UNIVERSITY OF GHANA

ASSESSING THE EFFICIENCY AND PRODUCTIVITY OF COOPERATIVE CREDIT UNIONS IN GHANA: A METAFRONTIER APPROACH

BY

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DECLARATION

I declare that this work was done by me and that references from other people's work have been duly acknowledged and cited. I also declare that the result of this study is from my original research work carried out under the supervision of Dr. Kwaku Ohene-Asare and Dr. Anthony Afful-Dadzie from the Department of Operations and Management Information Systems, University of Ghana. I also state that this work has not been presented anywhere for any other award and therefore all errors found in this thesis should be attributed to me.

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CERTIFICATION

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DEDICATION

This thesis is dedicated to The Holy Trinity; GOD the Father, GOD the Son and GOD the Holy Spirit.

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ABSTRACT

The aim of this study is to assess the efficiency and productivity change of three groups of cooperative credit unions (CCUs) in Ghana using a DEA metafrontier and the metafrontier Malmquist productivity index (MMPI) framework. The framework helps to decompose the technical efficiency change and technical change components in the standard Malmquist Productivity Index (MPI) into a pure technical catch-up (PTCU) and frontier catch-up (FCU) in order to account for the catch-up effect.

A total of 49 CCUs from the three groups/clusters (parish, community and workers) were assessed, using their audited financial report covering 2008-2012.

The empirical results for the metafrontier analysis shows an average group technical efficiency (GE) score of 70.2% and average meta-technical efficiency of 56.7%. The community group recorded the highest efficiency score of 88.1% with respect to the group frontier, while the parish group showed highest efficiency score of 63.3% relative to the metafrontier. The MMPI results show that all the groups declined in productivity, with the parish group being the only group to show progress under GMPI.

The PTCU effect showed that the workers' and the parish groups are shrinking the technology gap between the metafrontier and the group frontier, whereas the community group is increasing the technology gap. The FCU effect also indicated that the workers' and the parish groups are experiencing an upward shift in the group frontier at a faster rate than the metafrontier. The PTCU and FCU effects indicates that the parish and workers' groups are shrinking the whole band of technology.

The findings provide valuable insight for managers of CCUs to improve on the use of their input resources in order to be productive. Also, managers should keep more focus on

assessing their operational efficiency in dynamic settings rather than depending on static efficiency measures for improvement.

LIST OF ABBREVIATIONS

ACCOSCA:	African Confederation of Co-operative Savings and Credit Association
AE:	Allocative Efficiency
BCC:	Banker Charnes and Cooper
BOP:	Bottom of the Pyramid
CCR:	Charnes, Cooper and Rhodes
CCUs:	Cooperative Credit Unions
CE:	Cost Efficiency
CRBs:	Co-operative Rural Banks
CRS:	Constant Return to Scale
CUA:	Credit Unions Association
DEA:	Data Envelopment Analysis
DFA:	Distribution Free Approach
DMUs:	Decision Making Units
EU:	European Union
FNGOs:	Financial Non-Governmental Organizations
FCU:	Frontier Catch Up
FDH:	Free Disposal Hull
GDP:	Gross Domestic Product
GE:	Group-frontier Efficiency
GMPI:	Group-frontier Malmquist Productivity Index
GOG:	Government of Ghana
GPRS:	Growth and Poverty Reduction Strategy
MCP:	Malmquist Cost Productivity
MDGs:	Millennium Development Goals
ME:	Metafrontier Efficiency
MoFEP:	Ministry of Finance and Economic Planning

MFI:	Micro Finance Institutions
MI:	Malmquist Index
MIS:	Management Information Systems
MMPI:	Metafrontier Malmquist Productivity Index
MPCI:	Malmquist Productivity Change Index
MPI:	Malmquist Productivity Index
MTE:	Metatechnical Efficiency
MTFP:	Malmquist Total Factor Productivity
MTR:	Metatechnology Ratio
NBFIs:	Non-Bank Financial Institutions
NGOs:	Non-Governmental Organisations
SACCOS:	**S**avings and Credit Cooperative Organizations
SBs:	Savings Banks
SBM:	Slack Base Measure
SE:	Scale Efficiency
SFA:	Stochastic Frontier Analysis
SSA:	Sub Saharan Africa
T:	Technology set
TE:	Technical Efficiency
TEC:	Technical Efficiency Change
TC:	Technology Change
TFA:	Thick Frontier Approach
TFP:	Total Factor Productivity
TGRs:	Technology Gap Ratios
TGRC:	Technology Gap Ratio Change
OTE:	Overall Technical Efficiency
PPF:	Production Possibility Frontier

PPS:	Production Possibility Set
PTCU:	Pure Technological Catch Up
PTE:	Pure Technical Efficiency
U.S.A:	United States of America
VRS:	Variable Return to Scale
WOCCU:	World Council of Credit Unions

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

A number of Sub-Saharan African countries have taken steps to ameliorate poverty which is one of the key impediments to economic growth and development (Adams & Page, 2005). The Government of Ghana (GOG) recognizes that poverty reduction is a major contributor for achieving all the millennium development goals (MDGs) (MoFEP, 2008). The financial service sector plays a major role in alleviating poverty, through provision of loan and credit facilities to their clients. The financial service sector includes banks and non-bank financial institutions (NBFIs) (MoFEP, 2008; Ghana, 2008). The NBFIs are made up of savings and loans companies, cooperative credit unions (CCUs), susu collectors and financial NGOs, all of which are microfinance institutions. Whereas banks and the other microfinance institutions are profit-making, CCUs are not-for-profit organizations (Fried, Lovell, & Eeckaut, 1993; Garden & Ralston, 1999; Taylor, 1917). The CCUs are financial intermediaries basically owned and operated by individuals who are united by a common bond of interest and for the sole benefit of these members (Fried, Lovell, & Yaisawarng, 1999; Fried et al., 1993). The common interest could be of occupation, association, religion or residential location (Glass McKillop, Donal, Quinn, and Barry, 2014). The CCUs provide alternative sources of financing among the relatively poor population in Africa through the provision of a broad range of financial services (Kyessi & Furaha, 2010). Thus the CCUs are taking advantage to serve the majority of the people at the 'bottom of the economic pyramid' (BOP), a concept proposed by Prahalad and Hart (2002). Prahalad and Hart (2002) argued that there is fortune in serving those at the bottom of the pyramid, considered to be resource poor. In this regard, there is the need for integrated effort by all stakeholders in making CCUs an instrument for wealth creation.

Banks most often target people in the middle or upper class to offer financial credit, rather than the minority and the lower income group. This is because the people in the middle and upper class fit into the lending structure and represent more profitable lending activity (Birkenmaier & Tyuse, 2005). In order to access credit facility from the formal banking sector, one is required to provide collateral, which is hard for the relatively poor to obtain.

When banks deny credit to some people, CCUs are seen as tools against financial exclusion (McKillop, Glass, & Ferguson, 2002). The only requirement for accessing credit facility from a CCU is by being a member and having a guarantor who is also a member (Fried et al.,1993). In Ghana, after six months, a needy member can apply for a credit facility and the person would be offered a minimum interest rate payable within a period of time. The CCUs in Ghana have assisted members to construct or complete their houses, expand their businesses, educate their children and receive better healthcare services among others (Darko, 2013). Fried et al. (1993) reported that 14000 CCUs in the U.S. provided loans and deposit services to about 60 million members. Therefore, CCUs are considered as the engine for poverty alleviation (Birchall & Simmons, 2009). Another feature of CCUs is their relatively smaller in size compared to banks. In Ghana, CCUs hold total asset of GH₵571.43 million (WOCCU, 2013), whilst banks hold about GH₵27.2 billion in 2012 (BoG, 2013). CCUs main source of funding is from members savings and shares and provide credits from the funds received from members (Fried et al., 1993), whereas the formal banking sector has variety sources of funding (IMF, 2013). The CCUs operate to pursue both economic and social developmental objectives as they seek to maximize the welfare and benefits of members, whereas banks seek to maximise profit (Esho, 2001; Fried, Lovell, & Yaisawarng, 1999; Marwa & Aziakpono, 2014; Wheelock & Wilson, 2013). At the end of the financial year, the management of CCUs declares profit and shares among members' contributions. In Ghana, common of interests are categorized into workplaces, parish and communities. In brief, the membership of CCUs can hinge on regional finance and the finance of small and medium-sized local firms and this is what distinguishes CCUs from commercial banks (Fukuyama, Guerra, & Weber, 1999; Fukuyama, 1996). Although CCUs are not-for-profit and contribute to wealth creation, they face direct competition from profit-making financial institutions such as commercial banks and other microfinance institutions (Fried and Lovell, 1994; Wheelock and Wilson, 2013; Burke, 2014). Still, owners/members seek to maximize utility of interest received from deposits/shares and minimise interest paid on loans (Bauer, Miles, & Nishikawa, 2009). Again, because of their not-for-profit features, it is unsuitable to use conventional profitability ratios to assess their performance (Fried & Lovell, 1994).

Given their contributions to socioeconomic development, and given the fact that CCUs have to keep pace with the current financial sector competition, the goal of this study is to assess the operational dynamic productivity of CCUs that operate across different subgroups in Ghana and to decompose productivity change into several components in order to determine the drivers of change. The novelty of the study hinges also on the unique application of the metafrontier Malmquist productivity change index proposed by Chen and Yang (2011) to account for group heterogeneity.

1.2 Problem Statement

Regardless of widespread and copious research on efficiency and productivity of CCUs (Worthington, 1999; Glass & Mckillop, 2000; Wheelock & Wilson, 2013), we identify gaps in the CCUs efficiency literature. First, extensive studies are tilted towards US, UK and Australia, and other developed economies whereas few studies are observed in Africa (Magali & Lang'at, 2014; Magali & Pastory, 2013; Marwa & Aziakpono, 2014;

Tesfamariam, Tesfay, & Tesfay, 2013). To the best of the authors' knowledge, only Oteng-Abayie, Amanor and Frimpong, (2011) assesed the efficiency of microfinance institutions in Ghana and included CCUs. They however considered only static efficiency and not dynamic productivity. They also neglected group performance in their analysis and used stochastic frontier analysis (SFA). But SFA requires several model specifications and restrictive parametric assumptions (Aigner, Lovell, & Schmidt, 1977; Daraio & Simar, 2007). Besides, SFA usually requires a single dependent variable representing an output or input which could be unreal as many CCUs use several inputs to generate several outputs (Daraio & Simar, 2007).

Second, albeit studies on efficiency of CCUs exist (Glass, McKillop, Quinn, & Wilson, 2012; Glass, McKillop, & Rasaratnam, 2010; Glass, Colin, McKillop, Donal and Quinn, 2014; Servin, Lensink, & van den Berg, 2012; Wheelock & Wilson, 2013) but few considered efficiency of different groups of CCUs without using metafrontier framework (Brown, 2006; Asawarangpipop & Suwunnamek, 2014). Also, studies that considered group heterogeneity under metafrontier framework are few (Kontolaimou & Tsekouras, 2010). However, the conventional metafrontier framework, which capture technological differences does not consider productivity change over a period of time.

Lastly, few studies have assessed the dynamic productivity of CCUs using DEA-based Malmquist productivity change index (MPI) (Pasiouras & Sifodaskalakis, 2010; Worthington, 1999, 2010). However, the MPI does not appropriately consider the characteristics of group heterogeneity in its estimation (Lee & Oh, 2010). Therefore, vital information concerning technology differentials may be lost, especially when the CCUs under evaluation operate under different group technologies as in our case. Capturing group differentials in efficiency and productivity dynamics allow for disintegration of sources of productivity into several components, which could serve as directions for improvement. A metafrontier Malmquist Productivity Index (MMPI) has been introduced to appropriately cater for technology differentials in the traditional MPI (Lee & Oh, 2010; Chen & Yang, 2011). Whereas the classical MPI only decomposes productivity into efficiency change and technical change, the MMPI further decomposes productivity into pure technological catch-up (PTCU), frontier catch-up (FCU) and technology gap ratio change (TGRC) (Chen & Yang, 2011).

Worthington, (2010) conducted a survey of studies that assessed the efficiency and productivity of deposit-taking financial mutuals. Of the 27 studies surveyed, 56% were on CCUs, but none used the MMPI, which captures the group heterogeneous effect. A CCU may be efficient or productive when measured against its own group-frontier, but inefficient or unproductive when its performance is estimated relative to the metafrontier. Given the heterogeneity among the three groups of CCUs in our study - community, workers and parish groups – adopting the MMPI helps in identifying technology gaps among these three groups and their catch-up effects so that policies could be orientated towards affected groups.

The MMPI approach has been applied in analysing productivity of banks (Chen & Yang, 2011), energy efficiency and carbon emission (Lee & Oh, 2010; Wang, Zhao, Zhou, & Zhou, 2013; Zhang & Choi, 2013), regional productivity (Ahmed & Krishnasamy, 2013; Chen, Huang, & Yang, 2009; Krishnasamy & Musa, 2009; Sang-Mok, Moon-Hwee, & Hui-Lan, 2013) and government management units (Miszczyński, 2013). To the best of the our knowledge, only Juo, Lin, and Chen, (2015) have otherwise employed the metafrontier Malmquist-Luenberger indicator to assess the productivity growth of farmers' CCUs. However, Juo et al. (2015) approach was based on the global Malmquist of Pastor and Lovell (2005) and not the classical Malmquist of Färe, Grosskopf, Lindgren, and Roos

(1992). This current study employs the MMPI on financial CCUs for the first time in the credit union efficiency literature following the methodology proposed by Chen and Yang (2011).

1.3 Research Contributions

The current study first-hand uses the innovative MMPI of Chen and Yang (2011) to assess the productivity changes of different subgroups of CCUs based on a sample of CCUs in Greater Accra Region of Ghana. Second, in order to determine the drivers of dynamic productivity, the study decomposes the MMPI into several components and identifies those groups that are the "innovators" of the industry. Third, using several non parametric tests, the study determines the significance of changes in productivity among the different subgroups of CCUs. The policy prescriptions from this study are also important to the government regulatory body in Ghana that is currently developing a policy to regulate credit unions' activities.

1.4 Research Objectives

This study evaluates the productivity dynamics of CCUs in the Greater Accra region of Ghana over the five year period, 2008-2012. The goal is to determine the group heterogeneity among the CCUs based on their productivity change indices and to decompose the change into efficiency change, technical change, pure technological catch-up, frontier catch-up and technology gap ratio change. Specific objectives are:

1. To assess dynamic efficiency and productivity of the CCUs in Greater Accra Region of Ghana.
2. To investigate the sources of productivity change of the CCUs.
3. To assess whether group differences significantly affect the efficiency and productivity change of the CCUs operations.

1.5 Research Questions

1. What is the overall efficiency and productivity change of the subgroups of CCUs in the Greater Accra region of Ghana over the study period?
2. What sources of productivity change drives the productivity of CCUs in the subgroups?
3. Do group differences significantly affect productivity of the CCUs?

1.6 Significance of study

The study provides some important benefits to academic, corporate world and policy. The policy ramification concerns the novel application of the MMPI to the study of group dynamics in order to disentangle group dynamics from managerial performance. That way, managers of CCUs in Ghana become better informed of the key drivers of their performance and operational activities. It would guide management to orientate managerial policies towards the improvement target areas. From an academic perspective, researchers may be better informed of the important use of the MMPI and its components for group heterogeneity assessments and to extend the method both theoretically and empirically.

1.7 Limitations of the Study

This study is limited to, cooperative credit unions in Accra, although cooperative credit unions are spread throughout the ten regions in Ghana. This restricts the scope of the study. Further, the study considered only credit unions and did not include other non-bank financial institutions which perform similar roles like the credit unions. All of these undoubtedly stifle the sample size augmentation and hence, these are taken into account when interpreting results.

1.8 Chapters Outline

This research work has been divided into six chapters. Chapter one introduces the reader to the concept of credit union operations and the need to measure the efficiency of CCUs. The chapter identifies the research gaps that the study seeks to address in the problem statement. It further establishes the significance of the study. The objectives of the study from which the research questions are derived are also stated in chapter one. The scope of research and limitation of the study is highlighted to conclude the chapter. Chapter two discusses the theoretical and analytical framework for efficiency and productivity measurement. It also discusses the DEA framework, the concept and its application to the measurement of metafrontier efficiency and productivity. Finally, it reviews some empirical studies on efficiency and productivity measurement of CCUs as well as metafrontier and MMPI studies to conclude the chapter. Chapter three deals with the context of the study. A brief background and overview of CCUs evolution as well as CCUs operations and organisational structure in Ghana are discussed in this chapter. Chapter four of this thesis describes the methodological processes used in carrying out the study. The DEA based metafrontier, Malmquist productivity index and MMPI models used for this study are also discussed. It also discusses the choice of input and output variables used for this study. The analyses of the results are discussed in Chapter Five. This is followed by the discussions of the results and the findings. Lastly, chapter six provides a summary of the main findings from the study. The chapter also makes recommendations and gives directions for policy makers, management of CCUs and other stakeholders in the industry. The research limitations and directions for future research are discussed to conclude the chapter.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter reviews the theories of productivity growth that explains the factors that causes enhancement of economic and productivity growth. Since this study is concerned with measuring efficiency and productivity of CCUs using DEA and its MMPI extension, the technology heterogeneity in productivity is also discussed. The concept of efficiency and frontier techniques for efficiency measurement is also reviewed. These techniques are relevant in achieving the set objectives of the study. Empirical studies on the efficiency and productivity of CCUs and also on metafrontier and MMPI in general are also reviewed to conclude the chapter.

2.1 The Theory of Productivity Growth

The Theoretical underpin of economic growth was initiated independently by the works of (Harrod, 1939) and (Domar, 1946), dubbed the dynamic growth theory. This theory stated that economic growth emanates solely from capital accumulation, which at the short-run, increase savings of a firm. In this theory, they refer capital to all physical capital, including land, natural resources and minerals required for production. It is evident that, with the perfectly competitive environment, under a constant return to scale, firms continually add to their stock of capital (Jones & Manuelli, 1997; King & Rebelo, 1990; Rebelo, 1992). The Harrod-Domar model form the basis for the neoclassical or exogenous growth theory known as the "Solow Growth Theory", and the subsequent growth accounting model developed by Solow (1956), and the endogenous growth theory of (Romer, 1994). Although, there are differences in these theories, they are helpful in explaining productivity growth and technical progress (Stiroh, 2001). These growth models are explained below.

The Solow Growth Model

The standard neoclassical growth model, also known as the Solow growth model, provide a link between output/gross domestic product, Y, the stock human and physical capital, K, and labour input (unskilled labour), L, and is defined as a production function:

$$Y = Ae^{\mu t} K^{\alpha} L^{1-\alpha} \quad 2.1$$

From this production function, A is a constant representing the technological starting point of a firm, e^{μ} is the exogenous rate at which technology evolves, while α represents the percentage increase in gross domestic product resulting from a 1 percent increase in capital (Solow, 1956). When α is less than 1, then this production function displays diminishing returns to capital and labour (Pack, 1994). Therefore, from this production function, capital accumulation (increases in savings and investment) will generate additional growth over a period of time (Grossman & Helpman, 1994; Pack, 1994; Solow, 1956). However, output will decline as the ratio of capital to labour increases and therefore the economy will slow down to a steady state. At the steady state, the growth rate for output, capital and labour are constant (King & Rebelo, 1990; Pack, 1994). The growth in income per worker will rise such that it will equal the annual rate of productivity improvement, μ. In the neoclassical Solow Growth model, μ is interpreted in terms of improvement in knowledge or technology, or other changes that are unrelated to knowledge improvement. According to Stiroh (2001), the neoclassical production function also relies on the following assumptions:

1. The production function assumes constant returns to scale
2. Countries produce a single, homogenous good of output
3. Output is measured as units of a country's gross domestic product (GDP)
4. All factors of production are fully employed

5. Technology stock is considered exogenous

A firm's investment in tangible assets, education, training and other human capital accumulation, as well as research and development impacts on its productivity growth. Therefore, capital accumulation governs the relationship between investment in tangible assets, *I*, and capital stock, *S*, through an inventory equation:

$$S_t = (1-\delta).S_{t-1} + I_t, \qquad 2.2$$

Where δ represent depreciation and *I*, is assumed to be a proportion of fixed output or determined endogenously by profit-maximising firms. Under a simple neoclassical model, where a single product is produced, the capital stock *S*, and capital services *K*, are identical. However, the capital stock *S*, and capital services *K*, differ in a situation where many heterogeneous types of investment outputs are produced (Stiroh, 2001).

The striking implication of the neoclassical model is that, in the long run, per capita output and productivity growth are driven entirely by growth in exogenous technical progress (Grosskopf, 2003; Ha & Howitt, 2007; Romer, 1994) and they are independent of other structural parameters like the savings rate (Stiroh, 2001). If the savings rate and investment share increase, for example, the long-run level of productivity rises but the long-run growth rate eventually reflects only technical progress. Although the neoclassical growth model is useful tool for understanding the factors that contribute to productivity growth, it does not really a model growth in the long-run. This is because, it attributes productivity growth to exogenous and entirely unexplained technical progress (Aghion & Howitt, 2007; Pack, 1994; Romer, 1994; Stiroh, 2001).

The Growth Accounting Theory

The growth of output and production over time depends on how much capital, labour and technology a firm uses in the production process. Solow (1957) developed an analytical method for total factor productivity growth and named it growth accounting theory. This was to complement the neoclassical production function in order to account for the rate of technological progress. In growth accounting, a specific production function that can account for two sources of growth is required. In this regard, growth accounting assumes that increases in input will result in output maximisation as well as increases in productivity, due to improved technology and human capital investment . The growth accounting model assumes competitive factor market, full input utilisation and constant returns to scale (O'Mahony & Timmer, 2009; Stiroh, 2001). The production function, therefore, presents a relationship between inputs and outputs as:

$$Y_{jt} = A_{jt} . f_{jt}\left(K_{jt}, L_{jt}\right) \qquad 2.3$$

where Y is output, K is capital, L is labour, j represent a firm, with A representing total factor productivity. The higher the value of A, the more output is produced. A variable t, representing time, is introduced to allow for technical change over time (Solow, 1956). The technical change is an expression of any kind of shift over time in the production function. The shift could be a slowdowns, improvements in the education of labour force or speed-up (Solow, 1957).

Differentiating Equation 2.3 totally with respect to time and dividing by the output, Y_{jt} gives:

$$\frac{Y_{jt}^*}{Y_{jt}} = \frac{A_{jt}^*}{A_{jt}} + A_{jt}\frac{\partial f}{\partial K}\frac{K_{jt}^*}{Y_{jt}} + A_{jt}\frac{\partial f}{\partial L}\frac{L_{jt}^*}{Y_{jt}} \qquad 2.4$$

where star (*) represent derivative and $A_{jt}\frac{\partial f}{\partial K}$ and $A_{jt}\frac{\partial f}{\partial L}$ respectively represents capital share and labour share in productivity. Therefore, Equation 2.4 is interpreted as:

$$\text{Growth} = \text{labour share} \times \text{labour growth} + \text{capital share} \times \text{capital growth} + \text{total factor productivity growth}$$

Therefore, if the proportional growth rates of output, the capital stock and the labour force are determined in the production function, then the rate of total factor productivity can be calculated, using the growth accounting equation.

The Endogenous growth Theory

The neoclassical growth theory developed by Solow (1956, 1957), with its assumptions of decreasing return to capital, perfect competition and exogenous technology implies that countries share similar savings behaviour and technologies and that countries converge to a common level of per capita income (Grossman & Helpman, 1994). Romer (1994), challenged this assert, with the view that the neoclassical models cannot fully explain the cross country variations in per capita incomes and national growth rates. The purpose of endogenous growth theory is to seek some understanding of the interplay between technological knowledge and various structural characteristics of the economy and the society, and how such interplay result in economic growth.

These growth theories form the basis of dynamic productivity analysis, especially the MMPI methodology which can be used to assess group productivity dynamics and time series analysis by taking two adjacent time periods at a time. Readers are referred to Grosskopf (2003) for more details on comparison of the growth theories and the Malmquist productivity change index (MPI). The MPI form the basis for assessing CCUs productivity dynamics under the MMPI framework.

2. 2 Technology Heterogeneity and Productivity Measurement

Since the pioneering work of Charnes et al. (1978), several extension of the DEA model have been documented in literature. One of such extensions in the recent MMPI model by

Chen and Yang (2011). As the name implies, the MMPI combines two methodological approaches (metafrontier and Malmquist productivity index) in estimating productivity of DMUs belonging to different clusters or groups. The MPI is used to evaluate an observed input-output combinations of a DMU relative to two time periods (Caves, Christensen, & Diewert, 1982). Thus, the DEA-based MPI uses data collected from firms to derive an efficiency measure or the best practice frontier for year one relative to the prior year, while allowing the best practice frontier to shift (Grosskopf, 2003). This will show us whether the observed input/output combinations have improved relative to that best practice frontier over time. In MPI estimation, a value greater than unity indicates productivity progress, while a value less than one implies regress in productivity (Rolf Färe, Grosskopf, Norris, Zhang, et al., 1994). The MPI can be decomposed into efficiency change and technical change, which are sources of productivity improvement or decline (Grosskopf, 2003).

The metafrontier approach was developed by Battese and Rao (2002) and Battese, Rao, and O' Donnell (2004) in assessing the efficiency of DMUs under parametric approach, and was extended by O'Donnell, Rao, and Battese (2008), under non parametric framework. The development of the metafrontier approach for estimating the efficiency of firms was motivated by the problem of inequality in technology that may exist within a set of DMUs being evaluated. Production units in different regions face different environmental variables which determine their choices from different sets of feasible input-output combinations (Chen, Huang, & Yang, 2009). The differences in environmental variables could be of available stocks of physical, human, and financial capital, economic infrastructure, resource endowments, and any other characteristics of the physical, social, and economic environment in which production take place O'Donnell et al. (2008). Therefore, introducing the metafrontier framework in productivity analysis helps in capturing the technology differentials when decomposing the drivers of productivity O'Donnell et al. (2008).

2.3 Efficiency

The concept of relative efficiency and productivity change measurement was first proposed by Farrell (1957). The idea behind the development of relative efficiency is to depart from the assumption of perfect input-output allocation but to allow for inefficient operations (Farrell, 1957). The basis for the measure of inefficiency the radial contraction/expansion connecting inefficient observed points with reference(unobserved) points on the piecewise envelopment production frontier (Fried, Lovell, & Schmidt, 1993; Fried, Lovell, & Schmidt, 2008). If a firm's actual production point lies on the frontier, it is perfectly efficient. If it lies below the frontier then it is inefficient, with the ratio of the actual to potential production defining the level of efficiency of the individual firm (Charnes et al., 1978).

2.3.1 Types of Efficiency

There are two different components of economic efficiency depending on how narrow or wide the production process and freedom for making decisions associated with it are defined (Farrell, 1957). These are technical efficiency, allocative efficiency and overall economic efficiency.

Technical Efficiency

Technical or technological efficiency takes into account the amount of input consumed relative to the level of output produced. Farrell (1957) described technical efficiency as "*a firm's success in producing maximum output from a given set of inputs*". For a firm to transform inputs into outputs, certain kinds of technology will be needed. Technical efficiency specifically deals with the technology needed to transform certain inputs into output. Two different assumptions with respect to orientation prevail when measuring technical efficiency. These are input-orientation and output-orientation (Charnes et al., 1978). Input-oriented technical efficiency is measured by keeping outputs constant and inputs minimized. By making input constant and output maximized, an output-oriented technical efficiency is assessed (Charnes et al., 1978; Cooper, Seiford, & Zhu, 2004).

Allocative Efficiency

Allocative efficiency is concerned with choosing optimal inputs and/or outputs based on both the production technology and the relative input prices in the market (Berger & Humphrey, 1997a). Obviously, data on price is pre-requisite for measuring allocative efficiency. According to Farrell (1957), this type of efficiency can also be called price efficiency since input price is required in its assessment. Arguably, while technical inefficiency is reduced by using less input, allocative inefficiency may actually be reduced by producing more output given the input price (Coelli, Rao, O'Donnell, & Battese, 2005).

Overall Economic Efficiency

Overall economic efficiency is a combination of technical and allocative efficiency. That is, it requires technical/technological efficiency as well as allocative efficiency (Farrell, 1957). To be economically efficient, a firm has to choose its input and/or output mixes in order to optimize an economic goal, usually cost minimization or profit maximization (Mokhtar, AlHabshi, & Abdullah, 2006). It is quite possible to note that some firms that are relatively technically efficient may or may not be relatively economically efficient and therefore mix inefficiencies exists in efficiency measurement (Coelli et al., 2005; Cooper et al., 2004; Farrell, 1957). A firm's ability to be economically efficient depends on its managers' abilities to use the best technology and respond to market indicators (Berger & Humphrey, 1997a; Berger & Mester, 1997).

2.3.2 Measurement of Efficiency Using Frontier Techniques

Different measurement techniques have been utilized by financial institutions in particular and other organizational sectors in assessing their efficiency and performance. These techniques include DEA and SFA. Based on the pioneering work on DEA, a non-parametric frontier efficiency measurement approach developed by Charnes et al., (1978) and SFA, parametric frontier efficiency measurement developed by Aigner, Lovell, & Schmidt, (1977), many recent academic studies on efficiency used either parametric or non-parametric techniques. The DEA technique utilizes a vector of inputs and outputs to create an efficient frontier, whereas SFA technique assumes a functional form in estimating the efficient frontier.

