CREATING PUBLIC VALUE IN INFORMATION AND COMMUNICATION TECHNOLOGY: A LEARNING ANALYTICS APPROACH

by

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Declaration

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Creating Public Value in Information and Communication Technology: A Learning Analytics Approach

I declare that the above thesis is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

20th December, 2019

SIGNATURE DATE

Dedication

To all who seek wisdom, knowledge, and truth. It is indeed an arduous journey. Relent not, keep persevering, for truly better is the end of a matter, than the beginning thereof.

Acknowledgements

Peer-Reviewed Research Output

This **Doctoral Thesis** is not a collection of published papers. The papers below were presented/published at research workshops and conferences/journals during the process of conducting this PhD thesis.

1. Oyerinde, O.D. & Chia, P.A. (2017). Predicting Students' Academic Performances - A Learning Analytics Approach Using Multiple Linear Regression. *International Journal of Computer Applications, IJCA ISSN: 0975-8887 Vol 157 No 4, Jan 2017.*

2. Oyerinde, Y. & Bankole, F. (2018). Influence of Constant Returns to Scale and Variable Returns to Scale Data Envelopment Analysis Models in ICT Infrastructure Efficiency Utilization. *In Proceedings of the 11th Annual Pre-ICIS SIG GlobDev Workshop, San Francisco, USA, Thursday December 13, 2018*

3. Oyerinde, Y. & Bankole, F. (2019). Measuring Efficiency and Productivity of ICT Infrastructure Utilization. *In Proceedings of the 24th UK Academy for Information Systems International Conference, St Catherine's College, University of Oxford, 9th-10th April, 2019.*

4. Oyerinde, Y., Bankole F. (2019). Investigating the Efficiency of ICT Infrastructure Utilization: A Data Envelopment Analysis Approach. *In: Nielsen P., Kimaro H. (eds) Information and Communication Technologies for Development. Strengthening Southern-Driven Cooperation as a Catalyst for ICT4D.* ICT4D 2019. IFIP Advances in Information and Communication Technology, vol 551. Springer, Cham

5. Oyerinde, Y., Bankole F. (2019). Creating Public Value Using ICT: An Efficiency And Productivity Assessment Approach. *In Proceedings of the International Conference on Information Resources Management (Conf-IRM 2019), Auckland, New Zealand, May 27th – 29th, 2019.*

6. Oyerinde, Y., Bankole, F. (2020). Is There Any Public Value in ICT Developmental Outcomes? A Discourse View. *In Proceedings of The 53rd Hawaiian International Conference on Systems Science (HICSS 53), Hawaii, USA, Jan 7th – 10th, 2020.*

Creating Public Value in Information and Communication Technology: A Learning Analytics Approach

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Abstract

This thesis contributes to the ongoing global discourse in ICT4D on ICT and its effect on socio-economic development in both theory and practice. The thesis comprises five studies presented logically from chapters 5 to 9. The thesis employs Mixed Methods research methodology within the Critical Realist epistemological perspective in Information Systems Research. Studies 1-4 employ different quantitative research and analytical methods while study 5 employs a qualitative research and analytical method.

Study 1 proposes and operationalizes a predictive analytics framework in Learning Analytics by using a case study of the Computer Science Department of the University of Jos, Nigeria. Multiple Linear Regression was used with the aid of the Statistical Package for Social Sciences (SPSS) analysis tool. Statistical Hypothesis testing was then used to validate the model with a 5% level of significance. Results show how predictive learning analytics can be successfully operationalized and used for predicting students' academic performances.

In Study 2 the relative efficiency of ICT infrastructure utilization with respect to the educational component of the Human Development Index (HDI) is investigated. A Novel conceptual model is proposed and the Data Envelopment Analysis (DEA) methodology is used to measure the relative efficiency of the components of ICT infrastructure (Inputs) and the components of education (Outputs). Ordinary Least Squares (OLS) Regression Analysis is used to determine the effect of ICT infrastructure on Educational Attainment/Adult Literacy Rates. Results show a strong positive effect of ICT infrastructure on educational attainment and adult literacy rates, a strong correlation between this infrastructure and literacy rates as well as provide a theoretical support for the argument of increasing ICT infrastructure to provide an increase in human development especially within the educational context.

In Study 3 the relative efficiency and productivity of ICT Infrastructure Utilization in Education are examined. The research employs the Data Envelopment Analysis (DEA) and Malmquist Index (MI), well established non-parametric data analysis methodologies, applied

to archival data on International countries divided into Arab States, Europe, Sub-Saharan Africa and World regions. Ordinary Least Squares (OLS) Regression analysis is applied to determine the effect of ICT infrastructure on Adult Literacy Rates. Findings show a relatively efficient utilization and steady increase in productivity for the regions but with only Europe and the Arab States currently operating in a state of positive growth in productivity. A strong positive effect of ICT infrastructure on Adult Literacy Rates is also observed.

Study 4 investigates the efficiency and productivity of ICT utilization in public value creation with respect to Adult Literacy Rates. The research employs Data Envelopment Analysis (DEA) and Malmquist Index (MI), well established non-parametric data analysis methodologies, applied to archival data on International countries divided into Arab States, Europe, Sub-Saharan Africa and World regions. Findings show a relatively efficient utilization of ICT in public value creation but an average decline in productivity levels.

Finally, in Study 5 a Critical Discourse Analysis (CDA) on the UNDP Human Development Research Reports from 2010-2016 is carried out to determine whether or not any public value is created or derived from the policy directions being put forward and their subsequent implementations. The CDA is operationalized by Habermas' Theory of Communicative Action (TCA). Findings show that Public Value is indeed being created and at the core of the policy directions being called for in these reports.

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Acronyms and abbreviations

AA	Academic Analytics
BCC	Banker Charnes Cooper
BRM	Basic Radial Model
CCR	Charnes Cooper Rhodes
C-D	Cobb-Douglas
CDA	Critical Discourse Analysis
CI	Computer Infrastructure
CRS	Constant Returns to Scale
CS	Computer Science
D.E.A.O.S.	Data Envelopment Analysis Online Software
DEA	Data Envelopment Analysis
DM	Data Mining
DMU	Decision Making Unit
DRS	Decreasing Returns to Scale
EC	Efficiency Change
EDM	Educational Data Mining
EU	European Union
GDP	Gross Domestic Product
HDI	Human Development Index
HDR	Human Development Report
ICT	Information and Communication Technology
ICT4D	Information and Communication Technology for Development
IDRC	International Development Research Center
II	Internet Infrastructure
IRS	Increasing Returns to Scale
IS	Information Systems
IT	Information Technology
ITU	International Telecommunications Union
LA	Learning Analytics
LAK	Learning Analytics and Knowledge
LMS	Learning Management System
MDG	Millennium Development Goals
MI	Malmquist Index
ML	Machine Learning
MLR	Multiple Linear Regression
MPI	Malmquist Productivity Index
MTH	Mathematics
NMC	New Media Consortium
NMEICT	National Mission on Education through Information and Communication Technology
NPM	New Public Management
OECD	Organization for Economic Co-operation and Development

OLS	Ordinary Least Squares
PC	Pure efficiency Change
PV	Public Value
ROI	Returns On Investment
RTS	Returns To Scale
SAP	Student Academic Performance
SC	Scale efficiency Change
SLF	Sustainable Livelihood Framework
SNA	Social Network Analysis
SPSS	Statistical Package for Social Sciences
TC	Technical Change
TCA	Theory of Communicative Action
TFP	Total Factor Productivity
UK	United Kingdom
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
USA	United States of America
UTAUT	Unified Theory of Adoption and Use of Technology
VLE	Virtual Learning Environments
VRS	Variable Returns to Scale
WB	World Bank
WI-FI	Wireless Fidelity
WPSR	World Public Sector Reports
WSIS	World Society for Information Systems

CHAPTER 1

1.0 Introduction

1.1 Background

The growth of Information and Communication Technology (ICT) in recent years has been remarkable in all countries and sectors throughout the world because of its transformational power that favours productivity and efficiency (Kayisire & Wei, 2016). Many governments have heeded the call for increased investments in ICT with an aim to improve national development with respect to the Human Development Index (HDI) (Oyerinde & Bankole, 2019a). This call however is often premised on the assumption that such investments will lead to improvements in productivity and other aspects of development at the organizational and national levels (Samoilenko & Osei-Bryson, 2017).

Over the last three decades, the literature on national development research has been seen to to grow to encompass certain intervening variables and social factors such as education and some other aspects of human welfare. (Desai, 1991; Anand & Ravallion, 1993; Bankole & Mimbi, 2017). This is ever more evident considering that countries have defined policies that show an emphasis on creating support mechanisms for the use of ICT (Hinostroza, 2018), however, the opinions on the direction of ICT Infrastructure for development are from two perspectives vis a vis national development: The adoption of ICTs has the potential to empower communities and countries while secondly, the ICT revolution can lead to imbalances and inequalities through lack of ICT adoption, access and usage (Bankole, 2015).

In the on-going discourse on international human development within the ICT4D context, the concept of national development has been said to encapsulate the notion of human development as the means of enlarging people's choices with regards to knowledge acquisition, amongst others, in order to have access to the resources needed for a decent standard of living (UNDP, 2006; Bankole & Mimbi, 2017). When considering the importance of educational attainment, itself being one of the core indices for measuring development with respect to the Human Development Index (HDI) (UNDP, 2006; Bankole et al., 2011; Bankole et al., 2015), in the national development discourse, coupled with the considerable

successes of data analytics in business for decision making, it is not surprising that data analytics implementations have found their way into main stream Information and Communication for Development (ICT4D) research. Data analytics in education, otherwise known as Learning Analytics (LA), and other research investigating the educational component of the HDI is therefore relevant and applicable for ICT4D research as well as for policy/decision making and implementation.

The need to understand the relevance of education in Human Development is well known and adequately acknowledged. Economies depend on a well-educated population and as a result, many countries are investing in strengthening their educational systems (Friedman, 2005). With the potential of educational technologies to positively improve educational quality and attainment, there is great optimism that ICT in education can greatly increase both average literacy rates and educational attainment levels in developing economies (Oyerinde & Bankole, 2018) as use of analytics is increasingly being used not only in educational management, but also to inform fund-raising and donor decisions (Campbell et al., 2007; Veríssimo et al., 2017; Lee & Shin, 2018).

In its endeavour to increase social and economic developments, governments have understood the need for public sector reform, as its importance in socio-economic development cannot be over-emphasized. The objective of public sector reform, since its inception, has been geared towards innovative ways of bringing about socio-economic development (Mimbi & Bankole, 2016). ICT as enabler of public sector reforms has been implemented to reinvent governments for improved performance (Gauld et al., 2010; Bannister & Connolly, 2014; Nielsen & Goderdzishvili, 2017). Along this line, ICT is touted as having a potential for creating public value (Bannister & Connolly, 2014). With respect to education, and in line with incorporating the use of ICT for improved efficiency, governments are more than ever before defining policies that show an emphasis on creating support mechanisms for the use of ICT in education (Hinostroza, 2018) whether it be in teaching and learning or in decision and policy making. However, in providing and defining these policies, a crucial question that policy makers must answer is whether or not there is any corresponding value created by continuous investments in ICT Infrastructure and its utilization.

Many countries, having realized the critical role of ICT in socio-economic development promoted by a technocentric development effort (Hanafizadeh et al., 2019) and mostly guided

by a number of international development organizations, have expected ICT to enable a series of positive effects with respect to human, national and economic development. This has resulted in many countries and international organisations drawing up ostentatious ICT documents and policies which, for various reasons, have found adoption a serious challenge (Dabla, 2004; Stahl, 2008; Brown & Brown, 2008; Baqir et al., 2009; Bukht & Heeks, 2018). The result therefore has been that the actual outcomes have usually fallen short of these expectations. This has led to discussions about the reasons for this failure, as seen in (Heeks, 2002; Dada, 2006; Hasan, 2016).

In light of this situation, this research project contributes to the ongoing discourse on ICT for national development within the ICT4D field. The specific focus in this study is Public Value creation from ICT infrastructure utilization towards enhancing socio-economic development. International bodies and researchers have also recognised the importance of ICT in public administration with respect to creating public value. For example, the World Public Sector Report (WPSR) produced by the United Nations emphasises that ICT should be harnessed in public services to achieve socio-economic development (Oyerinde & Bankole, 2019b). Importantly, it emphasises that ICT should be a tool for creating public value (WPSR, 2015), whichever way, the use of ICT is ever more becoming a factor in public interactions and public service rendering.

1.2 Motivation for the Study

Information and Communication Technology (ICT) adoption and utilization has featured prominently in the recent discourse of ICT for Development (ICT4D) to guide countries in planned and strategic intervention of ICT in order to accelerate socio-economic development (Hasan, 2016). As a result, many developing countries have been making steady progress over the years with the implementation of ICT-based applications and initiatives, in the hope that these would lead to an increase in efficiency in the public sector, thereby providing public value and ultimately promoting socio-economic development (Hanafizadeh et al., 2019). Consequently, many international bodies and organisations have taken strong positions on the development and utilization of varying ICT policies with an aim to aid socio-economic development and growth. These bodies include the International Development Research Center (IDRC) (IDRC, 1999; Rathgeber, 2000); The Organization for Economic Cooperation

and Development (OECD) (OECD, 1992; Marcelle, 2000); The World Bank (WB); The International Telecommunication Union (ITU) (Nulens & Van Audenhove, 1999) and the United Nations via its United Nations Development Program (UNDP) Human Development Reports (HDR) which have been running annually since 1990.

The main aim of ICT4D research is to identify the objectives of empowerment and how they should be achieved in the practice of national development. These are unlike the physical objectives of ICTs that are essential to overcome the limitations of existing techniques of knowledge storing and sharing (Unwin, 2009; Walsham, 2017). The promotion of the use of ICT for the attainment of social and economic development has gained prominence since the end of World War II when seminal works regarding the role and importance of ICT utilization for achieving modernization and socio-economic development began to emerge (Dabla, 2004). Consequently, modernization theory has placed an emphasis on changing people's attitudes and beliefs and on promoting institutional change at the political, economic and social levels, and has advocated the use of communication to achieve these aims (Bernstein, 1971; Tipps, 1973; Dabla, 2004). Schmandt et al. (1989) stated that developing modern economies requires a commitment to the development of advanced communication systems and to the building of information services, and technologies that can be used to effectively manage and add value to economic activity and simultaneously increase employment opportunities.

ICT infrastructure is determined to be the physical stock that has been realized over time from previous investments made in ICT (Brynjolfrssn & Hitt, 1996; Dutta, 2001). ICT utilization is therefore related to a measure of direct and indirect usage of this stock, especially elements such as computing devices, the Internet and all channels of telecommunications (Pick & Azari, 2011). Increase in ICT infrastructure utilization is often assumed to lead to an increase in efficiency and productivity through improvements in the allocation of its resources, also referred to as technical efficiency, and growth in Total Factor Productivity (TFP) (Qiang & Pitt, 2004) which in turn is assumed to have an effect on socio-economic development (Solow, 1994; Fielding & Torres, 2009). This means that the contribution of ICT utilization to the society necessitates an examination of dimensions such as, efficiency and productivity (resource allocation), government effectiveness, transparency and freedoms (democracy and institutional quality) amongst others which influence national development (Tongia et al.,

2004) and public value (PV) creation (Blaug et al., 2006; Brewer et al., 2006; Mimbi & Bankole, 2016).

This thesis is situated in the context of ICT4D within the ongoing discourse on ICT utilization and socio-economic development. The focus is on public value creation from the utilization of ICT, particularly within the education sector, and the extent to which PV creation affects international policy making and discussions. This research addresses the efficiency and productivity of ICT infrastructure utilization on development from an international perspective (macroeconomic), and the resultant public value creation from the various policy implementations that reflect national interventions, using multiple data analysis techniques, from which inferences and conclusions are drawn. These multiple data analysis techniques reinforce the usage of analytics, in this case learning analytics, within the ICT4D domain and its benefits towards policy direction and decision making.

1.3 Research Objectives

The main objectives of this research are:

- To operationalize Learning Analytics for decision making
- To assess the relative efficiency and productivity of ICT infrastructure utilization in education with respect to national development.
- To investigate the efficiency and productivity of ICT Infrastructure utilization in public value creation with respect to education
- To determine if any public value is being created from ICT in education policy directions and interventions within the ICT4D global discourse.
- To inform practice on the viability of Learning Analytics in international ICT policy direction.

This thesis uses a multi-paper method to address these objectives. These five objectives are achieved through a study each presented in chapters 5 to 9. The study employs a variety of data analysis techniques that are used to extract ICT information from empirically verified data sources. At an abstract level, this thesis is concerned with using Learning Analytics (LA) research within the ICT4D context, thereby investigating the relative efficiency and

productivity of ICT infrastructure utilization within the education sector and its resultant effect or value on socio-economic development.

The first study in this thesis operationalizes the predictive analytics component of LA using a case study in order to lay the foundation for showing how LA can be utilized for decision making. In this study, multiple linear regression is used for the data analysis. *In the second study* the relative efficiency of ICT infrastructure utilization, with respect to the educational component of the Human Development Index (HDI) is investigated, and a novel conceptual model is proposed. This study has obtained worldwide international time series data from the United Nations Educational, Scientific and Cultural Organisation (UNESCO), the World Bank (WB), and the International Telecommunications Union (ITU). The research has shown how LA can be used for decision making within the ICT4D field while employing the same education indices as those introduced by Orbicom, (2005). Having established the viability of LA in the ICT4D context, *the third study* goes a step further by measuring the productivity of ICT infrastructure utilization over a 7-year period (2010-2016) and using same to inform policy direction within the IC4TD context. In *the fourth study,* the relative efficiency and productivity of ICT infrastructure is investigated with respect to public value creation. In this study, the concept of public value within ICT4D is introduced to the utilizatioin of LA for decision making. *The fifth study* carries out a Critical Discourse Analysis (CDA), operationalized by Habermas' Theory of Communicative Action (TCA), on the UN Human Development Reports (HDRs) from 2010-2016. This is done to critically investigate these policy direction documents to determine whether or not public value is created and/or is at the root of the policy directions being put forward by these HDRs. A hitherto unfamiliar theoretical approach is employed in this study and informs both theory and practice within the ICT4D discourse. The five studies, of which this thesis is comprised, are related by a common theme which is addressing the utilization of ICT, in this case LA, for decision making in order to enhance socio-economic development within the ICT4D discourse, using both quantitative and qualitative research methods. The five studies are as follows:

Study 1: Predicting Students' Academic Performances – A Learning Analytics Approach using Multiple Linear Regression.

Study 2: Investigating the Efficiency of ICT Infrastructure Utilization: A Data Envelopment Analysis Approach.

Study 3: Measuring Efficiency and Productivity of ICT Infrastructure Utilization.

Study 4: Creating Public Value Using ICT: An Efficiency and Productivity Assessment Approach.

Study 5: Is there Any Public Value in ICT Developmental Outcomes? A Discourse View.

The five studies expound on the transformative role that ICT is playing in socio-economic development especially within the ICT4D discourse. These studies also contribute to the ICT4D global discourse by offering useful insights into the presentation and application of different data analysis techniques to the knowledge base of Information Systems research.

1.4 Research Questions

The principal research question asked in this thesis is: is any public value being created by ICT infrastructure utilization in education and what are the resultant effect(s) on socio-economic development;

1. Is there any Public Value being created in ICT infrastructure utilization in education? The specific research questions are:

    - How can Learning Analytics be operationalized for decision making in order to provide value?

    - What is the effect of ICT infrastructure utilization in education on socio-economic development?

    - What are the relative efficiencies and productivity of ICT infrastructure utilization in education and its effect on socio-economic development?

    - What are the relative efficiencies and productivity of ICT infrastructure utilization in creating public value with respect to education?

    - Is any Public Value being created from ICT infrastructure policy formulation and calls with respect to education in the UNDP HDRs?

1.5 Research Design

This thesis employs a mixed methods research methodology. The thesis is comprised of 5 studies, chapters 5-9, which address the objectives of the thesis using quantitative and qualitative research methods. Each study attempts to answer a particular research question using empirically approved analysis methods. Figure 1 shows the flowchart of how the research has been conducted and the thesis put together.

Philosophically, mixed methods research makes use of the pragmatic method and system of philosophy. Its logic of inquiry includes the use of induction, discovery of patterns, deduction, testing of theories and hypotheses, and abduction, uncovering and relying on the best of a set of explanations for understanding results (de Waal, 2001). Mixed methods research also attempts to legitimize the use of multiple approaches in answering research questions, rather than restricting or constraining the researchers' choices. It is a broad and creative form of research, not a limiting form of research. It is inclusive, pluralistic, and complementary, and it suggests that researchers take a multifarious approach to method selection and the thinking about and conduct of research. What is most fundamental to mixed methods research is the research question. The research methods should follow the research questions in a way that offers the best chance in obtaining viable answers. Many research questions and combinations of questions are, more often than not, very well answered through mixed research solutions (Johnson & Onwuegbuzie, 2004).

Mixed method research is deemed suitable for this research because as noted by Greene et al. (1989) there are five major purposes or rationales behind conducting mixed methods research, namely:

- Triangulation: Seeking convergence and corroboration of results from different methods and designs studying the same phenomenon.
- Complementarity: Seeking elaboration, enhancement, illustration, and clarification of the results from one method with results from the other method.
- Initiation: Discovering paradoxes and contradictions that lead to a re-framing of the research question.
- Development: Using the findings from one method to help inform the other method.

- Expansion: Seeking to expand the breadth and range of research by using different methods for different inquiry components.

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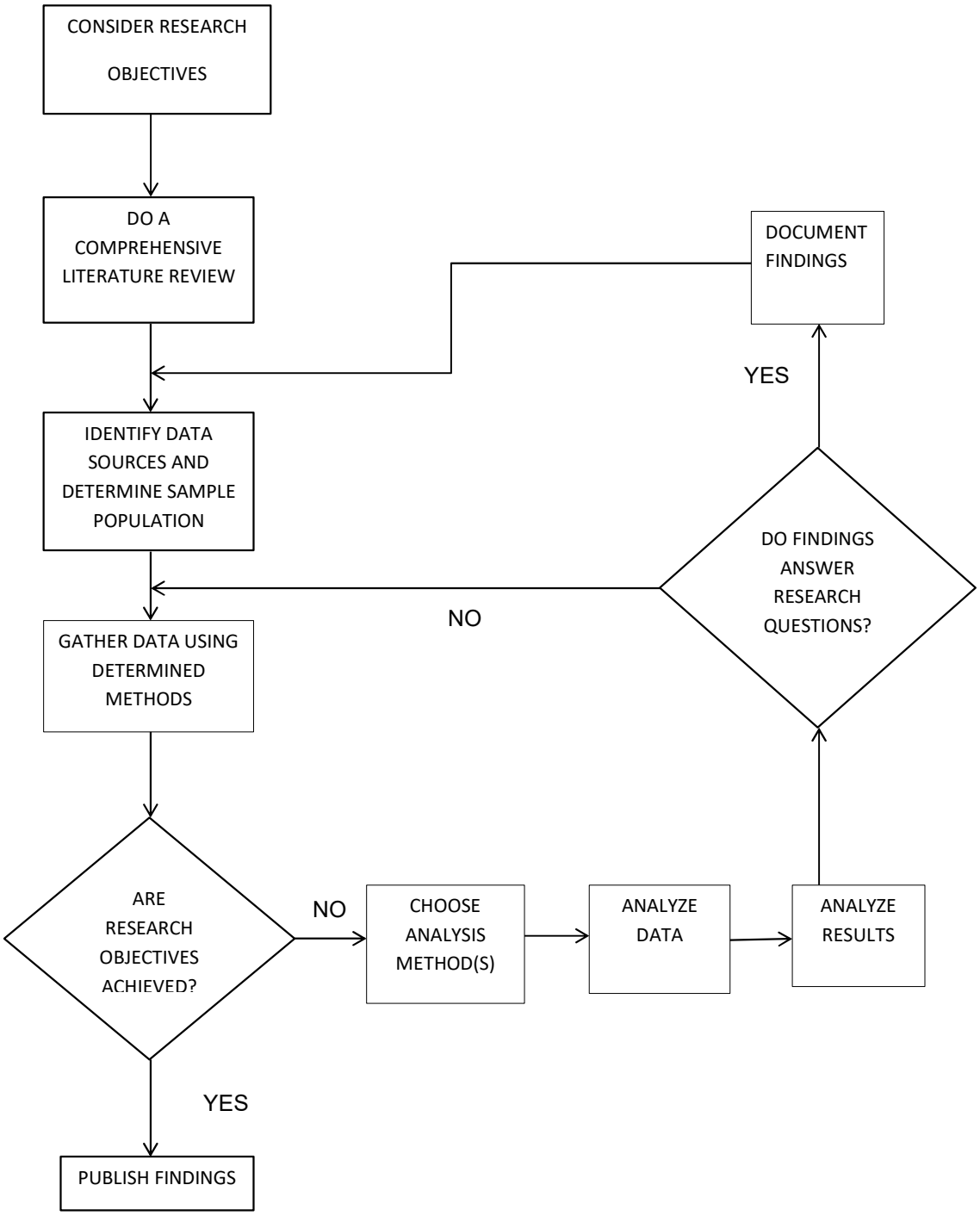

Figure 1: Flow Chart of Research Plan

The rationale behind this research which makes it suitable for mixed methods is expansion. This research seeks to expand the breadth and range of ICT4D research with respect to education and socio-economic development by using different methods for the different research questions and objectives. This research is conducted predominantly within the quantitative research paradigm and as such employs the QUAN→qual mixed method research design. This is appropriate because the first 4 studies, chapters 5-8 employ quantitative research methods in addressing the research objectives. These findings and outcomes inform the 5th study, chapter 9, which employs a qualitative research method seeking to go deeper into the phenomenon by critically interrogating the status quo, while addressing its research objectives, and ultimately informing both theory and practice by employing a hitherto unfamiliar theoretical approach not found within the existing literature.

1.6 Summary and Conclusion

This thesis sets out to achieve its aims and objectives by using a multi-paper approach with each paper addressing specific objectives and answering specific research questions. This is done within the Critical Research paradigm using Mixed Methods Research as an appropriate methodology. Using multiple quantitative methods and a single qualitative method, this research contributes to both theory and practice and is situated within the ICT4D global discourse.

The rest of this thesis is arranged as follows: Chapter 2 provides a literature review of the context of this research; Chapter 3 provides the research frameworks employed in the studies and chapter 4 provides the research methodologies employed in the studies. Chapter 5, Chapter 6, Chapter 7, Chapter 8, Chapter 9 present each of the studies and Chapter 10 provides the conclusions, explanation of answers to research questions, contributions to IS research, and recommendations for future work.

1.7 References

Anand, S., & Ravallion, M. (1993). Human Development in Poor Countries: On the Role of Private Incomes and Public Services. *The Journal of Economic Perspective*, *7*(1), 133–150.

Bankole, F. O., Shirazi, F., & Brown, I. (2011). Investigating the impact of ICT investments on human development. *The Electronic Journal of Information Systems in Developing Countries*, *48*(1), 1-19.

Bankole, F.O (2015). ICT Infrastructure and Its' Impact on National Development: A Research Direction for Africa Using Analytics. *In Proceedings of SIG GlobDev 2015 Pre-ECIS Workshop, Munster, Germany, May 26, 2015*

Bankole, F. O., Osei-Bryson, K. M., & Brown, I. (2015). The impact of information and communications technology infrastructure and complementary factors on Intra-African Trade. *Information Technology for Development*, *21*(1), 12-28.

Bankole Dr, F., & Mimbi, L. (2017). ICT Infrastructure and It's Impact on National Development: A Research Direction for Africa. *The African Journal of Information Systems*, *9*(2), 1.

Bannister, F., and Connolly, R. (2014). ICT, public values and transformative government: A framework and programme for research, *Government Information Quarterly* (31)1, 119-128.

Baqir, M. N., Palvia, P., & Nemati, H. (2009). Evaluating government ICT policies: An extended design-actuality gaps framework. In *Proceedings of Second Annual SIG GlobDev Workshop*

Bernstein, H. (1971). Modernization Theory and the Sociological Study of Development. *Journal of Development Studies*, *7*(2), 141–160.

Blaug, R., Horner, L., and Lekhi, R. (2006). Public value, politics and public management A literature review." www.theworkfoundation.com

Brewer, G. A., Neubauer, B. J., and Geiselhart, K. (2006). Designing and Implementing E-Government Systems Critical Implications for Public Administration and Democracy, *Administration & Society* (38)4, 472-499

Brown, W., & Brown, I. (2008). Next generation ICT policy in South Africa: Towards a human development-based ICT policy. In *IFIP International Conference on Human Choice and Computers* (pp. 109-123). Springer, Boston, MA

Brynjolfsson, E., & Hitt, L. M. (1996). Productivity, Profit and Consumer Welfare. Three Different Measures of Information Technology's Value. *MIS Quarterly*, 1–23

Bukht, R., & Heeks, R. (2018). Digital economy policy in developing countries (DIODE Working Papers No. 7). Manchester: University of Manchester.

Campbell, J. P., DeBlois, P. B., & Oblinger, D. G. (2007). Academic analytics: A new tool for a new era. *EDUCAUSE review*, *42*(4), 40.

Dabla, A. (2004). The role of information technology policies in promoting social and economic development: The case of the State of Andhra Pradesh, India. *The Electronic Journal of Information Systems in Developing Countries*, *19*(1), 1-21.

Dada, D. (2006). The failure of e-government in developing countries: a literature review. *The Electronic Journal of Information Systems in Developing Countries*, *26*(1), 1-10.

Desai, M. (1991). Human development. *European Economic Review*, *35*(2-3), 350–357. doi:10.1016/0014-2921(91)90136-7

de Waal, C. (2001). On Peirce. Belmont, CA: Wadsworth.

Dutta, A. (2001). Telecommunications and Economic Activity: An Analysis of Granger Causality. *Journal of Management Information Systems*, *17*(4), 71–95

Fielding, D., & Torres, S. (2009). Health, Wealth, Fertility, Education, and Inequality. *Review of Development Economics*, *13*(1), 39–55

Friedman, T. L. (2005). *The world is flat: A brief history of the twenty-first century*. Macmillan.

Gauld, R., Goldfinch, S., and Horsburgh, S. (2010). Do they want it? Do they use it? The 'Demand-Side'of e-Government in Australia and New Zealand, *Government Information Quarterly* (27)2, 177- 186.

Greene, J. C., Caracelli, V. J., & Graham, W. F. (1989). Toward a conceptual framework for mixed-method evaluation designs. Educational Evaluation and Policy Analysis, 11, 255–274.

Hanafizadeh, P., Khosravi, B., & Badie, K. (2019). Global discourse on ICT and the shaping of ICT policy in developing countries. *Telecommunications Policy*, *43*(4), 324-338.

Hasan, Z. (2016). Evaluation of a government ICT policy document from a communicative action perspective: A case of Bangladesh. *The Electronic Journal of Information Systems in Developing Countries*, *73*(1), 1-14.

Heeks, R. (2002). Information systems and developing countries: Failure, success, and local improvisations. *The information society*, *18*(2), 101-112

Hinostroza, J. E. (2018). New Challenges for ICT in Education Policies in Developing Countries: The Need to Account for the Widespread Use of ICT for Teaching and Learning Outside the School. In *ICT-Supported Innovations in Small Countries and Developing Regions* (pp. 99-119). Springer, Cham.

International Development Research Center (IDRC) (1999). The Acacia Initiative. IDRC, Ottawa, ON, Canada. www.idrc.ca/acacia

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational researcher*, *33*(7), 14-26

Kayisire, D., & Wei, J. (2016). Information Technology for Development ICT Adoption and Usage in Africa: Towards an Efficiency Assessment, *1102*. https://doi.org/10.1080/02681102.2015.1081862

Lee, I., & Shin, Y. J. (2018). Fintech: Ecosystem, business models, investment decisions, and challenges. *Business Horizons*, *61*(1), 35-46.

Marcelle, G. M. (2000). Getting gender into African ICT policy: A strategic view. *Gender and the Information Revolution in Africa*, 35-84

Mimbi, L., & Bankole, F. (2016). ICT and public service value creation in Africa: Efficiency assessment using DEA approach. *Proceedings OfThe 27th Australasian Conference on Information Systems*, 1–13.

Nielsen, M. M., & Goderdzishvili, N. (2017). Georgia on my mind: A study of the role of governance and cooperation in online service delivery in the Caucasus. In *International Conference on Electronic Government* (pp. 71-91). Springer, Cham.

Nulens, G., & Van Audenhove, L. (1999). An information society in Africa? An analysis of the information society policy of the World Bank, ITU and ECA. *Gazette (Leiden, Netherlands)*, *61*(6), 451-471.

Orbicom (2005) *From The Digital Divide To Digital Opportunities: Measuring Infostates for Development*, Montreal: Claude-Yves Charron

Organisation for Economic Co-operation and Development (OECD) (1992). New Technologies: opportunities and policy implications for the 1990s. OECD, Paris, France

Oyerinde, Y. & Bankole, F. (2018). Influence of Constant Returns to Scale and Variable Returns to Scale Data Envelopment Analysis Models in ICT Infrastructure Efficiency Utilization. *In Proceedings of the 11th Annual Pre-ICIS SIG GlobDev Workshop, San Francisco, USA, Thursday December 13, 2018*

Oyerinde, Y. & Bankole, F. (2019a). Investigating the Efficiency of ICT Infrastructure Utilization: A Data Envelopment Analysis Approach. *In: Nielsen P., Kimaro H. (eds) Information and Communication Technologies for Development. Strengthening Southern-Driven Cooperation as a Catalyst for ICT4D.* ICT4D 2019. IFIP Advances in Information and Communication Technology, vol 551. Springer, Cham

Oyerinde, Y., Bankole F. (2019b). Creating Public Value Using ICT: An Efficiency And Productivity Assessment Approach. *In Proceedings of the International Conference on Information Resources Management (Conf-IRM 2019), Auckland, New Zealand, May 27th – 29th, 2019.*

Pick, J. B., & Azari, R. (2011). A Global Model of Technological Utilization Based on Governmental, Business-Investment, Social, and Economic Factors. *Journal of Management Information Systems*, *28*(1), 49–84

Qiang, C. Z. & Pitt, A. (2004). Contribution of Information and Communication Technologies to Growth. T*he World Bank Working Paper, Vol: 24*

Rathgeber, E. M. (2000). Women, men and ICTs in Africa: Why gender is an issue. *Gender and the information revolution in Africa*, 17-34.

Samoilenko, S., & Osei-Bryson, K. M. (2017). An analytical framework for exploring context-specific micro-economic impacts of ICT capabilities. *Information Technology for Development*, *1102*, 1–25. https://doi.org/10.1080/02681102.2017.1336072

Schmandt, J., Williams, F., & Wilson, R. H. (1989). *Telecommunications policy and economic development: The new state role*. Praeger Publishers.

Solow, R. M. (1994). Perspectives on Growth Theory. *The Journal of Economic Perspective*, *8*(1), 45–54.

Stahl, B. C. (2008). Empowerment through ICT: A critical discourse analysis of the Egyptian ICT policy. In *IFIP international conference on human choice and computers* (pp. 161-177). Springer, Boston, MA

Tipps, D. C. (1973). Modernization theory and the comparative study of national societies: A critical perspective. *Comparative studies in society and history*, *15*(2), 199-226.

Tongia, R., Subrahmanian, E., & Arunachalam, V. S. (2004). *Information and Communications Technology for Sustainable Development: Defining a Global Research Agenda* (pp. 1–129).

UNDP: United Nations Development Programme. (2003) Human Development Index Reveals Development Crises, Human Development Reports. http://www.undp.bg/uploads/documents/1162_536_en.pdf

UNDP: United Nations Development Programme. (2006). The Millennium Development Goals. *UNDP*.

Unwin, T. (Ed). (2009). *ICT4D: Information and Communication Technology for Development*. *Cambridge: Cambridge University Press*.

Veríssimo, D., Vaughan, G., Ridout, M., Waterman, C., MacMillan, D., & Smith, R. J. (2017). Increased conservation marketing effort has major fundraising benefits for even the least popular species. *Biological Conservation*, *211*, 95-101.

Walsham, G. (2017). ICT4D research: reflections on history and future agenda. *Information Technology for Development*, *23*(1), 18-41.

WPSR: World Public Sector Report (2015). Responsive and Accountable Public Governance. *Department of Economic and Social Affairs*. United Nations, New York, 2015

CHAPTER 2

2.0 Literature Review

2.1 Introduction

This chapter provides a comprehensive review of the literature in which this thesis is situated. There is a need to understand the underlying concepts and fundamentals of the principles behind the phenomena investigated as well as understand what has happened and is ongoing within the domain of LA and PV within the ICT4D Discourse. Therefore, a review of the discourse and phenomena investigated has been carried out. Fundamentals and principles of Learning Analytics (LA) and Educational Data Mining (EDM) are presented, the concept of Public Value (PV) is discussed as well as a comprehensive presentation of the ICT4D Discourse.

The rest of this chapter is presented as follows: Section 2.2 introduces LA and EDM, section 2.3 discusses the history of LA while section 2.4 identifies the factors driving the development of LA and section 2.5 identifies the LA constructs. Section 2.6 presents the concept of PV, section 2.7 presents the link between ICT, socio-economic development and policy while section 2.8 presents an overview of the global discourses in ICT4D and section 2.9 is the conclusion of the chapter.

2.2 Learning Analytics and Educational Data Mining

The field of Data Analytics in Education, otherwise known as Learning Analytics (LA) and Educational Data Mining (EDM) is fast gaining ground in term of research interests and advancement in technology. Educational Data Mining is concerned with developing methods and analyzing educational content to enable a better understanding of student performance as well as being important for enhancing teaching and learning processes (Baker, 2010). Romero & Ventura (2013), believe EDM is more concerned with developing, researching and

applying computerized methods to detect patterns in large collections of educational data that would otherwise be hard or impossible to analyze, due to the enormous volume of data within which they exist. Learning Analytics (LA), on the other hand, is the area of research related to business intelligence, web analytics, academic analytics, action analytics and predictive analytics (Papamitsiou & Economides, 2014). According to the definitions introduced during the 1st International Conference on Learning Analytics and Knowledge (LAK), LA is "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and environments in which it occurs" (Learning Analytics & Knowledge, 2011). This definition could be taken to cover the majority of educational research, but it is typically coupled with two assumptions: that learning analytics make use of pre-existing, machine-readable data, and that its techniques can be used to handle 'big data', large sets of data that would not be practicable to deal with manually (Ferguson, 2012).

2.3 History of Learning Analytics

Before the widespread emergence of online learning or big data, educational institutions were already involved in institutional research and evaluation. In 1979, the Survey Research Department of The Open University in the UK reflected on ten years of monitoring the progress of their many thousands of open distance learning students, course by course, at several stages in the academic year (McIntosh, 1979). Even at this early date, McIntosh wrote about the richness and profusion of available data acting as a barrier to its use. Over the next two decades, the situation has changed with improvements in technology and its availability. With the emergence of the second-generation web, web 2.0, new possibilities opened up for collecting web content from diverse sources, processing it and exchanging the results with other programs (Berners-Lee et al., 2001). With extensive datasets increasingly available for analysis, the field of educational data mining gradually emerged.

Data Mining is a field of computing that applies a variety of techniques such as; decision tree construction, rule induction, artificial neural networks, instance-based learning, Bayesian learning, logic programming, statistical algorithms to databases in order to discover and display previously unknown, and potentially useful, data patterns (Chatti et al., 2012; Romero & Ventura, 2007). Educational data mining, a sub-set of this field, is concerned with

developing methods for exploring the unique types of data that come from educational settings, using those methods to better understand students, and the settings in which they learn (www.educational datamining.org).

EDM emerged from the analysis of logs of student-computer interaction and, until 2005, relationship-mining methods were the most prominent type of EDM research, followed by prediction methods (Baker & Yacef, 2009). Despite the data-driven basis of the field, it has always maintained a strong emphasis on teaching and learning. Zaïane (2001) identified the goal of EDM as turning learners into effective better learners with research focused on data mining and machine learning techniques, that could be used to enhance web-based learning environments for the educator, to better evaluate the learning process, as well as for the learners, to help them in their learning endeavour.

