3. Why was this product or service introduced onto the market?	3. Is this new production process used in the production of a new product or service?
4. Is this innovative product or service new to the local market or international market?	4. Is this innovative production process new to the local industry or international industry?
5. How did this establishment develop the idea for this innovative product or service?	5. How was the idea for this innovative production process developed?
6. Was this innovative product or service developed entirely by this establishment?	6. Was the innovative process developed entirely by this establishment?
7. Were employees hired specifically for the development of this innovative product or service?	7. Were employees employed specifically for the purpose of developing an innovative production process?
8. Has this establishment attempted to develop an innovative product or service that was abandoned?	



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UCT Commerce Faculty Office

30th October 2019

Ms Betty-Ann Ananeh- Frempong

School of Economics University of Cape Town

Dear Ms Ananeh-Frempong

REF: REC 2019/10/048

CASE STUDY OF THE LINKAGES IN THE GOLDMINING INDUSTRY IN GHANA

We are pleased to inform you that your ethics application has been approved. Unless otherwise specified this ethical clearance is valid for 1 year and may be renewed upon application.

Please be aware that you need to notify the Ethics Committee immediately should any aspect of your study regarding the engagement with participants as approved in this application, change. This may include aspects such as changes to the research design, questionnaires, or choice of participants.

The ongoing ethical conduct throughout the duration of the study remains the responsibility of the principal investigator.

We wish you well for your research.

Shandre Swain

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