Berger and Humphrey (1997) conducted a survey on studies that have implemented both parametric and non-parametric techniques in assessing efficiency. They concluded that no consensus exists in literature about the preferred frontier method of efficiency analysis to determine the best-practice frontier. Frontier efficiency measurement techniques have been employed by researchers to measure the productive performance of firms (Worthington, 2004) and particularly in cooperatives and financial mutual (Worthington, 2009). These techniques use a production possibility frontier to construct a locus of potentially technically efficient output combinations that an organisation could produce given input, within a specified period of time (See Charnes et. al, 1978, for DEA and Aigner, Lovell and Schmidt, 1977, for SFA).

The following section examines the two main frontier techniques; the parametric frontier technique, also known as the econometric approach and non-parametric or mathematical programming technique.

The Parametric Frontier Approach

This approach first specifies a production function and usually acknowledges that any deviation away from the given technology is due to error terms (Aigner, Lovell & Schmidt, 1977). It therefore decomposes the error terms into two; one being randomness or statistical noise and the other inefficiency. It further assumes that inefficiencies follow an asymmetric half-normal distribution and that random errors are normally distributed (Meeusen & Van Den Broeck, 1977). In other words, a parametric function is fitted into the data, in a manner that no observed point should lay outside it. Any observed point found outside it is considered inefficient.

According to Mokhtar et al. (2006), there are three main parametric techniques for measurement of efficiency. These are Stochastic Frontier Analysis (SFA), Distribution Free Approach (DFA) and the Thick Frontier Approach (TFA). Among these parametric techniques, research have extensively employed Stochastic Frontier Analysis developed by Aigner et al., in 1977. Some of the studies that utilized Stochastic Frontier Analysis include (Darko, 2013; Denizer, Dinc, & Tarimcilar, 2007; Erkoc, 2012; Oteng-Abayie, Amanor, & Frimpong, 2011).

Non-parametric Frontier Approach

This is also called mathematical linear programming approach which seeks to evaluate the efficiency of an organisation relative to other organizations in the same industry. Unlike the parametric frontier technique which specify the functional form of the efficient DMUs, the non-parametric approach do not require any specific preconceived functional form for identifying efficient DMUs (Cooper et al., 2004). Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH) are the common techniques under the non-parametric approach to efficiency measurement. Both DEA and FDH are non-stochastic methods in that they assume all deviations from the frontier are as a result of inefficiency (Berger & Humphrey, 1997a).

The most commonly employed technique among the non-parametric methods in recent literature of efficiency measurement is data envelopment analysis (DEA) developed by Charnes et al., (1978). DEA uses a piecewise linear programming procedure in identifying the empirical production functions based on the actual data. It compares homogeneous units in a given population by taking multiple outputs and inputs variables into account simultaneously. DEA constructs a piecewise linear convex on the best practice frontier to envelop the observed DMUs (Charnes et al., 1978). Two basic DEA models have most frequently been employed in empirical studies. These are the model developed by Charnes, Cooper and Rhodes, also known as the CCR-model (Charnes et al., 1978) and the BCC-model developed by (Banker, Charnes, & Cooper, 1984). The main difference between these two models is the way they treat the return to scale. The BCC model takes into account variable returns to scale, while the CCR model considers all DMUs to operate under constant returns to scale.

In situations when commonly agreed functional form relating inputs to outputs is difficult to prove or find especially for financial institutions, DEA is best adopted (Okuda, Poleng, & Aiba, 2014, citing Hababou, 2002). The DEA technique is also preferred to the parametric method in situations when the sample size of the DMUs is small (Okuda et al., 2014, citing Canhoto and Dermine, 2003).The main weakness of DEA is its assumption that data are free from measurement errors and also it is sensitive to outliers. In addition, since the measurement of efficiency is relative, an efficient DMU identified in the analysis cannot be compared with DMUs outside the sample (Okuda et al., 2014).

Some recent studies on efficiency measurement in CCUs that employed data envelopment analysis can be found in Xiang, Shamsuddin, and Worthington (2011), Glass, McKillop, and Rasaratnam (2010), Goddard, McKillop, and Wilson (2008), Magali and Lang'at (2014), Magali and Pastory (2013), Tesfamariam, Tesfay, and Tesfay (2013), Worthington (2010) and Marwa and Aziakpono (2014). This current research adopts the DEA technique to examine technical efficiency and productivity dynamics of CCUs operating under heterogeneous technologies. DEA model was chosen because it can handle multiple inputs and outputs simultaneously as oppose to SFA and also because of inadequate relevant data on input prices which is a requirement for SFA.

2.4 Empirical Review

There is an extensive body of literature on the efficiency and measurement of financial institutions across the globe, especially in the commercial banking sector. However, studies on CCUs performance is limited, especially under metafrontier, MPI and MMPI techniques (Worthington, 2010). This section reviews some empirical on efficiency and productivity analysis of CCUs. Since the analysis of productivity dynamics and technology heterogeneity are very limited in CCUs efficiency and productivity literature, some studies on metafrontier and MMPI in general will also be highlighted.

2.4.1 Empirical Evidence from CCUs MPI Studies

Othman, Kari and Hamdan (2013) evaluated the nature and extent of productivity change of the cooperative, Islamic and conventional banks in Malaysia. The study was conducted on 14 banks, which constitute one co-operative bank, eight other conventional banks and five other Islamic banks in Malaysia. A balanced panel data covering the period 2006-2010 was collected for the study. One output variable (Loans) and two input variables (labour and total assets) were used based under intermediation approach for the estimation. A non-parametric Data Envelopment Analysis (DEA) methodology and Malmquist productivity index (MPI) was employed to estimate the individual bank efficiency and productivity changes within the period specified above. The study also utilized second stage Tobit regression to evaluate factors that contribute to productivity change. The study observed that 64.3% of banks studied had total factor productivity (TFP) progressed. Out of this 44% were Islamic banks. The MPI index showed that TFP regressed in 2007 by 6.2%. TFP annual mean for the 5 year period, however, showed a progressed in TFP of 1.5% that was contributed by 2.7% increase in technical efficiency. The results from the second stage Tobit regression suggested that the bank's assets, status and loan intensity are statistically significant in determining TFP. However, environmental factors were found to be insignificant determinant.

This study could not be used to generalize productivity change of cooperative credit unions due to the small sample size and the fact that only one credit union was included in the sample. "*Cooperative banks pursue social and economic development objectives and may be subject to a lack of capital market discipline, which will result in differences in their performance compared to the profit- maximizing commercial banks*" (Goddard, Molyneux, & Wilson, 2004; page 367). From this assertion by (Goddard et al., 2004), cooperative banks operate under different structure relative to the traditional banks and therefore the results could have been better represented if different cooperative banks are compared.

Pasiouras and Sifodaskalakis (2010) investigated the total factor productivity (TFP) change in the Greek cooperative banking industry. The data used consists of a balanced panel dataset of 78 observations from 13 Greek cooperative banks over the period 2000-2005. Both intermediation and production approaches were followed by the study. Under the intermediation approach, three inputs and two outputs were considered. The three inputs are: fixed assets, number of employees and deposits, as loans, and liquid assets and investments were selected as output variables. Under the production approach, deposits also become an output. It therefore used two inputs and three outputs. Loans, liquid assets and investments, and deposits were chosen as output variables as inputs were number of employees and fixed assets. The study applied Malmquist index for the estimation under both the intermediation approach and the production approach. The results were mixed. The intermediation approach indicated a small decrease (3%) in TFP whereas the production approach showed an increase by 6.6% due to an increase in both efficiency change (4.6 percent) and technological change (1.9 percent). Comparing the results on the basis of banks' size found TFP growth to be higher for smaller co-operative banks on average over the entire period. However, this relationship between size and productivity is not robust across the years. The study, however, did not find any statistical difference between the groups.

This study was conducted in a developed economy, which may operate under different technology set and environment compared to credit co-operatives operating in a developing economy like Ghana. It is therefore imperative to consider total factor productivity change on cooperative credit unions in a developing economy like Ghana to ascertain whether the results could be compared to their counterparts in the developed world.

2.4.2 Empirical Evidence from CCUs Studies

Paxton (2006) studied technical efficiency of a sample of 350 Popular Savings and Credit Institutions (PSCI) in Mexico using a nonparametric frontier data envelopment analysis. The sample included Co-operative Savings and Loans, Savings and Credit Societies, Credit Unions, Cajas Solidarias, Civil Associations and others. A confidential data for the year 2001 was used for the analysis. In model specification, the study used both production and intermediation approaches under VRS assumption. In the production specification, the number of outstanding loans and the number of savings accounts were considered as outputs, with inputs being the capital and the number of employees. Alternatively, the intermediation approach utilized the outstanding loan portfolio, investments and demand deposits as output variables while inputs included the capital, the number of employees and loanable funds.

The study highlighted the heterogeneity of the sector and found most institutions to be highly inefficient, with mean efficiency score under production approach ranging between 0.65 and 0.45 for the groups studied. Alternatively, the intermediation approach produced efficiency scores ranging between 0.65 and 0.45. The second stage of analysis found primary determinants of efficiency to be institutional factors rather than client profile.

Methodologically, the study did not consider Metafrontier efficiency estimation for group specific efficiency score relative to the metafrontier, although it stated that heterogeneity exists in the groups studied. The study also used a single year for the analysis and therefore did consider the trend of efficiency scores or productivity change. The current study will go further to assess the heterogeneity in a Metafrontier framework and will also consider the productivity changes of the credit unions using a five year data.

Brown (2006) used a sample of 254 Australian credit unions in addressing the problem of data heterogeneity in DEA. The study stratified the credit unions into more homogeneous subgroups that share a common bond of association and argued that a common bond is an important environmental factor in efficiency estimation. The study considered operating cost as the only input variable and eight output variables comprising Housing loans, All non-housing loans, Deposits at call, All deposits not at call, Average interest rate paid on deposits at call, Average interest rate paid on deposit not at call, Reciprocal of average interest rate received from housing borrowers, Reciprocal of average interest rate received from non-housing borrowers. Two different groups (NSW and Victorian States) and their subgroups being community, industrial and parish groups were considered. The results for the pooled data suggest that Victorian credit unions are less efficient than NSW credit unions over the sample period (1993-1995). However, there were no parish credit unions in NSW over the period of study. Therefore, when parish credit unions were excluded from the Victorian sample, the efficient frontier shifted downwards and the Victorian credit unions became less efficient in its own group compared to NSW. It however, argued that the efficiency of parish credit unions may be due to cost savings through the use of voluntary labour.

Although this study considered the subgroups (parish, community and industrial) credit unions, it did not estimate their efficiency frontiers separately. Also, the study did not consider the productivity estimation for the different groups studied. The present study seeks to address these two limitations.

Chen and Hsiao (2014) used dynamic network DEA to estimate the operating efficiency and profitability of credit unions associated with farmer's associations in Taiwan over the period 2006-2011. The study used profit as the only output variable, while capital expense, labour expense, and common element devotion used as inputs. Common loans, policy loans, and non-performing loans were considered as intermediate variables. The results from this study suggest that operating efficiencies have worsening phenomenon and most inefficiencies are directly from the profitability inefficiencies.

Worthington (2001) employed a two stage process to analyse the role of efficiency in merger and acquisition activity in Australian credit unions during the period 1993-1997. The study used DEA to measures of efficiency. In the first stage, a panel data was used in the probit model to relate pure technical efficiency, along with other managerial, regulatory and financial factors, to the probability of merger activity, either as an acquiring or acquired entity. The findings show that loan portfolio diversification, management ability, earnings and asset size are a significant influence on the probability of acquisition, though the primary determinant of being acquired is smaller asset size. In terms of pure technical efficiency, the results indicated that there is no significant difference between acquired and non-acquired credit unions.

McKillop, Glass, and Ferguson (2002) investigated the cost performance of 104 Credit Unions in UK. The study used DEA to estimate radial and non-radial efficiency measures. The data used for the study was obtained from 1996 financial information published by credit unions. Employing the intermediation approach, three outputs and four inputs were specified. Loan to members, investments and deposits to other institutions were considered as outputs, with input variables being salaries, other management expenses, dividends and non-management expenses. The efficiency estimation was conducted under three different models. The first model employed three outputs and two input specification while the second model used three outputs and three inputs specification. For the third model, the study considered three outputs and four input specification. The overall (mean) cost efficiency scores were 0.7730, 0.7914 and 0.8774 for model 1, model 2 and model 3 respectively. The study also reveal that 37% of credit unions in UK under-spend on labour costs (salaries, wages and national insurance) indicating that their performance was relatively efficient.

With regard to returns to scale, the study found 29 credit unions to be scale efficient. Of the 75 scale inefficient DMUs, 28 were operating under increasing returns to scale and 47 under decreasing returns to scale.

This study considered credit unions in the UK, a developed economy. The data for the study was only one (1) year data. Therefore the study could not investigate the trend of efficiency scores or the productivity change which requires a balanced panel. Also, the study did not consider the efficiency estimations based on the type of bonds of the credit unions investigated.

Bauer, Miles, and Nishikawa (2009) conducted a study on effect of merger on the performance of Credit Union in U.S.A., using parametric and non-parametric approaches. The study used Call Report data from 1994 through 2004 and included a total of 1,569 useable mergers. The input variables used for the study are pre-event savings and loan rates, post-event reserves as a percent of assets and post-event percent growth in assets. Asset quality, capital, Earnings and liquidity were the output variables used. The results shows that the owners/members of target firms tend to benefit from merger activity. The parametric test finds evidence of benefits to owners/members of the target firm. The non-parametric tests found evidence of improved performance. Overall, capital ratios decline from pre-event to post-event. Asset quality declines using a parametric test, but was consistent with the control group on a non-parametric basis. This suggests that some merged institutions experience extreme levels of asset deterioration post-merger. The logit model suggests that target performance depends on the relative size of the acquiring firm and the age of the target firm.

Ganesan (2009) assessed the technical efficiency of State and District Cooperative banks in India using DEA. Data for the study was selected from annual publications from 30 State Cooperative Banks and 20 District Cooperative Banks for the period 2002 to 2006. The input parameters taken for the analysis were membership, number of branches, labour, and borrowed funds. Deposits, investments and advances were the outputs selected for the study. The mean efficiency of State Cooperative Banks during 2002-2006 was 74.5% while that of District Cooperative Banks was 72.51%. Even though five year data was assessed in the study, this study did not show whether the firms' performance progressed or regressed over the study period.

Garcı´a-Cestona ans Surroca (2008) used unbalanced-panel data, under production approach on a sample totalling 238 over the period 1998 to 2002, to assess the performance of Spanish Savings Banks/Credit unions. Three inputs; employees expenditure, operating expenses and depreciation expenses were selected. The study considered five outputs, which are average balance of deposits, profits after taxes, interest rates for overdrafts, charitable-social programs and loans to public administrations. The results indicated that insider private Savings Banks exhibited higher performance indexes than public Savings Banks in every efficiency measure with average efficiency score being 82.7% of the insider Savings Bank and 75.45% for public Savings Banks. It pointed out that the observed differences in performance indexes of the insider SBs and the public SBs are all statistically significant, which suggest that insider SBs operated closer to the pooled frontier than public SBs.

The study used an unbalanced panel data for a five year period. The researchers therefore could not assess the productivity changes to determine whether the units progressed or regressed in their efficiency score during the five year period. Assessing the productivity change index require a balanced panel data. It must also be noted that different groups within an industry face different production opportunities in terms of resources and environment (O'Donnell et al., 2008). In situations where group differences exist, efficiency measures are better compared across groups and within groups using Metafrontier framework to account for group differences. However, this paper could not account for the group differences.

Bui (2013) employed input-oriented DEA technique under CRS and VRS assumptions on a sample of 189 to measure the efficiency Australian Superannuation Funds from four sectors (i.e., Corporate, Industry, Public and Retail). Data covered seven (7) year period (2005-2012) with five inputs and three outputs selected for the study. The study took individual years and the period (2005-2012) into account. For individual years, the following input variables were selected: investment expenses, operating expenses, management, administration and director fees and total expenses. Average net assets, member account and return before tax were chosen as outputs. For the period 2005-2012, investment expenses, operating expenses, management, administration and director fees, total expenses and volatility/standard deviation of return were inputs whereas outputs were average net assets, member account and multiple period return. The findings indicated that most Australian superannuation funds are inefficient relative to the efficiency frontier. Averagely, efficient and inefficient DMUs under CRS model were 9 and 174 respectively, over the entire period of study, with mean efficiency score of 0.217. The average efficient and inefficient DMUs under VRS assumption was 28 and 155 respectively, with mean efficiency score of 0.422.

Although the study assessed different sectors of Australian Superannuation Fund, it could not consider the heterogeneity in the industry. This could have been addressed by assessing their efficiency score relative to the Metafrontier and the group specific frontier. However their results are relevant to this current study in the sense that it considered different groups in the efficiency study.

Skully and Haq (2010) examine the cost efficiency of 39 microfinance institutions across Africa, Asia and the Latin America in 2004 using non-parametric data envelopment analysis. The sample consists of 13 bank MFIs, 8 NBFI-MFIs, 6 cooperatives/credit unions MFIs, 11 NGO-MFIs, and another non classified MFI. Both input and output oriented models were applied for the study. The study also followed the production and intermediation approaches under both constant return to scale (CRS) and variable return to scale (VRS) assumptions. Inputs selected under production approach are labour, cost per saver and cost per borrower, while selected outputs consist of number of savers per staff and number of borrowers per staff. Under intermediation approach, total number of staff and operating expenses are identified as inputs, whereas gross loan portfolio and total savings as outputs. Two models are specified. Model 1 incorporates two-stage analysis. In the first stage it uses controllable inputs in computing MFIs efficiency scores, while the second stage separated the effect of uncontrollable inputs from the technical efficiency. The study reported that non-governmental microfinance institutions, particularly under production approach were the most efficient and that the result was consistent with their fulfillment of dual objectives: alleviating poverty and simultaneously achieving financial sustainability. However, the study found bank-microfinance institutions to be more efficient under intermediation approach.

This study did not take into account possible technology heterogeneity that may exist within a specific country which may affect their efficiency. Chen and Yang (2011) argued that direct cross-group or cross-country comparison is prohibited since the efficiency measure of the two groups are gauged using distinct bases, i.e., the respective group frontier. Thus, the metafrontier technique is necessary. The technological differences, as well as technology gaps could have been better accounted for if the study had employed the metafrontier framework that disentangles the group-frontier from metafrontier.

Marwa and Aziakpono (2014) used data from 2011 audited financial statements to measure the efficiency of 103 Savings and Credit Cooperative from four regions in Tanzania. The study used Non-parametric data envelopment analysis framework in estimating technical, pure technical and scale efficiency scores. Total loans and total revenue were the output measure, while total expenditure, total deposit, and total assets were considered as input variables. The results show that average efficiency scores are 42%, 52% and 76% for technical efficiency, pure technical efficiency and scale efficiency respectively. In terms of firm size, the study reported that too small firms and very large firms were relatively less efficient compared to medium and large firms. About 77% of the firms were operating in an increasing return to scale while 15% and 8% of the firms were operating at constant and decreasing returns to scale respectively.

Although the study was relevant and showed credible results as it has been cited in peer reviewed journals and articles, it used a cross sectional data and therefore could not account for relative productivity changes of the firms studied. Secondly, the study indicated that data were taken from four regions which suggest that the regions may be operating at different technology and therefore might be experiencing some heterogeneity which may affect their efficiency scores. Such heterogeneity and productivity changes could have been better accounted for if they had used panel data to assess the productivity change and heterogeneity of the firms using Malmquist Metafrontier productivity indices (MMPI) technique.

Magali and Pastory (2013) used total number of members, total savings and deposits and total expenses as inputs while total loans was considered as output, to model the technical efficiency of Savings and Credits Cooperative Societies in Tanzania. The main source of data is from SACCOS' audited and current financial reports. This study employed a cross sectional sample of 37 DMUs selected from Dodoma, Kilimanjaro and Morogoro regions. The study used data envelopment analysis and adopted intermediation approach. This study observed that the technical efficiency of SACCOS varies across and within the regions. The efficiency scores for Morogoro, Dodoma and Kilimanjaro regions were 62%, 60.28% and 46.49% respectively. Findings from the study suggest that higher costs of operations for rural SACCOS are attributed to low efficiency.

This study compared the efficiency scores of different regions in Tanzania which may have technological heterogeneity in terms of size and operating environment. However, the study did not consider the heterogeneity in the regions observed. Metafrontier framework is the best use of such difference as it allows the DMUs to be assessed relative to their group specific frontier and the Metafrontier. However, this study is relevant to the study of cooperative credit unions in Ghana since it is within the context of Sub-Saharan Africa efficiency study.

Tesfamariam et al., (2013) applied the DEA method to evaluate the relative efficiency of SACCOs in Tigrai region of Ethiopia. Data were collected from 329 rural SACCOs during the year 2012. The result showed that the extent of technical efficiency varies across geographical location and scale size of the cooperatives. The results from the study show only 18 efficient SACCOs out of the 329 peers, with mean efficiency score of 21.3%, suggesting that there is substantial amount of inefficiency among rural SACCOs in Ethiopia. The study also identified that large SACCOs had higher technical efficiency scores compared to their smaller counterparts and also indicated that the highest mean efficiency for the southern and the western zones are 0.276 and 0.259 respectively. The study also identified that most rural SACCOs that received award from the government are efficient.

DEA intermediation approach was used by Jayamaha and Mula (2011) to assess the efficiency of Cooperative Rural Banks (CRBs) in Sri Lanka. Variables considered as outputs are loans pawning, Interest income and other income while total expenses was the only input variable used. Data used for the study covered three year period, from 2003 to

2005. The study made comparison of efficiency between years 2003 to 2005. Using an unbalanced panel data on 108 CRBs, the results showed a downward trend in mean average technical efficiency (TE) from 2003 to 2005 (66.0% in 2003, 59.7% in 2004 and 53.2% in 2005). A similar trend was found in mean pure technical efficiency (PTE) scores (80.2% in 2003, 77.4% in 2004 and 63.7% in 2005). The study also reported that although scale efficiency (SE) declines from 82.0% to 78.0% from 2003 to 2004, it re-gains to 86.0% in 2005.

A similar study by Jayamaha (2012) attempted to evaluate the overall efficiency of Small Financial Institutions in Sri Lanka from 2005 to 2010. The study considered 1,933 CRBs that were in operation in 2010. Data envelopment analysis (DEA) was used to measure efficiency, taking into consideration both CRS and VRS assumptions. Deposits, number of deposit accounts and number of branches were identified as inputs with output variables being loans and advances and the number of loans and advances accounts. Technical Efficiency, Pure Technical Efficiency and Scale Efficiency were estimated. The efficiency analyses were also done by size as well as by location. The study established that efficiency scores of CRBs declined during the study period from 2005 to 2010. It also identified significant differences in the efficiency of CRBs by geographical locations. The size of the bank was also found to have a significant relation with efficient.

Ghana’s CCUs have not been left out in efficiency and performance assessment, although empirical evidence is limited in this area and also the CCUs were compared with other MFIs under parametric, SFA framework. Two studies were identified in this direction; Darko (2013) and Oteng-Abayie et al. (2011).

A study Darko, (2013) focused on technical efficiency of 273 MFIs in Sub-Saharan Africa (SSA), including Ghana. Data was obtained from Microfinance Information eXchange

(MIX) market database, for the period 2005 – 2011 from 35 countries. These are period before the global financial crisis (2005 – 2007) and the period during the crisis (2008 – 2011). The study employed Data Envelopment Analysis (DEA) to estimate the OTE, PTE and SE and a second stage truncated regression, to investigate the determinants of OTE and PTE. The input variables for the study were personnel expense, administrative expense and financial expense. Financial revenue and Net Loans were selected as outputs. The results found average technical efficiency score of 62.88%, with inefficiencies attributed to inappropriate management practices. Also 17.86% and 10.08% were found fully efficient under VRS and CRS respectively. The study also observed that commercial MFIs consistently remained better off than non-commercial MFIs in terms of their overall efficiency scores. With regards to the charter type of MFIs, it was found that credit unions consistently remained the most efficient type of MFI in SSA before and during the financial crisis compared to rural banks.

This study compared different microfinance institutions (i.e., MFI banks, Credit Unions, NBFIs and Financial NGOs) which operate under different scale of economies or technologies. However, (Brown, 2006) argued that results across firms should not be directly compared due to differences in their production technology. Such comparison of credit unions with other MFIs should take into account the complexity of the behavioural objectives of the institutions (Worthington, 2004a). For example, as MFI banks are interested in profit maximization but credit unions are concerned with maximizing the services provided to members (Fried, Lovell, & Eeckaut, 1993).

Oteng-Abayie et al. (2011) applied SFA technique to analyse the economic efficiency of 135 MFIs in Ghana and its determinants for the period 2007 – 2010. Their results show efficiency scores ranging between 0.0712 – 0.7992, with an average score of 0.5629. With regards to the determinants of efficiency, they found that the total savings, cost per borrower, age, average loan balance per borrower, average saving balance per saver are significant determinants of efficiency. However, apart from the average saving balance per saver which was negative, all the other coefficients were positive.

2.4.3 Empirical Evidence on Metafrontier and MMPI Studies

Kontolaimou and Tsekouras (2010) employed a non-parametric metafrontier to study efficiency of 1540 cooperative, 541 commercial and 735 savings banking firms from six European countries. The data for the study covers 8 years period from 1997 to 2004.The study period was divided into two four-year intervals (1997–2000 and 2001–04) in order to avoid fluctuations in financial data due to business cycles. Following the intermediation approach (which consider banking firms are as intermediaries between savers and investors, transforming deposits and purchased funds into loans and financial investments), the study considered expenses, deposits and equity as input variables and loans, other earning assets and off-balance sheet items as output variables. The results indicated that cooperative banking firms had an average technical efficiency score of 81% in the first period and 78% in the second. Additionally, the dispersion of the TE scores within the cooperative bank type was 10–11%, which is relatively low in both time periods. With regard to commercial and savings banking firms, the study reported significantly different distribution patterns of TE scores in terms of tendency and dispersion. The commercial banking firms recorded a considerable average technical inefficiency of 32–33% associated with high dispersion in the corresponding TE scores. Savings bank firms showed the average technical inefficiency below 20%; a rather low variation in TE scores relative to the commercial banks. By applying input-oriented meta-technical efficiency (MTE), the cooperative banking firms registered an MTE score of 77%, while their commercial banking counterparts scored 75% meta-technical efficiency. On the other hand, the metatechnology ratio (MR) recorded by the study for the cooperative and the commercial banking firms was 76% and 91% respectively.

Although the study used Metafrontier framework to assess the technological differences across countries, it did not include any sample from a developing economy in Asia or

Africa. More so, the study did not show whether groups' efficiency scores progressed or regressed over the period of study. This could have performed using Malmquist Metafrontier technique.

Fang and Hu (2009) utilized the DEA under zero sum gain (ZSG) metafrontier approach to study the impact of foreign ownership, the membership and a variety of services on efficiency in 92 Financial Holdings Companies (FHC) including securities brokerage firms (SBFs) and integrated securities firms (ISFs). Using a cross sectional data for 2006, the paper considered market share a single output, with inputs being fixed asset, capital, general expenses, total asset, while the ratio of capital to asset, year of services, trading amount (VOL), number of branches were selected as explanatory variables. These variables were modelled under output-oriented ZSG-DEA and BCC-DEA. The paper arranged all securities firms into four groups, namely, foreign-owned securities firms including foreign-owned ISFs and SBFs as the first group, the subsidiaries in FHC are the second group, the non-FHC ISFs are the third group, and the domestic SBFs are the fourth group. The results find that the foreign-owned securities group's technology is 97 percent of that represented by the metatechnology, whereas the Domestic non-FHC ISFs represented the least with 43 percent.

Wang, Zhang, and Zhang (2013) proposed a new Malmquist CO2 emission performance index for measuring changes of CO2 emission performance over time using the metafrontier framework. The estimation of the distance function was based on DEA. By incorporating CO2 as an undesirable output into the input-output indicators in the standard MMPI, Wang et al., (2013) suggested that their index may be helpful to further understand the impact of environmental variation on national CO2 emission performance. However, this paper focused on methodological issues and therefore could not provide any empirical evidence in decomposing their metafrontier Malmquist CO2 emission performance into its respective constituents.

Applying the metafrontier framework, Sang-Mok, Moon-Hwee, and Hui-Lan (2013) analysed provincial technology and productivity gaps in China. The study sample consists of thirty one province in three regions of China, with data from 1995 through 2008. They decomposed the productivity into technical change (TC) and technical efficiency change (EC), and found differences in group technical efficiency (or productivity) and meta-technical efficiency (or productivity) of provinces studied. The findings indicated that the average technical efficiency for the whole China is 0.900. For the three regions, central region reported the highest technical efficiency of 0.937, while the eastern and western regions had 0.903 and 0.874, respectively. The metafrontier scores for the whole China were 0.790, and 0.851 and 0.647 for central and western region respectively. The eastern region recorded the highest efficiency score of 0.902. Regarding productivity change, the whole China recorded 1.014 and 0.995 for the group-frontier and the metafrontier respectively, with TC (1.017) and EC (0.997) for the group-frontier, and TC (1.005) and EC (0.990) for the metafrontier. Therefore, productivity progress of 1.4 and 0.05 percent respectively for the group-frontier and the metafrontier was attributed to TC. However, the study showed that productivity decline of in the central and western regions was due to the drop on the EC, while the productivity growth in the eastern region has been driven by the technical progress.

Although this study employed the metafrontier in analysing productivity changes, it failed to properly account for the catch-up effects, which show whether the technology gap or the whole band of technology is increasing or decreasing.

