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Essays on Rethinking African Development: Contextual and Methodological Advances

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Essays on Rethinking African Development: Contextual and Methodological Advances

Olumayokun Soremekun

A dissertation
submitted in partial fulfillment of the
requirements for the degree of

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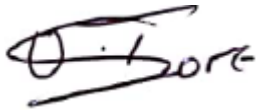

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Date _____03/21/2018_____

DEDICATION

Dedicated to my husband Kolade Fadeyibi, my parents Kayode and Rebecca Soremekun and my children Jigiola and Ayoola Fadeyibi. Thank you for supporting me on this journey and helping me to succeed.

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Abstract

Essays on Rethinking African Development:
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This research study sets out to provide analytical answers to the questions of African development and inequality. We examine various aspects of development from the issue of inequality among African countries to unravelling the synergies among the MDG goals and finally to investigating the progress if any that African countries have made towards attaining the MDG goals.

This research is broken down into three main studies: measuring inequality of opportunity, examining the synergies between the Millennium development goals at a particular point in time and lastly assessing the progress that has been made towards attaining the MDG goals in Africa. There are five main objectives of this research. First, to provide a detailed exploration and analysis of development in Africa. Second, to estimate and measure the inequality of opportunity for children in African countries. Third, to analytically answer the

question of linkages of the MDGs and in so doing identify the goals that can be prioritized by African countries. Fourth, to assess the progress that African countries have made towards attaining the MDG goals. Finally, provide policy recommendations that would enhance growth and development in Africa.

This research study applies novel methodologies to the study of African development by employing methodologies such as Kohonen maps and directed acyclic graphs. We expand an existing Human Opportunity Index (HOI), developed by Barros et al and which has only been applied to Latin America and the Caribbean, to the African continent. We identify the existence of linkages between the Millennium Development Goals at particular points in time through the use of directed acyclic graphs and structural equation modelling. The linkages identified allow us to highlight select MDG goals that can be prioritized by African countries. Focusing on these select goals would in turn have a cascading effect on other goals. We are able to identify substantial differences within Africa which separate the northern and southern regions from the central, eastern and western regions patterns in development within Africa. Finally, we propose a one

dimensional Kohonen map to obtain a ranking of African countries with regard to MDG progress and achievement.

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1. Introduction – Examining African Development

More than a decade has passed since the declaration of the Millennium Development Goals (MDGs) by the United Nations (UN) in September of 2000. The MDGs represent a "hard-won consensus on how to tackle a range of issues… (including how to) promote sustainable development for the world's poor" (Manning, 2009, p. 5). The issues facing the poor in the developing world also continue to capture a great deal of attention from the World Bank, the International Monetary Fund, and many bilateral aid agencies. While there has been tremendous progress in the fight against poverty over the past decade, the recent extraordinary tide of political events and revolutions in Tunisia, Egypt and Libya have brought to the fore a host of pressures that have been brewing below the surface. These issues include but are not limited to economic and social exclusion, youth unemployment, governance failures and a lack of genuine democracy. The uprisings in these African countries have highlighted the fact that while there have been tremendous strides in closing the poverty gap, these strides are not sufficient as too many Africans have been excluded from its benefits. Growth is effective when it is said to be inclusive i.e. creating economic opportunities while also ensuring equal access to these

opportunities. Unfortunately growth in Africa has been narrowly concentrated and has caused inequality to be more pronounced and visible. In many ways, inequality in access to basic services and opportunities appears to have widened and increased.

Young Africans are being excluded from the labour market and the formal economy. Access to education has expanded in some countries but the few who have succeeded in making it through the education system face a job market with bleak prospects of finding gainful employment. Growth in Africa has failed to deliver jobs especially in labour intensive industries that have the potential to lift millions of people out of poverty. The African Development Bank (AFDB) report on Africa argues that on the other hand, poverty alleviation in South Asian economies is in part due to the growth that has been seen in labor intensive manufacturing. Land reform policies in these economies also contributed to improving the productivity of the rural poor leading to higher buying power. They advocate that investments in areas such as health and education would create more job opportunities, which would in turn lead to a more productive and better paid workforce (AFDB, 2008).

The past decade has seen the most dynamic economic growth in Africa's history. Africa has outperformed the global average, with per capita GDP increasing every year since 2000. Growth in 2011 is projected to be at 3.7% and should accelerate to around 6% in the coming years (AFDB, 2008). However increases in per capita GDP have not translated into equal benefits for African countries. This discrepancy is as a result of persistent inequality in Africa. Africa's Gini index (the standard measure of income inequality) in 2005 stood at 0.45 and this is only slightly better than it was in 1980. As a result of the high inequality in African countries, economic growth has translated to much less in terms of poverty reduction. During a period of rapid growth in most African countries (2005 to 2009) the proportion of people living on less than a dollar a day experienced a small decline from 47% to 43%. Similarly, other development indicators in Africa such as life expectancy at birth and the human development index had only a marginal improvement as seen in Table 1.

Table 1: Human Development Indicators in Africa

	1990	2005	2006	2007	2008	2009
Expenditure on education (% of GDP)	5	5	4.9	4.8	4.6	5.1
School Enrollments, primary (% gross)	81.2	96.9	99.4	98.4	102.7	102.7
Under 5 mortality rate (per 1000)	168.3	139.6	137.3	134.8	132.3	129.8
Life expectancy at birth (years)	52.7	54.4	54.7	55	55.3	55.7
Human development Index	0.39	0.41	0.41	0.42	0.42	0.42

Source: AFDB Statistics Department

Looking at the pattern of growth in many areas of African economies, it is not difficult to see why inequality and hampered development prevail. Inequality is first and foremost a result of unequal opportunities. Poor people are constantly hampered by their lack of resources, place of residence and lack of access to markets. Despite their motivation and inherent ability and potential, they are held back from achieving these potentials. Poverty leads to social and political exclusion which invariably affects their circumstances, thus leaving them powerless and unable to access basic opportunities that can possibly improve their circumstances and pull them out of the poverty cycle.

The Millennium Development Goals (MDGs) were put forward in September 2000 as an avenue to providing sustainable development for the world's poor thus tackling some of the development and growth issues that we raised above. There are eight MDGs, twenty-one

targets and sixty indicators for measuring progress between 1990 and 2015 when the goals are expected to be met. Seven of the MDGs have a number of clearly specified time bound targets mostly relating to poverty in its various dimensions. The first goal focuses on the eradication of extreme poverty and hunger with the specific target of halving the proportions of people whose income is less than $1 dollar a day and who suffer from hunger between 1990 and 2015. The remaining MDGs are focused on achieving universal primary education, promoting gender equality and empowering women, reducing child mortality, improving maternal health, combating HIV/AIDS and other major diseases, ensuring environmental sustainability and developing a global partnership for development. The full list of the MDG goals, targets and indicators for monitoring progress are outlined in detail in Table 2. For the purpose of this research study, we will examine a subset of the targets and indicators based on availability of data for the African countries under consideration.

Table 2: Millennium Development Goals

Millennium Development Goals (MDGs)	
Goals and Targets (from the Millennium Declaration)	**Indicators for monitoring progress**
Goal 1: Eradicate extreme poverty and hunger	
Target 1.A: Halve, between 1990 and 2015, the proportion of people whose income is less than one dollar a day	Proportion of population below $1 (PPP) per day Poverty gap ratio * Share of poorest quintile in national consumption
Target 1.B: Achieve full and productive employment and decent work for all, including women and young people	Growth rate of GDP per person employed Employment-to-population ratio Proportion of employed people living below $1 (PPP) per day Propotion of own-account and contributing family workers in total employment
Target 1.C: Halve, between 1990 and 2015, the proportion of people who suffer from hunger	Prevalence of underweight children under-five years of age Proportion of population below minimum level of dietary energy consumption
Goal 2: Achieve universal primary education	
Target 2.A: Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling	Net enrolment ratio in primary education Proportion of pupils starting grade 1 who reach last grade of primary Literacy rate of 15 – 24 year olds, women and men
Goal 3: Promote gender equality and empower women	
Target 3.A: Eliminate gender disparity in primary and secondary education, preferably by 2005, and in all levels of education no later than 2015	Ratios of girls to boys in primary,secondary and tertiary education Share of women in wage employment in the non-agricultural sector Proportion of seats held by women in national parliament
Goal 4: Reduce child mortality	
Target 4.A: Reduce by two-thirds, between 1990 and 2015, the under-five mortality rate	Under-five mortality rate Infant mortality rate Proportion of 1-year old children immunized against measles
Goal 5: Improve maternal health	

Target 5.A: Reduce by three quarters, between 1990 and 2015, the maternal mortality ratio	Maternal mortality ratio Proportion of births attended by skilled health personnel
Target 5.B: Achieve by 2015 universal access to reproductive health	Contraceptive prevalence rate Adolescent birth rate Antenatal care coverage (at least one visit and at least four visits) Unmet need for family planning
Goal 6: Combat HIV/AIDS, malaria and other diseases	
Target 6.A: Have halted by 2015 and begun to reverse the spread of HIV/AIDS	HIV prevalence among population aged 15-24 years Condom use at last high-risk sex Percentage of population aged 15-24 years with comprehensive correct knowledge of HIV/AIDS Ratio of school attendance of orphans to school attendance of non-orphans aged 10-14 years
Target 6.B: Achieve by 2010, universal access to treatment for HIV/AIDS for all those who need it	Proportion of population with advanced HIV infection with access to antiretroviral drugs
Target 6.C: Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases	Incidence and death rates associated with malaria Proportion of children under 5 sleeping under insecticide-treated bednets Proportion of children under 5 with fever who are treated with appropriate anti-malarial drugs Incidence, prevalence and death rates associated with tuberculosis **0** Proportion of tuberculosis cases detected and cured under directly observed treatment short course
Goal 7: Ensure environmental sustainability	

Target 7.A: Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation	Proportion of land area covered by forest CO2 emissions, total, per capita and per $1 GDP (PPP) Consumption of ozone-depleting substances Proportion of fish stocks within safe biological limits Proportion of total water resources used
Target 7.B: Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation	Proportion of terrestrial and marine areas protected Proportion of species threatened with extinction
Target 7.C: Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation	Proportion of population using an improved drinking water source Proportion of population using an improved sanitation facility
Target 7.D: By 2020, to have achieved a significant improvement in the lives of at least 100 million slum dwellers	**0** Proportion of urban population living in slums
Goal 8: Develop a global partnership for development	
Target 8.A: Develop further an open, rule-based, predictable, non discriminatory trading and financial system. Includes a commitment to good governance, development and poverty reduction – both nationally and internationally	Official development assistance Net ODA, total and to the least developed countries as percentage of OECD/DAC donors' gross national income Proportion of total bilateral, sector-allocable ODA of OECD/DAC donors to basic social services (basic education, primary health care, nutrition, safe water and sanitation) Proportion of bilateral official development assistance of OECD/DAC donors that is untied ODA received in landlocked developing countries as a proportion of their gross national incomes ODA received in small island nations as a proportion of their gross national incomes Market Access
Target 8.B: Address the special needs of the least developed countries includes: tariff and quota free access for the least developed countries exports; enhanced programme of debt relief for the heavily indebted poor countries (HIPC) and cancellation of official bilateral debt; and more generous ODA for countries committed to poverty reduction	
Target 8.C: Address the special needs of landlocked developing countries and small island developing states	
Target 8.D: Deal comprehensively with the debt problems of developing countries through national and international measures in order to make debt sustainable in the long term	

	Proportion of total developed country imports (by value and excluding arms) from developing countries and least developed countries admitted free of duty Average tariffs imposed by developed countries on agricultural products and textiles and clothing from developing countries Agricultural support estimate for OECD countries as a percentage of their gross domestic product Propotion of ODA provided to help build trade capacity Debt Sustainability **0** Total number of countries that have reached their HIPC decision points and number that have reached their HIPC completion points (cumulative) **1** Debt relief committed under HIPC and MDRI Initiatives **2** Debt service as a percentage of exports of goods and services
Target 8.E: In cooperation with pharmaceutical companies, provide access to affordable essential drugs in developing countries	**3** Proportion of people with access to affordable essential drugs on a sustainable basis
Target 8.F: In cooperation with the private sector, make available the benefits of new technologies, especially information and communications	**4** Fixed telephone lines per 100 inhabitants **5** Mobile cellular subscriptions per 100 inhabitants **6** Internet users per 100 inhabitants

Source: https://www.unicef.org/statistics/index_24304.html

The goals were considered to be the world's biggest promise aimed at reducing poverty and human deprivation at an unprecedented rate through collaborative action. The United Nations (2011) recently produced an annual Millennium Development Goals Report. The report indicates that overall, poverty is in decline, and some of the world's poorest countries – mostly in Sub-Saharan Africa - have made the greatest improvements in education. Child mortality is also in decline while malaria, HIV-related and tuberculosis deaths have all dropped dramatically since 2000. While every region has shown improvement in access to clean drinking water, the report indicates that women and children in the world's poorest regions continue to struggle in achieving sanitary conditions and employment opportunities. Specifically, the overall assessment of Africa's progress toward the MDGs reveals that while progress has generally been positive, performance has been mixed across indicators and countries. Based on current trends, the overall pace of progress is insufficient to achieve the MDGs by the target date of 2015. Seemingly optimistic forecasts suggest that the income poverty target (Goal 1) will not be achieved in sub-Saharan Africa until 2147 (UNDP, 2003).

The natural question to ask here is why? Why is the pace of progress so slow in Africa? There are probably many reasons why and also many different answers and in turn many different possible solutions that can be put forward. Some of the reasons that can be put forward include but are not limited to the food, fuel, financial crises and political instability in a variety of African countries such as Egypt, Libya over the past few years.

For African countries that invariably have less resources than other developing countries, a basic first question that can be asked is: can all the MDGs be achieved simultaneously? This leads to other questions such as: are the MDGs interrelated and compatible with each other? Are subsets of the MDGs linked so that they can be reached simultaneously? Are the MDGs complementary to each other i.e. will the achievement of one goal have a positive influence on achieving other goals, thus providing an integrated approach and in turn accelerating the achievement of these goals? A recent African Development Bank report appears to suggest that the answer to these questions is yes. The AFDB report (AFDB, 2008) indicates that the MDGs are closely interlinked and policymakers would do well to prioritize those goals that would have the

greatest effect on a wider range of indicators. They argue that gender empowerment, education, poverty and health are inextricably linked and African countries would do well to exploit these relationships in their bid to achieving the millennium development goals.

This research study sets out to provide analytical answers to the questions of African development and inequality. With our research we attempt to contribute to the African development literature by providing answers that can potentially influence the policy debate. Based on our analytical analysis we hope to provide policy recommendations that would: first help to reduce inequality of opportunities in Africa and second highlight the MDG goals that can be prioritized by African countries and in turn have a cascading effect on other goals and thus accelerate the rate of progress in achieving the MDGs.

Research Motivation

My main research interest is to examine the concept of development in Africa. We examine various aspects of development from the issue of inequality among African countries to unravelling the synergies among the MDG goals and finally to investigating the progress if any that African countries have made towards attaining the MDG goals. This research is broken down into three

conceptually related essays. All three essays can be viewed within a common development framework. This framework consists of the social/spatial divide and the development divide. These essays allow us to consider these specific areas of development in Africa and thus provide a detailed investigation and analysis into these areas.

The first paper looks at inequality of opportunity in the provision of basic services such as water, sanitation, education and durable flooring. This essay examines the social and spatial inequalities within Africa particularly in relation to these services (Roemer, 1998; Birsdall, 2006). The social divide indicates the wide gap that exists between the rich and the poor and how this inequality gap in opportunities leads to unequal outcomes in life. The spatial divide on the other hand shows the physical evidence of inequalities. In the same country, or geographical area, one can view pockets of luxury, as well as pockets of poverty. This study seeks to re-think the social and spatial divide in Africa, by introducing the concept of equality of opportunity. The thesis around equal opportunities here is 'leveling the playing field' from childhood for everyone.

According to Roemer (1998), "leveling the playing field means guaranteeing that those who apply equal degrees of effort end up with equal achievement, regardless of their circumstances" (Roemer, 1998:12). This research will help to identify root causes for unequal outcomes so that policies might be better designed to address them. In the words of Charles de Montesquieu "In the state of nature … all men are born equal, but they cannot continue in this equality. Society makes them lose it, and they recover it only by the protection of the law" (UN-HABITAT, 2010).

The second and third papers examine the MDG goals within the African context. The first section within chapter three considers the Sisyphus, (i.e. endless and unavailing) challenge that African countries face with regard to achieving the MDGs. The chapter attempts to highlight the goals that can be prioritized in order to get countries closer to achieving these goals. The second section in chapter 3 applies the Kohonen self-organizing map methodology to assess the progress if any, that African countries have made towards attaining the MDG goals. The paper focuses on the subject of the development divide and it can also be considered as a freedom divide (Sen,1999). The purpose of 'development' is, therefore, to guarantee 'growth' so that ultimately

other freedoms can, at some indeterminate time in the future, be enjoyed. The basic proposition put forward by Sen is that development can be considered in terms of "the expansion of the capabilities of people to lead the kinds of life that they value and have reason to value". Such expansion of capabilities that he refers to here includes but is not limited to the provision of facilities such as basic education, health care and social safety nets. These amenities and provision of these amenities constitute development. "Freedoms," he argues, "are not only the primary ends of development, they are also among its principal means." Development should be seen as a process of expanding freedoms. "If freedom is what development advances, then there is a major argument for concentrating on that overarching objective, rather than on some particular means, or some chosen list of instruments". In order to achieve development, he argues that there needs to be a removal of poverty, tyranny, lack of economic opportunities, social deprivation, neglect of public services, and the machinery of repression. The MDGs thus embody development as they envision a world with less poverty, less hunger and disease. A world with equal opportunity for women, greater survival rates for mothers and their children, education for all, an improved living environment and a partnership between developed and

developing countries. Achieving the MDGs is seen as one avenue through which the development divide/gap between African countries and more developed countries can be lessened if not eliminated. Identifying and highlighting priority MDG goals for the African context is one major step in that direction.

Research Objectives

Specifically the objectives of my research include:

1. To provide a detailed exploration and analysis of development in Africa.
2. Estimate and measure the inequality of opportunity for children in African countries.
3. Analytically answer the question of linkages of the MDGs and in so doing identify the goals that can be prioritized by African countries. This will be done at a particular point in time using directed acyclic graphs (DAGs) and partial least squares methodology.
4. Assess the progress that African countries have made towards attaining the MDG goals using Kohonen Self Organizing Maps.
5. Apply novel methodologies to the study of African development by employing methodologies such as Kohonen maps and directed acyclic graphs.

The Thesis

1.1. Thesis topic

The thesis is entitled "Essays on Rethinking African Development – Contextual and Methodological Advances".

1.2. Explication of the thesis topic

This research is broken down into three main studies:first, measuring inequality of opportunity, second, examining the synergies between the Millennium development goals at a particular point in time and lastly assessing the progress that has been made towards attaining the MDG goals in Africa

1.2.1. Equality of opportunity is about leveling the playing field so that circumstances such as gender, ethnicity, place of birth, or family background do not influence an individual's chances in life. Access to opportunities such as education, water and sanitation, housing etc should largely depend on people's choices, effort and talents, not solely on their circumstances at birth. We measure inequality of opportunities in Africa with an innovative Human Opportunity Index. Our methods are applied to gauge inequality of opportunities in access to basic services for children.

1.2.2. In 2000, the Millennium declaration was adopted by the 189 member countries of the United Nations. This declaration is coded in eight measurable goals, targeted at ensuring a better world where poverty, hunger, disease, maternal and infant mortality, female inequality, poor sanitation are things of the past. Ten years later, with only five years to go, we examine the synergies and interdependence between the MDG goals using directed acyclic graphs (DAGs) and partial least squares (PLS). Based on these synergies, we propose to identify the MDG goals that can be prioritized by African countries which would in turn have a cascading effect on other goals and thus have implications for achieving the MDGs.

1.2.3. This paper introduces Kohonen Self-Organizing Maps (SOMs) to the scholarly discussion of the United Nations (UN)'s Millennium Development Goals (MDGs). We use data through the MDGs' approximate mid-point (2000-2010) to analyze the African region. Major differences have been identified within Africa separating the northern and southern regions from the central, eastern and western regions. This substantial difference within Africa appears to be mainly attributable to deficiencies in education and ICT infrastructure, both areas that are important for the achievement of other

MDGs. The paper demonstrates SOMs to be a useful tool in evaluating differential convergence over the two time periods under investigation.

1.3. Novel aspects

In this section we list novel contributions that arise from the dissertation. They are organized below as follows:

In the area of the study of African development

1. In this study, we expand an existing Human Opportunity Index (HOI), developed by Barros et al and which has only been applied to Latin America and the Caribbean, to the African continent.

2. We identify the existence of linkages between the Millennium Development Goals.

a. We identify the linkages at particular points in time through the use of directed acyclic graphs and structural equation modelling.

b. The linkages identified allow us to highlight select MDG goals that can be prioritized by African countries. Focusing on these select goals would in turn have a cascading effect on other goals.

3. We explore and tell the story of MDG progress in Africa. We identify substantial differences within Africa which separate the northern and southern regions from the central, eastern and western regions patterns in development within Africa. We propose a one dimensional Kohonen map to obtain a ranking of African countries with regard to MDG progress and achievement.

2. Rethinking Sustainable Urbanization and Development: Measuring Inequality of Opportunity for Children in select countries in Africa

Introduction

Traditionally, the debate surrounding development has focused mainly on the prevalence and effects of poverty and minimal economic growth (Chen and Ravallion, 2008). Some studies have also attempted to present explanations for this present situation of poverty and low economic growth. In all, a plethora of studies exist covering such issues as: aid versus investment (Moyo, 2009); globalization (Kaplinsky, 2005); migration and the effects of the brain drain (Rivera-Batiz, 2008); corruption and the need for good governance (Rivera-Batiz, 2002); the resource curse (Sala-i-Martin and Subramanian, 2003); the ubiquitous effects of colonialism (Maathai, 2009); and geography (Gallup et al, 1999). This study invites us to examine how inequality of circumstances leads to unequal opportunities, ceteris paribus.

A report by the United Nations Human Settlements Program (UN-HABITAT, 2008), noted that Sub Saharan Africa ranks 2nd after Latin America and the Caribbean for the highest levels of disparity between the urban rich and the urban poor. However, while inequality

could lead to undesirable social effects, international development efforts have concentrated less on unequal disparities and more on poverty reduction (UN-HABITAT, 2008). In many African countries, "…economic inequalities remain largely understudied. While … the study of equality of opportunity is only at its beginning" (Cogneau et al, 2008:4). Many African cities however show a wide gap between the rich and the poor (Figure 2), as reflected by the Gini coefficient.[1] The question is why is it that within the same country, and between countries with similar path dependencies, we find some individuals living in poverty and others being extremely wealthy. An issue of interest is to what extent ensuing outcomes can be explained by unequal circumstances, as indicated by the lack of one or more of the following – access to improved water, access to improved sanitation facilities, sufficient-living area, durable housing, and education.[2] Are unequal outcomes in access to opportunities reflective of choice, or of circumstances beyond the individual's control? Circumstances in this case are situations beyond a particular individual's control. An individual

[1] The Gini coefficient measures the gap in income between the rich and the poor, and ranges from 0 to 1, with 0 depicting no inequality and 1 reflecting high levels of inequality (UN-HABITAT, 2008:64).

[2] Access to basic services such as water and sanitation tend to define a slum condition and decent living. In turn, these conditions define the health and hygienic environment in which a person grows up. Again unequal opportunity gap manifests itself in the wide difference in educational facilities that exist in poor and rich environments of a city.

has no control over his gender or his region of birth. Opportunities on the other hand are situations which can be influenced by the actions or inactions of individuals. Basic opportunities can be defined as services that are critical to a child's development. Examples of these opportunities include access to primary education, minimum nutritional levels, access to clean water, sanitation and electricity. Access to these services are not controlled by the child but are dependent on external factors determined by family or society as a whole. The universal provision of these basic services is considered to be a valid social goal as evidenced by such declarations as the millennium development goals. In the case of children, access defines opportunity as children cannot be expected to make the effort needed to access these basic services by themselves. This begs the question, how is a child's access to basic services and opportunities influenced by his/her circumstances?

The rest of this chapter is organized as follows. The next section looks at the literature review, highlighting inequality in Africa in particular. We then outline the research questions followed by a discussion around the data and research methodology. We discuss the findings of our analysis and share the

conclusions as well as suggestions for further research in the last sections.

In this study, we focus on how inequality of circumstances leads to inequality of outcomes, concentrating particularly on those factors that are not dependent on individual choices, talents or motivations. The diagram in Figure 1 presents an analytical framework for this study. The framework is largely the same as that used by Barros et al (2008), in their paper entitled "Measuring Inequality of Opportunities for Children," albeit without the policy linkages. The area of focus of this study is thus highlighted in red in the framework.

Inequality of outcome consists of the observable disparities in livelihood among people that can be observed across different dimensions e.g. income, education, shelter, living standards and so on. As seen in the model, it arises because of differences in the choices people make or due to inequality of opportunities.