Alongside the data-driven approach to analytics, socially and pedagogically driven approaches to analytics began to emerge in the early 21st century. A significant development was the integration of Social Network Analysis (SNA) within the learning analytics toolkit. The works of Aviv et al. (2003) and De Laat et al. (2006) were explicitly situated within the constructivist paradigm that considers knowledge to be constructed through social negotiation (Aviv et al., 2003; De Laat et al., 2006). Their use of SNA, a method developed in the social sciences, allowed them to carry out detailed investigations of networks made up of actors and the relations between them. SNA refers to actors with a relationship between them as tied, and these ties can be classified as strong or weak, depending on their frequency, quality or importance (Granovetter, 1973). In the context of learning, social network analysis can be used to investigate and promote collaborative and cooperative connections between learners, tutors and resources, helping all participants to extend and develop their capabilities (De Laat et al., 2007; Haythornthwaite, 2006; Haythornthwaite & de Laat, 2010).

By 2007, learning analytics researchers had begun to address both educational and technological challenges. At this point, development of the field began to increase as it was presented with a new set of challenges and associated new funding streams. The Educause Review (Campbell et al., 2007) presented a bleak view of the US education system trailing other developed countries, with some graduates lacking even basic competencies. They proposed that academic analytics, which was emerging as a new tool, could address what

seemed like intractable challenges. Goldstein & Katz (2005) actually coined the term academic analytics to describe the application of the principles and tools of business intelligence to academia. Unlike educational data mining, which seeks to search for and identify patterns in data, academic analytics marries large data sets with statistical techniques and predictive modelling to improve decision making. The goal of these researchers was to study the technological and managerial factors that impact how institutions collect, analyse, and use data. Campbell & Oblinger (2007) set out a definition of academic analytics. This definition linked the technological aspect of learning technologies with the educational aspect of EDM from the context of the political and economic implications and standpoint. Table 1 gives a brief explanation of LA and AA.

Table 1: Learning Analytics & Academic Analytics

Types of Analytics	Level or Object of Analysis	Who Benefits
Learning Analytics	**Course Level:** Social networks, conceptual development, discourse analysis, "intelligent curriculum"	Learners, Faculty
	Departmental: Predictive modeling, patterns of	Learners, Faculty
Academic Analytics	**Institutional:** Learner profiles, performance of academics, knowledge flow	Administrators, Funders, Marketing
	Regional (State/Provincial): Comparisons between systems	Funders, Administrators
	National and International:	National Governments, Educational Authorities

The influence of political drivers on the field of analytics, together with the growing maturity of the field of EDM, were key factors associated with a split between analytics and EDM. As a result, the literature of the two diverged and the key EDM references identified by Romero & Ventura (2007) were displaced in the analytics literature by generic references to overviews of the EDM field (Romero & Ventura, 2007; Baker & Yacef, 2009). In 2010, however, a major split in the field of analytics came to the fore with the emergence of learning analytics as a field in its own right (Learning Analytics & Knowledge, 2011; Ferguson, 2012). This meant that there were now separate groupings focusing on each of the challenges driving analytics research:

- Educational data mining focused on the technical challenge: How can we extract value from these big sets of learning-related data?
- Learning analytics focused on the educational challenge: How can we optimise opportunities for online learning?

- Academic analytics focused on the political/economic challenge: How can we substantially improve learning opportunities and educational results at national or international levels?

Overlaps between the three groupings remain, but there have been several attempts to disambiguate the fields. Long & Siemens (2011) have focused on current and future meanings, distinguishing between learning analytics, which benefit learners and faculty and are focused at the level of courses and department, and academic analytics, which benefit funders, administrators and marketing at institutional level; funders and administrators at regional level; and governments and education authorities at national and international level. Baepler & Murdoch (2010) have examined the distinctions between data mining, academic analytics and audit of institutional systems. Educause, which has developed its definitions of analytics over several years, has taken a longer-term view, setting out a wider landscape of terminology and highlighting the varied definitions that have emerged over the last decade (van Barneveld et al., 2012).

Consequently, LA has evolved to become a comprehensive and extensive area of analytics research. It has spread its reach to encompass varying scopes and research scenarios and although an emerging field of research within Information Systems, LA has established itself as a prominent area of research contributing to Information Systems theories, tools and discourse. Therefore, use of LA for expounding on IS theory and practice are valid and can be used to seek new insights into various research discussions or contribute to on going discourses.

2.4 Factors driving the development of Learning Analytics

2.4.1 Big Data

Society is faced with the growing challenge posed by big data, datasets whose size is beyond the ability of typical database software tools to capture, store, manage and analyse (Manyika, 2011). Businesses employ analytics to extract value from such datasets, using them to drive recommendation engines, identify patterns of behaviour and develop advertising campaigns. The widespread introduction of virtual learning environments (VLEs), also known as learning management systems (LMSs), such as Blackboard and Moodle, has meant that educational institutions deal with increasingly large sets of data. Each day, their systems amass ever-increasing amounts of interaction data, personal data, systems information and academic information (Mazza & Milani, 2004; Romero et al., 2008). Although student-tracking capabilities are typically included as generic software features, the depth of extraction and aggregation, reporting and visualisation functionality of these built-in analytics has often been basic or non-existent (Dawson, 2009). In addition, significant amounts of learner activity take place externally, and so records are distributed across a variety of different sites with different standards, owners and levels of access. The first driver, then, is a technical challenge. This challenge is summed up by the question: How can value be extracted from these big sets of learning-related data?

2.4.2 Online Learning

The rise of big data in education mirrors the increase in take-up of online learning. Learning online offers many benefits, but it is also associated with problems. Students may feel isolated due to lack of contact with teachers or peers; they may become disorientated in the online space, experience technical problems or lose their motivation (Mazza & Dimitrova, 2004). At the same time, teachers lack the visual cues that can signal when students are not sufficiently challenged, when they are bored, confused, overwhelmed or simply absent. Teachers may also struggle to interpret and evaluate the learning and quality of participation of individuals, when these are buried within hundreds of student contributions to discussions that have lasted several weeks (Dringus & Ellis, 2005). The second driver is therefore an

educational challenge. This challenge is summed up by the question: How can opportunities for online learning be optimised?

2.4.3 Political Concerns

There is an increasing demand for educational institutions to measure, demonstrate and improve performance. This demand is evident in many countries (Campbell et al., 2007; EU Expert Group, 2010; Daud et al., 2017). This demand is growing more widespread as education, more importantly Educational Attainment, is one of the core indices for measuring national development with respect to the Human Development Index (UNDP, 2006; Bankole et al., 2011; Bankole & Mimbi, 2017). It is, now ever more than before, evident that successes in Learning Analytics research and implementations can have overwhelmingly positive impacts on the Human Development Index (HDI) and it is not surprising that Data Analytics has found its way into the Education Sector especially in ICT4D research. In the context of analytics, it has been most clearly articulated where countries have defined policies that show an emphasis on creating support mechanisms for the use of ICT, including for example, technical and pedagogical support, as well as placing special attention on the use of ICT in teaching and learning (Hinostroza, 2018). An example of this and its economic implications is within the USA, where the government aims to increase the overall educational attainment of the population and has been prepared to invest billions of dollars in order to achieve this (Norris et al., 2008). The third driver is therefore a political/economic challenge. This challenge is summed up by the question: How can learning and educational results be optimised at national or international levels?

These three drivers draw attention to three different interest groups: governments, educational institutions and teachers/learners. Although the interests of all three groups overlap, they require analytics work on different scales and at different granularities. The choice of target audience therefore affects how researchers conceptualise problems, capture data, report findings, act on their findings and refine their models. For this research, the focus is on the third driver. This driver is being led by political/economic concerns which in turn affect the direction of government policy that is geared towards the improvement of socio-economic development.

2.5 Learning Analytics Constructs

The development of learning analytics has been boosted by its inclusion in the 2011 New Media Consortium (NMC) Horizon Report (Johnson et al., 2011). This report is one of a series focused on emerging technologies and their potential impact on and use in teaching, learning and creative enquiry. It identifies learning analytics as a technology to watch. The 2012 NMC Horizon Report (Johnson et al., 2012) also includes learning analytics, judging it to be two to three years from widespread adoption, as well as a subset of the field, social learning analytics. These analytics are strongly grounded in learning theory and focus attention on elements of learning that are relevant when learning in a participatory online culture (Ferguson & Shum, 2012). Approaches to analytics that can be classified in this way include intrinsically social forms of analytics: social network analytics and discourse analytics (De Liddo et al., 2011; Ferguson & Shum, 2011). Discourse analytics are a relatively recent addition to the learning analytics toolset, but they draw on extensive previous work in such areas as exploratory dialogue (Mercer & Wegerif, 1999; Mercer, 2002), latent semantic analysis (Landauer et al., 1998) and computer-supported argumentation (Thomason & Rider, 2008).

Data Analytics, and by extension, social learning analytics and all its sub-sets consist theoretically of three main types of analytics. These are prescriptive analytics, predictive analytics and descriptive analytics (Soltanpoor & Sellis, 2016). Descriptive analytics is focused on the past. It summarizes the data and produces information from diverse set of heterogeneous data (Delen & Demirkan, 2013). Predictive analytics, on the other hand, is a forecasting analytics and is concerned with the future (Eckerson, 2007) by building accurate predictive models based on the unified data. Prescriptive Analytics is concerned with recommendation and guidance and provides organizations with adaptive, automated and time dependant sequences of operational actions (Delen & Demirkan, 2013). Figure 2 shows an example of these 3 main types of data analytics. In this thesis, 5 studies covering these 3 types of analytics have been researched within the learning analytics/academic analytics framework with a focus on the third driver of learning analytics development.

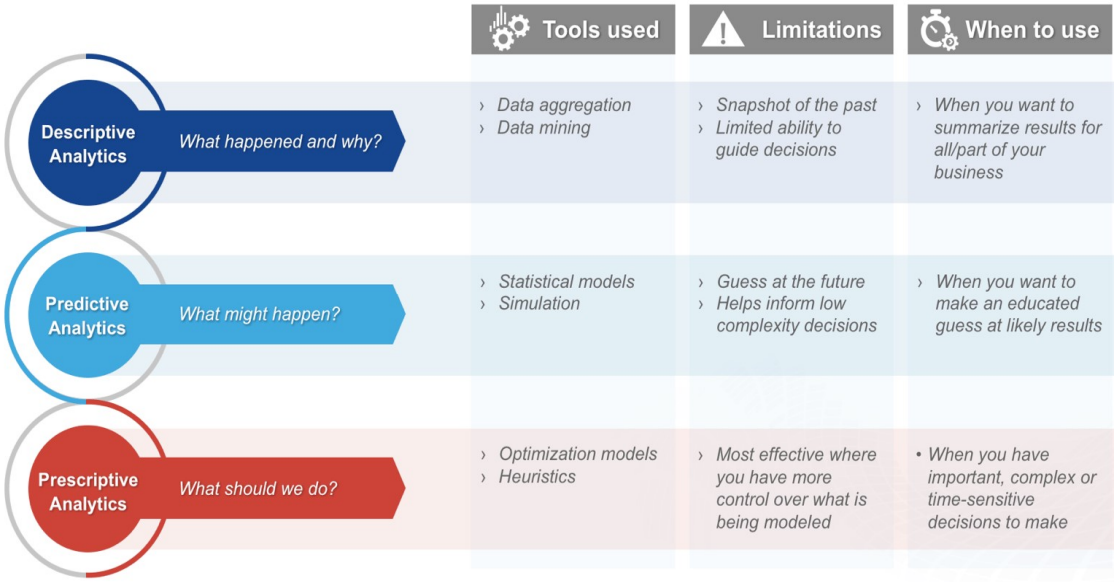

Figure 2: Types of Analysis – Adapted from Davenport & Harris (2017)

2.5.1 Descriptive Analytics

This type of Analytics is known as the data summarization phase and reports the past. It answers the question: What has happened? It extracts information from raw data (Delen & Demirkan, 2013). Business and management reports including sales, customer and operations are examples of descriptive analytics. There is also an extension to the descriptive analytics named diagnostic analytics, which reports the past but tries to answer questions like: Why did it happen? It helps organizations in understanding the events that happened in the past and why they happened. Diagnostic analytics gives the enterprises the cognition to understand relationships between different kinds of data.

2.5.2 Predictive Analytics

This type of analytics can best be described as forecasting or extrapolation, and incorporates the descriptive analytics output as well as some Machine Learning (ML) algorithms and simulation techniques, to build accurate models that predict future behavior or results from past occurrences. It answers the questions: What will happen and why will it happen (Delen & Demirkan, 2013; Eckerson, 2007)? Predictive analytics assists enterprises in identifying future opportunities and likely risks by distinguishing specific patterns arising from the historical data. A key challenge in predictive analytics is having as much data as possible.

More data means more validated models and therefore more accurate predictions. Some prominent techniques which are utilized in this phase are Data Mining (DM), text/web/media mining, and forecasting approaches. The output of predictive analytics is multiple predictions and their equivalent probability scores. Forecasting the demand for goods in a certain region or for a specific group of customers and adjusting the production based on that forecast is an example of predictive analytics (Delen & Demirkan, 2013).

2.5.3 Prescriptive Analytics

This type of analytics is known as the recommender or guidance (Adomavicius & Tuzhilin, 2005) analytics and provides enterprises with adaptive, automated, time-dependent, and optimal decisions (Basu, 2013). Its goal is to bring business value through better strategic and operational decisions. In general, prescriptive analytics is a form of predictive analytics which describes one or more courses of actions and shows the likely outcome/influence of each action. It answers the questions: What should I do and why should I do it? It is purely built on what-if scenarios (Haas et al., 2011). The main elements of prescriptive analytics are optimization (Liberatore & Luo, 2011; Schniederjans et al., 2014), simulation, and evaluation methods (Bertsimas & Kallus, 2019). Simply put, it provides advice based on predictions and an enterprise's constraints. Prescriptive analytics takes into consideration the output of predictive analytics, and together with compliance rules and business constraints aims to generate best courses of action and optimal decisions. In other words, it takes a solid, actionable predictive model and the feedback data collected from those actions and recommends optimal decisions to assist decision makers in reaching their desired outcomes (Apte, 2010; Marathe et al., 2014). Prescriptive analytics systems generally have two important characteristics:

- They provide the enterprise with actionable outcomes. These outputs generate comprehensible prescriptions in terms of actions.
- They support feedback mechanisms, in terms of tracking the suggested recommendations, as well as the occurrence of unprecedented events in a system's lifetime.

2.6 Public Value Concept

The concept of Public Value (PV) can be traced back to the new public service theory. PV has been influential in public services reform initiatives since the mid-nineties. This concept is linked to the seminal work of Moore (1995). Public value refers to value that citizens and their representatives seek in relation to strategic outcomes and experience of public services (Moore, 1995). Public value also refers to the value created by government through services, laws regulation and other actions (Kelly et al., 2002). Public value focuses on performance evaluation of public organisation in delivery of services (social outcomes) as desired by the collective (Mimbi & Bankole, 2016). Brewer et al., (2006) argue that ICT public value creation as a priority refers to embracing the information revolution as a means of improving governance and enhancing the democratic process. PV therefore focuses on the wider notions of valued public services and efficiency that call for the additional accountability of public managers (Blaug et al., 2006).

2.6.1 Creating Public Value

The essence of public value creation is to evaluate the extent to which public organisations have achieved their set goals and objectives. In public administration, these objectives are set by either individual countries or by international bodies such as the United Nations (UN). However, these objectives are the same worldwide. Importantly, the value created must be agreed upon by all concerned stakeholders like those of the Millennium Development Goals (MDGs) (Blaug et al., 2006). Therefore, meeting goals of value creation requires a participatory approach by engaging public managers and citizens in discourse in order to agree on the value to be created. Figure 3 shows the strategic triangle model introduced by Moore (1995) for viewing public value. Based on the new public service and governance theories, the government has a constitutional obligation to implement public policies that ensure that collective or shared public values are created. Thus, the government is responsible to the citizens for creating public value (Blaug et al., 2006). The public value moves beyond the value for individuals by serving the wider public interests. For example, public interests are served best by a government with public values that focus on efficiency and provision of public services with impartiality (Ahrens, 2007; Teorell, 2009). The question now is whether these values are created and if so how? In the present study, the focus is on the values oriented to duty, service and social aspects of public administration. The theory of new

governance puts an emphasis on a collaborative approach to public administration. Governments and other stakeholders (non-governmental organisations such as citizens, civil societies etc.) have a role to play in public value creation.

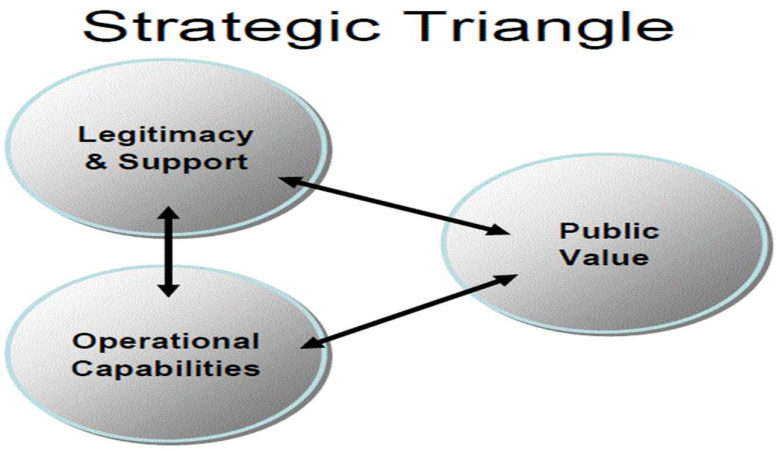

Figure 3: Public Value Strategic Triangle – Adapted from Moore (1995)

Public value has attracted various approaches with regards to what exactly should be measured. There are competing and conflicting claims about the dimensions of value, since some of them overlap. PV requires a careful selection of performance elements that can be included in the evaluation program (Talbot, 2008). However, the literature suggests that values must be convertible into some behavioural form to have meaning (Bannister & Connolly, 2014). In this context, ICT can be viewed as a tool that can enable this conversion. Therefore, ICT use in public administration is both an enabler and embedder. It is an enabler because it makes possible actions or activities related to public value that would be impractical in its absence. It is an embedder because by using it, it is possible to create value within systems (Bannister & Connolly, 2014). In addition, ICT use is also seen as a systemic enhancer and disruptor of processes and structure providing agility, transparency, sustainability and efficient engagement. Consequently, ICT is expected to impact on all three dimensions related to public value: duty oriented public value; service oriented public value; and socially oriented public value (Bannister & Connolly, 2014).

2.6.2 Duty Oriented Public Value

In this category, public values are related to the duties of the public servant to the government or to the state. Basically, these are non-financial related values that amount to accountability

of the public servant (Bannister & Connolly, 2014). Accountability arises from the fact that public servants must be controllable and answerable for their actions in public administration (Gregory & Hicks, 1999). Accountability has been used to enforce ethically related values of individuals, including integrity and honesty, by forcing individuals to comply with the law guiding public service provision (Bannister & Connolly, 2014; Gregory & Hicks, 1999). Furthermore, Gregory & Hicks (1999) posit that accountability instils the spirit of doing things right by choosing the right thing, into the public servant. ICT in the duty oriented public value affects the accountability value.

The literature indicates various mechanisms in which ICT can ensure accountability of public servants, in this case governments. Under the principal – agent environment, public servants are agents and citizens are principals. As agents, public servants are accountable for their actions to the principals in this case, the citizens. For the public servants to be accountable there must be one prerequisite condition, transparency. Without transparency it is almost impossible for a public servant to be held accountable (Heeks, 2009; Islam, 2006). For citizens to hold the public servant accountable they must know what the public servant is doing (Heeks, 2009). This means that performance information about the public servant must be available to the citizens. In this case ICT, and in particular, the Internet, makes the performance information transparent and available to a wider population, the citizenry, by means of which they can evaluate the performance of the public servant. While ICT helps in providing information that can assist in performance evaluation of the public servant, it can also force the public servants to comply with the laws and behave in an honest manner (Bannister & Connolly, 2014). Knowing that performance information about public servants is available to the public helps in ensuring the responsiveness, integrity and honesty of public servants (Gregory & Hicks, 1999; Islam, 2006). However, ICT cannot make people more honest, but can make people behave in a more honest manner (Bannister & Connolly, 2014). Several empirical studies show that ICT increases honesty, improves compliance with the law and improves fairness, by removing the human element in process and decision-making chains (Bannister & Connolly, 2014; Quah, 2011).

2.6.3 Service Oriented Public Value

Service oriented public value refers to values related to the provision of high-level public administration services to the citizens. This is analogous to provision of good services by

private companies to their clients or customers (Bannister & Connolly, 2014). The values in this category are considered to be of New Public Management (NPM) (Van Der Wal et al., 2008). They include effectiveness, efficiency, and transparency. Government effectiveness is a pivotal public value for provision of public services in the new governance. According to the World Bank, government effectiveness refers to the perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies (Kaufmann et al., 2008). Unfortunately, effectiveness and efficiency are two phenomena that may not co-exist because there is always a trade-off between them. In the present study, only government effectiveness will be considered as a public value rather than government efficiency.

Since the 1990s, measuring government performance has been a top agenda item and governments have established performance measures in public services. For instance, the Government Performance Project in the US has been one of the most elaborate projects for assessing government effectiveness across all levels of government (Lee & Whitford, 2009). Government effectiveness initiatives focus on making the citizenry happy by providing high value public services. Research evidences show that there is a relationship between government effectiveness and the happiness of citizenry. For instance, Ott (2010) has found that quality of government is positively related to happiness. The literature also suggests that when the citizenry are happy they tend to feel respected by the government and consequently trust their government (Ott, 2010).

On the other hand, transparency is important in ensuring accountability of the government (Grigorescu, 2003). Transparency refers to the full flow of information within a society (Hollyer et al., 2014). Importantly, the full flow of information should lead to useful information that can assist the citizenry in performance evaluation of governments (Grigorescu, 2003). Transparency is the lateral value of accountability which assumes the prerequisite condition for government accountability and responsiveness (Grigorescu, 2003; Hollyer et al., 2014). Previous studies indicate that transparent governments are more accountable than opaque ones and tend to govern better than opaque ones (Islam, 2006).

ICT, as a tool for enabling government functions, has a potential to create or transform effectiveness and transparency values (Bannister & Connolly, 2014). The transformative impact of ICT on effectiveness is a well-established phenomenon in the Information Systems literature. Effectiveness was one of the motivations of implementing ICT systems in both the public and private sectors. However, recently, the Internet in particular has transformed transparency, so that citizenry are now expecting more from government disclosure. ICT has changed the way transparency is viewed, by opening additional avenues for information to be available to the wider public (Hollyer et al., 2014; Pang et al., 2014). The essence of ICT in service oriented public values is to enable or create effectiveness and transparency in public administration in order to improve service provision for citizenry satisfaction (Mimbi & Kyobe, 2017). For instance, ICT can facilitate transparency strategies by exposing wrongdoing thereby deterring public servants from committing a crime by indulging in corrupt practices (Jaeger & Bertot, 2010). In this way, citizenry may be assured of improved public services.

2.6.3 Socially Oriented Public Value

Public values in this category refer to those which incorporate quasi-political views encompassing broader social goals. They include aspects of providing public services to all citizens (inclusiveness), by treating them equally in a just way and granting them access to public services. Socially oriented public value can be bundled together to refer to impartiality in public services provision (Bannister & Connolly, 2014).

Impartiality refers to the norm on the output side that is most compatible with the normative principle of treating everyone with equal concern and respect (Teorell, 2009). Rothstein & Teorell (2008) add that when implementing laws and policies, government officials should not take into consideration anything about the citizen/case that is not beforehand stipulated in the policy or the law. These values are implemented under the banner of rule of law, defined as the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, the police, and the courts, as well as the likelihood of crime and violence (Kaufmann et al., 2008). This means that rule of law ensures impartiality by ensuring laws are applied equally to all people (Ahrens, 2007). ICT in public services offers a relatively much less expensive mode of access than the traditional face-to-face approach, thereby significantly impacting equity and access. Recognising this impact,

several governments have implemented ICT for public value creation in this regard. For example, the UK and Denmark governments have established an ICT policy of digital by default, in providing public services (Bannister & Connolly, 2014). In this section, the literature points out how ICT can have impact on or create public values. ITU (2006) recommends that ICT impacts can be assessed in two ways, via its efficiency or via its impacts on social dimensions. For the purpose of this research, the impact of ICT will be assessed via its efficiency.

2.7 ICT, Socio-Economic Development and Policy

The literature generally considers ICT and development from two broad perspectives. These perspectives, the dominant perspective and the critical thinking perspective, have traditionally been theoretically divided in two. A brief outline of these perspectives on the relationship between ICT, socio-economic development and policy is presented in the following sections.

2.7.1 Dominant Perspective of ICT and Development

Within this perspective, otherwise known as the mainstream or liberal perspective, a distinction can be made between two main theoretical perspectives. These are the modernist and the neoliberal theories. The modernist perspective is generally more positive about the impact of ICT's especially in developing economies. Research within this perspective stresses the pervasive potentials of technology for social, cultural and economic development (Pool, 1990; Tsui, 1991). As technology is predominantly viewed as neutral, research is focused on the organizational and institutional factors impeding the manifestation of its potentials (Tsui, 1991; Hudson, 1998). Within the context of development, ICT, as an important means of sharing and disseminating information, is considered an important link in the developmental process (Hudson, 1998). The use of ICT serves society as a whole, both in economic terms by way of increased efficiency, effectiveness and equity, and also socially by means of social service delivery (Parker & Hudson, 1995; Hudson, 1998). It is also believed that government has an important stimulating role in the adoption and use of ICT's for social and economic development. This is so that there can be a movement towards an integrated approach between ICT and development policies while taking into consideration the economic and social implications of these policies (Parker & Hudson, 1995). This view on active government involvement, however, is not shared by all modernization authors. Pool (1990),

presses for an accelerated use of ICT for development, but argues that the pervasive benefits of modern ICT's are best served in a predominantly liberal national and international environment.

Neoliberal theorist authors working within the field of ICT perceive technology as an important mover of socio-economic development. However, research within this perspective has primarily been concerned with questions regarding the efficiency and effectiveness of the sector and its underlying organization (Nulens & Van Audenhove, 1999). These authors argue that monopolistic corporations and operators as well as state intervention have hindered the development of ICTs and thus curtailed their contributions towards human development. Although there is a general acknowledgement that the use of ICT is characterized by certain external factors, Neoliberalists argue that the development of ICTs and society as a whole is best served by a liberalization of the sector. They believe however that social policies, restricted to promoting universal access to ICTs, can be part of government regulation.
In general, the dominant perspective of ICT and development, tends to take an idealistic and techno-centric stance with regards to the relation between technology and society as well as the consequences for those in power. However, Neoliberalists tend to argue for minimal government intervention while Modernists argue for government as a facilitator and as a constituting factor of ICT and socio-economic development.

2.7.2 Critical Thinking Perspective of ICT and Development

This perspective can also be divided in two main theoretical perspectives, the dependency theorists and the communitarianism theorists. The dependency disposition is clearly inspired by Marxism and focuses mainly on the structural conditions shaping international communications and its resultant effects on the economic, political and cultural spheres of developing economies. There is a belief that technologies which bring about major societal changes such as satellite broadcasting, data storage and data communications in the hands of a few transnational corporations are merely reproductions of old patterns of dependencies (Reeves, 1993). The proliferation of ICTs is seen as an evolution in the function of transnational industrial and service corporations. Commercialization, by way of mergers, alliances and acquisitions, by these corporations may have devastating effects on access to quality and diverse information. Schiller (1992) refers to ICTs as an all-embracing service supplying a cultural media environment and considers them as vehicles of cultural

imperialism. At the policy development level, in early versions, the dependency theorists argue for a complete and radical rejection of capitalism and a subsequent dissociation from the world's capital markets (Tsui, 1991). Nationalism via the state is seen as the proper driving force of development and thus the focal point of any revolutionary change that will be in the interests of the public and bring about public value.

The second disposition is known as communitarianism, participatory communication, multiplicity and another development. These theorists are characterized by a more in-ward looking perspective. Here, the main focus of analysis is centered at the micro-level of the community. The cultural aspects of ICT and development are stressed, and the argument is against a linear approach to development. The position of these theorists towards ICT is rather ambivalent, as early research rejects modern technologies and emphasizes alternative and popular communication strategies (Nair & White, 1993). However, they also stress the possibilities of interactive ICT for local level communication of a participatory nature (Nair & White, 1993). They believe these interactive ICTs can possibly transfer the control of technology from powerful corporations to the people themselves. Tehranian (1990) posits that technology, in this case ICT, is neither intrinsically good or bad, but that each technology has both democratic and authoritarian characteristics and therefore their implementation and impacts are mediated by the context in which they operate. Nair & White (1993) also state that communitarianism proposes that policy development starts from the community level and emphasize self-management, self-reliance, the right to communicate, indigenous knowledge and people's participation in decision making and change.

The stance of dependency theory on the relation between ICT and society is clearly rooted in a materialistic technophobic view. Here, ICT is seen as part and parcel of society and has rather negative impacts on society. Although communitarianism can be seen as part of the critical thinking perspective, its view is rather more balanced. Communitarianists argue that ICT is part of the society but has inherent qualities which have an impact on the society (Nulens & Van Audenhove, 1999). Tehranian (1990) labels this view as characterized by interdependence. This author's view on the relation between ICT and power is therefore much more cautious as they believe that ICT development and use largely depend on the context in which they are being implemented. The critical school is rather averse towards

capitalism, but communitarianism theorists do not share the optimism of the dependency theorists in their sole reliance on nationalism and the state.

2.8 The Global Discourse on ICT for Development

The concept of ICT for Development (ICT4D) emerged in the 1990s with the availability of affordable personal computers and the rising diffusion of digital systems across the world (Walsham, 2017). However, the ICT4D field has iterated and metamorphosed from the main focus of computers, technologies and systems design. Research within the dominant and critical thinking theoretical perspectives have evolved over the years. Current researches study ICT4D, not just as a fixated domain on computational technologies, but as a multidimensional and complex social practice-oriented domain, which is always situated in the challenging context of different times and locations (Avgerou, 2010). This evolution of the research has led to an ongoing global discourse on ICT and its effect/impact on socio-economic development within the ICT4D literature. The researchers mostly agree that ICTs are no longer a magical one type fixes all solution providing simple and linear formulas to complex social and economic problems (Aziz, 2018). In fact, Heeks (2010) argues that ICT adoption and implementation may even exacerbate the growing inequality while demanding high investments of resources and time.

Heeks (2010) argues that ICT4D study suggests that Information Technology (IT) interventions have not created any considerable and sustainable impact on societies except where they have been implemented in long-term development strategies. Zheng et al. (2018) also point out that from the beginning of the Millennium Development Goals (MDGs), the attention in ICT4D research began to shift to a more holistic view of development beyond economic development. In addition to the Sustainable Livelihood Framework (SLF), Sen's human development view, expressed through his Capability Approach (Sen, 1990), has been largely adopted in the ICT4D framework. However, this wholistic view is criticized as being less critical on other related topics like, neoliberalism and its ramifications, which predominantly exist as a development model across the world (Zheng et al., 2018).

In considering different theoretical discourses and conceptual frameworks, Avgerou (2010) postulates that Information Systems (IS) innovation can be categorised into four discourses, as shown in figure 3. The discourses are framed within two axes; the vertical axis relates to

the nature of the ICT innovation process and transformation while the horizontal axis relates to the diffusion and innovation of knowledge to either a techno-centric adaptation approach or a socially and culturally embedded knowledge perspective.

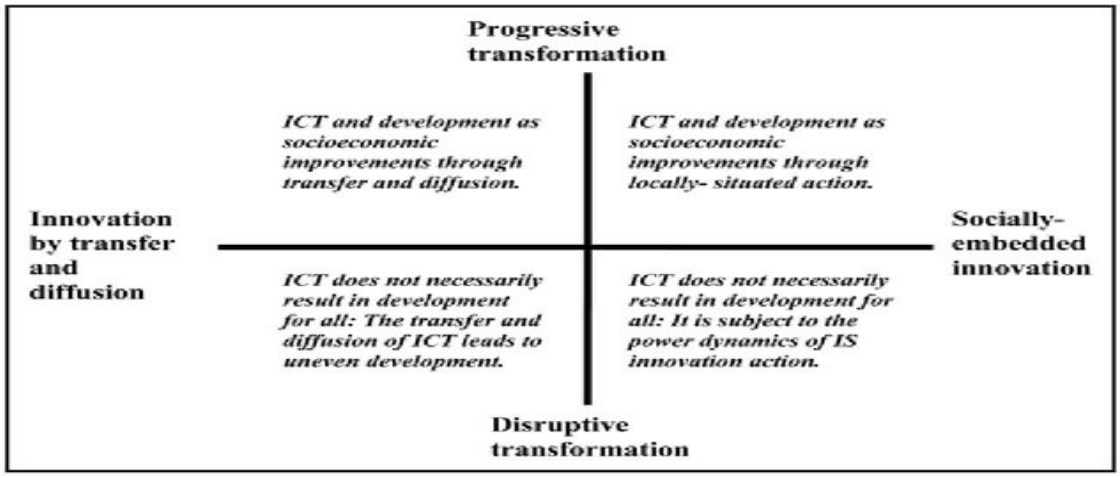

Figure 4: The Four Discourses of ICT4D – Adapted from Avgerou (2010)

Going clockwise from the top right quadrant, a brief description of the discourses is given in the following sections.

2.8.1 First Discourse of ICT4D

This discourse is formed by combining the *social embeddedness perspective* of ICT innovation and organizational change with the *progressive transformation perspective* of development. This discourse assumes that the ICT can contribute towards improving life while realizing the local context and historically shaped power relationships (Aziz, 2018). It challenges over-centralised and authoritarian policy mechanisms and administration while addressessing democratic ICT policies and appropriate professional practices, like user participation (Sahay & Walsham, 2006). This discourse is cautious about ICT intervention with prevailing development ideas and policies.

2.8.2 Second Discourse of ICT4D

This discourse combines *socially embeddedness* and *disruptive prospective* and criticises the dominant interpretation about ICT and development. This discourse is considered a critical discourse in the sociological aspect of critical theory and is concerned with power and

inequalities in specific socio-economic contexts regarding ICT interventions. In relation to ICT policy, it is likely to focus on the local context, realizing the power inequalities in different communities and groups, that can increase further exclusion. This discourse proposes that the power gap needs to be reduced through more comprehensive policy mechanisms with individual awareness and motivation.

2.8.3 Third Discourse of ICT4D

This discourse combines the *transfer and diffusion perspective* of ICT innovation with the *disruptive transformation perspective* of development. This discourse is considered as a critical view of positivist approaches, realizing the potentially negative impact of ICTs on socially marginalised and poor people while the ICT system is controlled and operated by the powerful elite minority. Generally, it challenges the effectiveness of development policies such as globalization, liberalization, ICT and productivity, and even doubts the intentions of powerful actors, such as the international development interventions, policy makers, and corporate agencies. The preferred policy mechanism here is to liberate control of ICT intervention from monopolistic corporations and authoritative governments in order to ensure the inclusion and empowerment of marginalised groups (Gurumurthy, 2010).

2.8.4 Fourth Discourse of ICT4D

This discourse is formed by a combination of the *transfer and diffusion perspective* of Information System (IS) innovation with the *progressive transformation perspective* of development. This discourse proposes that the top-down distribution of ICT infrastructure and services will bring a positive outcome to people's lives, economic growth and benefits in developing countries. This discourse often posits that developing countries need to accept the technologies and institutions in the same way that developed countries have, in order for perceived development and economic growth. This view can be related to the modernisation discourse in the 1950/1960s and the digital divide debate of the 1990s and early 2000s (Nulens & Van Audenhove, 1999; Sparks, 2007). Regarding this discourse, policymakers are likely to initiate supply-side interventions, expecting to maximise the use of technology and to enable the integration of marginalized people into ICT networks.

2.9 Conclusion

This chapter has provided a comprehensive review of the focal areas of Information Systems that this thesis covers. These include Learning/Academic Analytics and Educational Data Mining, the Public Value concept and ICT4D. This review is necessary for understanding the context within which this thesis is situated. Studies 1, 2 and 3 (chapters 5, 6 and 7) contribute to the Learning/Academic Analytics research within ICT4D using quantitative methods, which are discussed in chapter 4. Study 4 (chapter 8) contributes to the Public Value research within ICT4D, using quantitative methods, while study 5 (chapter 9) contributes to the Public Value research and Global Discourse within ICT4D, using a qualitative method. All studies contribute to research on ICT and human development with particular emphasis on education.

In the following chapter, chapter 3, the philosophical and theoretical frameworks guiding this research are introduced and discussed. The epistemology within which this research is situated is also presented as well as an ontological stance taken.

2.10 References

Adomavicius, G., & Tuzhilin, A. (2005). Toward the next generation of recommender systems: A survey of the state-of-the-art and possible extensions. *IEEE Transactions on Knowledge & Data Engineering*, (6), 734-749.

Ahrens, J. (2007). Governance in the process of economic transformation. System Transformation in Comparative Perspective. Affinity and diversity in institutional, structural and cultural patterns, *Munster: LITVerlag*

Apte, C. (2010). The role of machine learning in business optimization. In *Proceedings of the 27th International Conference on Machine Learning (ICML-10)* (pp. 1-2).

Avgerou, C. (2010). Discourses on ICT and development. *Information Technologies & International Development*, *6*(3), pp-1.

Aviv, R., Erlich, Z., Ravid, G., & Geva, A. (2003). Network analysis of knowledge construction in asynchronous learning networks. *Journal of Asynchronous Learning Networks*, *7*(3), 1-23.

Aziz, A. (2018). *ICT Policy Challenges for Digital Inclusion in Bangladesh* (Doctoral dissertation, Vrije Universiteit Brussel).

Baepler, P., & Murdoch, C. J. (2010). Academic analytics and data mining in higher education. *International Journal for the Scholarship of Teaching and Learning*, *4*(2), 17.

Baker, R. & Yacef, K. (2009). The State of Educational Data Mining in 2009: A Review and Future Visions. Journal of Educational Data Mining (JEDM), 1(1), 3–17.

Baker, R. S. J. D. (2010). Data mining for education. *International encyclopedia of education*. B.McGaw, P. Peterson, and E. Baker, Eds., 3rd ed. Oxford, U.K.: Elsevier, *7*, 112-118.

Bankole, F. O., Shirazi, F., & Brown, I. (2011). Investigating the impact of ICT investments on human development. *The Electronic Journal of Information Systems in Developing Countries*, *48*(1), 1-19.

Bankole Dr, F., & Mimbi, L. (2017). ICT infrastructure and it's impact on national development: a research direction for Africa. *The African Journal of Information Systems*, *9*(2), 1.

Bannister, F., & Connolly, R. (2014). ICT, public values and transformative government: A framework and programme for research, *Government Information Quarterly* (31)1, 119-128.

Basu, A. T. A. N. U. (2013). Five pillars of prescriptive analytics success. *Analytics magazine*, 8-12.

Berners-Lee, T., Hendler, J., & Lassila, O. (2001). The semantic web. *Scientific american*, *284*(5), 28-37.

Bertsimas, D., & Kallus, N. (2019). From predictive to prescriptive analytics. *Management Science*.

Blaug, R., Horner, L., & Lekhi, R. (2006). Public value, politics and public management A literature review." www.theworkfoundation.com

Brewer, G. A., Neubauer, B. J., & Geiselhart, K. (2006). Designing and Implementing E-Government Systems Critical Implications for Public Administration and Democracy, *Administration & Society* (38)4, 472-499

Campbell, J. P., & Oblinger, D. G. (2007). Top-ten teaching and learning issues, 2007. *Educause Quarterly*, *30*(3), 15-22.

Campbell, J. P., DeBlois, P. B., & Oblinger, D. G. (2007). Academic analytics: A new tool for a new era. *EDUCAUSE review*, *42*(4), 40.