The metafrontier framework was also applied by Ahmed and Krishnasamy (2013) to analyse the technological gap and level of catch-up of the three regions in Asia namely, Southern Asia, Eastern Asia and ASEAN5. The data used for the study covers the period 1980–2006. The result indicated that productivity improvement for the countries in Southern Asia region relative to the Asian frontier is attributed to an improvement in technical efficiency rather than technological advancement and also, all three regions recorded technological regress relative to the best practice frontier. The study also found the countries in Eastern Asia and ASEAN5 recording relatively stronger productivity growth with respect to the group-frontier than the countries in Southern Asia. Moreover, the study reported technology gap ratio below 1.00 for Southern Asia and ASEAN5 regions, prior to the 1997/98 financial crisis, whereas the Eastern Asia region kept pace with the benchmark frontier by recording technology gap ratio of 1.0 during the pre and post financial crisis. Therefore, countries in Eastern Asia region define the best practice frontier for Asia.

Oh (2010) incorporate group heterogeneities into the conventional Malmquist–Luenberger productivity growth index is assessing environmentally sensitive productivity growth. This approach was used to measure productivity growth and its decomposition for economic agents operating under different technologies in 46 countries observed between 1993 and 2003. The approach was also used to capture changes in the technological gap between regional and global frontier technologies.

The main finding indicates that Europe leads in the world frontier technology and are therefore identified as innovators, while the Asian countries, described as imitators, have attempted to catch up by moving towards the world frontier technology.

Chen and Yang (2011) provided an extension of the metafrontier Malmquist productivity index to account for the effect of scale efficiency change in its decomposition for both the non-parametric and parametric frameworks. The study also decomposed the 'catch-up' in the index into pure technological catch-up and frontier catch-up. The empirical application was conducted under parametric framework, using unbalanced panel data from 1993 to 2007, involving 41 Taiwanese and 12 Chinese commercial banks. Employing the intermediation approach, outputs are defined as loans, investments and non-interest revenues, while labour, physical capital and borrowed funds were considered inputs. The results reported average technical efficiency score of 79.31% and 70.54% relative to the group-frontier for the Taiwanese and Chinese banks respectively. For the metafrontier, the Taiwanese banks and Chinese banks were respectively 75.9% and 64.1% technically efficient. This suggests that the banks in Taiwan operate at better technology than the banks in China. Also, Taiwanese banks' productivity increased by an 87.69%, while Chinese banks increased productivity by 71.33% The results reveal that the adverse scale efficiency change is the key factor to inducing the inferior productivity growth seen in Chinese banks compared with Taiwanese banks. Meanwhile, the PTCU and FCU together imply that the technology adopted by the Taiwanese banks converged towards potential technology.

Although the empirical evidence from this study was based on parametric frontier technique, the current study adopts the non-parametric approach from Chen and Yang (2011) to assess the productivity dynamics of CCUs in Ghanaian context. This is because, unlike the other MMPI model found in literature, Chen and Yang (2011) model better explains the catch-up effects. This will help in the current study in identifying the dynamics of CCUs operations in Ghana in order to provide policy directions.

2.5 Analytical and Conceptual Framework

This section discusses the analytical and conceptual framework for efficiency analysis. The section firstly discusses the framework for efficiency analysis. It then discusses the concept of efficiency analysis and follows with the conceptual framework for efficiency analysis of co-operative credit unions.

2.5.1 Analytical Framework for Efficiency Measurement

As discussed earlier, efficiency analysis of a production or service unit, also referred to as DMU deals with the comparison between the outputs and inputs used in the production process either for producing a product or services (Charnes et al., 1978; Cooper et al., 2004; Farrell, 1957). A simplified framework for efficiency analysis in a production process is shown in Figure 1

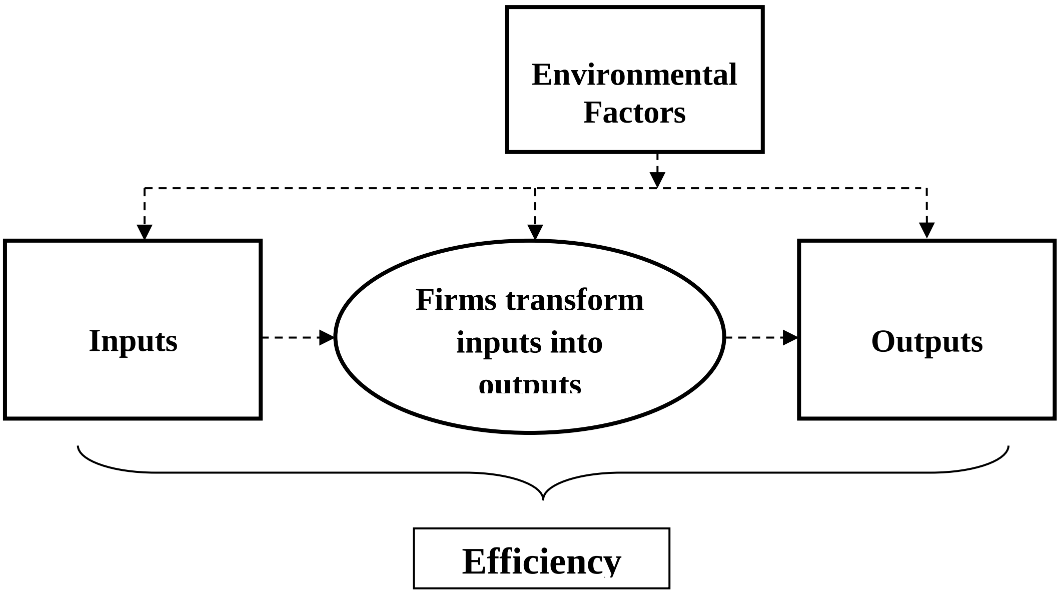

Figure 1: The Framework for Efficiency Measurement

Source: (Chu & Lim, 1998)

A firms performance and productivity is measured by taking into consideration its efficiency and effectiveness (Worthington, 2004). As efficiency measurement takes into consideration how inputs are combined to produce optimal output, effectiveness is concerned with yielding the appropriate result by taking into consideration quality indicators (Worthington, 2004b). For example, an efficiency measure for credit unions could consider the relative cost of a process without evaluating whether the use of the process was appropriate. Similarly, an efficiency measure could evaluate the relative cost of loans without considering whether the interest charged on loans is reasonable and appropriate to serve the social benefit credit union members.

Efficiency can be measured with respect to maximization of output, minimization of cost or maximization of profits (Camanho & Dyson, 2008). In general, efficiency is divided into two components; technical and allocative (Charnes et al., 1978; Coelli, Rao, O'Donnell, & Battese, 2005; Farrell, 1957). A firm is regarded as technically efficient if it is able to obtain maximum outputs from given inputs or minimise inputs used in the production of given outputs (Charnes et al., 1978). In technical efficiency measurement, the objective a producer is to avoid waste. On the other hand, allocative efficiency relates to the optimal combination of inputs and outputs at a given price (Charnes et al., 1978; Coelli et al., 2005). The objective a producer with regards to allocative efficiency might entail the production of given outputs at minimum costs or using a given inputs to maximise the revenue, or the allocation of inputs and outputs for profit maximization (Mokhtar et al., 2006). Allocative efficiency can also be called economic efficiency; here the objective of a producer is to attain a higher degree of economic efficiency (cost, revenue or profit efficiency) (Coelli et al., 2005).

Based on the efficiency framework shown in Figure 1, the conceptual model in Figure 2 was developed for the present study on CCUs efficiency and productivity analysis. The objective here is to measure technical efficiency and productivity, taking into consideration the credit union types in a Metafrontier framework. Chapter four reviews the details of the methodologies used in the study.

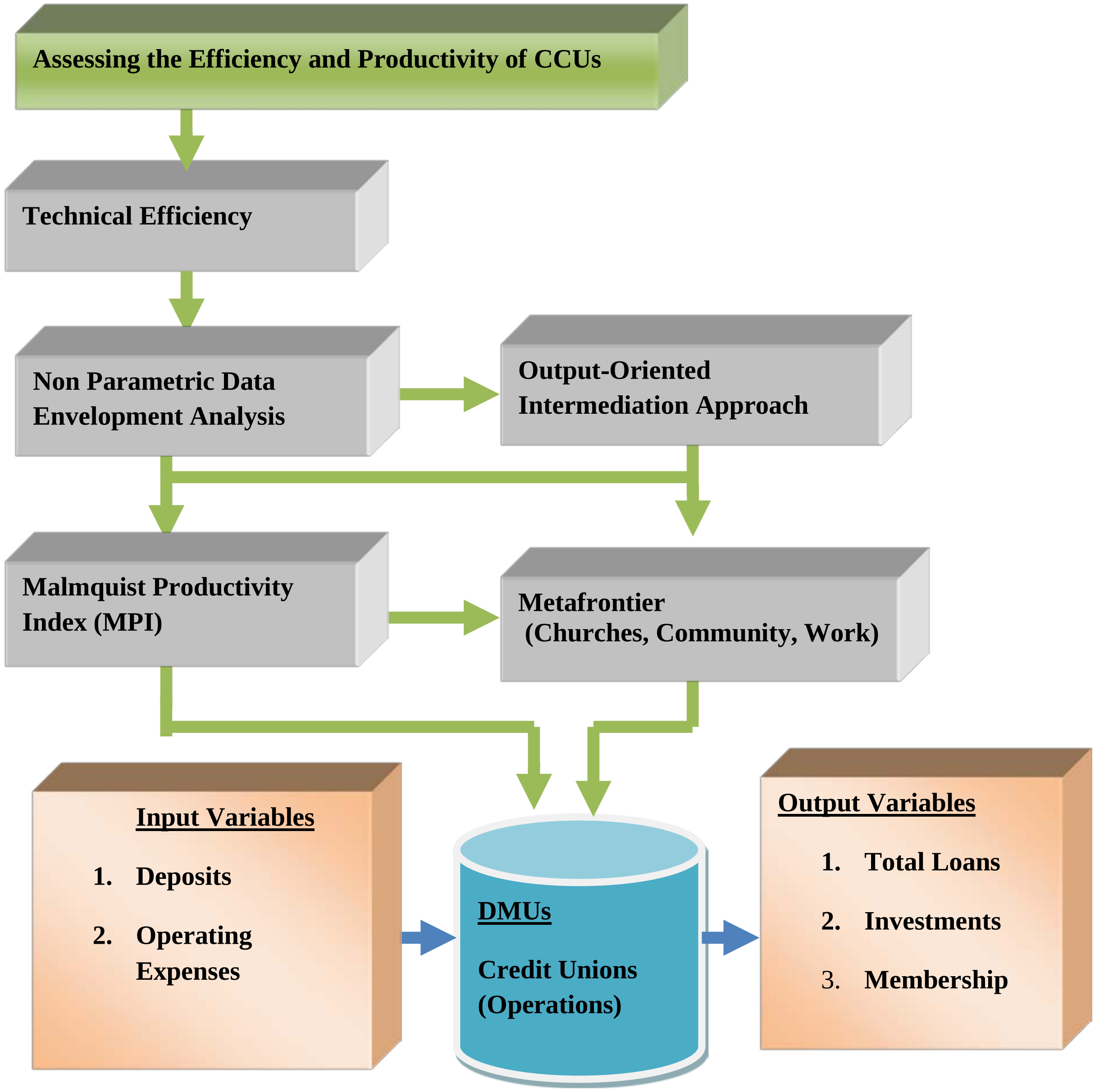

Figure 2: The Conceptual Framework for CCUs Efficiency and Productivity Meaurement

Source: Author (2015)

2.6 Research Hypothesis

To answer the research questions above, the study tested the following hypotheses which were derived from malmquist productivity literature and Co-operative Credit Union's operations in Ghana.

Hypothesis 1: *The main source of productivity growth in Ghanaian Co-operative Credit Unions is Technical Efficiency Change.*

This research employed the concept of Malmquist total factor productivity index, which decomposes total factor productivity into two components – technical efficiency change and technological change. Technical efficiency change is attributed to improvements in efficiency from a specific production technology applied to current production conditions. On the other hand, technology change refers to improvements in applying new production knowledge and technical innovations to firm's operational activities. The research expects technical efficiency change to be the major component of total factor productivity growth of Credit unions in Ghana rather than technological change. Thus, technical efficiency change was expected to be the main reason explaining growth in Credit Unions productivity over the period 2008-2012. This is because unlike the conventional banks in Ghana, the credit unions have not embraced the use of technological innovations like internet banking and the automatic teller machine (ATM) in their operations.

Hypothesis 2: *There are technological gaps among groups of credit unions in Ghana.*

The thesis is expected to find gaps in production technology among the three groups of credit unions due to their respective production conditions. This is due to the fact that almost all parish group credit unions operate on church premises and therefore do not pay rent for occupancy as compared to the workers and community groups which operate at either rented or owned offices. Another important fact that would influence technological differences among groups of credit unions is that most workers' credit unions have a scheme that ensures individual members deposits and loan repayment are made through deductions from their monthly salaries from source, whereas the parish and community groups make individual payments at their own will.

These hypotheses were empirically tested using DEA based meta-frontier Malmquist productivity change index.

CHAPTER THREE

CONTEXT OF THE STUDY

3.0 Introduction

In this chapter, the historical overview and the emergence of CCUs in the world and the CCUs in Ghana are presented. The chapter also describes briefly, the organizational structure of CCUs in Ghana and their operations. It then continues with a section on the credit union concept in Ghana.

3.1 Historical Overview of Cooperative Credit Union Development

Cooperative Credit unions (CCUs) are financial intermediaries basically owned and operated by individuals who are united by a common bond and for the sole benefit of these members (Fried, Lovell, & Eeckaut, 1993). The world council of Credit Unions (WOCCU) also describes CCUs as member-owned**,** not-for-profit financial cooperatives that provide financial services such as savings, loans and other services to their members. The CCUs membership is based on a common bond, which could be of occupation, association, religion or by residential location (Goddard, McKillop, & Wilson, 2008; Ofei, 2002). CCUs began with a simple idea that people could pool their money or resources together and make loans to one another (Nembhard, 2013). These pooled resources could be of labour power, products, purchasing power, and funds (Conover, 1959). In this regard, CCUs exist to serve the interest of their members only. It therefore, encourages people who want to benefit from credit unions to join in pooling their financial resources together in order to serve their financial and socioeconomic needs (Nembhard, 2013).

Historically, the first documented consumer cooperative was Fenwick Weavers' Society, founded in 1769 by a group of weavers (Fairbairn, 1994). Following this, several cooperative societies were formed in decades later, and were in operation (D. W. Adams, 1995; Zeuli & Cropp, 2004). The cooperative members believe in the ethical values of trust, honesty, openness, social responsibility and caring for others especially the underserved (Majee & Hoyt, 2009).

In 1844, the Rochdale Society of Equitable Pioneers established the 'Rochdale Principles' on which they ran their cooperative. These cooperative pioneers subscribed to shares, payable in small amounts weekly, in order to raise capital to buy goods at less than retail costs and sell them to their members at a savings (Mckillop & Wilson, 2011; Moody & Fine, 1971).Members were paid 5% interest on their shares and were entitled to a proportionate division of the society's savings or surplus at the end of the year.

The 'Rochdale Principles' formed the basis for development and growth of the modern cooperative movement (Zeuli & Cropp, 2004; Fairbairn, 1994; Conover, 1959). These principles include:

1. Voluntary and open membership - open to all persons able to use their services and willing to accept the responsibilities of membership, without gender, social, racial, political or religious discrimination

2. Democratic member control – they are controlled by their members, who actively participate in setting their policies and making decisions. People serving as elected representatives are accountable to the membership. In primary co-operatives members have equal voting rights (one member, one vote) and co-operatives at other levels are also organised in a democratic manner.

3. Member economic participation - members contribute equitably to, and democratically control, the capital of their co-operative. At least part of that capital is usually the common property of the co-operative

4. Autonomy and independence – They are formed as a self-help organizations controlled by their members. If they enter into agreements with other organizations, including governments, or raise capital from external sources, they do so on terms that ensure democratic control by their members and maintain their co-operative autonomy

5. Education, training and information - cooperatives provide education and training for their members, elected representatives, managers and employees so they can contribute effectively to the development of their co-operatives. They inform the general public, particularly young people and opinion leaders about the nature and benefits of co-operation turbulence

6. Cooperation among cooperatives - cooperatives serve their members most effectively and strengthen the co-operative movement by working together through local, national, regional and international structures

7. Concern for community - cooperatives work for the sustainable development of their communities through policies approved by their members.

The first successful CCU was established in Germany in 1852, by a co-operative pioneer Hermann Schulze-Delitzsch (Mavenga, 2010; Mckillop & Wilson, 2011). The credit unions founded by Hermann Schulze-Delitzsch focused on saving and credit from traders, shop owners and artisans in urban areas and stressed paying dividends to members, and applied limited liability principle (Mavenga, 2010). The CCU was extended to rural communities in Germany by Wilhelm Raiffeisen in 1864 (Mckillop, 2005). By the early part of the 1900s these two cooperative strains merged and spread throughout Germany with nearly one-third of the rural households being members (Mavenga, 2010).

Raiffeisen's approach to credit cooperative was to address the unique problems of the rural poor populace by exploiting the strong bonds of solidarity and deep Christian values in the typical village (Mavenga, 2010).

The credit union movement, then spread throughout the world and are organized at the local, national and international levels of association (Mckillop, 2005).

The rapid growth and development of credit unions in other parts of the world and emerging economies led to the creation of the World Council of Credit Union (WOCCU) in 1970. The mandate of WOCCU is to promotes the sustainable development of CCUs globally, so that the CCUs can empower people through access to high-quality, low-cost financial services (MacPherson, 1999; Mellor, 2009). WOCCU advocates on behalf of the global credit union system before international organizations and works with national governments to improve legislation and regulation. Its technical assistance programs introduce new tools and technologies to strengthen credit unions' financial performance and increase their outreach (MacPherson, 1999; Mellor, 2009).

According to the 2012 statistical report of the World Council of Credit Unions, there are 55,952 credit unions operating in 101 countries in the world with membership strength of 200,243,841. In the year 2012, the total reserves and assets of the World Council of Credit Unions stood at US$161,810,986,319 and US$1,693,949,441,328 respectively (WOCCU Statistical Report, 2012).

In some places credit unions are called by different names, for example, in many African countries they are called savings and credit co-operative organizations (SACCOs) and credit co-operative organizations, to emphasize savings before credit. In Spanish speaking countries, they often called cooperative as deahorroy credito. French terms for credit union include caisse populaire and banque populaire. Others also called credit unions as financial mutuals or mutual funds (Worthington, 2010).

3.2 Historical Background and Emergence of Credit Unions in Ghana

Evidence suggests that the first CCU in Africa was formed in 1955 at Jirapa in the North – West, now the Upper West Region in Ghana, by Rev. Father John McNulty an Irish Canadian Catholic priest (Ziem & Bebelleh, 2014; Adusei, 2013). The CCUs then spread to other parts of the country and some African countries (WOCCU, 2014). These CCUs provide the opportunity for people to save and access credit for economic activities (Akomea & Adusei, 2013). In 1967, the CCUs in the Northern Ghana were united in a chapter. The idea of forming the chapter was to bring them together for training and sharing of experiences and therefore the idea was replicated by the CCUs in the southern part of Ghana. In 1968, the Credit Union Managers Association (CUMA) International organised a meeting in Lesotho. Following this meeting, the idea of a National Association in Ghana was conceived. A follow-up conference was held in Tamale and that gave birth to the Ghana National Union and Thrift Association, the forerunner of the Ghana Cooperative Credit Unions Association (CUA) Limited. The duties of the CUA limited were to promote, educate, organize and support the Credit Union Movement nationally and internationally. The CUA is affiliated to the African Confederation of Co-operative Savings and Credit Association (ACCOSCA) and the World Council of Credit Unions (WOCCU). Currently, there are 25 countries in Africa operating credit unions. These 25 countries, including Ghana form the African Confederation of Co-operative Savings and Credit Association (ACCOSCA), with its headquarters in Nairobi – Kenya. All the 25 credit unions in Africa are also members of the World Council of Credit Unions (WOCCU). The special nature of CCUs as a co-operative credit institution therefore sets them apart from other microfinance institutions, in a sense that they operate as privately owned democratic institutions or adhere to other rules and norms (Ofei, 2002). According to Ghana Co-operative Credit Unions Association (CUA) about 90% of the country's population do not have access to bank loans due to high interest rates and security requirements. Due to the problem of high cost incurred by the banks in monitoring small and medium loans and therefore the banks deny low and middle income groups access to loan facilities. These challenges are what the credit unions seek to address.

3.3 The Organisational Structure of the CCUs in Ghana

The CCUs in Ghana are structured in a three tier system which comprises societies (local), regional chapter and national associations. These CCUs are affiliated to CUA Ghana, the apex body of the CCUs. The Apex body is managed by a General Manager and assisted by Deputy Directors. The regional Chapters are managed by theRegional Manager and a Chapter Board whose members are elected from the various primary societies. The organisational structure of CUA, Ghana is shown in Figure 3.

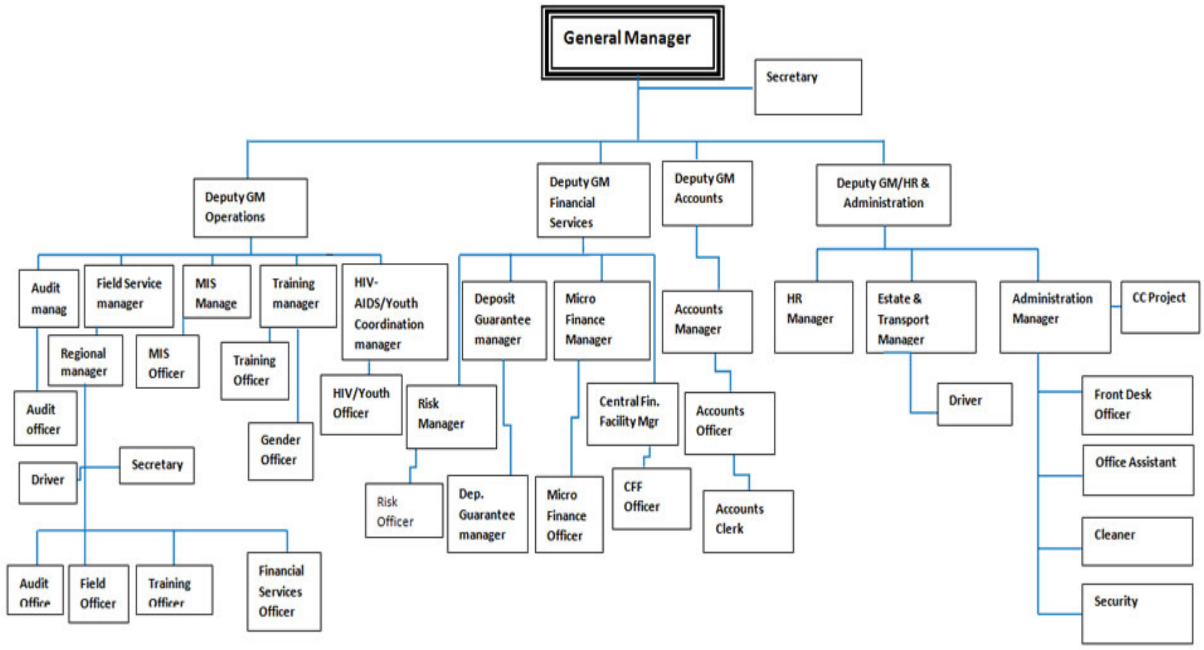

Figure 3: The Organisational Structure of CUA Ghana

Source: CUA, Ghana

The Ghana Credit Unions Association (CUA) operates at all the ten regional Chapters and serves as the apex body for CCUs. The apex body plays a supervisory role for the CCUs. It is the apex body which represents Credit Unions in Ghana at the International level. The apex body also provides financial and technical services to members.CUA holds its general meeting of delegates' biennial. The general meeting is the highest decision making body of credit unions and it is at this meeting that the National Board is elected (Appiah, 2012). The Board then appoints a General Manager for the Association. The objectives of the CUA are to assist in the organisation and the development of credit unions, provision of educational programmes, develop products and services and formulate bylaws as well as standardized book-keeping systems for credit union operations. CUA also gives legal advice to its affiliated credit CCUs in suits, collects statistics and other relevant data and conducts research into the possibilities for improvement of credit unions.

At the society level, CCUs are run and managed by board members and a manager, who report to the board. The board members have the overall responsibility for the management and direction of the credit union. The board members are democratically elected by members of the credit union. The elections are held at their annual general meeting with all members having equal right to vote and be voted for. The annual general meeting is also the platform for the board members to account for their stewardship to members of the credit union (Appiah, 2012; Ofei, 2002). The board members appoint other committees such as Education, Investment and Loan Collection Committees who meet at least once every month to discuss issues and development of the credit union.

These board members work on voluntary service as it is one of the basic principles of credit unions (Goddard et al., 2008b). It is interesting to note that some CCUs have a permanent manager and other personnel who manage the day to day activities of the credit union while others are being run solely by volunteers.

3.4 The CCU Groups in Ghana

At the Society/Local level, the CCUs operate under three different groups. These are parish, work and community based. The parish group are run and managed by members of a same church who belong to a particular parish/assembly and therefore, members are bonded by the church they attend. The Work based CCUs are bonded by a group of workers in the same employment, whereas the Community group are run and managed by people living or working in the same community. However, all the CCUs groups are open to the general public and that members of the general public can join any of the groups stated above regardless of the common bond.

3.5 The Concept of Credit Unions

The CCUs concept is such that people with a common interest come together in a society to mobilize funds regularly so that they can have access to funds in times of need and to grow their businesses (Amegashie-viglo & Ahorlu, 2014). After six months, when a needy member applies for a credit facility, he/she would be offered with a minimum interest rate payable within a period of time. In a close of a financial year, management declares profit and shared among members' contributions. Therefore, members at all levels of the CCUs are encouraged to save on a regular basis. This is aimed at building a fund of money for their own interest and that of their dependants. They are also taught on how to use money wisely and to manage their limited pooled resources efficiently. The concept is appreciated and promoted in workplaces, parish and communities.

CHAPTER FOUR

METHODOLOGY

4.0 Introduction

The aim of this chapter is to explain the methodology behind this study. The chapter begins with the study design and continues with the concept of efficiency and technicalities of DEA. It further discusses the DEA-based MPI, the metafrontier and the Metafrontier Malmquist productivity index (MMPI) methodologies in analysing productivity dynamics within groups.

4.1 Study Design

The study design is based on a panel data of CCUs sampled from 2008 to 2012. The panel study allows the researcher to highlight the reasons why these subjects have changed with time (Neuman, 2011). There are 444 CCUs currently operating in Ghana (CUA, 2013). However, this study concentrates on CCUs in the Greater Accra chapter.

This is because we observed that most of the CCUs that were in full operation and with consistent data over the five year period belong to the Greater Accra Chapter of CUA. Also, Greater Accra Chapter has the largest representation of CCUs in Ghana. The Greater Accra chapter of CCUs has a total number of 132 CCUs (local credit unions) comprising 75 affiliated groups and 57 study groups. The affiliated groups are the credit unions who have fully been registered by the Department of Cooperatives Ghana, and are affiliated to the Credit Unions Association of Ghana (CUA). The study clusters or groups constitute the credit unions that have existed for less than one year in operation and have not been fully registered by the Department of Cooperatives and are therefore not affiliated to the CUA. These credit unions are assigned a resource personnel by CUA to educate them on how to manage their financial records until they become fully affiliated. Only fully affiliated credit unions submit their financial records to CUA for auditing. Therefore, the sample population for this study is the 75 affiliated credit unions in Greater Accra Region of Ghana.

4.2 The Technicalities of basic DEA model

Frontier efficiency and dynamic productivity techniques have been employed by researchers to assess the productive performance of firms (Worthington, 2004) and particularly in cooperatives and financial mutuals (Worthington, 2010). These methods are used to assess the performance of decision making units (DMUs). It began with the leading ideas of Debreu (19951), Koopmans (19951), Debreu (1951), Koopmans (1951) and Shephard (1953). In situations where several inputs and outputs are needed, a company is said to be efficient if it is able to generate the maximum outputs from a given set of inputs, or contract the set of input resources given the level of outputs (Banker, et al., 1984). This implies managerial or technical efficiency (Farrell, 1957). Farrell (1957) defined input-oriented technical efficiency as the radial reduction in inputs that is possible. A complete debate on the evolution of frontier methods could be found in Kumbhakar and Lovell (2003), Coelli et al. (2005), and Cooper et al., (2004). In general, efficiency assessment briefly involves identifying an efficient technology boundary and then assessing the (in)efficiency of an observed DMU relative to this constructed efficiency boundary. The assessment is done using either parametric, econometric approach or nonparametric, mathematical programming approach (Berger & Humphrey, 1997). The main parametric frontier techniques are Stochastic Frontier Analysis, (SFA) developed by developed by Aigner, Lovell and Schmidt (1977) and extended by Meeusen and Broeck (1977), Thick Frontier Analysis (TFA) by Berger & Humphrey (1992), and Distribution-Free Approach (DFA) proposed by Berger et al.(1993). The nonparametric deterministic frontier techniques include Data Envelopment Analysis (DEA) developed by Charnes et al. (1978) and extended by Banker et al. (1984) and Free Disposal Hull (FDH) proposed by Deprins et al. (1984). This thesis adopts the DEA technique to estimate the efficiency and productivity dynamics of clusters of CCUs in Ghana. Emphasis is placed on the three types of credit unions (parishes, work and community-based unions) in Ghana. This is to account for the heterogeneity or technological differences embedded within the groups or clusters. The firms belong to a common frontier technology set but operate under separate clusters.