Inequality due to choice consists of those disparities that arise from different choices that individuals make, for instance at a basic level, the choice to be diligent or to be lazy. These choices eventually lead to different outcomes, only because individuals faced

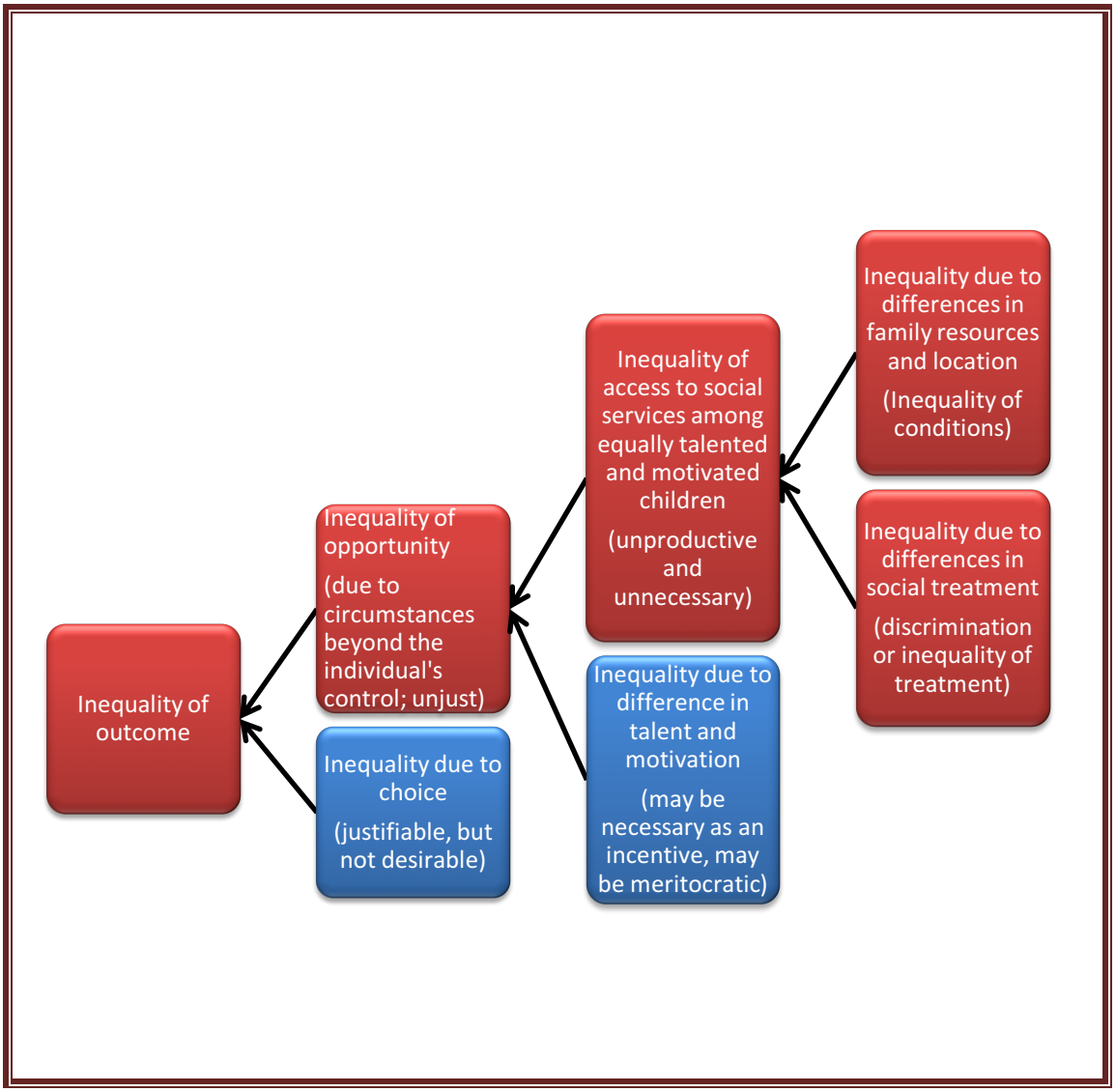
with similar choices made different choices (Barros et al, 2008). Inequality of opportunity, which is the main focus of this study, is the inequality that ensues due to differences in circumstances beyond a person's control, which then affects the outcomes the individuals have in life. These circumstances include such things as place of birth, education of parents, gender, and race. Inequality of opportunities is itself broken into inequality due to talent and motivation, and that due to unequal access to social services.

Inequality due to talent and motivation takes into consideration the fact that individuals are born with different talents and are motivated by different things. Many of these factors are innate, and may thus be seen to be uncontrollable by the child. Inequality of access to social services, even among those who are equally talented and motivated, can be broken into inequality due to differences in family circumstances, and differences in social treatment.

Inequality due to differences in family resources and location is that which occurs because individuals experience varying family circumstances as indicated by such factors as the education of the parents, father and mother's income, which could affect the opportunities that would be made available to the

child. Inequality due to differences in social treatment, on the other hand, are those caused by discrimination towards certain groups of people, based on particular societal criteria, including race, ethnicity and gender. By better understanding the level of inequality of opportunities in African countries, we hope to present policies that would help to mitigate these inequalities and level the playing field.

Figure 1: Analytical Framework for Inequality of Outcome and Opportunity



Source: Adapted from Barros et al (2008)

**Only parts of the framework for which we have data are covered in the dissertation*

Literature Review

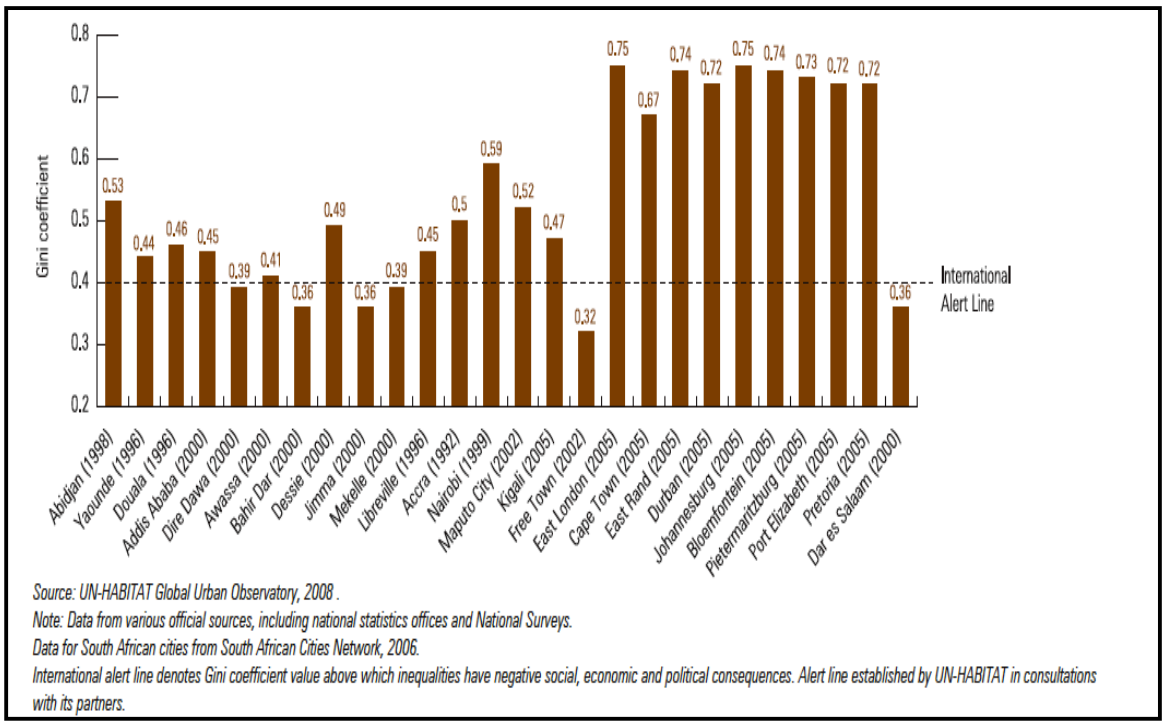
Inequality in Africa

Inequality in Africa is evident and measurable on various dimensions. A UN-HABITAT (2008) report highlights the economic, spatial, social, urban and opportunity divides. In this section, we briefly discuss these various dimensions of inequality, before laying emphasis on inequality of opportunity, which is the main focus of this paper.

Inequality based on economics is the traditional way in which inequality is measured, using the Gini coefficient as an indicator. Various explanations have been given for the high levels of socio-economic inequalities in the continent. Nicolas van de Walle (2009) for instance provides a political explanation that "the surprisingly high levels of inequality in Africa can be understood as resulting from a process of class formation linked to dynamics of state building that have their origins in the economic institutions of the early colonial state." Gyimah-Brempong (2002) found that "increased corruption is positively correlated with income inequality. The combined effects of

decreased income growth and increased inequality suggest that corruption hurts the poor more than the rich in African countries." From Figure 2, we see cities in South Africa displaying the highest levels of inequalities. South Africa's inequalities can be linked to the historical disadvantages caused between various groups during apartheid.

Figure 2: Gini Coefficients for selected African cities



Source: UN-HABITAT Global Urban Observatory, 2008 .
Note: Data from various official sources, including national statistics offices and National Surveys.
Data for South African cities from South African Cities Network, 2006.
International alert line denotes Gini coefficient value above which inequalities have negative social, economic and political consequences. Alert line established by UN-HABITAT in consultations with its partners.

Cogneau and Mesple-Somps (2008) examined inequality of income opportunity in five comparable countries in sub-saharan Africa. Their study considered between country differences and in-country differences on the effects of social origins and position on education, occupation and income potential. Specifically they found that two

former British colonies (Uganda and Ghana) have higher educational and occupational mobility than the other three countries which happen to be former French colonies. Ghana particularly stood out from the other countries in the study with its lower levels of inequality while in-country there were marked differences of income equality based on birth place regional influences (Cogneau and Mesple-Somps, 2008).

However, there are other forms of visible inequalities. The spatial divide shows the physical evidence of inequalities. In the same country, or geographical area, one can view pockets of luxury, as well as pockets of poverty. People could also suffer stigmatization based on the geographic area in which they live. For example, slums are a physical manifestation of poverty. In a task force report on slum dwellers (Garau et. al, 2005), it was reported that

According to the most recent international estimates, more than 900 million people can be classified as slum dwellers, most living under life- and health- threatening circumstances, often lacking several of the following conditions: access to adequate clean water, access to improved sanitation facilities,

sufficient living space, dwellings of sufficient durability and structural quality, and security of tenure. Almost one out of three urban dwellers (one out of every six people worldwide) already lives in a slum.

The aforementioned conditions correspond to the UN-HABITAT's indicators for slum households. Analyzing this spatial divide, the UN-HABITAT study (2008), notes that the spatial divide in developing country cities is reflective of not just "income inequalities among households; it is also a byproduct of inefficient land and housing markets, ineffective financial mechanisms and poor urban planning." The report however goes on to highlight these six challenges – severe job restrictions, high rates of gender disparities, deteriorated living conditions, social exclusion and marginalization, lack of social interaction and high incidence of crime – that arise from the ensuing "physical and social distance between poor and rich neighborhoods."

Table 3: Proportion of Urban Population in Slum Areas

	1990	1995	2000	2005	2007	2010
Developing regions	46.1	42.8	39.3	35.7	34.3	32.7
Northern Africa	34.4	28.3	20.3	13.4	13.4	13.3
Sub Saharan Africa	70.0	67.6	65.0	63.0	62.4	61.7
Latin America and Caribbean	33.7	31.5	29.2	25.5	24.7	23.5

Source: UN-HABITAT, 2008

Sub Saharan Africa has one of the highest urban populations living in slum areas. Table 3 shows the proportion of urban population in slum areas among developing regions, and three other regions in the world. Among these regions, Sub Saharan Africa has the highest of these proportions.

Inequalities in health have also been a focus of study for health scientists and economists. Ataguba and colleagues (2011) looked at socio-economic related health inequality in Africa and found that the major categories of ill-health and disability are much more prevalent among the lower socio-economic groups when compared to the higher groups. Mutangadura et al (2007) also examined health inequities in selected African countries and found that large inequalities in accessing health care are due to income and the rural/urban divide. They advocate that specific policies geared towards geographical and financial

access to health is of utmost importance. Sahn and Stifel (2004) examined the relative impact of rural versus urban areas with regard to poverty and other related living standard indicators. They found that living standards including health inequality in rural areas lag behind those of the urban areas. They also found no evidence of a decline in the gaps between the urban and rural living standards.

Inequality of Opportunity

This study seeks to re-think urban development in Africa, by introducing the concept of equality of opportunity. The emphasis is thus on equal opportunities which imply 'leveling the playing field' at the childhood level, as opposed to an emphasis on equal outcomes. This emphasis relies on the belief that access to basic opportunities that a child enjoys, will invariably affect his/her outcome in life, measured in terms of his well-being.

According to Roemer (1998), "leveling the playing field means guaranteeing that those who apply equal degrees of effort end up with equal achievement, regardless of their circumstances" (Roemer,1998). In many African countries, because of certain circumstances beyond their control, individuals might be prevented from having access to the same opportunities, and in turn to

achieving the same goals as their counterparts. Proponents of equality of opportunity thus believe that determinants of people's ability to succeed should therefore be their own choices, efforts and talents, and not circumstances that they cannot control such as birthplace, ethnicity, family background, and gender (Barros et al. 2008).

Inequality of opportunity thus applies the concept of path dependency in that it embeds the idea that "happenings at an earlier point in time will likely affect possible outcomes at a subsequent point in time" (Isaac, 1997). One approach to leveling the playing field would be through an equal-opportunity (EOp) policy, which is an intervention that would guarantee such equal achievements for the same degree of effort applied (Roemer, 1995).

Prior studies on inequality of opportunities in the labor markets have focused on factors that contribute to differences across countries in similar geographies or regions. Due to data limitations, a large number of studies focused on developed countries to the detriment of developing countries (Pasquier-Doumer, 2013). The few studies that included developing countries in their analysis (Grusky and Hauser 1984; Ganzeboom et al. 1989) considered them along the same strata as the

developed countries. Pasquier-Doumer identifies this as a limitation as while the labor market in developed countries are largely constituted by the formal sector, the opposite is the case in developing countries where the informal sector is largely prevalent thus exigent contexts prevail beyond the traditional. Three studies (Bossuroy and Cogneau 2008; Cogneau et al. 2007; Congneau and Mesple-Somps 2008) address these literature gaps by looking at inequalities of social mobility and income opportunity in Africa. Specifically they consider five African countries: Cote d'Ivoire, Ghana, Guinea, Madagascar and Uganda in their studies but encounter a comparability problem due to the differences in surveys utilized (Pasquier-Doumer, 2013). Pasquier-Doumer in her study across seven French-speaking West African countries (Benin, Burkina Faso, Cote d'Ivoire, Mali, Niger, Senegal and Togo) is able to overcome this limitation as the dataset provides detailed comparable information. The study finds that social origin plays an important part in determining the sector of the labor market in which an individual is employed.

Cogneau and Mesplé-Somps (2008) studied the inequality of income opportunity in Africa. They examined the relationship between a particular adult's current

income and his/her childhood circumstances. They found that unequal circumstances tended to reflect unequal income outcomes. However, Cogneau and Mesplé-Somps limited their explanatory variables to father's education, own education and region of birth, while this study expands the explanatory variables to include living conditions that might contribute to a child's success in life.

This study also extends the body of work on the African perspective as we utilize DHS surveys which are standardized across countries with the same categories and category definitions thus allowing us to make comparable conclusions across the countries under study.

Velez et al (2012) utilized the Human Opportunity Index to examine the evolution of 16 opportunity indicators in Egypt over a nine year period. These indicators were placed in four broad groups – education, housing, childhood development and nutrition. They found that parents education, area of residence (urban/rural), number of siblings, regional location and income per capita are the most important factors that affect equality of opportunity in Egypt.

Research Questions

The first motivation for this study is the availability of the means to quantify the inequality of opportunity in Africa. Birdsall (2006) noted that equity, reflective of equality of opportunity is more difficult to measure. Barros et al (2008) also express the same concerns, writing that the development community previously lacked the methodological tools to systematically measure inequality of opportunity. However, Barros et al (2008) have developed a tool (Human Opportunity Index - HOI) which enables such calculations, and allows for the analysis of basic opportunities. They define basic opportunities as a subset of goods and services for children, such as access to education, to safe water, or to vaccinations, that are critical in determining opportunity for economic advancement in life." (Barros et al, 2009:3). Their study measured inequality of opportunity for children in Latin America. Overall their study concluded that for equality of opportunity to prevail, exogenous circumstances should not have a role. They identified countries with high inequality rates in Latin America and also found that birthplace matters in Latin America. Specifically, it determines a child's access to clean water, sanitation, and electricity. Parental education was also found to be important; it

explains access to early secondary schooling and access to water and sanitation, and is strongly related to economic and educational achievement. This study on the other hand takes a step towards determining the levels of inequality of opportunity for children in selected countries in Africa.

The second motivation for this study is to identify root causes for unequal opportunities. If policy makers can identify root causes for unequal outcomes, they may be better able to design policies to address them. This study adds to the literature by highlighting some of the root causes of unequal opportunities and can enable policy makers to go beyond only focusing on unequal opportunities. Inequality in opportunities between and within countries is clearly evident and our study goes further to examine the cause of these unequal outcomes.

This research study sets out to understand the levels of inequality of opportunity by systematically examining the issue of access to basic services /opportunities for all, within an equal opportunities framework; the question being not necessarily one of equality i.e. equal rewards for all, but one of equity i.e. equal chances for all (Barros et al, 2008). With this understanding, it is easier to show how the playing field can be leveled so that individuals can be

given similar opportunities to succeed, and are not constrained by circumstances beyond their control. This study thus considers at a more micro level how characteristics of children's access to basic opportunities such as water, sanitation, electricity, durable housing and education relate to circumstances such as ethnicity, gender, parents' education, parents' income, and area of residence (urban vs. rural) for six countries in Africa.

We outline three specific research objectives for this study:

1. First we estimate and measure the level of inequality of opportunity for children in six select African countries by constructing the Human Opportunity Index. This is novel as it was originally developed by Barros et al and applied to countries across Latin America. Velez et al (2012) applied the HOI to Egypt but our study extends the scope to an additional number of countries in Africa and we show that this process and calculation can be applied to all African countries. Specifically we estimate and measure the level of inequality of opportunity for children in six African countries using logistic regression.

2. Second, by calculating the HOI we identify the determinants of inequality of opportunity across the African landscape. How do circumstances which a child has no control over affect his/her access to basic services and opportunities (education, water, sanitation etc.) which are necessary for his/her growth and development? How does a child's circumstance influence access to basic services and opportunities which would influence his prospects for a high standard of living in the future?

Data

For the purpose of our study, we use Demographic and Health Survey (DHS) data to estimate the Human Opportunity Index for children in select countries in Africa. The countries chosen for this study span aross Africa, and include Kenya and Uganda in East Africa, Nigeria and Ghana in West Africa, Egypt in North Africa and Zambia in the Southern part of the continent (Table 5). These countries were chosen as they are key economic hubs and representative of countries across Africa. Data from the African Development Bank shows that Egypt, Kenya, South Africa and Nigeria are part of the ten largest economies in Africa (AFDB, 2008). On the other hand with regard to per capita GDP, these countries fall along the full spectrum for African

countries with South Africa having the highest at 5614, followed by Egypt at 1702, Zambia at 958, Nigeria (837), Kenya at 795, Ghana (632) and finally Uganda at 355 (AFDB 2008b). This enables us to project our process across the African landscape. We note though that these countries are all Anglophone countries and there are no Francophone countries in our sample.

The DHS surveys that we use are the DHS-V surveys which were administered in these countries over a period of 2 years (2006 to 2008). These surveys represent nearly 302,000 children aged 0 – 17 from Africa (Table 5). A major advantage of using DHS data is that DHS surveys are standardized across countries with the same categories and category definitions. This helps us to overcome a major challenge in research where datasets for different countries have different categories/indicators or different definitions for categories/indicators. DHS surveys are nationally-representative household surveys that provide data for a wide range of monitoring and impact evaluation indicators in the areas of population, health, and nutrition. DHS surveys collect information on household characteristics, including availability of electricity, water and sanitation facilities, as well type of flooring material and cooking fuel.

We consider four opportunities in this study: access to electricity, clean water, sanitation and durable flooring (Table 4). A child's access to adequate housing conditions is an essential element of the opportunity to live a healthy life. These opportunities are considered to be very important for a child's growth and development. The circumstances considered in this study are, gender (gender of the child and gender of the household head), wealth and household characteristics (area of residence, level of education for household head) (Table 4).

DHS indicators that we will explore in our research include:

Opportunities

- Education(child): All respondents provide the highest level of education achieved and school enrollment. The DHS dataset includes a number of education indicators which are used to measure the educational level or attainment of household members. We use the highest educational level indicator (It consists of four levels: 0 – "no education", 1 – "primary education", 2 – "secondary education" and 3 – "higher education") (Table 4). For the purpose of our analysis (children between the ages of 5 to 17), we recode the education variable into a 1 if the child has access to education

and a 0 otherwise. Ideally children between the ages of 5 and 17 should currently be in school. We use this as a proxy for measuring access to education.

- Water and Sanitation: In terms of water, the survey asks if the source of water is piped into dwelling, piped into yard/plot, public tap/standpipe, tube well or borehole, protected well, unprotected well, protected spring, unprotected spring, river/dam/lake, rainwater, tanker truck, cart with small tank and bottled water (Table 4). The survey asks if the type of toilet facility is flush, traditional pit latrine, improved ventilated pit latrine or no facility. Many studies have looked at the impact of improved water and sanitation on children's mortality rates (Abou-Ali Hala 2003, Galiani et al 2005, Russtein 2000). Also, ensuring access to water and sanitation for all is part of the Millennium Development Goals vision of the United Nations as indicated in goal 7 of the MDGs. We recode the access to water variable into a binary improved water variable (0 – no access, 1 – access). We follow the UN definition of improved water sources which include house connections, public stand pipes, protected wells, protected springs etc by coding these as 1. Types of sources that do not give reasonable and ready access to water such as tanker trucks and bottled

water are not considered improved and they are coded 0. We also recode the sanitation variable into a binary improved sanitation variable (0 – no access, 1 – access). This is based on the UN definition of improved sanitation which includes connection to a sewer or septic tank system, flush toilet, ventilated or improved pit latrine. These are coded as 1 while all others are coded as 0.

- Electricity: Access to electricity is also a very important opportunity. Electricity improves the lives of all household members by providing lighting, energy sources for cooking and heating, access to information through the radio, television or the internet. Electricity also has an effect on a child's education and health. Gustavsson (2007), find that children are able to spend more time studying when electricity is provided. Also the provision of electricity reduces eye irritation, coughing and nasal problems in children thus improving their health. The DHS survey asks a dichotomous question with regard to electricity – "does your household have electricity? " A yes is coded as a 1 while a no is coded as a 0 (Table 4).

- Durable Floor: The DHS survey asks what the floor in the household is made of (Table 4). The options include natural floor (earth/sand, dung), rudimentary floor

(wood planks, palm/bamboo) and finished floor (parquet or polished word, vinyl or asphalt, ceramic tiles, cement, carpet). Durable floor represents a dwelling that provides physical security, shelter from weather, and protection from threats to health like structural hazards and disease for its occupants. The type of flooring in a home is an indicator of the type of housing that it is. For example, a floor that is made of sand or earth will most likely be found in a mud hut with thatched roofs. Durable floor is measured by looking at the main floor material. Natural and rudimentary materials such as earth, sand, dung or wood planks are considered to be non-durable while finished floors such as polished wood, ceramic, cement or carpet are considered durable. The variable is set equal to 1 if a child has access to a durable floor and 0 otherwise. Habitability is one of the many aspects of the human right to housing. Habitable housing provides the occupants with adequate space, physical security, shelter from weather, and protection from threats to health like structural hazards and disease.

Opportunities for the purpose of this study are defined as a subset of goods and services for children which are essential for determining opportunity for economic advancement. With regard to children, there is a

general consensus on the importance of a basic set of opportunities and while different societies might have different standards about what constitutes the right set, there is some consensus on a few of them such as education, shelter (water, sanitation, electricity, flooring) in the same vein as there is some consensus about the Millennium Development Goals (Barros et al. 2008).

Circumstances

- Education of head of household: All respondents provide the highest level of education achieved and school enrollment. The DHS dataset includes a number of education indicators which are used to measure the educational level or attainment of household members. We use the highest educational level indicator (It consists of four levels: 0 – "no education", 1 – "primary education", 2 – "secondary education" and 3 – "higher education") (Table 4).

- The wealth index: The wealth index is a composite measure of the cumulative living standard of the household. The weath index utilized in this paper is calculated using data on a household's ownership of selected assets such as televisions, bicycles, materials for housing construction and types of water access and sanitation facilities. Each household asset

for which information is collected is assigned a weight or factor score generated through principal components analysis. The resulting asset scores are standardized in relation to a standard normal distribution with a mean of zero and a standard deviation of one. These standardized scores are then used to create the break points that define wealth quintiles as: Lowest (Poorest), Second (Poorer), Middle, Fourth (Richer), and Highest (Richest) (Table 4). The wealth index is used in our study as a proxy for household income. We note that the wealth index measure includes access to water and sanitation which are opportunities that we consider in this study. It would be ideal to have an index that does not incorporate some of the opportunities that are considered in our study but unfortunately the wealth index is the only available proxy for household income.

- Gender: The gender of the child and gender of head of household (Table 4). The gender variable is recoded into a binary variable where a male is coded as 1 while a female is coded as 0.

- Area of residence: Urban vs. Rural (Table 4). Area of residence is also coded into a binary variable. Urban is a 1 while rural is coded as a 0.

Table 4: DHS Variables

Variable	Definition	Description
Opportunities		
Education	Highest level of education the household member attended	0 – "no education" (Did not attend school – 0) 1 – "primary education" (Attended school – 1) 2 – "secondary education" (Attended school – 1) 3 – "higher education" (Attended school – 1)
Water and Sanitation	Water: Major source of water for household use Sanitation:Type of toilet facility in the household.	**Water** Piped into dwelling (Access – 1) Piped into yard/plot (Access – 1) Public tap/standpipe (Access - 1) Tube well or borehole (No Access – 0) Protected well, protected spring (Access – 1) Unprotected well, unprotected spring, river/dam/lake, rainwater, tanker truck, cart with small tank and bottled water (No Access – 0) **Sanitation** Flush toilet (Access – 1) Pit toilet latrine (No Access – 0) No Facility (No Access – 0) Composting toilet(No Access – 0) Pit - Bucket toilet (No Access – 0) Pit - Hanging toilet/latrine (No Access – 0)
Electricity	Household access to electricity	Yes (Access – 1) No (No Access – 0)
Durable Floor	Main material of the floor in the household	Natural floor (earth/sand, dung) (Non Durable Floor – 0) Rudimentary floor (wood planks, palm/bamboo) (Non Durable Floor – 0) Finished floor (parquet or polished word, vinyl or asphalt, ceramic tiles, cement, carpet) (Durable Floor – 1)
Circumstances		
Education Head of Household	Highest level of education the head of household attended	0 – "no education" (Did not attend school - 0) 1 – "primary education" (Attended school – 1) 2 – "secondary education" (Attended school – 1) 3 – "higher education" (Attended school – 1)

Wealth Index	The wealth index is a composite measure of a household's living standard. The wealth index is calculated based on household's ownership of items such as televisions and bicyles, materials used in housing construction,sources of water and sanitation facilities	Lowest (Poorest) Second (Poorer) Middle Fourth (Richer) Highest (Richest)
Gender	Gender of Head of Household Gender of Child	Male (1) Female (0)
Area of Residence	Type of area in which the household lives	Rural (0) Urban (1)

The indicators (opportunities) considered in this study are guided by the choice of variables in Barros et al (2008). We consider five basic opportunities for children in these countries. We place these opportunities into two groups: Education and Housing. While Barros et al, 2008 looked at only three housing opportunities (electricity, water and sanitation), we include durable floor as an additional opportunity. We include durable floor because it is one of the variables that connotes "habitability".