Chatti, M.A., Dyckhoff, A.L., Schroeder, U., & Thüs, H. (2012). A reference model for learning analytics. *International Journal of Technology Enhanced Learning*, 4(5/6), 318–331.

Daud, A., Aljohani, N. R., Abbasi, R. A., Lytras, M. D., Abbas, F., & Alowibdi, J. S. (2017). Predicting student performance using advanced learning analytics. In *Proceedings of the 26th international conference on world wide web companion* (pp. 415-421).

Davenport, T., & Harris, J. (2017). *Competing on analytics: Updated, with a new introduction: The new science of winning*. Harvard Business Press.

Dawson, S. (2010). 'Seeing'the learning community: An exploration of the development of a resource for monitoring online student networking. *British Journal of Educational Technology*, *41*(5), 736-752.

De Laat, M., Lally, V., Lipponen, L., & Simons, R. J. (2006). Analysing student engagement with learning and tutoring activities in networked learning communities: A multi-method approach. *International Journal of Web Based Communities*, *2*, 394-412.

De Laat, M., Lally, V., Lipponen, L., & Simons, R. J. (2007). Investigating patterns of interaction in networked learning and computer-supported collaborative learning: A role for Social Network Analysis. *International Journal of Computer-Supported Collaborative Learning*, *2*(1), 87-103.

Delen, D., & Demirkan, H. (2013). Data, information and analytics as services. *Decision Support Systems,* 55(1), 359–363.

De Liddo, A., Shum, S. B., Quinto, I., Bachler, M., & Cannavacciuolo, L. (2011, February). Discourse-centric learning analytics. In *Proceedings of the 1st international conference on learning analytics and knowledge* (pp. 23-33). ACM.

Dringus, L. P., & Ellis, T. (2005). Using data mining as a strategy for assessing asynchronous discussion forums. *Computers & Education*, *45*(1), 141-160.

Eckerson, W. W. (2007). Predictive Analytics. Extending the Value of Your Data Warehousing Investment. TDWI Best Practices Report. Q1 2007.

EU Expert Group (2010) Assessing Europe's University-Based Research, European Commission, Brussels, Belgium.

Ferguson, R., & Shum, S. B. (2011). Learning analytics to identify exploratory dialogue within synchronous text chat. In *Proceedings of the 1st International Conference on Learning Analytics and Knowledge* (pp. 99-103). ACM.

Ferguson, R. (2012). Learning analytics: drivers, developments and challenges. *International Journal of Technology Enhanced Learning*, *4*(5/6), 304-317.

Ferguson, R., & Shum, S. B. (April). Social learning analytics: five approaches. In *Proceedings of the 2nd international conference on learning analytics and knowledge* (pp. 23-33). ACM.

Goldstein, P. J., & Katz, R. N. (2005). *Academic analytics: The uses of management information and technology in higher education* (Vol. 8, pp. 1-12). Educause.

Granovetter, M.S. (1973) 'The strength of weak ties', *American Journal of Sociology*, Vol. 8, pp. 1360-1380

Gregory, R., & Hicks, C. (1999). Promoting public service integrity: A case for responsible accountability. *Australian Journal of Public Administration*, *58*(4), 1-15.

Grigorescu, A. (2003). International organizations and government transparency: Linking the international and domestic realms. *International Studies Quarterly*, *47*(4), 643-667.

Gurumurthy, A. (2010). From social enterprises to mobiles-seeking a peg to hang a premeditated ICTD theory. *Information Technologies & International Development*, *6*(SE), pp-57.

Haas, P. J., Maglio, P. P., Selinger, P. G., & Tan, W. C. (2011). Data is Dead... Without What-If Models. *PVLDB*, *4*(12), 1486-1489.

Haythornthwaite, C. (2006). Facilitating collaboration in online learning. *Journal of Asynchronous Learning Networks*, *10*(1), 7-24.

Haythornthwaite, C., & De Laat, M. (2010). Social networks and learning networks: Using social network perspectives to understand social learning. In *Proceedings of the 7th international conference on networked learning* (pp. 183-190). Aalborg, Denmark: Lancaster University.

Heeks, R. (2009). IT and the World's' Bottom Billion'. *Communications of the ACM*, *52*(4), 22-24.

Heeks, R. (2010). Do information and communication technologies (ICTs) contribute to development? *Journal of international development*, *22*(5), 625-640.

Hinostroza, J. E. (2018). New Challenges for ICT in Education Policies in Developing Countries: The Need to Account for the Widespread Use of ICT for Teaching and Learning Outside the School. In *ICT-Supported Innovations in Small Countries and Developing Regions* (pp. 99-119). Springer, Cham.

Hollyer, J. R., Rosendorff, B. P., & Vreeland, J. R. (2014). Measuring transparency. *Political analysis*, *22*(4), 413-434.

Hudson, H. E. (1998). Global connections. International Telecommunications Infrastructure and Policy. *Telecommunications Policy*, *22*(4), 455.

Islam, R. (2006). Does more transparency go along with better governance? *Economics & Politics*, *18*(2), 121-167.

Jaeger, P. T., & Bertot, J. C. (2010). Transparency and technological change: Ensuring equal and sustained public access to government information. *Government Information Quarterly*, *27*(4), 371-376.

Johnson, L., Smith, R., Willis, H., Levine, A., & Haywood, K. (2011). *NMC Horizon Report: 2011 Edition*. The New Media Consortium.

Johnson, L., Adams, S., & Cummins, M. (2012). NMC Horizon Report: 2012 K-Austin, TX: The New Media Consortium.

Kaufmann, D., Kraay, A., & Mastruzzi, M. (2008). *Governance matters VII: aggregate and individual governance indicators 1996-2007*. The World Bank.

Kelly, G., Mulgan, G., & Muers, S. (2002). Creating Public Value: An analytical framework for public service reform. *London: Strategy Unit, Cabinet Office*.

Landauer, T. K., Foltz, P. W., & Laham, D. (1998). An introduction to latent semantic analysis. *Discourse processes*, *25*(2-3), 259-284.

Learning Analytics & Knowledge. (2011). *1st International Conference on Learning Analytics and Knowledge 2011.* Retrieved from https://tekri.athabascau.ca/analytics/

Lee, S. Y., & Whitford, A. B. (2009). Government effectiveness in comparative perspective. *Journal of Comparative Policy Analysis*, *11*(2), 249-281.

Liberatore, M., & Luo, W. (2011). INFORMS and the analytics movement: The view of the membership. *Interfaces*, *41*(6), 578-589.

Long, P., & Siemens, G. (2014). Penetrating the fog: analytics in learning and education. *Italian Journal of Educational Technology*, *22*(3), 132-137.

Manyika, J. (2011). Big data: The next frontier for innovation, competition, and productivity. *http://www.mckinsey.com/Insights/MGI/Research/Technology_and_Innovation/Big_data_The_next_frontier_for_innovation*.

Marathe, M. V., Mortveit, H. S., Parikh, N., & Swarup, S. (2014). Prescriptive analytics using synthetic information. In *Emerging Methods in Predictive Analytics: Risk Management and Decision-Making* (pp. 1-19). IGI Global.

Mazza, R., & Dimitrova, V. (2004). Visualising student tracking data to support instructors in web-based distance education. In *Proceedings of the 13th international World Wide Web conference on Alternate track papers & posters* (pp. 154-161). ACM.

Mazza, R., & Milani, C. (2004). Gismo: a graphical interactive student monitoring tool for course management systems. In *International Conference on Technology Enhanced Learning, Milan* (pp. 1-8).

McIntosh, N. E. (1979). Barriers to implementing research in higher education. *Studies in Higher Education*, *4*(1), 77-86.

Mercer, N. & Wegerif, R. (1999). 'Is "exploratory talk" productive talk?', in Light, P. and Littleton, K. (Eds): Learning with Computers: Analysing Productive Interaction, Routledge, London and New York, pp.79–101.

Mercer, N. (2002). *Words and minds: How we use language to think together*. Routledge.

Mimbi, L., & Bankole, F. (2016). ICT and public service value creation in Africa: Efficiency assessment using DEA approach. *Proceedings of The 27th Australasian Conference on Information Systems*, 1–13.

Mimbi, L., & Kyobe, M. (2017). Public perceptions of the role of IT in resolving governance challenges in a transition state: The case of Tanzania. *The Electronic Journal of Information Systems in Developing Countries*, *78*(1), 1-25.

Moore, M. (1995). *Creating public value: Strategic management in government.* Cambridge, MA: Harvard University Press

Nair, K. S., & White, S. A. (1993). *Perspectives on development communication*. Sage Publ.

Norris, D., Baer, L., Leonard, J., Pugliese, L., & Lefrere, P. (2008). Action analytics: Measuring and improving performance that matters in higher education. *EDUCAUSE review*, *43*(1), 42.

Nulens, G., & Van Audenhove, L. (1999). An information society in Africa? An analysis of the information society policy of the World Bank, ITU and ECA. *Gazette (Leiden, Netherlands)*, *61*(6), 451-471.

Ott, J. C. (2010). Good governance and happiness in nations: Technical quality precedes democracy and quality beats size. *Journal of Happiness Studies*, *11*(3), 353-368.

Pang, M. S., Lee, G., & DeLone, W. H. (2014). IT resources, organizational capabilities, and value creation in public-sector organizations: a public-value management perspective. *Journal of Information Technology*, *29*(3), 187-205.

Papamitsiou, Z., & Economides, A. (2014). Learning Analytics and Educational Data Mining in Practice: A Systematic Literature Review of Empirical Evidence. *Educational Technology & Society*, *17* (4), 49–64.

Parker, E. B., & Hudson, H. E. (1995). *Electronic byways: State policies for rural development through telecommunications, 2nd Edition*. Washington DC: The Aspen Institute.

Pool, I. D. S. (1990). *Technologies without boundaries: On telecommunications in a global age*. Cambridge, MA: Harvard University Press.

Quah, J. S. (Ed.). (2011). *Curbing corruption in Asian countries: An impossible dream?*. Emerald Group Publishing Limited.

Reeves, G. W. (1993). *Communications and the 'Third World'*. Routledge.

Romero, C., & Ventura, S. (2007). Educational data mining: A survey from 1995 to 2005. *Expert systems with applications*, *33*(1), 135-146.

Romero, C., Ventura, S., & García, E. (2008). Data mining in course management systems: Moodle case study and tutorial. *Computers & Education*, *51*(1), 368-384.

Romero, C., & Ventura, S. (2013). Data mining in education. *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery, 3*(1), 12–27.

Rothstein, B. O., & Teorell, J. A. (2008). What is quality of government? A theory of impartial government institutions. *Governance*, *21*(2), 165-190.

Sahay, S., & Walsham, G. (2006). Scaling of health information systems in India: Challenges and approaches. *Information Technology for development*, *12*(3), 185-200.

Schiller, H. I. (1992). *Mass communication and American empire*. Boulder.

Schniederjans, M. J., Schniederjans, D. G., & Starkey, C. M. (2014). *Business analytics principles, concepts, and applications: what, why, and how*. Pearson Education.

Sen, A. (1990). Development as capability expansion. *The community development reader*, 41-58.

Soltanpoor, R., & Sellis, T. (2016). Prescriptive analytics for big data. In *Australasian Database Conference* (pp. 245-256). Springer, Cham.

Sparks, C. (2007). *Globalization, development and the mass media*. Sage.

Talbot, C. (2008). Measuring Public Value: A Competing Values Approach. *The Work Foundation Research Report*.

Tehranian, M., & Dervin, B. (1990). *Technologies of power*. Greenwood Publishing Group Inc..

Teorell, J. (2009). The impact of quality of government as impartiality: theory and evidence. In *APSA 2009 Toronto Meeting Paper*.

Thomason, N. & Rider, Y. (2008). 'Cognitive and pedagogical benefits of argument mapping: L.A.M.P. guides the way to better thinking', in Okada, A. Buckingham Shum, S. and Sherborne, T. (Eds): Knowledge Cartography: Software Tools and Mapping Techniques, Springer, London

Tsui, L. S. (1991). The use of new communication technologies in third world countries: A comparison of perspectives. *Gazette (Leiden, Netherlands)*, *48*(2), 69-93.

UNDP: United Nations Development Programme. (2006). The Millennium Development Goals. *UNDP*.

Van Barneveld, A., Arnold, K. E., & Campbell, J. P. (2012). Analytics in higher education: Establishing a common language. *EDUCAUSE learning initiative*, *1*(1), l-ll.

Van Der Wal, Z., Pevkur, A., & Vrangbaek, K. (2008). Public sector value congruence among old and new EU member-states?: Empirical evidence from the Netherlands, Denmark, and Estonia. *Public Integrity*, *10*(4), 317-334.

Walsham, G. (2017). ICT4D research: reflections on history and future agenda. *Information Technology for Development*, *23*(1), 18-41.

Zaiane, O. (2001). Web usage mining for a better web-based learning environment.

Zheng, Y., Hatakka, M., Sahay, S., & Andersson, A. (2018). Conceptualizing development in Information and Communication Technology for Development (ICT4D), *Information Technology for Development, 24*(1), 1-14, DOI: 10.1080/02681102.2017.1396020

CHAPTER 3

3.0 Research Framework

3.1 Introduction

The chapter discusses the research framework upon which this thesis is based and the epistemological and ontological perspectives within which the research is situated. The main purpose of this chapter is to present an overview of the theoretical and philosophical frameworks that provide the foundation, structure and support for this thesis.

The rest of this chapter is organized as follows: Section 3.2 discusses the choice of research paradigms which may be used to guide this research, while sections 3.3 and 3.4 discuss the two research frameworks upon which this thesis is built: the Cobb-Douglas Production function for the quantitative research aspects and Habermas' Theory of Communicative Action for the qualitative research aspect.

3.2 Research Paradigm

In information Systems (IS) research, there are three main philosophical assumptions or epistemologies that can be selected to provide guidance for research. These are positivist, interpretive and critical epistemological views (Orlikowski & Baroundi, 1991; Mingers, 2003). These three epistemological views describe the assumptions about knowledge and how it can be obtained and employed in research (Myers, 1997). These are expanded as follows:

- Positivist Research: This is principled on the reality of a priori relationships within an occurrence using structured instruments. It typically involves testing of a theory to increase the predictive understanding of the situation, evidence of propositions, quantifiable measures of variables, hypotheses testing, drawing of inferences from the sampled population and the use of statistical techniques (Orlikowski & Baroundi, 1991; Straub, Boudreau & Gefen, 2004).

- Interpretive Research: This is the assumption whereby the research attempts to determine certain phenomena by interrogating the meanings assigned to them. It presumes that subjective and inter-subjective meanings are associated to phenomena through societal interaction. This assumption seeks to determine the values, beliefs and meaning of societal phenomena through human experiences (Orlikowski & Baroundi, 1991).
- Critical Research: This aims to question beliefs and conditions by exposing and challenging the status quo within the social systems (Orlikowski & Baroundi, 1991). It tends to explain social inequalities and injustices and how individuals can make changes.

Choosing a specific philosophical position for a research project has a considerable impact on the research design and the level of the insight of the researcher. This thesis is firmly situated in the **Critical Research philosophical epistemology** being approached from a critical realism ontological perspective. Critical Realism, as an ontological perspective, assumes a reality that exists independent of the observer, but which can only be apprehended imperfectly because of the complexity of social phenomena; it also recognizes the possibility of the researcher's own beliefs and values affecting what is being observed (Rehman & Alharthi, 2016).

The research attempts to critically investigate and challenge the status quo and inform theory and practice of ICT infrastructure utilization within the ICT4D discourse by employing Mixed Methods Research. In implementing mixed methods research methodology, this research uses a multi-method quantitative approach using multiple quantitative research methods within the Cobb-Douglas theoretical framework and a qualitative research method operationalized by Jürgen Habermas' Theory of Communicative Action. For the quantitative study, this thesis employs the Cobb-Douglas Production function framework, as applicable in the Data Envelopment Analysis (DEA) and Malmquist Productivity Index (MPI) analysis methodologies. For the qualitative study, this thesis employs Habermas Theory of Communicative Action (TCA) operationalized in a Critical Discourse Analysis (CDA) methodology. These fit with the aim of the thesis which is to contribute critically towards the on-going ICT4D global discourse.

3.3 Cobb-Douglas (C-D) Production Function

The quantitative research framework within which this thesis is structured is the Cobb-Douglas production function. This function is used to represent the relationship of an output to inputs, where production output is determined by certain factors, such as labour and capital, which are referred to as inputs which affect the performance of the economy (Tan, 2008). The concept of Cobb-Douglas functional form was introduced by Knut Wicksell (1851-1926) and has proved to be accurate, based on statistical evidence by Charles Cobb and Paul Douglas in 1928 (Tan, 2008). The assumptions of the C-D production function are that the performance of the supply side (input) of the economy is determined by the growth rate of the potential output (Hajkova & Hurnik, 2007). This potential output, consequently, considers different factors of an economy's productive capacity, such as labour, capital and total factor productivity (TFP), which are often not obtained in reality, and are therefore only approximations (Hajkova & Hurnik, 2007). The use of the C-D production function involves the estimation of the supply side performance on the basis of the realistic developments in the quantity of labour, capital and total factor productivity. Thus, an increase in capital growth along with an increasing trend in TFP, indicates an improvement in the supply side performance of the economy. If neither of these factors is increasing, then the supply side is ineffective (Hajkova & Hurnik, 2007).

The practical application of the C-D production function requires assumptions on the functional form of the production technology, Returns To Scale (RTS), technological process and the overall market performance (Tan, 2008). RTS refers to a technical property of production which examines changes in output subsequent to a proportional change in all inputs, assuming all inputs increase by a constant factor. If output increases by that same proportional change, then there is a constant returns to scale, simply referred to as, RTS. However, if output increases by a smaller proportional change, then there is a Decreasing Returns to Scale (DRS). And finally, if there is a greater proportional increase in output, then there is an Increasing Returns to Scale (IRS)

The function used to model the production is of the form:

$$P(L, K) = AL^{\alpha}K^{\beta}$$

where:

P = total production (the monetary value of all goods produced in a year)

L = labour input (the total number of person-hours worked in a year)

K = capital input (the monetary worth of all machinery, equipment, and buildings)

A = total factor productivity

α and β are the output elasticities of labour and capital, respectively. These values are constants determined by available technology. Figure 4 is the graphical representation of this function.

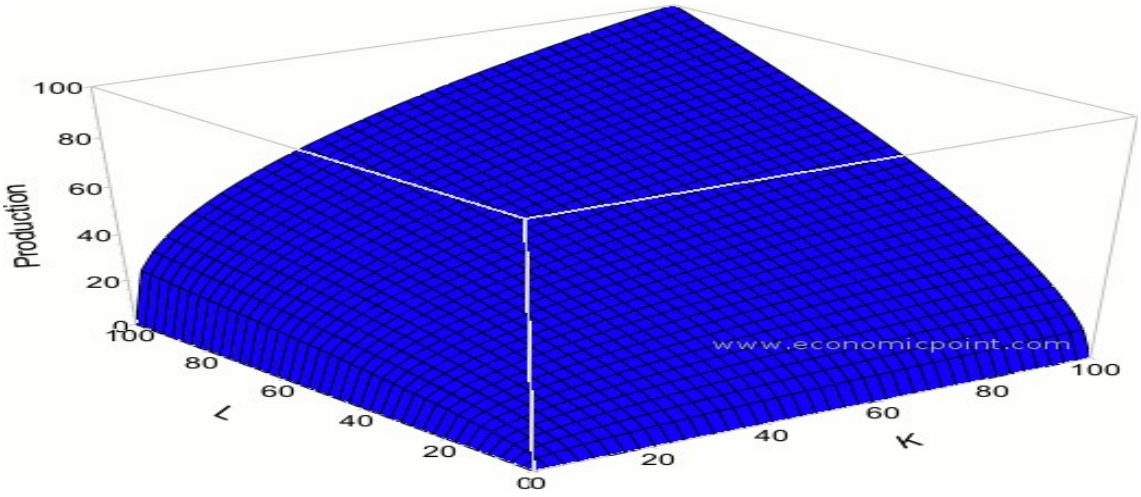

Figure 5: Graphical Representation of The Cobb-Douglass Production Function – Adapted from www.economicpoint.com

Considering the different returns to scale: if $\alpha + \beta = 1$ the production function is said to have RTS. However, if $\alpha + \beta < 1$ then the production function is said to have DRS and alternatively, if $\alpha + \beta > 1$ the production function is said to have IRS. Assuming perfect conditions, α and β can be shown to be labour and capital's share of output (Tan, 2008).

The C-D production function is a useful and powerful tool for macro analysis and government structural policies evaluation (Hajkova & Hurnik, 2007). In summary, the C-D production function assumptions are stated as follows (Tan, 2008):

a) Production becomes extinct when labour and capital are not obtained

b) The amount of production per unit of labour is proportional to the marginal productivity of such labour.

c) The amount of the production per unit of capital is proportional to the marginal productivity of such capital

Considering these assumptions and assuming the production function is denoted by $\mathrm{P} = \mathrm{P}(\mathrm{L}, \mathrm{K})$, then the partial derivative $\frac{\partial \mathrm{P}}{\partial \mathrm{L}}$ is the rate at which production changes with respect to the amount of labor. This is referred to as the marginal production with respect to labour or the marginal productivity of labor. Likewise, the partial derivative $\frac{\partial \mathrm{P}}{\partial \mathrm{K}}$ is the rate of change of production with respect to capital and is referred to as the marginal productivity of capital.

Considering that the per unit production of labour is $\frac{P}{L}$, assumption 2 therefore states that:

$$\frac{\partial \mathrm{P}}{\partial \mathrm{L}} = \alpha \frac{P}{L}$$

for some constant α (in this case the output elasticity of labour). Keeping K constant $(K = K_0)$, then the partial differential equation becomes the ordinary differential equation:

$$\frac{dP}{dL} = \alpha \frac{P}{L}$$

This differential equation is solved by intergrating both sides:

$$\int \frac{1}{P} dP = \alpha \int \frac{1}{L} dL$$

$$\ln(P) = \alpha \ln(cL)$$

$$\ln(P) = \ln\left(cL^{\alpha}\right)$$

This finally leads to:

$$P(L, K_0) = C_1(K_0)L^{\alpha} \quad (1)$$

where $C_1(K_0)$ is the constant of integration and it can be written as a function of K_0 since it could depend on the value of K_0.

In similar fashion, assumption 3 states that:

$$\frac{\partial \mathrm{P}}{\partial \mathrm{K}} = \beta \frac{P}{K}$$

Keeping L constant $(L = L_0)$, the differential equation can be solved further to get:

$$P(L_0, K) = C_2(L_0)K^{\beta} \quad (2)$$

Finally combining equations (1) and (2) we get the C-D production function:

$$\mathrm{P(L, K)} \ = \ \mathrm{AL^{\alpha}K^{\beta}} \quad (3)$$

where A is a constant (Total Factor Productivity) that is independent of both L and K.

The two inputs capital K and labour L are derived from the inputs of capital and labour while TFP (referred to as Solow's residual) is the evaluation of overall efficiency of the economy in transforming inputs into outputs. This is measured independently of the amount of capital (e.g capturing the contribution to P which is left unexplained by inputs of capital and labour).

Productivity is commonly referred to as total factor productivity (TFP) and its growth can be measured by using the Malmquist Index (MI) which is based on the idea of productivity index (Malmquist, 1953). Consequently, MI is used to measure change in TFP growth (Cave, Christensen & Diewert, 1982) which can be constructed using Data Envelopment Analysis (DEA) (Cave et al., 1982; Fare et al., 1994; Samoilenko & Green, 2008). The limitation of the C-D production function is the uneasiness about its accuracy in different time periods because it is influenced by statistical evidence (fitting of least square regression) that have proved that labour and capital shares of output have been constant overtime. The uncertainty in this production function is whether constancy exists over time. The strength of the C-D production function is its mathematical ability to determine diminishing marginal returns as a factor of production (Tan, 2008). However, the C-D production function was not developed

to accommodate the knowledge of engineering or management of production processes, therefore there are no micro foundations for the function (Tan, 2008).

The Cobb-Douglass production function, with DEA analysis, is used in Chapters six, seven and eight to evaluate the relative efficiency and productivity of ICT infrastructure utilization.

3.4 Theory of Communicative Action (TCA)

The Theory of Communicative Action (TCA) combines multiple concepts: rationality; ideal speech situation; validity claims; and the notion of three worlds. These concepts are linked to the social use of language directed to reaching understanding, with a special focus on the justification of the validity claims offered by actors in performing social action through communication. Habermas (1984) developed the TCA mainly based on rationality. In his sense, rationality is a form of communicative action, which is actually connected to the reasons for peoples' natural engagement in communication (Stahl, 2008). An overview of the TCA is given in Table 2. Habermas divides communicative action into two kinds: consensual communication and strategic action.

Consensual communication: This is communication where people use language as a medium for communication aimed at intersubjective agreement through intersubjective mutuality of reciprocal understanding, shared knowledge, mutual trust, and accord with one another (Roberts, 1991).

Strategic action: in contrast, people use language as a force, a tool of domination to gain subjective purpose and to keep a subjective stand regardless of the discussion, debate and assumption on the topic of communication (Roberts, 1991).

Table 2: Overview of Theory of Communicative Action – Adapted from Habermas (1987)

Type of Rationality	Nature of World	Validity Claims	Acts of Speech
Teleological Model	Objective World	Objective Truth	Imperative Statements of Facts, Perlocutions
Normative Model	Objective World Social World	Objective Truth Normative Accuracy	Regulatory
Dramaturgic Model	Objective World Subjective World	Objective Truth Subjective Veracity	Expressive
Communicative Model	Objective World Social World Subjective World	Objective Truth Normative Accuracy Subjective Veracity	Illocutions

According to Habermas (1987), discourse is one means of coordination of action, in the sense that it mobilizes different types of rationality during the meaning creation process and its corollary actions. The understanding of meaning therefore requires understanding of the relationships between individuals and the three worlds to which they refer: the objective world; the social world; and the subjective world. The concepts of these three worlds are used as frames of reference that are supposed to be jointly shared, and in which the situational contexts can be ordered so that agreement, or a validity claim, is obtained on what the participants can sometimes treat as an established fact, sometimes as a valid norm, or sometimes as a subjectively lived experience (Habermas, 1987). The concept of the lived world represents the correlated processes of mutual understanding (Richardson et al., 2006).

From this point of view, the rationalization of an action needs to proceed through the evaluation which an individual forms of a situation, by raising three distinct validity claims: objective truth; normative accuracy; and subjective veracity, whereby each one of these claims can establish a specific relationship to each world, as shown in Table 2.

The raising of an objective truth validity claim establishes a relationship between an expression, or discourse, and the objective world to which an actor would refer. The objective world is defined as all the entities of the subject of which true statements are possible. At the semantic level, such true statements are presented as the propositional contents of sentences carrying the utterances or the intentions (Habermas, 1987). Similarly, the raising of a normative accuracy validity claim establishes a relationship between an expression and the social world to which an actor would refer. The social world is defined as all the interpersonal relations codified by laws. At the semantic level, existing norms are represented by the maxims of duty or the universal commandments which are held as legitimate by the recipients of the norm (Habermas, 1987). Finally, when an actor raises a subjective veracity validity claim, he establishes a relationship between the expression under consideration and the subjective world, defined as the lived experiences to which the actor has privileged access (Habermas, 1987). At the semantic level, subjective veracity is represented by statements expressing the lived experiences in a truthful way.

As an illustration, Habermas (1987) states that by "characterizing a situation or an object as being imposing, rich, exciting, dangerous, atrocious, we try to express and at the same time to justify a bias, in the sense that we seek to make it plausible while calling upon universal standards of evaluation, or in any case those of the considered culture." In order to improve

the understanding of the specific aspects of each rationality type, a brief description of the four main models of action identified by Habermas (1987) is presented as follows:

3.4.1 The Teleological Model

Within the teleological model of action, the individual achieves a goal or causes the fulfilment of a desired state by choosing and using the means which seem to lead to a positive outcome. Habermas classifies the teleological model of action as a concept presupposing only one world, the objective world. This model of action, which is often interpreted from a utilitarian point of view, equips the actor with a volitional cognitive complex which allows the subject, on the one hand, to form opinions (mediated by perception) on existing states of affairs, and on the other hand, to develop intentions whose objective consists of realizing the desired states of affairs. By his opinions and intentions, the actor can fundamentally establish two classes of relationships: For one of these directions, the question consists of asking whether the actor succeeds in putting his perceptions and opinions into agreement with what in the world is the case; for the other direction, it is a question of knowing whether or not the actor succeeds in granting that what occurs in the world is indeed in agreement with his wishes and intentions (Habermas, 1987; Richardson et al., 2006).

Finally, the teleological model is extended to the strategic model of action, when the actor includes in his/her calculation of expected consequences the anticipation of the decision of at least one additional actor acting for a given objective (Richardson et al., 2006).

3.4.2 The Normative Model

The normative model of action does not relate to the behaviour of an isolated individual, but it concerns the members of a social group who direct their actions according to common values (Richardson et al., 2006). The individual actor can observe a rule, or not, since the conditions, in which the norm finds its application, are fulfilled in a given situation. Here, the central concept of obedience to a norm means that the expected behaviour is realized. For Habermas, an "expected behaviour does not have the cognitive sense of an expected forecasted behaviour, but the normative sense of an expected behaviour legitimized by the members of the group" (Habermans, 1987). Habermas classifies the normative model as a concept which presupposes two worlds, the objective world and the social world. In fact, the

normative model presupposes that the actor is able to differentiate between the factual elements and the normative elements of a situation. Here, in the same way as in the teleological model, action is primarily understood as being a relationship between the actor and one of the three worlds (Richardson et al., 2006). However, in neither of these models is, "the actor himself presupposed as a world with regard to which he can refer, in a reflexive way" (Habermans, 1987).

3.4.3 The Dramaturgic Model

The dramaturgic model of action involves neither the isolated actor nor the member of a social group, but the participants of an interaction. According to Habermas (1987), when we consider a social interaction from the point of view of the dramaturgic model, we understand it as a meeting where the participants constitute a public of which each one occurs for the other and even presents to the other something of himself. Encounter and Performance are the key concepts of this model (Habermans, 1987).

An actor, or an object, if one considers an information system, creates a certain impression on the public, a certain image which is thereafter the subject of an evaluation based on subjective experiences (Richardson et al., 2006). Habermas classifies the dramaturgic model as a concept which presupposes two worlds, the objective (external) and the subjective (internal). Indeed, the "expressive demonstrations reveal subjectivity as a sphere distinct from the external world, vis-a-vis which, the actor can only adopt an objectifying attitude, but with a difference regarding what occurs in the case of the normative model, that is valid not only for the physical objects, but also for the social objects" (Habermas, 1987). The dramaturgic model of action basically specifies that stylistic traits are conventionally associated with certain roles and could often be superimposed on certain activities, e.g. politics, negotiation, and the likes, to heighten the validity of a claim. In summary, the dramaturgic model of action is essentially related to the evaluation of the impressions created and evaluated by the interacting parties (Richardson et al., 2006).

3.4.4 The Communicative Model

The model of communicative action relates to the interaction of at least two subjects who engage in an interpersonal relationship, whether by verbal or nonverbal means. The actors seek an agreement on a set of actions, in order to coordinate in a consensual way their action

plan and their actions. The central concept of interpretation aims initially at the negotiation of definitions in situations where a consensus is foreseeable. In this model of action, language occupies a preeminent place. However, the interest in this model lies primarily in the mechanism of rationalization which it describes. It differs from the three preceding models in that the model of communicative rationality stipulates that the individual action rises from the individual's recourse to the three worlds: objective; social; and subjective, to which the individual refers (Richardson et al., 2006).

3.4.5 Operationalizing the TCA

According to Habermas (1984), people communicate to "reach common understanding and to coordinate actions by reasoned argument, consensus, and cooperation rather than strategic action strictly in pursuit of their own goals" (Bolton, 2005). Therefore, he argues that communication should be conducted in an ideal speech situation. An ideal speech situation is a set of conditions defined as a communicative practice free from any form of distortion, coercion or ideology, excluding all forces except the force of the best argument (Cecez-Kecmanovic & Janson, 1999) for providing an acceptable outcome. Habermas points out four conditions for the ideal speech situation, which open up the way for reciprocity of communication to be realized. The conditions assure equal rights for all potential speakers to:

(i) participate in the discourse,
(ii) present interpretations, make assertions, recommendations, explanations or corrections, and argument, as well as justify the validity of such actions,
(iii) express their attitudes, feelings, needs and desires in an honest and transparent manner, and
(iv) command and deny commands, promise and refuse, be accountable for their own actions and demand accountability from others (Huttunen, 2000).

In line with this, when speakers engage in consensual communication, implicitly they make four validity claims in every statement, namely truth (veracity), legitimacy (rightness), sincerity (authenticity), and clarity (Hasan, 2016). These claims are often called:

(i) Communication competence (truth, legitimacy, sincerity), and
(ii) Linguistics competence (clarity)

These claims, in their turn, are related to the notion of the three worlds already discussed: the objective world; subjective world; and social world (Lyytinen & Hirschheim, 1988; Stahl, 2008). Each of these worlds, which are all essential for understanding social action, reflect a specific type of claim. The objective world holds the universal truth, the subjective world contains the internal beliefs of a person, and the social world states desirable actions, i.e. the normative truth. Chigona & Chigona (2008) have made a summary of the validity claims within the concept of these three worlds.

Table 3: Validity Claims Table – Adapted from Chigona & Chigona (2008)

Competence	World	Claim	Explanation
Communication	Objective	Truth	Utterance should match the case in reality
	Subjective	Sincerity	Checks the intention of the speaker. Cannot be observed, only inferred
	Social	Legitimacy	Utterance should be in accordance with socially accepted norms
Linguistics		Clarity	Utterance should be clear in terms of syntax and semantics

Accordingly, the essence of the TCA is that in every communication a speaker/writer should raise claims in which the truth relates to the accuracy of the facts or contents, which in turn reflect the objective world. Sincerity requires truthfulness and authenticity of the writer in the act of communication, which is part of the subjective world, and legitimacy applies to socially accepted norms, which echo the social world. Theoretically, each of these claims can be questioned and analysed whenever a reader would like to justify the validity of a specific document, resulting in a definite agreement or disagreement, or a decision to enter into a discussion about any presuppositions (Hasan, 2016).

3.5 Conclusion

This chapter has presented the epistemological and ontological perspective in which this thesis is situated and approached from: Critical Research and Critical Realism respectively. The chapter has also discussed the two philosophical and theoretical frameworks by which the research is guided, the Cobb-Douglas Production Framework for the quantitative research and Habermas' Theory of Communicative Action for the qualitative research. In the next chapter, chapter 4, the various research methodologies and analytical methods employed using these frameworks, within this epistemology and ontological perspective, are presented and explained.

3.6 References

Bolton, R. (2005). Habermas's theory of communicative action and the theory of social capital. *Association of American Geographers, Denver, Colorado, April*, *2*.

Caves, D., Christensen, L., & Diewert, W. (1982). The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity. *Econometrica*, *50*(6), 1393–1414.

Cecez-Kecmanovic, D., & Janson, M. (1999). Communicative action theory: an approach to understanding the application of information systems. In *ACIS, Australasian Conference on Information Systems*.

Chigona, A., & Chigona, W. (2008). MXit it up in the media: Media discourse analysis on a Mobile instant messaging system. *The African Journal of Information and Communication*, *2008*(9), 42-57.

Fare, B. R., Grosskopf, S., Norris, M & Zhang, Z. (1994). Productivity Growth , Technical Progress , and Efficiency Change in Industrialized Countries. *The American Economic Review*, *84*(1), 66–88.

Habermas, J. (1984). *The theory of communicative action* (Vol. 2). Beacon press.

Habermas, J. (1987), Théorie de l'agir communicationnel, Tome 1, Rationalité de l'agir et rationalisation de la société, Fayard (L'espace du politique).

Hajkova, A. D., & Hurnik, J. (2007). Cobb-Douglas Production Function: The Case of a Converging Economy. *Journal of Economics and Finance*, *57*, 9–10.

https://economicpoint.com/production-function/cobb-douglas Cobb Douglas Production Function

Huttunen, R. (2000) *Habermas' Ideal Speech Situation*. http://www.srcf.net/pipermail/theoryfrankfurt-school/2000-October/002820.html

Lyytinen, K., & Hirschheim, R. (1988). Information systems as rational discourse: An application of Habermas's theory of communicative action. *Scandinavian Journal of Management*, *4*(1-2), 19-30.

Malmquist, S. (1953). Index Numbers and Indifference Surfaces. *Trabajos de Estadistica y de Investigacion Operativa*, *4*(2), 209–242.

Mingers, J. (2003). A Classification of the Philosophical Assumptions of Management Science Methods. *The Journal of the Operational Research Society*, *54*(6), 559–570.

Myers, M. (1997). Qualitative Research in Information Systems. *MIS*, *1*(6), 241–243.

Orlikowski, W. J., & Baroudi, J. J. (1991). Studying Information Technology in Organizations: Research Approaches and Assumptions. *Information Systems Research*, *2*(1), 1–28.

Rehman, A. A., & Alharthi, K. (2016). An introduction to research paradigms. *International Journal of Educational Investigations*, *3*(8), 51-59.

Richardson, H., Kvasny, L., Pozzebon, M., Titah, R., & Pinsonneault, A. (2006). Combining social shaping of technology and communicative action theory for understanding rhetorical closure in IT. *Information Technology & People*.

Roberts, P. (1991). Habermas' varieties of communicative action: controversy without combat. *Journal of Advanced Composition*, 409-424.

Samoilenko, S., & Green, L. T. (2008). Convergence and Productive Efficiency in the Context of 18 Transition Economies: Empirical Investigation Using DEA. *Proceedings of the Southern Association for Information Systems Conference, Richmond, VA, USA. March 13th-15th, 2008* (pp. 1–6)

Stahl, B. C. (2008). Empowerment through ICT: A critical discourse analysis of the Egyptian ICT policy. In *IFIP international conference on human choice and computers* (pp. 161-177). Springer, Boston, MA.

Straub, D., Boudreau, M. C., & Gefen, D. (2004). Validation Guidelines for IS Positivist Research. *Communications of the AIS*, *13*(1), 380–427.

Tan, B. H. (2008). Cobb-Douglas Production Function. *Retrieved January, 10, 2012 from docente.fe.unl.pt/jamador/Macro/cobb-douglas.pdf.*

CHAPTER 4

4.0 Research Methodology

4.1 Introduction

This chapter presents and discusses the research methodologies and design used in this thesis. It also discusses the various methods of analysis employed in this research. The chapter is organized as follows: Section 4.2 presents the research design, section 4.3 discusses the DEA research methodology, section 4.4 presents the Malmquist Productivity Index research method while section 4.5 presents the Linear Regression Models used in this research. Section 4.6 discusses the Critical Discourse Analysis as applicable to this research and the chapter concludes with section 4.7.

4.2 Research Design: Mixed Methods Research

Philosophically, mixed methods research makes use of the pragmatic method and system of philosophy. Its logic of inquiry includes the use of induction - discovery of patterns, deduction - testing of theories and hypotheses, and abduction - uncovering and relying on the best of a set of explanations for understanding results (De Waal, 2001). Mixed methods research also attempts to legitimize the use of multiple approaches in answering research questions, rather than restricting or constraining a researcher's choices. It is an expansive and creative form of research, not a limiting form of research. It is inclusive, pluralistic, and complementary, and it suggests that researchers take an eclectic approach to method selection and the thinking about and conduct of research. What is most fundamental is the research question. The research methods should follow the research questions in a way that offers the best chance to obtain useful answers. Many research questions and combinations of questions are best and most fully answered through mixed methods research (Johnson & Onwuegbuzie, 2004).

