UNIVERSITY OF GHANA

COLLEGE OF HUMANITIES

SCHOOL OF SOCIAL SCIENCES

AN INVESTIGATION INTO THE ROLE OF R&D ON PRODUCTIVITY IN THE MANUFACTURING SECTOR IN GHANA

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DEPARTMENT OF ECONOMICS

JULY, 2019

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BY

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A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES IN PARTIAL FULFILMENT FOR THE AWARD OF THE DEGREE OF MASTER OF PHILOSOPHY IN ECONOMICS

DEPARTMENT OF ECONOMICS

JULY, 2019

DECLARATION

I, CARLOS KOKUVI TETTEH, hereby declare that this thesis was undertaken by me under the keen direction of my supervisors and nothing was taken from elsewhere except the works of other people who have been duly referenced. This thesis has neither in part nor in wholly been submitted for another degree at any academic institution elsewhere.

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ABSTRACT

Using a firm-level dataset of 209 firms from the World Bank Enterprise Survey 2013, this study presents evidence of the impact of R&D, product, and process innovation on labour productivity in the manufacturing sector in Ghana. It examines the role R&D plays in ensuring the likelihood of manufacturing firms to embark on product and process innovation. The study employed a Three-Stage Least Square (3SLS) approach for the analysis in achieving the stated objectives.

The study finds that labour productivity in the manufacturing sector in Ghana is determined by R&D, product innovation, foreign ownership, and the size of the firm. The results show a significant positive influence of R&D and product innovation on labour productivity in the manufacturing sector in Ghana.

The study recommends the integration of the Science, Technology, and Innovation Policy of Ghana into the national development strategy to create an enabling environment for manufacturing firms to invest more into R&D activities and thereby become more productive. The study also suggests the need for the Government to support research and development and innovation through a coordinated effort by implementing a multi-sector policy action that considers the needs of the firms.

DEDICATION

In memory of my beloved grandmother, Madam Agnes Abena Kuwornu.

ACKNOWLEDGEMENTS

My utmost gratitude goes to my supervisors, Dr. Festus Ebo Turkson and Dr. Emmanuel Codjoe for the immense support and guidance granted to me, without which this thesis would not have been completed. Special thanks to Dr. Michael Danquah for sharing the data with me and his motivation for me to undertake this study. I also thank Dr. Emmanuel Abbey for the superb support he rendered to me during this study.

I am grateful to Prof. Adusei Jumah, Prof. Anthony Amoah, and Mr. Edmund Kwabla at Central University for their assistance. Special thanks to my family especially my mother, Madam Susana Pinto, Mr. Richard MacCarthy, and Madam Alice Adu for their varied support in my education. I am immensely grateful to Pastor Desmond Aidoo and Mrs. Mercy Aidoo as well as Vivian Agbenyo for their support in prayers.

Special thanks to my colleagues, Mark Senanu Kudzordzi and Godfred Armah Mensah for their unflinching assistance in varied ways towards the completion of this thesis. GOD richly bless you all!

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LIST OF ACRONYMS

2SLS	Two-Stage Least Squares
3SLS	Three-Stage Least Squares
CDM	Crépon, Duguet and Mairesse
CIS	Community Innovation Survey
ERP	Economic Recovery Programme
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GPRS	Growth and Poverty Reduction Strategy
GSS	Ghana Statistical Service
ILO	International Labour Organisation
MESTI	Ministry of Environment, Science, Technology, and Innovation
MoE	Ministry of Energy
MoF	Ministry of Finance
MTDP	Medium-Term Development Plan
NDPC	National Development Planning Commission
NDPC	National Development Planning Commission
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
PICS	Productivity and Investment Climate Survey
R&D	Research and Development
RBC	Real Business Cycle

SSA	Sub-Saharan Africa
STI	Science, Technology and Innovation
SUR	Seemingly Unrelated Regression
TFP	Total Factor Productivity
UNCTAD	United Nations Conference on Trade and Development
WBES	World Bank Enterprise Survey

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

According to the Frascati Manual, "Research and development (R&D) comprise creative and systematic work undertaken to increase the stock of knowledge including knowledge of humankind, culture, and society and to devise new applications of available knowledge" (OECD, 2002, p.1). R&D activities involve a well-structured practice that creates knowledge and innovation in scientific technology (Wang, 2010). High-technology industries have emerged in the 21st century as the global economy took on R&D activity which has resulted in substantive growth in economies where progress in technology is affected by economic and institutional factors (Wang, 2010).

Mankiw et al. (1992) and Romer (1994) argued that knowledge creation and human capital formation were essential for long term economic growth. R&D investment plays a significant role in technological advancement and growth in the economy as identified by (Griliches, 1980; Mansfield 1988; Cohen & Levinthal, 1989; Feller, 1990; Adams & Griliches, 1996; Stephan, 1996; Madden et al., 2001; Fraumeni & Okubo, 2002; Maloney & Rodriquez-Clare, 2007). As a result, any economy that devotes adequate resources to research and development may advance in knowledge and improve productivity, thus achieving the desired growth target.

The African Union Executive Council in 2006 decided that member states of the African Union allocate 1% of their Gross Domestic Product (GDP) to Research and Development. The African

Innovation Outlook 2010 revealed that only South Africa, Uganda, and Malawi spend above the targeted 1% of their GDP on R&D. Out of the 19 countries surveyed, 16 countries spent between 0.2% - 0.48% on R&D. According to the World Development Indicators in 2010, the share of researchers in the African continent is 25 times lower than that of the United Kingdom and 28 times lower than the United States of America and this may contribute to the dearth of R&D investment in Africa due to the gap in resources and facilities required to undertake cutting-edge R&D activities. Ghana's investment in R&D expressed as a share of GDP was 0.23 in 2007 and 0.38% in 2010 which plummet below the African Union's target of 1% of GDP.

In 2010, the government of Ghana launched an Industrial Policy on a backdrop of attaining middle-income status by 2020 as a result of a rapid transformation of the economy into one driven by the industrial sector (Ghana Industrial Policy Report, 2010). The Industrial Policy advocates for the role of innovation and policies targeted at improving the level of research and development, and science and technology in the industrial sector. The main objective of the policy is to address the collection of challenges encountered by the manufacturing sector that influence the product quality, production capacity, and productivity in the sector (Ghana Industrial Policy Report, 2010). Effective implementation of the Industrial Policy is geared towards ensuring Ghanaian manufacturers offer high-quality products, processes, and services to become globally competitive.

Innovation involves the execution of an improved product or processes, improved marketing methods, and procedures (OECD, 2005). Griffith et al. (2006) and Mairesse & Mohnen (2010) have argued that firms that engage in R&D activities tend to introduce innovation which may ultimately lead to productivity. Baumann & Kritikos (2016) found no significant difference in the link between R&D, innovation, and productivity in the size of the firms. Thus, any firm irrespective of the size, that engages in R&D may drive innovation and eventually realize productivity.

1.2 Statement of the problem

Challenges with the availability of data and innovation measurements have accounted for the limited empirical studies on innovation and productivity in low-income countries (Wunsch-Vincent & Kraemer-Mbula, 2016). The extensive empirical literature on R&D, innovation, and productivity concentrated on the developed economies as well as the so-called ‘catching up’ economies (Fagerberg et al., 2010) using the Community Innovation Survey (CIS) in the framework of countries in the European Union and the Productivity and Investment Climate Survey (PICS) for some developing countries. Some studies have analyzed the impact of innovation on firm productivity (Goedhuys et al., 2008; Gebreeyesus, 2009) as well as its determinants (Robson et al., 2009; Goedhuys, 2007) for firms in low-income countries.

Most of the studies on developing countries found a statistically insignificant effect of one of the innovation variables on productivity (Fagerberg et. al. 2010). However, Goedhuys (2007) and Goedhuys et al (2008) failed to confirm any significant impact of innovation on productivity using the Productivity and Investment Climate Survey (PICS) dataset for some seven developing countries. In Tanzania, they found that, neither R&D, process nor product innovation enhances productivity and that the business environment plays a more relevant role.

However, Fu et al. (2018) found a significant positive impact of innovation on labour productivity in Ghana but did not account for the role of Research and Development (R&D) in ensuring the likelihood of firms to innovate. Innovation is undertaken in varied forms (process innovation, product innovation, managerial or organizational innovation as well as marketing innovation) (Fu et. al., 2018). This study, however, focuses on product and process innovation which are very essential for the manufacturing sector.

R&D is one of the key elements in determining product and process innovation and the role of R&D in influencing innovation and ultimately affecting productivity is of great concern. This study aims to fill this gap in the literature by accounting for the role of R&D in driving innovation and ultimately ensuring the productivity of manufacturing firms in Ghana.

1.3 Research questions

1. What determines labour productivity in the manufacturing sector in Ghana?
2. What is the role of R&D on labour productivity in the manufacturing sector?

1.4 Objectives of the study

The general objective of the study is to determine the effect of R&D and innovation on productivity in the manufacturing sector in Ghana.

The specific objectives are:

1. Examine the determinants of labour productivity in the manufacturing sector in Ghana.
2. Examine the role of R&D in labour productivity in the manufacturing sector.

1.5 Significance of the study

This study contributes to various literature that has examined the impact of R&D and innovation on productivity using firm, industry, and aggregate level data. The usual approach that has been employed in most studies is an estimation of the output elasticity of the R&D stock and its return using a Cobb-Douglas production function that comprises a factor for knowledge capital. This study, however, uses a different approach in line with Parisi et al. (2006) taking into account that productivity growth is affected by innovation output.

This study is significant on the basis that examining the role of R&D in the likelihood of firms to innovate and influence the productivity levels of manufacturing firms may aid business managers and policymakers to determine the significance of R&D activities and direct resources to productive factors in the economy.

1.6 Organization of the study

The study is organized into six (6) chapters with the following outline:

Chapter One provides a background to the study, discusses the problem statement, and outlines the significance and objectives of the study. Chapter Two gives an overview of R&D, innovation, and productivity in Ghana. Chapter Three reviews both theoretical and empirical literature on the relationship between R&D, innovation, and productivity at the firm level. Chapter Four then provides the methodology and the theoretical framework employed in this study. Chapter Five presents the results and the discussion of the results. Finally, Chapter Six presents the summary, conclusion, and policy recommendations based on the findings of the study.

CHAPTER TWO

OVERVIEW OF R&D AND INNOVATION IN GHANA

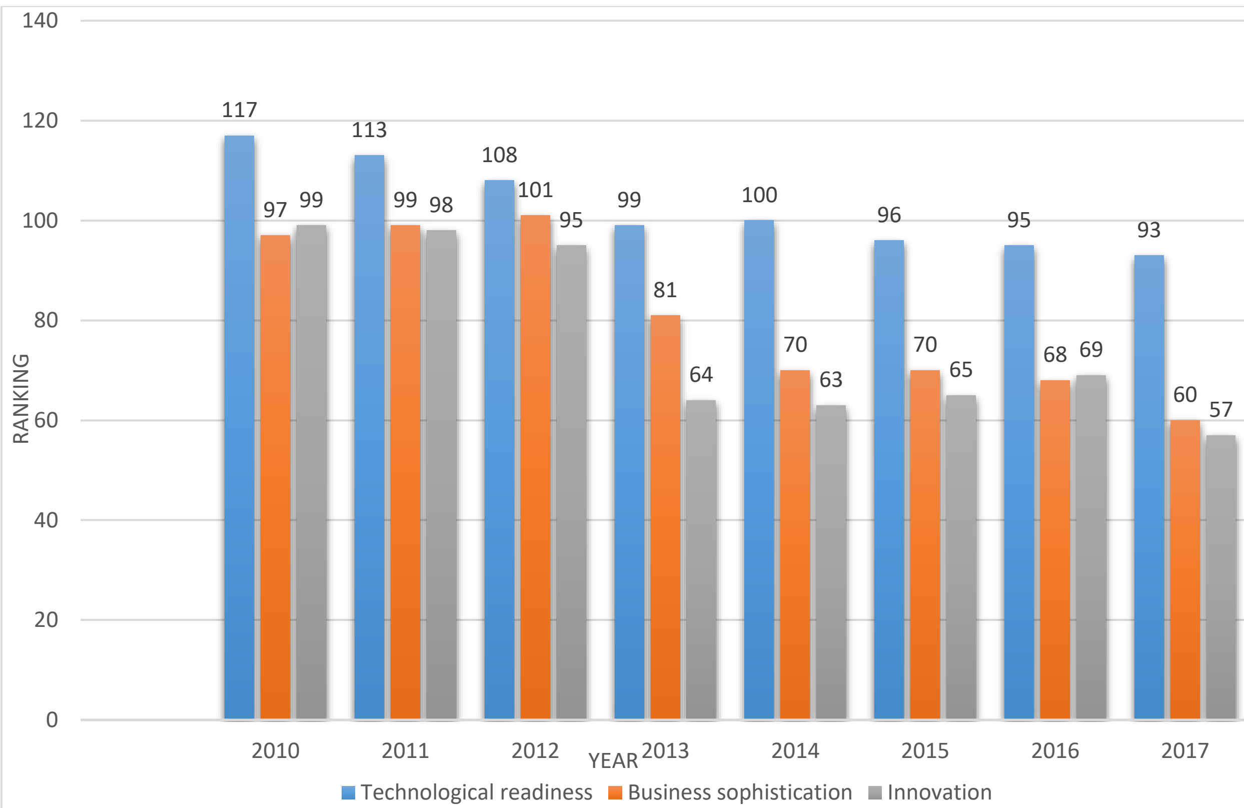
2.0 Introduction

This chapter provides a summary of the innovation, business sophistication, and technological readiness in Ghana. The chapter also presents the national innovation system, assessment of the nation's system of innovation as well as research and development funding in Ghana.