Table 5: Sample Description of dataset (DHS V Survey)

	Kenya	Uganda	Nigeria	Ghana	Egypt	Zambia
Sample Size - Children	38,515	45,170	47,724	46,421	89,279	35,449
Opportunities (%)						
Education (%)						
0 – "no education"	70.5	67.8	38.8	72.8	74.7	70.6
1 – "primary education"	25.2	27.9	44.1	18.5	13.0	22.7
2 – "secondary education"	3.5	3.2	16.6	8.0	9.5	5.9
3 – "higher education"	0.6	0.5	0.1	0.4	2.7	0.2
Water (%)						
Piped Water (10)	31.0	13.0	9.2	38.8	93.8	30.2
Tube(Well/Borehole)	9.9	32.0	23.6	36.6	2.0	0.0
Dug Well (30)	17.1	39.0	35.7	7.8	2.0	48.6
Surface Water (40)	42.1	16.0	31.5	16.9	2.3	21.2
Sanitation (%)						
No facility >30	21.0	14.9	37.3	31.7	0.6	23.3
Pit Toilet (20)	66.6	83.7	50.9	56.5	0.4	63.6
Flush (11)	12.4	1.5	11.9	11.9	99.0	13.0
Electricity (%)						
Yes (1)	19.6	8.1	41.2	50.0	99.5	20.3
No (0)	80.4	91.7	58.6	50.0	0.5	79.7
Durable Floor (%)						
Natural floor (11)	61.5	78.3	44.4	21.2	11.6	60.6
Rudimentary floor (20)	0.3	0.0	1.2	0.0	0.1	0.0
Finished floor	38.2	21.6	54.4	78.7	88.3	39.4
Circumstances (%)						
Education (HH) (%)						
0 – "no education"	68.3	74.2	33.8	70.6	75.3	68.5
1 – "primary education"	28.7	22.3	47.8	20.4	10.0	19.7
2 – "secondary education"	2.3	2.7	17.4	8.2	11.4	4.4
3 – "higher education"	0.7	0.8	0.1	0.4	3.2	0.1
Wealth Index (%)						
Lowest	24.3	23.6	24.4	26.9	19.8	18.0
Second	17.4	19.3	22.4	20.0	20.0	19.3
Middle	17.8	18.1	21.1	18.1	20.1	21.8
Fourth	18.4	18.6	17.9	17.8	20.1	22.2
Highest	22.0	20.4	14.2	17.2	20.0	18.7
Gender - Head of Household (%)						
Male	69.0	72.6	86.6	73.4	90.4	78.8
Female	31.0	27.4	13.4	26.6	9.6	21.2
Gender – Child (%)						
Male (1)	48.7	48.1	50.9	48.2	50.5	48.3
Female (2)	51.3	51.9	49.1	51.8	49.5	51.7
Area of residence (%)						
Rural (2)	74.9	86.9	72.4	60.7	58.5	61.3
Urban (1)	25.1	13.1	27.6	39.3	41.5	38.7

Methodology

Human Opportunity Index

Our research methodology involves cross-national calculations and comparison of inequality of opportunity for six African countries. The goal of this study is to measure inequality of opportunity for children by calculating a measurement index – the Human Opportunity Index (HOI). We adapt to the African context a Human Opportunity Index (HOI) which was previously introduced for studies of inequality of opportunity in Latin America (Barros et al. 2008).

The HOI can be defined as the proportion of existing opportunities in a given society that are available and have been allocated equitably – the equal opportunity principle. The HOI is a composite indicator that combines two elements: (i) the level of coverage of basic opportunities necessary for human development such as primary education, water, sanitation, electricity and durable flooring (ii) the distance between the distribution of circumstances (beyond an individual's control) for those with access and those without access to an opportunity. The second element can be regarded as a measure of inequality. Examples of these circumstances include but are not limited to gender and household characteristics like area of

residence, level of education of the head of household. This index assesses both the importance of improving overall access to basic opportunities and also ensuring equitable distribution of those opportunities.

We calculate HOIs by country for a set of opportunities related to education and housing (clean water, sanitation, electricity, and durable flooring). These separate HOIs are then summarized via the arithmetic mean or geometric mean into a single overall country index. As noted earlier, the HOI combines two elements – the coverage rate (C) and the inequality of access (D) based on differences in circumstances between those who have access and those who don't have access to that opportunity - in a single calculation. In this calculation, the coverage of a basic opportunity is adjusted by how unequally it is distributed.

The coverage rates i.e. average access rates of each opportunity can be better understood as the ratio of total opportunities available to total number of children. It can also be interpreted as the percentage of opportunities that are available relative to the total number that is needed for universal access. Based on this definition, we see that it represents the level of coverage of available opportunities but it is not reflective of the equity of distribution. It

represents average access to the selected opportunity in each country but does not take into consideration whether children of a certain gender or area of residence have different access rates.

The second component which is an inequality measure is a version of the dissimilarity index widely used in sociology and applied to dichotomous outcomes (Morgan, 1983, Barros et al. 2008). We can also refer to it as the D-Index (a measure of inequality of an opportunity). It measures the overall weighted difference between the estimated probability of access to the opportunity for each child (given his/her circumstances) and the probability of access to the opportunity as a whole. If this distance is zero, the implication is that the probability of access is independent of circumstances.

Example A

To illustrate the definition of the D-Index and the usefulness of the index as a measure of inequality of opportunity, we will discuss a simple hypothetical example that takes us through the steps of calculating the D-Index and interpreting it (Table 6). For the purpose of our example, we examine a child's access to education given the circumstance of area of residence (area1/area2). Let y = 1 if a child has access to

education and y = 0 if a child does not have access to education. Let x = x_1 if a child lives in area1 and x = x_2 if a child lives in area2.

The D-Index can be calculated using the formula:

$$D = \frac{1}{2\bar{p}}\sum_{k=1}^{2}\left|p(y=1|x_k) - \bar{p}\right|p\,(x=x_k) \qquad Equation\ 3.1$$

where $\bar{p} = p(y=1)$ is equal to the proportion of children with access to education. The rationale for the constant $\frac{1}{2\bar{p}}$ in Equation 3.1 will be made clear in the example that follows.

For the purpose of our example, Table 6 represents the distribution of students who attend or don't attend school in each area of residence (area1 or area2, yielding m = 2 groups). Based on the table:

- Probability of attending school $(y=1)$ in area1 (x_1) is 0.8 i.e. $p(y=1|x_1) = 0.8$
- Probability of attending school $(y=1)$ in area2 (x_2) is 0.3 i.e. $p(y=1|x_2) = 0.3$
- Probability of being in area1 is 0.5 i.e. $p(x=x_1) = 0.5$
- Probability of being in area 2 is 0.5 i.e. $p(x=x_2) = 0.5$
- Probability of attending school overall (overall coverage rate) $\bar{p}$ = 55/100 = 0.55

Table 6: Example Dataset

	Area1	Area2	Total
Student in School	40	15	55
Students not in School	10	35	45
Total	50	50	100

So the dissimilarity (D) of access to school as defined in Equation 3.1 can be calculated as:

$$\frac{1}{2*0.55}\{(|0.8-0.55|*0.5)+\left(\left|0.3-0.55\right|*0.5\right)\}=0.227$$

Moreover, if we were to assume that the probability of access is independent of circumstances, i.e. probability of going to school is the same in Area1 and Area2, that would mean that Area1 and Area2 should both have 27.5 possible school placings. Our example indicates (Table 6) that Area1 currently has 12.5 excess opportunities while Area2 is in deficit of 12.5 opportunities. This is the number of opportunities that needs to be rearranged to restore equality. This divided by the total number of school opportunities available gives us the proportion of opportunities that are not allocated equitably. i.e. $\frac{12.5}{55}=0.227$

This implies that 23% of opportunities to attend school are not allocated equitably. Equation 3.1 can be defined for any number m of groups. In the above example, we had m = 2 groups (area1 and area2). This

natural interpretation of the D-Index holds because of the factor $\frac{1}{2\bar{p}}$ (See also Barros 2008 – End of Section 2.1).

We follow Barros et al 2008 in their construction of the D-Index and the HOI. Their methodology is based on the assumption that we have access to a random sample of the population with information on whether a child (i) had access or not to a given opportunity. We also have a vector of variables with his/her circumstances ($x_i = (x_{1i}, \ldots, x_{ni})$). We follow these steps to build the Human Opportunity Index:

1. We estimate a logistic regression to obtain the predicted probability of access $\hat{p}_i$ to an opportunity for each child in our sample. This regression is a function of his or her set of circumstances i.e. access to water is a function of circumstances such as gender of the child, gender of the head of household, education of the head of household etc.

2. Given the predicted probability of access ($\hat{p}_i$) from the logistic regression, we can calculate the overall coverage rate $\bar{p}$ for each opportunity which is defined as:

   $\bar{p} = \frac{1}{n}\sum_{i=1}^{n}\hat{p}_i$, where n is the number of children.

We note that by properties of logistic regression models, $\bar{p}$ also equals the overall probability of access to the opportunity.

3. We compute the dissimilarity D in access rates:

$$D = \frac{1}{2\bar{p}} \sum_{k=1}^{m} \left| p(y = 1|x_k) - \bar{p} \right| p\,(x = x_k).$$

Details of the D-Index can found in Appendix A.

4. HOI is then equal to the coverage rate multiplied by the similarity in access i.e. $\bar{p}\,(1 - D)$.

The HOI can thus be interpreted as the proportion of opportunities that are available and have been allocated equitably across circumstances in a given society. Based on the above example, the overall measure of educational opportunity will be given by:

$\bar{p}\,(1 - D)$ = 0.55*(1-0.227) = 0.42515

Therefore the overall measure of opportunity for going to school given the area of residence is 0.42515. In other words, 43% of educational opportunities are available and have been allocated equitably across circumstances. A higher HOI implies higher levels of coverage or lower levels of inequality of access.

We first consider the opportunity variables.

It is important to note here that "access" to these different opportunities does not take into consideration the level or quality of these services. An example is electricity where a child might be recorded to have access but this does not guarantee uninterrupted 24 hour service or high wattage. Low quality of service would certainly reduce the benefits of having access to electricity. These issues of quality also apply to education, water and sanitation. The fact that water is from a public stand pipe does not guarantee its cleanliness. Also with regard to education, we do not consider access to the different levels of education relative to circumstances, i.e. access to primary education, access to secondary education etc. Our dichotomous approach is a limitation and a possible direction for future research is to expand the opportunity variables from binary indicators to indicators with 3 or more levels and utilizing multinomial regression as a technique of choice.

Results

Coverage of Opportunities

We look at coverage rates of each opportunity (Table 7). Egypt has the highest coverage rate across the board for all the opportunities. Uganda has the lowest

coverage rates for electricity and durable floor. Zambia has the lowest coverage rates for water and sanitation. These coverage rates do not reflect the equality of distribution or whether children with different circumstances have better or less access to these services. They are a reflection of just how many children have access to these services.

Table 7: Coverage of Opportunities – calculated from the survey data

Coverage of Opportunities (in % for children ≤ 17 years of age)						
	Kenya	Uganda	Nigeria	Ghana	Egypt	Zambia
Electricity	20	8.1	46	50	99.5	20
Water	61	69	53	78	98	43
Sanitation	45	70	52	60	99.4	35
Durable Floor	38	22	59	79	86	39
Education	55	57	64	55	65	54

Dissimilarity Index: The D-Index

In order to compute the D-Index for the different opportunities (based on the methodology discussed above), we run logistic regressions by country to obtain the predicted probability of access $\hat{p}_i$ to an opportunity for each child in each country. For Kenya, a test of the full model against a constant only model for electricity was statistically significant, indicating that the predictors, as a set, reliably distinguished between access and no access to electricity in Kenya(chi square = 20316.913, p < .001 with df = 8). Prediction success overall was 92% (93.9% for no access and 83.5% for access. The Wald criterion demonstrated that all variables made a significant contribution to prediction (p = .001 for Gender Household Head while all other variables had p = 0.000). The Exp(B) – odds ratio confirms that children in the highest wealth index across all countries in our sample are most likely to have access to electricity. Egypt is an exception where the wealth index classification has no significance and does not determine the likelihood of access to electricity. Area of residence is also significant across all countries (with the exception of Egypt) where children who live in urban area are more likely to have access to electricity. Table 8 below shows the model summary

discussion for access to electricity for all six countries while tables 9 & 10 shows the regression coefficients for the logistic regression for access to electricity for all six countries. Tables of the Regression results and discussion of fit for the other opportunities can be found in the Appendix B; Tables 22 - 33.

Table 8: Access to Electricity - Model Fit Discussion

	Uganda	Kenya	Ghana	Nigeria	Egypt	Zambia
Overall Model Fit	**Sig:** 0.000	**Sig:** 0.000	**Sig:** 0.000	**Sig:** 0.000	**Sig:** 0.000	**Sig:** 0.000
Prediction Success Overall	93.4%	92%	86.2%	85.7%	99.5	95.3%

Our logistic models reveal that the education of the household head is an important determinant for access to electricity in all the countries under study except for Ghana (Tables 9 & 10). With regard to electricity, area of residence is also significant for all countries with the exception of Egypt. This is intuitive as Egypt has 99.5% coverage so Egypt currently provides universal access to electricity regardless of area of residence. Access to electricity in Egypt as a % of population was reported at 99.8% in 2014 according to

the World Bank collection of development indicators (tradingeconomics.com). We see that a female as head of household in Ghana is more likely to influence access to electricity rather than a male head of household. This result can be understood when placed in context as Ghana is a matrilineal society where descent is traced through the mother and maternal ancestors. In a matrilineal society, an individual is considered to belong to the same descent group as his/her mother. Thus the female is culturally considered to be the head of the household and in some cases last names are handed down from mother to daughter. We also find that parental education matters with regard to access to electricity, sanitation and education in Africa. Area of residence is also an important factor for access to electricity, water and sanitation (Tables in Appendix B). Urban and class biases could explain this result as it has been shown that electrification efforts for example focus first on urban customers as cities have higher population density and also tend to have more economic, political and cultural influences (UNDESA, 2014).

We compute the D – Index based on the results of the logistic regression. This allows us to calculate the level of inequality for these opportunities in the six

countries selected for this study. It is important to note here that the process is consistent whether we keep or drop the non-significant variables in our calculation of the D – Index. Following Barros et al (2008), we have decided to keep the non-significant coefficients in the calculation as the D – Index was not materially different without the inclusion of the non-significant coefficients. We keep the coefficients because we want our calculations to be consistent across all countries i.e. the same variables are going into the calculations for each country. In general the signs of the coefficients are as expected but in cases where they are contrary to our expectations, we keep all the coefficients at their estimated values as it enables us to be consistent with the process to make it applicable across all African countries. For example, one might argue that intuitively you would expect that urban areas should have greater access to opportunities than rural areas. However, in the case of Zambia, our regression coefficients for electricity seem to indicate that access to electricity is more likely in rural areas ceteris paribus. Data from the AFDB shows that a majority of the population in Zambia reside in rural areas with a 65% ratio (AFDB 2008b).

Table 9: Logistic Regression Results - Access to Electricity

	Uganda			Kenya			Ghana		
	B	**S.E.**	**Exp(B)**	**B**	**S.E.**	**Exp(B)**	**B**	**S.E.**	**Exp(B)**
Gender	-0.013	0.046	0.988	-0.145*	0.041	0.865	0.047	0.030	1.048
Gender HH	0.095	0.051	1.100	0.158*	0.047	1.171	-0.122*	0.032	0.885
Educ HH	0.205*	0.054	1.228	0.248*	0.048	1.281	0.047	0.030	1.048
Area	1.550*	0.046	4.711	0.635*	0.047	1.88	0.233*	0.035	1.263
W – Second	15.213	424.12	4046.92	1.816*	0.471	6.15	2.304*	0.060	10.009
W – Middle	14.986	424.115	3223.69	3.294*	0.454	26.94	3.978*	0.061	53.416
W – Fourth	15.70	424.12	6550.89	5.178*	0.441	177.35	5.693*	0.071	296.840
W – Highest	19.88	424.12	4306.82	7.878*	0.441	2638.43	7.457*	0.110	1732.71
Constant	-21.43	424.12	0.020	-7.466	0.432	0.001	-3.499	0.062	0.030

significant at 0.05 level

Table 10: Logistic Regression Results - Access to Electricity

	Nigeria			Egypt			Zambia		
	B	S.E.	Exp(B)	B	S.E.	Exp(B)	B	S.E.	Exp(B)
Gender	0.001	0.028	1.001	0.075	0.094	1.078	-0.014	0.053	0.986
Gender HH	0.003	0.038	1.003	0.013	0.152	1.013	0.322*	0.068	1.380
Educ HH	-0.084*	0.033	0.920	0.179*	0.094	1.196	0.177*	0.062	1.194
Area	1.166*	0.033	3.208	0.130	0.151	1.139	-0.667*	0.070	0.513
W – Second	2.302*	0.085	9.997	4.007	0.357	54.966	1.585	47.227	4.879
W – Middle	3.673*	0.084	39.364	3.492	18.981	32.864	1.578	54.328	4.845
W – Fourth	5.619*	0.087	275.541	3.504	21.441	33.248	1.968	32.425	7.156
W – Highest	6.770*	0.101	871.365	3.414	13.957	30.387	2.403	28.327	11.056
Constant	-4.196	0.089	0.015	3.594	0.152	36.385	-2.157	47.227	0.020

significant at 0.05 level

The D – Index enables us to analyze the inequality of opportunity in electricity, education, water, sanitation and durable floor. Given the predicted probabilities of access for each child ($\hat{p}_i$) from the logistic regression, we can calculate the overall coverage rate in each country which is defined as $\bar{p} = \frac{1}{n}\sum_{i=1}^{n}\hat{p}_i$ where n is the number of children in the country.

Note that for a given country and opportunity, children are split into $m = 2^8$circumstance groups corresponding to the set of circumstances of the child. Consequently,

$\hat{p}_i$ is the same for all children within the same circumstance group and so, from Equation 3.1,

$$D = \frac{1}{2\bar{p}} \sum_{k=1}^{m} \left| \hat{p}_i - \bar{p} \right| * (\#\ of\ children\ in\ group\ k\ /n)$$

$$= \frac{1}{2n\bar{p}} \sum_{k=1}^{m} \left| \hat{p}_i - \bar{p} \right| \#\ of\ children\ in\ group\ k$$

It follows that:

$$D = \frac{1}{2n\bar{p}} \sum_{i=1}^{n} \left| \hat{p}_i - \bar{p} \right|$$

A lower D – Index indicates greater equity while a higher D – Index indicates lower equity in the distribution of each opportunity. Recall that we can interpret the D – Index as the share of each opportunity that is not allocated equitably (See Example A). Egypt has the lowest level of inequality of opportunity (electricity) with a D – Index of 2% while Uganda has the highest with a D- Index of 77% followed by Zambia at 66% (Table 11).

In light of the D – Index calculations above, we can infer that in the case of Egypt, only 2% (Table 11) of the available electricity (99.5% coverage – see Table 7) is not allocated equitably. With respect to the other countries, Uganda shows higher levels of inequality of opportunity for electricity (77%) and flooring (64%). This implies that 77 percent (Table 11)

of the available electricity (8.1% coverage - Table 7) in Uganda is not allocated equitably across circumstance groups. This high level of inequality is associated with low levels of electricity coverage in Uganda (8.1% - Table 7). A country like Egypt which has high coverage rates is associated with low levels of inequality. This is intuitive as countries with high coverage are bound to have low inequality in access because almost everybody has access; there can then be no group that is systematically without access. These selected examples indicate that changes in average access to a basic opportunity may be accompanied by changes in inequality of access.

Table 11: D - Index

	Uganda	Kenya	Ghana	Nigeria	Egypt	Zambia
Electricity	77	63	36	41	2	66
Water	6	15	4	19	1.5	34
Sanitation	12	30	22	21	1.5	37
Floor	64	51	13	33	8	51
Education	35	32	30	32	33	26

Human Opportunity Index

The HOI is the combination of two components: the coverage rate and the index of inequality of opportunity – distribution of access. It allows us to estimate how equitably available opportunities are allocated across circumstances with regard to children in a country. Our results indicate that Egypt stands

out with regard to electricity, water and sanitation. These three opportunities exhibit the highest level of both access and equality of access. In Uganda and Zambia respectively, only 2% and 7% of electricity is available and allocated equitably (Table 12).

The overall Human Opportunity Index is estimated to be the average of all the summary HOI indices (Barros, 2008). It gives us a picture of how equitably available opportunities have been allocated. That analysis indicates that Egypt has the highest HOI (83%), Ghana is second (48%) while Nigeria is third (39%) and this is followed by Uganda (31%), Kenya (26%) and Zambia (20%) respectively (Table 12). This indicates that Egypt is very different and has a much higher degree of equality of opportunity than the other African countries. Egypt though an African country is also considered as a part of the Middle Eastern countries. It has thus enjoyed trade and relations with other Middle Eastern countries leading to higher levels of development than other traditional African countries. This can also be said to be true for other Northern African countries that are considered a part of the greater Middle East. One might be surprised to see that Ghana has a higher HOI than Nigeria. This is interesting as Nigeria is considered to be an oil rich

nation and the giant of Africa. Unfortunately years of military rule and high levels of corruption have ensured that the majority of Nigeria's citizens are very poor and cannot enjoy basic opportunities. Ghana on the other hand has been turning things around and has become one of the fastest growing economies in Africa. Despite years of military rule, an economic recovery program was established in 1983 which began to encourage economic recovery. Ghana also became a democratic society again in 1992 and has enjoyed a stable democracy.

Alternatively we see a case for using the geometric mean rather than the average of the HOI indices for our five opportunities to calculate the overall Human Opportunity Index. Our case is based on the premise that if we multiply all five coverage rates, we obtain the coverage rate for all opportunities and if we multiply all five "(1-Ds)", we estimate the probability that all five opportunities are correctly allocated. We found that the top three countries in our sample remained the same with Egypt having the highest HOI followed by Ghana and then Nigeria. The order for the bottom three countries changed with Kenya having the fourth highest overall HOI, followed by Zambia and lastly Uganda with the lowest HOI. Given that we have a

small number of opportunities, it would be interesting to see how much of a difference arises if you use the geometric mean rather than average to calculate the overall HOI index when you have a larger sample of opportunities. An interesting finding is that countries can rank differently when measuring different opportunities. For instance Uganda performs relatively well for water and sanitation but relatively poorly for electricity and flooring. Zambia though ranks consistently across most dimensions with the exception of electricity (which is the lowest).

Table 12: Human Opportunity Index

	Uganda	Kenya	Ghana	Nigeria	Egypt	Zambia
Electricity	2	7	32	26	100	7
Water	63	51	75	43	91	28
Sanitation	61	31	47	41	100	24
Floor	8	19	68	39	82	19
Education	21	20	19	44	43	21
Overall[1]	31	26	48	39	83	20
Overall[2]	17	21	43	38	80	18

1-Average, 2-Geometric mean

Conclusions, New Directions and Limitations

Equality of opportunity is about leveling the playing field for everyone from the beginning of their lives. In a region such as the African region which is characterized by pervasive inequality of education, health, and income opportunities to name a few, and

where groups of the population are left out of socioeconomic progress, a shift in the debate toward equality of opportunities has a strong potential to be a better guide for public policy (Barros et al. 2008). It represents a shift in the debate and in the attention of policy makers, who recognize that much more progress can be made if countries confer a sense of urgency to the need to give the same chances to all (UN Habitat, 2010). To do that, measuring inequality of opportunity—better, deeper, and more systematically is valuable.

The Human Opportunity Index is one such measure and it provides us with an understanding of the level of equality of opportunity. Equality of opportunity guarantees that basic opportunities necessary for the development and growth of a child are distributed equally regardless of his/her circumstances. It is a very important policy instrument because it guides government and policy makers in not only the provision of basic opportunities but also the equitable allocation of these opportunities.

This study uses comparable data based on DHS surveys to identify circumstances which affect access and inequality of opportunity. We find that parental education matters with regard to access to electricity,

sanitation and education in Africa. Area of residence is also an important factor for access to electricity, water and sanitation (Tables in Appendix B). Our results are consistent with the study by Barros et al (2008) on Latin American countries where they found that in addition to birth place, parental education is important for access to schooling and access to water and sanitation. Here, our study extends the work of Barros et al by validating that parental education is an important factor in access to opportunities in Africa similar to Latin America.

Similar to our results, the UN Habitat study on the state of the urban youth and the study by Velez et al (2012) also found that parents' education and area of residence both have key impacts on inequality of opportunity. In addition, they find that circumstances such as gender, income per capita, father's occupation as well as number of siblings have an impact on youth inequality of opportunity. We also add to the work by Velez and colleagues by expanding the scope on the number of countries where we consider five additional countries in addition to Egypt. We find that parental education and area of residence are important not only in Egypt but in other African countries as well. We validate the UN-Habitat survey study by quantifying

these effects further through a quantitative research application of the Human Opportunity Index to these opportunities and circumstances.

Our study identified that area of residence is also an important factor for access to electricity, water and sanitation. Access to clean water and sanitation are key to a healthy society and similar to the literature, our results are consistent with Ataguba and colleagues, Mutangadura et al (2007) and Sahn and Sitfel (2004) who all found that the rural/urban divide had a significant impact on health inequaities in Africa. We join the call from these authors that it is imperative that specific policies geared towards improving geographical access to health opportunities are prioritized by African governments.

This study has focused on six countries – Egypt, Ghana, Nigeria, Kenya, Uganda and Zambia which span across Africa. Though our sample is limited with only six countries, these countries cut across the full spectrum with regard to macro economic indicators such as GDP per capita and enable us to project our results from this study across the African continent.

This study provides a useful base for future studies. It is a good foundation for case study investigation and action. Egypt has been highlighted as a "success"

with low levels of inequality. It would be interesting to explore this further through case studies to determine factors that have encouraged this growth and how other African countries can leverage on the Egypt experience. Future research should also expand the pool of countries to all African countries. This would enable us to examine results not only on the country level but also on a regional basis within Africa. Methodologically, this study can be improved by expanding the opportunity variables from binary indicators to indicators with 3 or more levels and utilizing multinomial regression as a technique of choice.

The study can also be extended to cover other areas of the analytical framework that was shared earlier. Based on data availability we were limited to the study of inequality of opportunity based on circumstances beyond the individuals control. Other aspects of the framework such as inequality due to differences in social treatment or discrimination would make for useful and interesting research.

The opportunities and circumstance variables considered in this study can also be expanded. The opportunities and circumstances considered in this study were selected based on availability of data. It would be

interesting to see if we get the same results or different results if we have an expanded set of opportunity variables or a different set of variables all together. The opportunities considered in this study such as ensuring access to education, water and sanitation are targets with the Millennium Development goals framework (Goals 2 and 7 of the MDGs). Goal 2 - Target 2A aims to ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling. Goal 7 - Target 7.C is a call to halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation. Opportunities can be expanded to include additional health MDG targets such as (Reduce by two-thirds, between 1990 and 2015, the under-five mortality rate using proxies such as child mortality rate).

Given the fact that the opportunities we consider in our study are a part of the MDG targets, we argue that the HOI index is a useful tool that can be employed in the bid to achieving the MDG goals. One of the benefits of the HOI index is that it highlights the degree of inequality with regard to opportunities and also some of the circumstances that might be inhibiting equality particularly on an individual country basis. This would

be useful for countries and policy makers as they can better understand the circumstances that foster inequality and in turn formulate policies that help level the playing field within these opportunities.