As postulated by Sechrest & Sidana (1995), growth in the mixed methods or pragmatist research movement has the potential to reduce some of the problems associated with singular methods. By utilizing both quantitative and qualitative techniques within the same research

framework or study, mixed methods research can potentially incorporate the strengths of both methodologies. Most importantly, investigators who carry out mixed methods research are more likely to select methods and approaches with respect to their underlying research questions, rather than with regards to some preconceived biases about which research paradigm should have hegemony within the stipulated epistemology. There is a tendency among some researchers to treat epistemology and methods as being synonymous (Bryman, 1984; Howe, 1992). This is far from being the case because the logic of justification, itself an important aspect of epistemology, does not dictate what specific data collection and data analytical methods researchers must use. There is rarely entailment from epistemology to methodology (Johnson et al., 2004; Phillips, 2004). Therefore, by narrowing the divide between quantitative and qualitative researches, mixed methods research has a great potential to promote a shared responsibility in the quest for attaining accountability for educational quality (Johnson & Onwuegbuzie, 2004).

The majority of mixed methods research designs in the literature are seen to have been developed from the two major types of mixed methods research: mixed-model, mixing qualitative and quantitative approaches within or across the stages of the research process; and mixed-method, the inclusion of a quantitative phase and a qualitative phase in an overall research study. Six mixed-model designs, referred to as across-stage mixed-model designs because the mixing takes place across the stages of the research process, are shown in Figure 1, specifically Designs 2 – 7 as Designs 1 and 8 on the outer edges are mono-method designs.

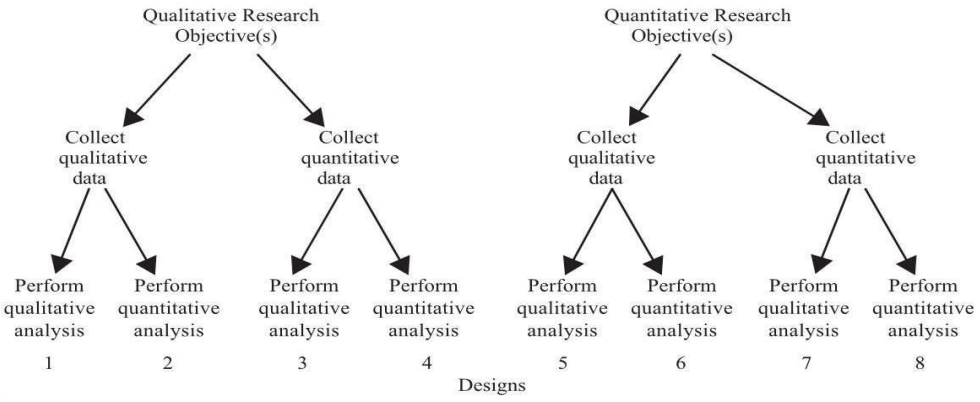

Figure 6: Mono-Method & Mixed-Method Research Designs – Adapted from Johnson & Onwuegbuize (2004)

Nine mixed-method designs are provided in Figure 7 with notation used based on Morse (1991). In this notation, "qual" stands for qualitative, "quan" stands for quantitative, "+" stands for concurrent, "→" stands for sequential, capital letters denote high priority or weight, and lower-case letters denote lower priority or weight. Johnson & Onwuegbuzie (2004) state that to construct a mixed-method design, the researcher must make two primary decisions:

(a) Whether to operate largely within one dominant paradigm or not;

(b) Whether to conduct the phases concurrently or sequentially.

However, unlike mixed-model designs, mixed-method designs are similar to conducting a quantitative mini-study and a qualitative mini-study in one overall research study. Nonetheless, to be considered a mixed-method design, the findings must be mixed or integrated at some point. For example, a qualitative phase might be conducted to inform a quantitative phase, sequentially, or if the quantitative and qualitative phases are undertaken concurrently the findings must, at a minimum, be integrated during the interpretation of the findings (Johnson & Onwuegbuzie, 2004).

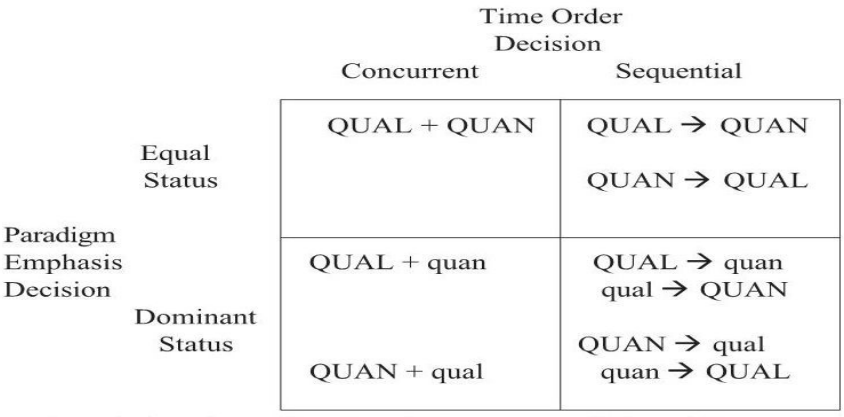

Figure 7: Mixed-Method Design Matrix – Adapted from Johnson & Onwuegbuize (2004)

The first study uses a quantitative method, multiple linear regression, to operationalize Learning Analytics for decision making. The predictive analytics model is carried out using data collected from the Computer Science Department of the University of Jos, Nigeria as a case study. The choice of University of Jos was purely out of convenience as University of

Jos is a second generation, federal university in Nigeria and access to this data would be easy and not cumbersome. Archival data was deemed suitable for this study as the research dealt with developing and testing of a framework for prediction of academic performance using previously attained results.

The second study investigates the relative efficiency of ICT infrastructure utilization in Northern Africa, Sub-Saharan Africa, select countries in Europe and North America and the world using the Data Envelopment Analysis, a quantitative research method. The study also uses another quantitative method, Ordinary Least Squares (OLS) regression to determine the relationship between ICT infrastructure and educational attainment and adult literacy rates. Most recent data available was collected for a time period of 6 years. This was from 2010-2016 to enable analysis over a particular time period and to mitigate against years where data was not available. This data was used for studies 2, 3 and 4. The groupings were considered for the DMU's in the manner which the data was available from the sources which would require limited extrapolation so as to minimize the researcher's influence on the data.

In the third study, the research employs two quantitative methods, DEA and Malmquist Productivity Index (MPI) to investigate the relative efficiency and productivity of ICT infrastructure utilization on adult literacy rates in Arab States, Europe, Sub-Saharan Africa and the world. The research further goes on to determine the relationship between ICT infrastructure and adult literacy rates using OLS regression analysis.

The fourth study employs both DEA and MPI to create public value in ICT using an efficiency and productivity assessment approach.

The fifth study uses a qualitative method, Critical Discourse Analysis (CDA), to determine if any public value is created from ICT developmental outcomes with respect to education from the United Nations (UN) Human Development Reports (HDRs) from 2010 through to 2016. A trend analysis on the policy direction with respect to ICT infrastructure utilization in socio-economic development is also carried out.

Therefore, this mixed method research seeks to expand the breadth and range of ICT4D research with respect to education and socio-economic development by using different methods, both quantitative and qualitative, for the different research questions and objectives.

This research is conducted predominantly within the quantitative research paradigm and as such employs the QUAN→qual mixed method research design.

4.3 Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is a well-known and established non-parametric linear programming methodology that has been widely used for data analysis within the Information Systems discipline and in quantitative research within the ICT4D context. DEA has been successfully used to measure efficiency for well over three decades and its applications spread over a wide range of thematic areas (Liu et al., 2013a). DEA is used for the assessment and measurement of the relative efficiency and performance of organizations (Cooper et al., 2006; Thanassoulis et al., 2008, 2011; Bankole et al., 2011c) and has also been used for understanding the impacts of IT investments on performance and productivity (Hatami-Marbini et al., 2010). It has long been recognized that DEA, by its use of mathematical programming, is particularly adept at estimating inefficiencies in multiple input and multiple output production correspondences (Banker et al., 2004). In the area of education, DEA has been widely used for the assessment of efficiency of the school provision at different levels (Färe et al., 2006; Portela et al., 2012), universities and their departments (Avkiran, 2001; Thanassoulis et al., 2011), and the impact of education policies (Bradley et al., 2001; Grosskopf & Moutray, 2001).

The value of Data Envelopment Analysis (DEA), as a non-parametric data analysis method, has been shown to lie in its capability to relatively evaluate the individual efficiency or performance of a decision-making unit (DMU) within a target group of interest that operates in a certain application domain (Liu et al., 2013). According to Golany & Roll (1989), DEA has been adopted in these application domains to evaluate the effectiveness of programs or policies and to create a quantitative basis for reallocating resources as well as for other purposes.

Data envelopment analysis (DEA) was first developed by Charnes et al. (1978), based on the assumption of a constant returns-to-scale (CRS). It is popularly known as the CCR (Charnes Cooper Rhodes) model and has remained the preferred technique for measuring the relative efficiency of decision-making units (DMUs) due to its intuitive ability to prescribe weights from assessments, which depend on multiple inputs and outputs. Banker et al. (1984) have

further extended the CCR model by including an accommodation for variable returns-to-scale (VRS), more popularly known as the BCC (Banker Charnes Cooper) model. Consequently, these two conventional models have traditionally been employed in DEA studies in all its application domains. The difference between CRS and VRS is such that the number of efficient DMUs of the CRS is a subset of the VRS (Ahn et al., 1988). This means that one expects that a conventional DEA model based on CRS will have a lower number of efficient DMUs than a VRS derived model (Ghasemi et al., 2018).

These returns to scale (RTS) classifications of DMUs in the DEA methodology have been the subject of study by numerous authors, including Banker (1984), who proposes using the most productive scale size concept and letting the sum of lambda values dictate the RTS, and Färe et al. (1994), who have proposed applying their scale efficiency index method. A problem in classifying RTS however, is the existence of multiple optima, meaning that the classification may be a function of the particular solution selected by the optimization software (Cook & Seiford, 2009). Various attempts have been made to provide a more definitive RTS classification assignment for a given DMU, including developing intervals for the various free variables arising from the multiple optima (Cook & Seiford, 2009). Zhu & Shen (1995) suggested a remedy for the CCR RTS method under multiple optima while Seiford & Zhu (1997; 1999) have reviewed the various methods and suggest computationally simple methods to characterize RTS, thereby avoiding the need for exploring all alternate optimal solutions.

The effect of the scale assumption on the measure of capacity utilization is shown in Figure 8. Four data points (A, B, C, and D) are used to estimate the efficient frontier and the level of capacity utilization under both scale assumptions using a set of fixed inputs. The frontier defines the full capacity output given the level of fixed inputs. With constant returns to scale, the frontier is defined by point C for all points along the frontier, with all other points falling below the frontier (hence indicating capacity underutilization). With variable returns to scale, the frontier is defined by points A, C and D, and only point B lies below the frontier i.e. exhibits capacity underutilization. The capacity output corresponding to variable returns to scale is lower than the capacity output corresponding to constant returns to scale (Cooper et al., 2000).

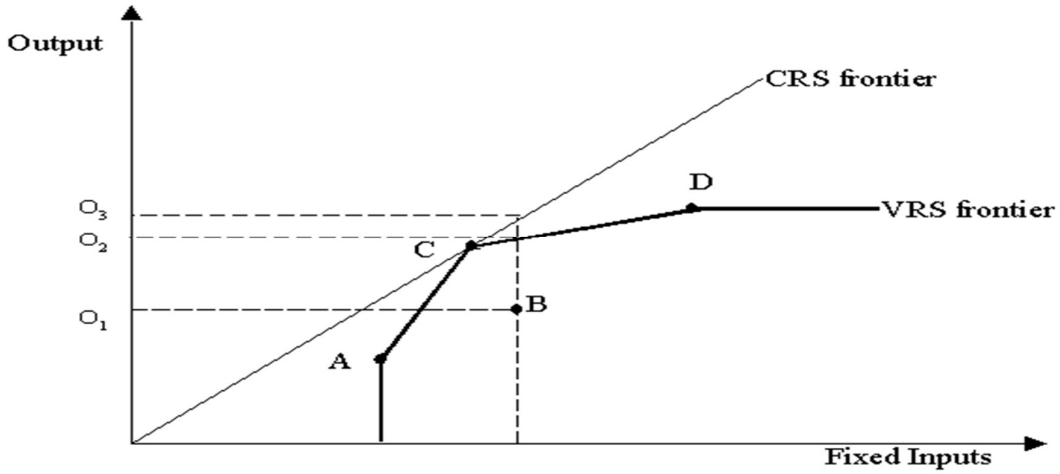

Figure 8: DEA CRS and VRS Frontiers

Another common challenge with applications of DEA is the low discriminating power of the model used. This is the ability of the DEA models to differentiate between good and bad performing Decision-Making Units (DMUs) by reflecting on their performance in a sufficiently wide range of efficiency scores (Cooper et al., 2007; Thanassoulis et al., 2008; Atici & Podinovski, 2015). It is well-known that the discrimination of a DEA model depends on a number of factors, including the number of inputs and outputs in relation to the number of units, the type (variable or constant) of returns-to-scale assumed (VRS and CRS, respectively) and, more generally, the particular dataset that is under investigation (Angulo-Meza & Lins, 2002; Podinovski & Thanassoulis 2007). Even, if the true (best practice) technology is assumed to be VRS, the reference, or benchmark, CRS technology is often used as a part of the scale efficiency calculations (Podinovski et al., 2014).

DEA therefore, is a data-oriented method for evaluating the performance (efficiency) of entities (DMUs) (Bankole et al., 2011c) which uses input-output data to compute an efficient production frontier produced by the most efficient DMUs. DEA, unlike a parametric method, is context specific with respect to the interpretations of the results of the analysis, which are restricted to the sample and should not be generalized beyond the sample (Samoilenko & Osei-Bryson, 2017). DEA, therefore, can then be viewed as a multiple-criteria evaluation methodology where there are alternative DMUs, and where DEA inputs and outputs are two sets of performance criteria where one set (inputs) is to be minimized and the other (outputs) is to be maximized (Cook et al., 2014).

In this thesis, the two prevalent DEA models are employed, the VRS and CRS models (Podinovski et al., 2014). The CRS model is derived by considering a set on *n* DMUs each with DMU_j, (*j=1, ..., n*) using *m* inputs x_{ij}(*i=1, ..., m*) and generating *s* outputs y_{rj}(*r=1, ..., s*). If the multipliers $\bar{u}_r$, $\bar{v}_i$ associated with outputs *r* and inputs *i*, respectively, are known, then borrowing from conventional cost/benefit theory, the efficiency $\bar{e}_j$ of DMU_j can be expressed as the ratio of weighted outputs to weighted inputs:

$$\sum_r \bar{u}_r y_{rj} \Big/ \sum_i \bar{v}_i x_{ij}$$

However, a common challenge that lies herein, is that more often than not, the multipliers, $\bar{u}_r$ and $\bar{v}_i$ are not known. To resolve this, Charnes et al. (1978), have proposed a model for deriving appropriate multipliers for a given DMU. This model, popularly referred to as the CCR (Charnes, Cooper and Rhodes) model is expressed as:

$$e_0 = \max \sum_r u_r y_{r0} \Big/ \sum_i v_i x_{i0}$$

$$s.t. \sum_r u_r y_{rj} - \sum_i v_i x_{ij} \leq 0, \quad all\ j$$

$$u_r v_i \geq \varepsilon, all\ r, i$$

where ε is a non-archimedian value designed to enforce strict positivity on the variables and is the solution to a fractional programming problem (Cook & Seiford, 2009). Subsequently, Banker et al. (1984) (BCC), extended this by providing for the variable returns to scale (VRS) model. The BCC ratio model differs from the CRS model, by way of an additional variable and is expressed as:

$$e_0^* = \max [\sum_r u_r y_{r0} - u_0] \Big/ \sum_i v_i x_{i0}$$

$$s.t. \sum_r u_r y_{rj} - u_0 - \sum_i v_i x_{ij} \leq 0, \quad j = 1, \dots, n$$

$$u_r \geq \varepsilon, \ v_i \geq \varepsilon, \forall i, r$$

where u_0 is unrestricted in sign (Cook & Seiford, 2009).

4.4 Malmquist Productivity Index

The Malmquist index was first introduced by Malmquist (1953) as a quantity measure for use in the analysis of the consumption of inputs. Subsequently, Fare et al. (1994) developed a Malmquist productivity index directly from input and output data utilizing DEA. This DEA-based Malmquist productivity index (DEA-MI), measures the productivity change of DMUs over time (Cook & Seiford, 2009).

The Malmquist Productivity Index (MPI) measures the productivity changes along with time variations and can be decomposed into changes in efficiency and technology with a DEA like non-parametric approach. Productivity decomposition into technical change and efficiency catch-up necessitates the use of a contemporaneous version of the data and the time variants of technology in the study period. The MPI can be expressed in terms of distance function (E) as Equation (1) and Equation (2) using the observations at time t and t+1.

$$MPI_I^t = \frac{E_I^t(x^{t+1}, y^{t+1})}{E_I^t(x^t, y^t)} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

$$MPI_I^{t+1} = \frac{E_I^{t+1}(x^{t+1}, y^{t+1})}{E_I^{t+1}(x^t, y^t)} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

where I denotes the orientation of MPI model.

The geometric mean of two MPI in Equation (1) and Equation (2) gives the Equation

$$MPI_I^G = (MPI_I^t MPI_I^{t+1})^{1/2}$$
$$= \left[\left(\frac{E_I^t(x^{t+1}, y^{t+1})}{E_I^t(x^t, y^t)}\right).\left(\frac{E_I^{t+1}(x^{t+1}, y^{t+1})}{E_I^{t+1}(x^t, y^t)}\right)\right]^{1/2} \dots\dots\dots\dots\dots\dots\dots\dots (3)$$

The input oriented geometric mean of MPI can be decomposed using the concept of input oriented technical change (TC) and input oriented efficiency change (EC) as given in the Equation

$$MPI_I^G = (EC_I).(TC_I^G)$$
$$= \left(\frac{E_I^{t+1}(x^{t+1}, y^{t+1})}{E_I^t(x^t, y^t)}\right).\left[\left(\frac{E_I^t(x^t, y^t)}{E_I^{t+1}(x^t, y^t)}\right).\left(\frac{E_I^t(x^{t+1}, y^{t+1})}{E_I^{t+1}(x^{t+1}, y^{t+1})}\right)\right]^{1/2} \dots\dots (4)$$

The first and second terms represent the efficiency change (EC) and the technology change (TC) respectively. MPI given by Equation (3) and Equation (4) can be defined using a DEA like distance function. That is, the components of MPI can be derived from the estimation of distance functions defined on a frontier technology. Färe et al., (1994) have provided the formal derivation of MPI and it is the most popular method among the various methods that have been developed to estimate a production technology (Coelli et al., 2005; Thanassoulis 2001). By utilizing both CRS and VRS DEA frontiers to estimate the distance functions in Equation (4), the TC can be decomposed into scale efficiency change (SC) and pure technical efficiency change (PC) components. SC is given in equation (5) and PC is given in equation (6) (Lee et al., 2011).

$$SC = \left[\frac{E_{vrs}^{t+1}(x^{t+1}, y^{t+1})/E_{crs}^{t+1}(x^{t+1}, y^{t+1})}{E_{vrs}^{t+1}(x^{t}, y^{t})/E_{crs}^{t+1}(x^{t}, y^{t})} \cdot \frac{E_{vrs}^{t}(x^{t+1}, y^{t+1})/E_{crs}^{t}(x^{t+1}, y^{t+1})}{E_{vrs}^{t}(x^{t}, y^{t})/E_{crs}^{t}(x^{t}, y^{t})}\right]^{1/2} \quad \ldots\ldots(5)$$

$$PC = \frac{E_{vrs}^{t+1}(x^{t+1}, y^{t+1})}{E_{crs}^{t}(x^{t}, y^{t})} \ldots\ldots\ldots\ldots\ldots(6)$$

Conceptually, however, the mechanism for estimating changes in a DMU using DEA is intuitive as the position of a DMU changes over time and is thus measured by means of MI. The change in the position of a DMU, and the corresponding value of MI, is comprised of two components, the changes in Efficiency (EC) and changes in Technology (TC). With regards to the changes in MI, a value equal to 1 means no change in productivity, while a value greater than 1 or less than 1 denotes a growth or decline in productivity, respectively (Samoilenko & Osei-Bryson, 2017).

The classic Malmquist Index is determined by the equation:

$$MI = EC * TC = PC * SC * TC$$

where:

MI - Malmquist Index

EC – Efficiency Change

TC - Technical Change

PC - Pure efficiency Change

SC - Scale efficiency Change

Traditionally, the Malmquist Index can be calculated using three calculation methods:

(a) Fixed base: This method assumes the selection of one of the researched time moments as a base moment. All further calculations are performed relative to this base moment. This calculation method is illustrated on Figure 1.

Figure 9: Fixed-Base Method of Malmquist Index Calculation

Here moment t_1 is selected as the base time moment. Calculations are performed for the following time moment pairs:

t_1 and t_2
t_1 and t_3
...
t_1 and t_n

Which can further be represented as:
$MI(t_1t_2)$ $MI(t_1t_3)$ ... $MI(t_1t_n)$

(b) Adjacent base: This method assumes that each time moment is selected as the base moment and the moment next to base is considered as the analysed time moment. This calculation method is illustrated on Figure 10.

Figure 10: Adjacent-Base Method of Malmquist Index Calculation

Each moment is subsequently selected as the base moment and the one next to it the analyzed moment and so on. Calculations are performed for the following time moment pairs:

t_1 *and* t_2

t_2 *and* t_3

…

t_{n-1} *and* t_n

Which can further be represented as:

$MI(t_1t_2)$ $MI(t_2t_3)$ … $MI(t_{n-1}t_n)$

(c) Seasonal calculation: This method assumes that each of the moments is considered as the base moment and the analyzed moment is shifted to a given number of time moments (season length) relative to the base. This calculation method is illustrated in Figure 3 where, in this case, the season length parameter is set to 2. The Seasonal method is particularly useful when it is necessary to calculate Malmquist Index for periodical data such as annual, quarterly and monthly data.

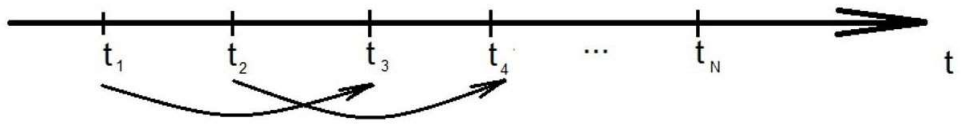

Figure 11: Seasonal Method of Malmquist Index Calculation

Calculations are performed for the following time moment pairs:

t_1 *and* t_3

t_2 *and* t_4 *(With Season length = 2)*

…

t_{n-2} *and* t_n

Which can further be represented as:

$MI(t_1t_3)$ $MI(t_2t_4)$ … $MI(t_{n-2}t_n)$

4.5 Linear Regression Models

4.5.1 Ordinary Least Squares (OLS) Regression

OLS regression is one of the most popular statistical techniques used for prediction and explanation of two or more variables. OLS regression assumes that all variables entered into the analysis are continuous and the regression procedure attaches importance to actual values (Hutcheson, 1999). In data analysis, OLS is used for estimating the unknown parameters in a linear regression model. The goal is to minimize the differences between the collected observations in some arbitrary dataset and the responses predicted by the linear approximation of the data. A simple OLS regression can be expressed as:

$$y = \alpha + \beta x$$

Where α is the intercept of the line on the y axis, and β is the slope of the line. This equation describes a direct linear relationship between x and y where the value of y can be precisely calculated from the value of x. The slope of the line can be described as the change in y which is associated with a unit change in x. For example, as x increases from 2 to 3 (a unit change), y increases by the value of β, the slope of the line. This slope is also known as the regression coefficient and shows the effect that the explanatory variable has on the response variable. Figure 12 depicts the regression line for two variables which are perfectly linearly related and shows the regression coefficient, β, and the intercept, α.

In reality, however, perfect relationships of the type shown in Figure 12 are the exception rather than the rule, as relationships are rarely direct and measurement rarely error-free. The best that can be hoped for is to calculate a line of best-fit, in order to approximately describe the relationship between variables x and y. For OLS regression, the most common method for calculating this line is to use the least-squares procedure which minimizes the sum of the squared deviations (also known as the error, or residual) of each data point from the line (Crawshaw & Chambers, 1984; Hays, 1994). The equation $y = \alpha + \beta x + \varepsilon$ expresses the OLS regression model and includes a term, ε, which indicates the degree to which data points deviate from this perfect line of best fit.

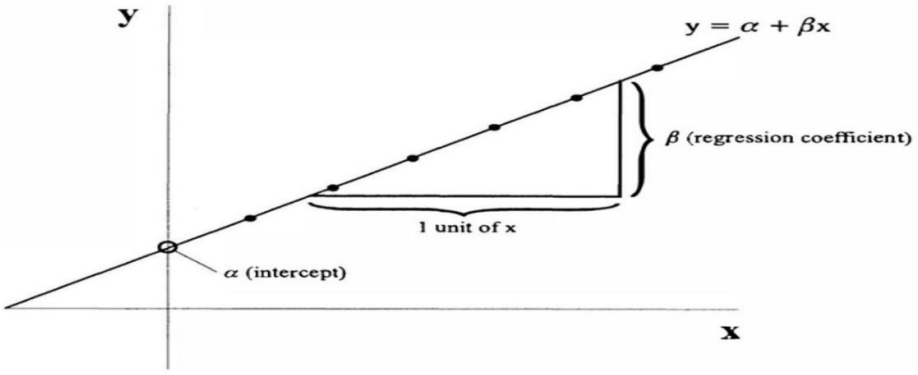

Figure 12: An OLS Regression Model Showing a Perfect Linear Relationship

The deviation, or error, is often represented as the difference between the observed value of *y* and the value of *y* predicted from the model *(ŷ)*. The term *y–ŷ* provides a measure of the size of the error when *y* is predicted using the regression model. The term 'error' simply indicates that the relationship between the variables is not exact. Therefore, α now represents the average value of y when x = 0, whilst β represents the average change in y which is associated with a unit change in x. Figure 13 shows the parameters α and β for a line of best-fit which models the relationship between two imperfectly related variables.

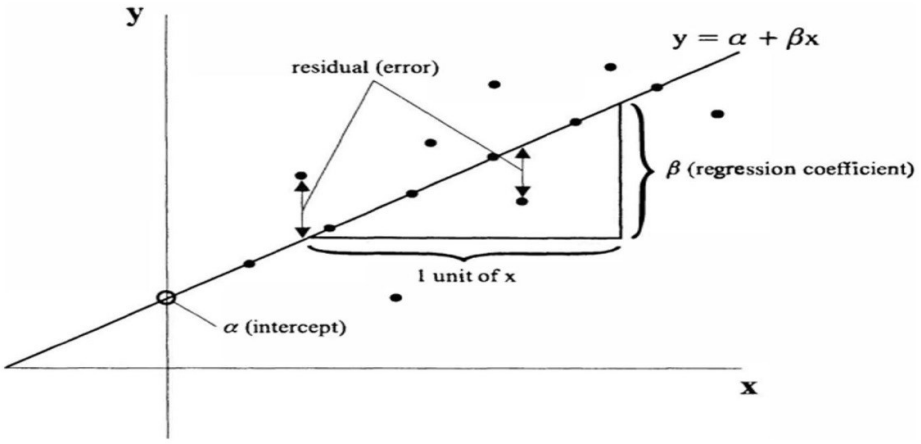

Figure 13: Line of Best-Fit

OLS regression analysis allows for the prediction of the value of y, even though at the very least an average value, for every given value of x, to a reasonable level of significance, within the limits of observation.

4.5.2 Multiple Linear Regression

In statistics, regression analysis is a statistical process for estimating the relationship between a dependent variable and one or more independent variables (Draper & Smith, 1998). Specifically, regression technique helps a researcher to understand how the typical value of the dependent variable (or 'criterion variable') changes when any one of the independent variables is varied, while the other independent variables are held fixed.

Thus, Multiple Linear Regression (MLR) can be defined as the relationship between a dependent variable and two or more independent variables. The theoretical assumption is that, for every one-unit change in the independent variable, there is a consistent and uniform change in the dependent variable. Multiple Linear Regression is therefore the extension of OLS regression that involves more than one explanatory variable. The statistical model for multiple linear regression is given by:

$$Y = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots\ldots\ldots\ldots \beta_k X_{ik} + \varepsilon$$

Where Y is the Dependent variable, $X_{i1}, X_{i2}, \ldots, X_{ik}$ are independent variables, $\beta_0 =$ constant value and $\beta_1, \beta_2 \ldots \beta_k$ = regression coefficients and ε = error or residual terms of the model. Each regression coefficient represents the change in Y relative to a one-unit change in the respective independent variable. In the multiple regression situation, β_1, for example, is the change in Y relative to a one-unit change in X_1, holding all other independent variables constant. Again, as in OLS regression, statistical tests can be performed to assess whether each regression coefficient is significantly different from zero.

According to Kenton (2019), the multiple regression model is based on the following assumptions:

- There is a linear relationship between the dependent variables and the independent variables.
- The independent variables are not too highly correlated with each other.
- Y observations are selected independently and randomly from the population.
- Residuals should be normally distributed with a mean of 0 and variance σ.

The coefficient of determination (R-squared) is a statistical metric that is used to measure how much of the variation in outcome can be explained by the variation in the independent variables. R^2 always increases as more predictors are added to the MLR model even though the predictors may not be related to the outcome variable. R^2 by itself cannot thus be used to identify which predictors should be included in a model and which should be excluded. R^2 can only be between 0 and 1, where 0 indicates that the outcome cannot be predicted by any of the independent variables and 1 indicates that the outcome can be predicted without error from the independent variables. When interpreting the results of a multiple regression, beta coefficients are valid while holding all other variables constant ("all else equal"). The output from a multiple regression can be displayed horizontally as an equation, or vertically in table form (Kenton, 2019).

Linear (OLS) regression compares the response of a dependent variable given a change in some explanatory variable while multiple regression attempts to explain the behaviour of a dependent variable using more than one independent variable. Multiple regressions can be linear and nonlinear but are based on the assumption that there is a linear relationship between all the dependent and independent variables. It also assumes no major correlation between the independent variables. Therefore, MLR is used in chapter 5 as prediction is the aim of the regression study carried out in that research, while OLS is used in chapters 6 and 7 as effects of the independent variables on the dependent variables is the aim of the regression analysis carried out in both these studies.

4.6 Critical Discourse Analysis

CDA is concerned with understanding and interpreting meaning as it is produced in the social context. CDA allows researchers to establish an association between language and context, by showing that discourse i.e. language use by social actors in specific social contexts (Bankole et al., 2010; Hanafizadeh et al., 2019) is constitutive of social reality and as such, not only has demonstrable effects but also plays an important role in power relations within the society (Chouliaraki & Fairclough, 1999). CDA also provides an integrated notion that allows the construction and communication of a coherent interpretation of reality presented in a text. It is applied when drawing a critical conclusion about texts, the methods of their production and their effects within a certain social context. The method also applies to developing a theoretical understanding of different types of discursive practice (Hasan, 2016).

Since the late 1980s, critical discourse analysis (CDA) has become a well-established field in the social sciences. CDA can be defined as a problem-orientated interdisciplinary research programme, subsuming a variety of approaches, each with different theoretical models, research methods, and agendas. CDA does not study a linguistic unit, per se, but rather social phenomena which are necessarily complex and thus require a multi/inter/transdisciplinary and multi-methodological approach (Fairclough, 2013). CDA is characterized by the common interest in demystifying ideologies and power through the systematic and retroductable investigation of semiotic data (written, spoken, or visual) (Fairclough, 2013). CDA is primarily interested in the latent type of everyday beliefs, frequently appearing disguised as conceptual metaphors and analogies (Lakoff & Johnson 1980; Lakoff & Johnson 1999). It is concerned with critically analyzing the status quo, the dominant ideologies or beliefs, which lead to hegemonistic tendencies within the society (Gramsci, 1978).

CDA is not so much a direction, school or specialization when compared to the many other approaches in discourse studies. Rather, it aims to offer a different mode or perspective of theorizing, analysis and application throughout the whole field (Van Dijk, 2001). Since CDA is not a specific direction of research, it does not have a unitary theoretical framework. It is therefore common for CDA research to refer to leading social philosophers and social scientists when theorizing the context of the discourse being analyzed (Van Dijk, 2001). For the purpose of this study, the CDA is operationalized by Habermas' TCA in chapter 9.

4.7 Summary and Conclusion

This chapter provides an overview of the research paradigm, research design and methodologies employed in this thesis. In this thesis, use is made of both the CRS and VRS models in measuring relative efficiency. These are used in studies 2, 3 and 4 which are presented in chapters 6, 7 and 8. In calculating the productivity, use is made of the adjacent-base MI calculation method. This is used in studies 3 and 4 which are presented in chapters 7 and 8. For prediction, Multiple Linear Regression analysis is employed. This is used in study 1 where predictive LA is operationalized within a local context and presented in chapter 5. To determine the relationship between ICT infrastructure and educational attainments/adult literacy rates, OLS regression analysis is carried out. This is used in studies 2 and 3 and presented in chapters 6 and 7. Finally, a CDA, operationalized by Habermas' Theory of

Communicative Action, on ICT developmental outcomes with respect to public value creation, is carried out for the qualitative study, study 5 which is presented in chapter 9.

4.8 References

Ahn, T., Charnes, A., & Cooper, W. W. (1988). Efficiency characterizations in different DEA models. Socio-Economic Planning Sciences, 22(6), 253-257

Angulo-Meza, L., & Lins, M. P. E. (2002). Review of methods for increasing discrimination in data envelopment analysis. *Annals of Operations Research*, *116*(1-4), 225-242.

Atici, K. B., & Podinovski, V. V. (2015). Using data envelopment analysis for the assessment of technical efficiency of units with different specialisations: An application to agriculture. *Omega*, *54*, 72-83.

Avkiran, N. K. (2001). Investigating technical and scale efficiencies of Australian universities through data envelopment analysis. *Socio-Economic Planning Sciences*, *35*(1), 57-80.

Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management science*, *30*(9), 1078-1092

Banker, R. D., Cooper, W. W., Seiford, L. M., Thrall, R. M., & Zhu, J. (2004). Returns to scale in different DEA models. *European Journal of Operational Research*, *154*(2), 345-362.

Bankole, O. O., Bisimwa, K., van Vuuren, I. J., Onumajuru, P. U., & Chigona, W. (2010). The SEACOM Undersea Fibre Optic Cable Project: A Critical Discourse Analysis. *In Proceedings of International Development Informatics Association IDIA2010 Conference.*

Bankole, F. O., Osei-Bryson, K. M., & Brown, I. (2011). ICT infrastructure utilization in Africa: Data envelopment analysis-based exploration. In *Proceeding of special interest group on ICT and global development at Americas Conference on Information System (AMCIS) Workshop, Detroit, USA*.

Bradley, S., Johnes, G., & Millington, J. (2001). The effect of competition on the efficiency of secondary schools in England. *European Journal of Operational Research*, *135*(3), 545-568.

Bryman, A. (1984). The debate about quantitative and qualitative research: a question of method or epistemology? *British journal of Sociology*, 75-92.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision-making units. *European journal of operational research*, *2*(6), 429-444.

Chouliaraki, L., & Fairclough, N. (1999). *Discourse in Late Modernity: Rethinking Critical Discourse Analysis (Critical Discourse Analysis EUP)*. Edinburg, UK: Edinburg University Press.

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). *An introduction to efficiency and productivity analysis*. Springer Science & Business Media.

Cook, W. D., & Seiford, L. M. (2009). Data envelopment analysis (DEA)–Thirty years on. *European journal of operational research*, *192*(1), 1-17.

Cook, W. D., Tone, K., & Zhu, J. (2014). Data envelopment analysis: Prior to choosing a model. *Omega*, *44*, 1-4.

Cooper, W. W., Seiford, L. M., & Tone, K. (2000). Data envelopment analysis. *Handbook on Data Envelopment Analysis, 1st ed.; Cooper, WW, Seiford, LM, Zhu, J., Eds*, 1-40.

Cooper, W. W., Seiford, L. M., & Tone, K. (2006). Introduction to data envelopment analysis and its uses. *New York: Springer*.

Cooper, WW, Seiford, LM and Tone, K. (2007). Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software.

Crawshaw, J., & Chambers, J. (1984). *A concise course in A-level statistics*. Nelson Thornes Limited.

De Waal, C. (2001). On Peirce.

Draper, N. R., & Smith, H. (1998). *Applied regression analysis* (Vol. 326). John Wiley & Sons.

Fairclough, N. (2013). *Critical discourse analysis*. R. Wodak (Ed.). London: Sage.

Färe, R.S., Grosskopf, S., & Lovell, C.A.K. (1994). *Production Frontiers*, Cambridge University Press.

Färe, R., Grosskopf, S., Forsund, F. R., Hayes, K., & Heshmati, A. (2006). Measurement of productivity and quality in non-marketable services: with application to schools. *Quality Assurance in Education*, *14*(1), 21-36.

Ghasemi, M. R., Ignatius, J., & Rezaee, B. (2018). Improving discriminating power in data envelopment models based on deviation variables framework. *European Journal of Operational Research.*

Golany, B., & Roll, Y. (1989). An application procedure for DEA. *Omega,* 17(3), 237-250

Gramsci, A. (1978). Selections from the Political Writings, ed. and trans. Q. Hoare.

Grosskopf, S., & Moutray, C. (2001). Evaluating performance in Chicago public high schools in the wake of decentralization. *Economics and Education Review, 20, 1–14*.

Hanafizadeh, P., Khosravi, B., & Badie, K. (2019). Global discourse on ICT and the shaping of ICT policy in developing countries. *Telecommunications Policy*, *43*(4), 324-338.

Hasan, Z. (2016). Evaluation of a government ICT policy document from a communicative action perspective: A case of Bangladesh. *The Electronic Journal of Information Systems in Developing Countries*, *73*(1), 1-14.

Hatami-Marbini, A., Saati, S., & Tavana, M. (2010). An ideal-seeking fuzzy data envelopment analysis framework. *Applied Soft Computing*, *10*(4), 1062-1070.

Hays, W. L. (1994). *Statistics (5th edition)*. Harcourt Brace College Publishers.

Howe, K. R. (1992). Getting over the quantitative-qualitative debate. *American Journal of Education*, *100*(2), 236-256.

Hutcheson, G. D. (1999). *The multivariate social scientist*: SAGE Publications, Ltd. doi: 10.4135/9780857028075

Johnson, R. B., Meeker, K. M., Loomis, E. J., & Onwuegbuzie, A. J. (2004). Development of the philosophical and methodological beliefs inventory. In *annual meeting of the American Educational Research Association, San Diego, CA*.

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational researcher*, *33*(7), 14-26.

Kenton, W. (2019). Multiple Linear Regression – MLR Definition. Article. Investopedia. https://www.investopedia.com/terms/m/mlr.asp. Accessed on October 2nd 2019

Lakoff, G. & Johnson, M. (1980). *Metaphors We Live By.* Chicago. University of Chicago Press.

Lakoff, G. & Johnson, M. (1999). *Philosophy in the Flesh.* New York. Basic Books.

Lee, K. R., Leem, B., Lee, C. W., & Lee, C. (2011). Malmquist Productivity Index using DEA frontier in Stata. *Stata Journal*, *2*(2), 1-9.

Liu, J. S., Lu, L. Y., Lu, W. M., & Lin, B. J. (2013). Data envelopment analysis 1978–2010: A citation-based literature survey. *Omega*, *41*(1), 3-15

Malmquist, S. (1953). Index numbers and indifference surfaces. *Trabajos de Estadistica y de Investigacion Operativa*, *4*(2), 209-242.

Morse, J. M. (1991). Approaches to qualitative-quantitative methodological triangulation. *Nursing research*, *40*(2), 120-123.

Phillips, D. C. (2004). Is mixed methods research an epistemological oxymoron. In *annual meeting of the American Educational Research Association, San Diego, CA*.

Podinovski, V. V., & Thanassoulis, E. (2007). Improving discrimination in data envelopment analysis: Some practical suggestions. *Journal of Productivity Analysis*, *28*(1-2), 117-126.

Podinovski, V. V., Ismail, I., Bouzdine-Chameeva, T., & Zhang, W. (2014). Combining the assumptions of variable and constant returns to scale in the efficiency evaluation of secondary schools. *European Journal of Operational Research*, *239*(2), 504-513.