The efficiency and dynamic productivity of a firm could be assessed by first determining the firm's input and output resources. All aspects of economic activities or business operations involve transformation of certain input resources into goods and services that are beneficial to customers Grönroos and Ojasalo (2004). The input resources that undergo transformation may include labour, capital, materials, energy, machines and technology (Grossman & Helpman, 1994; Solow, 1957). Farrell, (1957) viewed efficiency as how well an organisation is able to utilize its input resources in order to maximize outputs. The production possibility set (PPS), simply called technology set (*T*) form the basis of efficiency analysis. A convenient way by which multiple-input, multiple-output framework could be demonstrated is by the use of the technology set (*T*) (Farrell, 1957). This is because once the technology set (*T*) is established, the location of a DMU within the PPS will help estimate its relative performance, given the returns to scale (Ohene-Asare, 2011).

To formalise DEA, the technology can be represented by the set (T) as:

$$T = \{(x, y) \in \Re_{+}^{m+s} \mid x \text{ can produce } y\} \quad (4.1)$$

These form the basis for constructing the efficient frontier. Using the technology set is appropriate because a firm is capable of producing certain levels of outputs that belong to the technology set, given certain input quantities (Coelli et al., 2005). Once the input and output vectors are identified for a set of DMUs, the PPS within which the DMUs operate are constructed. Additionally, it is assumed that each DMU uses at least one positive input to produce one positive output (Cooper et al., 2004). Charnes et al. (1978) defined the input-oriented efficiency of a target $\text{DMU}_o(y_{ro}, x_{io})$ as maximum of the ratio of weighted sum of outputs to the weighted sum of inputs subject to the condition that similar ratios representing the efficiency measures for each DMU be less than or equal to one. The objective of this fractional programming model is mathematically formulated as:

$$\max ho(u,v) = \frac{u_1 y_{1o} + u_2 y_{2o} + \ldots + u_r y_{ro}}{v_1 x_{1o} + v_2 x_{2o} + \ldots + v_i x_{io}} = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}}$$

This can also be written as:

$$\text{Maximize } \theta = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} \quad (4.2)$$

Where:

j = number of decision making units (DMUs) being compared in the DEA analysis

DMU_j = A particular DMU number j

θ = efficiency rating of the decision making unit being evaluated by DEA

y_{rj} = amount of output *r* used by DMU_j

x_{ij} = amount of input *i* used by DMU_j

i = number of inputs used by the DMUs

r = number of outputs generated by the DMUs

u_r = coefficient or weight assigned by DEA to output *r*

v_i = coefficient or weight assigned by DEA to input *i*

The data required for DEA evaluation are the actual observed outputs produced y_{rj} and the actual inputs used x_{ij}, during one time period for each DMU in the set of units being evaluated (Cooper et al., 2004; Ohene-Asare, 2011). The fractional programming model in Equation (2) can be converted to an equivalent output-oriented envelopment linear model under VRS assumption, using the Charnes-Cooper transformation as:

$$\begin{aligned} &\phi^* = \underset{\lambda_j,\phi}{Max}\ \phi \\ &\text{subject to:} \\ &\quad \sum_{j=1}^{n} \lambda_j x_{ij} \le x_{i0}; \qquad \forall i = 1,2,\ldots,m \\ &\quad \sum_{j=1}^{n} \lambda_j y_{rj} \ge \phi y_{r0}; \qquad \forall\, r = 1,2,\ldots,s \\ &\quad \sum_{j=1}^{n} \lambda_j = 1 \quad (vrs) \\ &\quad \lambda_j \ge 0; \quad j = 1,2,\ldots n; \quad \phi \quad free \end{aligned} \tag{4.3}$$

Where ϕ^* represents the radial output oriented efficiency score of the DMU under evaluation. Equation (4) is the BCC model and is distinct from the CCR model which ignores the convexity constraint, $\sum_{j=1}^{n} \lambda_j = 1$. After solving this envelopment linear programming problem, the efficiency scores of each unit are obtained, inefficient units are recognized, role models or benchmarks and targets identified, and also policy prescriptions can be provided. The DMUs that form the efficient frontier serve as peers for other DMUs under evaluation (Malhotra & Malhotra, 2012). The best-performing or efficient DMUs are assigned as core of $\theta = 1$ (Banker et al., 1984; Charnes et al., 1978). In the output-oriented model, the inefficient DMUs are rated with Farrell efficiency scores $\phi > 1$ which is just the reciprocal of the Shephard distance function (Banker et al., 1984; Charnes et al., 1978). After the evaluation of the relative efficiency of the DMUs in the dataset, DEA shows how much input and output levels have to be changed in order to maximize the efficiency of the target DMU. Therefore DEA suggests benchmarks for each inefficient DMU at the level of its individual mix of inputs and outputs (Cooper et al., 2004).

The present study uses DEA as the basics for modelling dynamic efficiency and productivity of CCUs in Ghana via the metafrontier Malmquist productivity Index (MMPI).

4.3.1 DEA-Based Metafrontier Analysis

Homogeneous DMUs may belong to a common technology set but may operate under different clusters or may operate in different environment from their peers in other groups during the production process (Battese & Rao, 2002;Battese & Rao, 2004; O'Donnell et al., 2008). In other words, they make choices based on different sets of production opportunities that each firm is endowed with. It has thus been argued in the frontier efficiency literature that comparing their efficiency scores measured against their group-specific frontiers can be misleading (O'Donnell et al., 2008). This is because it is uncommon to find frontiers estimated for two different clusters or groups likely to be similar enough to facilitate the use of a single frontier. The different technology set may be due to differences in stocks of human and financial capital, economic infrastructure and any other group-specific or firm-specific characteristics of the physical infrastructure, size, social and economic environment in which production takes place (O'Donnell et al., 2008). It is for this reason that some empirical works reject the null hypothesis of constancy of the production frontier across different groups (O'Donnell et al., 2008). The presence of technological differences have led to the estimation of separate frontiers for different groups of firms (Battese & Rao, 2002; Battese & Rao, 2004; O'Donnell et al., 2008). In order to delve deeper into the technological heterogeneities, the estimation of efficiency and technology gaps relative to a common metafrontier has also been suggested (O'Donnell et al., 2008). The metafrontier is defined to be the boundary of an unrestricted technology set, which envelops the group frontiers, defined as the boundaries of the restricted technology sets (Battese & Rao, 2002; Battese & Rao, 2004; O'Donnell et al., 2008).

The metafrontier concept due to Hayami and Ruttan, (1970), is related to the concept of metaproduction function defined to be the envelope of commonly conceived neoclassical production functions. The estimated frontiers empirically represents the whole meta-technology set and the group-specific technology set (O'Donnell et al., 2008; Sang-Mok et al., 2013). To undertake the metafrontier analysis, one must ascertain the group technology set and the metatechnology set. Given multiple inputs and outputs, an evaluated DMU uses the input vector $x \in \Re_{+}^{m}$ to generate the output vector $y \in \Re_{+}^{s}$. To formalise the concept, let *k=1,2,…,K*, where *k* is one cluster and *K* is the total number of groups/clusters in a particular industry. K has group-specific features (e.g. technology, regulation, regions, culture) that make it different from other groups. Consequently, group *k's* technology set is the technologically feasible input-output combinations within and on group *k* and can be defined as:

$$T^k = \left\{ \left(x^k, y^k\right) \in \Re^{m+s} \; \middle| x^k \text{ can produce } y^k \right\} \tag{4.4}$$

whereas the metatechnology set can be defined as:

$$T^M = \left\{ \left(x, y\right) \in \Re^{m+s} \; \middle| x \text{ can produce } y \right\} \tag{4.5}$$

The output-oriented envelopment linear programming problem under variable returns to scale (VRS) for the estimation of the group efficiency (GE) score for a DMU in group *k* can be defined as:

$$\begin{aligned}
& Max \;\; \phi_0^k (x_o, y_o) \\
& \quad \text{s.t} \\
& \sum_{j=1}^{n} \lambda_j^k x_{ij}^k \le x_{i0}^k \qquad \forall i = 1,2,\ldots,m \\
& \sum_{j=1}^{n} \lambda_j^k y_{rj}^k \ge \phi \, y_{r0}^k \qquad \forall r = 1,2,\ldots,s \\
& \sum_{j=1}^{n} \lambda_j^k = 1 \\
& \lambda_j^k \ge 0; \; j = 1,2,\ldots,n
\end{aligned} \tag{4.6}$$

where $\phi_0^k (x_j^k, y_j^k)$ is the output-oriented efficiency score that measures the proportional increase in output of a DMU necessary to be efficient given the level of inputs. Note that $\phi_0^k (x_j^k, y_j^k) \ge 1$ if and only if $(x_j^k, y_j^k) \in \phi^k$, also, $\phi_0^k (x_j^k, y_j^k) = 1$ if and only if (x_j^k, y_j^k) is located on the production frontier or the technology set (Fare et al., 1994). Notice here that the output-oriented Farrell efficiency score is greater than 1 for inefficient firms since it measures the ratio of expected output to current output. The inverse of this is the Shephard distance function, which expresses the output-oriented efficiency in the more common sense from 0 to 1, where 1 represents an efficient firm (O'Donnell et al., 2008). This model is formulated using the VRS assumption because size is considered to matter in cooperative credit union operations. The model can be reformulated under constant returns to scale (CRS) assumption by simply removing the convexity constraint $\sum_{j=1}^{n}\lambda_j^k = 1$ from equation 4.6.

Similarly, the output-oriented *metaefficiency* (ME) score is obtained after solving the LPP in equation 4.7:

$$
\begin{aligned}
& Max\ \phi_0^m(x_o, y_o) \\
& \quad \text{s.t} \\
& \sum_{j=1}^{n}\lambda_j^m x_{ij}^m \le x_{i0} \qquad \forall i = 1,2,\ldots,m \\
& \sum_{j=1}^{n}\lambda_j^m y_{rj}^m \ge \phi\, y_{r0} \qquad \forall r = 1,2,\ldots,s \\
& \sum_{j=1}^{n}\lambda_j^m = 1 \\
& \lambda_j^m \ge 0\ ;\ j = 1,2,\ldots,n
\end{aligned}
\tag{4.7}
$$

In principle, a DMU is said to be inefficient when $\phi > 1$. Still, in this study, the reciprocal of the score is used for easy interpretation. This means that $0 < \phi_0^k(x_j^k, y_j^k) \le 1$. The output-oriented technical efficiency score of DMU_j measured against the metafrontier is $\phi_j^m(x_j, y_j)$ and the resulting efficiency score of that same DMU_j in group *k* is its *group efficiency* (GE)- $\phi_j^k(x_j, y_j)$

From the ME and GE, the output-orientated Technology Gap Ratio (TGR) (Battese et al., 2004) or Metatechnology Gap Ratio (MTR)(O'Donnell et al., 2008) for a group *k* can be defined as:

$$TGR_j^k(x_j, y_j) = \frac{\phi_j^m(x_j, y_j)}{\phi_j^k(x_j, y_j)} = \frac{TE_j^m(x_j, y_j)}{TE_j^k(x_j, y_j)} \tag{4.8}$$

The TGR represents the difference in the technology within the reach of the k^{th} group, relative to the technology within the reach of the all groups or the metafrontier (O'Donnell et al., 2008). The distance between the group frontier and the metafrontier is attributed to the greater technological features of the "best-practice technology" (Battese & Rao,2002). Since the output-oriented technical efficiency score is between 0 and 1, given the reciprocal property between Shephard distance function and Farrell efficiency score, the metafrontier envelops the group frontiers, which implies that $\phi_j^m(x_j, y_j) \leq \phi_j^k(x_j, y_j)$ and therefore $0 < TGR^k(x_j, y_j) \leq 1$ (see, O'Donnell et al., 2008; Chen & Yang, 2011). When the TGR is closer to 1, then the distance between the group frontier and the metafrontier is decreasing and therefore the corresponding technological heterogeneity is lower. On the other hand, when the TGR is approaching 0, then the difference between the efficiencies, relative to the two reference technology sets is increasing.

Table 1contains a sample of hypothetical data set used to illustrate the metafrontier analysis. It is composed of 12 DMUs, each of time periods 1 and 2, resulting in 24 observations. Each of the 12 DMUs also belongs to one of the three groups or clusters. DMUs A to D are within cluster 1, DMUs E to H are in cluster 2 and DMUs I to L are in cluster 3. The data need not necessarily be balanced. Each DMU uses one input (x) to produce two outputs (y1, y2). Figure 4 graphically depicts the observations.

However to illustrate the metafrontier, assume away the 12 observations in the period 2 for now. When we remove the 12 observations in the period 2, then the metafrontier would be formed by the technology lying between Mt1 and t1 as shown in Figure 4. Thus the metafrontier is formed by the technology Mt1. The three groups enveloped by (within) the metatechnologyMt1are depicted as K1, K2 and K3 for cluster 1, cluster 2 and cluster 3 respectively. Graphically, it can be observed that the 3 clusters operate under different technologies and that cluster 2 lies very close to the metafrontier technology, whereas cluster 1 is far away from the metafrontier technology. It can also be identified from the graph that the metafrontier technology is formed by cluster 2 and cluster 3.

Table 1: Sample dataset for illustrating metafrontier Malmquist

Period	Cluster	DMU	Input (x)	Output (y1)	Output (y2)
1	1	A1	1	1	3
1	1	B1	1	3	2
1	1	C1	1	1.5	2.5
1	1	D1	1	2	3.5
1	2	E1	1	2.5	5.5
1	2	F1	1	2	5
1	2	G1	1	4	2.5
1	2	H1	1	3	4
1	3	I1	1	2	4
1	3	J1	1	4.5	3
1	3	K1	1	3.5	2.5
1	3	L1	1	2	3.5
2	1	A2	1	2	6.5
2	1	B2	1	7	4
2	1	C2	1	5	5.5
2	1	D2	1	5.5	6.5
2	2	E2	1	5	8
2	2	F2	1	3	7
2	2	G2	1	6	5.5
2	2	H2	1	4.5	6
2	3	I2	1	5	8
2	3	J2	1	8	6
2	3	K2	1	7.5	5
2	3	L2	1	4	7.5

After forming the metafrontier technology, we can assess the efficiency of each of the 12 observed DMUs under the two different technologies – group-specific technology set and the metatechnology set. First, we assess the group efficiency, GE, of each DMU, that is, with respect to their respective/restricted clusters or groups. Second, each DMUs meta-efficiency, ME, score is assessed relative to the unrestricted technology, the boundary of which is the metafrontier. A DMU may be efficient with respect to the group frontier and hence metafrontier but can also be inefficient against the metafrontier. Under both group frontier and metafrontier technologies, a DMU's efficiency score must lie between 0 and 1.

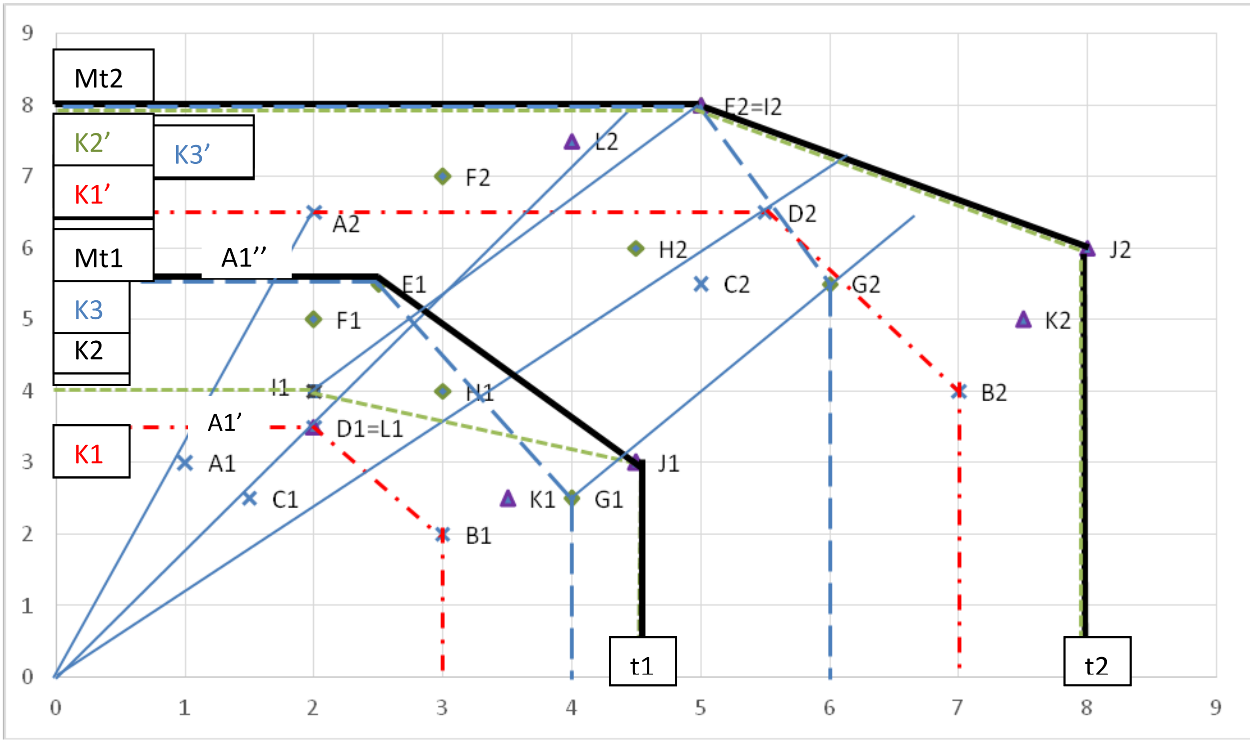

Figure 4: Graphical Representation of the Metafrontier Malmquist Productivity Index

Source: Author

After computing the GE and ME, the TGR in Equation 4.8 can be assessed as the ratio of ME to GE using Equation 4.9:

$$TE^{m}(x_j, y_j) = TGR^{k}(x_j, y_j) \times TE^{k}(x_j, y_j) \qquad (4.9)$$

The dataset in Table 1 is used to illustrate the computation of GE, ME and TGR for cluster 1 using the non-parametric LPP in Equation (4.6), (4.7) and the TGR in Equation (4.8).The output-oriented VRS efficiency for DMU A1 in cluster 1 measured with respect to the group frontier is given as:

$$\phi_{A1}^{k} = Max\phi_{A1}^{k}$$

s.t:

$$\begin{aligned}
&1\lambda_1 + 3\lambda_2 + 1.5\lambda_3 + 2\lambda_4 \geq \phi \\
&3\lambda_1 + 2\lambda_2 + 2.5\lambda_3 + 3.5\lambda_4 \geq 3\phi \\
&1\lambda_1 + 1\lambda_2 + 1\lambda_3 + 1\lambda_4 \leq x \\
&\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 = 1 \\
&\lambda_j \geq 0, \\
&j = 1, \dots 4
\end{aligned}$$

The output-oriented efficiency of DMU A1 measured relative to the metafrontier is mathematically modelled under VRS as:

$$\phi_{A1}^{M} = Max\phi_{A1}^{M}$$

s.t:

$$\begin{aligned}
&1\lambda_1 + 3\lambda_2 + 1.5\lambda_3 + 2\lambda_4 + 2.5\lambda_5 + 2\lambda_6 + 4\lambda_7 + 3\lambda_8 + 2\lambda_9 + 4.5\lambda_{10} + 3.5\lambda_{11} + 2\lambda_{12} \geq \phi \\
&3\lambda_1 + 2\lambda_2 + 2.5\lambda_3 + 3.5\lambda_4 + 5.5\lambda_5 + 5\lambda_6 + 2.5\lambda_7 + 4\lambda_8 + 4\lambda_9 + 3\lambda_{10} + 2.5\lambda_{11} + 3.5\lambda_{12} \geq 3\phi \\
&1\lambda_1 + 1\lambda_2 + 1\lambda_3 + 1\lambda_4 + 1\lambda_5 + 1\lambda_6 + 1\lambda_7 + 1\lambda_8 + 1\lambda_9 + 1\lambda_{10} + 1\lambda_{11} + 1\lambda_{12} \leq x_1 \\
&\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 + \lambda_6 + \lambda_7 + \lambda_8 + \lambda_9 + \lambda_{10} + \lambda_{11} + \lambda_{12} = 1 \\
&\lambda_j \geq 0, \\
&j = 1, \dots, 12
\end{aligned}$$

The output-oriented efficiency score for DMU A1 can also be determined graphically with respect to the group frontier, K1 by taking the radial distance from the origin (0) to A1 over an input-output point of a virtual DMU A1’ located on the group K1 technology (by drawing a radial distance from the origin (0) through A1 to the frontier formed by K1 technology). From Figure 4, the GE score of A1 is:

$$GE_{A1} = TE^{k}(x, y) = \frac{0A1}{0A1'} = \frac{3}{3.5} = 0.857$$

Similarly, the output-oriented ME score of A1 is:

$$ME_{A1} = TE^{m}(x, y)\frac{0A1}{0A1''} = \frac{3}{5.5} = 0.545$$

This is interpreted as, for a given input vector, potential output with respect to the group technology is 85.7% and that of the metafrontier technology is 54.5%. Therefore DMU A1 is 14.3% inefficient with respect to the group frontier (cluster 1) and 45.5% inefficient in relation to the metafrontier. The TGR for A1is:

$$TGR_{A1}^{k}(x\ ,y\ ) = \frac{ME_{A1}}{GE_{A1}} = \frac{TE^{M}(x\ ,y\ )}{TE^{k}(x\ ,y\ )} = \frac{0.545}{0.857} = 0.636$$

From this illustration, it is evident that there is a technological difference between the three clusters since DMU A1 is 36.4% away from reaching the metafrontier technology.

4.3.2 The Malmquist Productivity Index (MPI)

Capacity decisions, in operations management concerns proper resource allocation and such decisions in resource planning have positive net effect on productivity (Chowriwar, Lade, Sawaitul, & Kamble, 2014). Excess capacity results in low productivity, whereas inadequate capacity, have impact on poor customer satisfaction due to less output delivery. Therefore, organisations need to manage their input mix in order remain productive and meet customer satisfaction. One of the tools that have been employed over the years is productivity measurement. Ratio techniques have been employed over the years to assess productivity, but this technique compares single-input, single-output at a time. DEA has been incorporated into productivity analysis framework to deal away with the single-input, single output ratios. This is because DEA is a linear programming model that allows multiple-input, multiple-output. The Malmquist Productivity Index (MPI) is used to evaluate the productivity change of a DMU between two time periods (Färe et al., 1994). This DEA-based MPI was developed by Färe et al. (1992; 1994), who combined Farrell (1957) efficiency measure and productivity change measurement introduced by Caves, Christensen, and Diewert (1982). The MPI is based on input data such as labour and expenses and output data like loans and investments which are considered as one observation in two time periods, *t* and *t+1*(Färe et al., 1994).

The MPI proposed by Färe et al. (1992; 1994) was based on CRS assumption to avoid infeasibility in the computation and it can be decomposed into efficiency change (catching up) and technical change (frontier shift) components. However, Chen and Yang (2011) argued that the MPI decomposition into efficiency change and technical change is incomplete since it does not take into consideration the potential scale efficiency effect on productivity. Therefore the potential impact on the size of a firm could be addressed by modelling the MPI under VRS assumption.

To define the mathematical model of the MPI, assume $x^t \in \Re_+^m$ and $y^t \in \Re_+^s$ respectively represent i real positive inputs and r real positive outputs vectors of a CCU in period $t = 1, ..., T$. The production possibility set (T^t), which corresponds to the set of all feasible input-output vectors in period t is given as:

$$T^t = \{(x^t, y^t) \in \Re_+^{s+m} \mid x^t \text{ can produce } y^t\} \qquad (4.10)$$

T^t satisfies the conditions that nothing can be produced without inputs; finite input vector cannot produce infinite outputs (bounded); less outputs is likely to be produced with more inputs, and vice versa (strong free disposability) and that T^t is closed and convex (Coelli et al., 2005; Färe et al., 1994; Grifell-Tatje & Lovell, 1999).

The MPI measures productivity changes from period *t* to period *t+1* in a given input-output data points. Therefore the MPI is calculated as the geometric mean of the two indices (Coelli et al., 2005; Färe et al., 1994).

To estimate the MPI, we need to define own-period and cross-period efficiency scores relative to T^t using distance functions. However, the efficiency measure proposed by Farrell (1957) corresponds to the inverse of Shephard (1953) distance function:

$$0 \leq \phi^{t}\left(x^{t}, y^{t}\right) = \mathrm{D}^{t}\left(x^{t}, y^{t}\right) \leq 1 \qquad (4.11)$$

Therefore, this study uses Farrell's (1957) efficiency scores to assess the MPI. The output-oriented technical efficiency score, $\phi^{t}\left(x^{t}, y^{t}\right)$, under VRS assumption, of a given CCU in period t relative to technology frontier t, can be determined by solving the following LPP:

$$\begin{aligned} & Max\ \phi_0^t(x^t, y^t) \\ & \quad \text{s.t} \\ & \sum_{j=1}^{n} \lambda_j^t x_{ij}^t \leq x_{i0}^t \qquad \forall i = 1,2,\ldots,m \\ & \sum_{j=1}^{n} \lambda_j^t y_{rj}^t \geq \phi\, y_{r0}^t \quad \forall r = 1,2,\ldots,s \\ & \sum_{j=1}^{n} \lambda_j^t = 1 \\ & \lambda_j^t \geq 0; \quad \forall j = 1,2,\ldots,n \end{aligned} \qquad (4.12)$$

Where $\phi_0^t(x^t, y^t)$ represents the output-oriented efficiency score that measures the proportion at which outputs of the CCU under evaluation could be augmented in order to be efficient, given the level of inputs. Note that $\phi_0^t(x^t, y^t) \geq 1$ if only, if the CCU under evaluation is located inside the technology set (T^t) and therefore it is inefficient. When $\phi_0^t(x^t, y^t) = 1$, it indicates that the CCU under evaluation is on the efficient frontier (Fare et al., 1994). The model above is formulated under the VRS assumption since there is large variation about the size of the cooperative credit unions in our study sample. However, the model can be reformulated under the CRS assumption by simply removing the convexity constraint $\sum_{j=1}^{n} \lambda_j = 1$ from the model.

Equation 4.12 is the own-period efficiency estimation for the frontier in period t. The corresponding own-period efficiency score for the frontier in period $t+1$ is given as:

$$
\begin{aligned}
& Max \quad \phi_0^{t+1}(x^{t+1}, y^{t+1}) \\
& \quad \text{s.t} \\
& \sum_{j=1}^{n} \lambda_j^{t+1} x_{ij}^{t+1} \leq x_{i0}^{t+1} \qquad \forall i = 1,2,\ldots,m \\
& \sum_{j=1}^{n} \lambda_j^{t+1} y_{rj}^{t+1} \geq \phi\, y_{r0}^{t+1} \qquad \forall r = 1,2,\ldots,s \\
& \sum_{j=1}^{n} \lambda_J^{t+1} = 1 \\
& \lambda_j^{t+1} \geq 0
\end{aligned}
\tag{4.13}
$$

The cross-period or mixed-period efficiency scores for period t and period $t+1$ are respectively shown in Equation 4.14 and 4.15 as:

$$
\begin{aligned}
& Max \quad \phi_0^{t+1}(x^{t}, y^{t}) \\
& \quad \text{s.t} \\
& \sum_{j=1}^{n} \lambda_j^{t+1} x_{ij}^{t+1} \leq x_{i0}^{t} \qquad \forall i = 1,2,\ldots,m \\
& \sum_{j=1}^{n} \lambda_j^{t+1} y_{rj}^{t+1} \geq \phi y_{r0}^{t} \qquad \forall r = 1,2,\ldots,s \\
& \sum_{j=1}^{n} \lambda_j^{t+1} = 1 \\
& \lambda_j^{t+1} \geq 0
\end{aligned}
\tag{4.14}
$$

$$
\begin{aligned}
& Max \quad \phi_0^t(x^{t+1}, y^{t+1}) \\
& \quad \text{s.t} \\
& \sum_{j=1}^{n} \lambda_j^t x_{ij}^t \le x_{i0}^t \qquad \forall i = 1,2,\ldots,m \\
& \sum_{j=1}^{n} \lambda_j^t y_{rj}^t \ge \phi\, y_{r0}^t \qquad \forall r = 1,2,\ldots,s \\
& \sum_{j=1}^{n} \lambda_j^t = 1 \\
& \lambda_j^t \ge 0
\end{aligned} \tag{4.15}
$$

The cross period efficiency scores, $\phi_0^t(x^{t+1}, y^{t+1})$ and $\phi_0^{t+1}(x^t, y^t)$, may be less than, greater than or equal to 1, since their corresponding input-output observations may not belong to the frontier in period t or period $t+1$.