This study is innovative in the African context as it expands the body of work on the Human Opportunity Index to African countries with the application and calculation of the HOI for selected African countries. This has enabled us to quantify the inequality of opportunity for children within these countries. These results are important for policy discussions as they highlight the success story of a country like Egypt relative to other countries. This is a basis for future research as this "star" country could be explored in greater detail. This research contributes to the policy debate by providing a policy instrument that would guide policy makers in the equal provision of basic opportunities for all. This study also contributes to the body of work on inequality of opportunity in developing countries as it focuses particularly on a representative sample of African countries. As a result of the surveys employed in this study we are also able to make comparable analyses across countries which was a limitation identified in prior research (Pasquier-Doumer, 2013).

3. Millennium Development Goals in Africa – Synergies, achievements, evolution and progress

3.1. Unraveling the synergies between the Millennium Development Goals

Introduction

A decade has passed since the declaration of the Millennium Development Goals (MDGs) by the United Nations (UN) in September of 2000. The MDGs were signed by 189 country leaders, and since 2002 represent the policy of 192 UN member states. This policy formally recognizes the need for assisting impoverished economies. The declaration has also set out a number of specific targets that are expected to be met by 2015. Therefore, as a basis for a more detailed structure of the MDGs, eight goals, 18 targets, and 48 indicators constitute the MDG framework. Following the UN summit in 2005, this framework was updated to incorporate 20 targets and 60 indicators.

The MDGs were intended as a benevolent tool for advocating greater development efforts in poor countries, especially those in Africa (Easterly, 2009). Several studies have set forth guidelines to monitor and assess the progress of the MDGs (Deaton, 2003; Sali-i-Martin, 2006; United Nations, 2009). However, there are limited studies on how the MDG goals

complement each other. Larson et al. (2006) pointed out that limited empirical analysis exists in identifying the complementarities among these MDG targets. For countries with scarce resources like African countries, trying to achieve all the goals and targets of the MDGs may result unfortunately in not attaining any at all. It is therefore important to determine what areas an economy's scarce resources should be allocated in order to achieve the best result.

This study therefore attempts to identify the synergies and complementary relationships among the MDG goals so as to determine the goals that can be prioritized and that would in turn have a cascading effect on other goals. Given the interrelationships among the goals, it is likely that one economy's competitive advantage in achieving one or more goals may not be another's prerogative. Therefore, our study investigates the synergies between the MDGs in order to facilitate the achievement of an effective and efficient best outcome in Africa. This paper applies the techniques of directed acyclic graphs and partial least squares in order to better understand the links between the eight MDGs in the African context. We analyse all eight MDGs with variables that represent their corresponding

targets (Table 13). In total, we examine eighteen (18) indicators for 48 African countries. Our choice of indicators and targets is based on the indicators for which we have comprehensive data availability.

Following a special summit session held by the UN General Assembly in September 2010 to review the progress of the MDGs, the likelihood exists for expanded discussion on the push to secure maximum progress on the various goals at the international level by 2015 (see, for example, *The Economist*, 2010). We believe that our study is timely and invaluable to the member states of the UN General Assembly in understanding the progress of the MDGs, especially with regard to Africa. We seek to contribute to the growing literature on the MDGs by examining how best Africa can achieve the seemingly insurmountable goals of the MDGs through the effective prioritization of specific goals.

This paper is organized as follows: The next section reviews relevant literature on the MDG initiatives and the achievement of the goals. We decscribe our dataset and go ahead to perform our analyses and investigate the linkages and synergies between the MDGs. We also discuss in detail the methodologies to be employed and present and discuss the results. And finally we share

our conclusions, draw implications, highlight drawbacks and make some suggestions for further studies.

Literature Review

The pledge by all members of the United Nations to meet the eight MDGs by the year 2015, has given rise to a considerable amount of literature For example, Hulme (2009, p. 47) regarded the MDGs as a "product of intense political negotiation informed by analytical work", a product of global public policy rather than as a result of technical and empirical analysis. Further, he refers to them as the "world's biggest promise", intended to reduce poverty and human deprivation collaboratively. The UN declaration is simple and ambitious. In short, it aims at reducing the poverty rate by half compared to its 1995 level; attaining a universal primary education enrollment by 2015; gender equality; reducing by two-thirds the child mortality rate; reducing by three-quarters the maternal mortality rate; fighting HIV/AIDS, TB, and malaria; reducing the proportion of people without clean water by half; and increasing global partnership for development. A complete overview of the MDGs can be found on the UN's web site at http://www.un.org/millenniumgoals/, with an update on the September 2010 summit available at http://www.un.org/en/mdg/summit2010/.

A few studies have considered the interdependencies among the MDG goals (Larson et al, 2006; Fielding et al. 2005, Wiebe, 2009). Larson et al, (2006) found that the achievement of poverty, education, and drinking water targets, are not independent endeavors. They noted in their study that reducing poverty and improving education will alter household choices related to water access. Improving access to water could lead to the intended result of expanding actual water use by households. Increasing quantities of potable water used by households for hygienic purposes could then lead to a reduction in under-five mortality rates. Fielding et al, 2005 also found that higher levels of sanitation and education are associated with lower mortality rates. Weibe, (2009) found that increasing the net primary enrollment rate is complementary to reducing the under-5 mortality rate and to increasing the proportion of the population with access to improved water sources. Given these inter-dependencies, they wondered why little empirical analysis exists to identify the complementarities among these MDG targets. It is therefore intuitive for governments to realize the importance of prioritizing actions in the design of policies to achieve the stated targets.

Mixed study results about the progress of the MDGs notwithstanding, the UNDP (2003) study suggests that most developing countries are on track. On the other hand, sub-Saharan African countries are not even remotely close to achieving the goals by 2015, especially goal number one - eradicate extreme poverty and hunger. Further, the study pointed out that it would take about 132 additional years (by 2147) for sub-Saharan Africa to achieve the income poverty target even among optimistic forecasts (UNDP, 2003). They also note that it will take Sub-Saharan Africa until 2129 to achieve universal primary education and until 2165 to cut child mortality by two-thirds.

Economists have long been aware of the importance of links between the various well-being dimensions and their implications for poverty. Studies have looked at ways in which material wealth or income of a population is linked to standards of education and health, and also to fertility (Becker, 1981). Findings indicate that average standards of education and health are elements of human capital that are likely to determine a region's overall productivity level, and hence its *per capita* income. On the other hand, due to lowering returns to scale, higher fertility and population growth lead to lower labor productivity. Yet, other

things being equal, a household's decision about human capital investment and the number of children to produce may depend on its current income level, especially with imperfect capital markets.

MDG Progress in Africa

Progress or lack of progress in achieving the MDGs by member countries can sometimes be obscured by a number of factors. Studies by Fukuda-Parr (2010), Leo and Barmeier (2010), Easterly (2009), and Clement, Kenny and Moss (2007) noted that the MDGs were unrealistically ambitious for some regions and countries. They are seen as a set up for failure for most Sub-Saharan countries because they start off at a low base and it would take a monumental task to achieve that goal. It would take, for example, 41 percentage points, on average, by a low-income country to achieve the MDG goal on education. Easterly (2009) is one of the more vociferous critics of the MDGs, particularly with regard to their implications for Sub-Saharan Africa. Citing several accounts of the regions "failure" to meet the goals, he points out that the methodology of analysis is problematic and unfair to Africa. He criticizes the benchmark year, linearity of data, absolute versus percentage changes, and the relative nature of targets and indicators as arbitrary

and inconsistent across the goals. He goes on to review what he calls a "bias against Africa" in the case of each of the goals, adding that bad press as a failed region does not help Africa's prospects for development. Much of Easterly's (2009) paper is informed by the underlying criticism of international development policy laid out in more detail in his 2006 book *The White Man's Burden: Why the West's Efforts to Aid the Rest Have Done So Much Ill and So Little Good.*

Fukuda-Parr (2010) succinctly pointed out that in most countries and with regard to most indicators, MDGs should be used as benchmarks of progress rather than fixating on attaining a specific level of output. Progress should be evaluated by asking whether since implementation, the pace of poverty reduction has accelerated along the dimensions of the MDG goals. Leo and Barmeier (2010) documented that in spite of Africa's poverty, about 5 of the top 15 star MDG performers in their sample of only 76 countries (50% African countries), were from Africa. This also agrees with their observation on large African MDG laggards like Nigeria and the Democratic Republic of Congo, which weigh down regional aggregates thus presenting the picture that Africa as a whole has failed. On the other hand, Africa's progress in ICT, for example, is

championed by a handful of outlier countries including Seychelles, Mauritius, Cape Verde, Tunisia, Morocco, Botswana, and South Africa. These outlier countries raise the regional aggregates positively while hiding the struggles of their other African counterparts.

Leo and Barmeier (2010) found countries that they refer to as the MDG "trailblazers" in their working paper for the Center for Global Development. They included index plots supported by goal-specific performance tables with scorecards for each country in their results. They found evidence of overall progress in Honduras, Laos, Ethiopia, Uganda, Burkina Faso, Nepal, Cambodia, and Ghana, pointing out that some of the best performances are to be found in sub-Saharan countries, contrary to Easterly's (2009) expectations. The countries that showed the most disappointing scores included Afghanistan, Burundi, the Democratic Republic of Congo, and Guinea-Bissau.

The Overseas Development Institute (ODI, 2010), provides a succinct report summarizing "the Big Picture" with an MDG report card. For absolute progress (based on aggregated rankings across the first seven MDGs, the Institute highlights Benin, Mali, Ethiopia, Gambia, Malawi, Vietnam, Uganda, Nepal, India, Cambodia, Bangladesh, Honduras, Mauritania, Ghana,

China, Burkina Faso, Rwanda, Nicaragua, Guatemala, and Togo. Acknowledging some data limitations, the authors also caution that their findings do not suggest that "all boats are rising" within these countries. The report also lists countries that have made progress relative to MDG targets overall, and with regard to each of the specific targets, but fails to list those countries that fall short.

Several more recent empirical studies also endeavor to assess MDG success. AbouZahr & Boerma (2010) find evidence of extremely uneven progress. Globally, for example, they see a fall in child mortality, greater access to safe water, and decline in HIV infections and tuberculosis. They note daunting challenges in bringing safe water and sanitation to many low-income countries.

The trans-disciplinary team of Lozano et al. (2011) track the progress of the health MDGs – specifically Goals 4 and 5 (maternal and child mortality). They update and remodel their estimated systematic analysis of 2010 with data from 2011, enabling them to show a significant decline in deaths under the age of five (Goal 4) and maternal mortality (Goal 5). Although the pace of progress is slow across the developing world, they find evidence that a total of 44 countries will

achieve at least one of these goals, and nine countries will achieve both.

The United Nations (2011) produces an annual Millennium Development Goals Report. The 2011 report cites empirical evidence that overall, poverty is in decline, and that some of the world's poorest countries (mainly in Sub-Saharan Africa) have made the greatest improvements toward education yardsticks. Child mortality is in decline, while HIV-related and tuberculosis deaths have all dropped dramatically since 2000. While every region has shown improvement in access to clean drinking water, the report points out that women and children in the world's poorest regions, particularly in rural areas and locations prone to conflict, continue to struggle in obtaining sanitary conditions and employment prospects.

The literature on MDGs represents different points of view expressed by both academics and professionals about the purposes and intentions of the MDGs. These range from a crucial mid-station on the path to ending extreme poverty by the year 2025 (Sachs, 2005), to poorly and arbitrarily designed goals designed to measure progress against poverty and deprivation while making Africa look worse than it really is (Easterly,

2009), to a view that the MDGs are simply a feel-good gimmick (Antrobus, 2003).

Research Questions

Notwithstanding these divergent perspectives, given the harsh realities of economic hardship experienced in poor countries, it would be difficult to dispute the MDG framers' belief that socioeconomic advancement can be made. The literature discussion above affirms that inter-dependencies exist among the MDG targets, which would impact the progress of achieving the MDGs. Therefore, to identify the complementarities that exist among the MDG targets, we develop the following research questions (RQ):

RQ1. Are there significant positive linkages that exist among the MDG targets in Africa?

RQ2. Based on these linkages, what goals can we identify as priority goals in Africa that would have a cascading effect on other goals?

Data

Our dataset, explained in Table 13, represents a subset of the official yardsticks/indicators set forth by the United Nations to assess the eight MDGs. For the purpose of this research study, we will examine 18

indicators which represent a smaller set of the targets and indicators as limited data was available across the 60 indicators for all the 48 African countries under consideration.

The MDGs were officially declared in the year 2000 but for the purpose of our analysis, we examine the most recent years available to us (2008 – 2010). For each country, we average the data for each variable from 2008 to 2010. In order to avoid the elimination of a whole country's data due to missing values of one or two observations, we use multiple imputation models in the statistics module of PASW (SPSS 19) to handle missing values in the dataset – specifically the fully conditional specification (FCS).

The fully conditional specification (FCS) is an iterative Markov chain Monte Carlo (MCMC) method that can be used when the pattern of missing data is arbitrary. For each iteration and for each variable in the order specified in the variable list, the fully conditional specification (FCS) method fits a univariate (single dependent variable) model (linear regression) using all other available variables in the model as predictors, then imputes missing values for the variable being fit. The method continues until the maximum number of iterations is reached, and the

imputed values at the maximum iteration are saved to the imputed dataset. The FCS method uses the default number of 10 iterations unless otherwise stated. We refer to PASW Missing Values (2011) for a detailed description. Pre-analysis, the data was checked against TETRAD assumptions (normality and linearity). These assumptions are discussed further in the methodology section.

To construct the Directed Acyclic Graphs (DAGs), we take the average of the specific indicators related to each goal from Table 13 and then take the log. For example with regard to Goal 1 which is focused on eradicating extreme poverty and hunger, we take the average of the poverty gap ratio, the employment to population ratio and the proportion of "prevalence of under weight children" and then take the log. The Goal 1 variable in the DAG model is thus made up of the log of the average of all three indicators. The PLS model which is based on the result of the DAG analysis is then built on the individual indicators associated with each Goal in the DAG. For example, the Poverty construct (Goal 1) has three measured variables – the poverty gap ratio, the employment to population ratio and the proportion of prevalence of under weight

children. All variables outlined in Table 13 are utilized in both the DAGs and the PLS models.

Table 13: MDG Goals - Selected targets and indicators in our model

Millennium Development Goals (MDGs)	
Goals and Targets	**Indicators**
Goal 1: Eradicate extreme poverty and hunger (Poverty)	
Target 1.A: Halve, between 1990 and 2015, the proportion of people whose income is less than one dollar a day	Poverty gap ratio *
Target 1.B: Achieve full and productive employment and decent work for all, including women and young people	Employment-to-population ratio
Target 1.C: Halve, between 1990 and 2015, the proportion of people who suffer from hunger	Prevalence of underweight children under-five years of age
Goal 2: Achieve universal primary education (PrimaryEducation)	
Target 2.A: Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling	Net enrolment ratio in primary education Proportion of pupils starting grade 1 who reach last grade of primary Literacy rate of 15 – 24 year olds, women and men
Goal 3: Promote gender equality and empower women (GenderEquality)	
Target 3.A: Eliminate gender disparity in primary and secondary education, preferably by 2005, and in all levels of education no later than 2015	Ratios of girls to boys in primary and secondary education
Goal 4: Reduce child mortality (ChildMortality)	
Target 4.A: Reduce by two-thirds, between 1990 and 2015, the under-five mortality rate	Under-five mortality rate Infant mortality rate
Goal 5: Improve maternal health (MaternalHealth)	
Target 5.A: Reduce by three quarters, between 1990 and 2015, the maternal mortality ratio	Proportion of births attended by skilled health personnel
Goal 6: Combat HIV/AIDS, malaria and other diseases (Disease)	
Target 6.A: Have halted by 2015 and begun to reverse the spread of HIV/AIDS	HIV prevalence among population aged 15-24 years
Target 6.C: Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases	Incidence, prevalence and death rates associated with tuberculosis
Goal 7: Ensure environmental sustainability (H2O_SAN)	
Target 7.C: Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation	Proportion of population using an improved drinking water source

	▪ Proportion of population using an improved sanitation facility
Goal 8: Develop a global partnership for development (ICT)	
Target 8.F: In cooperation with the private sector, make available the benefits of new technologies, especially information and communications	▪ Fixed telephone lines per 100 inhabitants ▪ Mobile cellular subscriptions per 100 inhabitants ▪ Internet users per 100 inhabitants

**Poverty gap ratio is defined as the average poverty gap in the population as a proportion of the poverty line*
Data Source: United Nation (2010) MDG dataset: http://mdgs.un.org/unsd/mdg/Data.aspx (accessed 20 April 2013)

Table 14: Summary Statistics – Dataset (2008 – 2010)

DAG Variable/ PLS Latent Construct	Measured Indicators	Mean	Median	Min	Max	Std Dev
Poverty	Poverty Gap Ratio	18.76	17.88	0.5	40.80	11.28
	Employment to Population Ratio	61.81	64.62	39.87	83.80	13.63
	Ratio of Underweight Children	18.09	17.23	0.87	39.90	7.91
Primary Education	Net Enrollment Ratio - Primary	80.26	83.04	40.88	109.07	15.76
	Proportion of students who finish Grade 6	64.89	66.80	27.80	97.20	17.04
	Literacy rate of 15 – 24 year olds	75.74	77.55	24.64	99.10	17.72
Gender Equality	Ratio of Girls to Boys in Primary School	0.92	0.94	0.70	1.04	0.08
	Ratio of Girls to Boys in Secondary School	0.84	0.83	0.41	1.35	0.20
Child Mortality	Under five mortality rate per 1000	98.31	98.87	13.82	185.50	45.54
	Infant mortality rate per 1000 live births	63.17	64.32	11.78	113.90	25.95
Maternal Health	Proportion of births attended by skilled health personnel	61.95	60.98	17.70	100.56	20.91
Disease	HIV Prevalence ratio	6.09	3.35	0.10	25.83	6.99
	TB Incidence Rates	349.14	311.24	21.74	1169.47	247.85
Water_Sanitation	Proportion of population with improved drinking water	72.32	72.10	42.00	115.42	17.22
	Proportion of population with improved sanitation	39.41	32.20	9.00	95.30	25.36

ICT	Fixed telephone lines per 100 inhabitants	3.94	1.31	0.04	28.74	6.21
	Mobile cell subscriptions per 100 inhabitants	37.80	30.93	2.32	109.62	25.07
	Internet users per 100 inhabitants	7.30	4.48	0.48	38.69	8.45

Methodology

Directed Acyclic Graphs

Using directed acyclic graphs (DAGs) and subsequently partial least squares (PLS), this study attempts to identify and assess the linkages between the MDGs. In evaluating the above objective, this study considers the following research question: What linkages exist between the eight MDGs? How are the goals linked together in Africa? Directed acyclic graphs allow us to identify potential directions of association between variables in our dataset while also identifying variables that have common antecedents; even if these antecedents are not known.

Directed Acyclic Graphs as a technique has been applied in a number of related studies. Haughton et al., (2006), and Haughton and Haughton (2011), emphasize that DAG modeling is a powerful analytic tool to consider in conjunction with, or in place of, path analysis, structural equation modeling, and other statistical techniques. In the case of this paper, we will be using DAGs modeling in conjunction with partial least squares. Eshghi et al. (2007) investigated the

determinants of customer loyalty among wireless service providers by applying DAGs to derive causal models under restrictive conditions. Similarly, Bessler (2003) and Bryant et al. (2009) used DAGs to sort-out causal patterns among sets of measures deemed relevant to the incidence of world poverty and disproving causal relationships using observational data, respectively. It is important to note here that categorically establishing causality relations using DAGs is quite hard if not impossible to accomplish given a number of strong assumptions that need to be satisfied (one of which is: the dataset is a causally sufficient set of variables i.e. all causal variables are included in the data). For the purpose of this paper, DAGs will give us some useful insights into the directed linkages that might exist within the MDG goals. The goal of this study is to first investigate the directional relationships among the Millennium development goals in Africa using DAGs. We then build upon the results of the DAGs to estimate structural equation models which would confirm the linkages that we have identified among the MDGs.

Directed acyclic graphs enable us to identify both linkages between variables and also sets of variables that have common latent causes which might not be

present in the dataset. A directed acyclic graph is a picture representing the directional links among a set of variables. It is a path diagram that shows the path between variables. Consider a set of variables, X, Y and Z. The variables are called vertices in the graph while the linkages between the variables/vertices are known as edges. The symbols attached to the end of the edges are called marks. A directional fork where X is an antecedent of both Y and Z can be shown as Y ← X→ Z. A graph contains an ordered triple <V, M, E> where V is a non-empty set of vertices (variables), M is a non-empty set of marks (symbols attached to the end of undirected edges) and E is a set of ordered pairs where each member of E is called an edge (Bessler 2003, Zhang et al. 2006).

Vertices (variables) linked by an edge are considered adjacent. Given a set of vertices, {Primary Education (P.E), Water (H2O), Sanitation (SAN)}, an undirected edge, i.e. P.E, – H2O indicates that either variable causes the other or they share a common latent cause or both. A directed edge, i.e. H2O → SAN, represents an edge where water has a directed effect on sanitation. A directed acyclic graph is different from a directed graph in that it has no directed cyclic paths. That is,

a directed acyclic graph has no path that leads away from a variable only to return to that same variable.

Directed Acyclic Graphs are directional pictures where the variables are represented by nodes, and the edges represent the conditional dependence among the variables (Haughton et al 2006, see also Haughton and Haughton 2011, chapter 5). An example of a directed acyclic graph is in Figure 3 below. A directed edge from GDP to Mobile indicates that GDP is an antecedent of Mobile.

For each directed acyclic graph, a set of conditional independence relations are associated among the variables in the dataset. Let $V_1 \ldots V_n$ be the set of variables in the dataset and let antecedent (V_i) represent the set of antecedents of each variable V_i, i.e. variables with an arrow leading directly to each V_i. A DAG represents conditional independence relations f among the variables:

$$f(V_1 \ldots V_n) = \prod_{i=1}^{n} f\left(V_i \middle| antecedent(V_i)\right) \qquad Equation\ 4.1$$

where on the left hand side, f is the probability of events for each variable $V_1 \ldots V_n$ and on the right side, each term represents the conditional probability distribution function of each variable V_i given its

antecedents (Bessler 2003, Eshghi et al 2007, Haughton et al, 2006, Zhang et al 2006, Haughton and Haughton, 2011). This implies that each variable is dependent only on its immediate antecedents (Pearl, 2000). For a simple example of DAGs (adapted from Haughton and Haughton, 2011), consider three variables {Primary Education (P.E), Water (H2O), Sanitation (SAN)} and three cases:

1. $P.E \rightarrow H2O \leftarrow SAN$: Primary education is linked to water and Sanitation is linked to water but primary education and sanitation are not directly linked i.e. they are unconditionally independent because water blocks the paths from primary education to sanitation. Water in this case is a collider and we can only infer that primary education and sanitation are dependent given water.

2. $P.E \leftarrow H2O \rightarrow SAN$: In this case, primary education and sanitation have a common cause – water. This implies that they are not independent. If we condition on water though, then primary education and sanitation are independent given water.

3. $P.E \rightarrow H2O \rightarrow SAN$: Primary education and Sanitation are independent if we condition on water. Water is dependent on primary education while sanitation is

dependent on water but primary education and sanitation are independent.

We can also consider a simple illustration of equation 1 above using case 2. We can verify that primary education and sanitation are independent if we condition on water:

$$P(P.E\,, H2O, SAN) = P(P.E|H20)\,P(SAN|H20)\,P(H20)$$
$$= P(P.E|H2O)\,P(SAN, H20)$$

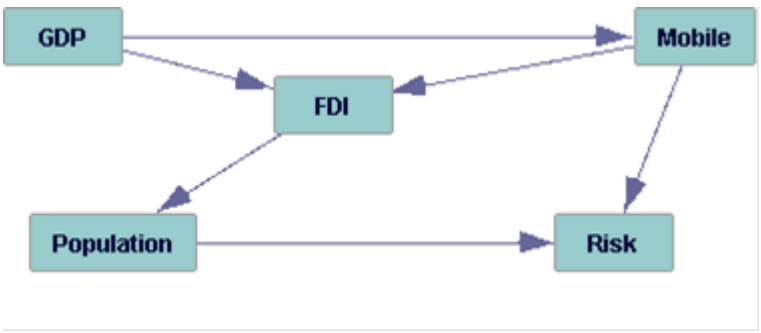
On the other hand, by the definition of conditional probability, $(A|B) = \frac{P(A \wedge B)}{P(B)}$, we have:

$P(P.E\,, H2O, SAN) = P(P.E|H20, SAN)P(SAN, H20)$ where $P.E$ denotes A and $H20$ and SAN denote B

Therefore, $P(P.E|H20, SAN) = P(P.E|H2O)$

Thorough introductions and discussions of the DAG methodology and case studies can be found in a variety of papers (Pearl 2000, Bessler 2003, Haughton et al 2006, see also Haughton and Haughton 2011, chapter 5).

Figure 3: DAG Pattern by PC algorithm



Directed Acyclic Graphs using TETRAD

The software package TETRAD IV (Tetrad Project, 2012) is used in this paper to construct DAGs from data. Tetrad IV provides a number of different search algorithms which allow us to determine the directional linkages between variables in a dataset. Most of these search algorithms are based on underlying assumptions about the structure of the data. Such assumptions include; (i) normality of the dataset i.e. the distribution of each variable is normal and (ii) if the data set consists of continuous variables, it is assumed that the causal relation between any two variables is linear (Tetrad Manual 2012). TETRAD indicates that many of the different search algorithms often succeed even when these assumptions do not strictly hold. TETRAD allows us to investigate and discover these linkages between variables but we cannot categorically infer that we establish causality. Establishing causality requires strong assumptions which in most cases are impossible to satisfy. One such assumption is that the set of variables is a causally sufficient set of variables i.e. all the causal variables are included in the dataset – in most cases it is impossible to truly determine this. The program is given no prior knowledge or hypothesis about which variables are causes or which are effects, thus the

results are driven by the structure of the data. TETRAD IV can be accessed at no cost from http://www.phil.cmu.edu/projects/tetrad.

TETRAD contains a suite of different search algorithms such as the PC (Partial Correlation), GES (Greedy Equivalence Search), PC Pattern, PCD algorithms etc. For the purpose of our study, we focus on the PC algorithm because, in the absence of theory, we need guidance to potential directed links among the variables to enable us build an SEM model(Bessler and Loper, 2001; Bessler 2003, Zhang et al. 2006). The PC algorithm begins by creating a complete undirected graph where each variable represents a vertex and undirected edges connect all the variables. Edges between the variables are removed on the basis of significance tests of zero correlation or zero conditional correlation (Haughton et al 2006; Zhang et al 2006, Haughton and Haughton 2011, chapter 5). The undirected edges that remain in the graph are now "directed" by taking each triplet *x*, *y*, *z* where pairs (*x*, *y*) and (*y*, *z*) are linked but (*x*, *z*) is not linked. Conditional correlation is tested and if y is not a part of a set of variables which, when conditioned on, make x and z independent, then the triplet *x*, *y*, *z* is oriented as $x \rightarrow y \leftarrow z$ and *y* is identified as a *collider*.