Portela, M. C. S., Camanho, A. S., & Borges, D. (2012). Performance assessment of secondary schools: the snapshot of a country taken by DEA. *Journal of the Operational Research Society*, *63*(8), 1098-1115.

Samoilenko, S. V., & Osei-Bryson, K. M. (2017). *Creating Theoretical Research Frameworks Using Multiple Methods: Insight from ICT4D Investigations*. Auerbach Publications.

Sechrest, L., & Sidani, S. (1995). Quantitative and qualitative methods: Is There an Alternative? *Evaluation and program planning*, *18*(1), 77-87.

Seiford, L. M., & Zhu, J. (1997). An investigation of returns to scale in data envelopment analysis. *Omega*, *27*(1), 1-11.

Seiford, L. M., & Zhu, J. (1999). An investigation of returns to scale in data envelopment analysis. *Omega*, *27*(1), 1-11.

Thanassoulis, E. (2001). *Introduction to the theory and application of data envelopment analysis*. Dordrecht: Kluwer Academic Publishers.

Thanassoulis, E., Portela, M. C., & Despic, O. (2008). Data envelopment analysis: the mathematical programming approach to efficiency analysis. *The measurement of productive efficiency and productivity growth*, 251-420.

Thanassoulis, E., Kortelainen, M., Johnes, G., & Johnes, J. (2011). Costs and efficiency of higher education institutions in England: A DEA analysis. *Journal of the Operational Research Society, 62*, 1282–1297.

Van Dijk, T. A. (2001). 18 Critical discourse analysis. *The handbook of discourse analysis*, 349-371.

Zhu, J., & Shen, Z. H. (1995). A discussion of testing DMUs' returns to scale. *European journal of operational research*, *81*(3), 590-596.

CHAPTER 5

5.0 Predicting Students' Academic Performances – A Learning Analytics Approach using Multiple Linear Regression

5.1 Introduction

The field of learning analytics, also known as data analytics in education or educational data mining is fast gaining ground in education management, government and industry as a result of advancement in ICT. The ever increasing demand for knowledge and knowledge management drives the thirst for technological advancements in the area of learning delivery (Romero & Ventura, 2007). With the overwhelming successes gained in Big Data analysis in the business sector, many efforts have been taken by scholars to partake in the Big Data era (Baker & Yacef, 2009). As new findings and outcomes of research crop up daily, it is evident that amongst these successes, one that is potentially identifiable, the prediction of students' academic performance, could have strong positive influences in knowledge management and delivery in sub-Saharan Africa, thereby adding more quality to the learning experience.

Recently, researchers and developers in the education community have begun to explore the potentials for adopting analogous techniques for gaining insight into learning management and delivery. Two major areas currently under development, as a result of this, and which are oriented towards the inclusion and exploration of big data capabilities in the educational environment, are Educational Data Mining (EDM) and Learning Analytics (LA) (Papamitsiou & Economides, 2014). Research has shown that Data Mining techniques are widely being used in the educational field to find new and/or hidden patterns from student data. These hidden patterns can then be used to understand some of the problems that arise in education management and delivery (Aziz et al., 2013).

Predicting Students' Academic Performance (SAP) is one of the important research areas in Higher Learning Institutions. The main objectives of Prediction methods in EDM are to study the features of model that are essential for predicting SAP and to provide information about the underlying construct (Sachin & Vijay, 2012). There have been numerous pieces of research on constructing predictive models for various purposes in the education field (Arsad et al., 2011). The Data Mining prediction technique is used to classify the most effective factors to use in order to determine a Student's Academic Performance (SAP). These factors are applied to measure the Student's Academic Performance in particular subjects and courses. An effective predictive model requires good input data (parameter), suitable data quality mining methods and tools for the data analysis (Arsad et al., 2011; Barth, 2019). The main aim of this research is to operationalize LA for decision making by providing a framework for standardizing student data collections to enable learning providers and managers to predict students' academic performances. This framework will operationalize the predictive model of LA and show how prediction can be used for decision making within the context of the study.

The rest of the chapter is organized as follows: Section 5.2 provides the overview of literature, section 5.3 discusses the research framework, section 5.4 provides the research methodology, section 5.5 provides the analysis, section 5.6 provides the conclusion and future work.

5.2 Overview of Literature

Various data mining methods and techniques have been implemented in research cases for prediction. A comparison of machine learning methods has been carried out to predict success or failure in a course in Intelligent Tutoring Systems (Hämäläinen & Vinni, 2006). Other comparisons of different data mining algorithms have been made to predict students' final marks based on Moodle usage data (Romero et al., 2008), to predict student final grade based on features extracted from logged data (Minaei-bidgoli et al., 2003) and to predict University students' academic performance (Ibrahim & Rusli, 2007).

Bayesian networks in particular have been used to predict student applicant performance (Hien & Haddawy, 2007), to model user knowledge and predict student performance within a tutoring system (Pardos et al., 2007) and also to predict a future graduate's Cumulative Grade

Point Average based on the students background at the time of admission (Hien & Haddawy, 2007). Bayesian networks have (also) been used to model two different approaches, to determine the probability a multi skill question has of being correct (Pardos et al., 2008) and to predict future group performance in face-to-face collaborative learning (Stevens et al., 2005). These networks have also been used to predict end-of-year exam performance through observations of student activity with online tutors (Ayers & Junker, 2006) and to predict item response outcome (Desmarais et al., 2006).

Different types of neural network models have been used in prediction as well. Back-Propagation and Feed Forward Neural Networks have been used to predict final student grades (Gedeon & Turner, 1993) and to predict the number of errors a student will make (Wang & Mitrovic, 2002). Back Propagation and Counter Propagation have been used to predict performance from test scores (Fausett & Elwasif, 1994). Radial basis functions have been used to predict students' marks (pass or fail) from Moodle logs (Calvo-Flores et al., 2006) while multilayer perception topology has been used for predicting the likely performance of an applicant being considered for admission to a university (Oladokun et al., 2008).

Different types of rule-based systems have also been used for prediction. Fuzzy association rules have been applied to predict student performance i.e. mark prediction in an e-learning environment (Nebot et al., 2006) while key formative assessment rules have been used to predict learner performance, based on the learning portfolios compiled (Chen et al., 2007). Rule induction has been used for prediction, monitoring and evaluation of student academic performance (Ogor, 2007) while Shangping & Ping (2008), have used a genetic algorithm to find association rules, in order to predict final grades, based on features extracted from logged data in an education web-based system. Zafra & Ventura (2009), have used grammar guided genetic programming to predict student grades in Learning Management Systems while Decision Trees have been used to predict student performance and provide timely lessons in web-based eLearning systems (Chan, 2007). Etchells et al. (2006), have used an orthogonal search-based rule extraction algorithm, to predict online students' marks.

In the same vein, several regression techniques have also been used for predication. Kotsiantis & Pintelas (2005), have used model trees, linear regression, neural networks, support vector machines and locally weighted linear regression, to predict students' marks in an open university. Linear regression prediction models have been used for predicting end-of-

year accountability assessment scores (Anozie & Junker, 2006) while a multivariable regression model was used by Yu et al. (1999) to predict student performance from log and test scores, in web-based instruction. Stepwise linear regression has been used for predicting student academic performance (Golding & Donalson, 2006) while multiple linear regression has used for predicting time to be spent on a learning page (Arnold et al., 2005). Martinez (2001) has identified variables that could predict success in college courses using multiple regression while Thomas & Galambos (2004), used regression and decision trees analysis for predicting university students' satisfaction. Linear regression has been used for predicting exam results in distance education courses (Myller et al., 2002), for predicting end-of-year accountability assessment scores (Anozie & Junker, 2006) and also for predicting the probability that the student's next response is correct (Beck & Woolf, 2000). Logistic regression has been used for predicting when a student will get a question correct and association rules have been used to guide a search process to find transfer models to predict a student's success (Freyberger et al., 2004). Robust Ridge regression algorithm has been used to predict the probability of a student giving the correct answer to a problem (Cetintas et al., 2009) while stepwise regression has been used to predict a student's test score (Feng et al., 2005).

Correlation analyses have been applied together to predict web-student performance in on-line classes (Wang & Newlin, 2002), to predict a student's final exam score in online tutoring (Pritchard & Warnakulasooriya, 2005) and for predicting high school students' probabilities of success in universities (McDonald, 2004).

Table 4: Review of Research where Data Mining Techniques have been Implemented in Educational Systems – Adapted from Romero & Ventura (2007)

S/N	Author	Mining Task	Educational System
1	Sanjeev & Zytkow (1995)	Sequence Pattern	Traditional Education
2	Zaïane et al. (1998)	Statistic and Sequence Pattern	LCM Systems
3	Beck & Woolf (2000)	Prediction	AIWBE System
4	Becker et al. (2000)	Association and Classification	Traditional Education
5	Chen et al. (2000)	Classification	Web-based Course
6	Ha et al. (2000)	Association	Web-based Course
7	Ma et al. (2000)	Association	Traditional Education
8	Tang et al. (2000)	Text Mining	AIWBE System
9	Yu et al. (2001)	Association	Web-Based Course
10	Zaïane & Luo (2001)	Sequence Pattern	LCM System
11	Luan (2002)	Clustering and Prediction	Traditional Education
12	Pahl & Donnellan (2003)	Sequence Pattern and Statistics	LCM System
13	Shen et al. (2002)	Visualization	LCM System
14	Wang (2002)	Association and Sequence Pattern	Web-Based Course
15	Merceron & Yacef (2003)	Statistic	AIWBE System
16	Minaei-Bidgoli & Punch (2003)	Classification	Web-Based Course
17	Shen et al. (2003)	Sequence Pattern and Clustering	Web-Based Course
18	Zarzo (2003)	Statistic	Web-Based Course
19	Arroyo et al. (2004)	Prediction	AIWBE System
20	Baker et al. (2004)	Classification	AIWBE System
21	Chen et al. (2004)	Text Mining	AIWBE System
22	Freyberger et al. (2004)	Association	AIWBE System
23	Hamalainen et al. (2004)	Classification	AIWBE System
24	Heiner et al. (2004)	Statistic	AIWBE System
25	Lu (2004)	Association	AIWBE System
26	Merceron & Yacef (2004)	Association	AIWBE System
27	Minaei-Bidgoli et al. (2004)	Association	Web-Based Course
28	Mor & Minguillon (2004)	Clustering	LCM System
29	Romero et al. (2004)	Association	AIWBE System
30	Talavera & Gaudioso (2004)	Clustering	LCM System
31	Ueno (2004b)	Outlier Detection	Web-Based Course
32	Ueno (2004a)	Text Mining	Web-Based Course
33	Wang et al. (2004)	Sequence Pattern and Clustering	LCM System
34	Li and Zaïane (2004)	Association	LCM System
35	Avouris et al. (2005)	Statistic	Web-Based Course
36	Castro et al. (2005)	Outlier Detection	LCM System
37	Dringus & Ellis (2005)	Text Mining	LCM System
38	Feng et al. (2005)	Prediction	AIWBE System
39	Hammouda & Kamel (2005)	Text Mining	Web-Based Course
40	Markellou et al. (2005)	Association	Web-Based Course
41	Mazza & Milani (2005)	Visualization	LCM System
42	Mostow et al. (2005)	Visualization	AIWBE System
43	Muehlenbrock (2005)	Outlier Detection	AIWBE System
44	Nilakant & Mitrovic (2005)	Statistic	AIWBE System
45	Tang & McCalla (2005)	Clustering	AIWBE System
46	Zorrilla et al. (2005)	Statistic	LCM System
47	Damez et al. (2005)	Classification	AIWBE System
48	Bari & Benzater (2005)	Text Mining	LCM System

5.3 Research Framework

A suitable framework is proposed, shown in figure 14, for EDM implementation, with the aim of identifying the elements needed to make the prediction. The features of the framework are:

a. Framework for guidance.
b. Focused on students' performances.
c. The framework would allow other projects to be replicated
d. Comfort factor for new adopters.
e. Flexible and can use different data.
f. It is reliable for people with little data mining skills.

The framework is based on the Markov principle which states that, to predict the future, the past is irrelevant given the present.

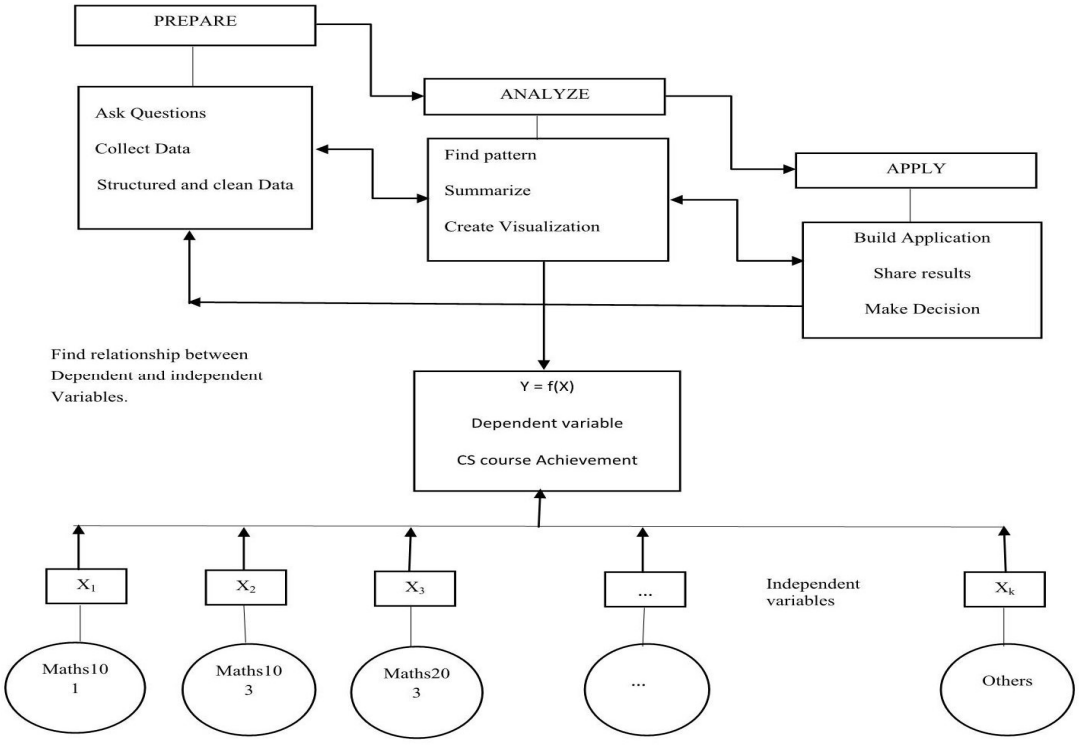

Figure 14: The Model Framework with Extracted Elements Needed for Prediction

5.4 Research Methodology

The objective of prediction is to estimate the unknown value of a variable that describes the student. In education the values normally predicted are performance, knowledge, score or mark. These can be numerical/continuous values (regression task) or categorical/discrete values (classification task) (Romero & Ventura, 2007). Regression analysis finds the relationship between a dependent variable and one or more independent variables (Draper & Smith, 1998). The type of data used in this research is archival data. They have been extracted from the computer science department, University of Jos.

This research is meant to predict students' academic performances (SAP) using Regression analysis. In statistics, regression analysis is a statistical process for estimating the relationship between a dependent variable and one or more independent variables. Specifically, regression technique helps one to understand how a typical value of the dependent variable (or 'criterion variable') changes when any one of the independent variables is varied, while the other independent variables are held fixed.

Multiple Linear Regression has been described in the previous chapter. The theoretical assumption is that, for every one-unit change in the independent variable, there is a consistent and uniform change in the dependent variable. The statistical model for multiple linear regression is given by:

$$Y = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots\ldots\ldots\ldots \beta_k X_{ik} + E$$

Where Y is Dependent variable, $X_{i1}, X_{i2}, \ldots, X_{ik}$ are independent variables

β_0 = constant value and $\beta_1, \beta_2 \ldots \beta_k$ = regression coefficients]

In order to select the relevant variables that could predict performances effectively, a list of potential attributes were identified from the literature. However, due to data accessibility restrictions, MTH204, MTH205, MTH103, and CS201 were the only available data as at the time of conducting this study. The relevant attribute chosen was total score of students in each course.

The data analysis process adopted is a step-by-step approach to making sense of data available. The process is made up of the following paradigms:

Prepare	Analyze	Apply
Ask Question	Find pattern	Model development
Collect Data	Summarize Data	Share results
Organize Data	Create Visualization	Make Decision
Cleanse Data		

From Figure 15, the forward-backward arrow between prepare and analyze indicates that both forward and backward movement is possible during data preparation and analysis, by means of evaluation and validation of the model. Secondly, between analyze and apply there is again a two-way arrow. This allows the analyst to make corrections when the results of an analysis cannot be communicated positively. It is also possible to go back and forth between apply and prepare, when it is discovered the data collected has not been structured and cleaned properly. However, it is not possible to move from prepare to apply, since "Analyze" is the "processor" of the system.

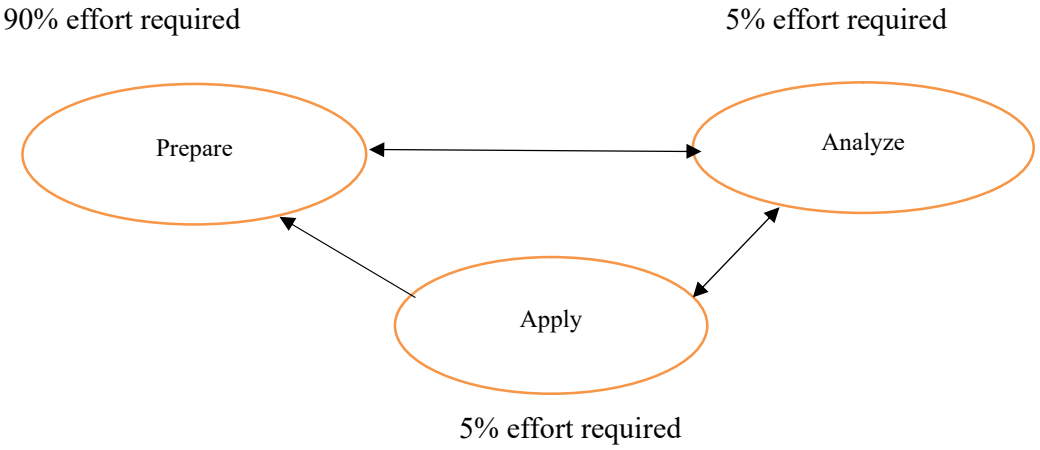

Figure 15: Workflow Diagram of the Proposed Framework

5.5 Analysis

Patterns and relationships are found by comparing or correlating the independent variables and dependent variable. Statistical Packages for Social Scientists (SPSS) was used following the regression equation below: $Y = \beta0 + \beta1X1 + \beta2X2 + \beta3X3$

Where Y is the dependent variable = CS201

X_1 = Student total score in Math103

X_2 = Student total score in Math204 …the predictors

X_3 = Student total score in Math205

and $\beta_0, \beta_1, \beta_2, \beta_3$ are attributes associated with the variables.

Hypothesis Testing was used with the Null hypothesis, H_0, being that there is no relationship between the predictors (Mathematics Courses) and the predicted (CS 201) variables. The Alternate hypothesis, H_1, therefore is that to a reasonable level of significance, in this case 5%, there is a relationship between the predictors and the predicted.

H_0: Students' performance in CS201 is NOT determined by their performance in MTH103, MTH203 and MTH205

H_1: Students' performance in CS201 is determined by their performance in MTH103, MTH203 and MTH205.

With $\alpha = 0.05$ Level of significance.

$H_0: \beta_i = 0$ for all i = 0, 1.2.3 … whenever the parameters are not significant

$H_1: \beta_i \neq 0$ parameters are significant; leads to rejection of null hypothesis.

(Where H_0 and H_1 are the null and alternative hypotheses, respectively and β_i the parameters used in the model.)

If the p-value has a level of significance below 5%, then the alternate hypothesis is accepted, and the null hypothesis is rejected; otherwise the hypothesis remains in its default state (null hypothesis). The results below were obtained from the SPSS viewer.

Table 5: Model Summary[c,d]

Model	R	R Square[b]	Adjusted R Square	Std. Error of Estimate
1	0.943[a]	0.89	0.883	18.208

In the model summary in table 5, R-squared is .890, meaning 89.0% of the variation from the dependent (CS201) can be explained by variation in the independent variables (MTH103, MTH204, and MTH205). The remaining 11% can be explained by other factors that are not in the model. With these results, it can be concluded that the mathematics courses have strong predictive powers, as these variables account for about 89.0% of the variation in CS201 performance. The Anova table shown in table 6 reveals that the regression equation is significant. It implies that, at least one parameter of the model is significant.

Table 6: Anova[c,d]

Model 1	Sum of Squares	df	Mean Square	F	Sig
Regression	126018.412	3	42006.137	126.706	0.000[a]
Residual	15581.588	47	331.523		
Total	141600.000[b]	50			

From the coefficients table presented in table 7, it can be seen that the math 204 parameter, that is, β_1, is significant, since the p-value is 0.02, the math205 parameter, which is, β_2, is significant since the p-value is 0.00 and the math103 parameter is significant as well, since the p-value is 0.04. Given that none of the coefficients ($\beta_1 = 0.298$, $\beta_2 = 0.396$ $\beta_3 = 0.314 \neq 0$), is equal to zero, then the null hypothesis is rejected, and the alternate hypothesis is accepted, which says:

H_a: students' performance in CS201 is determined by their performance in MTH103, MTH203 and MTH205

Table 7: Coefficients[a,b]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig
1	B	Std. Error	Beta		
MTH 204	0.500	0.148	0.298	3.367	0.002
MTH 205	0.537	0.126	0.396	4.260	0.000
MTH 103	0.453	0.149	0.314	3.043	0.004

Tables 6 and 7 show that the model is significant since all the p-values are less than 0.05, indicating that the parameters for determining the performance of computer science students that sat for CS201 are significant. For a detailed explanation of tables 5, 6 and 7, please see appendix A.

Therefore, the valid model is given by the relationship:

$Y = 0.298X_1 + 0.396X_2 + 0.314X_3 + E$ (where E, the random error is usually neglected)

Where Y = the predicted score of the student per percentage increase in math courses

X_1 = the total score of the student in math204,

X_2 = the total score of the student in math205,

X_3 = is the total score of the student in math103

Table 8 shows the variables of five students that will be used in the model to predict their performance in CS201.

Table 8: Five Students' Variables

X1	X2	X3
40	8	5
19	40	50
27	54	5
41	23	16
48	8	34

$Y = 0.298X_1 + 0.396X_2 + 0.314X_3 + E$ (E=random error. Usually neglected)

Table 9: Regression Results

Y	=	β1X1	+	β2X2	+	β3X3
16.658		11.92		3.168		1.57
37.202		5.662		15.84		15.7
31		8.046		21.384		1.57
26.35		12.218		9.108		5.024
28.148		14.304		3.168		10.676

From the regression results, it can be concluded that for the student with these score variables (40, 8, and 5) in mathematics, then the best prediction for percentage performance in CS201 is 16.658. The same predictive pattern is valid and can be used for all the other four students.

5.6 Conclusion and Future Work

The study was able to achieve the objective of operationalizing LA for decision making, by building a model to predict students' academic performance. This model was tested, and the outcome provides a valuable aid to decision making since it is able to predict how well students are likely to perform in certain subjects based on the history of their performance in others. The analysis shows that students who perform well in mathematics courses have better chances of succeeding in Computer Science courses, than those who do not.

This model is also limited in its scope for prediction of academic performance. The researcher acknowledges that there may be other salient and non-salient factors which may affect student academic performance and an area of future research would be to incorporate these other fuzzy elements in the model to discover more possible insights.

Further research into LA and its applications can be carried out to determine if LA can be used for decision making outside the classroom or indeed in any educational institution environment. Research can look into worldwide educational data and propose models or frameworks for decision making that can affect policy directions, governmental spending, donor funding and much more. The effect of other analytical measurement and assessment tools in this regard can also be investigated.

In the next chapter, the horizon of this field of research is expanded to include worldwide data at a macro-economic decision making and policy direction level, with respect to educational data.

5.7 References

Anozie, N., & Junker, B. W. (2006). Predicting end-of-year accountability assessment scores from monthly student records in an online tutoring system. Educational Data Mining: Papers from the AAAI Workshop. Menlo Park, CA: AAAI Press.

Arnold, A., Scheines, R., Beck, J.E., & Jerome, B. (2005). Time and Attention: Students, Sessions, and Tasks. In AAAI2005 Workshop on Educational Data Mining, Pittsburgh, 62-66.

Arsad, P. M., Buniyamin, N., Ab Manan, J. L., & Hamzah, N. (2011). Proposed academic students' performance prediction model: A Malaysian case study. In *Engineering Education (ICEED), 2011 3rd International Congress on* (pp. 90-94). IEEE.

Ayers E., & Junker B.W. (2006). Do skills combine additively to predict task difficulty in eighth grade mathematics? In AAAI Workshop on Educational Data Mining: Menlo Park, 14-20.

Aziz, A. A., Ismail, N. H., & Ahmad, F. (2013). Mining Students' Academic Performance. *Journal of Theoretical & Applied Information Technology*, *53*(3).

Baker, R. S., & Yacef, K. (2009). The state of educational data mining in 2009: A review and future visions. *JEDM| Journal of Educational Data Mining*, *1*(1), 3-17.

Barth, K. (2019). *An analysis of semantic data quality deficiencies in a national data warehouse: a data mining approach* (Doctoral dissertation).

Beck, J. E., & Woolf, B. P. (2000, June). High-level student modeling with machine learning. In *International Conference on Intelligent Tutoring Systems* (pp. 584-593). Springer, Berlin, Heidelberg.

Cetintas, S., Si, L., Xin, Y. P., & Hord, C. (2009). Predicting Correctness of Problem Solving from Low-Level Log Data in Intelligent Tutoring Systems. *International Working Group on Educational Data Mining*.

Chan, C. C. (2007). A framework for assessing usage of web-based e-learning systems. In *Second International Conference on Innovative Computing, Informatio and Control (ICICIC 2007)* (pp. 147-147). IEEE.

Chen, C. M., Chen, M. C., & Li, Y. L. (2007). Mining key formative assessment rules based on learner profiles for web-based learning systems. In *Seventh IEEE International Conference on Advanced Learning Technologies (ICALT 2007)* (pp. 584-588). IEEE.

Calvo-Flores, M. D., Galindo, E. G., Jiménez, M. P., & Pineiro, O. P. (2006). Predicting students' marks from Moodle logs using neural network models. *Current Developments in Technology-Assisted Education*, *1*(2), 586-590.

Desmarais, M. C., & Gagnon, M. (2006). Bayesian student models based on item to item knowledge structures. In *European Conference on Technology Enhanced Learning* (pp. 111-124). Springer, Berlin, Heidelberg.

Draper, N. R., & Smith, H. (1998). *Applied regression analysis* (Vol. 326). John Wiley & Sons.

Etchells, T. A., Nebot, À., Vellido, A., Lisboa, P. J., & Mugica, F. (2006). Learning what is important: feature selection and rule extraction in a virtual course. In *ESANN* (pp. 401-406).

Fausett, L. V., & Elwasif, W. (1994, June). Predicting performance from test scores using backpropagation and counterpropagation. In *Proceedings of 1994 IEEE International Conference on Neural Networks (ICNN'94)* (Vol. 5, pp. 3398-3402). IEEE.

Feng, M., Heffernan, N. T., & Koedinger, K. R. (2005, July). Looking for sources of error in predicting student's knowledge. In *Educational Data Mining: Papers from the 2005 AAAI Workshop* (pp. 54-61).

Freyberger, J., Heffernan, N. T., & Ruiz, C. (2004). Using association rules to guide a search for best fitting transfer models of student learning. In *ICITS 2004 Workshop on Analyzing Student-Tutor Interaction Logs to Improve Educational Outcomes*.

Gedeon, T. D., & Turner, S. (1993). Explaining student grades predicted by a neural network. In *Proceedings of 1993 International Conference on Neural Networks (IJCNN-93-Nagoya, Japan)* (Vol. 1, pp. 609-612). IEEE.

Golding, P., & Donaldson, O. (2006). Predicting academic performance. In *Proceedings. Frontiers in Education. 36th Annual Conference* (pp. 21-26). IEEE.

Hien, N. T. N., & Haddawy, P. (2007). A decision support system for evaluating international student applications. In *2007 37th annual frontiers in education conference-global engineering: knowledge without borders, opportunities without passports* (pp. F2A-1). IEEE.

Hämäläinen, W., & Vinni, M. (2006). Comparison of machine learning methods for intelligent tutoring systems. In *International Conference on Intelligent Tutoring Systems* (pp. 525-534). Springer, Berlin, Heidelberg.

Ibrahim, Z., & Rusli, D. (2007). Predicting students' academic performance: comparing artificial neural network, decision tree and linear regression. In *21st Annual SAS Malaysia Forum, 5th September*.

Kotsiantis, S. B., & Pintelas, P. E. (2005). Predicting students marks in hellenic open university. In *Fifth IEEE International Conference on Advanced Learning Technologies (ICALT'05)* (pp. 664-668). IEEE.

Martinez, D. (2001). Predicting Student Outcomes Using Discriminant Function Analysis.

Mcdonald, B. (2004). Predicting student success. *J Math Teach Learn*, *1*, 1-14.

Minaei-Bidgoli, B., Kashy, D. A., Kortemeyer, G., & Punch, W. F. (2003). Predicting student performance: an application of data mining methods with an educational web-based system. In *33rd Annual Frontiers in Education, 2003. FIE 2003.* (Vol. 1, pp. T2A-13). IEEE.

Myller, N., Suhonen, J., & Sutinen, E. (2002). Using data mining for improving web-based course design. In *International Conference on Computers in Education, 2002. Proceedings.* (pp. 959-963). IEEE.

Nebot, A., Castro, F., Vellido, A., & Mugica, F. (2006, January). Identification of fuzzy models to predict students performance in an e-learning environment. In *The Fifth IASTED international conference on web-based education, WBE* (pp. 74-79).

Ogor, E. N. (2007). Student academic performance monitoring and evaluation using data mining techniques. In *Electronics, Robotics and Automotive Mechanics Conference (CERMA 2007)* (pp. 354-359). IEEE.

Oladokun, V. O., Adebanjo, A. T., & Charles-Owaba, O. E. (2008). Predicting students' academic performance using artificial neural network: A case study of an engineering course. In *Pacific Journal of Science and Technology, 9,1,* 72-79.

Papamitsiou, Z., & Economides, A. A. (2014). Learning analytics and educational data mining in practice: A systematic literature review of empirical evidence. *Journal of Educational Technology & Society*, *17*(4), 49-64.

Pardos, Z., Heffernan, N., Ruiz, C., & Beck, J. (2008). The composition effect: Conjuntive or compensatory? an analysis of multi-skill math questions in ITS. In *Educational Data Mining 2008*.

Pardos, Z. A., Heffernan, N. T., Anderson, B., & Heffernan, C. L. (2007). The effect of model granularity on student performance prediction using Bayesian networks. In *International Conference on User Modeling* (pp. 435-439). Springer, Berlin, Heidelberg.

Pritchard, D., & Warnakulasooriya, R. (2005). Data from a web-based homework tutor can predict student's final exam score. In *EdMedia+ Innovate Learning* (pp. 2523-2529). Association for the Advancement of Computing in Education (AACE).

Romero, C., & Ventura, S. (2007). Educational data mining: A survey from 1995 to 2005. *Expert systems with applications*, *33*(1), 135-146.

Romero, C., Ventura, S., Espejo, P. G., & Hervás, C. (2008). Data mining algorithms to classify students. In *Educational data mining 2008*.

Sachin, R. B., & Vijay, M. S. (2012). A survey and future vision of data mining in educational field. In *2012 Second International Conference on Advanced Computing & Communication Technologies* (pp. 96-100). IEEE.

Shangping, D., & Ping, Z. (2008, April). A data mining algorithm in distance learning. In *2008 12th International Conference on Computer Supported Cooperative Work in Design* (pp. 1014-1017). IEEE.

Stevens, R., Soller, A., Giordani, A., Gerosa, L., Cooper, M., & Cox, C. (2005). Developing a framework for integrating prior problem solving and knowledge sharing histories of a group to

predict future group performance. In *2005 International Conference on Collaborative Computing: Networking, Applications and Worksharing* (pp. 9-pp). IEEE.

Thomas, E. H., & Galambos, N. (2004). What satisfies students? Mining student-opinion data with regression and decision tree analysis. *Research in Higher Education*, *45*(3), 251-269.

Wang, A. Y., & Newlin, M. H. (2002). Predictors of web-student performance: The role of self-efficacy and reasons for taking an on-line class. *Computers in human behaviour*, *18*(2), 151-163.

Wang, T., & Mitrovic, A. (2002). Using neural networks to predict student's performance. In *International Conference on Computers in Education, 2002. Proceedings.* (pp. 969-973). IEEE.

Yu, C. H., Jannasch-Pennell, A., Digangi, S., & Wasson, B. (1999). Using online interactive statistics for evaluating web-based instruction. *Journal of Educational Media International*, *35*, 157-161.

Zafra, A., & Ventura, S. (2009). Predicting Student Grades in Learning Management Systems with Multiple Instance Genetic Programming. *International Working Group on Educational Data Mining*.

CHAPTER 6

6.0 Investigating the Efficiency of ICT Infrastructure Utilization: A Data Envelopment Analysis

6.1 Introduction

The field of Data Analytics in Education, otherwise known as Learning Analytics (LA) and Educational Data Mining (EDM) is fast gaining ground in terms of research interests and advancement in technology (Oyerinde & Chia, 2017). The ever-increasing demand for knowledge and knowledge management drives the thirst for technological advancements for support in the field of learning delivery (Romero & Ventura, 2007). With the overwhelming successes gained from Data Analytics in the Business Industry, it is little wonder that Data Analytics has found its way into the Education Sector especially in ICT4D research. Considering that the amount of data produced inside and outside higher education institutions is growing exponentially, more and more educational institutions seem to be exploring the potential benefits of Data Analytics (Moreira et al., 2017). As new findings and outcomes of research crop up daily, it is evident that successes in Data Analytics in Education can have overwhelmingly positive impacts on learning management and delivery. With Educational Attainment being one of the core indices for measuring Development with respect to the Human Development Index (UNDP, 2006; Bankole et al., 2011a; Bankole & Mimbi, 2017), there is no doubt concerning the viability of any Data Analytics in Education research.

Recently, researchers and developers in the education community have begun to explore the potential benefits of adopting analogous techniques for gaining insight into learning management and delivery. Two major areas currently under development and which are oriented towards the inclusion and exploration of big data capabilities in the educational environment are Educational Data Mining (EDM) and Learning Analytics (LA) (Papamitsiou & Economides, 2014). Romero & Ventura (2007), have postulated that although prior researches have focused mainly on the implementation of data mining techniques and models to discover educational data, EDM is however an emerging discipline for developing methods to explore unique types of data from within the educational context. In fact, according to

Zorrilla et al., (2010), EDM is an application of data mining techniques implemented in education for better comprehension of student learning processes and of acknowledging the ways they participate in these processes, with the sole aim of improving the quality of the educational system.

With regards to ICT4D, national development encapsulates the notion of human development as the means of enlarging people's choices of ways to acquire knowledge, and skills, in order to have access to the resources needed for a decent standard of living (UNDP, 2006; Bankole & Mimbi, 2017). Over the last three decades, the lexicon of national development has been expanded to include certain intervening variables and social factors, such as education and some other aspects of human welfare. (Desai, 1991; Anand & Ravallion, 1993; Bankole & Mimbi, 2017). In line with this, countries have defined policies that reveal an emphasis on creating support mechanisms for the use of ICT, including for example, technical and pedagogical support, and on giving special attention to the use of ICT in teaching and learning (Hinostroza, 2018). However, in providing and defining these policies, a crucial question all policy makers must answer is does increased investments in ICT infrastructure provide any improvement in human development, especially in Africa (Bankole et al., 2011b).

In this research, the aim is to investigate the efficiency of ICT Infrastructure utilization in Education as a component of National Development using adult literacy rates and educational attainment at post-secondary and tertiary education levels. This author also employs the education index, employed by Bankole et al. (2011a) introduced by Orbicom (2005) and ITU, to emphasize the impact of higher education on ICT development. With most of the research in Learning Analytics focusing on the teaching and learning activities, this research aims to show how LA can be implemented for policy and decision making within the general context of ICT4D research, and thus show it is not limited to enhancing classroom interactions.

The rest of the chapter is organized as follows: Section 6.2 provides the overview of literature, section 6.3 discusses the theoretical framework, section 6.4 provides the research methodology, section 6.5 provides the DEA analysis, section 6.6 provides a discussion of findings, section 6.7 the limitations and section 6.8 conclusion and future work.

6.2 Overview of Literature

The need to understand the relevance of education in Human Development cannot be over-emphasized. A lot of research postulates that an increase in ICT investments and penetration on the continent will bring about a corresponding increase in Human Development (Akpan, 2000; Neumayer, 2001). Ganju et al. (2015) believe that the use of ICT enables the transfer of information to communities that may not have access to education. However, in Africa, three quarters of the population is illiterate and lives in rural areas that lack basic facilities (Ngwenyama et al., 2006) and the lack of these facilities, which include infrastructure, on which ICT development depends, limit the effectiveness of ICT interventions and penetration, especially in education (Oyerinde, 2014). Even though the last decade has seen an explosion in the use of ICTs in developing countries (Walsham, 2017), it is important to consider the unequal distribution of access to and the affordability of ICT in Africa (Prinsloo, 2018).

Bankole et al. (2011b) has shown that any empirical investigation with regards to education for ICT4D research, needs to consider higher education as one of the main parameters. The empirical study carried out by Kiiski (2001) has found that tertiary education has a positive and statistically significant impact on ICT development. Briede (2017) believes this is so because those who have attained levels of higher education usually are the leading persons and have an important impact on public events and their development. Many Higher Education institutions in the Developing Economies have invested heavily in the use of ICT for teaching and learning i.e. use of mobile and/or home-based ICT infrastructure as tools to extend teaching and learning possibilities (Hinostroza, 2018) however, its impact has been minimal (Olaniyi & Ademola, 2014) despite the differences in the level of ICT development across countries (Hinostroza, 2018).

Recent studies also believe that the attainment of quality Higher Education is necessary to bridge the "digital divide" defined by (Norris, 2000; Molina, 2003; Gilhooly & Ocampo, 2005; Mimbi et al., 2011). An example of such is India's National Mission on Education through Information and Communication Technology (NMEICT) which seeks to bridge the digital divide by formulating an educational policy which has the aim, amongst others, of enhancing the use of computing devices for the purpose of teaching and learning among urban and rural teachers/learners in the Higher Education domain (Sahu, 2017). Also, the Plan Ceibal initiative in Uruguay (Hinostroza et al., 2011) seeks to bridge this digital divide by being both a social and an educational policy that, has the purpose, amongst others, of

establishing the conditions for equal access to ICT; of facilitating the construction of new learning environments adequate to the demands of the information and knowledge-based society; and of making available to students and teachers new tools that can widen their learning, increase their knowledge, and develop their awareness of lifelong learning (Hinostroza, 2018). ICT facilitates and improves students' knowledge and promotes a positive attitude to learning. Therefore, if students in developing economies are to compete with their counterparts in the developed world, effort must be made to develop their ICT abilities (Olaniyi & Ademola, 2014).

Moving to ICT and its effects on educational technologies, a New Media Consortium (NMC) Horizon report in 2013 has identified, amongst other things, emerging technologies that could have significant impacts on education within the following 5-year window. One of such technologies identified has been Learning Analytics which could have an impact on education by customizing the learning experience and/or measuring performance through the analysis of massive amounts of student learning data (Kadam, n.d.). In the context of higher education, Big Data and Learning Analytics promises increased efficiency and cost-effectiveness (Siemens, 2011; Siemens & Long, 2011; Siemens, 2012; Hargreaves & Braun, 2013; Papamitsiou & Economides, 2014). With the potential of educational technologies to positively improve educational quality and attainment, there is great optimism that ICT in education can greatly increase both average literacy rates and educational attainment levels in developing economies. However, despite these promised benefits, education policies that are directed towards ICT providing a positive impact on students' achievements, there is no conclusive evidence to show that such benefits have been achieved, especially in developing countries (Hinostroza et al., 2014). This situation has posed new questions to the research community and policy makers, who are now looking for much more precise definitions of the role of ICT in teaching and learning (Hinostroza, 2018). It is in order to search for these precise definitions that this study to investigate the efficiency of ICT infrastructure utilization on education with respect to human development, is carried out.