2.1 Innovation, Business Sophistication, and Technological readiness in Ghana

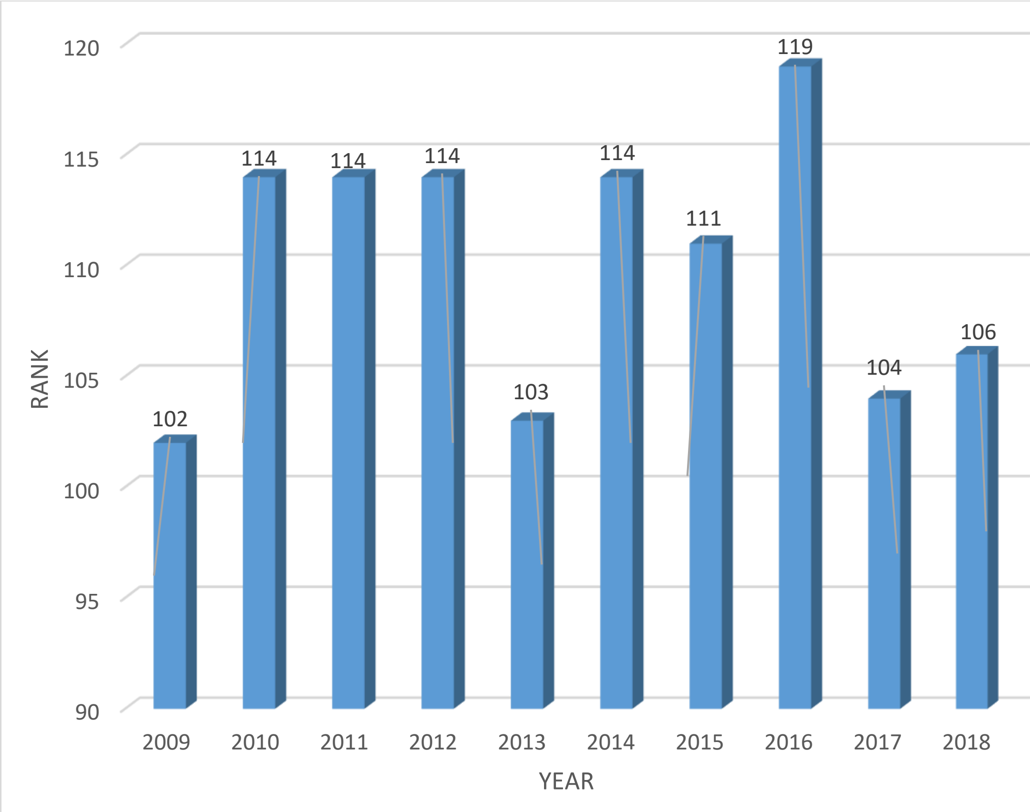
Figure 2.1 provides the rankings of Ghana for the period 2010 to 2017 based on the Global Competitiveness Index. Using the pillars of technological readiness, business sophistication, and innovation as the benchmark to measure the competitiveness of Ghana, it can be noted that these pillars are expedient in the determination of research development since technological readiness, business enlightenment, and innovation are intrinsically linked to the promotion of productivity. It is deduced that from 2010, Ghana's readiness to adapt to technology has improved considerably to 2017. However, there was a marginal decline in Ghana's readiness to adapt to technological progress in the year 2014 as this period witnessed an upward adjustment in Ghana being less prepared to adapt to technological progress from a ranking of 99 in 2013 to 100. Despite this setback, technological progress has thereafter improved from a ranking of 96 to 93 from 2015 to 2017. Generally, business sophistication has increased from 2010 to 2017. But for the reduction in 2012 to the ranking of 101, Ghana has seen an improvement in the ranking from 81 in 2013 to her topmost ranking yet in 2017 with a rank of 60.

Even though there was an advancement in the overall performance of Ghana's approach to innovation from 2010 to 2017 with a ranking from 99 to 57, 2016 was different. This is because, in 2016, Ghana dropped to the 69th position from a previously held position of 65th position in 2015. However, efforts in innovation improved significantly in 2017 as Ghana's ranking upgraded to the 57th position.



Source: World Economic Forum
Note: The highest-rank is 1 implying the economy is more competitive.

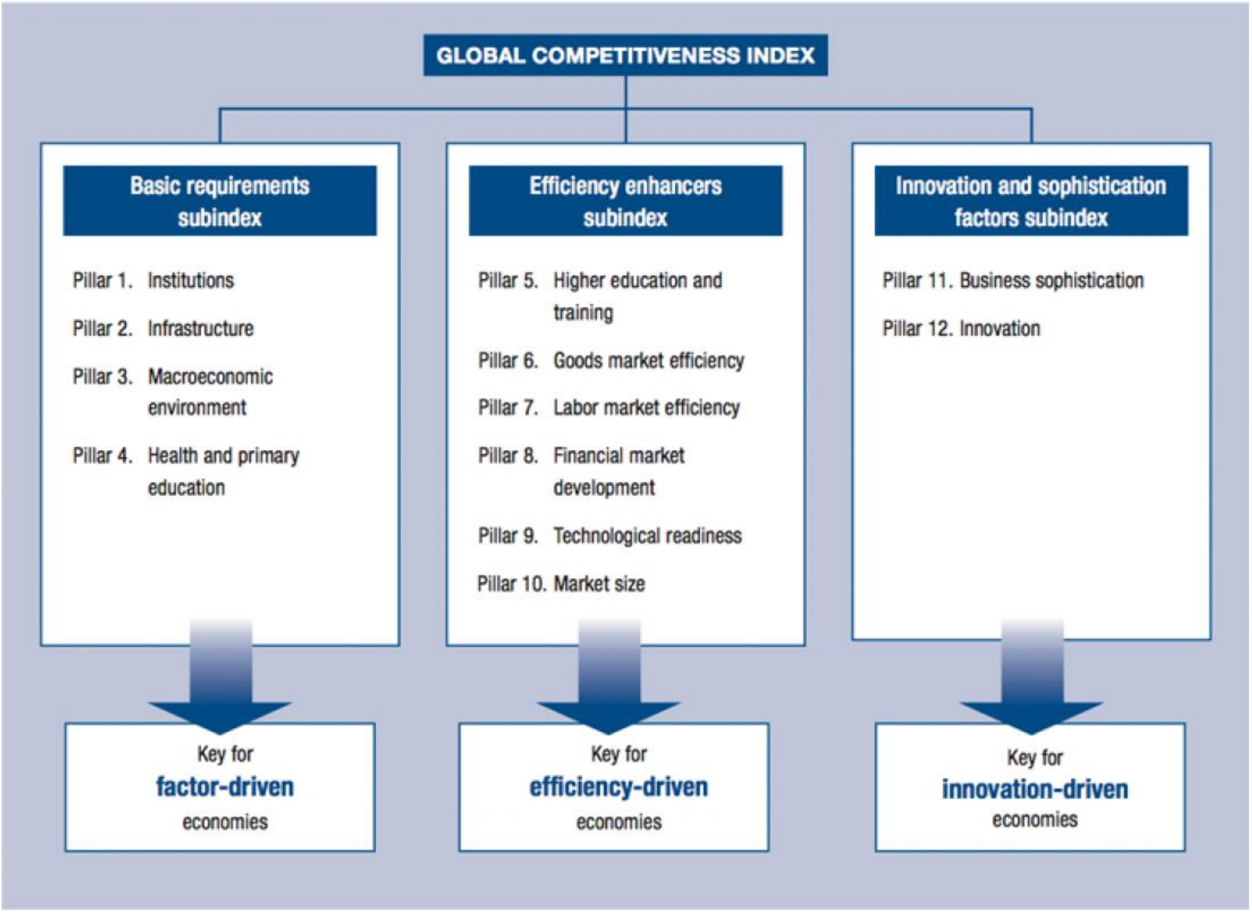
Figure 2.1: Innovation, Business sophistication and Technological readiness ranking for Ghana in 2010 – 2017



Source: World Economic Forum

Figure 2.2: Ghana's Global Competitiveness ranking from 2009 – 2018

From Figure 2.2 above, the 2018 Global Competitiveness Report revealed that, out of 140 countries, Ghana was ranked as the 106th most competitive country in the world. The competitiveness rank of Ghana on the average was 110th from 2009 until 2018, obtaining the worst rank in 2016 with 119th, and the best rank of 102th in 2009.



Source: World Economic Forum

Figure 2.3: The framework of the Global Competitiveness Index

From Figure 2.3 above, the stage of development of Ghana's competitiveness can be said to be at the bottom tier of countries since Ghana is mostly a factor-driven economy. Due to the reality of factor-driven economies being unable to have adequate ability to be innovative, add much value to their products as well as being plagued with finite managerial and organizational ability which translates into unsophisticated local enterprises, low commercial and technological visibility, and untrained labour amongst others, it becomes difficult for productivity to be realized. For this reason, for the Government of Ghana to shore up competitiveness and innovation in the economy, it is expedient that critical attention should be given to the aforementioned factors to change the economy from a "factor-driven" nation to an "innovation-driven" economy. Given this, the development of STI is of utmost importance to the government of Ghana. This is evidenced by the inclusion of STI development in policy-driven statements of the government.

2.2 National Innovation System of Ghana

The Global Competitiveness Index indicated the limitations Ghana faces in her support for technological progress to boost productivity and capitalize on the benefits of being competitive internationally through the creation of industries. Due to the seeming advantage that knowledge and innovation have on the turnaround of the economy and mitigating poverty, the government has ensured that STI progress assumes priority status. The inclusion of STI development has been duly represented in various partisan and policy statements. GPRS II proffer the view that a higher sense of appreciation for the use of science and technology may be a vital tool for successful progress. The National Development Planning Commission of Ghana thus prepared the medium-term development plan in which Ghana with the vision of transforming Ghana into a modernized economy that thrives on science and technology by 2020 (UNCTAD, 2011).

For this reason, changes are happening at the level of policy interventions. In present times, Ghana's discussions on STI has received support in various ways. The role STI policies may play in the desire to accelerate growth and be a part of knowledge enhanced economies does not stand in doubt. However, the situation that persists in Ghana is rather a lack of effective and applicable planning, and enactment of the STI policies and programs, suitable to meet the prominence specified to the STIs in the policy reports. Also, progress on the planning and active implementation of these policies and programs have been ineffective in cases where these policies exist although they were well-conceived.

UNCTAD (2011) established that so much evidence abounds on the need to recognize the relevance of an upgrade in technology and innovation, creation, and employment of knowledge as well as the production and taking on of innovative products as crucial elements to creating sustained economic growth and enhanced living standards. Though these are important drivers of advancement in commercial and societal life, and inducing competitiveness in trading, they cannot independently be a development solution. Extraordinary intensities in innovative capacity and undertakings result in the transformation of economies from low-income economies to middle and high economies.

The government of Ghana acknowledges the effect of knowledge and innovation in enhancing development in the economy, diminishing the effect of poverty, and improving its' competitiveness in trade. This acknowledgment has been featured in a considerable number of policy reports of the government. From time to time, policymakers and politicians in Ghana refer to the impact of science, technology, and innovation in economic development and the need to show commitment to R&D. Unfortunately, policies and political statements are scarcely supported by specific actions. The lack of an enabling environment also stampedes efforts made by the private sector to generate innovation of any kind which, consequently, makes it impossible to generate a forceful engine of growth in the medium and longer-term.

Ghana's innovation system is comparatively smaller and poorly developed to middle-income nations, for example, India. Although marginal successes have been attained in economic and political governance frameworks over the previous years, there is a gap in the modernity of regulations and enforcement (UNCTAD, 2011). Besides, these regulations have not been adjusted with growth and human development goals.

2.3 Assessment of the innovation system

The problems of having a debilitating effect on Ghana's system of innovation are as follows:

The country's inability to have adequately able and a renowned lead institution to superintend over advancements in technology, as well as innovation for economic growth and development, has often translated into poor institutional configuration and leadership. These institutions lack proper connectivity and are not collaborating to effectively promote technological progress in economic events. Another problem facing the promotion of the system of innovation in Ghana is the inadequate explicit national innovation policy and related strategy. Until 2010, the policy regulations have been largely hidden and dispersed in many government papers. In time past, there has been a deficiency of consistency in the attention and the way policy on innovation is met (UNCTAD, 2011).

Again, scarce funding may be attributed to poor performance in the nation's system of innovation. This is because allocation to funding in Ghana's spending on R&D and interrelated innovation undertakings are scarce. Funds channeled to research institutions are meant for the payment of remunerations and catering for some cost of operations. Presently, Ghana is poorly tackling innovation in both the public and the private sectors. Also, educational institutes hardly produce the human capital of the prerequisite value and number to boost industrial invention for economic growth (UNCTAD, 2011).

Unreliable and costly electricity which constitutes part of physical infrastructure amongst others is also a liable cause of the dwindling effect of the innovation system in both the private and state enterprises in Ghana. Indeed, insufficient political support for STI at peak levels in the past has been a major factor debilitating against the prominence of the system of innovation. Policy transformation in STI is usually subject to a high point of cutoff and there is a perception that seems to suggest that innovation policymaking requires a promoter and efficient leadership at the institutions.

Accordingly, Zachary (2003) asserts Ghana's political system has not provided sufficient response to STI issues even though there is ample proof to support the potential positive effects of STI in accelerating growth and development. To solve this, steps ought to be taken to stimulate and create a conducive environment for the private sector to strive and engage in an upgrade in technology and promote innovation.