After identifying all colliders for all triplets, the algorithm proceeds by looking at triplets x, y, z with a directed edge between x and y, i.e. if $\mathbf{x} \rightarrow \mathbf{y}$, where *y* and *z* are linked but *x* and *z* are not linked; if there is no arrowhead at y from z, then (*y*, *z*) is oriented as $\mathbf{y} \rightarrow \mathbf{z}$. Thus the final link between the triplet would be constructed as $x \rightarrow y \rightarrow z$ (Eshghi et al, 2007, Haughton and Haughton 2011, chapter 5). The algorithm is discussed in further detail in Spirtes et al. (2000). Studies have identified that the PC algorithm may make mistakes of edge inclusion and edge direction especially with small sample sizes (Demiralp and Hoover 2003; Spirtes et al 2000; Zhang et al 2006). However, Sprites et al (2000) suggest that higher significance levels may improve performance for small sample sizes. They however argue that edges that are included at the lower significance levels can be regarded as conservative. Despite our small sample size, we chose to use the lower significance level of 0.1 so that we can trust the edges that are included in the DAG model.

Partial Least Squares

Partial least squares (PLS) models are often visualized by drawing a path diagram. A path diagram consists of boxes and circles which are connected by arrows. Figure

4 shows an example of a simple path model. Measured variables are represented by a rectangular or square box while latent or unmeasured factors are represented by an ellipse. A single headed arrow is used to define a directed relationship in the model while double headed arrows indicate covariances or correlations between the two variables without a causal interpretation.

PLS models include and assess both a structural model and a measurement model in the same analysis. The structural model reflects the assumed association among a set of dependent and independent constructs while the measurement model shows the loadings of observed items on their expected latent variables. This results in a more rigorous analysis of the proposed research model and thus provides results with regard to the extent to which the research model is supported by the data.

In PLS, we must specify a model before we can start the analysis. The model specification is usually guided by a combination of theory and empirical results from previous research. For our purposes, our model is based on the result of the DAG analysis. The PLS process consists of two sequential analyses – the measurement model and the structural model. The first step is to validate the measurement model by representing the

relationship between the model's constructs and their indicators. The next step is to perform a path analysis to determine the fit of the structural model by determining the relationships between the latent constructs (Kline, 2005). PLS was chosen because it is more robust with fewer identifiability issues – See Pavlou and Gefen, 2004 and Hair et al, 2011 for a more detailed discussion of identifiability issues; sample size requirements are less demanding (in our case, we have 48 countries); non-normal data are acceptable and PLS is valuable in the analysis of large complex models (Chin et al., 2003; Pavlou and Gefen, 2004). PLS is appropriate for both formative and reflective models. PLS is also viewed as more appropriate for exploratory work where theory is less developed (Table 15). Specifically for our purposes we chose to use PLS because of the sample size, formative constructs and exploratory nature of our model. The partial least squares algorithm will be discussed in more detail in the next section.

Table 15: Rules of thumb for selecting PLS

Research Goals • If the goal is predicting key target constructs or identifying key "driver" constructs, select PLS. • If the research is exploratory or an extension of an existing structural theory, select PLS. **Measurement Model Specification** • If formative constructs are part of the structural model, select PLS. **Structural Model** • If the structural model is complex (many constructs and many indicators), select PLS. **Data Characteristics and Algorithm** • **Sample size considerations:** – If the sample size is relatively low, select PLS. – PLS minimum sample size should be equal to the larger of the following: (1) ten times the largest number of formative indicators used to measure one construct or (2) ten times the largest number of structural paths directed at a particular latent construct in the structural model. • If the data are to some extent non-normal, use PLS; **Model Evaluation** • If you need to use latent variable scores in subsequent analyses, PLS-SEM is the best approach.

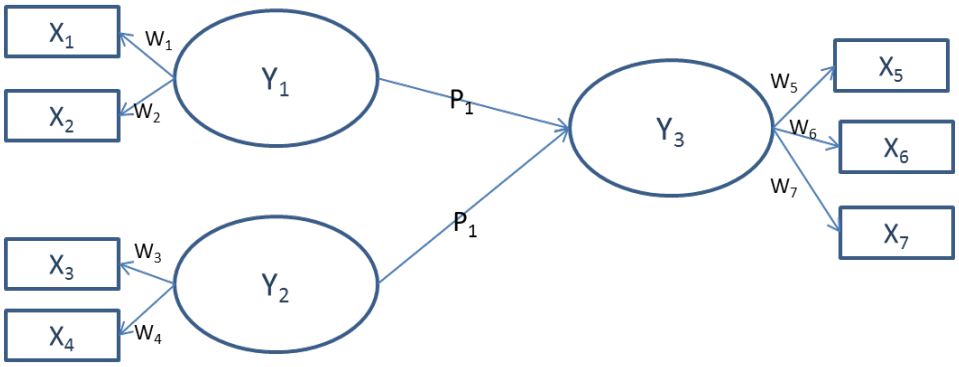
**Hair et al, 2011.*

One important thing to consider here is the use of the PLS for causal interpretation. The PLS model can be used to identify linkages between constructs which can in turn lead to an interpretation of the final model as a causal model. We should be cautious that correlational data and identifying directions of association do not imply causality. We can assume that we have identified directions of association and that the PLS model has been corroborated by the data but we have not established causality.

The two methodologies – DAGs and PLS will enable us to determine if linkages exist between the MDGs. Our first

approach will be to estimate a DAG using TETRAD. Since TETRAD is given no prior knowledge or hypothesis about which variables are potential causes or which are potential effects, the results will be driven by the structure of the data. The directional links that we find between different pairs of goals will be used to build the PLS. The PLS model specifications are guided by our empirical results from the DAG estimation. This enables us to answer our research question of whether there are positive and significant linkages that exist among the MDG targets in Africa and in so doing identify which goals can be prioritized by African countries. In the case where we have an undirected link, we can try both directions in a PLS model and see which link is more viable.

Figure 4: Simple Path Model Example



**Adapted from Hair et al. 2011*

Partial least squares (PLS) path modeling is a component based approach to structural equation

modeling that was originally developed by Wold (1975). Unlike covariance-based path models which attempt to reproduce the covariance matrix, PLS aims to maximize the amount of variance observed within the dependent variable that is explained by the independent variables (Haenlein & Kaplan, 2004). Instead of estimating the measurement and structural models simultaneously, PLS follows a two stage approach. In the first stage, the algorithm estimates the latent constructs' scores in the measurement model through a four step iterative process. We outline the stages in Table 16 using the example path diagram in Figure 4.

The second stage calculates the final estimates of the outer weights and loadings as well as the structural model's path coefficient using the ordinary least squares method for each partial regression in the PLS model (Tenenhaus, 2005; Hair et al.,2011). The path modeling process is called partial because the iterative PLS algorithm estimates the coefficients for the partial ordinary least square regression models in both the measurement models and the structural model.

Table 16: Stages and Steps in the Basic PLS Algorithm

Stage One: Iterative estimation of latent construct scores **Step 1:** Outer approximation of latent construct scores (the scores of Y1, Y2, and Y3 are computed based on the manifest variables' scores and the outer coefficients from Step 4) **Step 2:** Estimation of proxies for structural model relationships between latent constructs (P1 and P2) **Step 3:** Inner approximation of latent construct scores (based on scores for Y1, Y2, and Y3 from Step 1 and proxies for structural model relationships, P1 and P2, from Step 2) **Step 4:** Estimation of proxies for coefficients in the measurement models (the relationships between indicator variables and latent constructs with scores from Step 3; W1 to W7) **Stage Two:** Final estimates of coefficients (outer weights and loadings, structural model relationships) are determined using the ordinary least squares method for each partial regression in the PLS-SEM model.

Model evaluation and assessment in PLS follows a two-step process that involves separate assessments of the measurement model and the structural model. We examine the measures' reliability and validity according to certain criteria as a first step. It is important to determine that the measures represent the constructs of interest. If the measures prove to be adequate then the second step involves an assessment of the structural model estimates.

Hair et al, 2011 argue that we have to distinguish between reflective and formative measurement models to evaluate them. While reflective measurement models can be assessed using traditional statistical evaluation criteria this is not the case for formative models. Formative measurement models are assessed by examining the weight and loading of each indicator (Hair et al.

2011). Bootstrapping allows for testing the significance of an indicator's loading and weight on its construct. When both weight and loading are significant (critical t-value for a two-tailed test at the 5% significance level is 1.96 - (Hair et al, 2011)) there is empirical support for the indicator's relevance in providing content to the formative index. On the other hand if both weights and loadings are non-significant, there is no empirical support to retain the indicator.

To assess the structural model's explanatory power, we consider the R^2 measures and the level of significance of the path coefficients. The goal of the PLS approach is to explain the variance in the endogenous latent variables. This suggests that the level of R^2 should be high. The judgment of what level of R^2 is considered high depends on the specific area of research. R^2 values of 0.2 are considered high in areas of research such as consumer behavior while 0.75 is high for success driver studies. In marketing research, 0.75, 0.50 or 0.25 can be described as substantial, moderate or weak respectively. For the purpose our study, we adopt the guidelines from marketing research.

PLS also uses bootstrapping to test the significance of the estimated coefficients. PLS applies non-parametric

bootstrapping which involves repeated random sampling with replacement from the original sample to create a bootstrap sample to obtain standard errors for hypothesis testing. The procedure creates a large number of bootstrap samples by randomly drawing cases with replacement from the original sample (e.g. 5000 samples). Each bootstrap sample should have the same number of cases as the original sample. The PLS algorithm estimates the PLS results from each bootstrap sample (e.g. 5000 PLS estimations). The resulting path model estimations form a bootstrap distribution which can be viewed as an approximation of the sampling distribution. Standard errors of each measurement item can then be computed from the generated collection of samples. A t-test can be performed to measure the significance of path model relationships. Critical t-values for a two-tailed test are 1.96 (significance level of 5%). The effectiveness of the bootstrap depends on the sample being representative of the population (Hair et al, 2011).

For the purpose of our analysis, we use the SmartPLS software to analyze the PLS model. This software is available at http://www.smartpls.de (Ringle, Wende and Will, 2005). SmartPLS is a stand-alone software specialized for PLS path models. SmartPLS supports

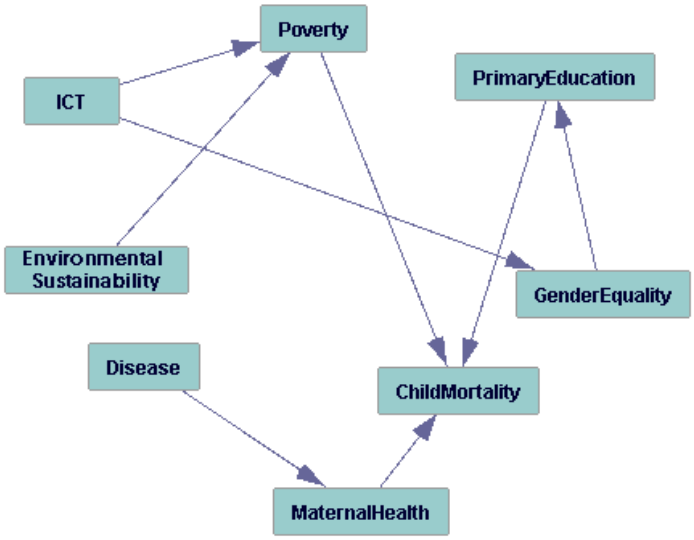
bootstrapping methods and also allows for the specification of interaction effects. Extensive discussions of the PLS algorithm can be found in Tenenhaus et al. 2005 and Hair et al., 2011.

DAG Results

The time period under consideration for our analysis is 2008-2010. We transformed each of the variables with the natural logarithm to ensure we satisfy normality requirements for the DAG analysis. TETRAD tests for normality using the Kolmogorov Smirnov test. All transformed log variables were found to be normal at the 5% significance level. We begin our analysis by using the PC algorithm in TETRAD IV on our dataset. Zhang et al (2006) suggest that higher significance levels may improve performance at small sample sizes. Despite our sample size of 48 countries, we analyze results for the PC algorithm at the 10% significance level. The graph that is produced using the PC search algorithm is the algorithm's estimate of the dependency structure that generated the data (TETRAD Tutorial, 2012). It is important to remember that the resulting DAG that is produced is data-driven without a priori knowledge of the directed links among the MDG goals and specified indicators.

The PC algorithm yields a DAG graph that only has directed edges (Figure 5). Primary education, poverty and improving maternal health all have directed edges leading into child mortality. Water and sanitation (H2O_SAN) and ICT have directed effects on poverty. Gender equality has an edge leading to universal primary education and combating disease has an edge going into improving maternal health.

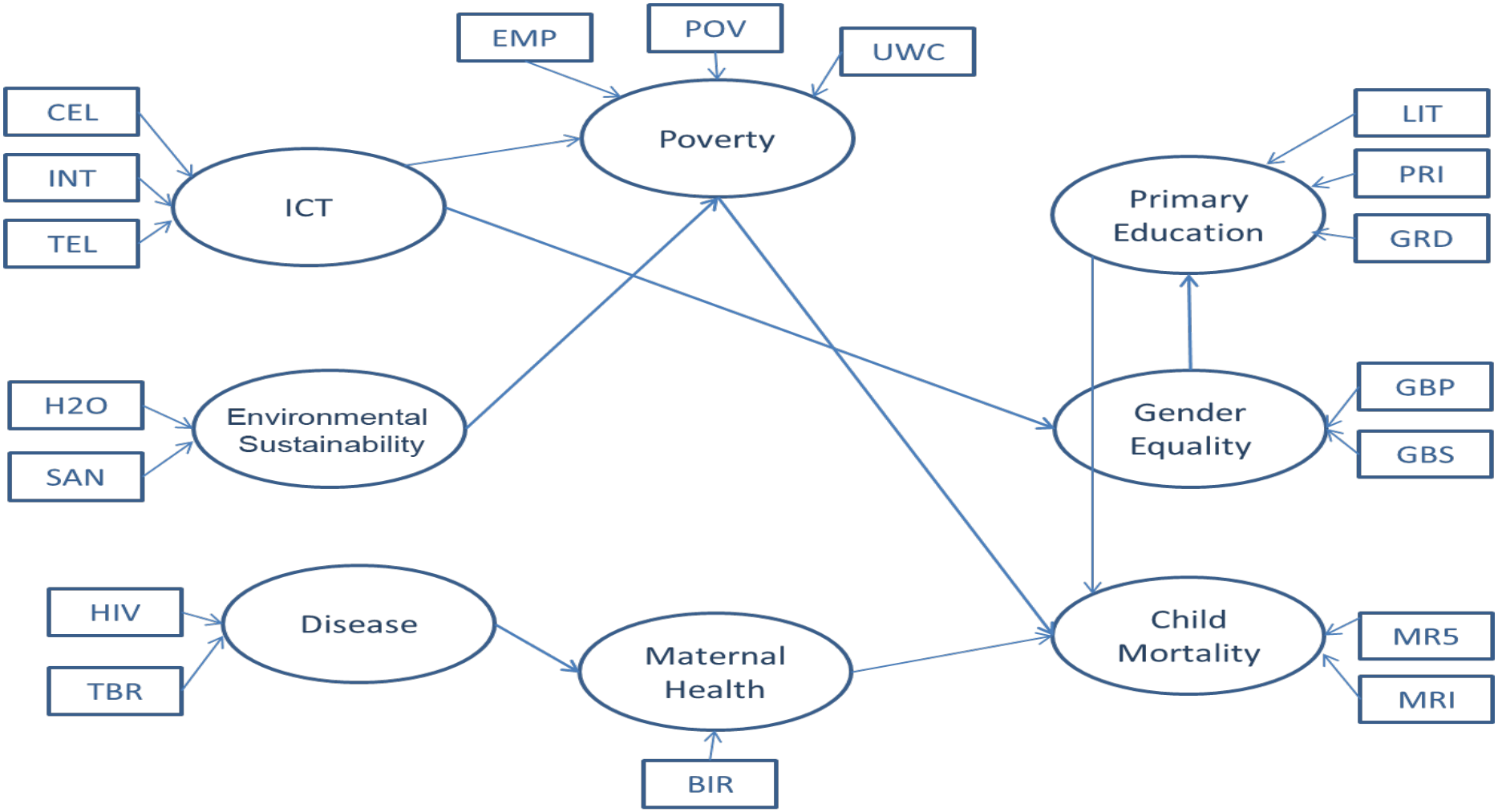
Figure 5: PC DAG Model



TETRAD has enabled us to not only deduce the existence of these directional links but also to identify pairs of goals that are linked to each other or dependent on each other, given all the goals within the MDG goals framework. This is only the first step in our analysis. The second step is to confirm these linkages using PLS. The PLS model to be estimated is displayed in Figure 6.

We estimate a formative model for our latent constructs i.e. MDG goals represent composite variables that summarize the common variation in a collection of indicators. Specifically the causal action flows from the independent variables (indicators) to the composite variable. As an example in our model, the ICT goal has three indicators – mobile subscriptions, fixed telephone lines and internet users. If the number of internet users increases, then the level of the ICT goal increases even if the number of mobile subscriptions and fixed telephone lines remain the same. An increase in the ICT goal does not imply a simultaneous change in the other indicators.

Figure 6: Research Model



Partial Least Squares Results and Analysis

The initial linkages between the MDGs from our earlier analysis of the DAGs are further analyzed using SmartPLS. The directional links that we find between different pairs of goals are used to build the PLS. The PLS model specifications are guided solely by the empirical results from the DAG estimation. It is important to point out that the resulting PLS model has a different number of indicators per goal. For example, the ICT construct has three measured variables – CEL,TEL and INT while Gender Equality has two variables – GBP and GBS and Maternal health has one variable – BIR. Chin et al (1996) in their study on the moderating effect of enjoyment on the perceived usefulness/IT adoption intention relationship constructed a PLS model with the perceived usefulness construct having six indicators and the enjoyment construct with three indicators. They acknowledge that the structural effects are likely being underestimated while the construct loadings are overestimated due to the difference in indicators per construct but the results indicate that enjoyment does play a role in predicting IT intention and usage behaviors.

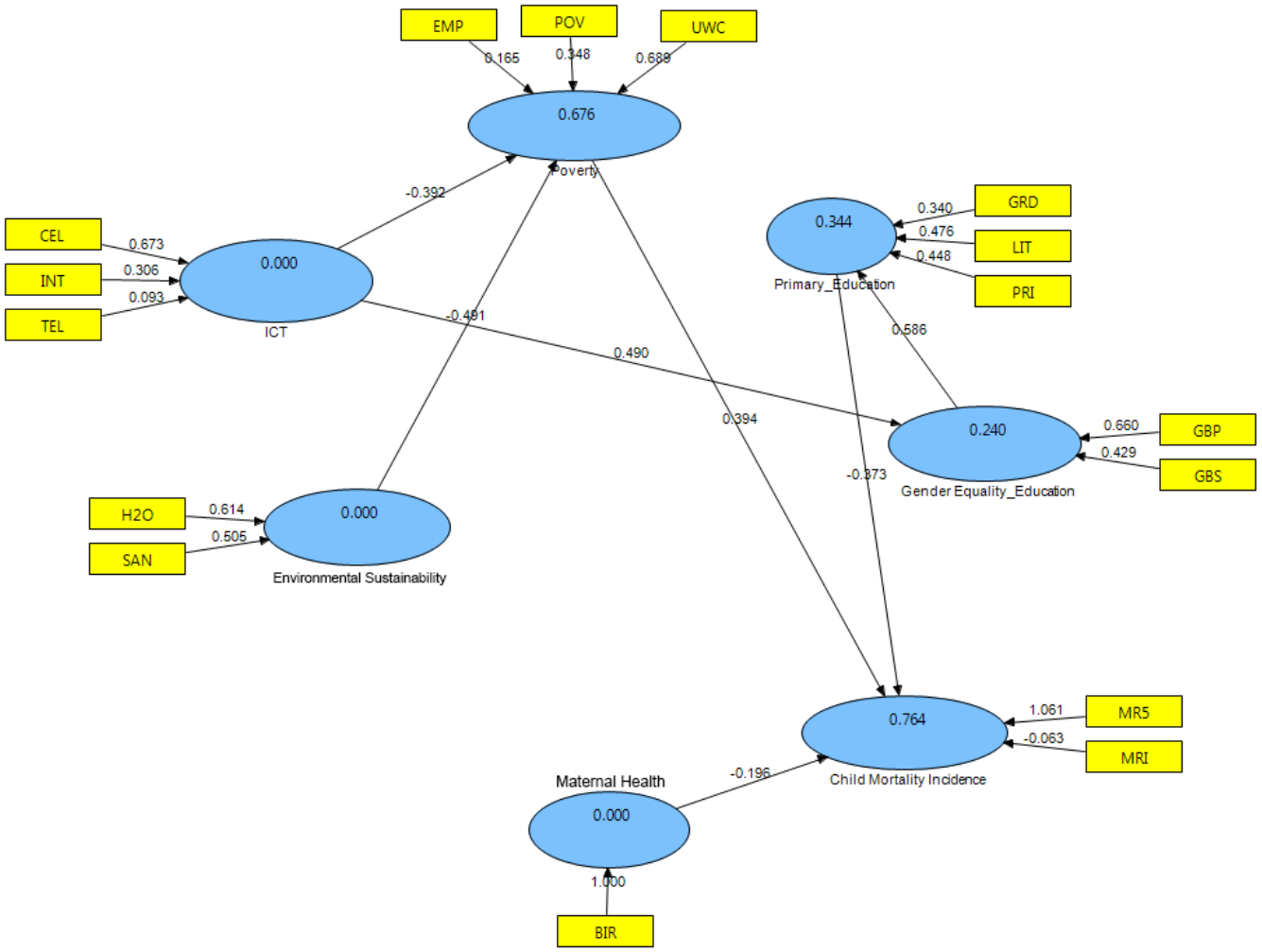
A partial least squares model (Figure 6) is used to test the DAG model (Figure 5). We examine the estimated

links between the goals in the PLS model. Disease had a path leading to skilled health births with a path coefficient of 0.283. This implies that high prevalence rates of HIV and TB would have a positive effect on skilled health births. This result is not an expected one as it does not make sense. We checked the relationship between HIV and skilled health births using a scatter plot. We found outlier countries such as South Africa and Botswana which had high HIV and TB rates and also had high number of skilled health births. South African countries have an HIV epidemic but they are also much more developed than other African countries in terms of the other MDG goals and indicators (Deichmann et al., 2013). We also checked the significance of the link and found it to be insignificant. Given that none of the other goals have a link into the Disease construct, we choose to eliminate it from the model and see if its exclusion makes a significant difference to the model. Our results indicate that the model results remain unchanged. We thus decide to keep the new model which does not include the Disease construct (Figure 7). Figure 7 shows the weight of each indicator on the link for the appropriate latent construct and the R^2 values for each endogenous variable are located in the middle

of each construct. The figure also shows the estimated path coefficients for each link between constructs.

We examined the loadings of the indicators. We found that all the loadings of all indicators on their respective constructs were significant (Table 17 – the skilled health birth construct has only one indicator).

Figure 7: PLS Formative Model



The model finds a positive link between ICT and gender equality with a coefficient of 0.5. This is a strong indication that an increase in ICTs positively influences gender equality in primary and secondary school enrollments and that an increase in gender equality positively influences Primary Education. Younger generations are particularly high adopters of the internet especially through their mobile phones. Higher adoption of ICTs leads to more exposure and better access to information particularly in populations that have traditionally suffered exclusion in these communities such as women. There is a higher awareness of the girl child's right to education and also an awareness of the ability to access information that was largely unavailable before. ICT can itself be a goal to be achieved but it can also be used as a tool to achieve other goals.

Based on our model, we see that primary education has a negative effect (-0.4) on child mortality rates while lower levels of poverty has a positive effect (0.4) on reducing child mortality rates. This implies that higher levels of education ultimately reduce infant mortality and higher levels of poverty increase child mortality. ICT and availability of water and sanitation

also have negative effects on poverty with -0.4 and -0.5 respectively.

According to Hair et al.'s recommendations, a bootstrapping procedure using 5000 subsamples was performed to evaluate the statistical significance of each path coefficient. Table 17 shows estimated path coefficients along with their bootstrap values and T values. All paths are significant with the exception of the effect of Maternal Health on child mortality which had a path coefficient of -0.165 and a t-statistic of 1.1905. This is surprising as one would expect that higher skilled births would have a significant effect on child mortality as over 70% of all child deaths occur in Africa and South East Asia (WHO, 2012). Closer examination reveals that globally, leading causes of child mortality include pneumonia, preterm birth complications, diarrhea, birth asphyxia and malaria. We note that 96% of all under-five deaths due to malaria worldwide happened in the African region (WHO, 2012). In the African region, a relatively modest proportion (30%) of child deaths occurs during the neonatal period (less than 28 days of life). This may explain the insignificant effect of skilled health births on child mortality in Africa. In order to reduce child mortality in Africa, eliminating malaria should be the major

objective. Given that none of the other goals have a link into the Skilled Health Births Construct, we eliminated it from the model to see if its exclusion makes a significant difference to the model. Our results indicate that the model results remain unchanged. We chose to include the skilled health births construct in the model as its inclusion enhances our discussion and opens up contexts that would otherwise have gone unnoticed.

An analysis of the R^2 values for the endogenous variables is done in order to evaluate the structural model's explanatory power. The model explained 68% of the variance in poverty, 34% of the variance in primary education, 24% of the variance in gender equality and 76% of the variance in child mortality. The R^2 values for poverty and child mortality can be described as substantial while the R^2 values for primary education and gender equality are weak based on the guidelines discussed earlier where 0.75, 0.50 or 0.25 can be described as substantial, moderate or weak respectively.

One of the objectives of our study is to identify both linkages and priority goals. Based on the path coefficients of our links, we find that an investment in ICTs has an effect on both lowering poverty (-0.4)

and increasing gender equality in education (0.5). This effect of ICT on gender equality implies a positive effect on primary education also (0.6). Lowering poverty rates in turn has an effect on lowering child mortality rates as our model currently indicates that high levels of poverty translates to high levels of child mortality incidence (0.3). Therefore we can identify ICT as a priority goal for African countries based on the paths from ICT that we have identified in the PLS model. An increase in ICT translates into significant effects on other MDG goals.