6.3 Theoretical Framework

This research falls within the progressive perspective of ICT-enabled development as postulated and defined by Avgerou (2010). The theory behind this perspective is that it considers ICT as an enabler of transformations in multiple domains of human activities. ICT-enabled developmental transformations are assumed to be achieved within the existing

international and local social order (Avgerou, 2010). Central in this theoretical perspective is the view that investment in and effective use of ICT do matter for the economic development of a country (Mann, 2003). It is however acknowledged that ICT needs to be accompanied by organizational or national restructuring to deliver productivity gains (Dedrick et al., 2003; Draca et al., 2007).

Within the Cobb Douglas production function standpoints, this research proposes a conceptual model for measuring efficiency of ICT Infrastructure on Education and, is derived from Bankole et al., (2011a) model for measuring Impact on Human development. From this study Human Development is expressed as:

HDI = f[Standard of living (GDP per capita), Education (Literacy rates / Enrolments) and Health (life expectancy)]

For this research focus is solely on the Education component of Human Development and a model is proposed which uses a linear equation, derived from the Bankole et al., (2011a) model, for measuring impact on education within the Human Development Index. This model makes use of ICT infrastructure available for utilization from 2010-2016 and obtained from ITU and not ICT investments, as is used by Bankole et al., (2011a). Focus is on educational attainment and not enrolment, as the research is measuring the impact of a utilized infrastructure within the educational context and not its potential utilization, which would be valid for enrolment. Finally, this research does not consider the interaction of the facets of ICT investments as Bankole et al., (2011a) do, because this study is not considering investments but solely the infrastructure available for utilization.

The model for this research is:

The effect on Education (Adult Literacy rates / Attainments) = f[Internet Infrastructure (II) + Computer Infrastructure (CI) + Mobile Phone Infrastructure (MPI)].

6.4 Research Methodology

The research methodologies employed in this study are the Data Envelopment Analysis (DEA) model and the Ordinary Least Squares (OLS) regression. DEA is a well-known non-parametric linear programming method for measuring the relative efficiency of ICT (Bankole et al., 2011c; Thanassoulis et al., 2011) and has also been used for understanding the impacts

of IT investments on performance and productivity (Hatami-Marbini et al., 2010) DEA is a data-oriented method for evaluating the performance (efficiency) of entities known as Decision Making Units (DMUs) (Bankole et al., 2011c) which uses input-output data to compute an efficient production frontier produced by the most efficient DMU's. DEA, unlike a parametric method, is context specific with respect to the interpretations of the results of the analysis, which are restricted to the sample and should not be generalized beyond the sample (Samoilenko & Osei-Bryson, 2017).

DEA, therefore, can then be viewed as a multiple-criteria evaluation methodology where DMUs are alternatives, and DEA inputs and outputs are two sets of performance criteria where one set (inputs) is to be minimized and the other (outputs) is to be maximized (Cook et al., 2014). In DEA, these multiple criteria are generally modelled in a ratio form, e.g., the CCR ratio model (Charnes et al., 1978; Cook et al., 2014) which is expressed as:

Maximise:

$$h_0 = \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i \, x_{i0}}$$

Subject to:

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1$$

Where:

$$j = 1, \dots, n, v_r v_i \geq 0; r = 1, \dots, s; i = 1, \dots, m.$$

where x_{ij} and y_{rj} represent DEA inputs and outputs of the jth DMU, and u_r, $v_i \geq 0$ are unknown variable weights to be determined by the solution of the problem (Charnes et al., 1978). Although x_{ij} and y_{rj} can be referred to in different terms, rather than "inputs" and "outputs", for this research, ICT infrastructure serves as the Input and Educational Attainment/Adult Literacy Rates serve as the Output.

There have been some studies that have used DEA to measure efficiency in education. Gupta & Verhoeven (2001) have measured the efficiency of education in Africa and Clements (2002) has measured efficiency of education in Europe. St. Aubyn (2002) and Afonso & St.

Aubyn (2005; 2006a; 2006b) have measured efficiency in education with respect to OECD countries. However, only Tondeur et al. (2007) and Gülbahar (2008) have examined the efficiency of countries in utilising their ICT resources for educational outputs and the Impact of ICT on education. Recently, Aristovnik (2012) has done a study on the efficiency of ICT and its impact on educational performance in selected EU and OECD countries, using DEA.

Based on the Bankole et al. (2011a) investigation of the impact of ICT investment on human development, this research goes a step further to measure ICT infrastructure available for utilization rather than investments in ICT which are available for potential utilization. Hence the indices used are individuals with access to computers, internet and mobile phones. Since the focus of this chapter is to investigate with respect to education only as an aspect of human development, the education component includes educational attainment from post-secondary level through to bachelors' level and adult literacy rates. An Input-Oriented Basic Radial Model (BRM) with Constant Returns to Scale (CRS) DEA approach is used for this research. This is based on the theoretical assumption that the ICT infrastructure (Input) is controllable and increases or decreases in the levels of these inputs is expected to bring about a corresponding increase or decrease in the levels of Educational Attainments and Literacy Rates (Output), respectively.

OLS regression is one of the most popular statistical techniques used for prediction and explanation of the relationship between two or more variables. OLS regression assumes that all variables entered into the analysis are continuous and the regression procedure attaches importance to actual values (Hutcheson, 1999). In data analysis, OLS is used for estimating the unknown parameters in a linear regression model. The goal is to minimize the differences between the collected observations in some arbitrary dataset and the responses predicted by the linear approximation of the data. A simple OLS regression can be expressed as:

$$y = \alpha + \beta x$$

Where α is the intercept of the line on the y axis and β is the slope of the line. This equation describes a direct linear relationship between x and y where the value of y can be precisely calculated from the value of x. The slope of the line can be described as the change in y which is associated with a unit change in x. For example, as x increases from 2 to 3 (a unit change), y increases by the value of β, the slope of the line. This slope is also known as the regression coefficient and shows the effect that the explanatory variable has on the response variable.

Figure 1 depicts the regression line for two variables which are perfectly linearly related and shows the regression coefficient, β, and the intercept, α.

However, perfect relationships of the type shown in Figure 16 are the exception rather than the rule, as relationships are rarely direct and measurement rarely error-free. The best that can be hoped for is to calculate a line of best fit to approximately describe the relationship between variables *x* and *y*. For OLS regression, the most common method for calculating this line is to use the least-squares procedure which minimizes the sum of the squared deviations (also known as the error, or residual) of each data point from the line (Crawshaw & Chambers, 1984; Hays, 1994). The equation $y = \alpha + \beta x + \varepsilon$ expresses the OLS regression model and includes a term, ε, which indicates the degree to which data points deviate from this perfect line of best fit.

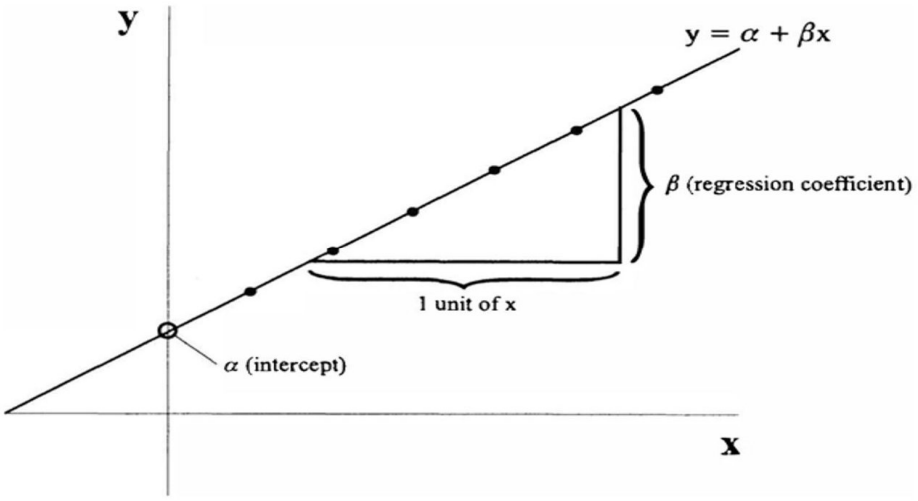

Figure 16: An OLS Regression Model Showing a Perfect Linear Relationship

The deviation, or error, is often represented as the difference between the observed value of *y* and the value of *y* predicted from the model *(ŷ)*. The term *y–ŷ* provides a measure of the size of the error when *y* is predicted using the regression model. The term 'error' simply indicates that the relationship between the variables is not exact. Therefore, α now represents the average value of y when x = 0, whilst β represents the average change in y which is associated with a unit change in x. Figure17 shows the parameters α and β for a line of best-fit which models the relationship between two imperfectly related variables.

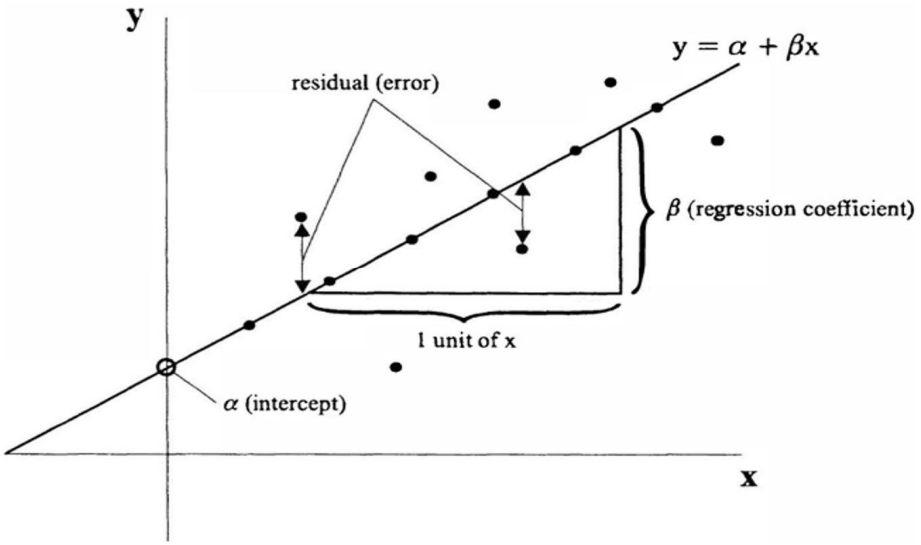

Figure 17: Line of Best-Fit

OLS regression analysis allows for the prediction of the value of y, even though at the very least an average value, for every given value of x to a reasonable level of significance within the observation.

For the purpose of this research, multiple simple OLS regression is used to determine the effect(s) and direction of the relationship of the identified units of ICT infrastructure (explanatory variables) on educational attainments and adult literacy rates (response variables). This allows for the determination and understanding of the type of relationship between the two sets of variables defined by the null hypothesis and the alternate hypothesis, with a 5% level of significance, stated as follows:

H_0 = ICT Infrastructure has no effect on Educational Attainments/Adult Literacy Rates

H_1 = ICT Infrastructure has an effect on Educational Attainments/Adult Literacy Rates

For this study, time series data from UNESCO; educational attainments; World bank; literacy rates and ITU; individuals with computers, internet and mobile phones, were obtained. Available data was collected for all countries in Sub-Saharan Africa, Northern Africa, and selected countries in Europe and Northern America. These were compared with world values to measure relative efficiency. Data for the past 7 years, 2010-2016 were collected and the average was calculated and used for the values representing each DMU.

6.5 Analysis Results

6.5.1 OLS Regression Analysis Results

The analysis was done using Easystat online software available online at https://easystat.com The data collected were cleaned and prepared using the easystat application and multiple simple OLS regression analysis carried out using OLS regression analysis in Python to determine the effect of ICT infrastructure variables on each of the educational attainment/adult literacy rates variables. Table 10 shows the results of the multiple simple OLS regression analyses carried out. For each of the discussions, the most significant line of best fit is presented, for all the graphs and python code please see appendix B.

Table 10: OLS Regression Results

Variables	Educational Attainment Post Secondary				Educational Attainment (Short-Cycle Tertiary)				Educational Attainment (Bachelors)				Adult Literacy Rates			
	Effect (Regular) *b*	Effect (Standardized) β	P-Value P	Significance Threshold of 5%	Effect (Regular) *b*	Effect (Standardized) β	P-Value P	Significance Threshold of 5%	Effect (Regular) *b*	Effect (Standardized) β	P-Value P	Significance Threshold of 5%	Effect (Regular) *b*	Effect (Standardized) β	P-Value P	Significance Threshold of 5%
Individuals using Computers	-0.02	-0.07	0.81	NO	-0.09	-0.43	0.001	YES	-0.11	-0.49	0.04	YES	-0.02	-0.06	0.71	NO
Individuals using Internet	0.26	0.62	0.05	NO	0.2	0.75	0.000004	YES	0.38	1.12	0.000005	YES	0.56	0.85	0	YES
Individuals using Mobile Phones	0.27	0.35	0.13	NO	0.52	0.6	0	YES	0.18	0.29	0.1	NO	0.23	0.2	0.08	NO

Green shows positive and significant effects, red shows negative and significant effects, while purple shows effects that are not statistically significant. The results are discussed further in section 6.6.

6.5.2 Data Envelopment Analysis Results

The analysis was done using the Data Envelopment Analysis Online Software (D.E.A.O.S.) available online at https://deaos.com. An Input oriented BRM model using the Constant Returns to Scale method was used for calculating the relative efficiency of the DMU's. Table 11 shows the data collected computed as ratios to population as well as the indices and their respective parameters. Tables 12 and 13 show the outcomes of the analysis carried out while table 14 gives an overview of the data statistics.

Table 11: Data Envelopment Analysis Values

Regions	Individuals using Computers	Individuals using Internet	Individuals using Mobile Phones	Educational Attainment (Post-Secondary)	Educational Attainment (Short-Cycle Tertiary)	Educational Attainment (Bachelors)	Adult Literacy Rates
	INPUT	INPUT	INPUT	OUTPUT	OUTPUT	OUTPUT	OUTPUT
Sub-Saharan Africa	0.24	0.1399	0.7495	0.1086	0.056	0.0288	0.6287
Northern Africa	0.4257	0.3004	0.8827	0.1235	0.1327	N/A	0.7236
Europe & North America	0.7631	0.7074	0.9134	0.2962	0.2539	0.2168	0.9915
World	0.61	0.4343	0.8772	0.2695	0.2167	0.1507	0.8559

Table 12: Basic Radial Models (Envelopment Forms) Weights

Regions	Individuals with Computers	Individuals with Internet	Individuals with Mobile Phones	Educational Attainment (Post-Secondary)	Educational Attainment (Short-Cycle Tertiary)	Educational Attainment (Bachelors)	Adult Literacy Rates
Sub-Saharan Africa	3.984	0	0.058	9.208	0	0	0
Northern Africa	2.349	0	0	0	4.737	0	0.475
Europe & North America	1.31	0	0	1.073	0	2.159	0.216
World	1.605	0	0.024	3.711	0	0	0

Table 13: Data Envelopment Analysis Summary for the Regions

DMU	DEA Parameters	Individuals with Computers	Individuals with Internet	Individuals with Mobile Phones	Educational Attainment (Post-Secondary)	Educational Attainment (Short-Cycle Tertiary)	Educational Attainmnet (Bachelors)	Adult Literacy Rates
Sub-Saharan Africa	Slacks	0	0	0	0	0	0	0
	Weights	3.984	0	0.058	9.208	0	0	0
	Values	0.24	0.14	0.75	0.109	0.056	0.029	0.629
	Targets	0.24	0.14	0.75	0.109	0.056	0.029	0.629
Northern Africa	Slacks	0	0.013	0.065	0.061	0	0.087	0
	Weights	2.349	0	0	0	4.737	0	0.475
	Values	0.426	0.3	0.883	0.124	0.133	0	0.724
	Targets	0.414	0.279	0.793	0.184	0.133	0.087	0.724
Europe & North America	Slacks	0	0	0	0	0	0	0
	Weights	1.31	0	0	1.073	0	2.159	0.216
	Values	0.763	0.707	0.913	0.296	0.254	0.217	0.992
	Targets	0.763	0.707	0.913	0.296	0.254	0.217	0.992
World	Slacks	0	0	0	0	0	0	0
	Weights	1.605	0	0.024	3.711	0	0	0
	Values	0.61	0.434	0.877	0.27	0.217	0.151	0.856
	Targets	0.61	0.434	0.877	0.27	0.217	0.151	0.856

Table 14: Data Statistics

Index	Minimum	Maximum	Mean	Standard Deviation
Individuals with Computers	0.24	0.7631	0.5097	0.1963
Individuals with Internet	0.1399	0.7074	0.3955	0.2081
Individuals with Mobile Phones	0.7495	0.9134	0.8557	0.0628
Educational Attainment Post-Secondary	0.1086	0.2962	0.1995	0.0841
Educational Attainment Short-Cycle Tertiary	0.056	0.2539	0.1648	0.0766
Educational Attainment Bachelors	0	0.2168	0.0991	0.0884
Adult Literacy Rates	0.6287	0.9915	0.7999	0.1369

6.6 Discussion of Findings

6.6.1 Effect of ICT Infrastructure on Educational Attainment (Post-Secondary)

From the regression analysis carried out, Individuals using Computers has a negative correlation of -0.02 with Educational Attainment (Post-Secondary). In other words, when Individuals Using Computers increases by one, Educational Attainment (Post-Secondary) decreases by -0.02. However, this result is *not* statistically significant. Since the *p*-value is 0.81, there is an 81% chance that the -0.02 change in Educational Attainment (Post-Secondary) observed by the change in Individuals Using Computers is all random. Since 81% chance is higher than the selected significance level threshold of 5%, the -0.02 change in Educational Attainment (Post-Secondary) associated with Individuals Using Computers is not statistically significant.

Individuals Using Internet has a positive correlation of 0.26 with Educational Attainment (Post-Secondary). In other words, when Individuals Using Internet increases by one, Educational Attainment (Post-Secondary) increases by 0.26. This result is statistically significant. Figure 18 shows the line of best fit from this regression. Since the *p*-value is 0.04, there is a 4% chance that the 0.26 change in Educational Attainment (Post-Secondary) observed by the change in Individuals Using Internet is all random. However, since 4% chance is less than the selected significance level threshold of 5%, the 0.26 change in Educational Attainment (Post-Secondary) associated with Individuals Using Internet is statistically significant.

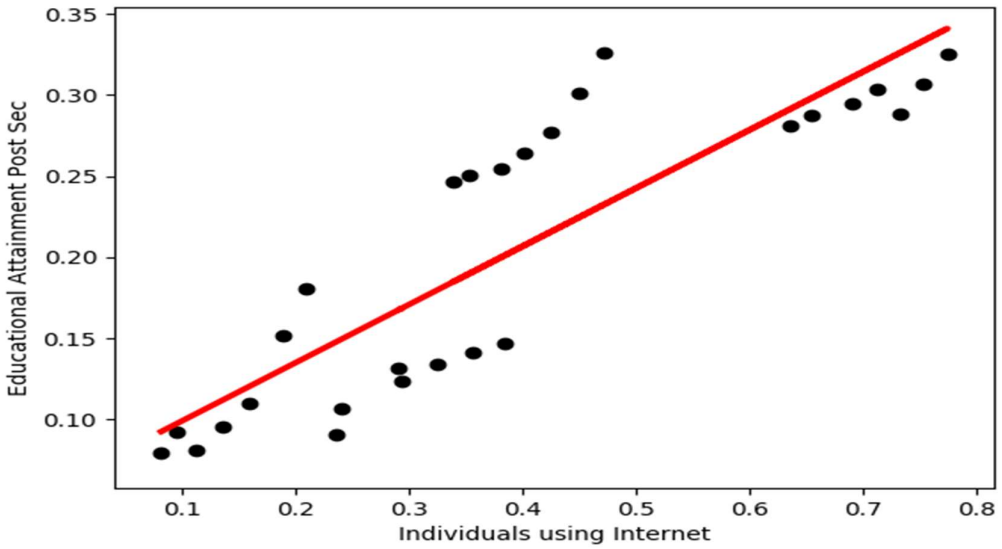

Figure 18: Line of Best-Fit for correlation between Individuals using Internet and Educational Attainment Post-Secondary

Individuals Using Mobile Phones has a positive correlation of 0.27 with Educational Attainment (Post-Secondary). In other words, when Individuals Using Mobile Phones increases by one, Educational Attainment (Post-Secondary) increases by 0.27. However, this result is not statistically significant. Since the *p*-value is 0.11, there is a 11% chance that the 0.27 change in Educational Attainment (Post-Secondary) observed by the change in Individuals Using Mobile Phones is all random. Since 11% chance is higher than the selected significance level threshold of 5%, the 0.27 change in Educational Attainment (Post-Secondary) associated with Individuals Using Mobile Phones is *not* statistically significant. The results of this simple OLS regression leads to a rejection of the null hypothesis, therefore the alternate hypothesis is accepted.

6.6.2 Effect of ICT Infrastructure on Educational Attainment (Short-Cycle Tertiary)

Individuals Using Computers has a negative correlation of -0.09 on Educational Attainment (Short-Cycle Tertiary). In other words, when Individuals Using Computers increases by one, Educational Attainment (Short-Cycle Tertiary) decreases by -0.09. This result is statistically significant. Since the *p*-value is 0.0010, there is almost a 0% chance that the -0.09 change in Educational Attainment (Short-Cycle Tertiary) observed by the change in Individuals Using Computers is all random. Since 0% chance is less than the selected significance level threshold of 5%, the -0.09 correlation of Educational Attainment (Short-Cycle Tertiary) with Individuals Using Computers is statistically significant.

Individuals Using Internet has a positive correlation of 0.20 on Educational Attainment (Short-Cycle Tertiary). In other words, when Individuals Using Internet increases by one, Educational Attainment (Short-Cycle Tertiary) increases by 0.20. This result is statistically significant. Figure 19 shows the line of best fit for this regression. Since the *p*-value is 0.000004, there is almost a 0% chance that the 0.20 change in Educational Attainment (Short-Cycle Tertiary) observed by the change in Individuals Using Internet is all random. Since 0% chance is less than the selected significance level threshold of 5%, the 0.20 correlation of Educational Attainment (Short-Cycle Tertiary) with Individuals Using Internet is statistically significant.

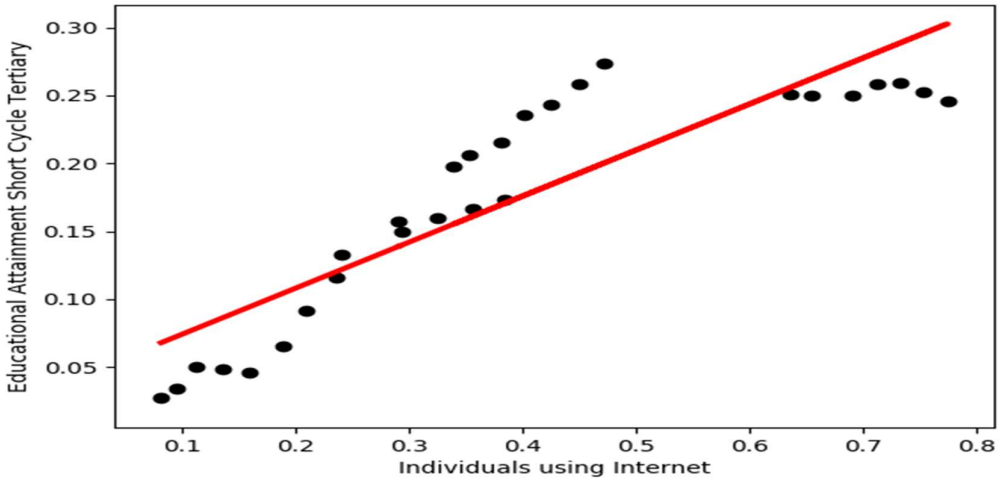

Figure 19: Line of Best-Fit for correlation of Individuals using Internet with Educational Attainment Short Cycle Tertiary

Individuals Using Mobile Phones has a positive correlation of 0.52 on Educational Attainment (Short-Cycle Tertiary). In other words, when Individuals Using Mobile Phones increases by one, Educational Attainment (Short-Cycle Tertiary) increases by 0.52. This result is statistically significant. Since the *p*-value is 0.00, there is almost a 0% chance that the 0.52 change in Educational Attainment (Short-Cycle Tertiary) observed by the change in Individuals Using Mobile Phones is all random. Since 0% chance is less than the selected significance level threshold of 5%, the 0.52 change in Educational Attainment (Short-Cycle Tertiary) associated with Individuals Using Mobile Phones is statistically significant. The results of this simple OLS regression leads to a rejection of the null hypothesis, therefore the alternate hypothesis is accepted.

6.6.3 Effect of ICT Infrastructure on Educational Attainment (Bachelors)

Individuals Using Computers has a negative correlation of -0.11 on Educational Attainment (Bachelors). In other words, when Individuals Using Computers increases by one, Educational Attainment (Bachelors) decreases by -0.11. This result is statistically significant. Since the *p*-value is 0.04, there is a 4% chance that the -0.11 correlation observed of Educational Attainment (Bachelors) with Individuals Using Computers is all random. However, since 4% chance is less than the selected significance level threshold of 5%, the -0.11 correlation of Educational Attainment (Bachelors) with Individuals Using Computers is statistically significant.

Individuals Using Internet has a positive correlation of 0.38 with Educational Attainment (Bachelors). In other words, when Individuals Using Internet increases by one, Educational Attainment (Bachelors) increases by 0.38. This result is statistically significant. Figure 20 shows the line of best fit for this regression. Since the *p*-value is 0.000005, there is almost a 0% chance that the 0.38 correlation observed between Educational Attainment (Bachelors) and Individuals Using Internet is all random. Since 0% chance is less than the

selected significance level threshold of 5%, the 0.38 correlation between Educational Attainment (Bachelors) and Individuals Using Internet is statistically significant.

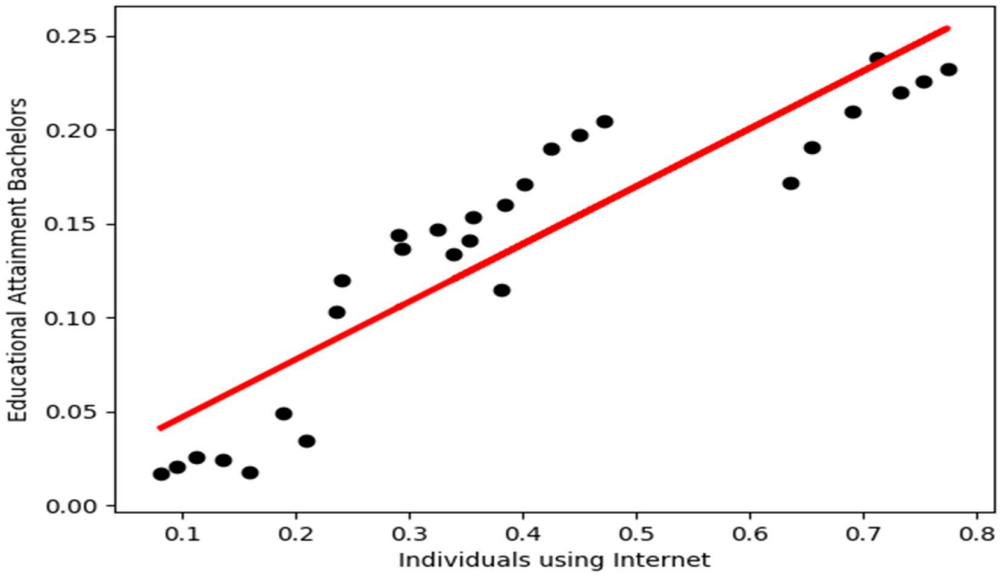

Figure 20: Line of Best-Fit for correlation between Individuals using Internet and Educational Attainment Bachelors

Individuals Using Mobile Phones has a positive correlation of 0.18 with Educational Attainment (Bachelors). In other words, when Individuals Using Mobile Phones increases by one, Educational Attainment (Bachelors) increases by 0.18. However, this result is not statistically significant. Since the *p*-value is 0.10, there is a 10% chance that the 0.18 correlation between Educational Attainment (Bachelors) and Individuals Using Mobile Phones is all random. Since 10% chance is higher than the selected significance level threshold of 5%, the 0.18 change observed in Educational Attainment (Bachelors) associated with Individuals Using Mobile Phones is not statistically significant. The results of this simple OLS regression leads to a rejection of the null hypothesis, therefore the alternate hypothesis is accepted.

6.6.4 Effect of ICT Infrastructure on Adult Literacy Rates

Individuals Using Computers has a negative correlation of -0.02 with Adult Literacy Rates. In other words, when Individuals Using Computers increases by one, Adult Literacy Rates decreases by -0.02. However, this result is not statistically significant. Since the *p*-value is 0.71, there is a 71% chance that the -0.02 change observed in Adult Literacy Rates associated with Individuals Using Computers is all random. Since 71% chance is higher than the selected significance level threshold of 5%, the -0.02 correlation of Adult Literacy Rates caused with Individuals Using Computers is not statistically significant.

Individuals Using Internet has a positive correlation of 0.56 with Adult Literacy Rates. In other words, when Individuals Using Internet increases by one, Adult Literacy Rates increases by 0.56. This result is statistically significant. Figure 21 shows the line of best fit for this regression. Since the *p*-value is 0.00, there is almost a 0% chance that the 0.56 change observed in Adult Literacy Rates associated with Individuals Using Internet is all random. Since 0% chance is less than the selected significance level threshold of 5%, the 0.56 correlation of Adult Literacy Rates with Individuals Using Internet is statistically significant. This is the strongest most significant correlation encountered in the regression analyses between ICT infrastructure indices and Educational Attainment/Adult Literacy Rates.

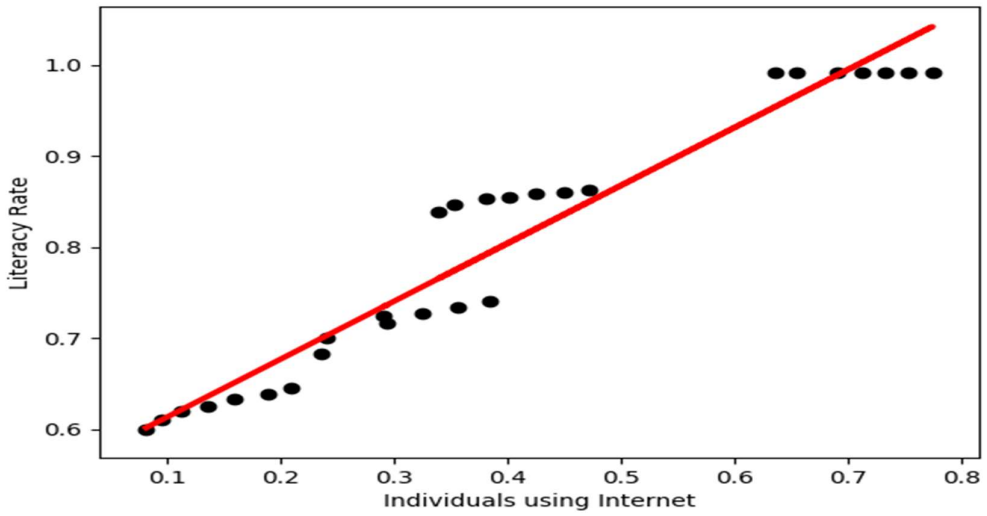

Figure 21: Line of Best-Fit for correlation between Individuals using Internet and Adult Literacy Rates

Individuals Using Mobile Phones has a positive correlation of 0.23 with Adult Literacy Rates. In other words, when Individuals Using Mobile Phones increases by one, Adult Literacy Rates increases by 0.23. However, this result is not statistically significant. Since the *p*-value is 0.08, there is an 8% chance that the 0.23 correlation between Adult Literacy Rates and Individuals Using Mobile Phones is all random. Since 8% chance is higher than the selected significance level threshold of 5%, the 0.23 correlation of Adult Literacy Rates and Individuals Using Mobile Phones is *not* statistically significant. The results of this simple OLS regression leads to a rejection of the null hypothesis therefore, the alternate hypothesis is accepted.

6.6.5 Discussion of DEA Analysis

From the analysis, we can see from table 15 that Northern Africa is 97.2% relatively efficient in its utilization of ICT Infrastructure for the educational component of National Development while Sub-Saharan Africa, Europe and North America and the World are optimally relatively efficient. Interesting to note, however is that even though Sub-Saharan Africa has the average lowest percentage of ICT infrastructure utilization, educational attainments, and adult literacy rates, it is optimally using its current ICT infrastructure with respect to Education in the Human Development Index. This may be as an outcome of a well-known bias of Data Envelopment Analysis where the DMU with the lowest input is more likely to have a high efficiency rating, however, this supports the notion that should there be an increase in ICT Infrastructure, there will be a somewhat corresponding increase in educational attainment and Adult Literacy rates which may have a positive effect on the Human Development Index.

Table 15: Efficiency Summary

DMU	Efficiency
Sub-Saharan Africa	100%
Northern Africa	97.20%
Europe and North America	100%
World	100%

As expected, Europe and North America have the highest average values for ICT Infrastructure utilization, educational attainments and literacy rates and are optimally relatively efficient in this regard. Although Northern Africa has higher average values than

Sub-Saharan Africa across most of the indices, the fact that there was no data available for Educational Attainment (Bachelors) may be a mitigating factor against their relative efficiency frontier, thus reducing the efficiency value. This is not to say however that Northern Africa is not efficient, but rather that it has the lowest relative efficiency in this grouping and within the context of the model used.

Another interesting finding from the analysis of the data, as presented in table 16, is the correlation between the input indices and the output indices. Individuals with computers has the strongest correlation with educational attainment and adult literacy rates, while individuals with mobile phones has the weakest correlation. This may also be a strong indication of the outcome of pedagogical changes in teaching and learning which now include higher usage of computers. This could be a result of the introduction of online learning and blended learning environments into education. It would be interesting to see, as m-learning initiatives pick up, whether the correlation between mobile phones and educational attainments and literacy rates will become stronger.

Table 16: Correlation Between Input and Output Indices

Index	Individuals with Computers	Individuals with Internet	Individuals with Mobile Phones
Educational Attainment (Post-Secondary)	0.9456	0.905	0.6947
Educational Attainment (Short-Cycle Tertiary)	0.9942	0.951	0.8794
Educational Attainment (Bachelors)	0.8972	0.8982	0.5709
Adult Literacy Rates	0.9932	0.9913	0.8246
AVERAGE	**0.9576**	**0.9364**	**0.7424**

6.7 Limitations

The main limitation of this study is the availability of the data for the dataset. The data was collected from the United Nations Educational, Scientific and Cultural Organization (UNESCO) - educational attainments; World bank - literacy rates and the International Telecommunication Union (ITU) - individuals with computers, internet and mobile phones. Considering that the years being investigated are the most recent and the sources of the data are credible and well cited sources for scientific data collection, it was unfortunate that some countries within each region did not have data available for one or more of the years being

investigated. This may have positive or negative effects on the regional averages calculated, as the data collected is represented as a percentage of the population of the countries. Also, the limitation in availability of data makes it difficult to carry out intra-regional comparative analysis in order to see how individual countries within each region compare with one another.

6.8 Conclusion and Future Work

This research has been able to show that ICT infrastructure available is currently having an effect on human development with respect to educational attainment and adult literacy rates. This is shown from the regression analysis carried out on each of the ICT infrastructure indices as they affect the Educational Attainment/Adult Literacy Rates indices. In all of the regression analysis the null hypothesis is rejected and therefore it has been statistically shown that ICT infrastructure has a predominantly strong positive and significant effect on educational attainment and adult literacy rates. This is evidenced by the fact that the data collected was data of ICT infrastructure currently available for utilization by the regions within the specified time and not investments made during this time. This answers one of the research questions which was to determine the effect of ICT infrastructure utilization in education on socio-economic development.

The research further shows that regions with significantly lower educational attainment and literacy rates are relatively efficiently utilizing their significantly lower ICT infrastructure, and this situation therefore provides an, albeit assumptive, basis for justifying increased spending in ICT infrastructure. Using the CRS model for the DEA analysis, the research has been able to show that while controlling the inputs (ICT Infrastructure) an increase in the input has a tendency to result in a corresponding increase in the output (Educational Attainment / Adult Literacy Rates) and vice-versa, therefore impacting positively the educational component of the Human Development Index.

The research has also been able to show that there is a strong correlation between ICT Infrastructure and Educational Attainment / Adult Literacy rates as shown in figure 22. The correlation is strongest between the individuals with computers index of the ICT Infrastructure variable and Educational Attainment (Post-Secondary) as shown in figure 23.

However, Individuals Using Internet has the most consistent positive significant correlation with Educational Attainment/Adult Literacy rates. This may be useful to policy makers and donors going forward, as investments in Internet infrastructure should now be the focus of ICT investments, as opposed to computer hardware.

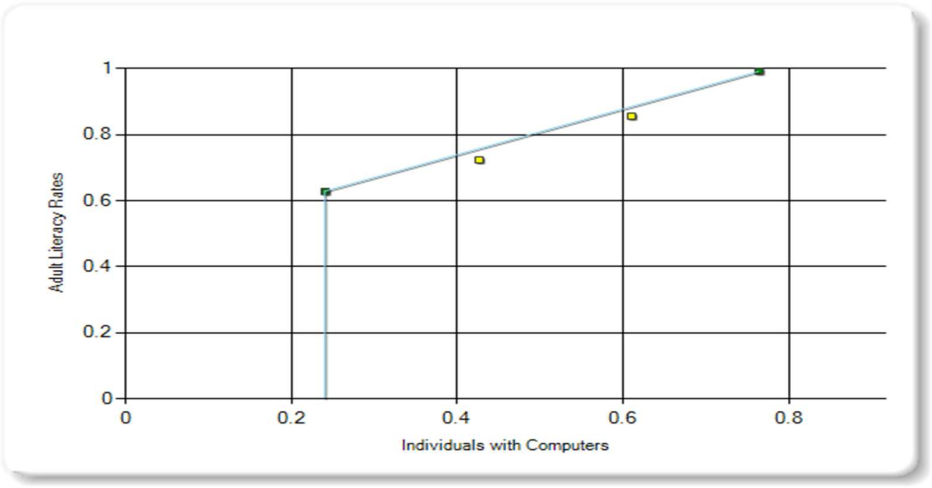

Figure 22: Correlation between Individuals with Computers and Adult Literacy Rates

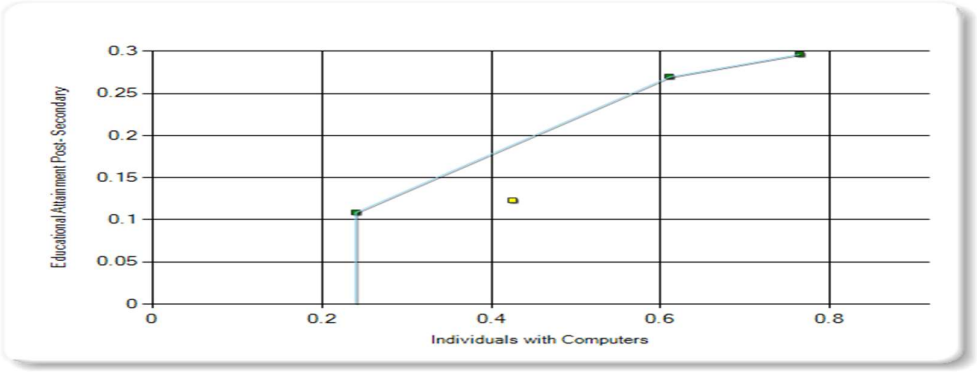

Figure 23: Correlation between Individuals with Computers and Educational Attainment Post-Secondary

While acknowledging that DEA as a methodology in itself is context specific, and by its very nature of being non-parametric does not allow for generalization beyond the context (Samoilenko & Osei-Bryson, 2017) the research has been able to show that within the sample itself and within the context of educational attainment / adult literacy rates, ICT has a strong impact on Human Development albeit within the Educational index. The research has also

been able to show how Learning Analytics can be applied for decision making outside the teaching and learning environment and for policy directions.