2.4 R&D funding in Ghana

In Ghana, R&D is mostly sponsored by the central government. In the preparation of the annual budget, a portion is allocated to the Ministry of Environment, Science, Technology and Innovation, and other related ministries representing about a minimum of 70 percent of allocations to the state-owned R&D institutions in the country. It is imperative to be aware of no definite institution mandated to finance research and development programmes in the country. Besides, to conduct R

& D activities, most of the state-owned R&D related institutions depend on the international community for grants. The funding of these programmes is mainly done on project-based and usually temporary (UNCTAD, 2003a).

Most estimates assume that the government of Ghana spends as little or below 0.3 percent of GDP on R&D, even though there is virtually a lack of authentic current statistics or records of public spending on R&D. This is in sharp contrast to the proposed target of 1 percent of GDP on R&D expenditure by the African Union. UNCTAD (2003a) noted that allocations to the Ministry of Environment, Science, Technology, and Innovation constitute only about 0.25 percent of the GDP, a reflection of the importance accorded to science and technology and the environment. Additionally, nearly two-fifths of the institutions' allocations for research and development is used for the purpose. Adarkwa (2008) opined that R&D financing per GDP remains unsteady in Ghana.

However, the budgetary allocations of the Ministry of Environment, Science, Technology, and Innovation (MESTI) for research and development shows a steady increment from 2016 to 2018 as depicted in Table 2.1 below

Table 2.1: Ministry of Environment, Science, Technology, and Innovation Budget allocation (2016 -2018)

Item	2016 (GH₵)	2017 (GH₵)	2018 (GH₵)
Management & Administration	23,355,581	106,426,557	46,455,202
Research & Development	162,893,063	180,175,440	227,969,159
Environmental Protection & Management	75,397,290	46,222,791	70,876,370
Spatial Planning	12,369,219	14,828,321	14,949,035
Biosafety Development	200,000	1,499,034	1,727,709
Total Allocation for the year	274,215,153	349,152,142	361,978,374

Source: Ministry of Finance

From Table 2.1, Research and Development budgetary allocation for 2016 was GH₵ 162,893,063 representing approximately 59.4% of the total budgetary allocation for the Ministry whereas, in 2017, Research and Development allocation increased to GH₵ 180,175,440 representing approximately 51.6%. However, in 2018 there was a significant increase in the allocation of R&D to GH₵ 227,969,159 which represented approximately 63% of the total allocation to the Ministry. This shows that the Government of Ghana is increasing funding in R&D.

2.5 Conclusion

This chapter identified that Ghana is making progress in terms of innovation, business sophistication, and technological readiness as revealed from the global competitive index for the period 2010 to 2017 which showed a year on year improvement and an indication of Ghana becoming more competitive in innovation. Also, it was identified that though Research and Development expenditure at the national level is increasing year on year, the percentage of R&D

expenditure as a share of GDP is less than 1 percent which does not meet the target of the African Union. Ghana has a long way to go in expanding the expenditure on research and development to benefit massively from it.

CHAPTER THREE

LITERATURE REVIEW

3.0 Introduction

This chapter reviews the theoretical and empirical literature of the study. The theoretical literature includes the innovation process, theoretical determinants of innovation, and theories of innovation and productivity. The empirical literature includes studies that examined the link between R&D, innovation, and productivity, the impact of R&D on innovation, and the determinants of innovation.

3.1 Theoretical Review

3.1.1 The innovation process

A firm may decide to innovate or not to innovate. When the firm chooses to innovate, then the firm's decision to innovate may influence the innovation intensity or innovation input employed by the firm. The innovation process links the innovation input to the innovation output, thus the kind of innovation input employed by the firm determines the innovation output through the innovation process. The innovative output of the firm then translates into the firm's performance or productivity level. This is illustrated pictorially in **Figure 3.1** below:

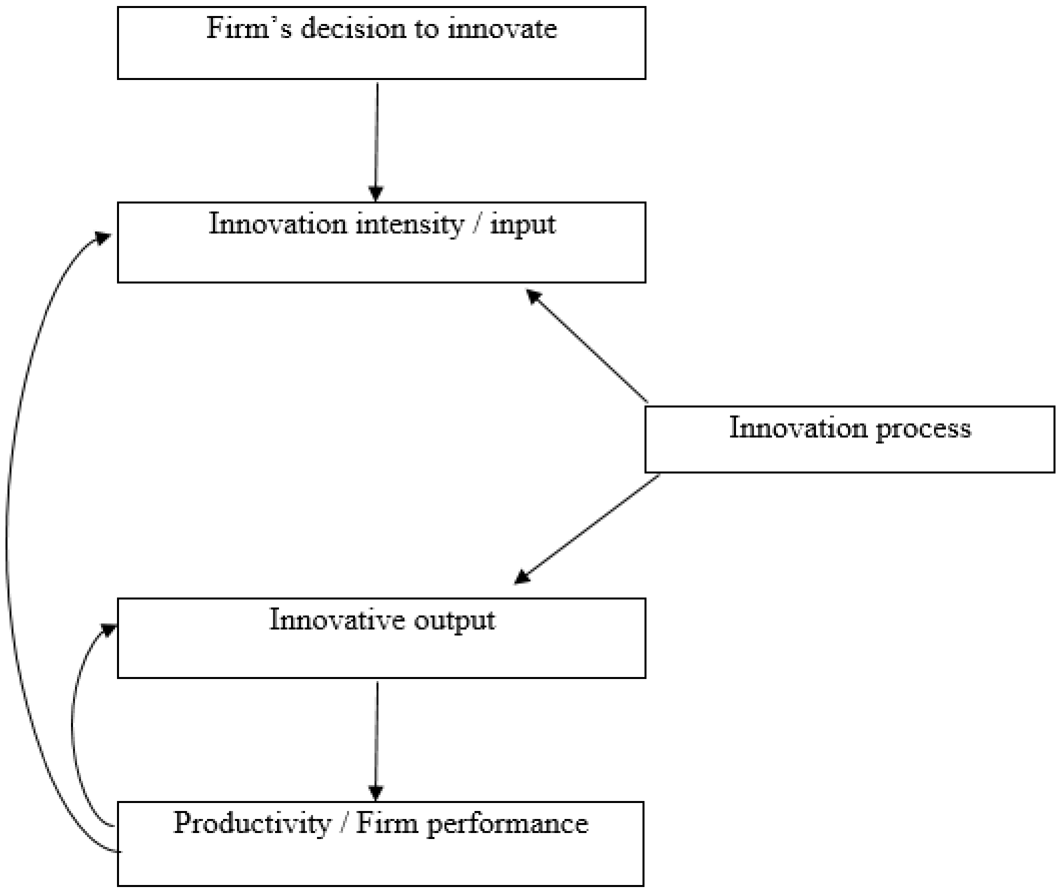


Figure 3.1: The Research Model

Source: (Kemp, Folkeringa, de Jong & Wubben, 2003)

3.1.2 Theoretical Determinants of Innovation

The theoretical factors that influence innovation at the firm level or the decision of the firm to embark on innovation activity are very essential in this study. According to Schumpeter (1912), with the introduction of the usage of the term innovation, earmarked some factors that determine innovation. Schumpeter (1912) postulated that firm size influences innovation positively. Large firms may engage in innovation and benefit from economies of scale. Large firms and small firms can undertake massive projects concurrently and thereby reduce R&D inclined risks. Also, large firms have a more extensive capacity to obtain huge credit facilities, amass a greater amount of human skills and knowledge than small firms.

Another factor that determines innovation is the age of the firm. Firm age is said to have a significant influence on innovation. Relatively younger firms tend to be more likely to engage in innovation activities since they may be driven by the need to grow and be competing with the larger firms whereas the larger firms may have set standards that may not be flexible enough to boost innovation. However, large firms may be more advantageous owing to their experiences.

Foreign ownership also affects innovation at the firm level. Firms that a fully foreign-owned or have a proportion of foreign ownership may have an advantage over the fully indigenous firms in terms of technology, managerial, and organizational skills and compete in the international markets. Firms with foreign capital ownership tend to innovate than firms that are locally owned. Harrison & McMilan (2003) argued that firms with foreign ownership are more likely to attract credit from foreign lenders and are fewer credit constraints compared to locally owned firms and thereby engage in innovative activities.

Firms that export are more likely to innovate due to the competition they are exposed to in the international market and the need to maintain their market share. Martinez-Ros (2000) argued that firms that export are more likely to innovate. In this regard, export has a positive influence on innovation.

3.1.3 Innovation and Productivity

Contemporary theories of economic growth account for the role of endogenous technological change in explaining the patterns of growth of the world economies. Romer (1986 & 1990a) and Aghion & Howitt (1992) describe the role of human capital as the main factor in determining growth through innovation. Romer (1990a) argues that people that are motivated to search for new ways of doing things drive innovation.

The Solow (1957) model fixed in continuous time includes four variables namely Labour denoted by L, Capital represented by K, Technology denoted by A, and Y representing Output. In this model, there exist two sectors, one sector involves knowledge accumulation to the existing stock of knowledge denoted by the R&D sector and a sector for the production of goods. A fraction of the labour force denoted (a_L) is used in the R&D sector and a fraction ($1-a_L$) used in the goods production sector. Also, capital stock is shared amongst the two sectors with a fraction a_K for the R&D sector and a fraction ($1-a_K$) for the goods production sector. The two sectors use the full level of technology (A). The quantities of labour, capital, and the technology level determine the production of new ideas:

$$\acute{A} = G\ (a_K K(t), a_L L(t), A(t)) \qquad (1)$$

Assuming the generalized Cobb-Douglas production function, this becomes;

$$\acute{A} = B[a_K\ K(t)]^{\beta}\ [a_L L(t)]^{\gamma}\ A(t)^{\theta} \qquad (2)$$

B>0, $\beta \geq 0$, $\gamma \geq 0$, $\theta \geq 0$

Introducing other important variables into the model to augment the endogenous conceptual framework in equation (1), this study proposes that innovation is influenced by firm age, research and development, foreign ownership, export, firm size, sector differences, and location differences.

3.2 Empirical Review

The section presents empirical studies on the link between R&D and productivity, innovation and productivity, the determinants of innovation research and development as well as the link between R&D, innovation, and productivity.

3.2.1 R&D and Productivity

Wakelin (2000) assessed productivity growth and R&D expenditure in a sample of 170 manufacturing firms in the UK using a Cobb-Douglas function with the role of R&D intensity. The study found that R&D expenditure plays a positive and significant role in the productivity growth of the firms. When the firms were separated into innovative and non-innovative firms, gains from R&D in the innovative firms were higher than the non-innovative firms. The study concluded that the innovation history of the firm plays a major role in determining the rate of return from R&D.

In a related study, Adeyeye, Jegede, & Akinwale (2013) examined the impact of technological innovation and R&D on firm performance in the Nigerian service sector using an innovation survey of 500 enterprises in 2008. The study revealed that in-house R&D, training, and technological acquisition have a positive impact on technological innovation. However, embodied knowledge and governmental support were found to insignificantly impact technological innovation whereas technology innovation and R&D were found to positively impact firm performance.

In another study, Robson et al. (2009) used data on 496 entrepreneurs in Ghana to account for the impact of the characteristics of the entrepreneur, the firm location, and the internal competencies of the firm on seven forms of innovation activities. The study found that incremental innovation was more intense compared to novel innovation and that the intensity of innovation was dependent on the level of education of the entrepreneur. The firm size and exports of the firm had a positive relationship. The study also found that firms in cities were far advanced in innovation compared to firms in the towns and recommended policies for the promotion of innovation and entrepreneurship.

3.2.2 Linking R&D, Innovation, and Productivity

Parisi, Schiantarelli & Sembenelli (2006) examined the link between R&D, innovation, and productivity using a very rich panel data from Mediocredito Centrale in Italy derived from two surveys taken in 1995 and 1998. The study analyzed the effect of product and process innovation on productivity accounting for the role played by R&D and fixed capital investment in the process. Process innovation was found to have a very significant impact on productivity. Expenditure on R&D was also found to be positively related to the probability of the firm introducing a new product whereas the level of fixed capital investment determined the probability of introducing a process innovation. The study also found that productivity growth is affected by R&D in the absorption of new technologies.

In a related study, Mairesse & Mohnen (2003) employed the Crépon, Duguet, and Mairesse (CDM) structural model to link innovation output, R&D, and productivity using an aggregate of microdata on innovation surveys for the United Kingdom, France, Spain, and Germany from 1994 to 1996. Given exogenous variables present in the structural model, problem of simultaneity and selectivity, and the measure of some of the variables, the study checked the robustness of the estimation results and recommended a framework for productivity and innovation to make it possible to compare innovation in the various sectors and across countries.

Also, Baumann & Kritikos (2016) used data from the German KfW Small and Medium Enterprise panel dataset to examine the link between R&D, innovation, and productivity in Micro, Small, and Medium-sized Enterprises (MSMEs) focusing on the majority firms classified as micro firms with less than 10 employees in Germany. The study examined the extent to which micro-firms differ from other firms in their innovation prowess and found that smaller firms have a relatively lower probability of engaging in innovative activities and the intensity of R&D is larger for smaller firms. Also, the study found that the probability of reporting innovation was positively correlated with the level of predicted R&D intensity. Product innovation was much more affected than process innovation. Given that, micro firms tend to increase labour productivity more than larger firms, they benefit more than larger firms in the innovation processes. The study concluded that the link between R&D, innovation, and productivity in smaller firms is not significantly different from larger firms.

Crèpon et al. (1998) introduced the Crépon-Duguet-Mairesse (CDM) model to link research, innovation, and productivity at the firm level. The CDM model explains the role of innovation output on productivity and research investment role on innovation output. The study used data from French manufacturing firms with several patents and a percentage share of innovation-related sales coupled with indicators of demand-pull and technology push factors. The econometric method controlled for simultaneity and selectivity bias and accounted for the statistical characteristics of the data. That is, a minimum percentage of the firms engage in R&D activities and or apply for patents; research, innovation, and productivity were determined endogenously.