Table 17: Indicator loadings and bootstrap results

Outer Loadings	Original Sample (O)	Bootstrap Sample Mean (M)	Bootstrap Standard Error (STERR)	Bootstrap T Statistics (|O/STERR|)
BIR -> Skilled Health Births	1	1	0	0
CEL -> ICT	0.9667	0.9358	0.0592	16.3168
EMP -> Poverty	0.6362	0.6204	0.1226	5.1904
GBP -> Gender Equality_Education	0.9484	0.9184	0.0841	11.2795
GBS -> Gender Equality_Education	0.873	0.8269	0.1696	5.1473
GRD -> Primary_Education	0.6634	0.6505	0.1399	4.7427
H2O -> H2O_SAN Availability	0.914	0.9135	0.0505	18.0997
INT -> ICT	0.8777	0.8682	0.0562	15.6081
LIT -> Primary_Education	0.8439	0.83	0.0649	12.993
MR5 -> Child Mortality Incidence	0.9999	0.9957	0.0061	163.2961
MRI -> Child Mortality Incidence	0.9651	0.9625	0.0315	30.6727
POV -> Poverty	0.7359	0.73	0.0727	10.1163
PRI -> Primary_Education	0.832	0.817	0.0809	10.2903
SAN -> H2O_SAN Availability	0.8699	0.8489	0.0861	10.0987
TEL -> ICT	0.8621	0.8576	0.0574	15.0165
UWC -> Poverty	0.9276	0.9223	0.0329	28.1737

Table 18: Path Coefficients with bootstrap values, T values

	Original Sample (O)	Bootstrap Sample Mean (M)	Bootstrap Standard Error (STERR)	Bootstrap T Statistics (|O/STERR|)
Gender Equality_Education -> Primary_Education	0.5864	0.6225	0.0863	6.7932
H2O_SAN Availability -> Poverty	-0.4915	-0.4676	0.1365	3.5999
ICT -> Gender Equality_Education	0.4899	0.5193	0.1091	4.4891
ICT -> Poverty	-0.3917	-0.4334	0.1338	2.9273
Poverty -> Child Mortality Incidence	0.3939	0.4022	0.1314	2.9974
Primary_Education -> Child Mortality Incidence	-0.3729	-0.382	0.1137	3.2812
Skilled Health Births -> Child Mortality Incidence	-0.1963	-0.1848	0.1368	1.4351

Conclusions and New Directions

We employed directed acyclic graphs and PLS modeling to investigate the linkages between the eight different millennium development goals. We investigated the existence of these links over a three year period (2008 – 2010). Prior research found that the achievements of poverty and education goals are not independent endeavors (Larson et al., 2006)). They noted in their study that reducing poverty and improving education will alter household choices related to water access. While our results also indicated a link between improving household choices related to water access and sanitation and the reduction of poverty, we found that increasing the availability of water has an effect on

reducing poverty. Fielding et al (2005) and Wiebe (2009) found that higher levels of education are associated with lower child mortality rates. These results are in agreement with our findings which indicate that primary education has a negative effect on the incidence of child mortality.

We found that within the African context, digital development i.e. the ICT goals – internet users, cell phone subscribers and telephone lines had a positive effect on gender equality – the ratio of boys to girls in primary and secondary schools. This is a very strong indication that an increase in ICTs influences both Primary Education and also Gender Equality in school enrollments. We also found that primary education had negative effects on child mortality rates i.e. reduced child mortality rates. Higher levels of education ultimately lead to less hunger and reduced infant and maternal mortality. We identify the ICT goal as a major goal to be achieved in itself but it is particularly an important tool that can be used to achieve the other goals. A higher adoption of ICTs opens the door to awareness and development. Poverty in African countries appears to be central to child mortality. The methodologies that we have employed in this study have allowed for an easy visualization of the potential

linkages between the millennium development goals and identified directed links among the goals.

This study has a number of limitations. A major limitation is that our sample size was a small one at 48 countries only. Given that our focus was on African countries, we were limited in terms of the number of countries that we could consider for the study. This limitation is however mitigated by the use of the bootstrap to compute standard errors. There is also a limitation in the data as many African countries are not reporting the indicator variables which unfortunately leads to inadequate information with regard to the full set of MDG indicators and targets for African countries. A last limitation is related to the goals themselves. The MDGs have been criticized for being moving targets which set African countries up for failure. They have also been criticized as lacking objectivity in measurement. Despite these criticisms, Fukuda-Parr (2010) points out that the MDGs can be used as a benchmark for progress. These goals despite their limitations are valuable for Africa as a whole in achieving socioeconomic advancement – a major goal of the framers of the MDGs. By focusing on achieving these targets, African countries can move closer to higher levels of development.

There have been calls for analyzing the interdependencies between the goals and this study is only the first step in that direction. Future research can build on this work by looking at other contexts besides the African context. It would be interesting to see what the results are for other developing regions such as Latin America and if results from Africa can be applied to other developing regions.

Exploratory research like this study is a good foundation for further confirmatory studies such as case studies. The linkages we have identified in this study can be explored further in case studies to better understand how the different goals can be integrated to achieve the MDGs and also how they may be applied to all developing countries. We found that digital development had a positive effect on gender equality and indirectly on education. We also found that environmental sustainability (availability of water and sanitation) also had an effect on reducing poverty.

In the last decade, Africa has witnessed a dramatic increase in the adoption and use of information and communication technologies (ICTs). These unprecedented growths in ICTs are revolutionizing the way Africans live, work and learn (LaFraniere, 2005). The traditional barriers of time and distance are gradually

being eliminated and allowing for easier transfer of information, skill and expertise from one place to another. ICTs have also been introduced within the educational process with educational delivery technologies such as educational radio and TV broadcast systems, computer (wireless and wireline) networks which are making it possible to improve access for a large population to limited educational resources.

A case in point is Ghana which has committed to a comprehensive program of rapid deployment, utilization and exploitation of ICTs within the educational system from primary school upwards (Dzidonu, 2010). Ghana is using ICTs to facilitate education and learning and also promote e-learning and e-education. Policy measures are also being put in place to promote the use of ICTs in technical and vocational training. Other countries that are also implementing various forms of e-education programs and ICT initiatives to improve and widen access to educational resources include Nigeria, Ethiopia, South Africa, Algeria and Tunisia. These initiatives include the deployment of e-education through avenues such as the implementation of SchoolNets – the SchoolNet approach uses the internet and its resources for development and delivery of educational programs at the pre-university level

(Dzidonu, 2010). SchoolNets allow for learner-teacher, learner-learner and teacher-teacher interactions and collaborations. Schools have been equipped with computers and computer laboratories with internet connections which facilitate access to educational resources and learning materials. In the case of Rwanda, only one school in the country had a computer in 2000; six years later over half of the primary and secondary schools had been equipped with hardware, over 2,000 teachers had received ICT training and all public schools were expected to be connected (Dzidonu, 2010; Farrell and Isaacs, 2007). These efforts by a number of these African countries will in the long-run improve and widen access to education within the school system within these countries.

A number of challenges to these ICT initiatives have been identified and these call for further study so they can be overcome. Most of these programs are donor-driven or supported and these would have sustainability challenges at the end of the initial project phase since there is limited public funding for education in Africa (Farrell and Isaacs, 2007). Also resource availability issues such as low human resource capacities, ICT infrastructure development (weak communications and computer network infrastructure,

limited computer resources) and ICT deployment (low level of internet access, limited bandwidth of access, high cost of access to subscribers and high cost of connectivity to internet backbones) are problems that hamper ICT-in-Education initiatives. With regard to low human resource capacities, there is a lack of expertise in developing and maintaining e-learning systems and networks in most African countries. Although a reasonable percentage of teachers are becoming computer literate, the majority are yet to acquire the expertise to develop and deliver electronic courses and instructional materials. Without an investment in training, most African schools will be unable to harness the emerging educational technologies that support teaching and learning (Farrell and Isaacs, 2007).

There are a lot of reasons why poverty has become prevalent in African countries. Some of such reasons include political instability, ethnic conflicts, climate change and a varity of others. One of the greatest though which is often overlooked is the access to clean drinking water (thewaterproject.org). Without access to clean water, it becomes a great challenge to come out of the cycle of poverty as you can’t grow food, you can’t stay healthy, you can’t go to school

and you are unable to continue working. By investing in providing clean water, African countries can ensure higher levels of economic prosperity for their citizens as the World Health Organization has shown that for every $1 invested in water and sanitation, there is an economic return of between $3 and $34 (thewaterproject.org).

The Water Project has provided Kenyan women with access to clean water through the provision of new wells. A new well was built for the Bishop Sulumeti Girls Secondary school and allows the students to attend school with the limitations of poor sanitation and in turn prepare themselves for a brighter future (thewaterproject.org). One major challenge to providing access to clean water is also the rural-urban divide. In the rural areas, not only is there poor access to water but even when the water is available, there are risks of contamination. Financial constraints hamper the proper maintenance of water facilities such that quality tests are perfomed as often as needed. The focus is usually on quantity of water rather than quality of water (Awuah et al, 2009). Urban areas on the other hand face a different set of challenges. Rapid population growth has led to the development of water supplies not matching up to the growth of human

waster which has in turn led to pollution of natural water bodies, irregular water supply, use of wastewater in agriculture etc (Van Rooijen et al, 2009).

This study is innovative with regard to the Millennium Development Goals and the African context. We have highlighted the linkages between goals and identified priority MDG goals for Africa using partial least squares. Previous studies have examined linkages between the MDG goals using regressions (Fielding et al., 2005, Larson et al., 2006, Wiebe, 2009) but our study goes a step further by applying a more holistic approach to considering the linkages between all the goals. Based on our innovative approach, we found the existence and significance of links by examining all the goals simultaneously rather than pairs of goals as had been approached in previous studies. We identify priority MDG goals and progress paths (identifying paths that lead from one to goal to other subsequent goals). We identified the path from ICT to poverty and then from poverty to child mortality. We also identified a second path from ICT to gender equality and then from gender equality to primary education. Our approach is innovative as we found the existence and significance of links by examining all the goals

simultaneously rather than pairs of goals (Poverty and Education, Mortality and Education).

3.2. Kohonen Self-Organizing Maps as a Tool for Assessing Progress toward the UN Millennium Development Goals

Introduction

As previously highlighted, a decade has passed since the declaration of the Millennium Development Goals (MDGs) by the United Nations (UN) in September of 2000. In the earlier section, we focused on unraveling the synergies between the goals and this helped us identify priority MDG goals for Africa. In this section, we focus on investigating the relative attainments and progress achieved towards for the goals by African countries using Kohonen Self-Organizing Maps (SOMs).

This paper adds to the growing literature on MDG progress by introducing the very useful and intuitively valuable technique of Kohonen self-organizing maps (SOMs) in order to better understand each African country's path toward attainment of the MDGs. The advantage of the SOM methodology is that it enables us to visualize in a two-dimensional plane how countries position themselves relative to each other on the basis of sixteen indicators, and to provide a meaningful interpretation of the vertical and horizontal dimensions of that plane. We analyse all eight MDGs with variables that represent their corresponding targets (Table 19). In total, we examine sixteen (16) indicators for 48 African countries. Our

choice of indicators and targets is based on the indicators for which we have comprehensive data availability.

Following a special summit session held by the UN General Assembly in September 2010 to review the progress of the MDGs, the likelihood exists for expanded discussion on the push to secure maximum progress on the various goals at the international level by 2015 (see, for example, *The Economist*, 2010). We believe that our study is timely and invaluable to the member states of the UN General Assembly in understanding the progress of the MDGs, especially with regard to Africa.

Our approach is to track the movements of MDG indicators over time by the using self-organizing maps (SOMs). The SOM methodology has been widely used as a tool for identifying clusters in datasets at a range of scales of analysis including national, regional, and global. For example, within the single country of Vietnam, Nguyen et al. (2008) apply the approach to look at levels of living standards across provinces. At the regional scale, Deichmann et al. (2003) use SOMs to examine determinants of foreign direct investment among Central and Eastern European transition countries, and at the global scale to examine the digital divide

between countries (Deichmann et al., 2007). Also at the global scale, Hua, Skaletsky and Westermann (2009) employ SOMs to evaluate Central Intelligence Agency (CIA) World Factbook data to find patterns among selected countries with regard to their population, economies, infrastructure, and militaries.

This paper is organized as follows: The next section shares a few highights from the detailed discussion in the earlier paper on relevant literature on MDG initiatives and the achievement of the goals. This is followed by a description of our dataset and methodology. We then investigate the achievements and progress of African countries with regard to the MDGs. Next, we present and discuss the results. Finally we present our conclusions, draw implications, highlight limitations and make some suggestions for further studies.

Literature Review

The Millennium Development Goals (MDGs) have given rise to a considerable literature and we acknowledge that divergent opinions of MDG success exist among academics and practitioners alike. Given the many countries in question, a variety of techniques, and a wide range of

goals and indicators, it is fairly straightforward to find anecdotal evidence of both success and failure. A literature review of the MDGs has been discussed in detail in the earlier paper and to avoid repetition our objective in this section is to share a few highlights and summary of relevant literature on the MDGs while referring to the earlier paper for a detailed discussion. We also aim to introduce Kohonen maps as a tool for analysis by any participants in the MDG debate.

The UN declaration is ambitious, yet straightforward. In short, it aims to reduce the poverty rate by half compared to the level in 1995; attain universal primary education enrollment by 2015; attain gender equality; reduce child and maternal mortality by two-thirds; fight HIV/AIDS, tuberculosis (TB), and malaria; reduce the proportion of population without clean water by half; and promote global partnership for development. A complete overview of the MDGs can be found on the UN's web site at http://www.un.org/millenniumgoals/, with an update on the September 2010 summit available at http://www.un.org/en/mdg/summit2010/.

Notwithstanding the good intentions of the MDGs, there has been a fierce debate around the MDGs in academic and professional circles (Hulme, 2009). Optimists such

as Sachs (2005) see them as a means of transforming the human condition, and Fukuda-Parr and Greenstein (2010) argue that they are essential to stretch ambitions and mobilize political commitment and public support. Others, including Clements et al. (2007) and Easterly (2009) argue that they represent poorly planned distractions from more appropriate and attainable targets, and that they fail to lead to effective policies and actions. Saith (2006, 1167) goes so far as to sarcastically deride them as a means to "envelope (one) in a cloud of soft words and good intentions and moral comfort". Such critics consider the MDGs as a conspiracy to obscure the truth about growing global inequality, alternatives to capitalism, and the empowerment of women.

Citing several accounts of the region's "failure" to meet the goals, critics have pointed out that the methodology of analysis is problematic and unfair particularly for Sub-Saharan Africa (Easterly, 2009). They point out concerns around the benchmark year of 1990 and using that data as a basis for comparison with current numbers, or for extrapolating to the present to determine regions/countries that are on course with the 2015 target date, the lack of linearity in relationships among variables, absolute versus

percentage changes, and the relative nature of targets and indicators as arbitrary and inconsistent across the goals (Easterly, 2009; Fukuda-Parr & Greenstein 2010). Easterly (2009) calls out a "bias against Africa" in the case of each of the goals, and adds "that bad press as a failed region further inhibits Africa's prospects for development" while Fukuda-Parr and Greenstein (2010) argue that the MDGs should be viewed as a set of "norms" rather than planning targets.

As discussed in the earlier paper, it is reasonable to infer that achieving the MDGs will be largely dependent on having the available infrastructure for supporting global action and the wellbeing of the citizenry, measured by income level. Sala-i-Martin (2006) demonstrates that income growth depends largely upon country-level factors such as policies, institutions, and other independent economy-wide elements. The convergence literature also suggests two economic divergences. First, the growth rates of poor countries have in general been lower than those of rich countries (Easterly, 2009). Second, the dispersion of income per capita across countries has increased over time, although falling short of statistical significance (Barro and Sala-i-Martin, 2003).

Fukuda-Parr and Greenstein take issue with the methodologies commonly used to assess progress toward MDG targets, presenting their own alternative. Fukuda-Parr and Greenstein (2010) evaluate two periods: 1991-2002, and 2003-2008, and observe that 64 out of 177 countries experienced accelerated improvement during the second period, indicating no evidence that the MDGs are having the desired overall impact. They add that progress may become increasingly more challenging as the goals are approached.

Research Questions

Notwithstanding the debates identified in the literature, given the harsh realities of economic hardship experienced in poor countries, it would be difficult to dispute the MDG framers' belief that socioeconomic advancement can be made via the goals. The literature discussion above affirms that some progress has been made in African countries with regard to the achieving the MDGs. Therefore, to evaluate the attainment of African countries towards the MDG goals, we outline the following research objectives(RO):

RO1: Introduce a novel technique – Kohonen Maps to the body of work on the MDGs as a tool for assessing progress toward the MDG goals

RO2: Identify the clustering and movement of African countries with regard to the MDG goals over an eleven year period.

RO3: Understand the African context and identify if African countries are homogenous with regard to achieving progress in the achievement of the MDG goals

Data

The variables in our dataset, explained in Table 19, represents a sample of the official yardsticks (targets and indicators) set forth by the United Nations to assess the eight MDGs for 48 African countries. Our choice of indicators and targets is based on comprehensive data availability. We examine the data over an eleven year time period (2000 – 2010) and we break the eleven years of time series data into two time periods: 2000-2005 and 2006-2010. For the purpose of our analysis we only use sixteen of the indicators. We exclude indicators 2.2 (Proportion of pupils starting grade 1 who reach last grade of primary) and 2.3 (Literacy rate of 15 – 24 year olds, women and men) which we used in the earlier study as these data were not available in the earlier years. For each country, we average the data for each variable for the time period. For the first period, we average the data from

2000 to 2005 while for the second period, we average the data from 2006 - 2010. In order to avoid the elimination of a whole country's data due to missing values of one or two observations, we use multiple imputation models in PASW statistics (SPSS 19) to handle missing values in the dataset – specifically the fully conditional specification (FCS). The fully conditional specification (FCS) is an iterative Markov chain Monte Carlo (MCMC) method that can be used when the pattern of missing data is arbitrary. For each iteration and for each variable in the order specified in the variable list, the fully conditional specification (FCS) method fits a univariate (single dependent variable) model (linear regression) using all other available variables in the model as predictors, then imputes missing values for the variable being fit. The method continues until the maximum number of iterations is reached, and the imputed values at the maximum iteration are saved to the imputed dataset. The FCS method uses the default number of 10 iterations unless otherwise stated. We refer to PASW Missing Values (2011) for a detailed description and Tables 20 and 21 below for summary statistics on the data.

Table 19: MDG Goals - Selected targets and indicators in our model

Millennium Development Goals (MDGs)	
Goals and Targets	**Indicators**
Goal 1: Eradicate extreme poverty and hunger	
Target 1.A: Halve, between 1990 and 2015, the proportion of people whose income is less than one dollar a day	Poverty gap ratio (POV) *
Target 1.B: Achieve full and productive employment and decent work for all, including women and young people	Employment-to-population ratio (EMP)
Target 1.C: Halve, between 1990 and 2015, the proportion of people who suffer from hunger	Prevalence of underweight children under-five years of age (UWC)
Goal 2: Achieve universal primary education	
Target 2.A: Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling	Net enrolment ratio in primary education (PRI)
Goal 3: Promote gender equality and empower women	
Target 3.A: Eliminate gender disparity in primary and secondary education, preferably by 2005, and in all levels of education no later than 2015	Ratio of girls to boys in primary education (GBP) Ratio of girls to boys in secondary education (GBS)
Goal 4: Reduce child mortality	
Target 4.A: Reduce by two-thirds, between 1990 and 2015, the under-five mortality rate	Under-five mortality rate (MR5) Infant mortality rate (MRI)
Goal 5: Improve maternal health	
Target 5.A: Reduce by three quarters, between 1990 and 2015, the maternal mortality ratio	Proportion of births attended by skilled health personnel (BIR)
Goal 6: Combat HIV/AIDS, malaria and other diseases	
Target 6.A: Have halted by 2015 and begun to reverse the spread of HIV/AIDS	HIV prevalence among population aged 15-24 years (HIV)
Target 6.C: Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases	Incidence, prevalence and death rates associated with tuberculosis (TBR)
Goal 7: Ensure environmental sustainability	

Target 7.C: Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation	Proportion of population using an improved drinking water source (H2O) Proportion of population using an improved sanitation facility (SAN)
Goal 8: Develop a global partnership for development	
Target 8.F: In cooperation with the private sector, make available the benefits of new technologies, especially information and communications	Fixed telephone lines per 100 inhabitants (TEL) Mobile cellular subscriptions per 100 inhabitants (CEL) Internet users per 100 inhabitants (INT)

**Poverty gap ratio is defined as the average poverty gap in the population as a proportion of the poverty line*
Data Source: United Nation (2010) MDG dataset: http://mdgs.un.org/unsd/mdg/Data.aspx (accessed 20 April 2013)

Table 20: Summary Statistics - Dataset Variables (2000 – 2005)

DAG Variable/ PLS Latent Construct	Measured Indicators	Mean	Median	Min	Max	Std Dev
Poverty	Poverty Gap Ratio	19.75	20.80	0.50	42.85	11.22
	Employment to Population Ratio	61.62	64.18	25.34	84.08	13.92
	Ratio of Underweight Children	22.47	22.50	4.00	47.20	9.92
Primary Education	Net Enrollment Ratio - Primary	65.76	64.81	29.49	95.87	18.99
Gender Equality	Ratio of Girls to Boys in Primary School	86.39	88.09	63.38	102.81	10.85
	Ratio of Girls to Boys in Secondary School	71.96	75.20	30.23	109.15	18.56
Child Mortality	Under five mortality rate per 1000	128.69	134.65	13.90	210.80	55.01
	Infant mortality rate per 1000 live births	80.67	84.18	14.25	125.06	29.61
Maternal Health	Proportion of births attended by skilled health personnel	56.92	56.65	5.65	98.45	21.64
Disease	HIV Prevalence ratio	6.13	3.38	0.10	26.10	7.19
	TB Incidence Rates	324.55	286.04	23.98	934.06	215.31
Environmental Sustainability	Proportion of population with improved drinking water	68.12	65.75	34.00	100.00	17.56
	Proportion of population with improved sanitation	36.64	32.00	4.00	94.00	21.76
ICT	Fixed telephone lines per 100 inhabitants	3.47	1.13	0.13	25.89	5.70
	Mobile cell subscriptions per 100 inhabitants	5.28	1.98	0.07	46.04	8.62
	Internet users per 100 inhabitants	1.76	0.57	0.03	12.91	2.68

Table 21: Summary Statistics - Dataset Variables (2006 - 2010)

DAG Variable/ PLS Latent Construct	Measured Indicators	Mean	Median	Min	Max	Std Dev
Poverty	Poverty Gap Ratio	18.76	17.88	0.50	40.80	11.28
	Employment to Population Ratio	61.81	64.62	39.87	83.80	13.63
	Ratio of Underweight Children	22.49	20.94	3.70	44.40	10.21
Primary Education	Net Enrollment Ratio - Primary	72.29	74.59	32.21	99.40	18.74
Gender Equality	Ratio of Girls to Boys in Primary School	89.38	89.97	66.95	106.50	9.54
	Ratio of Girls to Boys in Secondary School	74.48	75.55	34.08	118.89	18.49
Child Mortality	Under five mortality rate per 1000	119.02	123.35	5.34	209.00	56.05
	Infant mortality rate per 1000 live births	76.40	79.34	12.70	124.02	30.49
Maternal Health	Proportion of births attended by skilled health personnel	58.08	55.70	5.70	98.40	21.34
Disease	HIV Prevalence ratio	6.15	3.02	0.10	26.23	7.19
	TB Incidence Rates	349.14	311.24	21.74	1169.47	247.85
Water_Sanitation	Proportion of population with improved drinking water	70.12	70.00	42.00	100.00	16.37
	Proportion of population with improved sanitation	38.59	34.00	5.00	94.00	22.04
ICT	Fixed telephone lines per 100 inhabitants	3.92	1.23	0.06	28.64	6.13
	Mobile cell subscriptions per 100 inhabitants	21.44	14.41	1.07	81.65	20.57
	Internet users per 100 inhabitants	4.85	2.39	0.30	32.41	6.56

Methodology

Kohonen Self-Organizing Maps

Using Kohonen Self-Organizing Maps (SOMs), this study adds to the growing literature on MDG progress by using the SOM methodology to better understand the path of African countries toward convergence with the MDGs. Our approach is to track the movements of MDG indicators

over time by using self-organizing maps (SOMs). The advantage of the SOM methodology is that it enables us to visualize in a two-dimensional plane how countries position themselves relative to each other on the basis of sixteen indicators, and to provide a meaningful interpretation of the vertical and horizontal dimensions of that plane. The method is comparable to a factor analysis followed by a cluster analysis, but in our case, the factoring (dimension reduction, from sixteen to two) and the clustering (identification of groups of countries with similar sets of variables) are performed conjointly, and influence each other. This makes for an easier interpretation of the clusters of countries and of the two dimensions. For a comparison of the Kohonen map methodology to other methods such as traditional cluster analysis and latent class modeling,see Eshghi et al., 2011. We point out that our objective in this paper is broader than most in that we wish to observe the statistical clustering and movement of countries, while at the same time understand the meaning of vertical and horizontal directions on our visualizations.

Following the pioneering work of Kohonen (1982), our study employs the SOM approach for analyzing progress and evolution of the MDG goals in Africa. Kohonen's

(1982) paper was extended by his subsequent work and that of other scholars (see for example Kaski and Kohonen 1995, Kohonen 2001). Hua, Skaletsky, and Westermann (2009) demonstrate the usefulness of SOMs using CIA World Factbook Data, similar to the dataset used here. Following Deichmann et al.'s (2007) segmentation of time in their application of SOMs to a study of the international digital divide, a temporal dimension is added to the present analysis by breaking the eleven years of time series data into two time periods: 2000-2005 and 2006-2010. In the case of Ghana, for example, these time periods are labeled on our maps as GHA1, GHA2 respectively. By doing this, we enable the reader to trace the statistical movement of Ghana over time.

SOMs, a special case of neural networks are an exploratory data analysis technique where multi-dimensional data are projected onto a two dimensional space to allow for clear visualization of the data and easy identification of groups with similar characteristics. Kohonen maps can be thought of as a factor analysis combined with a cluster analysis. A major advantage of Kohonen maps is the self-organizing property of the map which makes estimated components vary in a monotonic way across the map (Deichmann et al., 2006). For example, looking at Figure 9, we see

that estimated components tend to decrease or increase as one moves from the top to the bottom of each of the sixteen graphs (with red denoting high values and blue denoting low values). This Self Organizing Map property (SOM) is what allows us to interpret the vertical dimension on the map (see Figure 8) more clearly.