An area of future research would be to expand this context by showing how ICT impacts on each of the components of the Human Development Index within the specified DMU's and determine the correlations, if any, between them. Another area of future research would be to explore the other DEA models available and determine if there are any other significant correlations or findings, which can have strong impacts on ICT infrastructure investments, on the individual Human Development Indices, as well as to measure the productivity over time of the ICT infrastructure utilization. Future research can also be carried out to investigate further the impact, if any, of the strong correlations between ICT infrastructure and educational attainment/adult literacy rates and what this may mean in the broader ICT4D context.

Another area of future research also, would be to incorporate soft ICT infrastructure such as IT Human Resource infrastructure into the model. This will help provide more valuable insights as it considers IT skills and capacities acquired and utilized by ICT personnel, however, it is acknowledged that accurate data about this soft ICT infrastructure would be extremely difficult to access and determine on a scale large enough to justify generalization using the current research methodology.

In the next chapter, chapter 7, the next step is to determine how productive the utilization of ICT infrastructure is by introducing the Malmquist Productivity Index. An attempt is made to mitigate against some of the limitations observed with the dataset in this research, by obtaining data already sorted into UNESCO regional groupings for adult literacy rates. These groupings then become the DMU's and the focus is solely on ICT Infrastructure indices as inputs and adult literacy rates as outputs. Having discovered that the most significant effect of ICT infrastructure is on Adult Literacy rates, this educational index is used and other ICT indices are introduced such as households with computers and households with Internet, to individuals using Internet and individuals using mobile phones.

6.9 References

Afonso, A., & St. Aubyn, M. (2005) Non-parametric approaches to education and health efficiency in OECD countries. Journal of Applied Economics, 8(2): 227-246

Afonso, A., & St. Aubyn, M. (2006a) Cross-country efficiency of secondary education provision: a semiparametric analysis with non-discretionary inputs. Economic Modelling, 23(3): 476-491

Afonso, A., & St. Aubyn, M. (2006b) Relative efficiency of health provision: a DEA approach with nondiscretionary inputs. ISEG-UTL, Department of Economics Working Paper nº 33/2006/DE/UECE

Akpan, P. (2000) Africa and the New ICTs: Implications for Development. Proceedings of the International Federation for Processing Conference (IFIP TC9), South Africa

Anand, S., & Ravallion, M. (1993) Human Development in Poor Countries: On the Role of Private Incomes and Public Services. The Journal of Economic Perspective, *7*(1): 133–150

Aristovnik, A. (2012) The impact of ICT on Educational Performance and its efficiency in selected EU and OECD countries: a non-parametric analysis. http://dx.doi.org/10.2139/ssrn.2187482

Avgerou, C. (2010) Discourses on ICT and development. Information Technologies & International Development, 6(3): 1

Bankole, F. O., Shirazi, F., & Brown, I. (2011a) Investigating the impact of ICT investments on human development. The Electronic Journal of Information Systems in Developing Countries, 48(1): 1-19

Bankole, F. O., Brown, I., & Osei-Bryson, K. M. (2011b) The Impact of ICT Infrastructure on Human Development: An Analysis of ICT-Use in SADC Countries. In Proceedings of the 11th International Conference on Social Implications of Computers in Developing Countries, Kathmandu, Nepal, May 2011

Bankole, F. O., Osei-Bryson, K. M., & Brown, I. (2011c). ICT infrastructure utilization in Africa: Data envelopment analysis based exploration. In Proceeding of special interest group on ICT and global development at Americas Conference on Information System (AMCIS) Workshop, Detroit, USA

Bankole, F., & Mimbi, L. (2017). ICT Infrastructure and It's Impact on National Development: A Research Direction for Africa. *The African Journal of Information Systems*, *9*(2): 1

Briede, B. (2017) Usage of the Goals for Sustainable Development in Formation of Learning Outcomes in Higher Education. In *Rural Environment. Education. Personality. (REEP).* Proceedings of the International Scientific Conference (Latvia). Latvia University of Agriculture

Charnes, A., Cooper, W. W., & Rhodes, E. (1978) Measuring the efficiency of decision-making units. European journal of operational research, 2(6): 429-444.

Clements, B. (2002) How efficient is education spending in Europe? European Review of Economics and Finance, 1: 3-26

Cook, W. D., Tone, K., & Zhu, J. (2014) Data envelopment analysis: Prior to choosing a model. Omega, 44: 1-4.

Crawshaw, J., & Chambers, J. (1984). *A concise course in A-level statistics*. Nelson Thornes Limited.

Dedrick, J., Gurbaxani, V., & Kraemer, K. L. (2003) Information technology and economic performance: A critical review of the empirical evidence. ACM Computing Surveys 35(1): 1–28.

Desai, M. (1991) Human development. European Economic Review, 35(2-3): 350–357. doi:10.1016/0014-2921(91)90136-7

Draca, M., Sadun, R., & Van Reenen, J. (2007) Productivity and ICTs: A review of the evidence. In R. Mansell, C. Avgerou, D. Quah, & R. Silverstone (Eds.), The Oxford handbook of information and communication technologies pp. 100–147. Oxford: Oxford University Press.

Ganju, K. K., Pavlou, P. A., & Banker, R. D. (2015) Does information and communication technology lead to the well-being of nations? A country-level empirical investigation

Gilhooly, D., & Ocampo, J. (2005) Creating an Enabling Environment: Toward theMillennium Development Goals, The United Nations Information and Communication Technologies Task Force, New York

Gülbahar, Y., (2008) ICT usage in higher education: a case study on preservice teachers and instructors, The Turkish Online Journal of Educational Technology, 7(1): 32-37

Gupta, S., & Verhoeven, M. (2001) The efficiency of government expenditure: experiences from Africa. Journal of policy modeling, 23(4): 433-467

Hargreaves, A., & Braun, H. (2013) Data-driven improvement and accountability. National Education Policy Centre, Boulder, CO. http://co.chalkbeat.org/wp-content/uploads/sites/2/2013/10/PB-LB-DDIA-POLICY-FINAL-EMBARGOED.pdf.

Hatami-Marbini, A., Saati, S., & Tavana, M. (2010) An ideal-seeking fuzzy data envelopment analysis framework. Applied Soft Computing, 10(4): 1062-1070

Hays, W. L. (1994). Inferences about population means. *Statistics*, *5*, 311-42.

Hinostroza, J. E., Jara, I., & Brun, M. (2011) Chapter 6: Case study: Uruguay. In R. B. Kozma (Ed.), Transforming education: The power of ICT policies pp. 125–164. Paris, France: UNESCO

Hinostroza, J. E., Isaacs, S., & Bougroum, M. (2014) Information and communications technologies for improving learning opportunities and outcomes in developing countries. In Learning and education in developing countries: Research and policy for the post-2015 UN development goals pp. 42-57. Palgrave Pivot, New York

Hinostroza, J. E. (2018) New Challenges for ICT in Education Policies in Developing Countries: The Need to Account for the Widespread Use of ICT for Teaching and Learning Outside the School. In ICT-Supported Innovations in Small Countries and Developing Regions pp. 99-119. Springer, Cham

Hutcheson, G. D. (1999). *The multivariate social scientist*.: SAGE Publications, Ltd. doi: 10.4135/9780857028075

Kadam, U. (n.d). Impact of Technology in Higher Education.

Kiiski, S. K. (2001) Cross country Diffusion of the Internet. UNU/WIDER Discussion paper WDP, 11

Mann, C. L. (2003) Information technologies and international development: Conceptual clarity in the search for commonality and diversity. Information Technologies & International Development 1(2): 67–79.

Mimbi, L., Bankole, F. O., & Kyobe, M. (2011). Mobile phones and digital divide in East African countries. In *Proceedings of the South African Institute of Computer Scientists and Information Technologists Conference on Knowledge, Innovation and Leadership in a Diverse, Multidisciplinary Environment* (pp. 318-321). ACM.

Molina, A. (2003) The digital divide: the need for a global e-inclusion movement. Technology Analysis & Strategic Management, 15(1): 137-152

Moreira, F., Gonçalves, R., Martins, J., Branco, F., & Au-Yong-Oliveira, M. (2017) Learning Analytics as a Core Component for Higher Education Disruption: Governance Stakeholder. In Proceedings of the 5th International Conference on Technological Ecosystems for Enhancing Multiculturality pp. 37. ACM

Neumayer, E. (2001) The human development index and sustainability—a constructive proposal. Ecological Economics, 39(1): 101-114

Ngwenyama, O., Andoh-Baidoo, F.K., Bolou, F. & Morawczynski, O. (2006) Is There a Relationship Between ICT, Health, Education and Development? An Empirical Analysis of Five West African Countries from 1997-2003. Electronic Journal on Information Systems in of Developing Countries, 23(5): 1-11

Norris, P. (2000) The worldwide digital divide. In Paper for the Annual Meeting of the Political Studies Association of the UK, London School of Economics and Political Science

Olaniyi, T. K., & Ademola, E.O. (2014) Deployment of Information and Communication Technology in Higher Education Learning Environment of Emerging Nigerian Economy. African Journal of Computer & ICTs, (7)1: 121-126

Orbicom (2005) From The Digital Divide To Digital Opportunities: Measuring Infostates for Development, Montreal: Claude-Yves Charron

Oyerinde, O. D. (2014) A review of challenges militating against successful e-learning and m-learning implementations in developing countries. International Journal of Science and Advanced Technology, 4(6): 1-5

Oyerinde, O. D., & Chia, P. A. (2017). Predicting students' academic performances–A learning analytics approach using multiple linear regression. International Journal of Computer Applications, 157(4): 37-44

Papamitsiou, Z., & Economides, A. (2014) Learning Analytics and Educational Data Mining in Practice: A Systematic Literature Review of Empirical Evidence. Educational Technology & Society, 17 (4): 49–64.

Prinsloo, P., & Slade, S. (2017) Big data, higher education and learning analytics: Beyond justice, towards an ethics of care. In Big data and learning analytics in higher education pp. 109-124. Springer, Cham

Prinsloo, P. (2018) Context Matters: An African Perspective on Institutionalizing Learning Analytics. Include us All! Directions for Adoption of Learning Analytics in the Global South, 24

Romero, C., & Ventura, S. (2007) Educational data mining: A survey from 1995 to 2005. Expert systems with applications, 33(1): 135-146

Sahu, S. (2017) Role of ICT in Enhancement of Quality Learning and Teaching in Higher Education

Samoilenko, S. V., & Osei-Bryson, K. M. (2017) Creating Theoretical Research Frameworks Using Multiple Methods: Insight from ICT4D Investigations. Auerbach Publications.

Siemens G (2011) Learning analytics: a foundation for informed change in higher education. http://www.educause.edu/library/resources/learning-analytics-foundation-informed-change-higher-education

Siemens, G., & Long, P. (2011) Penetrating the fog: Analytics in learning and education. EDUCAUSE review, 46(5): 30

Siemens, G. (2012) Learning analytics: envisioning a research discipline and a domain of practice. In Proceedings of the 2nd international conference on learning analytics and knowledge 4-8. ACM

St. Aubyn, M. (2002) Evaluating efficiency in the Portuguese health and education sectors. Economia, Vol. 26. Available at SSRN: https://ssrn.com/abstract=504942

Thanassoulis, E., Kortelainen, M., Johnes, G., & Johnes, J. (2011) Costs and efficiency of higher education institutions in England: a DEA analysis. Journal of the operational research society, 62(7): 1282-1297

Tondeur, J., van Braak, J., & Valcke, M. (2007) Towards a typology of computer use in primary education. Journal of Computer Assisted Learning, 23: 197-206

UNDP: United Nations Development Programme. (2006) The Millennium Development Goals. UNDP

Walsham, G. (2017) ICT4D research: reflections on history and future agenda, Information Technology for Development, (23)1: 18-41, DOI:10.1080/02681102.2016.1246406

Zorrilla, M., García, D., & Álvarez, E. (2010) A decision support system to improve e-learning environments. In Proceedings of the 2010 EDBT/ICDT Workshops 11. ACM.

CHAPTER 7

7.0 Measuring Efficiency and Productivity of ICT Infrastructure Utilization

7.1 Introduction

The growth of Information and Communication Technology (ICT) in recent years has been remarkable in all countries and sectors throughout the world because of its transformational power that favours productivity and efficiency (Kayisire & Wei, 2016). Many governments have heeded the call for increased investments in ICT with an aim to improve national development with respect to the Human Development Index (HDI). This is based on the assumption that increasing investments in ICT will lead to improvements in productivity and other aspects of development at the organizational and national levels (Samoilenko & Osei-Bryson, 2018). With Educational Attainment being one of the core indices for measuring Development with respect to the Human Development Index (Abbott & Doucouliagos, 2003; UNDP, 2006; Bankole et al., 2011a), and the overwhelming successes gained from Data Analytics in decision making, it is little wonder that Data Analytics has found its way into the Education Sector especially in ICT4D research.

This field of Data Analytics in Education, otherwise known as Learning Analytics (LA) is fast gaining ground in terms of research interest and advancement in technology (Oyerinde & Chia, 2017). Learning Analytics has been defined as the area of research related to business intelligence, web analytics, academic analytics, action analytics and predictive analytics (Papamitsiou & Economides, 2014). Consequently, the aim of business intelligence is to provide decision support mechanisms, e.g. performance indicators, critical to enabling attainment of overall goals and objectives while providing information for decision making and policy direction (Schutz, 2009; Kleesuwan et al., 2010). Therefore, Learning Analytics, by definition, adopts a wholistic view of Data Analytics in Education and therefore has

become relevant to ICT4D research, especially with respect to decision making and policy direction for the educational sector with respect to socio-economic development.

National development is said to encapsulate the notion of human development as the means of enlarging people's choices regarding the acquisition of knowledge, amongst other things, in order to have access to the resources needed for a decent standard of living (UNDP, 2006; Bankole & Mimbi, 2017). The need to understand the relevance of education in Human Development is well known and adequately acknowledged, as it is important for socio-economic development (Bankole & Assefa, 2017). It is therefore not a surprise that over the last three decades, research in national development has been expanded to certain intervening variables and social factors such as education and some other aspects of human welfare. (Desai, 1991; Anand & Ravallion, 1993; Bankole & Mimbi, 2017). This is ever more evident considering that countries have defined policies that show an emphasis on creating support mechanisms for the use of ICT, including for example, technical and pedagogical support, as well as giving special attention to the use of ICT in teaching and learning (Hinostroza, 2018). However, the opinions on the influence that ICT Infrastructure development can bring to bear on national development come from two perspectives: The adoption of ICTs has the potential to empower communities and countries, while secondly, the ICT revolution can lead to imbalances and inequalities through lack of ICT adoption, access and usage (Bankole & Mimbi, 2017).

In recent times, a lot of research has gone into ICT and its resultant impact/effects on national development and HDI (Sein & Harindranath, 2004; Ngwenyama et al., 2006; Brown & Brown; 2008; Bankole et al., 2011a; Jeremic et al., 2011; Samoilenko & Osei-Bryson, 2018; Oyerinde & Bankole, 2019). The results have shown that ICT does have a strong role to play in nations wishing to improve their socio-economic development and HDI. With the levels of ICT Infrastructure currently available and its well acknowledged importance to a nation's HDI, there is a need to understand the potential that exists for these nations to improve national development by investigating whether these ICT infrastructures are being utilized efficiently. By doing this it would be possible to measure their productivity levels over time with respect to the educational component of the HDI. In doing this, it is necessary to take into consideration the standardized ICT indicators as determined by the World Summit on the Information Society (WSIS) and the United Nations Conference on Trade and Development (UNCTAD) in June 2004. In order to explore the utilization efficiency of these ICT

infrastructure indicators, the following regional groupings are used as the Decision Making Units (DMUs); Arab States; Europe; Sub-Saharan Africa; World in order to measure their productivity with respect to these indicators.

The HDI is a composite index calculated from three socio-economic indicators that reflect three major dimensions of human development. These are longevity, educational attainment and standard of living. Longevity is measured by life expectancy at birth. Educational attainment is measured by a weighted average of the adult literacy rates (one-third) and the combined primary, secondary and tertiary gross educational enrolment ratios (two-thirds) (UNDP, 2000; Despotis, 2005). In this research, the efficiency and productivity of ICT Infrastructure utilization in education with respect to national development is measured vis a vis adult literacy rates. This indicator is used as it reflects educational attainment and not enrolment. This is on the premise that enrolled individuals are yet to use or are currently using the infrastructure while attainment indicates having completed a certain level of educational qualification. An OLS regression analysis is carried out on these indices to determine the effect of the ICT infrastructure indices on adult literacy rates. Data Envelopment Analysis (DEA) and Malmquist Index (MI) approaches are employed to carry out this research. The Malmquist Productivity Index is considered the most appropriate tool for measuring changes in efficiency and productivity (Arjomandi et al., 2015).

This research explores further the findings from the Oyerinde & Bankole (2019) research, in chapter 6, which investigated the relative efficiency of ICT infrastructure utilization in education with data collected for 2010-2016. The rest of this chapter is organized as follows: section 7.2 provides the background, section 7.3 discusses the theoretical framework, section 7.4 provides the research methodology, section 7.5 provides the data analysis, section 7.6 provides the discussion of findings, section 7.7 the limitations and section 7.8 the conclusion.

7.2 Background

There has been a rapid expansion during the last few decades in the use of non-parametric approaches in measuring the efficiency and productivity changes in education, albeit mostly in education institutions (Arjomandi et al., 2015). A large number of these studies have been undertaken in developed countries e.g. (Athanassopoulos & Shale, 1997; Abbott & Doucouliagos, 2003; Emrouznejad & Thanassoulis, 2005; Johnes, 2006). There have been

quite a lot of studies that have so far attempted to use the Malmquist Index for this purpose, among them are (Flegg et al., 2004; Carrington et al., 2005; Johnes, 2008; Worthington & Lee, 2008; Agasisti & Johnes, 2009; Bradley et al., 2010). Most of these studies have found productivity progress in different sectors, but this is mainly attributed to changes in technology and/or efficiency.

DEA has been used to measure efficiency for well over 4 decades and its applications spread over a wide range of thematic areas (Liu et al., 2013a; Emrouznejad et al., 2019). Some applications, such as education and health care, blossomed in the early days of DEA, while the application of DEA in other fields have only happened fairly recently (Liu et al., 2013b). A systematic survey of DEA applications has been carried out by Liu et al. (2013b) and the results have identified education as being one of the top five major application areas of DEA, making education prominent in DEA's grand development. Liu et al. (2013b) have discovered that historically, there have been two major groups of DEA applications in education in the literature. There is the one that studies the efficiency of higher education and that of basic education. The group for higher education includes Bessent et al. (1983), Sinuany-stern et al. (1994), Arcelus & Coleman (1997), Johnes (2006), and Johnes & Li (2008). The recent trend of efficiency studies in the education category clearly focuses on the higher education sector as articles mostly evaluate the performance of universities (Liu et al., 2013b).

There have been some studies that have used DEA to measure efficiency in education with respect to Human Development. Gupta & Verhoeven (2001) have measured the efficiency of education in Africa and Clements (2002) has measured efficiency of education in Europe. St. Aubyn (2002) and Afonso & St. Aubyn (2005; 2006a; 2006b) have measured with respect to OECD countries. Tondeur et al. (2007) and Gülbahar (2008) have examined the efficiency of countries in utilising their ICT resources for educational outputs and the Impact of ICT on education while Aristovnik, (2012) has carried out a study on the impact of ICT on educational performance and its efficiency in select EU and OECD countries using DEA.

A lot of research has been done in recent times to investigate the impact of ICT Infrastructure with respect to national development using DEA methodology. Sein & Harindranath, (2004) have focused on understanding the role of ICT in national development, Ngwenyama et al. (2006) have investigated the relationship between ICT, health, education and national development and Ngwenyama & Morawczynski (2009) have focused on ICT Infrastructure

expansion in emerging economies. Bankole et al. (2011) have investigated the impact of ICT investment on national development, Bankole et al. (2015) have investigated the impact of ICT and institutional quality on trade efficiency in Africa while Mimbi & Bankole (2016) have studied ICT and public value creation in Africa. Kayisire & Wei (2016) have investigated ICT adoption and usage in Africa, Bankole & Mimbi (2017) have investigated the impact of ICT infrastructure on national development and Oyerinde & Bankole (2018) have investigated the relative efficiency of ICT infrastructure utilization in education using both the CRS and VRS models of the DEA methodology.

With the potential of educational technologies to positively improve educational quality and attainment, there is great optimism that efficient ICT infrastructure utilization in education can greatly increase both average literacy rates and educational attainment levels in developing economies (Oyerinde & Bankole, 2018). However, despite these promises being included in education policies that are related towards achieving a positive impact of ICTs on student achievements, there is no conclusive evidence to support this (Hinostroza et al., 2014). It is against this backdrop that this research to investigate the productivity of ICT infrastructure utilization in education over time, is carried out using the Data Envelopment Analysis and Malmquist Index approaches. This research builds upon the Oyerinde & Bankole (2019) research presented in chapter 6 and is aimed at further showing how LA research can be used for decision making and policy direction within the ICT4D global discourse by carrying out a productivity assessment.

7.3 Theoretical Framework

This research builds upon the Oyerinde & Bankole (2019) model conceptualized in chapter 6 for measuring the efficiency of ICT Infrastructure with respect to Education theorized and operationalized by Bankole et al. (2011). This framework is based on the Theory of Replication in Information Systems as shown by Bankole & Bankole (2017). Central to this framework is the premise that one must first use a technology before one can achieve desired outcomes (Venkatesh et al., 2016), founded on the Unified Theory of Acceptance and Use of Technology (UTAUT), which is as a result of several pieces of research in the literature on technology adoption by groups and organizations e.g. (Sia et al., 2001; Sia et al., 2004; Sarker et al., 2005; Sarker & Valacich, 2010). This model considers ICT infrastructure available for

utilization and as such satisfies the premise that the technology is being used, as the ICT indicators used for this research are derived from usage. This model takes the form of a linear equation derived from the Bankole et al. (2011) model, for measuring the impact on education within the Human Development Index and expressed as:

$$Log(\mathbf{E}) = \alpha_o + \alpha_{HS} log(H) * log(S) + \alpha_{TH} log(T) * log(H) + \alpha_{TS} log(T) * log(S) + \xi$$

Where:

E - the educational component of the human development index (HDI),

H - the Hardware Infrastructure,

S - the Software Infrastructure,

T - the Telecommunication Infrastructure

It can be considered to be similar to another linear model, the translog production function framework (Ko & Osei-Bryson, 2004) which is rooted in the Cobb-Douglas Production Function (Meeusen & van Den Broeck, 1977) in that it allows for pairwise interactions between the components of ICT. Therefore, the model for this study which reflects the above logarithmic expression is:

The effect on Education (Adult Literacy rates) = f[Internet Infrastructure (II) + Computer Infrastructure (CI) + Mobile Phone Infrastructure (MPI)].

In investigating the productivity, the classic Malmquist Index calculation model defined by Färe et al. (1994) is used and expressed as:

$$MI = EC * TC = PC * SC * TC$$

where:

MI - Malmquist Index

EC – Efficiency Change

TC - Technical Change

PC - Pure efficiency Change

SC - Scale efficiency Change

This research falls within the progressive perspective of ICT-enabled development as postulated and defined by Avgerou (2010). The theory behind this perspective is that it considers ICT as an enabler of transformations in multiple domains of human activities. ICT-enabled developmental transformations are assumed to be achieved within the existing international and local social order (Avgerou, 2010). Central in this theoretical perspective is the view that investment in ICT and its effective use do matter for the economic development of a country (Mann, 2003). It is however acknowledged that ICT needs to be accompanied by organizational or national restructuring, whichever the case may be, to deliver productivity gains (Dedrick et al., 2003; Draca et al., 2006) hence the need for an empirical basis from which decisions can be made in order to bring about the much-needed restructuring, which this proposed framework aims to provide.

7.4 Research Methodology

For this study, time series data from the United Nations Educational, Scientific and Cultural Organization (UNESCO); adult literacy rates, being the most significantly affected educational index as discovered in chapter 6, and the International Telecommunication Union (ITU); individuals using internet and mobile phones, households with computers and internet, were obtained. The data from these sources have often been used in ICT research. The ITU is one of the UN groups which have the most reliable sources of data for the ICT sector (Bankole et al., 2015). Available data was collected for Arab States, Europe, Sub-Saharan Africa and World regional aggregates. These formed the four Decision Making Units (DMU's). Data for the past 7 years, 2010-2016 was collected in percentages (per 100 inhabitants) of the country population, with the ratio values computed annually as shown in Table 17.

From the literature, it can be seen that the wrong choice of variables may have negative implications on the outcome of the research (Mimbi & Bankole, 2016). Therefore, variables were carefully selected, based on research previously carried out within the context of this investigation and those studies upon which this research is further building (Ngwenyama & Morawczynski, 2009; Bankole et al., 2011; Samoilenko & Osei-Bryson, 2013; Bankole et al., 2015; Oyerinde & Bankole, 2018; Oyerinde & Bankole, 2019). These variables and indicators have successfully been used using the conventional DEA models. Here Data Envelopment

Analysis and Malmquist Index methodologies are employed to calculate the relative efficiency and productivity of the regions, respectively.

DEA is a well-known non-parametric linear programming method for measuring relative efficiency (Bankole et al., 2011; Thanassoulis et al., 2011). DEA is a data-oriented method for evaluating the performance (efficiency) of entities, known as Decision Making Units (DMUs), which uses input-output data to compute an efficient production frontier produced by the most efficient DMU's (Bollou, 2006). DEA, unlike a parametric method, is context specific with respect to the interpretations of the results of the analysis, which are restricted to the sample and should not be generalized beyond the sample (Samoilenko & Osei-Bryson, 2017). DEA, therefore, can then be viewed as a multiple-criteria evaluation methodology where DMUs are alternatives, and DEA inputs and outputs are two sets of performance criteria where one set (inputs) is to be minimized and the other (outputs) is to be maximized (Cook et al., 2014).

The Constant Returns to Scale (CRS) model is derived by considering a set on *n* DMU's each with DMU_j, (*j=1, …, n*) using *m* inputs x_{ij}(*i=1, …, m*) and generating *s* outputs y_{rj}(*r=1, …, s*). If the multipliers $\bar{u}_r$, $\bar{v}_i$ associated with outputs *r* and inputs *i*, respectively, are known, then borrowing from conventional cost/benefit theory, the efficiency $\bar{e}_j$ of DMU_j can be expressed as the ratio of weighted outputs to weighted inputs:

$$\sum_r \bar{u}_r y_{rj} \Big/ \sum_i \bar{v}_i x_{ij}$$

However, a common challenge that lies herein, is that more often than not, the multipliers, $\bar{u}_r$ and $\bar{v}_i$ are not known. To resolve this, Charnes et al. (1978), have proposed a model for deriving appropriate multipliers for a given DMU. This model is widely known as the CRS model or the CCR ratio model (Charnes et al., 1978; Cook et al., 2014) which is expressed as:

$$e_0 = \max \ \sum_r u_r y_{r0} \Big/ \sum_i v_i x_{i0}$$

$$s.t. \sum_r u_r y_{rj} - \sum_i v_i x_{ij} \leq 0, \ \ all\ j$$

$$u_r v_i \geq \varepsilon, all\ r, i$$

where ε is a non-archimedian value designed to enforce strict positivity on the variables and is the solution to a fractional programming problem (Cook & Seiford, 2009). However, Banker et al. (1984) extended this model by providing the Variable Returns to Scale (VRS) model, also known as the BCC model, (Banker et al., 1984) which is expressed as:

$$e_0^* = \max {[\sum_r u_r\, y_{r0} - u_0]}\Big/{\sum_i v_i x_{i0}}$$

$$s.t. \sum_r u_r y_{rj} - u_0 - \sum_i v_i x_{ij} \leq 0, \;\; j = 1, \dots, n$$

$$u_r \geq \varepsilon, \; v_i \geq \varepsilon, \forall i, r$$

where u_0 is unrestricted in sign (Cook & Seiford, 2009).

Considering the nature of the data used in this study, being that it is represented in ratio form (i.e. per 100 inhabitants), both the CCR and BCC models will be used for this research, although the use of the CCR model may be technically incorrect as shown by Hollingsworth & Smith (2003). However, this research builds upon findings of Oyerinde & Bankole (2018; 2019) which showed no significant difference between the two sets of outcomes obtained when both returns to scale models were used. Hence both models will be used for this particular study.

Table 17: Regional Data in Ratios to Population

DMU	Year	Individuals Using Internet	Individuals Using Mobile Phones	House Holds with Computers	House Holds with Internet	Adult Literacy Rates
Arab States	2010	0.243851	0.878879	0.29001	0.232158	0.705886
	2011	0.264767	0.992095	0.32822	0.285053	0.723635
	2012	0.301176	1.053982	0.34799	0.317884	0.735101
	2013	0.328239	1.10441	0.385256	0.352699	0.737778
	2014	0.362787	1.103706	0.416368	0.393087	0.743747
	2015	0.396576	1.093104	0.429814	0.438926	0.748119
	2016	0.417966	1.071321	0.432594	0.452841	0.752468
Europe	2010	0.66571	1.15018	0.718962	0.677246	0.991259
	2011	0.6777	1.16929	0.74234	0.705838	0.99195
	2012	0.69977	1.186281	0.760531	0.735699	0.992161
	2013	0.717408	1.198177	0.776394	0.760604	0.99236
	2014	0.738128	1.188474	0.777583	0.777855	0.992507
	2015	0.753289	1.181677	0.784886	0.800177	0.992685
	2016	0.779112	1.180181	0.795946	0.824782	0.992968
Sub Saharan Africa	2010	0.066549	0.453982	0.054487	0.038642	0.594201
	2011	0.082019	0.52484	0.061122	0.056485	0.610416
	2012	0.100362	0.590977	0.067181	0.074492	0.621054
	2013	0.121372	0.655498	0.069966	0.088046	0.626017
	2014	0.145319	0.707791	0.079257	0.113966	0.633275
	2015	0.175895	0.763712	0.086832	0.142042	0.63893
	2016	0.198949	0.745745	0.096419	0.162793	0.646231
World	2010	0.337062	0.906232	0.37934	0.323642	0.845641
	2011	0.363531	0.956908	0.408511	0.360708	0.845974
	2012	0.404172	0.999815	0.434492	0.405763	0.853639
	2013	0.430326	1.045377	0.458936	0.444529	0.854905
	2014	0.459529	1.070316	0.477992	0.477404	0.858093
	2015	0.491648	1.082437	0.492167	0.511062	0.860172
	2016	0.517076	1.089909	0.50448	0.534683	0.862478

Malmquist Productivity Index (MPI) measures the productivity changes along with time variations and can be decomposed into changes in efficiency and technology with a DEA like non-parametric approach. Productivity decomposition into technical change and efficiency catch-up necessitates the use of a contemporaneous version of the data and the time variants of technology in the study period. The MPI can be expressed in terms of distance function (E) as Equation (1) and Equation (2) using the observations at time t and t+1.

$$MPI_I^t = \frac{E_I^t(x^{t+1}, y^{t+1})}{E_I^t(x^t, y^t)} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

$$MPI_I^{t+1} = \frac{E_I^{t+1}(x^{t+1}, y^{t+1})}{E_I^{t+1}(x^t, y^t)} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

where $_I$ denotes the orientation of MPI model.

The geometric mean ^{G} of two MPI in Equation (1) and Equation (2) gives the Equation

$$MPI_I^G = (MPI_I^t MPI_I^{t+1})^{1/2}$$

$$= [\left(\frac{E_I^t(x^{t+1}, y^{t+1})}{E_I^t(x^t, y^t)}\right).\left(\frac{E_I^{t+1}(x^{t+1}, y^{t+1})}{E_I^{t+1}(x^t, y^t)}\right)]^{1/2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The input oriented geometric mean of MPI can be decomposed using the concept of input oriented technical change (TC) and input oriented efficiency change (EC) as given in the Equation

$$MPI_I^G = (EC_I).(TC_I^G)$$

$$= \left(\frac{E_I^{t+1}(x^{t+1}, y^{t+1})}{E_I^t(x^t, y^t)}\right).\left[\left(\frac{E_I^t(x^t, y^t)}{E_I^{t+1}(x^t, y^t)}\right).\left(\frac{E_I^t(x^{t+1}, y^{t+1})}{E_I^{t+1}(x^{t+1}, y^{t+1})}\right)\right]^{1/2} \ldots\ldots. (4)$$

The first and second terms represent the efficiency change (EC) and the technology change (TC) respectively. MPI given by Equation (3) and Equation (4) can be defined using DEA like distance function. That is, the components of MPI can be derived from the estimation of distance functions defined on a frontier technology. Färe et al. (1994) have provided the formal derivation of MPI and it is the most popular method among the various methods that have been developed to estimate a production technology (Thanassoulis, 2001; Coelli et al., 2005). By utilizing both CRS and VRS DEA frontiers to estimate the distance functions in Equation (4), the TC can be decomposed into scale efficiency (SC) and pure technical efficiency (PC) components. SC is given in equation (5) and PC is given in equation (6) (Lee et al., 2011).

$$SC$$

$$= [\frac{E_{vrs}^{t+1}(x^{t+1}, y^{t+1})/E_{crs}^{t+1}(x^{t+1}, y^{t+1})}{E_{vrs}^{t+1}(x^t, y^t)/E_{crs}^{t+1}(x^t, y^t)}.\frac{E_{vrs}^t(x^{t+1}, y^{t+1})/E_{crs}^t(x^{t+1}, y^{t+1})}{E_{vrs}^t(x^t, y^t)/E_{crs}^t(x^t, y^t)}]^{1/2} \quad \ldots\ldots. (5)$$

$$PC = \frac{E_{vrs}^{t+1}(x^{t+1}, y^{t+1})}{E_{crs}^t(x^t, y^t)} \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Conceptually, however, the mechanism for estimating changes in a DMU using DEA is intuitive as the position of a DMU changes over time and is thus measured by means of MI. The change in the position of a DMU, and the corresponding value of MI, is comprised of two components, the changes in Efficiency (EC) and changes in Technology (TC). With regards to the changes in MI, a value equal to 1 means no change in productivity, while a

value of greater than 1 or less than 1 reflects a growth or decline in productivity respectively (Samoilenko & Osei-Bryson, 2017).

An OLS regression analysis was also carried out to determine the effect of the ICT indices on Adult Literacy rates. Having previously established a predominantly positive and significant relationship in chapter 6, this is done to further strengthen findings from chapter six and discover if any of the newly investigated ICT indices has a stronger and more significant effect on adult literacy rates than individuals using internet.

7.5 Analysis

The Input-Oriented Data Envelopment Analysis was carried out to determine the relative efficiency of ICT Utilization. The Analysis was run for each year to determine the relative efficiency for each of the DMU's. Table 15 shows the summary of the results for both the Variable Returns to Scale and Constant Returns to Scale models.

Table 18: Data Envelopment Analysis Results

DMU	RTS	2010	2011	2012	2013	2014	2015	2016
Arab States	VRS	0.7657	0.8208	0.8279	0.8294	0.8261	0.8407	0.8523
	CRS	0.6136	0.6271	0.6637	0.6995	0.7532	0.817	0.8105
Europe	VRS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	CRS	0.6585	0.7294	0.7959	0.8672	0.9334	1.0000	0.9709
Sub-Saharan Africa	VRS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	CRS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
World	VRS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	CRS	0.7129	0.7601	0.8124	0.8563	0.8961	0.9477	0.9132

The choice of an Input-Oriented model is based on the theoretical assumption that the ICT Infrastructure (Input) indices are controllable and an increase or decrease in the levels of these inputs is expected to bring about a corresponding increase or decrease in the Adult Literacy levels (Output) indices respectively (Oyerinde & Bankole, 2018). Practically, however this may not be the case as effective utilization of the Inputs may or may not be properly controlled and therefore become subject to particular users and participants. Therefore, both the Constant Returns to Scale (CRS) and the Variable Returns to Scale (VRS) methods are used to enable measurement of the relative efficiency without assuming the inputs are controllable (Oyerinde & Bankole, 2018) and catering for both scenarios. Table 19 gives a more detailed DEA result where:

t-1 – Base time moment

t – New time moment

CRS (t-1) – CRS efficiency in base moment relative to base frontier

CRS (t) – CRS efficiency in analyzed moment relative to new frontier

CRSMix (t,t-1) – CRS efficiency in analyzed moment relative to base frontier

CRSMix2 (t-1,t) – CRS efficiency in base moment relative to new frontier

VRS (t-1) – VRS efficiency in base moment relative to base frontier

VRS (t) – VRS efficiency in analyzed moment relative to new frontier

The Malmquist Index Analysis was carried out using the KonSi Malmquist Index Software. Table 20 shows the outcome of the MI calculation. This software allows the calculation of the Malmquist index using three calculation methods:

i. Fixed base

ii. Adjacent base

iii. Seasonal calculation

Table 19: Detailed CRS & VRS Results

DMU	t-1	t	CRS (t-1)	CRS(t)	CRSMix (t,t-1)	CRSMix2 (t-1,t)	VRS (t-1)	VRS(t)
Arab States	2010	2011	0.6136	0.6271	0.5573	0.6906	0.7657	0.8208
	2011	2012	0.6271	0.6637	0.5997	0.6941	0.8208	0.8279
	2012	2013	0.6637	0.6995	0.6357	0.7303	0.8279	0.8294
	2013	2014	0.6995	0.7532	0.7056	0.7466	0.8294	0.8261
	2014	2015	0.7532	0.817	0.7649	0.8047	0.8261	0.8407
	2015	2016	0.817	0.8105	0.8382	0.7898	0.8407	0.8523
Europe	2010	2011	0.6585	0.7294	0.6481	0.741	1	1
	2011	2012	0.7294	0.7959	0.7191	0.8073	1	1
	2012	2013	0.7959	0.8672	0.7881	0.8757	1	1
	2013	2014	0.8672	0.9334	0.8744	0.9257	1	1
	2014	2015	0.9334	1	0.9389	0.9943	1	1
	2015	2016	1	0.9709	1.0016	0.9694	1	1
Sub Saharan Africa	2010	2011	1	1	0.9158	1.4229	1	1
	2011	2012	1	1	0.9257	1.2962	1	1
	2012	2013	1	1	0.9679	1.1998	1	1
	2013	2014	1	1	0.9369	1.2796	1	1
	2014	2015	1	1	0.9351	1.2353	1	1
	2015	2016	1	1	1.0357	1.1331	1	1
World	2010	2011	0.7129	0.7601	0.6754	0.8023	1	1
	2011	2012	0.7601	0.8124	0.7341	0.8413	1	1
	2012	2013	0.8124	0.8563	0.7782	0.894	1	1
	2013	2014	0.8563	0.8961	0.8395	0.914	1	1
	2014	2015	0.8961	0.9477	0.8882	0.9564	1	1
	2015	2016	0.9477	0.9132	0.9435	0.917	1	1

For this research the Adjacent base method is used and the results are presented in table 20. This method assumes that each time moment is selected as the base moment and the moment next to base is considered as the analysed time moment. Each moment is subsequently selected as the base moment and the one next to it as the analysed moment and so on. Calculations are performed for the following time moment pairs:

t_1 and t_2

t_2 and t_3

…

t_{n-1} *and* t_n

Which can further be represented as:

$MI(t_1t_2)\ MI(t_2t_3)\ \ldots\ MI(t_{n-1}t_n)$

Table 20: Malmquist Index Analysis Results

DMU	Base Time Moment (t - 1)	Analyzed Time Moment (t)	Efficiency Change (EC)	Pure Efficiency Change (PC)	Scale Efficiency Change (SC)	Technology Change (TC)	Malmquist Index (MI)
Arab States	2010	2011	1.022	1.072	0.953	0.889	0.908
	2011	2012	1.058	1.009	1.049	0.904	0.956
	2012	2013	1.054	1.002	1.052	0.909	0.958
	2013	2014	1.077	0.996	1.081	0.937	1.009
	2014	2015	1.085	1.018	1.066	0.936	1.015
	2015	2016	0.992	1.014	0.979	1.034	1.026
Europe	2010	2011	1.108	1	1.108	0.889	0.984
	2011	2012	1.091	1	1.091	0.904	0.986
	2012	2013	1.09	1	1.09	0.909	0.99
	2013	2014	1.076	1	1.076	0.937	1.008
	2014	2015	1.071	1	1.071	0.939	1.006
	2015	2016	0.971	1	0.971	1.032	1.002
Sub Saharan Africa	2010	2011	1	1	1	0.802	0.802
	2011	2012	1	1	1	0.845	0.845
	2012	2013	1	1	1	0.898	0.898
	2013	2014	1	1	1	0.856	0.856
	2014	2015	1	1	1	0.87	0.87
	2015	2016	1	1	1	0.956	0.956
World	2010	2011	1.066	1	1.066	0.889	0.947
	2011	2012	1.069	1	1.069	0.904	0.966
	2012	2013	1.054	1	1.054	0.909	0.958
	2013	2014	1.046	1	1.046	0.937	0.98
	2014	2015	1.058	1	1.058	0.937	0.991
	2015	2016	0.964	1	0.964	1.033	0.996

The data collected was cleaned and prepared using the easystat application and multiple simple OLS regression analysis was carried out using OLS regression analysis in Python, to determine the relationships of each of the ICT infrastructure variables with adult literacy rates. Table 21 shows the results of the multiple simple OLS regression analyses carried out. In presenting the results, only the most significant line of best fit is presented in figure 24, for all the graphs and python code please see appendix D. In presenting the results, green refers to positively significant effects, purple refers to insignificant effects and red refers to negatively significant effects. Implications are discussed further in section 7.6.1.