The study found an interaction between simultaneity and selectivity and that the sources of both biases must be accountable for. The results suggested that the probability of the firm that engages in R&D increase with the firm size, share, and the diversification of the market, as well as technology push and demand-pull related indicators. The research effort of the firm, the demand-pull, and technology push indicators directly or indirectly raises its innovation output through its effect on research. The productivity of the firm was also found to have a positive correlation with a higher innovation output of the firm given the skills of employees and the intensity of physical capital.

3.2.3 Innovation and Productivity

Fu et al. (2018) examined the role of innovation and productivity in formal and informal firms in Ghana using a revised Crépon-Duguet-Mairesse (CDM) structural model on a survey of 501 manufacturing firms in Ghana. The study found that innovation has a positive impact on labour productivity. When segmented into technological and managerial innovation, it was found that technological innovation impacts labour productivity more than managerial innovations. The study also found that innovation plays a greater role in the productivity of formal firms

However, Marchante-Mera et al. (2018) employed the CDM structural model to analyze the role of the impact of the environment in innovation and productivity of Spanish service sector firms using data obtained from the Technological Innovation Panel database. The results indicate that a reduction in the impact of the environment significantly and positively affects the probability of the firm to engage in R&D activities and its intensity as well as the likelihood of the firm to embark on innovations. The reduction in the environmental impact also affects the productivity of the services sector firms. Also, productivity was found to be 11% greater in eco-innovative firms than non-eco-innovative firms.

Koellinger (2008) analyzed the relationship that exists between different types of innovation, the usage of internet-based technologies, and firm-level performance using a dataset of 7,302 European enterprises in 2003. The empirical result attributed an important role of internet-related technologies as a factor for innovation. The study found that both internet-based and non-internet-based product and process innovations have a positive relationship with turnover and economic growth. Also, firms that depend on internet-enabled innovations at least grow at the same proportion as firms that depend on non-internet-based innovations, and thus innovation is not essentially linked with higher profitability.

3.2.4 Determinants of Innovation

Jaklič et al. (2008) study on innovation cooperation has been noted for its importance in explaining the determinant of enterprises’ innovation activity, productivity, and growth, and has often been cited in emerging research works. Exploring the crucial role innovation cooperation plays in the innovation activity of Slovenian enterprises, the questions of the most productive innovation cooperation as well as the location and foreign ownership of innovation cooperation were examined. Using Probit estimations, their work confirmed that after R&D spending, external innovation cooperation is the next important incentives for innovation activity. Despite the aforementioned confirmation, it must be noted that there is a significant influence on domestic and not for international innovation cooperation in general. Noticeably, the variation in efficiency is based on the type of partners. The probability of innovation did not increase for cooperation with universities and R&D institutes even though inter-firm innovation cooperation significantly increases the probability of innovation. They also realized that the effect of innovation varied by distance. In this sense, the commitment and result of EU partners to innovation activity grew higher than domestic partners. Likewise, the results of commitment to innovation from partners from other locations are likely to reduce the probability of innovation.

Almeida and Fernandes (2007) used firm-level data across 43 developing countries to examine international technology transfers. The results from their work highlighted importing and exporting activities as imperative channels for the transfer of technology. In their assessment, a lot of foreign-owned firms are unable to seek the services of technological innovations as compared to domestic firms. They also made suggestions to the effect that there is the dependence of foreign-owned subsidiaries on the direct transfer of technology from their parent company.

Srholec (2008) aimed at demonstrating how research on the geography of innovation can benefit from multilevel modeling. He made use of explanatory factors operating at different levels of the analysis to examine the hypothesis that regional innovation systems affect the firm’s likelihood to innovate. He thus used a logit multilevel model of innovation on microdata from the third Community Innovation Survey in the Czech Republic as his estimation technique. Results from his estimation proved that the quality of the regional innovation system has a direct impact on a firm's propensity to innovate and resolves the impact of some firm-level factors.

Hedge and Shapira (2007) made an inquiry into the "applicability of contemporary firm-level innovation concepts to a developing country context". They achieved this by lending credence to the results of a survey of Malaysian manufacturing and service establishments. Building on Keith Pavitt's 'technology trajectories' framework, they conducted an empirical test to ascertain the effect of firms' structure, resources, environment, and strategy on the probability of their product, process, and organizational innovations as it applies in diverse sectors. Their findings showed that, relatively, Malaysian firms performed better at high process and organizational innovation capabilities, but were abysmal at developing a new product. In furtherance to the above Malaysian firms often exploited a specific variation of 'soft factors' like training of employees, application of knowledge in management practices, and collaborating with market actors as inputs to innovation rather than formal R&D.

Sung and Carlsson (2007) used the Korean Innovation Survey (KIS) to analyze the determinants of firms' innovation activity. Focusing primarily on the role of external networks and technological opportunity in performing innovative activities, they employed product innovation, product improvement, and process innovation as proxies for innovative activity. They further considered firm size, lagged profitability, firm's age, market concentration ratio, and formal research and development activity as explanatory variables to estimate the logistic regression model for 1124 firms. The study indicated a strong positive effect of external networks on innovative output without taking into account the type of innovation. Regardless of this result, it was noteworthy to admit that network effects vary across the type of innovation and by other firms. Sung and Carlsson admitted to the fact that the determinants of a firm's innovative activities vary in comparison to the type of innovation and the technological opportunity. They also posited that with the exclusion of product improvement or process, high-technological opportunity firms engage in a higher form of innovation than low technological opportunity firms in product innovation.

Goedhuys (2007a) applied firm-level data to assess the various sources of firm learning, investment and linkages, and their relevance for product innovation in Tanzania. The analysis of his study unfolded significant differences in innovation strategies for foreign and local firms. He further asserted that foreign innovative firms have stronger vertical linkages with other foreign firms and made huge investments in human and physical capital. Local firms within the local industrial structure compensated for these shortfalls.

Using microdata from Brazilian manufacturing firms, Goedhuys (2007b) investigated the impact of a variety of innovation activities on firms' total factor productivity (TFP) and its eventual impact on firm growth, measured by sales. By controlling for the size and age of the firms, he ascertained that productivity levels and productivity growth of firms over time are important influencers of firm size adjustments.

Also, Lee (2004) performed an econometric analysis using firm-level data from the National Survey of Innovation. His analysis indicated that large firms have a higher propensity to innovate than small firms. He, however, alluded to his surprise that the propensity to innovate has a negative correlation with the share of exports in total sales. His work further provided there is no evidential prove that innovation is connected to the composition of foreign and local ownership of firms.

Pamukçu (2003) examining the determinants of innovation decisions of Turkish manufacturing firms from 1989 to 1993, emphasized determinants that are connected to trade policy reforms of the 1980s. Using plant-level data, he posited that positive effects of trade liberalization on innovation-decision are transferred through technology embedded in machinery that has been imported. Also, there is no guarantee of a positive bearing on being a technology licensee, an exporter, or having a foreign partner on a firm's probability to innovate or experience technology spillovers.

Crespi (2012) used microdata from innovation surveys from Latin American countries namely Uruguay, Panama, Costa Rica, Colombia, Chile, and Argentina to examine the determinants of technological innovation as well as its impact on labour productivity. The study found that firms that innovate have a higher level of labour productivity than firms that do not and the countries that spend on knowledge are more likely to introduce new technology. The tendency of the firm to have foreign ownership, exportation, and cooperation increase the likelihood of the firm to invest in innovation activities and encourage investment in one-half of the countries in the study.

3.2.5 Determinants of R&D

Karray and Kriaa (2010) in their bid to investigate the determinants of Tunisian firms' R&D investments provided new empirical evidence by taking into consideration the effect of innovation probability of firms on R&D investment. In so doing they estimated econometric models of selectivity correction as proposed by Heckman (1976 and 1979) and Lee (1976 and 1978) and sampled 321 firms during the period 2002-2005. Their investigation identified that R&D activities, human capital quality, experience in innovation and public subsidies on the probability of firms had a positive impact on firms' ability to innovate whereas they noticed a negative impact of ownership structure on innovation. Also taking into account the two groups of firms (innovating and non-innovating). The results showed there exist spillover effects only for innovating firms that have an absorptive capacity. Besides, foreign-controlled firms were presented with a significant impact on R&D by ownership structure.

Chun & Mun (2017) investigated the “determinants of research and development (R&D) cooperation in small and medium-sized enterprises (SMEs)” using a Korean Innovation Survey, they found a significant and positive impact between incoming spillovers of knowledge and a SMEs' decisions to engage in R&D. Also, knowledge spillover in R&D co-operation was found to be more intense or larger in smaller firms than in larger firms. The results also suggested that the establishment of external R&D linkages may negatively affect the SMEs due to their size limitations though it may be important to SMEs.

López (2008) used the impact of information flows and explore the determinants that underline R&D cooperation. One factor which distinguishes López's work from many other scholarly works is that he tested for the endogeneity whereas other works assumed endogeneity a priori. To him, choosing the right framework of endogeneity has consequential effects on the estimates. To this end, he concurred that cost-risk sharing and complementary have positive effects on R&D

cooperation. He further argued that the estimation method determines how important the explanatory variables are. Per this assertion, two-step procedures have the potential to overestimate the relevance of spillovers. A more cautious work on the determinant of R&D cooperation conducted in Spain showed that cost- risk sharing is the most important determinant thus providing enough grounds to believe that the relevance of spillovers is consistent with the existing literature.

In another development, Waterson & Lopez, (1983) assessed the connection between firm size, technological influences and market structure to R&D expenditures in the UK. The problem of the limited data set was addressed after initial attention was given to the analysis of R&D activity. In so doing, two approaches were adopted with the first approach being analyzing part of the relationship using a broadly based sample. The findings of this assessment showed that firm size and concentration do not have the power to affect R & D intensity in the UK among firms that enroll in R & D programmes.

Also, Ghaffar & Khan (2014) focused on the effect of research and development budget on the performance of the firms. The performance of a firm hinged on the amount of research and development that goes into a firm's operations. Thus, it was appropriate that this work focused attention on the relationship between research and development and firm performance.

Jones & Williams (2018) developed an endogenous growth model that included four obstacles in R&D activity namely duplication externality, knowledge spillovers, creative destruction, and surplus appropriability problem to determine whether a decentralized economy embarks on too little or too much R&D. The findings showed that the regionalized economy underinvests below the socially optimal level with the exclusion that the duplication externality is great with real interest rate equilibrium simultaneously high. R&D expenditure thus results in inefficiency in processes and the creation of competitive advantage and enhancement in firm performance.

3.2.6 Innovation and Employment

Baffour et al. (2018) studied on "Innovation and employment in manufacturing and service firms in Ghana" using a panel dataset of 421 firms in Ghana to investigate the relationship between employment and firm-level innovation. They employed panel fixed effects and a Hausman-Taylor estimation technique and found that process innovation has a robust statistically significant positive impact on employment whereas process innovation was statistically insignificant. The study recommended an intensified effort in the promotion of technology diffusion through foreign direct investment.

3.3 Conclusion

This study focused on two classifications of innovation namely the product and process innovation due to the availability of data in contrast to some of the studies that delve into managerial and organizational innovation. Most empirical studies employed labour productivity to measure productivity (Chudnovsky et al., 2006; Lee and Kang,2007; Raffo et al., 2008; Goedhuys & Srholec, 2009). De Negri et al. (2007) on the other hand employed capital productivity as a single factor measure of productivity in their approach following the CDM model. However, this study employs labour productivity as a measure for firm productivity. The three-stage least squares technique was chosen amidst the variant techniques of the CDM model.

CHAPTER FOUR

METHODOLOGY

4.0 Introduction

This chapter presents the measures of productivity, theoretical framework, model specification, data source and description, and the estimation strategy of the study. The a priori expectation of the regressors or independent variables are also presented in this Chapter.

4.1. Measures of productivity

There are diverse measurements of productivity. The selection of measurement is dependent on its purpose and in some cases, the availability of data. According to the OECD (2001), these measurements can be broadly categorized as “single-factor productivity measures”, which relates to a degree of output to a single degree of input or “multifactor productivity measures” which relates to a degree of output to a set of inputs. At the firm-level or otherwise the industry, productivity measures can be in a form that shares some degree of gross output to one or numerous inputs and those associated with the value-added concept to capture output movements.

Table 4.1: Overview of measures of productivity

Output Measurement	***Input Type***			
	Capital	***Labour***	***Labour and Capital***	***Labour, Capital and intermediary inputs***
Gross-output	Gross-output Capital productivity	Gross-output Labour productivity	Gross-output Labour-Capital MFP	Multifactor productivity
Value-added	Value-added Capital productivity	Value-added Labour productivity	Value-added Labour-Capital MFP	
	Single-factor Productivity measurement		***Multifactor Productivity (MFP) measurement***	

Source: OECD Manual, 2001

Tinbergen (1942) and Solow (1957) independently postulated a measurement of productivity in the form of a production function linking its economic growth analysis. Owing to the contribution of Diewert (2008), Jorgenson (2011) and Griliches (1988), the contemporary measurement of productivity in the perspective of production theory integrates the national accounts, the index number theory and the theory of the firm termed growth accounting techniques.

The OECD manual adopted the index number approach which determines the change in the industry's output resulting from a change in a combination of inputs based on multifactor productivity growth. (OECD Manual, 2001)

To construct an industry's output index, the various outputs are weighted per the share of total output, and to construct a collective inputs index, the proportion of adjustment of the various inputs, for example, capital, labour, and the intermediate inputs are weighted correctly. In the principle of production with its assumptions, the shares of factor incomes such as share of employee compensation in total cost are used as weights which approximate the production elasticities of a percentage change in individual inputs on output.