As a brief overview, the SOM algorithm can be briefly and intuitively described as a special case of a competitive neural network, where output nodes compete to become the winning node. The winning node is the one that carries the highest value for a certain score function. This node becomes the center of a neighborhood and attracts similar neurons to it. The weights of neighboring nodes are adjusted via a linear combination of the input vector and the current weight vector in order to improve the score function. Convergence occurs when little or no change arises in the vector of weights. After convergence, the estimated components in the vector of weights arrange themselves onto the hexagonal lattice in a structured manner (Larose, 2005). For a thorough explanation of how to interpret SOM output, we refer the reader to Kaski and Kohonen (1995), Kohonen (2001), Deichmann et al. (2007), Hua et al. (2009), Haughton and Haughton (2011).

A number of packages are available to construct Kohonen maps but for the purpose of our analysis, we use the MATLAB and the SOM Matlab toolkit (which can be downloaded at no cost from the website http://www.cis.hut.fi/projects/somtoolbox/). We choose Matlab because it is one of the more powerful SOM packages and it also produces clear and easily understood graphs.

The Kohonen algorithm begins by determining a suitable size for the maps based on the correlations among the variables. For the Kohonen map, the algorithm leads to five labeled columns and ten rows (with intervening columns of cells whose colors depict distances as further explained below), thus creating a map with 50 possible positions. A random sixteen-dimensional vector (corresponding to the number of variables) is then assigned to each of the map positions. In the initial iteration, the vector of the first country is considered and the Euclidean distance between the data vector for that country and each other random vector is computed. A best matching unit (BMU) is identified as the map position for which the Euclidean distance is smallest. After the identification of the BMU, the random vector at that position and sometimes at its

neighbors is modified, resulting in convergence with the actual data vector of that country.

The next iteration looks at another country and performs the same calculations. Through successive iterations, the BMUs and their modified vectors change at a lower rate leading to stabilization and convergence. At the end, the algorithm has computed a set of estimated vectors, one for each map position. In the case of this map, we have 50 estimated vectors, each with sixteen estimated components. Each country is positioned on the map on the basis of the smallest Euclidean distance between its data vector and each of the 50 estimated vectors obtained at convergence of the Kohonen algorithm described above. It is important that we point out here that the positioning of countries on each map is not based on geography but on the Euclidean distance between the actual and estimated vectors at convergence. This is not to say that countries in the same region cannot be clustered together on the Kohonen map. It is in fact quite possible because countries in the same geographical region often reflect indicator values that are quite similar.

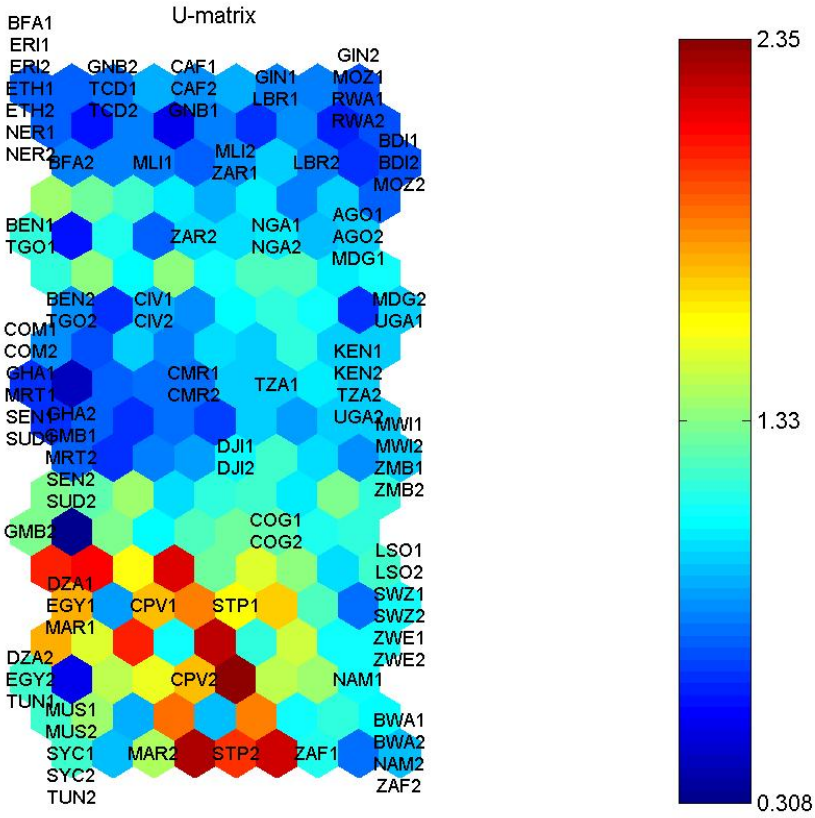
Results

The two dimensional Kohonen map and corresponding component map generated by the algorithm, followed by our interpretation, are presented in Figures 8 and 9. Component maps provide a visual picture of the estimated values of each variable at each map position. Each variable is displayed along a color spectrum of blue to red. The blue color indicates low values while the red color represents high values at the other end of the spectrum. The U-matrix of the Kohonen map contains not only the map positions, but also a hexagon between any two map positions. The color of this hexagon represents the Euclidean distance between the estimated vectors for the two bordering hexagons. Hexagons with darker red colors represent greater distances which in turn represent greater differences and boundaries between countries while hexagons with darker blue colors represent lesser distances. We are able to identify clusters or groupings of countries on the basis of the Euclidean distances between groups of countries as represented by the colored wall of hexagons which separate the groups, within which low distance hexagons appear. For example, a large cluster appears in the upper part of Figure 8, with predominantly low distance blue hexagons within it. We are also able to identify movement by countries over

time because we use data for two time periods, so we can identify if a country has changed its position over the eleven year period (2000 – 2010).

Figure 8 represents the main map for the countries of Africa. The positions of most African countries (identified by their Country Codes – See Table 34 in the appendix) on the U-Matrix (Figure 8) tend to be consistent with their geographic locations. In other words, eastern and western African states can be found mainly on the top of the map in a large, relatively homogeneous cluster, characterized by blue hexagons. Greater distances between hexagon weight vectors, indicated by reds, oranges, and yellows signal the presence of a "barrier". These barriers separate this large cluster of poorer countries from smaller clusters of northern Africa on the map's lower-left, and southern Africa on the lower right. The countries with corresponding country codes are listed in Table 34 in Appendix C.

Figure 8: Africa Kohonen MDG Map



The next step in our exercise is to determine the meaning of the positions, which involves a careful examination of Figure 9: the component maps for Africa. We note several vertical and horizontal patterns in the component scores. First, by examining economic (POV) and information communications technology (TEL, CEL, INT) measures, we find that the main axis from the top of our map (Figure 8) to the bottom can be interpreted as increasing economic wealth and an increase in information technologies. We find though that as you move from the top of the map to the bottom, we have lower employment to population ratios. This is an interesting result as it appears to be moving opposite

to the other MDG indicators. Countries at the top of the map have a high employment to population ratio while more stable countries at the bottom of the map have lower employment to population ratios. A possible contextual explanation is that in poorer and less stable economies, the working population is not limited by age. Children, young adults and even those in the retirement age bracket have to work to support their respective families. North African countries have low employment to population ratios as the formal working population tends to be restricted to only the male gender with women generally as stay at home mothers looking after the children (Anyanwu and Augustine, 2012). Similarly, Figure 9 clearly shows a progression in sanitation and water supply from the top right to the bottom left, favoring Northern Africa. Finally, the component maps point to a clear increase in health problems (HIV and TBR) from the top left to the bottom right, to the detriment of countries in southern Africa such as South Africa (ZAF), Botswana (BWA) and Namibia (NAM). Countries at the bottom of the Kohonen map reflect increased components of the Human Development Index (HDI). The HDI was developed and used by UNDP in ranking countries in terms of levels of human development. The HDI measures average achievements in a country in three basic dimensions of human development:

(i) a long and healthy life, as measured by life expectancy at birth (proxy in our study – low mortality rates); (ii) knowledge, as measured by the adult literacy rate and the combined primary, secondary and tertiary gross enrollment ratio (proxy in our study – high primary enrollment ratios, increased ratios of girls to boys in primary and secondary education); and (iii) a decent standard of living, as measured by the GDP per capita (in PPP US $ - proxy in our study poverty gap ratio). These interpretations are presented in simplified fashion in Figure 10.

Figure 9: Africa Component Map

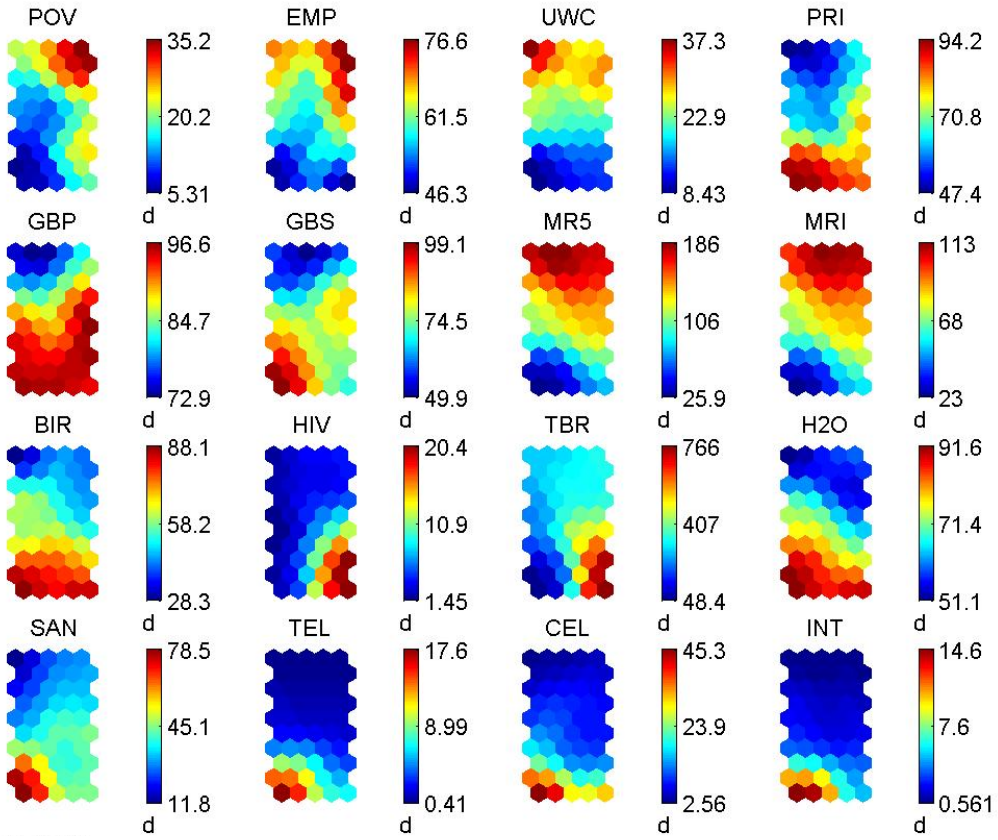
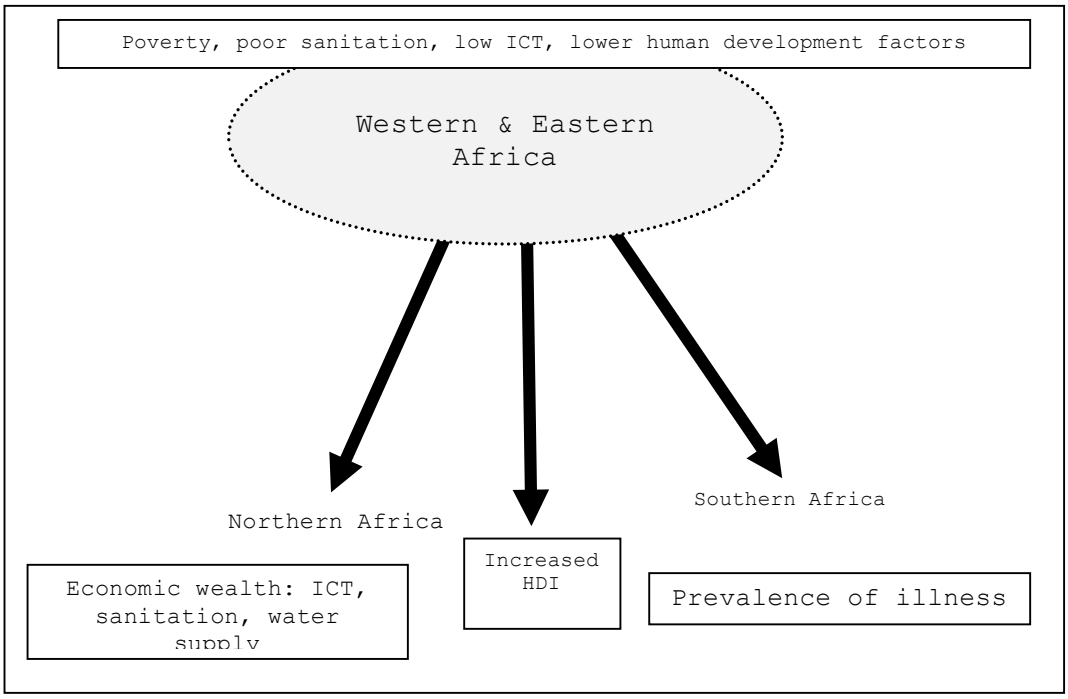


Figure 10: Interpretations of dimensions for Africa



As explained above, our dataset features a temporal component that allows us to track countries' progress over multiple time periods. Unfortunately we see that in Africa, very little movement is evident during the period 2000-2010. Exceptions that we note include modest progress in the cases of Morocco (MAR), Tunisia (TUN), and Egypt (EGY). Notably, South Africa (ZAF) moves toward the right, indicating a mounting prevalence of illnesses using the prescribed UN yardsticks of HIV prevalence (ages 15-24) and tuberculosis rates (TBR). We also note that Nigeria (NGA), Africa's most populous country, remains stable in the poorest and least ICT- intensive region of our map in spite of its size and regional prominence. Following Leo and Barmeier (2010), we acknowledge

Nigeria's internal diversity and complexity here, because considering it to be a single homogeneous statistical entity raises a composition problem that Deaton (2003) highlights in the analogous case of India. In spite of such data-related limitations at the sub-national scale, we find our observations of stark contrasts (countries at the top of the map are vastly different from their counterparts at the bottom of the map) in Figure 8 across the entire continent to be both enlightening and in many cases promising, given that most of the countries moving over time do so in the direction of the bottom of the map (toward economic affluence and ICT access).

Our analysis on Africa indicates that only a handful out of the 48 countries showed some sign of progress in improved economic wealth, sanitation and water supply, and these countries, including Egypt and Tunisia, are located mainly in northern Africa. We also observe modest progress in economic affluence in Burkina Faso, Senegal, Benin across the 2000 -2010 time period. Unfortunately, southern Africa (notably the Republic of South Africa, Botswana, and Namibia), also shows a mounting prevalence of illnesses and health problems such as HIV and tuberculosis. These results in Africa notwithstanding, stark contrasts are evident in Figure 8 across the entire continent.

Although the result of applying a very different technique, our results seem to be consistent with a number of previous studies. For example, Fukuda-Parr (2010), Leo and Barmeier (2010), Easterly (2009), and Clement, Kenny and Moss (2007) concur that the MDGs are unrealistically ambitious for some regions and countries. These authors see them as a set-up for failure in most Sub-Saharan countries because the starting point for African countries is so low that it would take a monumental task to achieve the goals. For example, it would require 41 percentage points, on average, for a low-income country to achieve the relevant education MDG (Leo and Barmeier, 2010). The authors also note that a typical African country would need to grow at an average rate greater than 7 percent over a twenty-five year period in order to reduce its poverty rate by half. So far, only Botswana and Equatorial Guinea have reached that target, and they account for only 0.3 percent of Africa's total population. Fukuda-Parr (2010) succinctly points out that overall, in most indicators for most countries, progress has not accelerated, suggesting that rather than fixating on attaining a specific level of output, it may be more valuable to examine whether changes in priorities have had any impact on countries' ability to meet the goals.

We also consider a one-dimensional Kohonen map (Figure 11). The one dimensional U-matrix (Figure 11) consists of the 16 map positions and a hexagon between any two map positions. The color of this middle hexagon represents the Euclidean distance between the estimated vectors for the two bordering hexagons. Based on the scale, hexagons with darker red colors in our study represent greater distances (Nguyen et al. 2008, Haughton and Haughton 2011). The U-matrix (Figure 11) shows a wall with a red hexagon separating countries like Tunisia and Egypt from South Africa and Sao Tome and Principe. Countries at the top of the map tend to have blue hexagons separating them. This indicates that these countries are not very different from each other in terms of the MDG goals. There is a wall that separates Northern and Southern African countries from the Eastern and Western African countries. The one dimensional U-matrix in conjunction with the one dimensional component map allows us to rank the countries on the basis of the MDG indicators in our study. Based on these maps, we can see that countries at the bottom of the map (Tunisia, Egypt) rank highest with regard to relative attainment in the MDG goals.

Figure 11: One dimensional Kohonen Matrix

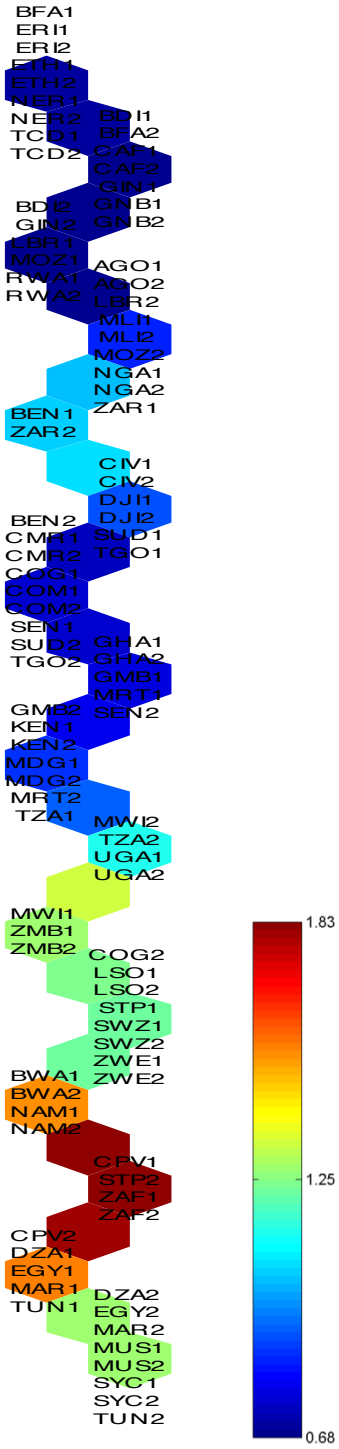
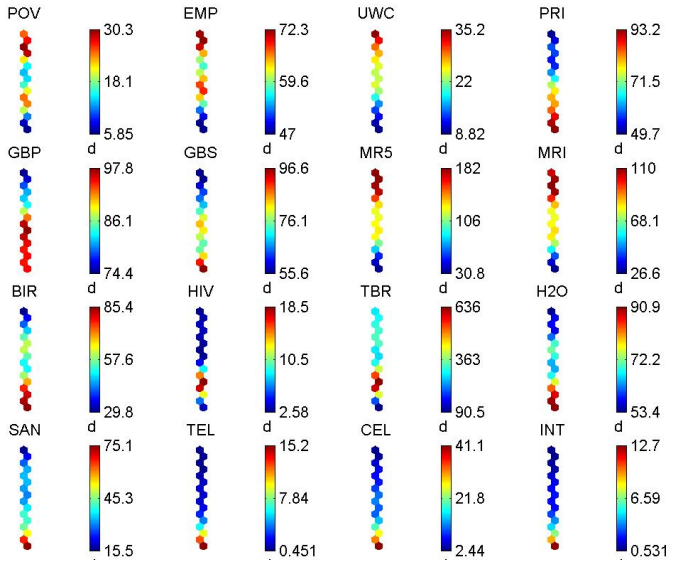


Figure 12: One dimensional Component Map



The one dimensional component maps (Figure 12) allows us to better understand the position of each country on the U-matrix relative to each variable. Each variable is displayed along a color spectrum of blue to red, where the blue color indicates low estimated values and the red represents high estimated values at the other end of the spectrum. We see that in most cases a vertical pattern on the component map with movement from the top to the bottom of the map indicates improvement in the MDG indicators. We note here that the SOM properties for the poverty, employment and disease indicators are violated. As we noted from the two dimensional map, a few south African countries are outliers with respect to the disease indicators and this provides a possible explanation for why we have violation of the SOM properties. The countries at the

bottom of the U-matrix (Egypt, Morocco, Seychelles, Tunisia, and Mauritius) show relatively high levels of attainment with regard to the MDG indicators and goals. The self-organizing property of the SOM algorithm is most evident with the child mortality component maps. As one moves from the top of the map to the bottom, child mortality rates decreases. Countries at the top of the U-matrix such as Burkina Faso, Ethiopia, Eritrea, Niger and Chad have the highest mortality rates while countries at the bottom of the matrix have the lowest mortality rates. Based on the component maps, we can rank the African countries with respect to the achievement of the MDGS. The analysis indicates that Tunisia, Seychelles, Mauritius, Egypt and Algeria are highest in terms of relative MDG attainment.

Conclusions and New Directions

This section demonstrates the application of a novel technique - Kohonen maps to evaluate progress toward the MDGs at the regional and individual country-level. We believe that this approach represents a useful tool that contributes to a better understanding of the MDGs within the African context. Although it is impossible to claim that any of the countries under consideration have made it successfully to the UN's "finish line", we

note evidence from the Kohonen maps that a few of the countries such as Tunisia and Egypt have demonstrated modest progress relative to majority of the African others which continue to languish. We conclude though that while the MDGs have not yet been met in any single case, most African countries are moving in the right direction. Introducing SOMs as a novel methodology in MDG progress analysis, we add insights to existing conclusions by other scholars including Leo and Barmeier (2010), Fukuda-Parr and Greenstein (2010), as well as the *United Nations Development Report* (2011) itself.

The SOM technique also allows us to achieve our second research objective. We find the continent of Africa to be statistically heterogeneous in that its northern and southern regions are distinct from a large group of eastern and western countries and from one another. For example, in Africa, northern African countries stand out at one end of the progress continuum, with a large group of eastern and western African states including Burkina Faso, Liberia, and Eritrea, at the other extreme. This is very different from most countries of Latin America and Asia, however, which have had similar levels of success in the MDG measures with a few exceptions that include Afghanistan, Haiti, and Bolivia

(Deichmann et al. 2013). Tunisia, Cape Verde, Sao Tome and Principe, Algeria and Egypt have found moderate success that distinguishes them from most of the continent.

While critics of the MDGs claim it is "hard to assign much credit to (them) at all" (The *Economist* 2010), governments do possess some instruments for promoting an environment that is conducive to progress. In order to offer policy recommendations, it is worthwhile looking at underlying conditions and what is being done differently by the governments of more successful countries such as the northern African countries vis-à-vis those of the eastern and western African countries, for example. In other words, the "trailblazers" or "high achievers" (to use labels by Leo and Barmeier [2010] and ODI [2010], respectively) can have a demonstration effect on laggards. This study has highlighted trailblazer countries such as Egypt and Cape Verde which while not perfect can be studied further to identify the success factors that have led to the success seen so far. These successes can be built upon by the other countries to achieve similar success. A further look at Egypt shows that the national priorities of the country were in line with the MDGs with the adoption of the Economic Reform and Structural Adjustment Program (ERSAP)(El-Saharty et al

2005). The ERSAP looked to move from a centrally-planned economy with a relatively small private sector to a decentralized, market-based economy where the private sector plays a major role and also stabilizing the economy through reform policies. The government also showed further commitment to the MDGS through the priorities highlighted in Egypt's National Development Plan (2002 to 2007). The plan was focused on overcoming economic stagnation, decreasing the unemployment rate, job creation, expanding basic services to undeserved areas,integrating Egypt into the global economy, developing Egypt's industry and access to technology and boosting exports. These specific policies and program initiatives have supported progress in poverty eradication, job creation and access to basic health and education services (El-Saharty et al 2005).

We note that in Africa, where the range of success is most extreme, very few countries have progressed on the most difficult-to-attain goals. Some goals though have been shown to impact other goals, and should arguably be prioritized. These include the ICT indicators in Africa, environmental sustainability (access to water and sanitation) which as identified in the earlier section have great potential to drive success in other areas of development. For this reason, we recommend

that international agencies and national governments alike focus on these priority goals to further drive overall MDG progress in African countries.

The Kohonen map analysis has allowed us to go one step further by identifying the African trailblazers and it has also allowed us to assess MDG progress and attainment for African countries holistically. The analysis enabled us to assess all the MDG goals simultaneously so our "trailblazers" are identified on the basis of a combination of all the goals. Considering each goal separately, trailblazers and success stories have the potential to change from goal to goal, but with our results we have identified them i.e. trailblazers for the MDG goals in general (Nguyen et al, 2008). It would be worthwhile to examine the ways in which goals are prioritized by these African countries. Compared to relatively successful countries like Tunisia and Morocco, do priorities differ for Liberia and Rwanda, which just recently emerged from the grasps of a bloody internal conflict? It would also be interesting to see what impact the Arab spring uprising has had on countries like Egypt. As developments are ongoing in these countries, it is premature to assess the success of the revolution and what impact these uprisings have had on the socio-

economic welfare of its citizens and also the impact on the continued achievement of the MDG goals. Further research can examine these events in great detail and its subsequent effects.

It is important to note that a limited set of indicators were utilized in this study due to the availability of data. The results are thus interpreted within the context of those specific indicators. As a more robust set of data becomes more easily accessible, it would be useful to reexamine African countries with respect to the achievement of the MDGs and identify if we have the same set of trailblazer countries and if we have more or less homogeneity along sub-regional lines as identified in this study.

As cautioned by Deaton (2003), limitations to using macro-level development data are numerous, and the inclusion of large, heterogeneous countries like Nigeria can confound clear interpretation. Further research could appropriately apply the Kohonen SOM technique to states at the regional or sub-national scale of analysis if the data were readily available. Suggestions on how to go about doing so have been set forth by Clements and Clements (2009), but to do so, the sheer volume of data to be collected across the

developing world and analyzed relegates this to be a formidable if not impossible undertaking.

We have highlighted examples of countries across the range of relative MDG achievement within Africa. This is innovative in this context as the SOM methodology allows us to consider all MDG goals and countries simultaneously in one analysis and in so doing provide a unique ranking based on the MDG indicators utilized in our study. Given 48 countries in our dataset, a thorough elaboration on each individual country is beyond our scope, however further insights can be gleaned on specific goals and individual countries from our study. Finally, we believe that the techniques and approaches that we have taken to the discussion on MDGs and the findings that are presented here are a helpful contribution to the development literature on Africa particularly with regard to the MDGs.