The Malmquist productivity index developed by Caves et al., (1982) is defined relative to the frontier in time period t frontier as:

$$
M_0\left(x^t, y^t, x^{t+1}, y^{t+1}\right) = \frac{\phi_0^t(x^t, y^t)}{\phi_0^t(x^{t+1}, y^{t+1})} \tag{4.16}
$$

and with respect to the frontier in time period $t+1$ as:

$$
M_0\left(x^t, y^t, x^{t+1}, y^{t+1}\right) = \frac{\phi_0^{t+1}(x^t, y^t)}{\phi_0^{t+1}(x^{t+1}, y^{t+1})} \tag{4.17}
$$

To avoid choosing an arbitrary benchmark technology, an MPI index was derived by Färe et al., (1992; 1994) as the geometric mean of these two indices in Equations 4.16 and 4.17 as:

$$
M_o\left(x^t, y^t, x^{t+1}, y^{t+1}\right) = \left[\frac{\phi_o^t\left(x^{t+1}, y^{t+1}\right)}{\phi_o^t\left(x^t, y^t\right)} \times \frac{\phi_o^{t+1}\left(x^{t+1}, y^{t+1}\right)}{\phi_o^{t+1}\left(x^t, y^t\right)} \right]^{1/2} \tag{4.18}
$$

Where,

$\phi_o^t(x^t, y^t)$ denotes the efficiency of the CCU under evaluation, at the input-output points in period t relative to the technology in period t,

$\phi_o^{t+1}(y^{t+1}, x^{t+1})$ represents the efficiency of the CCU under evaluation, at the input-output points in period $t+1$ relative to the period t+1 technology,

$\phi_o^{t+1}(x^t, y^t)$ denotes the efficiency of the CCU under evaluation, at the input-output points in period t relative to the technology in period $t+1$,

$\phi_o^t(x^{t+1}, y^{t+1})$ represents the efficiency of the CCU under evaluation, at the input-output points in period $t+1$ relative to the period t technology.

Equation 4.19 is the output-oriented MPI between period t (the base period) and period t+1 (the cut-off period). A value of $M_o(x^t, y^t, x^{t+1}, y^{t+1})$ greater than 1 implies productivity progress from period t to period $t+1$, while a value less than 1 shows a decline or productivity regress. When $M_o(x^t, y^t, x^{t+1}, y^{t+1})$ is equal to 1, it indicate productivity stagnation from period t to period t+1 (Färe et al., 1994, 1992; Ray & Delsi, 1997; Ohene-Asare, 2011).

Following Fare et al (1994), the MPI in Equation 4.18 can be further decomposed into efficiency change and technical change:

$$M_o(x^t, y^t, x^{t+1}, y^{t+1}) = \frac{\phi_o^{t+1}(x^{t+1}, y^{t+1})}{\phi_o^t(x^t, y^t)} \times \left[\frac{\phi_o^t(x^{t+1}, y^{t+1})}{\phi_o^{t+1}(x^{t+1}, y^{t+1})} \times \frac{\phi_o^t(x^t, y^t)}{\phi_o^{t+1}(x^t, y^t)} \right]^{1/2} \quad (4.19)$$

The first term at the right hand side of Equation 4.19 is the output-oriented technical efficiency change between period t and period t+1. It is the efficiency change component attributed to managerial expertise in input resources used in maximising output. On the other hand, the term inside the square bracket measures technical/technological change, which is the geometric mean of the shifts in technology observed in period t and t+1 (Färe et al., 1994). To illustrate the dynamic productivity, we continue to assume the two-year hypothetical data of 12 different CCUs depicted in Table 1. The clusters (groups) are ignored for the sake of simplicity for now. Note that the data for each year forms a separate frontier (year 1 and year 2 frontiers) which are not necessarily supposed to be parallel or Hicks-neutral. This is represented graphically in Figure 4, considering that the group frontiers in both periods are ignored. Therefore, the two thick-connecting metafrontiers represent the technology frontier in period t1 and t2. The technology frontier for year 1 is formed the thick line connecting Mt1, E1, J1 and t1. The corresponding production frontier in year 2 is represented by the thick-connecting lines Mt2, E2, J2 and t2.

The graph in Figure 4 indicates that apart from DMUs E1 and J1 which are on the year 1 frontier, the remaining DMUs in year 1 - A1, B1, C1, D1, F1, G1, H1, I1, K1 and L1 - are located within the period 1 technology. Similarly, for year 2 technology and the frontier, only three DMUs - E2, I2 and J2 - are on the frontier, with the remaining 9 DMUs found in the frontier 2 technology.

Referring to Table 1, the LPP required to compute the efficiency of DMU A in the year 1, relative to year 1 technology frontier can be defined using Equation 4.12 as:

$$Max\ \phi_A^1(x^1, y^1)$$

s.t.

$$1\lambda_A + 3\lambda_B + 1.5\lambda_C + 2\lambda_D + 2.5\lambda_E + 2\lambda_F + 4\lambda_G + 3\lambda_H + 2\lambda_I + 4.5\lambda_J + 3.5\lambda_K + 2\lambda_L \geq 1\phi$$
$$3\lambda_A + 2\lambda_B + 2.5\lambda_C + 3.5\lambda_D + 5.5\lambda_E + 5\lambda_F + 2.5\lambda_G + 4\lambda_H + 4\lambda_I + 3\lambda_J + 2.5\lambda_K + 3.5\lambda_L \geq 3\phi$$
$$1\lambda_A + 1\lambda_B + 1\lambda_C + 1\lambda_D + 1\lambda_E + 1\lambda_F + 1\lambda_G + 1\lambda_H + 1\lambda_I + 1\lambda_J + 1\lambda_K + 1\lambda_L \leq 1$$
$$\lambda_A + \lambda_B + \lambda_C + \lambda_D + \lambda_E + \lambda_F + \lambda_G + \lambda_H + \lambda_I + \lambda_J + \lambda_K + \lambda_L = 1$$
$$\lambda_j \geq 0,$$
$$j = 1, \ldots, 12$$

The corresponding efficiency of DMU A in the year 2, relative to year 2 frontier is formulated as:

$$Max\ \phi_A^2(x^2, y^2)$$

s.t.

$$2\lambda_A + 7\lambda_B + 5\lambda_C + 5.5\lambda_D + 5\lambda_E + 3\lambda_F + 6\lambda_G + 4.5\lambda_H + 5\lambda_I + 8\lambda_J + 7.5\lambda_K + 4\lambda_L \geq 2\phi$$
$$6.5\lambda_A + 4\lambda_B + 5.5\lambda_C + 6.5\lambda_D + 8\lambda_E + 7\lambda_F + 5.5\lambda_G + 6\lambda_H + 8\lambda_I + 6\lambda_J + 5\lambda_K + 7.5\lambda_L \geq 6.5\phi$$
$$1\lambda_A + 1\lambda_B + 1\lambda_C + 1\lambda_D + 1\lambda_E + 1\lambda_F + 1\lambda_G + 1\lambda_H + 1\lambda_I + 1\lambda_J + 1\lambda_K + 1\lambda_L \leq 1$$
$$\lambda_A + \lambda_B + \lambda_C + \lambda_D + \lambda_E + \lambda_F + \lambda_G + \lambda_H + \lambda_I + \lambda_J + \lambda_K + \lambda_L = 1$$
$$\lambda_j \geq 0,$$
$$j = 1, \ldots, 12$$

The two cross-period efficiency scores are formulated by taking the efficiency of DMU A in year 2 relative to technology frontier 1 and the efficiency of DMU A in the year 1 with respect to the technology in frontier 2 respectively as:

$$Max\ \phi_A^2(x^1, y^1)$$

s.t.

$$2\lambda_A + 7\lambda_B + 5\lambda_C + 5.5\lambda_D + 5\lambda_E + 3\lambda_F + 6\lambda_G + 4.5\lambda_H + 5\lambda_I + 8\lambda_J + 7.5\lambda_K + 4\lambda_L \geq 2\phi$$
$$6.5\lambda_A + 4\lambda_B + 5.5\lambda_C + 6.5\lambda_D + 8\lambda_E + 7\lambda_F + 5.5\lambda_G + 6\lambda_H + 8\lambda_I + 6\lambda_J + 5\lambda_K + 7.5\lambda_L \geq 6.5\phi$$
$$1\lambda_A + 1\lambda_B + 1\lambda_C + 1\lambda_D + 1\lambda_E + 1\lambda_F + 1\lambda_G + 1\lambda_H + 1\lambda_I + 1\lambda_J + 1\lambda_K + 1\lambda_L \leq 1$$
$$\lambda_A + \lambda_B + \lambda_C + \lambda_D + \lambda_E + \lambda_F + \lambda_G + \lambda_H + \lambda_I + \lambda_J + \lambda_K + \lambda_L = 1$$
$$\lambda_j \geq 0,$$
$$j = 1, \ldots, 12$$

$$Max\ \phi_{A}^{1}\left(x^{2}, y^{2}\right)$$

s.t.

$$1\lambda_A + 3\lambda_B + 1.5\lambda_C + 2\lambda_D + 2.5\lambda_E + 2\lambda_F + 4\lambda_G + 3\lambda_H + 2\lambda_I + 4.5\lambda_J + 3.5\lambda_K + 2\lambda_L \geq 1\phi$$
$$3\lambda_A + 2\lambda_B + 2.5\lambda_C + 3.5\lambda_D + 5.5\lambda_E + 5\lambda_F + 2.5\lambda_G + 4\lambda_H + 4\lambda_I + 3\lambda_J + 2.5\lambda_K + 3.5\lambda_L \geq 3\phi$$
$$1\lambda_A + 1\lambda_B + 1\lambda_C + 1\lambda_D + 1\lambda_E + 1\lambda_F + 1\lambda_G + 1\lambda_H + 1\lambda_I + 1\lambda_J + 1\lambda_K + 1\lambda_L \leq 1$$
$$\lambda_A + \lambda_B + \lambda_C + \lambda_D + \lambda_E + \lambda_F + \lambda_G + \lambda_H + \lambda_I + \lambda_J + \lambda_K + \lambda_L = 1$$
$$\lambda_j \geq 0,$$
$$j = 1,....,12$$

The own-period and cross-period efficiency scores can be estimated using Figure 4. The output-oriented efficiency of these firms is estimated by the proportion at which the output of the firm can be increased without altering the current input level. Graphically, these are measured by taking the vertical distance from the origin to the point where the DMUs being evaluated is located, divided by the vertical distance from the origin to the frontier. Assuming VRS technology, the own-period efficiency for A1 ($\phi_A^1(x^1, y^1)$), estimated relative to period 1frontier is 0.545 (i.e. 3/5.5) and that of A2($\phi_A^2(x^2, y^2)$ is given as 0.813 (i.e. 6.5/8). The cross-period efficiency score for A1, assessed with reference to period 2 frontier, A1 $\phi_A^2(x^1, y^1)$,is 0.375 (i.e. 3/8) whereas A2($\phi_A^1(x^2, y^2)$), estimated relative to period 1 frontier in is the super-efficient score of 1.182 (i.e. 6.5/5.5). The Malmquist Productivity Change Index and its components for credit union A can therefore be estimated, using Equation 4.19 as:

$$M_A\left(x^t, y^t, x^{t+1}, y^{t+1}\right) = \underbrace{\left[\frac{0.813}{0.545}\right]}_{\text{Efficiency Change}} \times \underbrace{\left[\frac{1.182}{0.813} \times \frac{0.545}{0.375}\right]^{1/2}}_{\text{Technical Change}}$$

$$M_A\left(x^t, y^t, x^{t+1}, y^{t+1}\right) = 1.489 \times 1.455$$

$$M_A\left(x^t, y^t, x^{t+1}, y^{t+1}\right) = 2.167$$

The Malmquist productivity change index result for DMU A (2.167) shows that it progressed from the period 1 to period 2 by 116.7%. On the sources of productivity change, it can be noted that both efficiency change and technical change contributed to CCUA's productivity progress by 48.9% and 45.5% respectively. The main driver of change is efficiency change. Using this principle the productivity change of all the 12 hypothetical CCUs can be estimated. However, note that these estimations ignore the group heterogeneities that are present in the data set but should be accounted for. The Malmquist productivity change indexes for the 12 CCUs in the example data are presented in Table 2.

Table 2: MPI Results for the 12 CCUs

CCU	A	B	C	D	E	F	G	H	I	J	K	L
MPI	2.167	2.333	2.588	2.138	1.550	1.401	1.686	1.500	2.092	1.816	2.117	2.113

It can also be noted that all the CCUs had productivity improvement. For example, CCU F had productivity progress of 40.1% and CCU C show a progress of 158.8%, representing the least and the highest productivity improvement respectively.

4.3.3 Metafrontier Malmquist Productivity Index (MMPI)

The standard Malmquist index has been extended into several ones in the literature (Lovell, 2003; Pastor & Lovell, 2005). These methodological extensions also include the Metafrontier Malmquist productivity index proposed by O'Donnell et al. (2008) and Chen and Yang (2011) and the Metafrontier Malmquist-Leunberger productivity proposed by Lee and Oh (2010). Other extension are bootstrapping Malmquist index (Simar & Wilson, 1999), biennial Malmquist (Pastor, Asmild, & Lovell, 2011), slack based measure (SBM) Malmquist (Liu & Wang, 2008; Lo & Lu, 2009) and non-radial Malmquist (Chen, 2003).

The current study adopts the Metafrontier Malmquist productivity index (MMPI) proposed by O'Donnell et al. (2008) and later extended by Chen and Yang (2011) to assess dynamic efficiency and productivity of CCUs in Ghana. The MMPI is a methodological approach that combines both the Malmquist productivity change index and the metafrontier analysis to estimate dynamic performance of relatively heterogeneous firms under separate frontiers (group frontier and metafrontier) (Chen & Yang, 2011; Lee & Oh, 2010).

Under the metafrontier Malmquist, two types of MPI's can be estimated; one defined with respect to group specific technology frontier (GMPI) and the other defined with respect to the metatechnology, the boundary of which is metafrontier (MMPI) (Chen & Yang, 2011). Assume that CCUs use multiple inputs to produce multiple outputs under each time period, $t:1,...,T$. Given that N CCUs in time t produce r non-negative outputs (denoted by $y_t \in \Re_+^s$), using i non-negative inputs (denoted by $x_t \in \Re_+^m$), and assuming there are K technology sets (groups of credit unions), the production possibility set (input-output combination set) can be defined as:

$$T_t^k = \{(x_t^k, y_t^k) \in \Re_+^{s+m} | x_t^k \text{ can produce } y_t^k\} \quad (4.20)$$

whereas the metatechnology set at time period t can be defined as:

$$T_t^m = \{(x_t^m, y_t^m) : x_t^m \text{ can produce } \mathrm{y}_t^m\} \quad (4.21)$$

where (x_t^m, y_t^m) is the input-output combinations for a DMU within the metatechnology in period t (O'Donnell et al., 2008). The output-oriented envelopment LPP VRS for estimation of the group efficiency score for a DMU in group k can be defined relative to period t and period $t+1$ as in Equation (4.12) and (4.113) respectively by introducing superscript k into the formulation. Similarly, we define the output-oriented envelopment LPP under VRS for the estimation of the metafrontier efficiency score for a DMU with respect to period *t* and period *t+1* as in Equation (4.12) and (4.13) respectively, this time by adding superscript *m* in the formulation.

The metafrontier benchmark technology envelops the group-specific frontiers and therefore the correlation between the technical efficiency measured relative to the metafrontier and group frontiers is that the metaefficiency score is less than or equal to the group efficiency score(Chen & Yang, 2011). For a firm belonging to cluster k, the group-specific MPI (GMPI) is $M^{k}_{t,t+1}(x_t, y_t, x_{t+1,} y_{t+1})$ and the metatechnology/metafrontier (MMPI) is $M^{m}_{t,t+1}(x_t, y_t, x_{t+1,} y_{t+1})$ (Chen & Yang, 2011).

Lee and Oh (2010) also decomposed the metafrontier Malmquist productivity index into three components; a contemporaneous benchmark technology set, an inter-temporal benchmark technology set, and a global benchmark technology set. However, Lee and Oh (2010) based their computations on the on global Malmquist productivity change index of Pastor and Lovell (2005) which is based on a single technology and beyond the scope of this thesis. Chen and Yang (2011) extended the metafrontier malmquist productivity index to account for the effect of scale efficiency change (SEC). The current study adopts Chen and Yang (2011) extension and estimates the metafrontier Malmquist productivity index (MMPI) of Co-operative Credit Unions in Ghana. The Group-specific Malmquist Productivity Index (GMPI) for a CCU belonging to the k^{th} group having an observed input-output combinations (x_t, y_t) and ($x_{t+1,} y_{t+1}$) in periods t and t+1 respectively can be defined and decomposed into technical efficiency change and technical change components as follows:

$$GMPI_{t,t+1}\left(x_t, y_t, x_{t+1}, y_{t+1}\right) = \left[\frac{\phi_t^k\left(x_{t+1}, y_{t+1}\right)}{\phi_t^k\left(x_t, y_t\right)} \times \frac{\phi_{t+1}^k\left(x_{t+1}, y_{t+1}\right)}{\phi_{t+1}^k\left(x_t, y_t\right)}\right]^{1/2}$$

$$GMPI_{t,t+1}\left(x_t, y_t, x_{t+1}, y_{t+1}\right) = \frac{\phi_{t+1}^k\left(x_{t+1}, y_{t+1}\right)}{\phi_t^k\left(x_t, y_t\right)} \times \left[\frac{\phi_t^k\left(x_{t+1}, y_{t+1}\right)}{\phi_{t+1}^k\left(x_{t+1}, y_{t+1}\right)} \times \frac{\phi_t^k\left(x_t, y_t\right)}{\phi_{t+1}^k\left(x_t, y_t\right)}\right]^{1/2}$$

(4.22)

The simplified version of Equation 4.22 is given as:

$$GMPI_{t,t+1} = TEC_{t,t+1}^k \times TC_{t,t+1}^k$$

(4.22a)

The first term on the right hand side of Equation 4.22 is technical efficiency change (TEC) measured relative to the group-specific (k^{th} cluster) frontier and the second part is the technological change defined to be the geometric mean of the frontier shift using a set DMUs of periods t and t+1 as a reference.

Similarly, the Metafrontier MPI (MMPI) can be defined and decomposed into technical efficiency change and technical change components as:

$$MMPI_{t,t+1}\left(x_t, y_t, x_{t+1}, y_{t+1}\right) = \frac{\phi_{t+1}^m\left(x_{t+1}, y_{t+1}\right)}{\phi_t^m\left(x_t, y_t\right)} \times \left[\frac{\phi_t^m\left(x_{t+1}, y_{t+1}\right)}{\phi_{t+1}^m\left(x_{t+1}, y_{t+1}\right)} \times \frac{\phi_t^m\left(x_t, y_t\right)}{\phi_{t+1}^m\left(x_t, y_t\right)}\right]^{1/2} \qquad (4.23)$$

Equation 4.23 can be simplified as:

$$MMPI_{t,t+1} = TEC_{t,t+1}^m \times TC_{t,t+1}^m \qquad (4.23a)$$

An $MMPI_{t,t+1}$ or $GMPI_{t,t+1}$ value greater than unity implies a shift a CCU's output towards the output level on the respective metafrontier or group-frontier. This refers to the definition of catch-up in Färe, et al.(1994).

Chen and Yang (2011) decomposed the MMPI and GMPI into technical efficiency change (TEC) and technological change (TC) through algebraic manipulations to yield the term technology gap ratio change (TGRC) also known as catch-up inverse. The TGRC was derived by first defining the technology gap ratios for the own period and the mixed period technologies.

The technology gap ratio (TGR) is defined with respect to period t or $t+1$, as the ratio of the metafrontier efficiency score to the group-frontier efficiency score

The TGR for the own period t and $t+1$ is defined respectively as:

$$TGR_t^k(x_t, y_t) = \frac{\phi_t^m(x_t, y_t)}{\phi_t^k(x_t, y_t)} \text{ and } TGR_{t+1}^k(x_{t+1}, y_{t+1}) = \frac{\phi_{t+1}^m(x_{t+1}, y_{t+1})}{\phi_{t+1}^k(x_{t+1}, y_{t+1})}$$

Similarly, the mixed period technology gap ratios for period t and $t+1$ is defined respectively as:

$$TGR_t^k(x_{t+1}, y_{t+1}) = \frac{\phi_t^m(x_{t+1}, y_{t+1})}{\phi_t^k(x_{t+1}, y_{t+1})} \text{ and } TGR_{t+1}^k(x_t, y_t) = \frac{\phi_{t+1}^m(x_t, y_t)}{\phi_{t+1}^k(x_t, y_t)}$$

Therefore, the TGRC for the own period and cross period technologies is expressed as:

$$TGRC_{t,t+1}^k = \left[\frac{TGR_{t+1}^k(x_{t+1}, y_{t+1})}{TGR_t^k(x_t, y_t)} \times \frac{TGR_t^k(x_{t+1}, y_{t+1})}{TGR_{t+1}^k(x_t, y_t)}\right]^{1/2} \quad (4.24)$$

According to Chen and Yang (2011), the technology gap ratio change $(TGRC_{t,t+1}^k)$ is also known as the catch up inverse $[catch-up_{t,t+1}^k]^{-1}$.

$$[catch-up_{t,t+1}^k]^{-1} = \left[\frac{TGR_{t+1}^k(x_{t+1}, y_{t+1})}{TGR_t^k(x_t, y_t)} \times \frac{TGR_t^k(x_{t+1}, y_{t+1})}{TGR_{t+1}^k(x_t, y_t)}\right]^{\frac{1}{2}} \quad (4.24a)$$

The first term and the second term at the right hand side of Equation 4.24 represent the own period technology gap ratio and the mixed period technology gap ratio respectively.

Therefore the $TGRC^{k}_{t,t+1}$ is defined as the square root of the product of the ratio between the own period technology gap ratio and the cross period technology gap ratio.

Chen and Yang (2011) also decomposed the MMPI into two main components; on being group specific productivity index (GMPI) and the other being the inverse group catch-up from period t to $t+1$ as:

$$MMPI_{t,t+1} = TEC^{k}_{t,t+1} \times \frac{TGR^{k}_{t+1}(x_{t+1}, y_{t+1})}{TGR^{k}_{t}(x_{t}, y_{t})} \times TC^{k}_{t,t+1} \left[\frac{TGR^{k}_{t}(x_{t}, y_{t})}{TGR^{k}_{t+1}(x_{t}, y_{t})} \times \frac{TGR^{k}_{t}(x_{t+1}, y_{t+1})}{TGR^{k}_{t+1}(x_{t+1}, y_{t+1})} \right]^{\frac{1}{2}}$$

(4.25)

By substituting Equation 4.23a, Equation 4.25 can be expressed as:

$$MMPI_{t,t+1} = TEC^{k}_{t,t+1} \times TC^{k}_{t,t+1} \times \left[\frac{TGR^{k}_{t+1}(x_{t+1}, y_{t+1})}{TGR^{k}_{t}(x_{t}, y_{t})} \times \frac{TGR^{k}_{t}(x_{t+1}, y_{t+1})}{TGR^{k}_{t+1}(x_{t}, y_{t})} \right]^{\frac{1}{2}} \quad (4.26)$$

Equation 4.26 can be simplified as:

$$MMPI_{t,t+1} = TEC^{k}_{t,t+1} \times TC^{k}_{t,t+1} \times [Catch - up]^{-1} \quad (4.26a)$$

By substituting Equation 4.23a, Equation 4.26a can be simplified as:

$$MMPI_{t,t+1} = GMPI_{t,t+1} \times [catch - up_{t,t+1}]^{-1} \quad (4.27)$$

Therefore, the $TGRC^{k}_{t,t+1}$ or the $[catch - up^{k}_{t,t+1}]^{-1}$ in Equation 4.24 and 4.24a is expressed as:

$$= \frac{MMPI_{t,t+1}}{GMPI_{t,t+1}} \tag{4.28}$$

and

$$catch-up_{t,t+1}^{k} = \frac{GMPI_{t,t+1}}{MMPI_{t,t+1}} \tag{4.29}$$

From Equation 4.25, the $TGRC_{t,t+1}^{k}$ is decomposed as:

$$TGRC_{t,t+1}^{k} = \frac{TGR_{t+1}^{k}\left(x_{t+1}, y_{t+1}\right)}{TGR_{t}^{k}\left(x_{t}, y_{t}\right)} \times \left[\frac{TGR_{t}^{k}\left(x_{t+1}, y_{t+1}\right)}{TGR_{t+1}^{k}\left(x_{t+1}, y_{t+1}\right)} \times \frac{TGR_{t}^{k}\left(x_{t}, y_{t}\right)}{TGR_{t+1}^{k}\left(x_{t}, y_{t}\right)}\right]^{\frac{1}{2}} \tag{4.30}$$

The technology gap ratio change $(TGRC_{t,t+1}^{k})$, also known as the inverse technological catch-up expressed in Equations 4.24 and 4.24a needs further clarification. The numerator of first term on the right -hand side of the equation is a technology gap ratio (TGR) lying between the metafrontier and the group frontier of period $t+1$ measured at the input-output combination of period $t+1$. The denominator, however, is the technology gap ratio (TGR) lying between the metafrontier and the group frontier of period $t+1$ measured at the input-output points of period t (Chen & Yang, 2011). On the other hand, the numerator of the second term is a TGR lying between the metafrontier and the group frontier of period t measure with respect to the input-output points of period $t+1$, whereas the denominator is the TGR lying between the metafrontier and the group frontier of period t measure with respect to the input-output points of period t. Therefore the first term measures the change in TGR from period t to $t+1$, whereas the second term refers to the change in TGR from period $t+1$ to period t (Chen & Yang, 2011).

It can be identified that Equation 4.30 captures two types of technology gap ratios. The first term on the right-hand side of the equals sign represent the change in TGR from period t to $t+1$, measured at the input-output points of period t and $t+1$ as:

$$PTCU_{t,t+1}^{k} = \frac{TGR_{t+1}^{k}\left(x_{t+1}, y_{t+1}\right)}{TGR_{t}^{k}\left(x_{t}, y_{t}\right)} \quad (4.31)$$

This term purely captures the catch-up in technology without considering the components of technical inefficiency with respect to a group-frontier and therefore it is singled out as pure technological catch-up (PTCU) (Chen & Yang, 2011). A value greater than one (1) suggests the shrinkage in technology gap (i.e., an increase in TGR), which refer to the 'catch-up' actually faced by a specific firm. The second term of Equation 44 is however a geometric of two inverse changes in TGR from period t to $t+1$, measured at the input-output points of period $t+1$ and t. Thus, this term implies that a change in a whole band of TGR lies between the group frontier and the metafrontier (O'Donnell et al., 2008). This term is known as the frontier catch-up (FCU), expressed as:

$$FCU_{t,t+1}^{k} = \left[\frac{TGR_{t}^{k}\left(x_{t+1}, y_{t+1}\right)}{TGR_{t+1}^{k}\left(x_{t+1}, y_{t+1}\right)} \times \frac{TGR_{t}^{k}\left(x_{t}, y_{t}\right)}{TGR_{t+1}^{k}\left(x_{t}, y_{t}\right)}\right]^{\frac{1}{2}} \quad (4.32)$$

A value less than unity suggests there is a shrinkage of the whole band of technology gap (i.e., an increase in the whole set of TGR). Thus the FCU captures the velocity of change of the metafrontier relative to that of the group frontier. When the upward shift in the group frontier is faster than the metafrontier, the FCU would exhibit a value less than unity. On the other hand, when the upward shift in the group frontier is less than the metafrontier, the FCU would yield a value greater than unity (Chen & Yang, 2011).

To illustrate the MMPI, assume a two-year hypothetical data of 12 different CCUs, depicted in Table 1. The data set is composed of 24 observations, that is, 12 DMUs, in two time periods where each period of 12 DMUs is made up of 3 groups or clusters. As discussed earlier, DMUs A to D are within the cluster 1, DMUs E to H are in cluster 2 and DMUs I to L are in group 3. Each DMU uses one normalised input (x) to produce two outputs (y1, y2). Figure 4 graphically depicts the observations with the different group frontiers and the metafrontiers in both period t1 and period t2 and used to compute the MMPI and the GMPI at time period t and t+1.

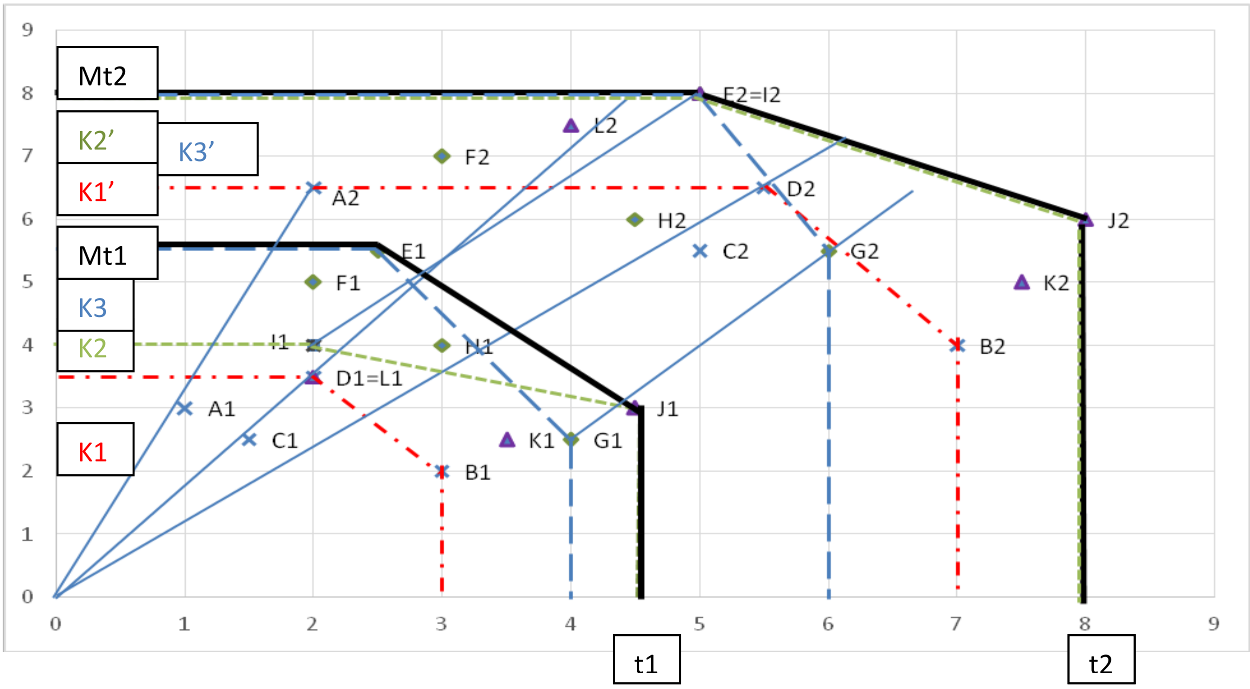

Figure 4: Graphical Representation of the Metafrontier Malmquist Productivity Index

Source: Author (2015)

These separate frontiers are allowed to shift between period t1 and period t2. The two metafrontiers in period t1 and t2 therefore envelop their respective group frontiers in period t1 and t2. Period t1 and period t2metafrontiers are those used to estimate the metafrontier Malmquist productivity change indices. Thus the metatechnology frontier for periodt1 is formed by the thick-connecting line E1, J1 and. The corresponding production frontier in year 2 is defined by the thick-connecting lines Mt2, E2, I2, J2 and t2 as in the standard Malmquist frontier explained earlier. Under the metafrontier Malmquist productivity index, two own-period and two cross-period efficiency scores are estimated for each of the 12 credit unions in the dataset in order to calculate both the group frontier and the metafrontier MPI. For the purposes of practical illustration, we compute the GMPI and MMPI for CCU A, which belongs to cluster 1 and show its decomposition. Following Equations 4.12 to 4.15, we estimate both own-period and cross-period efficiency scores relative to both the group frontier and the metafrontier. To compute the GMPI and the MMPI for DMU A using Equations 4.22 and 4.23, some efficiency scores have to be obtained first.