4.1.1 Capital Productivity

Capital productivity is measured as the share of the volume of output to the volume of capital input in production. Capital productivity indicates how capital is used efficiently to generate output. R&D investment, which is an example of an investment in intellectual property products contributes to the growth of the technological limitations of the firm and enhances the firm's ability in the adoption of existing technologies thereby playing a substantial role in the productivity level of the firm (OECD, 2019a).

4.1.2 Labour Productivity

Labour productivity, which is generally regarded as the most frequently measured productivity indicator, is the share of the amount of output produced to the labour input in production. Labour productivity to a large extent, depends on the existence of the other inputs in production such as physical capital, fixed assets used in production, technical efficiency, and organizational change. When data on total hours worked by labour cannot be estimated, the total persons engaged are often used as a proxy for labour input (OECD, 2019a). Multifactor productivity (MFP) shows the general efficiency with which capital and labour inputs are employed in the production process. Capital deepening may be realized when more capital per labour unit is used in production and this helps in improving the total efficiency at which capital and labour are used in the production process together. (OECD, 2019b)

4.1.3 Total Factor Productivity

The measure of choice of productivity has, undoubtedly, been Total Factor Productivity (TFP). More often than not, TFP is named as the Solow residual, thus placing much emphasis on the residual. Be that as it may, although Solow's original work was obtained from the Cobb-Douglas function, it does not necessarily mean that the TFP must be obtained from the same. In recent times, there abound numerous refined indices such as the Fisher and Törnqvist superlative measures that are exact for flexible functional forms of the production function. Notwithstanding the fact remains the reality that, as concurred above, TFP is the measure of choice of productivity because of its opaqueness as to the nature of the phenomenon. Prescott (1998) agrees that TFP does not present much insight into what goes on in that little black box of technology even though encompasses the effects of changes in technology, institutions, and other productivity shocks.

Total Factor Productivity (TFP) explains the part of output not attributable to the number of inputs employed in production. As a result, the intensity of use of the input as well as the efficiency of input depicts the level of TFP in production. The Solow residual quantifies the growth in TFP. Given the aggregate output growth rate denoted by g_Y , aggregate capital growth rate denoted by g_K and the aggregate labour growth rate represented as g_L with α being the capital share, the Solow residual is thus presented as:

$g_Y - \alpha * g_K - (1 - \alpha) * g_L$. It must be noted that TFP growth is precisely measured by the Solow residual given that:

(i) a neoclassical production function,

(ii) the factor market is perfectly competitive, and

(iii) there is an accurate measurement in the inputs growth rates.

The work TFP plays in warranting economic fluctuations, growth, and disparity in cross-country per capita income does not stand in doubt. In business cycle frequencies, observations are that there exists a strong correlation between TFP, amount produced and hours worked. Concerning this observation, Kydland and Prescott (1982) introduced the Real Business Cycle (RBC) literature. The usual business cycle model reveals that pro-cyclical labour supply and investment generate shocks to TFP, thus causing variations in output and labour productivity at business cycle frequencies with an amplitude that is similar to the United States of America data. Other works have, however, initiated the use of pro-cyclical fluctuations in measuring TFP by including unmeasured labour hoarding and/or capacity utilization in the standard structure (e.g. Burnside et al. (1995) and King and Rebelo, 1999).

Solow (1956) believes that growth in TFP stimulates per-capita income growth in the long-run in an economy with an aggregate neoclassical production function. Over the past three decades, the means through which fixed costs of innovation are paid in a perfectly competitive economy with constant returns to scale in capital and labour was the main conceptual hurdle faced when trying to endogenize TFP growth. By this, paying capital and labor their marginal products means that all output is lost. Due to this, there are not many resources available to pay for the innovation costs. Romer (1990) and Aghion & Howitt (1992) provided a solution to this problem by ensuring that the innovator is granted monopolistic rights over his innovation. This solution, to them, will enjoy continuity because of the patent system. The rationale in this suggestion is that innovators can make back their initial fixed costs of innovation through the profit margin they make from commercializing their patents.

Endogenous growth models, in the process, of shedding light on the determinants of TFP growth identify a linkage between the TFP growth rates to innovation. The marginal cost of conducting R&D is reduced and the rate of innovation development increases when R&D is subsidized and skilled labor is abundant. This, inadvertently, increases the size of markets, the innovators' revenues which thus paves the way for more innovation and higher TFP growth.

In a related development, Solow (1956) provided insight into how cross-country differences in technology have the potential to produce vital cross-country differences in income per capita. Klenow and Rodriguez-Clare (1997) and Hall and Jones (1999) have assented to the observation that the main cause of the gap in income per capita between rich and poor countries is connected to large cross-country differences in TFP.

Possibly, cross-country differences in TFP may be attributable to differences in the physical technology employed by countries or the level of efficiency in technologies employed. To provide an accurate description of the relative importance of these factors, it is important to have data on direct measures of technology. In a bid to contribute to the literature, Comin et. al (2006) compiled some choice worthy direct measures of technology for approximately 75 different technologies. Their compilation reveals that the cross-country differences in technology are roughly four times bigger than cross-country differences in income per capita. They further opine that technology has a positive correlation with income per capita. To this end, cross-country variation in TFP is, almost invariably, decided by the cross-country variation in physical technology.

4.1.4 The measure of Productivity – Econometric Approach

This approach to productivity measures the volume of inputs and outputs and avoids the assumption of the relationship between the elasticities of production and the share of income which has no correspondence with the reality (OECD, 2001). Morrison (1986) and Nadiri & Prucha (2001) asserted that the a priori requirement of the production function for the assumption of constant returns to scale is not available. Forms of technical change different from the Hicks-neutral formulation which is based on an index number approach can be investigated. Fully-fledged models at times question the robustness of results and raise econometric issues and that researchers with the constraint of the sample size of the observation need to especially revert to restrictions such as constant returns to scale to increase the degree of freedom provided in the estimation.

4.2 Theoretical Framework

4.2.1 R&D and Productivity

The works of Solow (1957) and Denison (1985) have attributed the role of technological progress to economic growth. These studies employed technical progress as a residual factor in the growth accounting approach without its measurement. Manfield (1968a) considers technical progress in the framework of a global event that involves changes in the methods of production and products that may eventually manifest in the system of organization and the procedures used by management.

Given the difficulty in the measurement of technical change, economists identify with research and development which is viewed as a defined collection of events that contribute directly or indirectly to changes in the production processes and products. Denison (1985) however, postulated that R&D contributes to about 20 percent of all technical changes and plays a significant role in industrial policies and corporate plans.

Most of the econometric studies that examine the influence of R&D on productivity at the firm level employed a Cobb-Douglas production function as the basis for the analytical framework. A factor for knowledge capital (R) which accounts for R&D is added to the standard factors in the production function, thus a Cobb-Douglas production function with three factors is derived as:

$$Q_i = Ae^{\sigma_i} K_i^{\alpha} L_i^{\beta} R_i^{\gamma} e^{\varepsilon_i} \quad (1b)$$

Where

Where Q is a measure of output for firm i (total sales)

K is a measure of physical capital

L is the number of labour employed

R is a measure of knowledge capital

A is a constant and

α, β, γ are elasticities of output for physical capital, labour, and knowledge capital respectively.

σ represents disembodied technical change.

ε is an error term

Taking the log of the variable and first differencing, we derive a linear relationship in terms of the change in labour productivity:

$$(q-1)_i = \sigma + \alpha(k-l)_i + \gamma r_i + \theta l_i + v_i \qquad \text{(2b)}$$

q, l, k, r are the rate of growth of output, labour, physical capital and knowledge capital respectively.

Assuming constant returns to scale in capital and labour coefficients as identified the econometric approach to productivity in Morrison (1986).

$$\theta = \alpha + \beta - 1 \qquad \text{or} \quad \alpha + \beta = 1$$

Taking the rate of return to R&D as the parameter of interest implies $\rho(\frac{R}{Q})$

The first difference of R is ΔR substituting gives $\rho(\frac{\Delta R}{Q})$

Assuming no depreciation in R&D, the change in the knowledge capital ΔR equals the present R&D expenditure (RD)

Mairesse and Sassenou (1991) noted that R&D expenditure by firms is very stable over time and that most of the variation is in the cross-section. As a result, they found that applying different lags to R&D has little impact on the results.

The productivity equation can thus be estimated as:

$$(q-1)_i = \sigma + \alpha(k-l)_i + \rho(\frac{RD}{Q})_i + \theta l_i + v_i \qquad \text{(3b)}$$

Where

$(\frac{RD}{Q})$ denotes R&D intensity which is the average of R&D expenditure over total sales.

Increases in R&D intensity increase labour productivity.

4.3 Model Specification

$$R\_D_{\boldsymbol{i}} = \beta_0 + \beta_1 lnFIRM\_AGE_i + \beta_2\, FIRM\_SIZE_i + \beta_3 EXPORT_i + \beta_4 FOREIGN_i + \beta_5 MANU_i + \beta_6 LOCATION_i + \mu_i$$

Where $R\_D_{\boldsymbol{i}}$ is a dummy for internal research and development activity regressed on $lnFIRM\_AGE_i$ which is the log of firm age, $FIRM\_SIZE_i$ is the size of the firm, $EXPORT_i$ denotes export dummy, $FOREIGN_i$ is a dummy for foreign ownership of the firm, $MANU_i$ denotes manufacturing dummy, $LOCATION_i$ represents the location dummy. β are parameter estimates and μ_i denotes the error term.

From equation (3), the Innovation models to be estimated are:

$$PRODIN_{\boldsymbol{i}} = \alpha_0 + \alpha_1 R\_D_i + \alpha_2\, lnFIRM\_AGE_i + \alpha_3\, FIRM\_SIZE_i + \alpha_4 EXPORT_i + \alpha_5 FOREIGN_i + \alpha_6 MANU_i + \alpha_7 LOCATION_i + \mu_i$$

$$PROCIN_{\boldsymbol{i}} = \gamma_0 + \gamma_1 R\_D_i + \gamma_2\, lnFIRM\_AGE_i + \gamma_3\, FIRM\_SIZE_i + \gamma_4 EXPORT_i + \gamma_5 FOREIGN_i + \gamma_6 MANU_i + \gamma_7 LOCATION_i + \mu_i$$

Where $PRODIN_{\boldsymbol{i}}$ and $PROCIN_{\boldsymbol{i}}$ denotes product and process innovation respectively regressed on research and development (R_D_i), the log of firm age ($lnFIRM\_AGE_i$), firm size ($FIRM\_SIZE_i$), export ($EXPORT_i$), foreign ownership ($FOREIGN_i$), manufacturing dummy

($MANU_i$), location dummy ($LOCATION$). α and γ are parameter estimates and μ_i denotes the error term.

Following Raffo et al. 2008 and Goedhuys & Srholec (2009), labour productivity may be dependent on firm size, firm age, internal R&D, export, differences in location of the firms, whether the firm has a percentage of foreign ownership and training or education of employees in developing countries. Thus, the labour productivity equation is given as:

$$PRODUCTIVITY_{\boldsymbol{i}} = \varphi_0 + \varphi_1 R\_D_i + \varphi_2 PROCIN_{\boldsymbol{i}} + \varphi_3\, PRODIN_i + \varphi_4\, TRAINING_i + \varphi_5\, EXPORT_i + \varphi_6\, FOREIGN_i + \varphi_7 FIRM\_SIZE_i + \varphi_8 MANU_i + \varphi_9 LOCATION_i + \mu_i$$

Where $PRODUCTIVITY_{\boldsymbol{i}}$ denotes labour productivity which is the log of total sales per labour.

R_D represents research and development. It's a dummy for internal research and development undertaken at the firm.

$PRODIN_i$ denotes product innovation, $PROCIN_{\boldsymbol{i}}$ for process innovation, foreign ownership represented by ($FOREIGN_i$), $EXPORT_i$ for export dummy, $TRAINING_i$ for formal training of the employees, $FIRM\_SIZE_i$ is a dummy for firm size and $MANU_i$ denotes manufacturing sector dummy. $\varphi_0, \varphi_1, \varphi_2, \varphi_3, \varphi_4, \varphi_6, \varphi_7, \varphi_8$ and φ_9 are parameter estimates and μ_i is the error term.

4.4 Data Source and Description

The World Bank Enterprise Survey, 2013 dataset was used. The 2013 Survey was the second phase and covered a sample of 720 firms from four regions in Ghana namely Greater Accra, Western, Ashanti, and Northern Region. The four regions were represented by Accra, Tema, Takoradi, and North (consisting of both Kumasi and Tamale). The firms represented in the survey were from the industrial and service sub-sectors in Ghana and was nationally representative.

A stratified sampling technique was used for the survey with firms stratified by three procedures namely; firm size, sector of activity, and the geographical location. Stratification based on firm size depended on the number of employees. Stratification based on the sector of activity was determined by the size of the economy based on Gross National Income measurement. The geographical location stratification was done in the urban centers.

The WBES 2013, focused on privately owned formal non-agricultural firms in the manufacturing and service industries such as construction, hospitality, communication, and hospitality firms excluding Agricultural biased and fully governmental firms.

The size of the firms in the World Bank enterprise survey was in three forms namely small, medium, and large firms. This classification was based on the number of employees. “Small firms” are firms with employees from 5 to 19, “Medium firms” are firms with employment from 20 to 99, whereas “Large firms” are firms with employment equal to above 100. **Table 4.1** shows the majority of firms constituting 65.56 percent are categorized as Small firms, with Medium firms constituting 26.25 percent, and Large firms, 8.19 percent. This shows the dominance of Small firms in Ghana.