4. Conclusions

This dissertation focuses on the concept of development in Africa. Various aspects of development are examined. These range from the issues of inequality to growth in development via the attainment of the MDG goals. This thesis focuses on two divides within the African development framework:

(i) The social/spatial divide

(ii) The development divide

The first study examines the concept of inequality of opportunity with regard to basic services such as access to water, sanitation, education and durable flooring relative to circumstances beyond an individual's control. The study seeks to re-think the social/spatial divide in Africa, by introducing the concept of equality of opportunity. The emphasis is thus on equal opportunities which imply 'leveling the playing field' at the childhood level. The specific research objectives that we examined include:

1. First we estimate and measure the level of inequality of opportunity for children in six selected African countries by constructing the Human Opportunity Index.

2. Second, by calculating the HOI we identify the determinants of inequality of opportunity across a set of African countries.

We apply the innovative Human Opportunity Index to estimate inequality of opportunities in Africa(Barros et al., 2008).

The results of this study indicate that parental education, area of residence are important determinants with regard to to certain opportunities such as access to electricity, access to water and sanitation and education. The results are consistent with Barros et al's results from applying the HOI estimation to Latin American countries. Similarly our findings are consistent with the UN Habitat study on the state of the urban youth and the study by Velez et al (2012) which also found that parents' education and area of residence both have key impacts on inequality of opportunity. We also add to the work by Velez and colleagues by expanding the scope on the number of countries where we consider five additional countries in addition to Egypt. We find that parental education and area of residence are important not only in Egypt but in the other African countries as well. We validate the UN-Habitat survey study by quantifying these effects further through a quantitative research

application of the Human Opportunity Index to these opportunities and circumstances.

In particular our study also contributes to the body of work on inequality of opportunities with regard to child welfare and development. Considering our opportunities – access to clean water and sanitation which are bedrocks of a healthy society; we find that, the rural/urban divide plays a significant role in child welfare and development inequities in Africa. Our results are consistent with those of Ataguba and colleagues, Mutangadura et al (2007) and Sahn and Sitfel (2004) who all found that the rural/urban divide had a significant impact on health inequalities in Africa. We join the call from these authors that it is imperative that specific policies geared towards improving geographical access to health opportunities are prioritized by African governments.

Overall our analysis indicates that Egypt has the highest HOI at 83% followed by Ghana at a distant second at 48%. Nigeria comes up third at 39% while Uganda is fourth at 31% and Kenya (26%) and Zambia (20%) at fifth and sixth respectively. This indicates that Egypt has a higher degree of equality of opportunity and has been able to more equitably

allocate the available opportunities than the other African countries in the study.

This study allowed us to accomplish the following in the area of inequality:

(i) Apply the Human Opportunity Index to selected African countries and estimate the HOI for each country.

(ii) Identify the circumstances or factors that have significant impact on reducing inequality of certain opportunities for children. The study found that parental education and area of residence are particularly important in determining access to opportunities in Africa.

(iii) Identify countries such as Egypt which have higher levels of access to the opportunities studied in this work and are a good foundation for case study investigation and action.

(iv) Contribute to the process for measuring inequality by highlighting the HOI index as a policy instrument that would guide policy makers in the equal provision and allocation of basic opportunities for all.

(v) Propose that the HOI index is a useful tool that can be employed in the bid to achieving the MDG goals.

This study is innovative in the African context as it applies for the first time the Human Opportunity Index to selected African countries. This enabled us to quantify inequality of some opportunities for children within these countries. The Human Opportunity Index has only previously been applied to Latin American and Caribbean countries (Barros et al., 2008).

The second study examines the development divide (Sen, 1999). Specifically it considers the Sisyphus, i.e. endless and unavailing, challenge that African countries face with regard to achieving the MDGs and attempts to highlight the goals that can be prioritized by identifying the synergies and interdependence between the MDG goals using directed acyclic graphs (DAGs) and partial least squares (PLS) among the goals. This will allow countries to get closer to achieving the MDGs by focusing on specific priority goals. It is important to note that not all indicators for each goal are used in the analysis as data availability guided the choice of indicators utilized. Achieving the MDGs can be seen as one avenue through which the development divide/gap between African countries and more developed countries can be lessened if not eliminated. Identifying and highlighting priority MDG goals for the

African context would be a major step in that direction.

The specific research questions that we considered include:

RQ1. Are there significant positive linkages that exist among the MDG targets in Africa?

RQ2. Based on these linkages, what goals can we identify as priority goals in Africa that would have a cascading effect on other goals

We found the existence of significant positive linkages among the MDG goals in Africa. Using the PLS methodology, we identified linkages from certain goals into other goals. For example, we found that within the African context, digital development i.e. the ICT goals – internet users, cell phone subscribers and telephone lines had a positive effect on gender equality – the ratio of boys to girls in primary and secondary schools. This is a very strong indication that an increase in ICTs influences both school enrollments and also gender equality in school enrollments. We also found that primary education and digital developments had negative effects on child mortality rates i.e. reducing child mortality rates. We also found that environmental sustainability (water and sanitation goals) had a positive effect on reducing poverty rates.

We identify the ICT goal and environmental sustainability goal as priority goals to be achieved in themselves but also as an important tool that would have a cascading effect on the other goals and that can be used to achieve other goals. A higher adoption of ICTs and increasing environmental sustainability opens the door to awareness, development and increased standards of living in Africa.

This study allowed us to accomplish the following with regard to the MDGs and Africa:

(i) Contribute to the extensive body of work on the MDGs

(ii) Extend this body of work by considering the existence of synergies between the MDGs.

(iii) Identify and illustrate the interdependence between the MDG goals – The DAG and SEM methodologies have allowed for easy measurement and visualization of potential linkages between the millennium development goals.

(iv) Identify goals that are antecedents of other goals thus highlighting them as priority goals which would in turn have an effect on other goals thus speeding up Africa's progress towards achieving the goals.

(v) Highlight effects of the ICT target on other targets and in turn recommend that this be explored further in country-specific case studies.

(vi) Contribute to the policy discussion on the MDGs.

This study is innovative with regard to the millennium development goals and the African context. We have highlighted the linkages between goals and identified priority MDG goals for Africa based on select indicators per goal. It is important to note that not all indicators for each goal are used in the analysis as data availability limited the choice of indicators utilized in the study. Despite this limitation, we believe that this study is very useful as it helps to provide insights into a starting point of potential priority goals for Africa. Previous studies have examined linkages between selected goals (Fielding et al., 2005, Larson et al., 2006, Wiebe, 2009) but to the best of our knowledge, this study is the first to consider the linkages between all the goals using partial least squares.

The third study in this dissertation examines the level of progress and relative attainment for 48 countries in Africa with regard to the MDGs. A major aim of the

study was to provide unique and innovative approaches to the MDG conversation.

The specific research objectives that we considered in this study are:

RO1: Introduce a novel technique – Kohonen Maps to the body of work on the MDGs as a tool for assessing progress toward the MDG goals.

RO2: Identify the statistical clustering and movement of African countries with regard to the MDG goals over an eleven year period.

RO3: Understand the African context and identify if African countries are statistically homogenous with regard to achieving progress in the achievement of the MDG goals.

We generated a two dimensional Kohonen map and a corresponding component map based on our data. Component maps provided us with a visual picture of the estimated values of each variable at each map position. The results of our study show that there is a remarkable disparity within the African countries with regard to the MDGs and that this disparity has increased over the years despite growth in ICT development. We also found the African countries were statistically homogenous with regard to achieving

progress in the achievement of the MDG goals. We found that countries tend to develop alongside other countries in the same region. North and South African countries tend to show higher levels of relative MDG attainment than their West and East African counterparts. These sub-regions were clustered together on the map and we were able to identify distinct separations between the North and South regions relative to the West and East African region. Northern and Southern African countries appear to be further along in their bid to attain the MDGs.

This study allowed us to accomplish the following with regard to MDG progress in Africa:

(i) Contribute to the MDG literature especially with regard to progress in African context – identify contrasts and relative progress and attainment.

(ii) Identify trailblazer African MDG countries.

(iii) Develop a unique ranking of African countries with regard to all MDG goals.

(iv) Confirm that geographical and regional characteristics may explain the observed patterns of MDG attainment in Africa (Sachs, 2012).

(v) Highlight areas for country-specific case study investigation.

This study provides a unique approach to the MDG discussion by applying Kohonen Self-Organizing Maps to explore relative progress and attainment (or lack thereof) in 48 African countries.

Future work

We summarize below directions for future work which arise from this dissertation; these directions are also outlined at the end of each chapter.

The Inequality of Opportunity Study:

First, this study has looked at inequality of opportunity for six African countries. Future research should also expand the pool of countries to all African countries; particularly to also include francophone countries. This would enable us to examine results not only at the country level but also on a regional basis within Africa. The opportunities and circumstance variables considered in this study can also be expanded. The opportunities and circumstances considered in this study were selected based on availability of data. It would be interesting to see if we get the same results or different results if we have

an expanded set of opportunity variables which could cover all the MDG goals for example.

Second, this study provides a useful base for future studies. Egypt has been highlighted as a "success" with low levels of inequality. Is Egypt a unique case in North Africa or do other North African countries share the same results? This question is worthy of future investigation.

Third, opportunities and circumstance variables can also be expanded. Ensuring access to education, water and sanitation are targets within the Millennium Development goals framework. Opportunities can be expanded to include other MDG targets/indicators such as health or ICT targets. It is important to keep in mind though that there might be data challenges especially with the disease indicators due to stigmatization which makes respondents unwilling to give accurate information.

Fourth, methodologically, this study on the social divide can be improved by expanding the opportunity variables from binary indicators to indicators with 3 or more levels and utilizing multinomial regression as a technique of choice. In the calculation of the overall HOI index, it would be interesting to explore

how or if at all the results differ if we employ the mean or geometric mean with a wider sample of opportunities.

The MDGs – Examining Synergies and Inter-dependencies:

First, our findings affirm that inter-dependencies and linkages exist among the different MDG goals which can impact and possibly influence the progress of achieving the MDGs in Africa. Future research can build on this work by looking at other contexts besides the African context. It would be interesting to see what the results are for other developing regions such as Latin America and if results from Africa can be applied to other developing regions especially in the context of local/regional differences.

Second, exploratory research like this study is a good foundation for further confirmatory studies such as case studies. The linkages we have identified in this study can be explored further in case studies to better understand how the different goals can be integrated to achieve the MDGs and also how they may be applied to all developing countries.

Third, this study has focused on selected targets within the MDG framework. Future research can expand

the data to include more of the targets. This would allow for a more robust analysis of the MDGs.

Fourth, methodologically, this study can be improved by investigating how the linkages between goals change over time. A good question that can be examined is whether the linkages change as countries get closer to achieving the goals.

The MDGs – Examining Progress and Relative Attainment:

First, We have highlighted examples of countries across the range of relative MDG achievement within Africa. Given 48 countries in our dataset, a thorough elaboration on each individual country is beyond our scope, however further insights can be gleaned on specific goals and individual countries from our study. Further research could appropriately apply the Kohonen SOM technique to states at the regional or sub-national scale of analysis.

Second, We find the continent of Africa to be heterogeneous in that its northern and southern regions are distinct from a large group of eastern and western countries and from one another. In order to offer policy recommendations, it is worthwhile to look at underlying conditions and what is being done

differently by the governments of more successful countries such as the northern African countries vis-à-vis those of the eastern and western African countries, for example especially with regard to the limited set of indicators considered in this study.

Third, We note that in Africa, where the range of success is most extreme, very few countries have progressed on the most difficult-to-attain goals. Some goals though have been shown to impact other goals, and should arguably be prioritized. It would be interesting to look further at the ripple effect a focus on certain goals would have on achieving other goals simultaneaously though indirectly.

5. Appendices

Appendix A – D-Index

The D-index can also be shown to measure the distance between the distribution of circumstances for those who have access and those who do not i.e.

$$D = \frac{1-\bar{p}}{2}\sum_{k=1}^{m}\left|p(x = x_k|y = 1) - p(x = x_k|y = 0)\right| - Equation\ A1$$

Recall that D is defined as:

- $$D = \frac{1}{2\bar{p}}\sum_{k=1}^{m}\left|p(y = 1|x_k) - \bar{p}\right|p\,(x = x_k) - Equation\ 3.1$$

We now show that equation A1 is equation to equation 3.1:

$$D = \frac{1-\bar{p}}{2}\sum_{k=1}^{m}\left|p(x = x_k|y = 1) - p(x = x_k|y = 0)\right| - Equation\ A1$$

$$= \frac{P(y=0)}{2}\sum_{k=1}^{m}\left|\frac{p(x = x_k, y = 1)}{p(y = 1)} - \frac{p(x = x_k, y = 0)}{p(y = 0)}\right|$$

$$= \frac{1}{2\bar{p}}P(y=0)\sum_{k=1}^{m}\left|p(x = x_k, y = 1) - \frac{p(x = x_k, y = 0)}{p(y = 0)}\bar{p}\right|$$

$$= \frac{1}{2\bar{p}}\sum_{k=1}^{m}\left|p(x = x_k, y = 1)P(y = 0) - p(x = x_k, y = 0)\,p(y = 1)\right|$$

$$= \frac{1}{2\bar{p}}\sum_{k=1}^{m}\left|p(y = 1|x = x_k)p(x = x_k)p(y = 0) - p(y = 0|x = x_k)p(x = x_k)\,p(y = 1)\right|$$

$$= \frac{1}{2\bar{p}}\sum_{k=1}^{m}p(x = x_k)\left|p(y = 1|x = x_k)p(y = 0) - p(y = 0|x = x_k)\,p(y = 1)\right|$$

$$= \frac{1}{2\bar{p}}\sum_{k=1}^{m}p(x = x_k)\left|p(y = 1|x = x_k)(1-\bar{p}) - p(y = 0|x = x_k)\,\bar{p}\right|$$

$$= \frac{1}{2\bar{p}}\sum_{k=1}^{m}p(x = x_k)\left|p(y = 1|x = x_k) - p(y = 1|x = x_k)\bar{p} - p(y = 0|x = x_k)\,\bar{p}\right|$$

$$= \frac{1}{2\bar{p}} \sum_{k=1}^{m} p(x = x_k) \left| p(y = 1 | x = x_k) - \bar{p} \right| - \textit{Equation } 3.1$$

Therefore equation 3.1 is equal to the alternative definition of the D index i.e. equation A1.

Appendix B

Table 22: Model Fit Summary – Education

	Uganda	Kenya	Ghana	Nigeria	Egypt	Zambia
Overall Model Fit	**Sig:** 0.000	**Sig:** 0.000	**Sig:** 0.000	**Sig:** 0.000	**Sig:** 0.000	**Sig:** 0.000
Prediction Success Overall	70.7%	71.7%	74.4%	94.4%	75.1%	72.7%

Table 23: Model Fit Summary – Water

	Uganda	Kenya	Ghana	Nigeria	Egypt	Zambia
Overall Model Fit	**Sig:** 0.000	**Sig:** 0.000	**Sig:** 0.000	**Sig:** 0.000	**Sig:** 0.000	**Sig:** 0.000
Prediction Success Overall	67%	67%	78.4%	70.3%	97.9%	81.8%

Table 24: Model Fit Summary - Sanitation

	Uganda	Kenya	Ghana	Nigeria	Egypt	Zambia
Overall Model Fit	**Sig:** 0.000	**Sig:** 0.000	**Sig:** 0.000	**Sig:** 0.000	**Sig:** 0.000	**Sig:** 0.000
Prediction Success Overall	74.4%	76.2%	77.6%	71%	99.3	81.6%

Table 25: Model Fit Summary - Durable Floor

	Uganda	Kenya	Ghana	Nigeria	Egypt	Zambia
Overall Model Fit	**Sig:** 0.000	**Sig:** 0.000	**Sig:** 0.000	**Sig:** 0.000	**Sig:** 0.000	**Sig:** 0.000
Prediction Success Overall	93.5%	90.5%	67.3%	87.9	88.1%	92.6%

Table 26: Logistic Regression Results - Water

	Uganda			Kenya			Ghana		
	B	S.E.	EXP(B)	B	S.E.	EXP(B)	B	S.E.	EXP(B)
Gender	-0.024	0.021	0.976	-0.049*	0.023	0.953	-0.043	0.023	0.958
Gender HH	0.008	0.024	1.008	-0.032	0.025	0.968	-0.150*	0.028	0.861
Educ HH	0.142*	0.021	1.152	0.016	0.025	1.016	-0.029	0.025	0.971
Area	1.165*	0.047	3.206	0.718*	0.051	2.051	0.078*	0.035	1.082
W – Second	-0.283*	0.031	0.753	0.495*	0.033	1.641	0.297*	0.032	1.346
W – Middle	-0.439*	0.031	0.645	0.809*	0.034	2.247	1.061*	0.042	2.890
W – Fourth	-0.159*	0.032	0.853	1.374*	0.036	3.952	1.201*	0.048	3.324
W– Highest	0.421*	0.039	1.523	2.466*	0.058	11.771	0.217*	0.046	1.242
Constant	0.632	0.031	1.882	-0.561	0.032	0.570	0.979	0.033	2.661

significant at 0.05 level

Table 27: Logistic Regression Results – Water

	Nigeria			Egypt			Zambia		
	B	**S.E.**	**EXP(B)**	**B**	**S.E.**	**EXP(B)**	**B**	**S.E.**	**EXP(B)**
Gender	-0.026	0.020	0.974	-0.025	0.048	0.975	0.051	0.029	1.052
Gender HH	-0.161*	0.030	0.851	-0.174*	0.086	0.840	-0.107*	0.036	0.899
Educ HH	-0.206*	0.024	0.814	0.027	0.049	1.028	0.021	0.031	1.021
Area	0.470*	0.027	1.600	1.375*	0.089	3.956	1.264*	0.043	3.541
W – Second	0.649*	0.031	1.914	0.599*	0.058	1.820	0.500*	0.051	1.649
W – Middle	1.238*	0.033	3.447	1.029*	0.072	2.789	0.959*	0.048	2.610
W – Fourth	2.144*	0.037	8.533	2.037*	0.129	7.668	1.847*	0.055	6.342
W– Highest	2.587*	0.044	13.291	0.761*	0.103	2.141	3.499*	0.071	33.069
Constant	-0.937*	0.038	0.392	3.011*	0.090	20.305	-2.113	0.052	0.121

significant at 0.05 level

Table 28: Logistic Regression Results - Sanitation

	Uganda			Kenya			Ghana		
	B	**S.E.**	**EXP(B)**	**B**	**S.E.**	**EXP(B)**	**B**	**S.E.**	**EXP(B)**
Gender	0.003	0.023	1.003	-0.035	0.025	0.965	0.001*	0.024	1.000
Gender HH	-0.050	0.026	0.951	0.043	0.027	1.044	-0.339	0.028	0.713
Educ HH	0.165*	0.023	1.180	0.124*	0.027	1.132	0.211*	0.024	1.235
Area	0.435*	0.057	1.545	0.238*	0.046	1.269	0.313*	0.032	1.368
W – Second	0.810*	0.031	2.248	0.921*	0.046	2.511	1.481*	0.032	4.398
W – Middle	1.439*	0.033	4.216	1.573*	0.044	4.821	2.281*	0.037	9.784
W – Fourth	1.708*	0.034	5.518	2.677*	0.045	14.537	2.939*	0.044	18.895
W – Highest	3.519*	0.065	33.754	3.835*	0.061	46.293	4.032*	0.062	56.400
Constant	-0.440	0.032	0.644	-2.218	0.044	0.109	-1.334	0.035	0.263

significant at 0.05 level

Table 29: Logistic Regression Results - Sanitation

	Nigeria			Egypt			Zambia		
	B	**S.E.**	**EXP(B)**	**B**	**S.E.**	**EXP(B)**	**B**	**S.E.**	**EXP(B)**
Gender	-0.053*	0.021	0.948	-0.138	0.099	0.871	0.015	0.031	1.015
Gender HH	0.269*	0.030	1.298	0.136	0.154	1.146	0.045	0.038	1.046
Educ HH	-0.294*	0.024	0.739	0.580*	0.101	1.786	0.101*	0.033	1.106
Area	0.502*	0.027	1.649	0.811*	0.192	2.250	-0.330*	0.046	0.719
W – Second	0.713*	0.032	2.054	3.271*	0.276	26.343	1.757*	0.082	5.793
W – Middle	0.983*	0.033	2.687	2.655*	0.225	14.225	2.504*	0.079	12.235
W – Fourth	1.873*	0.037	6.556	2.377*	0.237	10.777	3.802*	0.085	44.804
W– Highest	3.463*	0.051	32.099	33.998	0.181	5.825	7.348*	0.110	1553.59
Constant	-1.294*	0.039	0.272	3.453*	0.153	31.591	-3.697	0.083	0.025

significant at 0.05 level

Table 30: Logistic Regression Results - Education

	Uganda			Kenya			Ghana		
	B	**S.E.**	**EXP(B)**	**B**	**S.E.**	**EXP(B)**	**B**	**S.E.**	**EXP(B)**
Gender	0.050*	0.023	1.052	0.210*	0.025	1.233	0.136*	0.023	1.146
Gender HH	-0.466*	0.027	0.628	-0.548*	0.027	0.578	-0.266*	0.026	0.766
Educ HH	3.953*	0.060	52.077	3.319*	0.053	27.622	2.396*	0.032	10.979
Area	-0.360*	0.039	0.698	-0.243*	0.046	0.784	-0.027	0.032	0.973
W – Second	-0.055	0.039	0.946	-0.105*	0.041	0.900	-0.343*	0.036	0.710
W – Middle	0.071	0.039	1.073	-0.214*	0.041	0.807	-0.478*	0.039	0.620
W – Fourth	0.110*	0.038	1.116	-0.453*	0.041	0.635	-0.649*	0.043	0.522
W– Highest	0.061	0.041	1.063	-0.746*	0.054	0.474	-0.835*	0.046	0.434
Constant	-3.660	0.065	0.026	-2.908	0.057	0.055	-2.140	0.039	0.118

significant at 0.05 level

Table 31: Logistic Regression Results - Education

	Nigeria			Egypt			Zambia		
	B	**S.E.**	**EXP(B)**	**B**	**S.E.**	**EXP(B)**	**B**	**S.E.**	**EXP(B)**
Gender	1.700*	0.040	1.212	-0.172	0.017	0.842	0.145*	0.026	1.156
Gender HH	-0.342*	0.059	0.710	0.109	0.029	1.115	-0.353*	0.032	0.702
Educ HH	0.192*	0.041	209.301	7.588	0.311	1975.09	3.198*	0.056	24.495
Area	5.344*	0.054	0.902	-0.101	0.021	0.904	-0.152*	0.047	0.859
W – Second	-0.104	0.058	1.771	-0.313	0.029	1.115	-0.016	0.044	0.984
W – Middle	0.572*	0.062	3.457	-0.489	0.029	0.613	-0.014	0.043	0.986
W – Fourth	1.240*	0.069	4.360	-0.539	0.030	0.583	0.003	0.054	1.003
W– Highest	1.472*	0.078	5.472	-0.560	0.032	0.571	0.245*	0.061	1.277
Constant	-3.252*	0.076	0.039	-7.653	0.312	0.000	-3.301	0.066	0.037

significant at 0.05 level

Table 32: Logistic Regression Results - Durable Floor

	Uganda			Kenya			Ghana		
	B	**S.E.**	**EXP(B)**	**B**	**S.E.**	**EXP(B)**	**B**	**S.E.**	**EXP(B)**
Gender	0.114*	0.041	1.121	-0.003	0.038	0.997	0.006	0.028	1.006
Gender HH	-0.401*	0.047	0.670	-0.224*	0.041	0.799	-0.149*	0.036	0.861
Educ HH	0.191*	0.045	1.211	0.136*	0.042	1.146	-0.027	0.029	0.973
Area	0.855*	0.051	2.351	-0.382*	0.060	0.683	0.298*	0.050	1.347
W – Second	-1.486	0.905	0.226	2.614*	0.485	13.655	2.010*	0.035	7.461
W – Middle	2.107*	0.415	8.220	5.887*	0.469	360.260	2.098*	0.052	18.326
W – Fourth	5.701*	0.393	299.208	8.473*	0.469	4785.15	3.539*	0.072	34.435
W – Highest	8.855*	0.394	7010.61	11.566*	0.477	105437.9	4.015*	0.093	55.426
Constant	-7.151*	0.394	0.001	-7.348*	0.469	0.001	-0.254*	0.038	0.776

significant at 0.05 level

Table 33: Logistic Regression Results - Durable Floor

	Nigeria			Egypt			Zambia		
	B	**S.E.**	**EXP(B)**	**B**	**S.E.**	**EXP(B)**	**B**	**S.E.**	**EXP(B)**
Gender	-0.077*	0.030	0.926	-0.011	0.025	0.989	0.006	0.044	1.006
Gender HH	-0.289*	0.042	0.769	-0.057	0.041	0.944	-0.188*	0.055	0.829
Educ HH	0.266*	0.032	1.290	0.165*	0.025	1.179	0.193*	0.047	1.213
Area	-0.011	0.040	0.989	0.942*	0.044	2.565	-0.773*	0.065	0.462
W – Second	2.657*	0.065	14.265	1.765*	0.028	5.841	0.011	676.540	0.989
W – Middle	4.837*	0.068	125.514	3.641*	0.059	38.136	1.956	479.415	7.099
W – Fourth	6.399*	0.080	594.216	5.810*	0.189	333.592	2.311	479.415	10.085
W – Highest	8.693*	0.164	6042.31	7.574*	0.519	1946.67	2.968	479.415	19.453
Constant	-3.363*	0.075	0.033	0.066	0.043	1.068	-2.117	479.415	0.120

significant at 0.05 level

Appendix C: List of countries in the study (3.1 and 3.2)

Table 34: List of countries in the study

	Country Name	Country Code			Country Name	Country Code
1	Algeria	DZA		25	Liberia	LBR
2	Angola	AGO		26	Madagascar	MDG
3	Benin	BEN		27	Malawi	MWI
4	Botswana	BWA		28	Mali	MLI
5	Burkina Faso	BFA		29	Mauritania	MRT
6	Burundi	BDI		30	Mauritius	MUS
7	Cameroon	CMR		31	Morocco	MAR
8	Cape Verde	CPV		32	Mozambique	MOZ
9	Central Afr Rep	CAF		33	Namibia	NAM
10	Chad	TCD		34	Niger	NER
11	Congo, DR	ZAR		35	Nigeria	NGA
12	Comoros	COM		36	Rwanda	RWA
13	Congo, Rep	COG		37	Sao Tome	STP
14	Cote d'Ivoire	CIV		38	Senegal	SEN
15	Djibouti	DJI		39	Seychelles	SYC
16	Egypt	EGY		40	South Africa	ZAF
17	Ethiopia	ETH		41	Sudan	SDN
18	Eritrea	ERI		42	Swaziland	SWZ
19	Gambia	GMB		43	Tanzania	TZA
20	Ghana	GHA		44	Togo	TGO
21	Guinea	GIN		45	Tunisia	TUN
22	Guinea-Bissau	GNB		46	Uganda	UGA
23	Kenya	KEN		47	Zambia	ZMB
24	Lesotho	LSO		48	Zimbabwe	ZWE

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