The own-period efficiency scores for DMU A measured with respect to the group-frontier is computed as $\phi_1^k(x_1, y_1)$=0.857 (i.e. 3/3.5) and $\phi_2^k(x_2, y_2)$= 1 (i.e. 6.5/6.5) respectively for period 1 and period 2 and the corresponding cross-period efficiency scores calculated as: $\phi_1^k(x_2, y_2)$= 1.857 (i.e. 6.5/3.5) and $\phi_2^k(x_1, y_1)$= 0.462 (i.e. 3/6.5). Similarly the own-period efficiency scores for DMU A relative to the metafrontier is computed as $\phi_1^m(x_1, y_1)$ =0.545 (i.e. 3/5.5) and $\phi_2^m(x_2, y_2)$= 0.813 (i.e. 6.5/8) respectively for period 1 and period 2 and the corresponding mixed-period efficiency scores calculated are $\phi_1^m(x_2, y_2)$= 1.182 (i.e. 6.5/5.5) and $\phi_2^m(x_1, y_1)$= 0.375 (i.e. 3/8). Thus, the output-oriented GMPI and MMPI for credit union A is computed as:

$$GMPI(A)_{t,t+1} = \frac{1}{0.857} \times \left[\frac{1.857}{1} \times \frac{0.857}{0.462} \right]^{\frac{1}{2}}$$
$$= 1.667 \times [1.857 \times 1.857]^{\frac{1}{2}}$$
$$= 1.667 \times 1.857$$
$$= 2.167$$

$$MMPI(A)_{t,t+1} = \frac{0.813}{0.545} \times \left[\frac{1.182}{0.813} \times \frac{0.545}{0.375} \right]^{\frac{1}{2}}$$
$$= 1.489 \times [1.455 \times 1.455]^{\frac{1}{2}}$$
$$= 1.489 \times 1.455$$
$$= 2.167$$

The group-frontier and the metafrontier estimates for the 12 CCUs are shown in Table 3.

Table 3 Group-frontier and Metafrontier Results for the 12 CCUs

CCU	A	B	C	D	E	F	G	H	I	J	K	L
$MMPI_{t,t+1}$	2.167	2.333	2.588	2.138	1.550	1.401	1.686	1.500	2.092	1.816	2.117	2.113
$GMPI_{t,t+1}$	2.167	2.285	2.506	2.053	1.579	1.401	1.581	1.500	2.041	1.846	2.097	2.130

DMU A both within its group and in relation to the metafrontier improved its productivity by 116.7%. The group productivity progress was mainly driven by 85.7% progress in innovation and the meta-productivity progress was driven mainly by improvement in managerial skills or efficiency improvement from period 1 to period 2.

From equation 4.26, the Metafrontier Malmquist productivity index (MMPI) is decomposed into Group-specific Malmquist productivity index (GMPI) and an index of the change in technology gap ratio, also known as the catch-up index.

We therefore calculate the catch index for CCU A based on Equation 4.26 as:

$$MMPI_{t,t+1} = GMPI_{t,t+1} \times [catch - up]^{-1}$$

$$catch-up = \frac{GMPI_{t,t+1}}{MMPI_{t,t+1}} = \frac{2.167}{2.167} = 1$$

The catch-up index of 1 show that CCU A is catching up with the world technology (Metafrontier) over the periods t to $t+1$.

The technology gap ratio for CCU A with respect to the own-period and the mixed-period is given respectively as:

Own period:

$$TRG_t^k(x_t, y_t) = \frac{\phi_t^m(x_t, y_t)}{\phi_t^k(x_t, y_t)} = \frac{0.545}{0.857} = 0.636$$

$$TRG_{t+1}^k(x_{t+1}, y_{t+1}) = \frac{\phi_{t+1}^m(x_{t+1}, y_{t+1})}{\phi_{t+1}^k(x_{t+1}, y_{t+1})} = \frac{0.813}{1} = 0.813$$

Mixed period:

$$TRG_t^k(x_{t+1}, y_{t+1}) = \frac{\phi_t^m(x_{t+1}, y_{t+1})}{\phi_t^k(x_{t+1}, y_{t+1})} = \frac{1.182}{1.857} = 0.637$$

$$TRG_{t+1}^k(x_t, y_t) = \frac{\phi_{t+1}^m(x_t, y_t)}{\phi_{t+1}^k(x_t, y_t)} = \frac{0.375}{0.462} = 0.812$$

From Equation 4.24, the technology gap ratio change, $TGRC_{t,t+1}^k$ for CCU A is given as:

$$TGRC_{t,t+1}^k(\text{A}) = \frac{0.813}{0.636} \times \left[\frac{0.637}{0.813} \times \frac{0.636}{0.812}\right]^{\frac{1}{2}}$$

$$= 1.278 \times 0.783$$

Therefore, from Equations 4.31 and 4.32, the pure technological catch-up (PTCU) and the frontier catch-up (FCU) for CCU A are 1.278 and 0.783 respectively. The value for PTCU and FCU implies shrinkage of the technology gap and the whole band of the technology gap respectively. With regards to the FCU, we conclude that CCU A has experience an upward shift in the group frontier at a faster rate than the metafrontier, whereas the PTCU has also experience an increase in TGR.

4.4 Specification of Inputs and Output Variables

The most important and difficult part of efficiency assessment is to determine the input and output variables for model construction. The reason is that the inputs and outputs factors must relate to the production objectives of the DMUs, be consistent across DMUs, and must be quantifiable (Karaduman, 2006). There is no consensus in literature with regards to the specification of inputs and outputs in frontier efficiency modelling (Berger & Humphrey, 1997). However, the choice of variables in efficiency studies significantly affects the results and therefore researcher need to be mindful of the variable selection (Drake, 2001). The choice of input and output variables in DEA analysis depends on the approach for the efficiency analysis. As indicated earlier, there are different ways in modelling input and output variables for efficiency analysis of financial institutions. These are the production (Berger & Humphrey, 1997), the intermediation approach (Sealey & Lindley, 1977), the profitability model (Berger & Mester, 1997), and marketability model (Seiford and Zhu 1999).

The two main approaches are the production and the intermediation approaches. Since co-operative credit unions collect savings and shares from surplus spending members of the union and offer loans and other financial services to other members in need of funds, the intermediation approach is suitable for this study. In order to ensure that our variables are consistent with efficiency studies literature, we selected operating expenses (Bui, 2013; Garcı´a-Cestona & Surroca, 2008; Kontolaimou & Tsekouras, 2010), total assets (Othman et al., 2013) and membership (Ganesan, 2009) as input variables, whilst loans (Garcı´a-Cestona & Surroca, 2008; Kontolaimou & Tsekouras, 2010; Okuda et al., 2014; Othman et al., 2013; Pasiouras & Sifodaskalakis, 2010; Paxton, 2006) and investments (Bui, 2013; Ganesan, 2009; Pasiouras & Sifodaskalakis, 2010; Paxton, 2006) are considered as outputs for this study. Table 4 provides the description of the inputs and the outputs. Apart from membership which is measured in numbers, all the other variables are measured in Ghana Cedi. Membership was included in an output measure as a proxy for credit unions' social responsibility. Thus credit unions recording an increase in membership are an indication that they are meeting their social responsibility mandate by providing the social and financial needs of members. Those with the decline in membership suggests that they are not meeting the social needs of members they are withdrawing their membership. Goddard, McKillop, and Wilson, (2008) used membership growth as a performance indicator, but indicated that the appropriateness of membership growth as a performance measure is open to debate. Goddard, McKillop, and Wilson, (2008) argued that common bond is a major determinant with which new members are admitted into credit unions. However, in Ghana and in most part of the world, although common bond exists, it cannot be seen as a barrier for new entrants as all CCUs are open to the general public regardless of the bond structure.

Table 4: Description of input and output variables

Variable	Description	Measure
Inputs:		
1. Deposits	These are savings received from members	Ghana Cedis
2. Operating Expenses	This include personnel expenses, administrative cost, occupancy and security expenses	Ghana Cedis
Outputs:		
1. Loans	This include all types of loans granted to credit union members	Ghana Cedis
2. Investments	This constitutes liquid investments and other investments	Ghana Cedis
3. Membership	This refers to the total number of members in the credit union	Number of people

4.5 Analysis of Credit Unions Efficiency and Productivity

This study analyse the meta-technical efficiency and productivity of CCUs in the sample based on the methodology employed by Chen and Yang (2011). The study employs DEA-based Metafrontier approach in estimating the technical efficiency and productivity of CCUs. An important consideration in efficiency and productivity estimation is the choice of the orientation. Two models exist in the DEA literature for the estimation of efficiency and productivity, i.e. input and output orientation. An input orientation measure identifies technical efficiency as a proportional reduction in input usage while keeping output constant. On the other hand, an output-orientated measure identifies technical efficiency as a proportional increase in output levels with input levels held constant (Coelli et al., 2005; Cooper et al., 2004). Input orientation measure is well suited for cost minimization objective, while output orientation is recommended for impact or output maximization (Cooper et al., 2011). Thus the output orientation defines the level by which the outputs produced by a DMU can be increased while maintaining the level by which inputs are used (Ramanathan, 2003). The underlying goal of credit unions' performance measurement is to determine whether they are achieving their social objectives (Hinson & Juras, 2002). Therefore the estimation model for this study is based on output-oriented VRS. The motivation for using these models is that credit unions' operations seek to maximise members benefit to reflect their core mandate (granting loans and financial services to members) and also large variation exist between the sizes of CCUs in Ghana.

Another important point to consider in efficiency and productivity analysis is the choice of input and output variables. Two main approaches (intermediation and production) have been mostly used in efficiency and productivity studies (Berger & Humphrey, 1997). The intermediation approach assumes that financial institutions as being intermediaries of financial services between borrower and savers (Sealey & Lindley, 1977). Thus the transformation process under this approach begins by borrowing of funds from surplus spending units and lending those funds to others who are on the deficit spending side (Sealey & Lindley, 1977). The production approach perceive that financial institutions are production units, in a sense that they produce loans, deposits and other financial services by employing inputs such as labour and capital (Meeusen & Broeck, 1977; Gutierrez-Nieto et al., 2007). Since CCUs collect deposits and shares from members and use them as seed capital to grant loans and other financial and non-financial services to other members, the best approach for this industry is the intermediation approach. Therefore, this study follows the intermediation approach in selecting inputs and output variables.

The data for the analysis was run to estimate the metafrontier and the group frontier efficiency, the group-frontier Malmquist and metafrontier Malmquist productivity index and its decomposition using MaxDEA software. In MaxDEA, output oriented technical efficiency is measured between 0 and 1, and so the results and discussions presented in Chapter 5 is based on MaxDEA scores. DMUs with efficiency scores less than 1.00 are considered inefficient. On the other hand, productivity scores are interpreted in two ways, i.e., productivity progress or regress. The Malmquist index is computed as the geometric mean of adjacent year's index value. A productivity score less than 1 indicates a regress whereas productivity score greater than 1 show progress. A DMU is said to have stagnated if its productivity score is equal to 1.

One of the objectives of this study is to account for heterogeneity in credit union operations and its effect on efficiency and productivity. To achieve this objective, three different groups of Credit Unions were identified as in Appendix A2. MaxDEA calculates the MMPI for the pooled data (entire credit unions dataset), and the GMPI for the group-specific data set for two adjacent years (e.g. 2008 and 2009) and decompose them into efficiency change and technical change. The technical efficiency score and the productivity indices for an individual DMU are then respectively, compared relative to its own-group frontier and the Metafrontier. This would then help us analyse the catch-up or the technology gap ratio of the estimated Malmquist productivity index.

CHAPTER FIVE

DATA ANALYSIS AND DISCUSSIONS

5.0 Introduction

This chapter begins with the description of the data used for the study. The discussions of the results of this study are also presented. The discussion of the results is, however, presented based on the technical efficiency with respect to the group-frontiers and also the metafrontier. The analysis of the GMPI and MMPI as well as their decompositions, technology gaps and catch-up effects are also presented to conclude the chapter.

5.1 Description of data

The data used for this study is a secondary data extracted from the annual audited reports of the CCUs. The annual audited report for the financial year 2008 to 2012 was obtained from the Credit Unions Association of Ghana (CUA).

The five year study period was chosen because most CCUs were not in full operation prior to 2008 and therefore do not have consistent data. It was also observed that most of the CCUs that were in full operation and with consistent data over the five year period belong to the Greater Accra Chapter of CUA. A total of 75 affiliated credit unions belonging to the Greater Accra Chapter of CUA was initially included in the dataset. However, 11 credit unions were identified to be affiliated after 2008 and therefore their audited reports were not available, especially between 2008 and 2010, and so they were excluded from the dataset. Additionally, since the study was based on a balanced panel data, 15 credit unions with missing data were also eliminated from the dataset. For example, North Kaneshie Assemblies of God, Calvary Methodist, Jita Community and St. Theresa's credit unions were removed from the dataset because their audited financial report for 2008 and 2010 were not available. Similarly, Accra Metro Teacher and Madina Teachers credit unions have missing data for 2009 and 2010 respectively. More so, Global Evangelical cooperative credit union and CFFC had seized to be members of the CUA, whilst Ghana Co-operative Pharmacists have transferred their membership to the Tema Chapter of CUA and therefore they were also eliminated from the dataset. In all, 49 credit unions had complete data spanning the five year period under study (2008-2012). It was also found that the audited financial reports for the 2013 financial year was either not consistent or unavailable at the time of data collection and therefore it was excluded 2013.

Our final data for the analysis was a complete panel of annual observations on 49 Co-operative Credit Unions over a period of 5 years, making 245 total observations (49×5). The variables extracted from the audit report of the individual credit unions were deposits and operating expenses for inputs, whilst outputs were loans, investments and membership. In order to account for technology heterogeneity induced by different ownership type and for the purpose of technology gap and catch-up analysis, the 49 credit unions are grouped into three clusters, namely, worker (22), parish (18) and community (9) groups (see Appendix A for details). The descriptive statistics of the observed inputs and outputs for the pooled and the groups/clusters are shown in Table 5.

Table 5: Descriptive statistics of input and output variables used in the study (2008-2012)

	Mean	Standard Deviation	Median	Maximum	Minimum
Pooled					
Deposits	554900.63	1272076.69	192110.40	12707007.80	16462.63
Operating Expenses	39277.10	66557.79	14152.16	475811.63	992.07
Membership	710.09	850.24	371.00	4483.00	75.00
Loans	419195.89	1021828.62	111227.96	9785206.55	1684.90
Investments	222787.14	620642.23	55586.32	5744474.89	100.00
Community Group					
Deposits	522530.35	893019.55	172950.90	4549624.68	29549.97
Operating Expenses	42714.48	59491.54	16680.04	296455.71	3696.09
Membership	790.36	1005.18	447.00	4483.00	84
Loans	382293.10	646713.40	96156.83	3167394.00	7022.23
Investments	222787.14	620642.23	55586.32	5744474.89	100.00
Parish Group					
Deposits	176441.01	220437.18	93748.77	1248481.17	16462.63
Operating Expenses	14795.16	21598.86	8377.00	129518.61	992.07
Membership	430.92	373.45	304.50	2591.00	102.00
Loans	105325.33	143670.76	52014.30	928798.96	1684.90
Investments	75661.47	97977.02	44774.05	552974.31	4256.59
Workers Group					
Deposits	877791.8	1742652	387488.5	12707008	17322.37
Operating Expenses	57901.58	85188.87	25676.43	475811.6	1481.5
Membership	905.67	995.43	534.5	4235	75
Loans	691095.70	1412491.00	269720.4	9785207	5874.91
Investments	331435.2	829253.7	74812.08	5744475	100.00

We observed that the mean is quite larger than the median values, among all the variables for both the pooled and the sub-groups. This suggests that the distributions of the variables are skewed to the right, which shows that most credit unions are observed near the left tail of the distribution. This clearly shows that most credit unions have values lower than the average. However, there are also a few large unions that are dragging the mean to its current value. Also, there is a wide dispersion between the minimum and maximum values, suggesting higher levels of variation among the CCUs for all the variables in the dataset. The standard deviation for all the variables is also higher than the mean. This suggests that heterogeneity exists among the CCUs and thus credit unions differ in size.

This is consistent with other studies, like Kontolaimou and Tsekouras (2010) and Oh (2010), which also recorded higher standard deviations compared to the mean values.

More evidence in Table A1 of Appendix A shows the average levels and growth of the variables for the five year period under study. The average annual growth rate in deposit is 44%, whereas operating expenses grew by 37%. NAFTI recorded the highest growth rate of 130%, followed by ARI and St. Charles Lwanga with a growth rate of 100% and 99% respectively in deposit. St. Thomas Moore and Mail Finance however, had the least growth rate of 9% and 8% respectively in deposit. U.G. Legon (GH¢7,421,469.84) had the highest level of deposit, followed by KAMCCU (GH¢2,735,773.55) and IRS (GH¢2311584.73). KPC and GRM had the least levels of deposit by recording (GH¢36,540.52) and (GH¢21,811.81) respectively. In order to address our third objective of the study, a One-Way ANOVA and Kruskal Wallis test was performed to get a much clearer perspective on the differences in the variables across the three CCUs. Table 6 represents the results of both Kruskal Wallis and the one-way ANOVA.

Table 6: Test of differences in the averages of the three CCUs

	ANOVA		**Kruskal Wallis**	
	F-stat	**p-value**	**Chi-square**	**p-value**
Deposits	7.972	0.000	44.245	0.000
Operating Expenses	11.340	0.000	39.847	0.000
Membership	8.448	0.000	10.521	0.005
Loans	8.684	0.000	42.263	0.000
Investments	4.380	0.014	12.710	0.002

The Kruskal-Wallis test showed that there was a statistically significant difference in deposits $(\chi^2 = 44.25, p < 0.001)$, operating expenses $(\chi^2 = 39.85, p < 0.001)$, membership $(\chi^2 = 10.52, p < 0.01)$, loans $(\chi^2 = 42.26, p < 0.001)$ and investment

$(\chi^2 = 12.71, p < 0.01)$. This is corroborated by the results of the ANOVA which also reveals significant differences in the averages of the three CCUs. This shows that there is heterogeneity across the three groups since there are statistically significant differences among them. This also provides ample justification for the metafrontier analysis.

In DEA, it is assumed that an increase in inputs should result in an increase in outputs. This requirement is known as isotonic assumption in DEA. In order to determine and validate this isotonicity property between the inputs and outputs, correlation analysis is used to check relationship between the observed input and output variables. To satisfy this isotonic property, the coefficient derived from the correlation analysis must be positive and significant (Avkiran, 2006), results of which are presented in Table 7.

Table 7: Correlation coefficient of observed inputs and outputs

	Deposits	Operating Expenses	Membership	Loans	Investments
Deposits	1				
Operating Expenses	0.91***	1			
Membership	0.79***	0.85***	1		
Loans	0.90***	0.79***	0.70***	1	
Investments	0.91***	0.81***	0.73***	0.88***	1

*p<0.001****

Table 5.3 shows the correlation between the observed inputs and outputs of the dataset. It can be seen that there is highly significant positive correlation between the observed input and output variables. This is an indication that the isotonicity assumption in the DEA has not been violated and therefore our model fulfills the requirement for DEA estimation.

5.2 Group Technical Efficiency and Meta-technical Efficiency Estimations

The first objective is to estimate the efficiencies of the various CCUs. To achieve this objective, we employed both group technical efficiency and the meta-technical efficiency techniques to compute the efficiency scores of the various CCUs in the respective groups. This also enables us to further compute the differences of the efficiencies in the three groups. Table 8 presents the group-technical efficiency (GE), the meta-technical efficiency (ME) and the technology gap ratio (TGR) of the credit unions estimated. The ME is the efficiency measure of a CCU with respect to the metafrontier. The metafrontier envelops all the CCUs and shows how well a particular CCU is performing relative to all other CCUs in the dataset irrespective of the cluster. The GE is the efficiency scores measured relative the group-specific frontier, which shows how well a specific CCU is performing as compared to members of its own group. The TGR, however, is the technology gap, defined as the ratio between the ME and the GE, showing differences (as a ratio) between the efficiency of a CCU in its own group compared to the pooled set of all CCUs.

Table 8: Efficiency and Technology Gap (2008-2012)

Cluster Name	DMU	Cluster	ME	GE	TGR
Workers	Accra Aca	1	0.366	0.405	0.918
	ARI	1	0.335	0.359	0.935
	Associated	1	0.559	0.560	0.999
	GAG	1	0.952	0.983	0.969
	CSRI	1	0.212	0.223	0.952
	G. Breweries	1	0.444	0.310	0.829
	GAEC	1	0.300	0.314	0.961
	GBC	1	0.485	0.486	0.998
	GRM	1	0.648	0.759	0.849
	GSB	1	0.379	0.393	0.965
	IRS	1	0.710	0.721	0.984
	Lotto	1	0.256	0.270	0.952
	MMW	1	0.254	0.256	0.991
	NAFTI	1	0.278	0.282	0.988
	NVTI	1	0.462	0.610	0.762
	Presec	1	0.429	0.431	0.996
	Prisons	1	0.869	0.871	0.998
	Statistical	1	0.485	0.572	0.8
	T.Ladies	1	0.769	0.775	0.993
	TUC	1	0.205	0.206	0.997
	UG. Ghana	1	0.925	0.957	0.965
	UG.Med.	1	0.708	0.712	0.993
Parish	Accra Chapel	2	0.539	0.895	0.602
	AME	2	0.579	0.800	0.704
	Atico COP	2	0.560	0.888	0.623
	CBC	2	0.486	0.935	0.521
	Christ the King	2	0.952	0.991	0.960
	DCCOP	2	0.486	0.958	0.507
	KPC	2	0.948	0.999	0.949
	MUCC	2	0.800	0.961	0.835
	NFCOP	2	0.730	0.697	0.544
	Queen of Peace	2	0.686	0.993	0.69
	Sacred Heart	2	0.827	0.937	0.878
	SALEM	2	0.403	0.746	0.552
	St. Lwanga	2	0.585	0.754	0.784
	St .M. Mary	2	0.836	0.881	0.949
	St. Pauls	2	0.573	0.968	0.593
	St. T. Moore	2	0.524	0.845	0.602
	Tesano Baptist	2	0.443	0.729	0.619
	Trinity	2	0.375	0.819	0.444

Table 8 Continued.

Cluster Name	DMU	Cluster	ME	GE	TGR
Community	KAMCCU	3	0.971	0.993	0.978
	KMC	3	0.862	0.995	0.866
	Madina Comm.	3	0.641	0.986	0.650
	Mail Finance	3	0.523	0.729	0.692
	North End	3	0.450	0.833	0.540
	PWD	3	0.348	0.633	0.553
	Redemption	3	0.700	0.976	0.718
	Transcea	3	0.560	0.898	0.693
	USAID	3	0.365	0.890	0.371
Average	Workers	1	0.501	0.521	0.945
	Parish	2	0.630	0.833	0.686
	Community	3	0.602	0.881	0.673
	The Pooled		0.567	0.702	0.800

GE and ME represent group efficiency and metafrontier efficiency respectively, while TGR is the technology gap ratio.

The average group-technical efficiency for all (pooled) credit unions is 0.702. This indicates that given input level, the credit unions' on average, need to increase their outputs proportionally by 29.8%, in order to be efficient with respect to their individual group frontier technology. The community-based credit unions had the highest group efficiency score (0.881), while the parish group and the workers cluster recorded efficiency levels of 0.833 and 0.521 respectively, when assessed relative to the group frontier. This means that for the given input vectors, the community group credit unions need to augment their potential outputs by 11.9% in order to be fully efficient with regards to the group frontier technology, while the parish and workers groups need to increase their potential outputs by 16.7% and 47.9% respectively.

The average technical efficiency of the pooled data (all credit unions) is 0.567 with respect to the metafrontier technology. This shows that 56.7% of the credit unions' potential output, suggesting that the credit unions could improve their output levels by 43.3% in order to be efficient, relative to the metafrontier. Interestingly, the pooled ME result from this study is similar to that of Oteng-Abayie, Amanor and Frimpong (2011), who recorded an overall average economic efficiency of 56.29%, from a study conducted on Ghanaian microfinance institutions including CCUs, using SFA. This clearly shows that there is high level of inefficiency in credit union operations and microfinance institutions in general, as the financial structure in Ghana classify credit unions under microfinance institutions.

The average GE results in our study, which ranges between 52% and 88%, is higher as compared to the study by Magali and Pastory (2013) who identified average efficiency scores between 45% and 62% for three groups of Savings and Credit Cooperative Societies (SACCOS) in Tanzania. This shows that on average, the Ghanaian CCUs are performing better than the SACCOS in Tanzania in terms of efficiency. However the results by Magali and Pastory (2013) are the groups technical efficiency score only. Therefore, contrary to their findings this study provides meta-technical efficiency scores between 50% and 63% for the three groups of CCUs. The results from our study can also be compared with Kontolaimou and Tsekouras (2010) who identified average group technical efficiency score of 81% from six EU countries. In the current study, the GE score for parish and community groups is higher than the 81% GE score reported by Kontolaimou and Tsekouras (2010) for Cooperatives. However, the result for the workers group and the pooled are lower compared to Kontolaimou and Tsekouras (2010). Therefore by comparing the pooled result to that of Kontolaimou and Tsekouras (2010) show that the EU cooperatives (81%) are better off than the Ghanaian CCUs (70.2%) in terms of their GE scores. Therefore, the CCUs in the six EU countries are operating on a higher technology with respect to the group-frontier than the Ghanaian CCUs.

On average, the meta-technical efficiency (ME) score for the parish group was 63%, while the community and the workers group recorded 60.2% and 50.1% respectively. The results for the parish group is slightly higher than that of Kontolaimou and Tsekouras (2010), who report meta-technical efficiency scores of 62.3% for cooperative banks in the six EU countries. However, the community group, the workers group and the pooled results of our study are lower. Therefore, on average, the cooperative banks in the six EU countries are again operating on a better meta-technology relative the Ghanaian CCUs.

The current study, however, identified a mix match between the ME and the GE scores for the parish group and the community group. The community group had better efficiency score than the parish group, relative to ME. With regard to GE scores, the parish group out-performed the community group, whereas the workers' group lagged behind at both GE and ME measures. This is not consistent with the study by Glass, McKilllop and Quin (2014), which identified workers' group to be more efficient than the community group.

A critical look at the group-technical efficiency (GE) results show that in the workers' group, CAG had the highest technical efficiency of 0.983, followed by UG. Ghana with a technical efficiency score of 0.957. The worst performers in the workers' group are TUC and CSRI which recorded 0.206 and 0.233, representing 79.4% and 76.7% inefficiency respectively. In the parish group, KPC showed the highest, followed by Christ the King with an average technical efficiency score of 0.999 and 0.991 respectively. On the other hand, we identified Tesano Baptist (0.697) and NFCOP (0.729) as the worst in the parish group. The community group/cluster also showed that KMC had the maximum technical efficiency score of 0.995 with respect to GE, followed by KAMCCU with a technical efficiency score of 0.993. The last performer in the community group is PWD (0.633) and Mail Finance followed by recording a technical efficiency score of 0.729. These results show that on average, there is no credit union showing the maximum efficiency with regards to the GE.