Table 4.2: Firm size distribution

Firm size	Frequency	Percent	Cumulative
Small (>=5and <=19)	472	65.56	65.56
Medium (>=20 and <=99)	189	26.25	91.81
Large (>=100)	59	8.19	100
	720	100	

Source: Author's computation from the WBES dataset 2013

The WBES 2013 dataset also shows that 49.7 percent of the 720 manufacturing and service firms in the survey are located in Accra, 20.42 percent in Kumasi and Tamale, 7.92 percent, and 21.94 percent in Takoradi and Tema respectively. The majority of the firms are in the Greater Accra Region. Also, 49.15 percent of the firms in Accra are categorized as Small size whereas 47.09 percent and 62.71 percent are Medium and Large size respectively. For North (Kumasi and Tamale), 22.88 percent of the firms are Small size, 18.52 percent were Medium size, and 6.78 percent large size.

The majority of the firms were located in Accra representing 49.72% followed by Tema with 21.94% of the 720 firms. Takoradi, on the other hand, was represented by 7.92% of the firms. Accra had the majority concentration of all categories of firms (small, medium and large). Takoradi had the minimum number.

Table 4.3: Distribution of region of the establishment

Region	Small	Medium	Large	Total
Accra	64.8	24.86	10.34	100.00
	49.15	47.09	62.71	49.72
North	73.47	23.81	2.72	100.00
	22.88	18.52	6.78	20.42
Takoradi	68.42	28.07	3.51	100.00
	8.26	8.47	3.39	7.92
Tema	58.86	31.01	10.13	100.00
	19.7	25.93	27.12	21.94
Total	65.56	26.25	8.19	100.00
	100.00	100.00	100.00	100.00

Source: Author's computation from the WBES dataset 2013

4.5 Description of variables

The variables are segmented into endogenous (dependent) and exogenous (independent) variables. The endogenous variables are R&D, process innovation, product innovation, and labour productivity and the exogenous variables are training, firm age, export, and foreign ownership. The study controlled for the size, sector, and location of the firm by including firm size dummy, sector dummy, and location dummies respectively.

4.5.1 Endogenous variables

R&D is a dummy for a firm's expenditure on formal R&D activity over three consecutive years. It is denoted by 1 for a firm that spent on formal R&D activities and 0 otherwise

Process Innovation is a dummy for the introduction of any innovative methods of manufacturing products or offering services by the firm for the last three years. It takes the value 1 for a firm that introduced an innovative method of manufacturing or offering services and 0 for a firm that did not. OECD (2005) defines Process innovation as "the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software."

Product Innovation is a dummy for a new or significantly improved product introduced by the firm in the last three years. It takes the value 1 for a firm that introduced any new or improved product and 0 for a firm that did not. Product Innovation "is the introduction of a good or service that is new or significantly improved concerning its characteristics or intended uses. This includes significant improvements in technical specifications, components, and materials, incorporated software, user-friendliness, or other functional characteristics." (OECD, 2005)

Productivity is measured by labour productivity which is the ratio of annual sales to the number of employees. The annual sales was used as a proxy for output since there was no data on output in the dataset. This follows Palia and Lichtenberg (1999) where annual sales was used as a proxy for output in the productivity measurement.

4.5.2 Exogenous variables

Firm size is a dummy for the size categorized based on the number of employees employed by the firm. "Small firms" are firms that employed 5 to 19 employees, "medium firms" employed from 20 to 99 employees whereas “large firms” employed 100 employees and above. It assumes the value 1 for a "small firm", 2 for a "medium-firm" and 3 for a "large firm".

In (Firm age) is the log of the number of years since the firm began operation.

Training is a dummy for the training of employees in the last fiscal year. It takes the value 1 for firms that embarked on formal training and 0 for firms that do not.

Foreign ownership is a dummy for the percentage of the firm owned by foreign private companies, organizations, and individuals. It assumes the value 1 for a firm that has a proportion of foreign ownership and 0 otherwise.

Export is a dummy for the percentage of firm sales that is attributed to direct export in the last fiscal year. It assumes the value 1 for a firm that exported in the last fiscal year and 0 for firms that did not export.

Manufacturing is a dummy for the sectoral differences of the firms. It takes the value 1 for the manufacturing sector and 0 for firms in the services sector.

Location is a dummy for the location differences of the firms. It assumes the value 1 for firms in the capital city Accra, the value 2 for firms in Kumasi and Tamale (North), the value 3 for firms in Takoradi and takes the value 4 for firms located in the industrial city Tema.

4.6 Estimation Strategy

4.6.1 The Crèpon Duguet Mairesse (CDM) model

The CDM model introduced by Crèpon et. al (1998) remains a widely employed model to examine the link between R&D, innovation, and firm productivity. The model has three stages consisting of:

1. The choice of the firm to invest in R&D or not.
2. The R&D stock intensity of the firm and the realization of this investment into the process and product innovation outputs.
3. The relationship of the innovation types to the firm's level of productivity.

The model includes the whole process from the choice of the firm to innovate and the innovative effort of the firm and the firm's creation of innovation as output and its effect on productivity (Crèpon et. al, 1998). This model is also structured in a three-stage with nonlinear recursive equations. In the basic CDM model, there are three equations: a Tobit model which explains R&D (this is made up of two equations: a probit model which selects firms that perform R&D and an R&D-intensity equation), the model also includes an equation that links innovation output to R&D and a labour productivity equation linked with the innovation output.

The fraction of innovative sales is used to measure innovation output. The independent variables in the model may possess different or similar determinants.

Thus, from Crèpon et. al (1998),

Supposing that $i = 1, \ldots, N$ stands for the sum of firms and r_i^* stands for the firm's innovative effort. The R&D equation which includes the knowledge production function is given as:

$r_i^* = Z_i'\beta + e_i$ (1a)

Where r_i^* is an unobservable latent variable

Z_i signifies the vector of the determinants of the innovative effort of the firm.

β denotes the vector of estimated coefficients and

e_i is the error term.

Equation (1a) captures R&D expenditure internal to the firm and estimates the intensity of the innovative effort of only firms that invest in R&D, thereby introducing an undesirable selection bias. Equation (2a) is a selection equation that shows if a firm accounts for internal R&D or not. This equation is represented as follows:

$$rd_i = \begin{cases} 1 \ if \ \ rd_i^* = w_i' \propto + \varepsilon_i > c \\ 0 \ if \ \ rd_i^* = w_i' \propto + \varepsilon_i \leq c \end{cases} \qquad (2a)$$

Where

rd_i denotes an observed dependent binary variable that assumes the value 1 for firms that engage in internal R&D and the value 0 for firms that do not conduct internal R&D,

rd_i^* represents the equivalent latent variable that shows the decision by the firms to conduct R&D

w_i indicates the determinants of R&D,

α denotes the vector of the coefficients to be estimated, and

ε_i is the error term.

The decision on whether a firm may engage in innovation or not depends on the value of R&D investment estimated using equation (3a)

$$\begin{cases} r_i^* = Z_i'\beta + e_i & if \quad rd_i = 1 \\ 0 & if \quad rd_i = 0 \end{cases} \quad (3a)$$

Equations (2a) and (3a) can be estimated by maximum likelihood where the error terms e_i and ε_i follow a bivariate normal distribution with a zero mean, unit variances, and a correlation coefficient for both errors $\rho_{e\varepsilon}$.

The Innovation equation applies to product and process innovation and not organizational innovation due to data issues which are in contrast to Hollen et al. (2013).

The productivity equation can be estimated using the ordinary least square (OLS) approach.

$$y_i = w'_i\alpha_1 + I_i^* \propto_2 + v_i$$

Where

y_i represents labour productivity in logarithms,

w_i denotes a vector of determinants of productivity,

v_i denotes an error term

α_1 and $\propto_2$ are parameter estimates.

From Crepon et. al (1998), it is deduced from the above that labour productivity is used as a measure for a firm's productivity. The underlining perception held is that innovation increases the productivity of workers.

The innovation activity is decomposed into product ($ProdIN$) and process innovation ($ProcIN$) thus

$$ProdIN_i^* = Z_{i1}'\beta_1 + \varepsilon_{1i}$$

$$ProcIN_i^* = Z_{i2}'\beta_1 + \varepsilon_{2i}$$

In this case, ε_{1i} and ε_{2i} have a bivariate normal distribution. Due to this, estimation of the two models is carried out using a bivariate probit

$$ProdIN_i = \begin{Bmatrix} 1 \; if \; ProdIN_i^* > 0 \\ 0 \; if \; ProdIN_i^* < 0 \end{Bmatrix}$$

$$ProcIN_i = \begin{Bmatrix} 1 \; if \; ProcIN_i^* > 0 \\ 0 \; if \; ProdIN_i^* < 0 \end{Bmatrix}$$

Where $ProdIN_i$ and $ProcIN$ are binary variables equal to 1 for firms that involve in product and process innovation and 0 for firms that do not involve in the process and product innovation. The predicted values are then encompassed in the productivity equation.\

However, the two-step procedure for R&D was not employed in this study. Most of the firms do not report R&D expenditure though they engage in internal R&D. A dummy for R&D was however included in the productivity equation following empirical studies such as Goedhuys et al. (2008a; 2008b) in the case of developing countries where the majority of firms do not account for R&D expenditure in their financial statements.

4.6.2 The Three-Stage Least Squares (3SLS)

The system equation techniques are employed when there exist simultaneous modeling of several dependent variables using a separate regression equation. In this instance, the number of regression equation equates the number of the dependent variables (R_D, ProdIn and Productivity) model simultaneously. Though there may be a separate regression model, the parameters are estimated simultaneously accounting for the intertwined nature of the dependent variables.

Given a set of dependent, independent variables and random terms accounting for the random nature of the independent variable and the unobserved characteristics; the random terms may be correlated provided the unobserved characteristics are the same for the set of equations.

The selection of the system equation method relies on the relationship between the dependent variables. If the dependent variables say R_D, ProdIn and Productivity are endogenous, which means ProdIn belongs to some regressors used to explain the changes in R_D, then the Two-Stage Least Squares (2SLS) is required to estimate the parameters of the equation simultaneously.

Conversely, if the explained variables of the various equations have the same unobserved influential factors and the error terms are correlated, then the parameters can be estimated by the Seemingly Unrelated Regression Equation (SURE) method. This is because 2SLS does not justify the possibility of correlated disturbance terms. It can also be noted that the SURE does not assume the dependent variables are endogenous (Zellner and Theil, 1962).

Hence, if the explained variables are endogenous and the random terms are correlated, then the parameters of the equations are estimated by the 3SLS technique simultaneously. It combines SUR estimation and 2SLS. Both the SUR and the 2SLS techniques are used by the 3SLS to correct contemporaneous correlation and simultaneity bias respectively to estimate the structural coefficients (Zellner & Theil, 1962).

In the 3SLS, the first and second stages are the same as the 2SLS procedure. The entire system is fit using the SUR after estimating the variance-covariance matrix from 2SLS residuals. When the disturbances of the various equations are not correlated, then the 2SLS is equivalent to the 3SLS estimates (Kmenta, 1997; Greene, 2000). The two-stage least squares involve a 2-step approach, step one estimates the reduced form of the moment matrix of the residuals, and step two estimates the single structural equation coefficients in its transformation where the joint regressors are transformed by the moment matrix in step 1.

However, the 3SLS method uses the moment matrix of the structural disturbances estimated in the 2SLS to estimate the coefficients of the entire system simultaneously. In cases of non-diagonal moment matrix of the structural disturbances, there will be efficiency gain in the estimation of the identified equation provided others over-identified. The 3SLS also justifies restrictions on the parameters in the various structural equations. Where the errors of the equation are correlated, then the parameter estimates of the sequential model are inconsistent (Zellner & Theil, 1962).

In circumstances where "cross-equation error correlation" exist, the required model for estimation is a simultaneous equation technique, for example, the Two-Stage Least Squares (single equation) or the Three-Stage Least Squares (system methods). A single equation method which is also known as "limited information method for simultaneous models" produces consistent parameter estimates but the full information methods or system methods yield more efficient parameter estimates (Zellner & Theil, 1962).

4.7 A priori expectation of the regressors

Product innovation, R&D, process innovation, firm age, firm size, and training are expected to positively impact productivity. The expected signs of the regressors are given in Table 4.4 below

Table 4.4: A priori Expectation

Independent Variable	***Expected Sign***	***Dependent variable***
Product Innovation	Positive	Productivity
Process Innovation	Positive	Productivity
Firm age	Positive	Productivity,
Firm size	Positive	Productivity
R&D	Positive	Productivity
Training	Positive	Productivity

CHAPTER FIVE

RESULTS AND DISCUSSION

5.0 Introduction

This chapter presents and discusses the descriptive statistics, results from the Three-Stage Least Squares (3SLS), and the sequential regression estimation.

5.1 Descriptive Statistics

Table 5.1 below presents the descriptive statistics of the variables from the WBES, 2013 used in the study. Approximately 19.7 percent of firms involved in R&D activities whereas 27.7 and 48.6 percent of firms in the survey undertook product and process innovation respectively. Concerning firm size, approximately 69.3 percent of the firms are categorized as ‘small firms’ (employs a minimum of five (5) to a maximum of nineteen (19) employees), 26.3 percent are categorized ‘medium firms’ which employs twenty (20) to ninety-nine (99) employees and 4.4 percent are ‘large firms’ employing minimum of hundred (100) and above employees.

Firms with a proportion of foreign ownership constitute approximately 11 percent which is an indication of a high percentage of indigenously owned firms. Approximately 8 percent of firms surveyed export showing that a majority of the firms do not engage in the exportation of their products or services. On the sectorial distribution of firms, approximately 52.8 percent of the firms belong to the manufacturing sector whereas 48.1 percent belong to the services sector. Formal training is engaged in by 38 percent of the firms. Also, about 54 percent of the firms are in Accra, whereas 21 percent are located in the industrial city, Tema. About 6 percent of the firms are located in Takoradi and approximately 19 percent in Kumasi and Tamale (North).