The results in Table 5.4 also show that on average, the metafrontier technical efficiency is lower than the group-technical efficiency scores in all the three different clusters. With regards to the meta-technical efficiency, CAG and UG Ghana credit unions again recorded the highest technical efficiency of 0.952 and 0.925 respectively, whereas TUC (0.205) and CSRI (0.212) also showed the least in the workers' group. In the parish group, even though KPC was the highest in terms of GE score, it was overtaken by Christ the King when it comes to the ME score. Thus Christ the King, on average, shows the highest technical efficiency scores of 0.952, while KPC had 0.948 relative to the ME. Interestingly, the Trinity and SALEM credit unions respectively show the least scores of 0.375 and 0.403 relative to the ME, even though Tesano Baptist and NFCOP show the least with respect to GE in the parish group. The community group again saw KAMCCU as the highest, with and the technical efficiency score of 0.971, followed by KMC, showing technical efficiency score of 0.862. The least performer in the community group is PWD (0.348), while USAID (0.365) took over from Mail Finance as the second least performer with regards to metafrontier technology. We observed that the average technical efficiency is higher when it comes to the GE than in the meta-technical efficiency (ME). Taking a closer look, we identified that among the three clusters, the community group credit unions had a wider dispersion between the GE and ME scores. We identified that no DMU was on the efficient frontier for both the group-frontier and the metafrontier. The overall average meta-technical efficiency (ME) for the pooled credit unions is 0.567, indicating that the entire credit unions need to increase their output by 43.3% in order to be efficient, relative to the meta-technology, given their current input levels.

The gap between the group-technical efficiency (GE) and the meta-technical efficiency (ME) is the technology gap ratio (TGR). The technology gap shows how far the group-frontier is from the meta-frontier. A technology gap of one (1) indicates that both the group-frontier and the meta-frontier are the same and that the DMU in question is for the best or maximum efficiency frontier. The technology gap ratio for the pooled sample is 0.800. The gap between the group-technical efficiency (0.521) and the meta-technical efficiency (0.501) in the workers' group is the smallest level among the three credit union groups, and shows a technology gap of 0.945. However, the technology gap for the parish and community groups show 0.686 and 0.673 respectively, while the pooled recorded TGR of 0.800. These analyses interestingly suggest that the frontier of the group-technical efficiency of the workers group is much closer to the metafrontier than that of the parish and the community groups. These therefore supports our proposition that there are technological gaps among the groups of credit unions in Ghana. Moreover, no credit union shows a comparative advantage in any of the groups since their technology gap ratios are less than unity (1).

The graph in Figure 5 shows the five year average (2008-2012) estimations for the ME, GE and the TGR in their respective clusters or groups and the pooled. We observed that the workers' group GE and ME scores are close to each other, while the community group shows a wider distance between the GE and ME, relative to the overall average (pooled mean).

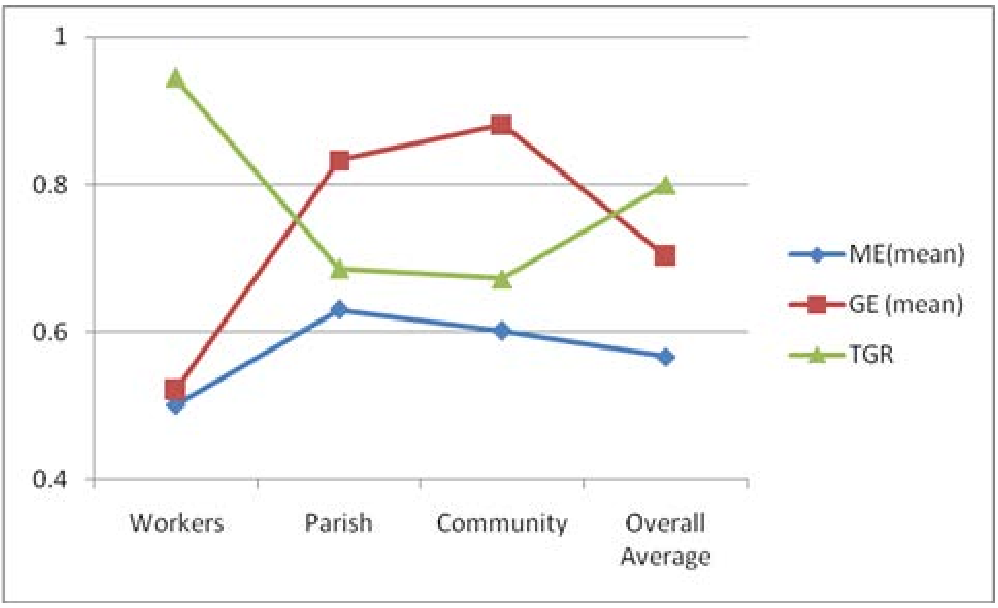

Figure 5: Average Meta-technical and Group-technical Efficiency and Technology Gap Ratio

However, it can be noticed that the technology gap ratios (TGR) for the workers' group drives the metafrontier, compared to the TGRs for the parish and community group. This is because the TGR for the workers' cluster is closer to 1.00, while the TGR for the community and parish groups are slightly below 0.70.

In order to further analyse the differences in the efficiency scores within the three clusters, the average GE and ME scores obtained from the study was plotted using kernel density estimator in R Software. Figure 5.2 and 5.3 shows the density plotted for the GE and ME scores for the three groups of CCUs in the study.

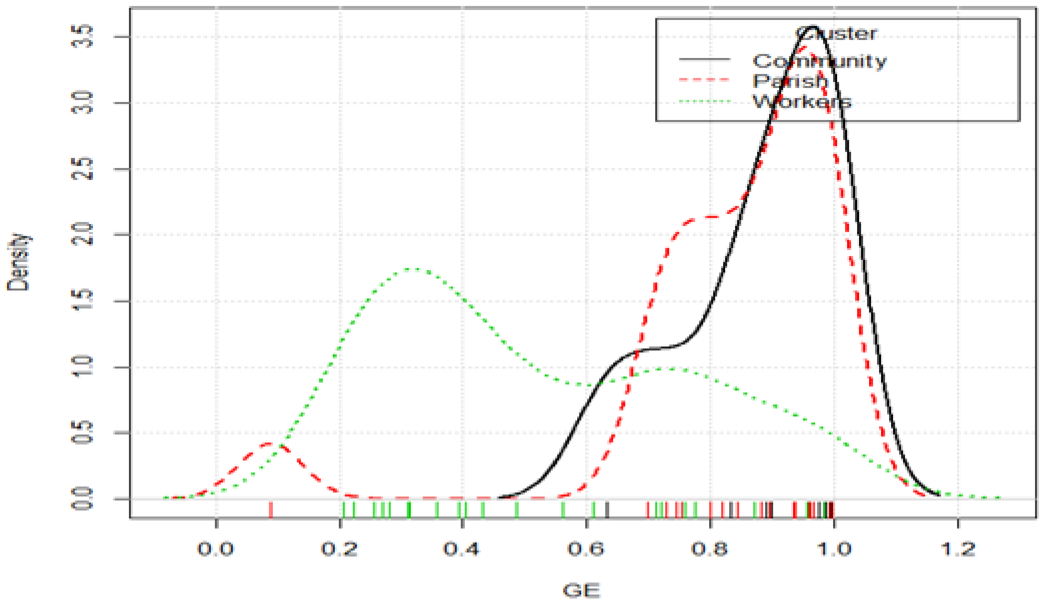

Figure 6: Kernel density plot based on GE scores

The kernel density plot in Figure 6 shows evidence of multi-modality patterns across the three groups with respect to the GE scores. This therefore indicates that the GE score are not normally distributed across the groups. The kernel density plot for the workers' group-frontier has bimodal peak, with the first peak around 0.3 and the second peak at around 0.77. The community group also has bi-modal peak. Unlike the workers' group, the first peak for the workers' group is around 0.7. However, the second peak for the community coincides with the third peak for the parish group at around 0.98. The density plot also shows evidence of multi-modality for the parish group with three peaks. As noted, the third peak is at the same level with the second peak for the community group, while the first and the second peaks are located at 0.1 and 0.78 respectively. Therefore, the distribution of the GE scores is not normal across the groups. There is clear evidence from these analyses that the workers' group did not perform well over the study period. Comparatively, the parish and the community group performed better than the workers' group as their highest peaks converge around 0.98, whereas 0.3 is the highest peak in the workers' group. Moreover, the community group relatively, performed better than the parish group, since their lowest peak is located at 0.1 and 0.7 respectively.

Figure 7 shows the kernel density plot of the metafrontier efficiency scores for the three clusters in the study.

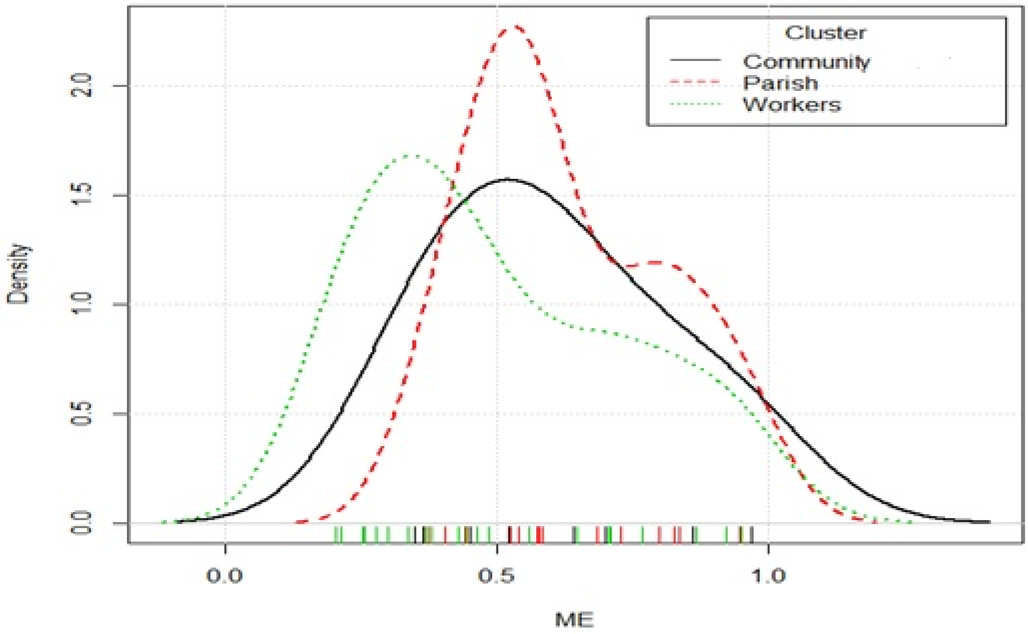

Figure 7: Kernel density plot based on ME scores

The kernel density plot for the community group-frontier is uni-modal, showing that their ME scores are normally distributed and peaks at 0.6. However, the workers' and the parish groups had bi-modal kernel density, indicating that their ME scores are not normally distributed. The first peak of the workers' group is located around 0.35, while that of the parish group peaks at 0.6. The second peaks are, however seen around ME score of 0.8

and 0.7 respectively, for the parish and the workers' group. The plot shows evidence that most of the ME scores within the workers' and the parish groups are respectively located around 0.6 and 0.35 for the parish and the workers group. These therefore suggest that the parish group and the community group performed relatively better than the workers group, when assessed with respect to the metafrontier. This analysis clearly shows that group heterogeneity exists among the CCUs in Ghana. Therefore, these analyses address research question 1, which seeks to find the overall efficiency of the subgroups of CCUs in our study and to show their differences.

5.3 Group-Malmquist and Metafrontier-Malmquist Productivity Indices and Decompositions

Table 9 presents a summary of the GMPI and MMPI and its decomposition and catch-up effects for the study period 2008-2012. The purpose of this is to answer our research question two and three, which seeks to find productivity change as well as the drivers of change among the three clusters of CCUs under investigation and to investigate whether group differences affect productivity. Note that the summary presented here is the geometric mean for the five year period studied. The last column of Table 9 represents the catch-up/lag effect for each group/cluster of credit unions. The details of the GMPI and MMPI and its decomposition and catch-up/lag effects with respect to the three credit union groups can be found in Appendix A3 to A5.

Table 9: GMPI and MMPI decomposition into TEC and TC with catch-up effect for the 3 clusters.

Cluster	TEC^k	TC^k	$GMPI$	TEC^m	TC^m	$MMPI$	$\frac{TEC^m}{TEC^k}$	$\frac{TC^m}{TC^k}$	$\frac{MMPI}{GMPI}$ $(TGRC)$
Workers	1.035	0.918	0.950	1.072	0.910	0.976	1.035	0.992	1.027
Parish	0.979	1.037	1.015	1.021	0.914	0.933	1.043	0.881	0.919
Community	1.035	0.850	0.879	1.005	0.924	0.928	0.971	1.087	1.056
Whole Sample	**1.014**	**0.960**	**0.974**	**1.036**	**0.911**	**0.943**	**1.021**	**0.949**	**0.968**

TEC^k - Group-technical efficiency change - TEC^m TC^m - Metafrontier technical efficiency change

TC_k - Group-technology change TC^m - Metafrontier technology change

MMPI - Group-frontier Malmquist productivity *GMPI*- Metafrontier Malmquist productivity

On average, the pooled sample shows that the credit unions decline in productivity by 2.6% relative to the GMPI and 5.7% with respect to the MMPI. This is slightly higher than the study by Worthington, (1999) who reported a productivity regress of 2.14% in Australian credit unions.

Table 9 also shows the Metafrontier Malmquist productivity index and its decomposition for the three groups to account for the group heterogeneity. With regards to the metafrontier Malmquist productivity Index, the average productivity for the parish group is slightly higher (0.943) than that of the community group (0.923) while the workers group showed the highest MMPI of 0.976. This suggests that on the average, the workers' group, the parish group, and the community group deteriorated in productivity growth by 2.4%, 6.7% and 7.2% respectively. The average productivity for the whole sample was 0.943, representing a productivity decline of 5.7%.

Table 9 shows that the productivity of the parish group is 1.015 with respect to the group frontier, which indicates 1.5% productivity improvement. Relatively, the productivity change for the workers and the community groups is 0.950 and 0.879, representing a decline of 5% and 12% respectively. The community and the workers' group also recorded low productivity in the group frontier measures than the entire credit unions, which had an index of 0.974, representing a 2.6% decline.

5.3.1 Sources of Group Malmquist and Metafrontier Malmquist Productivity Change

In order to account for the sources or drivers of productivity change, the GMPI and the MMPI is decomposed into Technical Efficiency Change (TEC) and Technical Change (TC). For the GMPI decomposition, the workers and the community groups had TEC of 1.035. However, the TC for the workers and community groups is 0.918 and 0.850 respectively. The differences in the TC for the workers and the community groups suggests that the workers group are making a conscious effort to improve on their technological innovative strategies to become productive, while the community group are lagging on innovation. On the contrary, the TEC and the TC for the parish group is 0.979 and 1.037 respectively. These indicate that whereas the sources of productivity growth for the parish cluster is due to technical change (TC), the productivity decline for the workers and the community credit unions is attributed to technical change (TC). This therefore suggests that the CCUs in the parish group have comparative advantage in technological innovation over their workers and community counterparts. Also the productivity regress for the entire credit unions can be attributed to technical change.

As indicated earlier, the MMPI can also be decomposed into technical efficiency change (TEC) and technical change (TC) and the technology gap ratio change (TGRC) to account for sources of productivity growth or decline. To account for the sources of productivity or decline, we compared the TEC and TC values with respect to the metafrontier. We observed that parish group/cluster had a TEC and TC value of 1.021 and 0.914 respectively. Therefore the parish credit unions productivity decline with respect to the metafrontier frontier is attributed to technical change (TC). Similarly, the decline in productivity with respect to the metafrontier for both the community and workers clusters is due the fact that they suffered technical innovation (technical change) as evident from their TEC and TC scores. The drivers of productivity decline of the parish group is not consistent with the GMPI measure which attributed productivity progress to TC. This suggests that some sort of bias may exist when groups are assessed differently without considering the metafrontier.

We also noted that the entire credit unions regress in productivity is attributed to technological change. One important point worth noting is that the workers and community clusters were regressed relative to the metafrontier and the group frontier. However, the evidence is mixed for the parish cluster because its sources of productivity growth with respect to the group frontier and productivity regress relative to the metafrontier are all attributed to technical change (TC). The results from Table 9 also show that TEC for the parish group (1.021) and the community group (1.005) was lower than that of the pooled sample. Comparatively, the workers group had the highest TEC with an index of 1.072. Further, we observed that there is no significant difference between the technical change in the parish group (0.914), the workers group (0.910) and the whole sample (0.911). The technical change for the community group (0.924) is slightly higher compared to the parish and workers group.

When the TEC is larger with respect to the metafrontier than the group frontier, then the technology gap ratio (TGR) has increased. Considering the decomposition of the MMPI in Table 9, it was observed that the workers' group and the parish group show advancement in technical efficiency change with respect to the metafrontier technology than their respective group frontiers during the study period. Contrary to this, the community group had higher TEC value with respect to the group frontier than the metafrontier. This therefore suggests that on average, the community credit unions have been narrowing the gap with the global technology whilst the parish and workers' group credit unions widening the gap with the global technology. The technical change of the pooled sample shows an overall index value of 1.036 with respect to the meta-technology and 1.014 relative to the group frontier, suggesting a widening gap with the global technology.

The last term in Table 9 is the technology gap ratio change (TGRC), which captures the catch-up or lag effect in MMPI estimations. The TGRC is further decomposed into the technical efficiency change ratio and technical change ratio is shown in the third and the second column from the right hand side of Table 9 respectively. The technical efficiency change ratio is also called pure technological catch-up (PTCU) because it captures the catch-up in technology without the components of technical inefficiency from the group frontier's point of view. A value of PTCU greater than 1 means a decrease in the technology gap. On the other hand, the technical change ratio, also known and the frontier catch-up (FCU) capture the velocity of change between the metafrontier and the group frontier. A value of FCU less than 1 is an indication that the whole band of the technology gap had reduced (i.e. an increase in the whole set of TGR). From Table 9, we observed the parish and workers experienced shrinkage with the credit unions' technology under both PTCU and FCU. This indicates that the workers' group and the parish group are moving at a faster rate than the metafrontier.

These differences in group performance may be due to the governance and operational structures being implemented by the groups. The parish group, for example, enjoys a competitive advantage over the community and workers groups. This is because, unlike the workers and community groups which employ personnel and also rent or build offices for their operations, most of the offices for the parish groups are donated by the church and also they use voluntary personnel for their operation. This competitive advantage may have impacted positively on the performance of parish group CCUs. Unlike the community and parish groups which may have a large proportion of unemployed members, the workers group have some comparative advantage because the majority of their members are in salaried employment and therefore operate direct payroll deduction for savings and loan repayment plan. Although the workers group enjoys this advantage more than their counterparts, they were found to be less efficient relative to the community and the parish groups. Therefore, the inefficiencies of the workers group may be due to high operating expenses for salaries of their personnel are comparatively tagged to the workers' salary scale. Also the community CCUs performed better than the workers group probably because of sound managerial practices that impact positively on operating expenses.

The pattern of annual average MMPI and GMPI and its decomposition over the five year period are shown in Figure 8a and 8b.

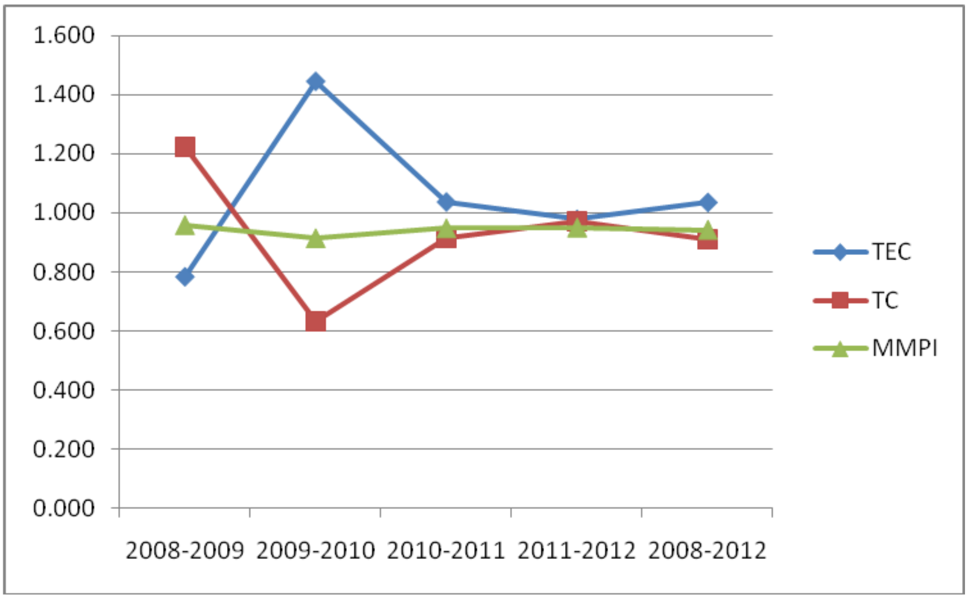

Figure 8a: The TEC and Technical Chan relative to the MMPI (2008-2012)

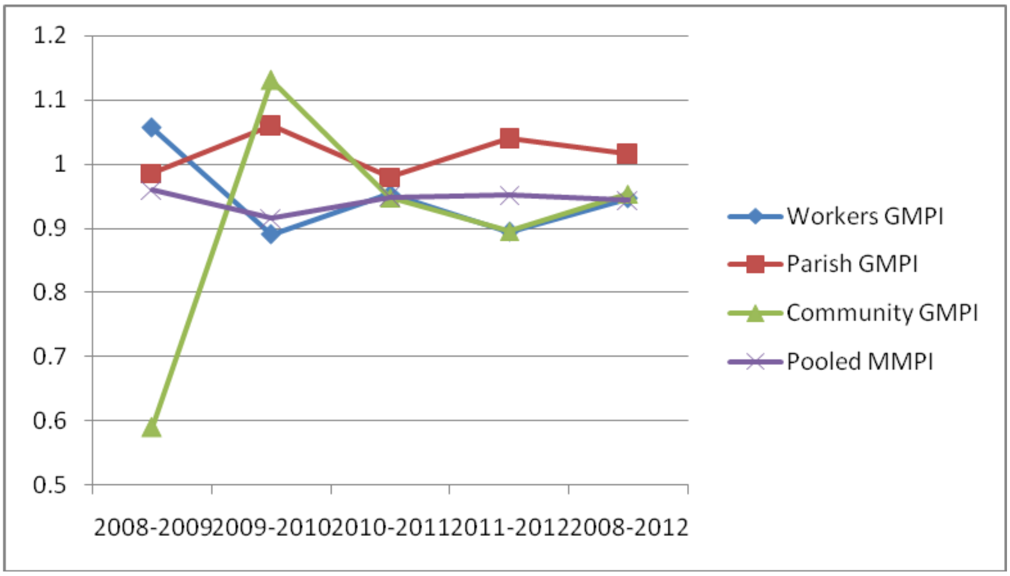

Figure 8b: Annual Credit Unions GMPI (2008-2012)

Figure 8a shows the trend of the pooled annual metafrontier malmquist productivity growth, whereas Figure 8b represents the annual trend of productivity growth measured relative to the GMPI and the MMPI, over the period 2008-2012.

The trend in Figure 8a shows that on average, the productivity decline for the pooled sample is due to technical change. Figure 8b shows that the workers group and the community group specific-frontiers' productivity growth indexes almost coincided with the pooled MMPI during the period 2010-2011, with an average productivity score of about 0.950. During this period, the productivity growth index for the parish group frontier was slightly higher (about 0.98) comparing to the pooled, the community and workers' group-specific frontiers. This shows that all the metafrontier and the three groups-specific frontiers declined in productivity within their respective frontiers. During the period 2008-2009, the parish group frontier moved closer to the pooled (metafrontier), showing a productivity decline of about 1.5% and 4.1respectively. However, the workers' group shows a productivity progress of about 5.6%, whereas the community group shows a productivity regress of about 41% during the period 2008-2009. Surprisingly, the community group frontier saw a sharp progress in productivity over the period 2009-2010, by showing an improvement of about 13.1%. The trend of productivity also indicates that community group and the workers' group coincided during the period 2011-2012, showing a productivity regress of 10.6% and 10.5% respectively.

The period 2011-2012 also saw the parish group frontier, showing a productivity advancement of about 3.9%, while the MMPI (pooled) declined by 4.9%. On average, the workers and the community group-specific frontiers almost coincided with the metafrontier technology over the period 2008-2012, with a productivity decline of about 5.4%, 4.7% and 5.7% respectively. The parish group frontier, however, shows productivity gain of about 1.5% over the period 2008-2012. The revelation from the productivity growth/decline supports the assertion that the three groups are operating on separate frontier. The evidence of the trend of technical efficiency change and technical change shown in Figure 9a and 9b also confirm that the three groups are operating under different technologies.

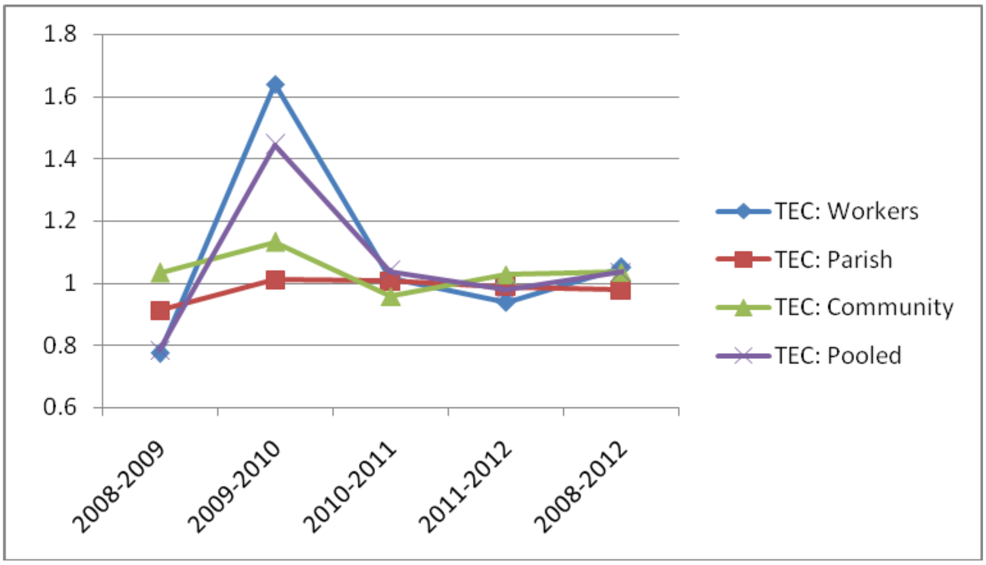

Figure 9a: Annual Credit Unions' TEC Pattern by Group (2008-2012)

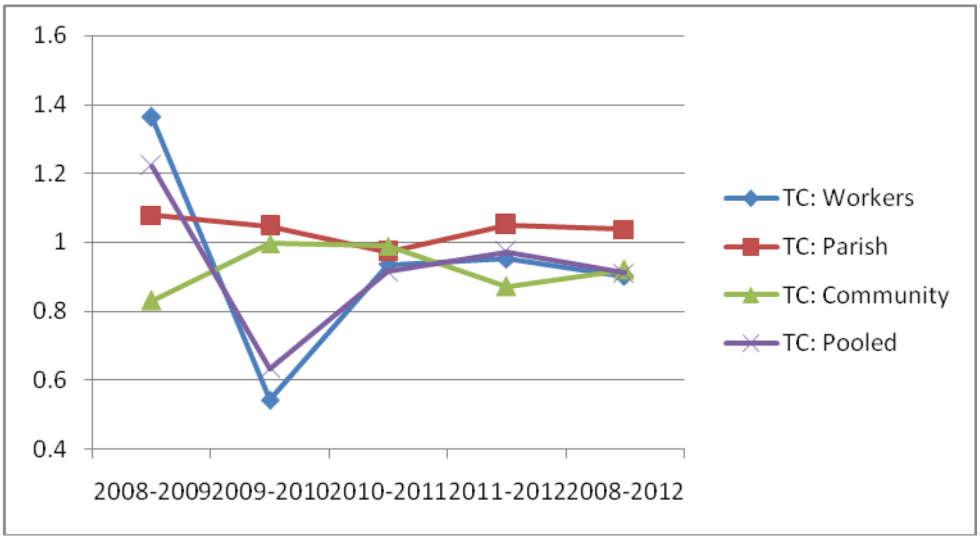

Figure 9b: Annual Credit Unions' TC Pattern by Group (2008-2012)

Figures 9a and 9b respectively shows the trend of the technical Efficiency Change and Technical Change components of the group-specific frontiers and the Metafrontier, over the period 2008-2012. The graphs show that the sources of productivity decline in the community and workers group frontiers are attributed to technical change rather than technical efficiency change. The regress in productivity under the metafrontier technology (pooled) is also attributed to technical change rather than technical efficiency change. However, the parish group frontier's productivity improvement over the five year period under study is attributed to technical change rather than technical efficiency change.

Table 10 shows the summary results of the group-Malmquist productivity change index (GMPI) and the meta-Malmquist productivity change index (MMPI) innovators for the three different groups/clusters. Thus the table shows the total number of credit unions that experienced productivity progress, under their respective group-frontier and the Metafrontier and their percentages. All the estimates are based on the geometric mean covering the five-year period under study. Interestingly, 10 out of 18 DMUs, i.e. Accra Chapel (9.2%), CBC (20.6%), Christ the King (13.8), DCOP (2.5%), KPC (3.8%), MUCC (2.3%), Queen of Peace (15.6%), St. M. Mary (1.7%), Tesano Baptist (3.6%) and Trinity (4.6%) experienced productivity progress when assessed relative to the parish group-frontier. However, only 3 DMUs i.e. Christ the King (17.2%), Queen of Peace (1.2%) and Trinity (0.8%) showed productivity progress with respect to the metafrontier Malmquist technology.

The geometric mean for the five year period under study shows that 14 Credit Unions, representing 28.6% of the data set experienced Metafrontier Malmquist productivity progress. Thus, these 14 credit unions had a geometric mean greater than 1.00. Among the

14 credit unions that experienced productivity progress with respect to the metafrontier technology, 9 belong to the workers cluster. These are GRM (1.425), ARI (1.001), CSRI (1.044), GSB (1.004), IRS (1.035), NAFTI (1.028), NVTI (1.072), TUC (1.002), and U G Legon (1.255).