Table 5.1: Descriptive Statistics

Variable	№ of Observations	Mean	Std. Deviation
R&D	426	0.1972	0.3983
Process Innovation	426	0.277	0.448
Product Innovation	426	0.4859	0.5004
Firm size			
Small (5 -19)	426	0.6925	0.462
Medium (20 - 99)	426	0.2629	0.4407
Large (≥ 100)	426	0.0446	0.2067
ln(firm age)	426	2.5647	0.9755
Training	426	0.3685	0.483
Foreign Ownership	426	0.1127	0.3166
Export	426	0.0751	0.2639
Sector			
Manufacturing	426	0.5282	0.4998
Services	426	0.4718	0.4998
Location			
Accra	426	0.5399	0.499
North	426	0.1878	0.391
Takoradi	426	0.0657	0.2481
Tema	426	0.2066	0.4053

Author's computation from the WBES dataset, 2013

5.2 Discussion of results

5.2.1 Innovation and R&D

From **Table 5.2** below, product innovation is significantly influenced by R&D and export.

R&D has a significant positive impact on product innovation at 1 percent significance level. This implies that firms that invest in research and development are more likely to engage in product innovation than firms with no investment in research and development. Holding all other variables constant, manufacturing firms that engage in research and development are 43.5 percent more likely to embark on product innovation than firms that do not engage in research and development.

This confirms to various studies such as Srholec (2008); Karray & Kriaa (2008); Hedge & Shapira, (2007); Jaklic et al. (2008); Goedhuys (2007a), and Almeida & Fernandes (2008) for some developed and developing countries.

Export has a significant negative influence on R&D. Export is significant at 5 percent significance level. The result indicates that manufacturing firms in Ghana that export are less likely to embark on product innovation than manufacturing firms that do not export. This deviates from the expected sign of a significant positive relationship.

Empirical studies have found mixed results of the impact of export on the tendency for a firm to engage in research and development. Falk (2008) found a significant positive influence of export on research and development for six (6) European countries whereas Sung and Carlsson (2007) found no significant influence of export on the tendency of a firm to engage in research and development.

Process innovation is significantly affected by Research and Development (R&D) at 1 percent significance level. R&D significantly influence the tendency for a manufacturing firm to embark on process innovation. This implies firms that involve in R&D activities tend to engage in process innovation than manufacturing firms that do not. This shows that R&D is a very essential factor in determining process innovation at the firm level. This result conforms with Gonçalves et al. (2007); Hedge & Shapira (2007) and Almeida & Fernandes (2008). In contrast, Sung and Carlsson (2007) found R&D to be insignificantly different from zero in a study of North Korea.

However, R&D is significantly influenced by export, sector, and firm size dummy. Export is statistically significant at 5 percent significance level. Also, large and medium-size firms significantly embark on R&D activity than small-size firms. The manufacturing sector significantly embarks on research and development than the services sector at 5 percent significant level.

Table 5.2: Three Stage Least Squares Regression

Variables	(1) R&D	(2) Product Innovation	(3) Productivity	(4) Process Innovation	(5) Productivity
R&D		0.435***	0.779***	0.245***	0.541*
		(0.077)	(0.298)	(0.080)	(0.289)
Product Innovation			-0.537**		
			(0.245)		
Process Innovation					0.053
					(0.239)
Training			-0.151		-0.205
			(0.247)		(0.249)
ln (Firm_age)	0.020	0.036		0.040	
	(0.031)	(0.034)		(0.036)	
Export	-0.239**	0.384***	-0.059	0.113	-0.277
	(0.113)	(0.127)	(0.460)	(0.132)	(0.456)
Foreign Ownership	0.036	0.171	0.730*	0.068	0.629*
	(0.095)	(0.106)	(0.378)	(0.109)	(0.380)
Firm size dummy					
Medium size	0.182**	0.060	0.904***	-0.019	0.885***
	(0.071)	(0.080)	(0.294)	(0.083)	(0.297)
Large size	0.616***	-0.128	1.969***	-0.172	2.058***
	(0.144)	(0.168)	(0.600)	(0.174)	(0.608)
Sector dummy					
Manufacturing	0.222**	0.339***	9.246***	0.146	9.017***
	(0.103)	(0.116)	(0.288)	(0.120)	(0.279)
Location differences	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	209	209	209	209	209
R-squared	0.343	0.615	0.976	0.361	0.975
P(chi2)	0.000***	0.000***		0.000***	0.000***

1%, 5% and 10% significance are represented by ***, **,* respectively
Source: Authors computation using the World Bank Enterprise Survey, 2013

5.2.2 Determinants of productivity

Labour productivity in the manufacturing sector is significantly influenced by Research and Development (R&D), product innovation, foreign ownership, and the size of the firm.

R&D has a significant positive influence on labour productivity. R&D is highly significant at 1 percent significance level implying that firms that engage in Research and development tend to be more productive compared to firms that do not engage in research and development. Holding all else constant, firms that engage in research and development may be approximately 43.5 percent more productive than firms that do not engage in research and development in the manufacturing sector in Ghana.

This result conforms to Goedhuys (2008b) firm-level study on five (5) developing countries (Brazil, Bangladesh, Ecuador, South Africa, and Tanzania) where research and development was found to have a significant positive impact on labour productivity.

Product innovation has a significant influence on labour productivity. Product innovation is significant at 5 percent significance level. However, product innovation does not have the expected positive sign. It was expected that manufacturing firms that engage in product innovation may be more productive than manufacturing firms that do not engage in product innovation.

This is in contrast with Damijan et al. (2008a), Raffo et al. (2008), and Masso & Vahter (2008) where product innovation was found to have a significant positive influence on the level of labour productivity for both developed and developing countries.

Firm size positively influences the level of productivity. Large and Medium-sized firms were found to be more productive compared to small-sized firms. Holding all else constant, medium-size firms are approximately 90.4 percent more productive than small-size manufacturing firms whereas large size manufacturing firms were found to be approximately 197 percent more productive than the small-size manufacturing firms. This implies that the size of the firm is a highly significant factor in determining labour productivity of manufacturing firms in Ghana.

Empirical studies such as Benavente (2006); Lee and Kang (2007); De Negri et al. (2007); Raffo et al. (2008) and Goedhuys & Srholec (2009) confirm this result for most developing countries. Conversely, Chudnovsky et al. (2006); Goedhuys, (2007b); Roud, (2007), and Damijan et al. (2008a) found a significant negative influence of firm size on productivity in the developed countries.

However, other studies such as Goedhuys et al. (2008a); Goedhuys et al. (2008b), and Raffo et al. (2008) showed firm size to be statistically not different from zero in the developed countries. This shows a mixed result of the impact of firm size on the levels of productivity in the framework of most developed countries.

Foreign ownership has a significant positive influence on labour productivity. Foreign ownership is significant at 10 percent significance level. From column (4), this implies that holding all other variables constant, firms that have a proportion of foreign ownership are approximately 73 percent more productive than wholly indigenous manufacturing firms.

This conforms to Jefferson et al. (2006) in the case of China and Goedhuys et al. (2008a) for Tanzania where firms with a percentage of foreign ownership were found to be more productive than firms with no foreign ownership. However, this is in contrast with Chudnovsky et al. (2006) in the case of Argentina.

5.3 Sequential regression

A sequential regression model was also employed to compare with the parameter estimates of the Three-stage least squares. A Tobit regression model was employed to estimate the R&D equation as presented in **Table 5.3** The innovation equations for both process and product innovation were estimated by a bivariate probit regression model in **Table 5.4** The productivity equation was estimated using the ordinary least squares approach as presented in **Table 5.5**

The parameter estimates from the single equation models (Tobit, Bi-probit, and OLS) are inconsistent with the simultaneous equation model. The R&D, innovation, and productivity equation have some similar determinants and this may result in a cross-equation error correlation.

It can be concluded that the regressors and disturbances are correlated since the three equations possess some similar determinants. Employing the Ordinary Least Squares (OLS) approach will result in estimates that are inconsistent with model parameters and biased. Estimates from 3SLS are thus, consistent and unbiased and in some instances, more asymptotically efficient than estimates from a single equation at a time.

Hence, the Three-Stage Least Squares approach is preferred to account for the endogeneity and cross-equation error correlation. This conforms to Bolton and Chapman (1986) who compared the simultaneous and sequential estimation techniques for a "multi-stage model of choice, perception, and preference" exploring the condition required to employ a relatively complex simultaneous estimation technique to replace a sequential approach using a simpler single equation at a time. They focused on the degree to which the sequential procedure may encounter a shortfall of the presence of cross-equation error correlations.

Table 5.3: Tobit regression estimation result of the R&D equation

Variables	Coefficient	Standard Error
ln (firm_age)	0.231**	(0.092)
Export	-0.556	(0.422)
Foreign Ownership	0.003	(0.320)
Firm size dummy		
Medium Firm	0.224	(0.220)
Large Firm	1.049**	(0.450)
Sector dummy		
Manufacturing	0.405**	(0.194)
Location dummy		
Accra	-0.390	(0.245)
Takoradi	0.384	(0.376)
Tema	-0.577*	(0.307)
Constant	-1.749***	(0.404)
var(e.R_D2)	1.931***	(0.369)
Pseudo R2	0.0494	
Prob > chi2	0.0010	
Uncensored	84	
Left-censored	342	
Right-censored	0	
Observations	426	

1%, 5% and 10% significance are represented by ***, **,* respectively
Source: Authors computation using the World Bank Enterprise Survey, 2013

Table 5.4: Bivariate probit regression estimation

Variables	Process Innovation	Product Innovation
R&D	0.579***	1.136***
	(0.164)	(0.179)
ln(firm_age)	-0.002	-0.063
	(0.072)	(0.068)
Export	0.102	0.495*
	(0.269)	(0.265)
Foreign Ownership	-0.270	0.310
	(0.230)	(0.218)
Firm size dummy		
Medium Firm	0.215	0.148
	(0.157)	(0.156)
Large Firm	0.154	-0.259
	(0.358)	(0.353)
Sector dummy		
Manufacturing	0.314**	-0.022
	(0.136)	(0.129)
Location dummy		
Accra	0.213	-0.109
	(0.183)	(0.175)
Takoradi	0.083	0.066
	(0.300)	(0.291)
Tema	0.015	-0.462**
	(0.219)	(0.210)
Constant	-1.057***	-0.019
	(0.271)	(0.251)
Wald chi2 (20)	70.10	
Prob > chi2	0.0000	
Rho	0.462***	
Observations	426	426

1%, 5% and 10% significance are represented by ***, **,* respectively
Source: Authors computation using the World Bank Enterprise Survey, 2013

Table 5.5: Ordinary Least Squares estimation result of labour productivity measured by the log of Annual Sales per labour

Variables	Coefficients	Standard errors
R&D	0.752**	(0.309)
Product Innovation	-0.590**	(0.259)
Process Innovation	0.177	(0.249)
Training	-0.157	(0.254)
Export	-0.062	(0.473)
Foreign Ownership	0.726*	(0.389)
Firm size dummy		
Medium size	0.913***	(0.302)
Large size	1.996***	(0.619)
Location differences	Yes	
Constant	9.229***	(0.298)
Observations	209	
R-squared	0.190	

1%, 5% and 10% significance are represented by ***, **,* respectively
Source: Authors computation using the World Bank Enterprise Survey, 2013

CHAPTER SIX

SUMMARY, CONCLUSIONS AND POLICY RECOMMENDATION

6.0 Introduction

The summary of the findings, conclusions, policy recommendations, and limitations confronted in the study are presented in this chapter. The recommendations stated below are of immense importance to the various manufacturing sector firms in Ghana, government agencies, and ministries especially, the Ministry of Environment, Science, Technology, and Innovation (MESTI) and the Ministry of Trade and Industry (MOTI). The recommendations are also valuable to policymakers and stakeholders concerned with R&D, innovation, and productivity.

6.1 Summary of the findings

The study determines the effect of R&D and innovation on labour productivity in the manufacturing sector in Ghana. The specific objectives are to examine the determinants of labour productivity in the manufacturing sector in Ghana and to examine the role of R&D on labour productivity in the manufacturing sector in Ghana.

The study employed a Three-Stage Least Square (3SLS) regression approach on a dataset of 720 firms from the World Bank Enterprise survey in 2013 to achieve its' objective. Due to missing values in some of the variables used in the study, 209 firms were observed. The study also employed a sequential regression mode1, estimating the R&D equation by a Tobit regression model, a bivariate probit regression model for product and process innovation, and an ordinary least squares regression model for the productivity equation in line with a modified Crepon, Duguet, and Mairesse (CDM) model. The analysis was made based on the three-stage least squares regression results.

The study finds that R&D and product innovation have a significant positive influence on the level of labour productivity in the manufacturing sector in Ghana. R&D plays a significant role in determining process, product innovation, and labour productivity in the manufacturing sector in Ghana. Labour productivity in the manufacturing sector in Ghana is determined by research and development, product innovation, foreign ownership, and the size of the firm.

6.2 Conclusions of the study

In contrast to the studies by Goedhuys et al. (2008a, 2008b) where the impact of R&D and innovation on the levels of productivity in the framework of some developing countries revealed that R&D and innovation insignificantly influence productivity but the business environment plays a significant role; this study finds a significant impact of R&D and product innovation on labour productivity at the manufacturing sector in Ghana.

6.3 Policy recommendations

To boost the capacity of Ghanaian firms in embarking on research and development, the following are policy recommendations per the findings of the study:

Firstly, the Government of Ghana must integrate research and development into the national development strategy to create an enabling environment for local firms to be involved in research and development activities and be productive. The requirement for R&D initiatives has become very expedient in Ghana's development challenges. It is in this regard that state-owned research institutions should assist the firms and liaise with them on their research needs. Besides, universities should incorporate the provision of skills training to students rather than simply providing an educated workforce. This can be achieved by working diligently with the private sector and undertake industrial attachments and internships.

Secondly, the Government needs to support research and development through a coordinated effort by implementing a multi-sector policy action that considers the needs of the firms. This multi-sector policy may present a fertile ground for knowledge spillovers and exchange of information.

Thirdly, Government legislation and macroeconomic policies must create a competitive environment devoid of monopolies. The existence of competition at the market offers a favorable environment for firms to innovate and thereby endure and be successful.

Finally, there is a need for the establishment of a fund towards R&D to enhance innovation and productivity in Ghana. The fund must be used to support the various research institutions in the country to equip them with the required research ability and tools to embark on problem-solving research at the firm and industry level.

6.4 Limitations of the study

The study had challenges with the dataset on missing values. Some of the variables have missing values to a high degree (example; the cost of assets, number of skilled production workers) which made the researcher exclude such variables in the model. Also, the firms surveyed were mainly in the major urban areas in Ghana (Accra, Tema, Takoradi, Kumasi, and Tamale) leaving the firms situated in the relatively minor urban areas and the rural areas excluded in the study.

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APPENDIXES

First-stage regressions

Three-stage least-squares regression

Equation	Obs	Parms	RMSE	"R-sq"	chi2	P
R_D	209	9	.3884772	0.3429	109.06	0.0000
Product	209	10	.4336057	0.6148	333.52	0.0000
Productivity	209	11	1.534774	0.9756	8344.97	0.0000

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
R_D						
lnfirm_age	.0203655	.0308389	0.66	0.509	-.0400776	.0808087
1.export1	-.2386453	.1129034	-2.11	0.035	-.4599319	-.0173588
1.for_own1	.0364241	.0946127	0.38	0.700	-.1490134	.2218617
firm_size						
Medium >=20 and <=99	.1821198	.0709083	2.57	0.010	.043142	.3210976
Large >=100	.6159908	.1443929	4.27	0.000	.332986	.8989955
1.sector2	.221535	.1029693	2.15	0.031	.0197188	.4233512
location						
Accra	-.1520836	.0711042	-2.14	0.032	-.2914452	-.012722
Takoradi	.1853251	.1289814	1.44	0.151	-.0674738	.438124
Tema	-.1303885	.0876131	-1.49	0.137	-.302107	.0413301
Product						
1.R_D2	.4354044	.0772069	5.64	0.000	.2840816	.5867272
lnfirm_age	.0360632	.0344571	1.05	0.295	-.0314715	.1035978
1.export1	.3843643	.1273589	3.02	0.003	.1347455	.6339831
1.for_own1	.1706263	.1056411	1.62	0.106	-.0364265	.3776791
firm_size						
Medium >=20 and <=99	.0603269	.080385	0.75	0.453	-.0972249	.2178787
Large >=100	-.1282499	.168038	-0.76	0.445	-.4575982	.2010985
1.sector2	.3389183	.1161976	2.92	0.004	.1111751	.5666615
location						
Accra	-.1361795	.0802281	-1.70	0.090	-.2934238	.0210647
Takoradi	.0846361	.144674	0.59	0.559	-.1989198	.3681919
Tema	-.1563614	.0983078	-1.59	0.112	-.3490411	.0363183
Productivity						
1.R_D2	.7785921	.2982837	2.61	0.009	.1939669	1.363217
1.prodIn2	-.5369559	.2452568	-2.19	0.029	-1.01765	-.0562614
1.training2	-.1505522	.2468033	-0.61	0.542	-.6342779	.3331734
1.export1	-.0590983	.4601909	-0.13	0.898	-.9610558	.8428592
1.for_own1	.7295496	.378198	1.93	0.054	-.0117049	1.470804
firm_size						
Medium >=20 and <=99	.9036683	.2937617	3.08	0.002	.327906	1.479431
Large >=100	1.968983	.6004182	3.28	0.001	.7921848	3.145781
1.sector2	9.246345	.2878578	32.12	0.000	8.682154	9.810536
location						
Accra	.0287397	.2857415	0.10	0.920	-.5313033	.5887827
Takoradi	.8093052	.5089231	1.59	0.112	-.1881659	1.806776
Tema	.6887339	.3500604	1.97	0.049	.0026281	1.37484

Endogenous variables:
Exogenous variables: R_D2 lnfirm_age 0.export1 1.export1 0.for_own1 1.for_own1 1.firm_size 2.firm_size 3.firm_size 1.sector2 1.location 2.location 3.location 4.location prodIn2 0.R_D2 1.R_D2 productivity3 0.prodIn2 1.prodIn2 0.training2 1.training2

First-stage regressions

Three-stage least-squares regression

Equation	Obs	Parms	RMSE	"R-sq"	chi2	P
R_D	209	9	.3884772	0.3429	109.06	0.0000
Process	209	10	.4493089	0.3607	117.93	0.0000
Productivity	209	11	1.552814	0.9750	8147.48	0.0000

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
R_D						
lnfirm_age	.0203458	.0308389	0.66	0.509	-.0400974	.080789
1.export1	-.2386416	.1129034	-2.11	0.035	-.4599281	-.017355
1.for_own1	.0364215	.0946127	0.38	0.700	-.1490161	.221859
firm_size						
Medium >=20 and <=99	.1821242	.0709083	2.57	0.010	.0431464	.321102
Large >=100	.6160093	.1443929	4.27	0.000	.3330045	.8990141
1.sector2	.2215871	.1029694	2.15	0.031	.0197708	.4234035
location						
Accra	-.1520865	.0711042	-2.14	0.032	-.2914481	-.0127249
Takoradi	.1853159	.1289814	1.44	0.151	-.067483	.4381147
Tema	-.1303923	.0876131	-1.49	0.137	-.3021108	.0413263
Process						
1.R_D2	.2452627	.080003	3.07	0.002	.0884596	.4020657
lnfirm_age	.0397817	.035705	1.11	0.265	-.0301989	.1097623
1.export1	.1127947	.1319712	0.85	0.393	-.1458642	.3714536
1.for_own1	.0681183	.109467	0.62	0.534	-.146433	.2826696
firm_size						
Medium >=20 and <=99	-.0193887	.0832962	-0.23	0.816	-.1826463	.1438689
Large >=100	-.1716256	.1741236	-0.99	0.324	-.5129015	.1696503
1.sector2	.1456148	.120406	1.21	0.227	-.0903766	.3816062
location						
Accra	.0335399	.0831336	0.40	0.687	-.129399	.1964788
Takoradi	.0640718	.1499135	0.43	0.669	-.2297532	.3578968
Tema	-.07155	.101868	-0.70	0.482	-.2712077	.1281077
Productivity						
1.R_D2	.5411016	.2891374	1.87	0.061	-.0255973	1.1078
1.procIn2	.0531739	.2387442	0.22	0.824	-.4147562	.521104
1.training2	-.2045218	.2490381	-0.82	0.412	-.6926275	.283584
1.export1	-.2766848	.4562427	-0.61	0.544	-1.170904	.6175345
1.for_own1	.6287412	.380403	1.65	0.098	-.1168349	1.374317
firm_size						
Medium >=20 and <=99	.8852351	.2971482	2.98	0.003	.3028353	1.467635
Large >=100	2.058292	.6077287	3.39	0.001	.8671652	3.249418
1.sector2	9.016984	.2788365	32.34	0.000	8.470475	9.563494
location						
Accra	.0998723	.2872114	0.35	0.728	-.4630517	.6627963
Takoradi	.7717493	.5147519	1.50	0.134	-.2371459	1.780645
Tema	.775049	.3525354	2.20	0.028	.0840923	1.466006

Endogenous variables:
Exogenous variables: R_D2 lnfirm_age 0.export1 1.export1 0.for_own1 1.for_own1 1.firm_size 2.firm_size 3.firm_size 1.sector2 1.location 2.location 3.location 4.location procIn2 0.R_D2 1.R_D2 productivity3 0.procIn2 1.procIn2 0.training2 1.training2

```
Iteration 0:   log likelihood = -537.86019
Iteration 1:   log likelihood = -345.59971
Iteration 2:   log likelihood = -270.64872
Iteration 3:   log likelihood = -253.79292
Iteration 4:   log likelihood = -252.08352
Iteration 5:   log likelihood = -252.07598
Iteration 6:   log likelihood = -252.07598

Tobit regression                                Number of obs     =        410
                                                   Uncensored     =         79
Limits: lower = 0                                  Left-censored  =        331
        upper = +inf                               Right-censored =          0

                                                LR chi2(9)        =      32.49
                                                Prob > chi2       =     0.0002
Log likelihood = -252.07598                     Pseudo R2         =     0.0605
```

R_D2	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnfirm_age	.2568648	.0953441	2.69	0.007	.069428	.4443015
1.export1	-.6866041	.4652639	-1.48	0.141	-1.601265	.2280571
1.for_own1	.1310669	.3229621	0.41	0.685	-.5038435	.7659774
firm_size						
Medium >=20 and <=99	.2021837	.2280253	0.89	0.376	-.2460906	.650458
Large >=100	1.152405	.4596709	2.51	0.013	.2487395	2.056071
1.sector2	.3727796	.1964582	1.90	0.058	-.0134371	.7589962
location						
Accra	-.5217149	.2497955	-2.09	0.037	-1.012787	-.0306425
Takoradi	.3678862	.3788361	0.97	0.332	-.3768668	1.112639
Tema	-.7107072	.3137437	-2.27	0.024	-1.327495	-.0939192
_cons	-1.722076	.4090626	-4.21	0.000	-2.526251	-.9179011
var(e.R_D2)	1.902654	.3746165			1.291987	2.801957

```
Bivariate probit regression                     Number of obs     =        410
                                                Wald chi2(20)     =      64.63
Log likelihood = -468.90431                     Prob > chi2       =     0.0000
```

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
procIn2						
1.R_D2	.5341768	.1693574	3.15	0.002	.2022425	.8661111
lnfirm_age	.0376556	.0739357	0.51	0.611	-.1072557	.1825668
firm_size						
Medium >=20 and <=99	.2134402	.1610349	1.33	0.185	-.1021825	.5290629
Large >=100	.0068672	.3715078	0.02	0.985	-.7212748	.7350092
1.export1	.1670833	.2817508	0.59	0.553	-.385138	.7193046
1.for_own1	-.2662152	.2353403	-1.13	0.258	-.7274736	.1950433
1.sector2	.279346	.1380043	2.02	0.043	.0088626	.5498294
location						
Accra	.1278527	.1863049	0.69	0.493	-.2372982	.4930036
Takoradi	.0924623	.3030916	0.31	0.760	-.5015864	.686511
Tema	-.0397763	.2223443	-0.18	0.858	-.4755631	.3960104
_cons	-1.089266	.2744842	-3.97	0.000	-1.627245	-.551287
prodIn2						
1.R_D2	1.062708	.1830513	5.81	0.000	.7039343	1.421482
lnfirm_age	-.0429296	.0699406	-0.61	0.539	-.1800107	.0941514
firm_size						
Medium >=20 and <=99	.1683122	.1593369	1.06	0.291	-.1439823	.4806067
Large >=100	-.1757422	.3640848	-0.48	0.629	-.8893352	.5378509
1.export1	.5992664	.2806713	2.14	0.033	.0491607	1.149372
1.for_own1	.3087838	.2235786	1.38	0.167	-.1294222	.7469898
1.sector2	-.0221955	.1311181	-0.17	0.866	-.2791823	.2347913
location						
Accra	-.1532941	.1784737	-0.86	0.390	-.5030962	.1965079
Takoradi	.0898987	.2961085	0.30	0.761	-.4904634	.6702607
Tema	-.537169	.2139525	-2.51	0.012	-.9565082	-.1178297
_cons	-.0376643	.2549045	-0.15	0.883	-.537268	.4619395
/athrho	.4878522	.0954833	5.11	0.000	.3007084	.674996
rho	.4525101	.0759316			.2919607	.5882567

```
Wald test of rho=0: chi2(1) = 26.1049                    Prob > chi2 = 0.0000
```

Source	SS	df	MS			
				Number of obs	=	209
				F(11, 197)	=	4.21
Model	115.459382	11	10.4963074	Prob > F	=	0.0000
Residual	491.042386	197	2.49260095	R-squared	=	0.1904
				Adj R-squared	=	0.1452
Total	606.501768	208	2.91587389	Root MSE	=	1.5788

productivity3	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
1.R_D2	.7520465	.3086619	2.44	0.016	.1433408	1.360752
1.prodIn2	-.5899495	.2593062	-2.28	0.024	-1.101322	-.0785773
1.procIn2	.1771976	.2494864	0.71	0.478	-.3148092	.6692045
1.training2	-.157339	.2540582	-0.62	0.536	-.6583618	.3436838
1.export1	-.0615571	.4734427	-0.13	0.897	-.9952235	.8721094
1.for_own1	.7263959	.3891153	1.87	0.063	-.0409703	1.493762
firm_size						
Medium >=20 and <=99	.9127541	.3023485	3.02	0.003	.316499	1.509009
Large >=100	1.996393	.6185414	3.23	0.001	.776581	3.216206
1.sector2	0	(omitted)				
location						
Accra	.0147705	.294373	0.05	0.960	-.5657564	.5952974
Takoradi	.8062841	.5235722	1.54	0.125	-.2262416	1.83881
Tema	.6924283	.3602167	1.92	0.056	-.0179475	1.402804
_cons	9.229109	.2980137	30.97	0.000	8.641402	9.816815