Table 10: Metafrontier and Group-frontier Productivity Gain Ranking (2008-2012)

Group	Number on GMPI	Percentage (%)	Number on MMPI	Percentage (%)
Workers (n=22)	7	31.8	9	40.9
Parish (n=18)	7	38.9	4	18.1
Community (n=9)	4	44.4	1	11.1
All (n=49)	18	36.7	14	28.6

Source: Authors

Interestingly, only one credit union, PWD (1.060), belong to the community group, with the remaining four credit unions Christ the King (1.172), Queen of Peace (1.012), Trinity Church (1.008) and SALEM (1.000) affiliated with the parish group. SALEM however stagnated for the five year period. Also, the credit union that shows the highest productivity is GRM, recording a productivity progress of 42.5%, whereas ARI had the least productivity progress of 1%.

A total of 18 credit unions shows productivity progress relative to the group-frontier technology. Although 9 credit unions in the workers' group progressed with respect to the Metafrontier, 7 show productivity improvement when assessed against the group-frontier. The 7 credit unions are Associated (1.015), GBC (1.042), Lotto (1.272), NVTI (1.038), NAFTI (1.206) Presec (1.017) and Statistical (1.335). The parish group frontier also saw 5 members being productive, with 2 stagnant members. Those that experienced progress in the parish group are St. M. Mary (1.017), St. Pauls (1.036), St. T. Moore (1.046), Tesano Baptist (1.068) and NFCOP (1.319), while Trinity (1.000) and Christ the King (1.000) stagnated over the five year period. Although only 1 credit unions in the community group progressed, relative to the metafrontier, 4 credit unions in this group i.e. KMC (1.125), Mail Fin. (1.092), North End (1.025), and PWD (1.156) shows progress with respect to the group-frontier. These unfolding results suggest that, on average, the community group is more distanced from the metafrontier than the parish and workers' group. This revelation is also depicted in the graph in Figure 8a.

The kernel density plots show the differences in productivity patterns across the three groups of the CCUs estimated with respect to the group frontier and the metafrontier.

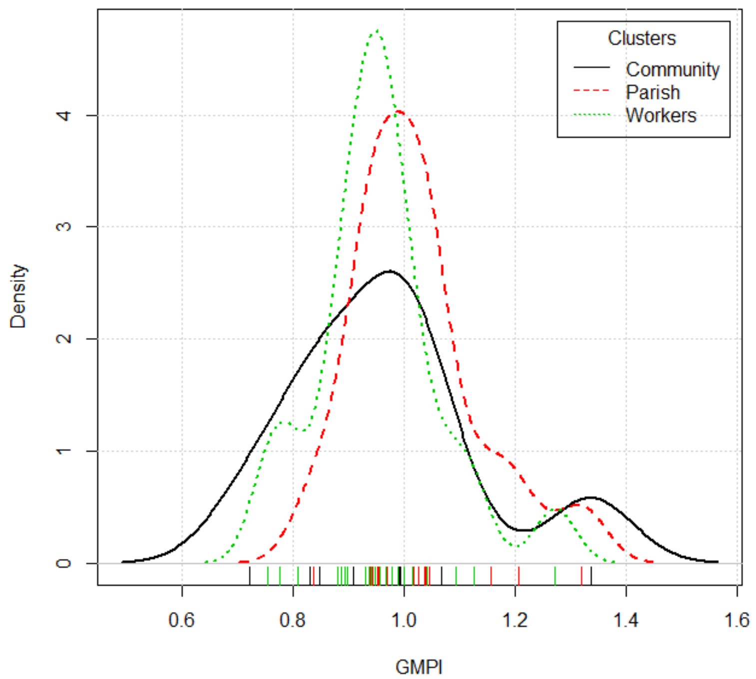

Figure 10: The GMPI Kernel Density graph for the three Clusters

Figure 10 shows the kernel density graph for the GMPI results obtained from the three clusters in the study. The graph show in evidence of multi-modality and therefore the GMPI results from this study are not normally distributed across the three groups. The GMPI distribution of the community cluster is bimodal with the first mode peaking around 0.95 and the second peak located around 1.3. The graph also shows that the GMPI for most of the CCUs in the community cluster are distributed between 0.8 to 1.1, with a few CCUs located above 1.1 productivity level. The distribution of the GMPI for the CCUs in the parish and workers cluster did not show much difference. However, the kernel density graph for the workers' cluster show evidence of multi-modality, with the second peak at 0.95 being the highest and the first and the last peak located around 0.75 and 1.25 respectively. The parish group has a bimodal density graph with the GMPI for most of the CCUs, located within the first peak at about 0.98 and few CCUs located within the second peak at about 1.3. These analyses obviously show that the parish group had better GMPI results compared to the community and workers cluster. Comparatively the workers cluster also outperformed the community group as depicted in the graph.

Alternatively, the kernel density graph for the MMPI results obtained from the three clusters in the study is shown in Figure 11.

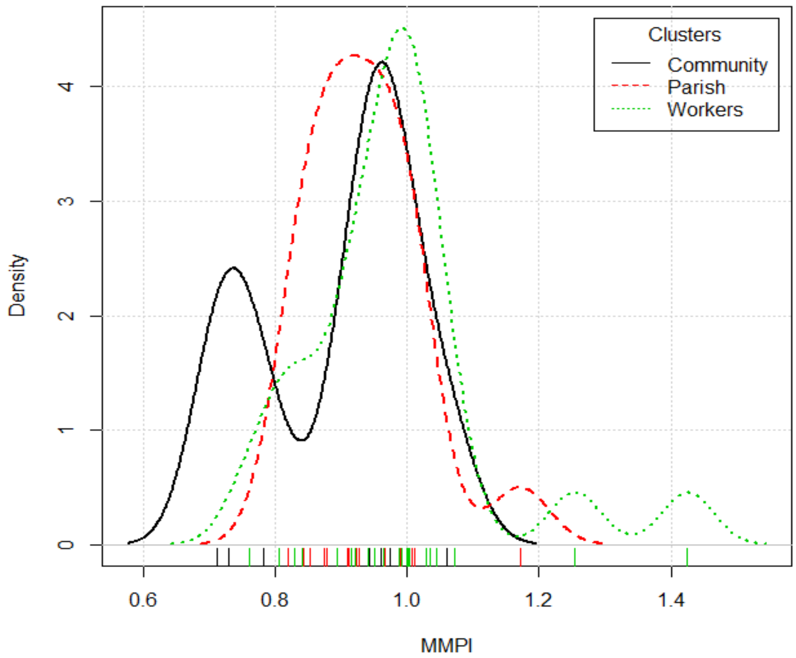

Figure 11: The MMPI Kernel Density plots for the Three Groups

The kernel density plots for the community group-frontier is bimodal and shows that most of the CCUs in this cluster had MMPI scores of about 0.6, where the second peaks is located. However, the workers' and the parish groups had bi-modal kernel density, indicating that their ME scores are not normally distributed. The first peak for the workers' group is located around 0.35, while that of the parish group peaks at 0.6. However, the second peak is seen around ME score of 0.8 and 0.7 respectively, for the parish and the workers groups respectively. The plot shows evidence that most of the ME scores within the workers' and the parish groups are respectively located around 0.6 and 0.35 for the parish and the workers' group. These therefore suggest that the parish group and the community group performed relatively better than the workers' group, when assessed with respect to the metafrontier.

CHAPTER SIX

SUMMARY, CONCLUSION AND POLICY DIRECTIONS

6.0 Introduction

The primary aim of this study is to assess the technical efficiency and productivity of cooperative credit unions in Ghana. This chapter provides the summary of the findings of the study. The chapter is organised into four sections. The summary of the main findings of the study is discussed in Section 6.1. Section 6.2 discusses the policy directions derived from the study, while Section 6.3 gives the limitations of this research and some future directions, while Section 6.4 provides conclusion for the study.

6.1 Summary of the Findings

Credit unions are financial cooperatives, which seek to provide services that liberate its member from financial and socioeconomic constraints, especially those under the bottom of the economic pyramid, through micro savings and lending. The credit unions have gone through several transformations over the years and currently face direct competition in market shares due to the influx of microfinance institutions. These developments make it imperative for credit unions to assess their operational activities and identify sources of improvement to keep them in this current competition. Therefore, this research aims to assess the technical efficiency and productivity growth of cooperative credit unions in Ghana.

Credit unions in Ghana are organised under a bond of cooperation and that, bond structure may have an impact on credit unions productivity measures. Three bond structures were identified in Ghanaian cooperative credit unions. These are workers, community and parish groups of credit unions. To account for the characteristics of group inequality or heterogeneity in credit union operations, a rigorous methodological consideration is needed. In this regard, this thesis first adopted DEA-based metafrontier concept as a means for accurately assessing the efficiency of credit unions in this context. The motivation for choosing this methodology is mainly because all the three groups of credit unions face a potentially common metafrontier irrespective of the natural boundary or geographical limitation that would bind them to a group-specific frontier. In order to show how these credit unions have performed over time and identify sources of improvement, the study employed a dynamic DEAmetafrontier framework also known as metafrontier malmquist productivity indexes. This framework further decomposes the technical efficiency change and technical change components in normal MPI into a pure technical catch-up (PTCU) and frontier catch-up (FCU) in order to account for the catch-up effect.

A total of 49 credit unions from the three groups/clusters is assessed, using data from credit unions audited financial report covering 2008-2012. Findings from the study shows mixed results between the two methodologies employed. The metafrontier analysis shows an average group technical efficiency (GE) score of 70.2% and average meta-technical efficiency of 56.7%. These results clearly show that differences exist between the metafrontier and the group-frontiers. Zeroing it down to the group-specific frontiers and the metafrontier, the community group recorded the highest group-technical efficiency of 88.1%, while the parish and workers' group credit unions followed with the average GE score of 83.3% and 52.1% respectively. However, the parish group outclassed the community and workers' groups when levels of efficiency are assessed relative to the metafrontier. The average meta-technical efficiency for the parish group and community group is 63.3% and 60.2% respectively. However, mean efficiency levels of the workers group is particularly low under both GE and ME. In all indications, the metafrontier score is lower than the group frontier score.

In addition to the empirical analyses of the metafrontier technical efficiency, we empirically investigated the credit unions productivity changes and meta-productivity changes of the 49 credit unions for year 2008 through 2012. The findings from our metafrontier Malmquist productivity growth of the credit unions provided the following information: Firstly, regarding the metafrontier productivity, the workers' group rather show the highest level of productivity among the three groups, even though all the three groups declined in productivity. With respect to the group-frontier, the parish group is the only group that show productivity progress, while the other groups declined.

Secondly, evidence from the study shows the sources of productivity growth and regress as follows: The parish group's productivity gain with regards to the group-frontier is attributed to technical change rather than technical efficiency change. Moreover, the productivity regress in the parish group, with respect to the metafrontier is also due to technical change. Also the productivity decline for both the community and workers' groups, with respect to the two technologies is attributed to technical change.

Thirdly, the pure technological catch-up (PTCU) effect shows that the workers' group and the parish group are shrinking the technology gap between the metafrontier and the group frontier, whereas the community group is increasing the technology gap. Interestingly, the frontier catch-up (FCU) effect also shows that the workers' group and the parish group are experiencing an upward shift in the group frontier at a faster rate than the metafrontier. This is an indication that again the parish and workers' groups are shrinking the whole band of technology.

6. 2 Policy Directions

The evidence from this study show that the credit unions are not operating at the level of the best practice frontier. All the three groups showed a decline productivity with respect to the metafrontier/best practice technology during the full period of study. This suggests that there is significant room for improvement in terms of technological advancement. Refering to Table 8, the CCUs on average need to increase their outputs proportionally by 29.8%, in order to be efficient with respect to the group frontier technology. The community group CCUs had the highest group efficiency score of 0.881, while the parish group and the workers groups recorded score of 0.833 and 0.521 respectively, when assessed relative to their group frontiers. This means that for the given input vectors, the community group CCUs need to augment their potential outputs by 11.9% in order to be fully efficient with regards to the group frontier technology, while the parish and workers' groups need to increase their potential outputs by 16.7% and 47.9% respectively. However, the metafrontier estimation shows that the parish group need to augment their potential outputs by 37%, while the community and the parish groups could potentially increase their output by almost 40% and 50% respectively.

The estimated results and the gaps between group frontiers and the metafrontier, under both static and dynamic settings could be used to design programmes that will help the CCUs to improve upon their performance. For example, some CCUs were seen to be performing creditably within their own frontier, but at times, they performed badly when assessed against the meta-technology. In this regard, the CCUs are not using the right input mix to produce their current levels of output. Therefore, the CCUs policy makers, specifically CUA should concentrate more on efficiency measure that captures group differentials.

In order to keep the CCUs in the current competition in the financial market, CUA should develop measures that would improve upon the usage of input resources, especially operating expenses to make the CCUs more productive. This may include measures to equip the CCUs with the necessary infrastructure and human capital development, through government social support.

This study also shows an important revelation worth mentioning, when we compared the two methodologies employed in the study, i.e. the metafrontier and the MMPI. The community group is identified as the best group under the metafrontier technical efficiency estimation, but when assessed under metafrontier Malmquist technology; the community group shows the highest level of productivity decline. This suggests that static efficiency analysis shields certain characteristics and therefore does not reflect the true measure of productivity improvement. Therefore, managers should keep more focus on assessing their operational efficiency in dynamic settings rather than depending on window analysis or static efficiency measures for improvement.

6.3 Limitations of the Research

This research adopted a DEA-based metafrontier Malmquist productivity index in assessing the efficiency and productivity of the three groups of cooperative credit unions in Ghana. The study focused only on credit unions in Greater Accra Region due to data availability and credit unions concentration. Therefore, this research can be extended in a regional context to assess regional differences and their effect on efficiency and productivity of credit unions in Ghana. Another important issue to note is that since members of the credit unions are not required to bring collaterals in accessing loans, some members tend to be delinquent in paying back loans, which in effect put more pressure on the credit union managers. Therefore, researchers are directed to incorporate other models like bad outputs to analyse how the credit unions are performing by augmenting good outputs and decreasing bad outputs.

5.4 Conclusion

This study successfully implemented the DEA-based metafrontier malmquist productivity index in assessing credit unions in Ghana. The study accounted for the heterogeneous effect on efficiency and productivity estimations and showed that indeed group heterogeneity exist among the three groups of CCUs in Ghana. The study identified various levels of inefficiencies and productivity regress among the credit union groups. The sources of productivity regress are clearly identified, as well as their catch-up effects. The ensuing results clearly support that different operating environment exists in the credit union groups and that these environmental differences have effect on credit union operations. Therefore the objectives of this study, which seeks to identify the levels of efficiency and productivity of credit unions as well as sources of productivity progress or regress, have been met. Based on these research results, we have addressed some policy considerations for credit unions performance improvement.

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APPENDIX

Table A1: Average levels and growth rates of input and output variables of credit unions under study period 2008-2012

Name of DMU	Deposits(GH¢) Average	Growth	Operating Expenses (GH¢) Average	Growth	Membership Average	Growth	Loans (GH¢) Average	Growth	Investments (GH¢) Average	Growth
Accra Chapel	57157.54	0.61	2070.19	0.44	155	0.84	31148.47	0.57	28647.17	0.45
AME	132481.95	0.25	10632.40	0.24	375	1.02	81005.14	0.44	46326.34	0.14
Atico COP	88644.66	0.16	7270.91	0.10	255	0.76	67562.24	0.25	48437.94	0.18
CBC	635544.00	0.30	70580.52	0.24	1007	0.95	411104.37	0.42	210182.87	0.19
Christ the King	80259.23	0.28	2401.56	0.49	390	0.54	26886.03	0.10	51257.23	0.21
DCCOP	338771.42	0.25	30721.39	0.25	651	0.81	264963.20	0.29	121425.43	0.25
KPC	36540.52	0.41	1798.97	0.59	232	0.39	19591.56	0.43	21651.76	0.41
MUCC	77463.58	0.17	9818.53	0.07	370	0.30	30889.71	0.19	51368.96	0.20
NFCOP	82059.21	0.26	8815.22	0.25	169	0.53	44732.52	0.67	45421.60	0.10
Queen of Peace	706895.98	0.32	48144.29	0.18	1445	0.38	366421.51	0.21	361621.67	0.49
Sacred Heart	231307.91	0.78	9353.89	0.27	872	1.18	108302.35	1.57	44027.28	0.30
SALEM	179562.12	0.55	14122.80	0.57	371	0.93	117878.24	0.89	60148.54	0.05
St C Lwanga	77186.93	0.99	7289.38	1.71	283	1.50	42976.95	1.25	33660.23	0.77
St M Mary	43928.99	0.58	6577.73	0.57	268	0.86	20099.06	0.84	14150.04	0.86
St Paul's	107701.86	0.14	10276.07	0.17	299	0.43	24466.96	0.05	93904.36	0.22
St Thomas Moore	108792.95	0.09	7749.39	0.06	260	0.44	68244.94	0.01	52670.62	0.20
Tesano Baptist	88680.09	0.24	8604.14	0.65	209	0.62	55410.91	0.28	45099.08	0.20
Trinity Church	102959.27	0.18	10085.44	0.13	146	0.53	114171.68	0.13	31905.41	0.41
Name of DMU	Deposits(GH¢) Average	Growth	Operating Expenses (GH¢) Average	Growth	Membership Average	Growth	Loans (GH¢) Average	Growth	Investments (GH¢) Average	Growth
Accra Aca	372244.05	0.29	32735.87	0.11	548	0.62	298881.30	0.40	76728.29	0.11
ARI	550586.32	1.00	41325.57	0.23	635	0.73	348614.33	0.37	43998.61	0.61
Associated	592369.87	0.24	73837.43	0.35	1122	0.76	642074.07	0.58	111128.90	0.23
CAG	1727860.76	0.39	154432.01	0.19	2952	0.97	439097.76	0.80	1276534.17	0.34
CSRI	309673.28	0.56	22537.17	0.61	219	1.09	160485.38	0.43	150902.32	0.22
GAEC	370077.07	0.36	28881.37	0.37	446	0.79	242491.98	0.31	84171.92	0.69
G Breweries	536416.89	0.24	7978.98	0.26	277	0.66	515561.94	0.25	63615.38	0.20
GBC	975176.79	0.39	131008.47	0.25	1238	0.79	506458.99	0.27	141936.65	0.53
GRM	21811.81	0.78	2715.17	0.64	108	1.22	97758.66	1.62	108596.58	0.46
GSB	995249.02	0.37	56075.26	0.23	838	0.37	891938.09	0.35	380700.94	0.36
IRS	2311584.73	0.12	146775.53	0.08	2155	0.26	2120786.00	0.04	681330.59	0.37
Lotto	273750.58	0.56	25631.17	0.24	225	1.10	101502.88	1.03	188069.04	0.36
MMW	67610.10	0.77	6391.36	0.44	96	1.00	58710.03	0.71	67138.13	0.55
NAFTI	82818.91	1.30	14112.53	1.04	135	1.15	25864.00	1.90	64102.11	0.95
NVTI	372331.18	0.63	13097.52	0.68	552	0.83	358186.03	0.49	2603.09	0.78
Presec	417507.94	0.26	53787.17	0.20	636	0.76	190076.23	0.88	62297.10	1.59
Prisions	891496.54	0.19	68472.70	0.30	2053	0.77	1255112.33	0.99	119978.89	0.03
Statistical	199739.85	0.48	9495.01	0.20	294	1.13	438873.35	0.56	75570.79	0.18
Treasury Ladies	66847.60	0.58	4757.16	0.16	322	1.40	44135.66	0.10	13785.28	0.02
TUC	76640.50	0.36	7096.88	0.41	80	1.02	42931.47	0.47	52248.22	0.25
U G Legon	7421469.84	0.32	328111.25	0.40	3560	0.79	4945242.17	0.33	3049502.08	0.24
U G Med Sch	678155.67	0.64	44579.29	0.48	1432	0.96	1479322.27	0.55	476635.48	0.65
Name of DMU	Deposits(GH¢) Average	Growth	Operating Expenses (GH¢) Average	Growth	Membership Average	Growth	Loans (GH¢) Average	Growth	Investments (GH¢) Average	Growth
KAMCCU	2735773.55	0.35	154062.64	0.14	3444	0.63	1965221.69	0.40	1662814.59	0.24
KMC	82033.41	0.79	19407.79	0.39	450	0.86	58920.30	0.67	15275.73	1.73
Madina Com	335739.51	0.17	51432.39	0.09	915	0.40	274151.04	0.21	25259.31	0.16
Mail Fin	384242.24	0.08	87205.19	0.23	681	0.54	193339.44	0.08	10514.13	0.11
North End	33274.22	0.83	8354.16	1.14	118	2.02	20159.19	3.91	8856.40	0.86
PWD Prestige	209171.92	0.51	13372.20	0.25	308	0.89	93682.26	0.68	123494.21	0.21
Redemption	175032.83	0.32	19757.12	0.22	615	0.62	99759.03	0.49	122800.99	0.15
Transcea	79227.93	0.63	9258.93	0.18	280	0.67	43759.34	2.69	27606.26	0.83
USAID	668277.52	0.53	21579.93	0.42	302	0.95	761161.72	0.48	298704.67	3.18
Total	**554900.63**	**0.44**	**39277.10**	**0.37**	**710.09**	**0.81**	**420614.59**	**0.65**	**223445.05**	**0.47**

Appendix A2: List of Credit Unions by Groupings

Community Group	**Parish Group**	**Workers Group**
1. KAMCCU 2. Kwashieman Motorway 3. Madina Community 4. Mail Finance 5. Noth End 6. P. W.D Prestige 7. Redemption 8. Transcea 9. USAID	1. Accra Chapel 2. AME Zion 3. Atico C.O.P 4. Calvary Baptist 5. Christ the King 6. Darkuman C.O.P 7. Kaneshie Presby 8. Martyrs of Uganda 9. New Fadama C.O.P 10. Queen of Peace 11. Sacred Heart 12. SALEM 13. St. Charles Lwanga 14. St. Margaret Mary 15. St. Paul's 16. St. Thomas Moore 17. Tesano Baptist 18. Trinity United	1. Accra Academy 2. Animal Research 3. Associated Teacher 4. Controller 5. CSIR Secretariat 6. Ghana Atomic Energy 7. Ghana Breweries 8. Ghana Broadcasting 9. Ghana Prisons Service 10. Ghana Registered Midwives 11. Internal Revenue 12. Lotto Recievers 13. Museum and Monuments Board 14. NAFTI 15. NVTI 16. Presec Staff 17. Treasury Ladies 18. TUC National 19. Statistical Service 20. Standards Board 21. University of Ghana 22. University of Ghana Medical School

Source: Authors

Appendix Table A3: The group-frontier, meta-frontier Malmquist index and its decomposition and Technology gap ratio change in the Workers Group

No.	DMU	TEC^k	TC^k	$GMPI$	TEC^m	TC^m	$MMPI$	$\frac{TC^m}{TC^k}$	$\frac{TEC^m}{TEC^k}$	$\frac{MMPI}{GMPI}$ $(TGRC)$
1	Accra Aca	1.075	0.834	0.897	1.121	0.860	0.964	1.042	1.031	1.075
2	ARI	1.169	0.817	0.955	1.234	0.811	1.001	1.056	0.992	1.047
3	Associated	0.977	0.828	0.808	0.988	0.839	0.829	1.011	1.014	1.026
4	CAG	0.975	0.910	0.888	0.948	0.943	0.894	0.972	1.036	1.008
5	CSRI	1.265	0.802	1.015	1.294	0.807	1.044	1.023	1.006	1.029
6	G Breweries	1.032	0.947	0.977	1.124	0.882	0.991	1.089	0.931	1.014
7	GAEC	1.052	0.850	0.894	1.079	0.855	0.922	1.025	1.006	1.032
8	GBC	1.064	0.890	0.947	1.055	0.892	0.941	0.991	1.003	0.994
9	GRM	1.000	1.000	1.000	0.894	1.594	1.425	0.894	1.594	1.425
10	GSB	1.050	0.903	0.948	1.157	0.868	1.004	1.102	0.961	1.058
11	IRS	0.961	1.029	0.988	1.085	0.954	1.035	1.129	0.927	1.047
12	Lotto	1.157	0.837	0.968	1.220	0.809	0.987	1.055	0.967	1.020
13	MMW	1.085	0.858	0.931	1.207	0.821	0.992	1.113	0.958	1.065
14	NAFTI	1.066	0.977	1.042	1.128	0.911	1.028	1.058	0.933	0.987
15	NVTI	0.956	0.811	0.775	1.275	0.841	1.072	1.334	1.037	1.383
16	Presec	0.753	1.002	0.755	0.921	0.875	0.806	1.223	0.873	1.068
17	Prisions	1.072	0.820	0.879	0.739	1.029	0.761	0.690	1.254	0.865
18	Statistical	1.048	1.073	1.125	1.106	0.860	0.951	1.055	0.801	0.845
19	Treasury Ladies	1.093	0.861	0.942	0.935	0.900	0.842	0.856	1.044	0.894
20	TUC	0.983	1.294	1.272	1.173	0.854	1.002	1.194	0.660	0.788
21	U G Legon	1.134	0.826	0.937	0.993	1.263	1.255	0.876	1.529	1.339
22	U G Med Sch	0.916	1.192	1.092	1.098	0.834	0.916	1.198	0.700	0.838
	Geometric Mean	**1.035**	**0.918**	**0.950**	**1.072**	**0.910**	**0.976**	**1.035**	**0.992**	1.027

Appendix Table A4: The group-frontier, meta-frontier Malmquist index and its decomposition and Technology gap ratio change for the Community

No.	DMU	TEC^k	TC^k	GMPI	TEC^m	TC^m	MMPI	$\frac{TEC^m}{TEC^k}$	$\frac{TC^m}{TC^k}$	$\frac{MMPI}{GMPI}$ (TGRC)
1	KAMCCU	1.207	1.107	1.336	0.981	0.961	0.943	0.813	0.868	0.706
2	KMC	1.171	0.912	1.068	1.066	0.931	0.992	0.910	1.021	0.929
3	Madina Com	1.014	0.977	0.990	1.036	0.880	0.911	1.022	0.900	0.920
4	Mail Fin	0.838	0.992	0.831	0.826	0.884	0.730	0.986	0.891	0.878
5	North End PWD	1.000	1.000	1.000	0.892	0.799	0.713	0.892	0.799	0.713
6	Prestige	1.159	0.783	0.908	1.196	0.886	1.060	1.032	1.131	1.167
7	Redemption	1.078	0.921	0.993	1.057	0.922	0.975	0.981	1.001	0.982
8	Transcea	0.958	0.885	0.848	1.015	0.946	0.960	1.060	1.069	1.133
9	USAID	0.956	0.754	0.721	0.815	0.959	0.782	0.852	1.273	1.085
	Geometric Mean	**1.036**	**0.920**	**0.953**	**0.980**	**0.906**	**0.888**	**0.946**	**00.985**	0.932

Appendix Table A5: The group-frontier, meta-frontier Malmquist index and its decomposition and Technology gap ratio change in the Parish Group

No.	DMU	TEC^k	TC^k	GMPI	TEC^m	TC^m	MMPI	$\frac{TEC^m}{TEC^k}$	$\frac{TC^m}{TC^k}$	$\frac{MMPI}{GMPI}$ (TGRC)
1	Accra Chapel	0.916	1.192	1.092	0.937	1.003	0.940	1.023	0.841	0.861
2	AME	0.918	0.966	0.887	0.926	0.911	0.844	1.008	0.943	0.951
3	Atico COP	0.899	1.049	0.943	0.946	0.892	0.844	1.052	0.851	0.895
4	CBC 2008	0.951	1.269	1.206	1.020	0.856	0.874	1.073	0.675	0.724
5	Christ the King	1.138	1.159	1.319	1.127	1.040	1.172	0.990	0.897	0.888
6	DCCOP	0.980	1.046	1.025	1.008	0.902	0.909	1.029	0.862	0.887
7	KPC	1.000	1.038	1.038	1.000	0.988	0.988	1.000	0.952	0.952
8	MUCC	1.023	0.994	1.017	1.048	0.945	0.990	1.024	0.951	0.974
9	NFCOP	0.997	0.945	0.942	1.086	0.851	0.924	1.089	0.901	0.981
10	Queen of Peace	0.950	1.217	1.156	1.142	0.886	1.012	1.202	0.728	0.875
11	Sacred Heart	0.827	1.011	0.837	0.893	0.955	0.852	1.079	0.944	1.018
12	SALEM	0.970	0.983	0.954	1.154	0.867	1.000	1.190	0.881	1.049
13	St C Lwanga	0.982	0.969	0.951	0.995	0.932	0.927	1.014	0.962	0.975
14	St M. Mary	0.972	0.998	0.970	0.979	0.930	0.911	1.007	0.933	0.939
15	St Pauls	0.957	0.980	0.938	0.970	0.906	0.878	1.013	0.924	0.936
16	St T Moore	1.014	1.002	1.017	0.982	0.835	0.820	0.968	0.833	0.806
17	Tesano Baptist	1.055	0.982	1.036	1.089	0.887	0.966	1.032	0.903	0.932
18	Trinity Church	1.118	0.936	1.046	1.139	0.885	1.008	1.019	0.946	0.964
	Geomean	**0.979**	**1.037**	**1.015**	**1.021**	**0.914**	**0.933**	**1.043**	**0.881**	**0.919**