Table 21: OLS Regression Results

Variables	Adult Literacy Rates					
	Effect (Regular)			Effect (Standardized)	P-Value	Significance
	Effect (*b*)	SE (*b*)	95% Confidence Interval	β	P	Threshold of 5%
Individuals using Internet	2.08	0.33	1.41 to 2.76	3.32	0.000002	YES
Individuals using Mobile Phones	0.04	0.05	-0.06 to 0.14	0.07	0.39	NO
Households with Computers	0.71	0.12	0.47 to 0.95	1.28	0.000004	YES
Households with Internet	-2.09	0.34	-2.79 to -1.38	-3.69	0.000003	YES

7.6 Discussion of Findings

7.6.1 Discussion of OLS Regression Analysis

Individuals Using Internet has a positive correlation of 2.08 with Adult Literacy Rates. In other words, when Individuals Using Internet increases by one, Adult Literacy Rates increases by 2.08. This result is statistically significant. Individuals Using Internet has the most *positive* correlation with Adult Literacy Rates of all four variables in this analysis. Individuals Using Internet also has the 2nd most *absolute* effect on Adult Literacy Rates of all four variables in this analysis. The line of best fit graph is shown in figure 24. Since the *p*-value is 0.000002, there is almost a 0% chance that the 2.08 change in Adult Literacy Rates associated with Individuals Using Internet is all random. Since 0% chance is less than the selected significance level threshold of 5%, the 2.08 change in Adult Literacy Rates associated with Individuals Using Internet *is* statistically significant. There is a 95% chance that the true change in Adult Literacy Rates observed with Individuals Using Internet is between 1.41 and 2.76. This means that the outcome is 95% confident that when Individuals Using Internet increases by one, Adult Literacy Rates increases by some value between 1.41 and 2.76. However, 2.08 is the *most likely* change in Adult Literacy Rates associated with Individuals Using Internet. Furthermore, there is a 2.5% chance that the true change in Adult Literacy Rates associated with Individuals Using Internet is lower

than 1.41, and a 2.5% chance that the true change in Adult Literacy Rates associated with Individuals Using Internet is higher than 2.76. Hence, there is a 5% chance that the true change in Adult Literacy Rates associated with Individuals Using Internet is *not* between 1.41 and 2.76. Since 0.00 is outside the confidence interval from 1.41 to 2.76, 0.00 is an unlikely value. Thus, it is unlikely that the true change in Adult Literacy Rates associated with Individuals Using Internet is 0.00.

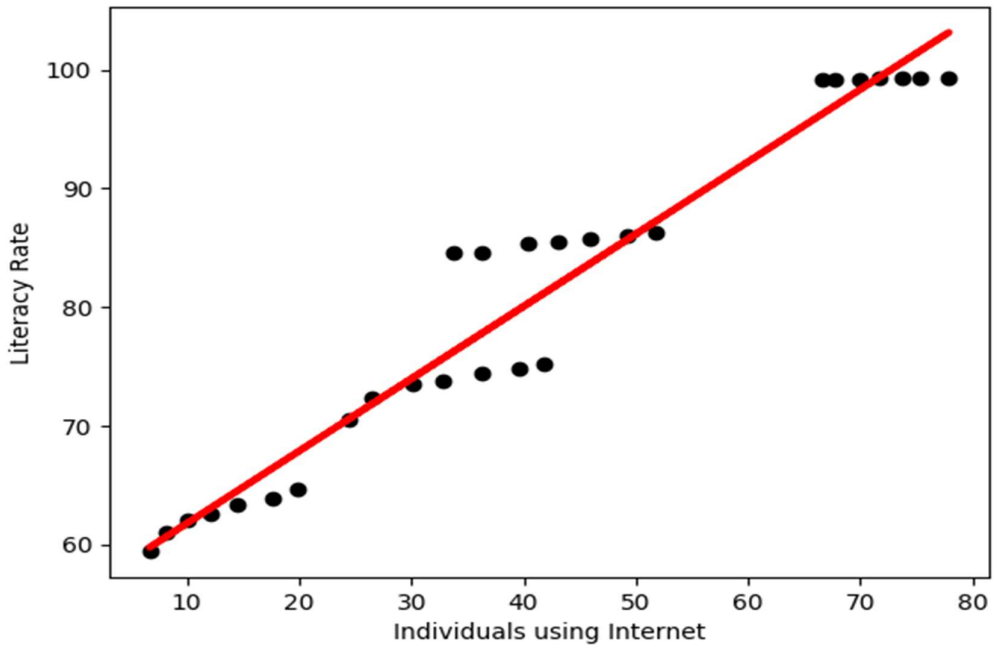

Figure 24: Line of Best-Fit for correlation of Individuals using Internet with Adult Literacy Rates

Individuals Using Mobile Phones has a positive correlation of 0.04 with Adult Literacy Rates. In other words, when Individuals Using Mobile Phones increases by one, Adult Literacy Rates increases by 0.04. However, this result is *not* statistically significant. Individuals Using Mobile Phones has the 3rd most *positive* correlation with Adult Literacy Rates of all four variables in this analysis. Individuals Using Mobile Phones also has the 4th most *absolute* correlation with Adult Literacy Rates of all four variables in this analysis. Since the *p*-value is 0.39, there is a 39% chance that the 0.04 change in Adult Literacy Rates observed with Individuals Using Mobile Phones is all random. Since 39% chance is higher than the selected significance level threshold of 5%, the 0.04 change in Adult Literacy

Rates associated with Individuals Using Mobile Phones is *not* statistically significant. There is a 95% chance that the true change in Adult Literacy Rates associated with Individuals Using Mobile Phones is between -0.06 and 0.14. This means that there is a 95% confidence level that when Individuals Using Mobile Phones increases by one, Adult Literacy Rates decreases or increases by some value between -0.06 and 0.14. Further, there is a 2.5% chance that the true change in Adult Literacy Rates associated with Individuals Using Mobile Phones is lower than -0.06, and a 2.5% chance that the true change in Adult Literacy Rates associated with Individuals Using Mobile Phones is higher than 0.14. Hence, there is a 5% chance that the true change in Adult Literacy Rates associated with Individuals Using Mobile Phones is *not* between -0.06 and 0.14. Since 0.00 is inside the confidence interval from -0.06 to 0.14, 0.00 is a likely value. Thus, it is likely that the true change in Adult Literacy Rates associated with Individuals Using Mobile Phones is 0.00.

Households with Computers has a positive correlation of 0.71 with Adult Literacy Rates. In other words, when Households with Computers increases by one, Adult Literacy Rates increases by 0.71. This result is statistically significant. Households with Computers has the 2nd most *positive* correlation with Adult Literacy Rates of all four variables in this analysis. Households with Computers also has the 3rd most *absolute* correlation with Adult Literacy Rates of all four variables in this analysis. Since the *p*-value is 0.000004, there is almost a 0% chance that the 0.71 change in Adult Literacy Rates observed with Households with Computers is all random. Since 0% chance is less than the selected significance level threshold of 5%, the 0.71 change in Adult Literacy Rates associated with Households with Computers *is* statistically significant. There is a 95% chance that the true change in Adult Literacy Rates associated with Households with Computers is between 0.47 and 0.95. This means that there is a 95% confidence level that when House Holds with Computers increases by one, Adult Literacy Rates increases by some value between 0.47 and 0.95. However, 0.71 is the *most likely* change in Adult Literacy Rates associated with Households with Computers. Further, there is a 2.5% chance that the true change in Adult Literacy Rates associated with Households with Computers is lower than 0.47, and a 2.5% chance that the true change in Adult Literacy Rates associated with Households with Computers is higher than 0.95. Hence, there is a 5% chance that the true change in Adult Literacy Rates associated with Households with Computers is *not* between 0.47 and 0.95. Since 0.00 is outside the confidence

interval from 0.47 to 0.95, 0.00 is an unlikely value. Thus, it is unlikely that the true change in Adult Literacy Rates observed with Households with Computers is 0.00.

Households with Internet has a negative correlation of -2.09 with Adult Literacy Rates. In other words, when House Holds with Internet increases by one, Adult Literacy Rates decreases by -2.09. This result is statistically significant and is very interesting. Households with Internet has the most *negative* correlation with Adult Literacy Rates of all four variables in this analysis. Households with Internet also has the most *absolute* correlation with Adult Literacy Rates of all four variables in this analysis. The line of best fit graph is shown in figure 25. Since the *p*-value is 0.000003, there is almost a 0% chance that the -2.09 change in Adult Literacy Rates observed with Households with Internet is all random. Since 0% chance is less than the selected significance level threshold of 5%, the -2.09 change in Adult Literacy Rates associated with Households with Internet *is* statistically significant. There is a 95% chance that the true change in Adult Literacy Rates associated with Households with Internet is between -2.79 and -1.38. This means that there is a 95% level of confidence that when Households with Internet increases by one, Adult Literacy Rates decreases by some value between -2.79 and -1.38. However, -2.09 is the *most likely* change in Adult Literacy Rates associated with Households with Internet. Further, there is a 2.5% chance that the true change in Adult Literacy Rates observed with Households with Internet is lower than -2.79, and a 2.5% chance that the true change in Adult Literacy Rates associated with Households with Internet is higher than -1.38. Hence, there is a 5% chance that the true change in Adult Literacy Rates associated with Households with Internet is *not* between -2.79 and -1.38. Since 0.00 is outside the confidence interval from -2.79 to -1.38, 0.00 is an unlikely value. Thus, it is unlikely that the true change in Adult Literacy Rates associated with Households with Internet is 0.00.

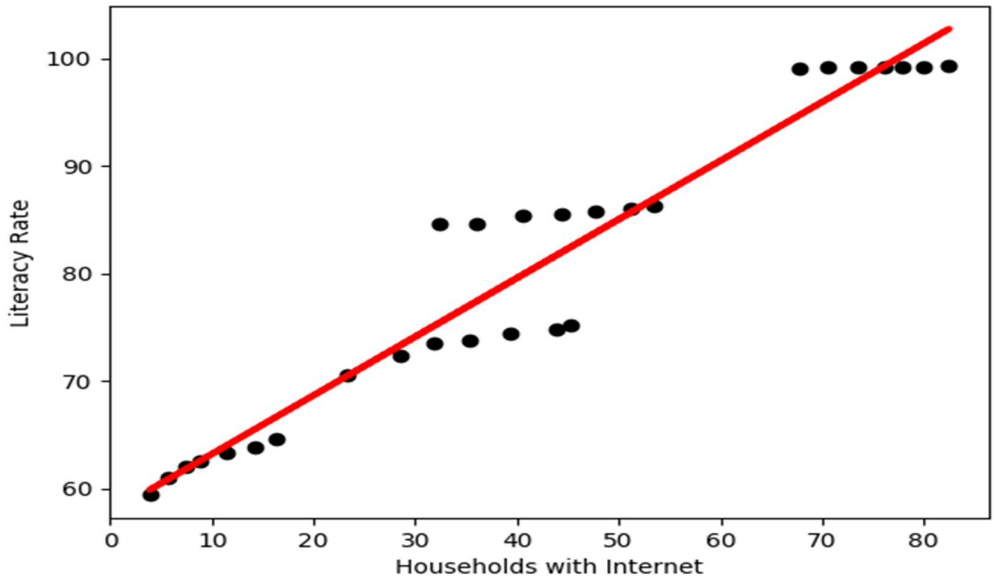

Figure 25: Line of Best-Fit for correlation of Households with Internet with Adult Literacy Rates

7.6.2 Discussion of DEA Analysis

The result of the analysis shows that using both the CRS and VRS methods of the Input Oriented Data Analysis Model, the regions being researched seem to be using their ICT infrastructure relatively efficiently, with respect to the educational component of the HDI and within the context of this research. There has been a marginal increase from 2010 to 2016 in the relative efficiencies of ICT infrastructure utilization in education for the regions being investigated. The Europe, Sub-Saharan Africa and World regions show an optimal relative efficiency score using the VRS model with the Arab States being the least relatively efficient. With the CRS, however, only Sub-Saharan Africa has optimal relative efficiency although the others still have a decent relative efficiency score. From the research, it is interesting to see that from 2010 to 2016 all regions being investigated show a steady increase in relative efficiency from year to year as seen in Table 16. This can mean that there is a steady growth in the ICT infrastructure utilization efforts for education in the regions, as the literature has shown that there has been a steady increase in the call for increased investments in ICT by countries, in order to aid socio-economic development. This is obviously based on the

premise that increased investments in ICT will bring about an increase in national development. This premise has been the core of national ICT policy direction over the years. This supports the notion that should there be in increase in ICT infrastructure in these regions it may, amongst other factors, aid in yielding an increase in adult literacy rates, if efficiently utilized within the education sector. An increase in adult literacy rates will bring about an increase in quality of life and human development with respect to the Nations HDI (Oyerinde & Bankole, 2018). Table 22 shows the average Relative Efficiency and MI values for the years of study.

Table 22: Relative Efficiency & Malmquist Index Values

DMU	Relative Efficiency		Malmquist Index
	VRS	CRS	
Arab States	0.8233	0.7121	0.9787
Europe	1.0000	0.8508	0.9960
Sub-Saharan Africa	1.0000	1.0000	0.8712
World	1.0000	0.8427	0.9730

7.6.3 Discussion of MPI Analysis

In measuring Productivity, this research has been able to show that during the years of study there has also been a steady yearly increase in productivity across all regions. However, there is still opportunity for continuous growth in productivity as the values show that on average, the regions are still operating in a declining state of productivity. It can be seen in Table 17 that the Arab states and Europe have moved into a state of growth in productivity from 2013, with Sub-Saharan Africa and the World still yet to score above 1.0000 MI productivity values, in spite of showing a steady increase in productivity scores.

These results may prove useful for policy makers and potential donors to the Sub-Saharan region for example, as it can be seen that the region is optimally relatively efficient in its utilization of ICT infrastructure for education. However, there is a big opportunity here for growth in its productivity in order to increase its HDI. Calls for increased investments in ICT for education can therefore be justified and a strong case made for digital inclusion in education. Sustained investments and educational policies with regards to ICT infrastructure

utilization in Europe, for example, can be justified to enable more digital inclusive models be developed and employed.

7.7 Limitations

The main limitation of this study is the availability of the data for the dataset. The data was collected from the United Nations Educational, Scientific and Cultural Organization (UNESCO) - educational attainments; World bank - literacy rates and the International Telecommunication Union (ITU) - individuals with computers, internet and mobile phones. Considering that the years being investigated are the most recent and the sources of the data are credible and well cited sources for scientific data collection, it was disappointing that some countries within each region did not have data available for one or more of the years being investigated. This necessitated collecting the data that was available for the regional groupings. Having the raw data for the individual countries within the regions would have allowed for a more individualistic analysis, which would have shown not only how the regions compare amongst themselves, but also how constituent countries fare in relation to each other.

7.8 Conclusions

The research has been able to contribute to the global discourse on the use and application of Learning Analytics. It has shown that LA can be used to measure efficiency and productivity of ICT infrastructure utilization thereby enabling decision makers and policy makers to make more informed decisions and policies regarding the educational component of the HDI vis a vis ICT infrastructure investments and utilizations. The research has also been able to show that ICT Infrastructure has a strong and significant positive correlation with Adult Literacy Rates. This is shown with individuals using the Internet having the most positive and significant relationship and that, surprisingly, households with Internet has the most negative and significant relationship with Adult Literacy Rates. These results provide validation of the premise behind this research as well as providing a strong basis for the justification of an increase in ICT infrastructure investments and efficient utilization, for socio-economic growth and development. Again, these results also provide an interesting disposition towards

the impact of ICT in the ICT4D discourse, with the prevailing assumptions being that Internet access has mostly a positive effect on national development.

While acknowledging that DEA as a methodology is context specific and by its very nature of being non-parametric, does not allow for generalization, the research has been able to provide a means of not only measuring the relative efficiency but also of being able to investigate productivity as well. An area of future research would be to incorporate soft ICT infrastructure as suggested in chapter 6 as well in order to enhance the scope of the model and present further insights into the investigation.

The next chapter introduces the concept of Public Value (PV) to this discussion. Chapter 8 seeks to determine if any public value is created through the use of ICT, by expanding the scope of the previous efficiency and productivity assessment research to include PV indicators.

7.9 References

Abbott, M., & Doucouliagos, C. (2003). The efficiency of Australian universities: a data envelopment analysis. *Economics of Education review*, *22*(1), 89-97.

Afonso, A., & Aubyn, M. S. (2005). Non-parametric approaches to education and health efficiency in OECD countries. *Journal of applied economics*, *8*(2), 227-246.

Afonso, A., & Aubyn, M. S. (2006a). Cross-country efficiency of secondary education provision: A semi-parametric analysis with non-discretionary inputs. *Economic modelling*, *23*(3), 476-491.

Afonso, A., & St Aubyn, M. (2006b). Relative efficiency of health provision: A DEA approach with non-discretionary inputs. *ISEG-UTL economics working paper*, (33).

Agasisti, T., & J. Johnes. (2009). Beyond Frontiers: Comparing the Efficiency of Higher Education Decision-Making Units Across More Than One Country. *Education Economics* 17: 59-79.

Anand, S., & Ravallion, M. (1993). Human Development in Poor Countries: On the Role of Private Incomes and Public Services. *The Journal of Economic Perspective*, *7*(1), 133–150.

Arcelus, F. J., & Coleman, D. F. (1997). An efficiency review of university departments. *International Journal of Systems Science*, *28*(7), 721-729.

Aristovnik, A. (2012). The impact of ICT on educational performance and its efficiency in selected EU and OECD countries: a non-parametric analysis. Available at SSRN: https://ssrn.com/abstract=2187482 or http://dx.doi.org/10.2139/ssrn.2187482

Arjomandi, A., Salleh, M. I., & Mohammadzadeh, A. (2015). Measuring productivity change in higher education: an application of Hicks–Moorsteen total factor productivity index to Malaysian public universities. *Journal of the Asia Pacific Economy*, *20*(4), 630–643. https://doi.org/10.1080/13547860.2015.1045323

Athanassapoulos, A., & E. Shale. 1997. Assessing the Comparative Efficiency of Higher Education. *Education Economics 5:* 117_134.

Avgerou, C. (2010). Discourses on ICT and development. *Information Technologies & International Development*, *6*(3), pp-1.

Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management science*, *30*(9), 1078-1092.

Bankole Dr, F., & Mimbi, L. (2017). ICT Infrastructure and It's Impact on National Development: A Research Direction for Africa. *The African Journal of Information Systems*, *9*(2), 1.

Bankole, F. O., Shirazi, F., & Brown, I. (2011). Investigating the impact of ICT investments on human development. *The Electronic Journal of Information Systems in Developing Countries*, *48*(1), 1-19.

Bankole, F. O., & Bankole, O. O. (2017). The effects of cultural dimension on ICT innovation: Empirical analysis of mobile phone services. *Telematics and Informatics*, *34*(2), 490-505.

Bankole, F. O., Osei-Bryson, K. M., & Brown, I. (2015). The impacts of telecommunications infrastructure and institutional quality on trade efficiency in Africa. *Information Technology for Development*, *21*(1), 29-43.

Bankole, F., & Assefa, Z. (2017). Improving the Quality of Education and Research Output In Africa A Case of Ethiopian Education and Research Network (ETHERNET). *The Journal of Applied Global Research*, *10*(24), 31-51.

Bessent, A. M., Bessent, E. W., Charnes, A., Cooper, W. W., & Thorogood, N. C. (1983). Evaluation of educational program proposals by means of DEA. *Educational Administration Quarterly*, *19*(2), 82-107.

Bollou, F. (2006). ICT Infrastructure Expansion in Sub-Saharan Africa: An Analysis of Six West African Countries from 1995 to 2002. *The Electronic Journal of Information Systems in Developing Countries*, *26*(1), 1-16.

Bradley, S., Johnes, J., & Little, A. (2010). Measurement and determinants of efficiency and productivity in the further education sector in England. *Bulletin of Economic Research*, *62*(1), 1-30.

Brown, W., & Brown, I. (2008, September). Next generation ICT policy in South Africa: Towards a human development-based ICT policy. In *IFIP International Conference on Human Choice and Computers* (pp. 109-123). Springer, Boston, MA.

Carrington, R., T. Coelli, & D.S.P. Rao. (2005). The Performance of Australian Universities: Conceptual Issues and Preliminary Results. *Economic Papers* 24: 145-163.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision-making units. *European journal of operational research*, *2*(6), 429-444.

Clements, B. (2002). How efficient is education spending in Europe? *European Review of Economics and Finance, 1: 3-26*.

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). *An introduction to efficiency and productivity analysis*. Springer Science & Business Media.

Cook, W. D., & Seiford, L. M. (2009). Data envelopment analysis (DEA)–Thirty years on. *European journal of operational research*, *192*(1), 1-17.

Cook, W. D., Tone, K., & Zhu, J. (2014). Data envelopment analysis: Prior to choosing a model. *Omega*, *44*, 1-4.

Dedrick, J., Gurbaxani, V., & Kraemer, K. L. (2003). Information technology and economic performance: A critical review of the empirical evidence. *ACM Computing Surveys (CSUR)*, *35*(1), 1-28.

Desai, M. (1991). Human development: concepts and measurement. *European Economic Review*, *35*(2-3), 350-357.

Despotis, D. K. (2005). Measuring human development via data envelopment analysis: the case of Asia and the Pacific. *Omega*, *33*(5), 385-390.

Draca, M., Sadun, R., & Van Reenen, J. (2006). Productivity and ICT: A Review of the Evidence. In R. Mansell, C. Avgerou, D. Quah, & R. Silverstone (Eds.), *The Oxford handbook of information and communication technologies pp. 100–147*. Oxford: Oxford University Press.

Emrouznejad, A., & E. Thanassoulis. (2005). A Mathematical Model for Dynamic Efficiency Using Data Envelopment Analysis. *Applied Mathematics and Computation* 160: 363_378

Emrouznejad, A., Banker, R. D., & Neralic, L. (2019). Advances in Data Envelopment Analysis: Celebrating the 40th anniversary of DEA and the 100th anniversary of Professor Abraham Charnes' birthday. *European Journal of Operational Research*, *278*(2), 365-367.

Färe, R., Grosskof, S., Norris, M., & Zhang, Z. (1994). Productivity Growth, technical progress and efficiency change in industrial countries. *Am Econ Rev.* 84(1): 66-83.

Flegg, A.T., D.O. Allen, K. Field, & T.W. Thurlow. 2004. Measuring the Efficiency of British Universities: A Multi-Period Data Envelopment Analysis. *Education Economics* 12: 231-249.

Gülbahar, Y., (2008). ICT usage in higher education: a case study on preservice teachers and instructors, *The Turkish Online Journal of Educational Technology, 7(1)*: 32-37.

Gupta, S., & Verhoeven, M. (2001). The efficiency of government expenditure: experiences from Africa. *Journal of policy modeling*, *23*(4), 433-467.

Hinostroza, J. E., Isaacs, S., & Bougroum, M. (2014). Information and communications technologies for improving learning opportunities and outcomes in developing countries. *In Learning and education in developing countries:Research and policy for the post-2015 UN development goals* (pp. 42-57). Palgrave Pivot, New York.

Hinostroza, J. E. (2018). New Challenges for ICT in Education Policies in Developing Countries: The Need to Account for the Widespread Use of ICT for Teaching and Learning Outside the School. In *ICT-Supported Innovations in Small Countries and Developing Regions* (pp. 99-119). Springer, Cham.

Hollingsworth, B., & Smith, P. (2003). Use of ratios in data envelopment analysis. *Applied Economics Letters*, *10*(11), 733-735.

Jeremic, V., Markovic, A., & Radojick, Z. (2011). ICT as Crucial Component of Socio-economic Development. *Management (1820-0222)*, (60).

Johnes, J. (2006). Data envelopment analysis and its application to the measurement of efficiency in higher education. *Economics of Education Review*, *25*(3), 273-288.

Johnes, J. (2008). Efficiency and Productivity Change in the English Higher Education Sector from 1996/97 to 2004/5. *Manchester School* 76: 653_674.

Johnes, J., & Li, Y. U. (2008). Measuring the research performance of Chinese higher education institutions using data envelopment analysis. *China economic review*, *19*(4), 679-696.

Kayisire, D., & Wei, J. (2016). Information Technology for Development ICT Adoption and Usage in Africa : Towards an Efficiency Assessment, *1102*. https://doi.org/10.1080/02681102.2015.1081862

Kleesuwan, S., Mitatha, S., Yupapin, P. P., & Piyatamrong, B. (2010). Business intelligence in Thailand's higher educational resources management. *Procedia-Social and Behavioral Sciences*, *2*(1), 84-87.

Ko, M., & Osei-Bryson, K. M. (2004). Using regression splines to assess the impact of information technology investments on productivity in the health care industry. *Information Systems Journal*, *14*(1), 43-63.

Lee, K. R., Leem, B., Lee, C. W., & Lee, C. (2011). Malmquist Productivity Index using DEA frontier in Stata. *Stata Journal*, *2*(2), 1-9.

Liu, J. S., Lu, L. Y., Lu, W. M., & Lin, B. J. (2013a). Data envelopment analysis 1978–2010: A citation-based literature survey. *Omega*, *41*(1), 3-15.

Liu, J. S., Lu, L. Y., Lu, W. M., & Lin, B. J. (2013b). A survey of DEA applications. *Omega*, *41*(5), 893-902.

Mann, C. L. (2003). Information technologies and international development: conceptual clarity in the search for commonality and diversity. *Information Technologies & International Development*, *1*(2), pp-67.

Meeusen, W., & van Den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composed error. *International economic review*, 435-444.

Mimbi, L., & Bankole, F. O. (2016). ICT and public service value creation in Africa: Efficiency assessment using DEA approach.

Ngwenyama, O., & Morawczynski, O. (2009). Factors affecting ICT expansion in emerging economies: An analysis of ICT infrastructure expansion in five Latin American countries. *Information technology for development*, *15*(4), 237-258.

Ngwenyama, O., Andoh-Baidoo, F. K., Bollou, F., & Morawczynski, O. (2006). Is there a relationship between ICT, health, education and development? An empirical analysis of five West African countries from 1997–2003. *The Electronic Journal of Information Systems in Developing Countries*, *23*(1), 1-11.

Oyerinde, O. D., & Chia, P. A. (2017). Predicting students' academic performances–A learning analytics approach using multiple linear regression. *International Journal of Computer Applications*, *157*(4).

Oyerinde, Y., & Bankole, F. (2018). Influence of Constant Returns to Scale and Variable Returns to Scale Data Envelopment Analysis Models in ICT Infrastructure Efficiency Utilization. *In Proceedings of the 11th Annual Pre-ICIS SIG GlobDev Workshop, San Francisco, USA, Thursday December 13, 2018*

Oyerinde, Y. & Bankole, F. (2019). Investigating the Efficiency of ICT Infrastructure Utilization: A Data Envelopment Analysis Approach. *In: Nielsen P., Kimaro H. (eds) Information and Communication Technologies for Development. Strengthening Southern-Driven Cooperation as a Catalyst for ICT4D.* ICT4D 2019. IFIP Advances in Information and Communication Technology, vol 551. Springer, Cham

Papamitsiou, Z., & Economides, A. A. (2014). Learning analytics and educational data mining in practice: A systematic literature review of empirical evidence. *Journal of Educational Technology & Society*, *17*(4), 49-64.

Samoilenko, S., & Osei-Bryson, K. M. (2013). Using Data Envelopment Analysis (DEA) for monitoring efficiency-based performance of productivity-driven organizations: Design and implementation of a decision support system. *Omega*, *41*(1), 131-142.

Samoilenko, S. V., & Osei-Bryson, K. M. (2017). Creating Theoretical Research Frameworks Using Multiple Methods: Insight from ICT4D Investigations. Auerbach Publications.

Samoilenko, S., & Osei-Bryson, K. M. (2018). An analytical framework for exploring context-specific micro-economic impacts of ICT capabilities. *Information Technology for Development*, *24*(4), 633-657.

Sarker, S., Valacich, J. S., & Sarker, S. (2005). Technology adoption by groups: A valence perspective. *Journal of the Association for Information Systems*, *6*(2), 3.

Sarker, S., & Valacich, J. S. (2010). An alternative to methodological individualism: a non-reductionist approach to studying technology adoption by groups. *Mis Quarterly*, *34*(4), 779-808.

Schutz, D. (2009). Educational Intelligence: Bringing Schools into the 21st Century. *Available at SSRN 1336243*.

Sein, M. K., & Harindranath, G. (2004). Conceptualizing the ICT artifact: Toward understanding the role of ICT in national development. *The information society*, *20*(1), 15-24.

Sia, C. L., Lee, M. K., Teo, H. H., & Wei, K. K. (2001). Information instruments for creating awareness in IT innovations: An exploratory study of organizational adoption intentions of ValuNet. *Electronic markets*, *11*(3), 206-215.

Sia, C. L., Teo, H. H., Tan, B. C., & Wei, K. K. (2004). Effects of environmental uncertainty on organizational intention to adopt distributed work arrangements. *IEEE Transactions on Engineering Management*, *51*(3), 253-267.

Sinuany-Stern, Z., Mehrez, A., & Barboy, A. (1994). Academic departments efficiency via DEA. *Computers & Operations Research*, *21*(5), 543-556.

St. Aubyn, M. (2002). Evaluating efficiency in the Portuguese health and education sectors. *Economia, Vol. 26*. Available at SSRN: https://ssrn.com/abstract=504942

Thanassoulis, E. (2001). Introduction to the theory and application of data envelopment analysis. Dordrecht: Kluwer Academic Publishers.

Thanassoulis, E., Kortelainen, M., Johnes, G., & Johnes, J. (2011). Costs and efficiency of higher education institutions in England: A DEA analysis. *Journal of the Operational Research Society, 62*, 1282–1297.

Tondeur, J., van Braak, J., & Valcke, M. (2007). Towards a typology of computer use in primary education. *Journal of Computer Assisted Learning, 23,* 197-206.

UNDP: United Nations Development Programme. Human development report 2000. (2000). Oxford: Oxford University Press. http://www.undp.org/hdr2000/english/HDR2000.htm

UNDP: United Nations Development Programme. (2006). The Millennium Development Goals. *UNDP*.

Venkatesh, V., Thong, J. Y., & Xu, X. (2016). Unified theory of acceptance and use of technology: A synthesis and the road ahead. *Journal of the Association for Information Systems*, *17*(5), 328-376.

Worthington, A.C., & Lee, B.L. (2008). Efficiency, Technology and Productivity Change in Australian Universities, 1998_2003. *Economics of Education Review* 27: 285-298.

CHAPTER 8

8.0 Creating Public Value Using ICT: An Efficiency And Productivity Assessment

8.1 Introduction

Many governments have heeded the call for increased investments in ICT with the aim of improving national development with respect to the Human Development Index (HDI). As such, the growth of Information and Communication Technology (ICT) in recent years has been remarkable in all countries and sectors throughout the world, mainly because of its perceived transformational power which favours productivity and efficiency (Kayisire & Wei, 2016). This is based on the assumption that increasing investments in ICT will lead to improvements in productivity and other aspects of development at the organizational and national levels (Samoilenko & Osei-Bryson, 2017a). It is therefore not a surprise that over the last three decades, research in national development has been expanded to certain intervening variables and social factors such as education (Desai, 1991; Anand & Ravallion, 1993; Bankole & Mimbi, 2017) as education has been determined to be important for social and economic development (Bankole & Assefa, 2017).

While striving to increase socio-economic development, governments have understood the importance of public sector reform in this regard. The objective of public sector reform since its inception has been focused on innovative ways of bringing about socio-economic development (Mimbi & Bankole, 2016a). Performance management is the concept of the New Public Management (NPM) that has its roots in the agenda of continuously doing better in public administration (Van Dooren et al., 2015). Public value is fundamental in public administration to ensure citizen satisfaction and trust (Moore, 1995; Ott, 2010). The increased pressure from the citizenry for public value has contributed to the adoption of an entrepreneurial approach to governance (Blaug et al., 2006). Consequently, under the banner

of New Public Management (NPM), reinventing governments has been touted as a solution to many government inefficiency related challenges (Mimbi & Bankole, 2016).

ICT as enabler of public sector reforms has been implemented to reinvent governments for improved performance (Bannister & Connolly 2014; Gauld et al., 2010). In a similar way, ICT is touted as having the potential to create public value (Bannister & Connolly, 2014). With respect to education, and in line with incorporating the use of ICT for improved efficiency, governments are, more than ever before, defining policies that show an emphasis on creating support mechanisms for the use of ICT in education, whether it be in teaching and learning or in decision and policy making. However, the discourse on how ICT Infrastructure bears on development has two major perspectives with respect to national development: The adoption of ICTs has the potential to empower communities and countries while secondly, the ICT revolution can lead to imbalances and inequalities through lack of ICT adoption, access and usage (Bankole, 2015), whichever perspective is held, the use of ICT continues to be an increasing factor in public interactions and public service rendering.

Therefore, certain questions arise with respect to whether this increasing use of ICT brings any corresponding value to the public and to the rendering of public service. Most of the research in the area of Information Systems and value creation has focused mainly on business (private) values. Value creation in private organisations is different from that of public organisations. In private organisations, value creation is normally premised on economic value such as Return On Investment (ROI) while in public organisations, being non-profit making entities, the focus is on public value creation (Pang et al., 2014; Moore, 1995). International bodies and researchers have recognised the importance of ICT in public administration in creating public value. For example, the World Public Sector Report (WPSR) produced by the United Nations emphasises that ICT should be harnessed in public services to achieve socioeconomic development. Importantly, it emphasises that ICT should be a tool for creating public value (WPSR, 2015).

In this research, the investigation is on the efficiency and productivity of ICT Infrastructure utilization in public value creation with respect to education. This is done by analysing the data of ICT, public values, and adult literacy rates using Data Envelopment Analysis (DEA) and Malmquist Index (MI). The Malmquist productivity index is considered the most appropriate tool for measuring changes in efficiency and productivity (Arjomandi et al., 2015). This research explores further the findings from the Mimbi & Bankole (2016a) and

Oyerinde & Bankole (2018) researches. The concept of PV is introduced at this point in the research, having established the predominantly positive and significant correlation between ICT infrastructure and the educational indices, most especially adult literacy rates, of the educational component of the HDI. With this in mind, the objective is to determine, using an efficiency and productivity assessment methodology, whether PV is created within this context, based on the previously discussed PV indicators from chapter 2.

The rest of the chapter is organized as follows: section 8.2 provides the background, section 8.3 discusses the theoretical framework, section 8.4 provides the research methodology, section 8.5 provides the data analysis, section 8.6 provides the discussion of findings, section 8.7 the limitations and section 8.8 the conclusion.

8.2 Background

The concept of public value (PV) can be traced from the new public service theory. PV has been influential in public services reform initiatives since the mid-nineties. This concept is linked to the seminal work of Moore (1995). Public value refers to value that citizens and their representatives seek in relation to strategic outcomes and experience of public services (Moore, 1995). Public value also refers to the value created by government through services, laws regulation and other actions (Kelly et al., 2002). Public value focuses on performance evaluation of public organisations in delivery of services (social outcomes) as desired by the collective (Mimbi & Bankole, 2016b). Brewer et al. (2006) argue that ICT public value creation as a priority refers to embracing the information revolution as a means of improving governance and enhancing the democratic process. ICT PV creation therefore focuses on the wider notions of valued public services and efficiency that call for more accountability of public managers (Blaug et al., 2006).

With performance management being one of the growing research areas in Computer Information Systems and Public Administration, there seems to be a resultant growth, particularly in governments, driven by increased citizen demands for government accountability in service delivery (Mimbi & Bankole, 2016a). It has therefore become important to determine the efficiency of governments in converting inputs into outputs and measuring the resultant productivity over time. ITU (2006) contends that the best way to examine ICT impact is to assess its efficiency in producing outputs. This means that ICT is an

input which is used to produce output (public values). Efficiency is a measure of how well the government resources are utilised to achieve specific goals (Neely et al., 1995), while productivity is essentially a study of how this efficiency changes over a period of time.

Mimbi & Bankole (2016) have shown that ICT value creation is a performance (efficiency) phenomenon that can be analysed using the DEA methodology. DEA is appropriate where the objective of the investigation is to evaluate efficiency of a production organisation, or of regional groupings, as shown by Oyerinde & Bankole (2019), in which inputs are converted into final outputs (Saranga & Moser, 2010). Since ICT and public value represent input and output respectively, then DEA is an appropriate methodology to analyse the present phenomenon. As such, DEA provides performance managers with a comprehensive measurement that enables them to take strategic actions on DMUs performance that lag behind the others (Easton et al., 2002). Many researchers have investigated efficiency using DEA (Bankole et al., 2011a; Bankole et al., 2011b; Kayisire & Wei 2015; Mimbi & Bankole 2016a; Oyerinde & Bankole 2018). Furthermore, it is possible to assess the efficiency productivity over time to determine whether or not there is any growth as shown by Oyerinde & Bankole (2019).

8.3 Research Methodology

For this study, time series data from the United Nations Educational, Scientific and Cultural Organization (UNESCO); adult literacy rates, the International Telecommunication Union (ITU); individuals with computers, internet and mobile phones as well as World Bank; governance indicators (control of corruption, government effectiveness, regulatory quality and rule of law) have been obtained as shown in Table 23. These sources are used as this research is in furtherance of the Mimbi & Bankole (2016a) study which has categorized public value into: duty oriented public value; socially oriented public value; and service oriented public value, and the Oyerinde & Bankole (2019) research which has investigated efficiency and productivity of ICT Infrastructure Utilization. Available data has been collected and aggregated into the following regional groupings: Arab States, Europe, Sub-Saharan Africa and World regional aggregates. This was done in order to mitigate against some of the limitations presented in chapter 6 on the availability of data. ITU already had ICT indicators data in these groupings and made the need for extrapolation reduced. These form the four Decision Making Units (DMU's). Data for the years 2010-2016 has been collected in

percentages of the country population, with the ratio values computed annually as shown in Table 24. Data Envelopment Analysis and Malmquist Index methodologies are employed to calculate the Relative Efficiency and Productivity of the regions, respectively.

Table 23: Input/Output Variables

S/N	VALUE / DIMENSION	INPUT / OUTPUT
1	ICT Infrastructure	Individuals Using Mobile Phones (I)
		Households with Computers (I)
		Individuals Using Internet (I)
2	Duty Oriented Public Value	Voice and Accountability (O)
3	Service Oriented Public Value	Government Effectiveness (O)
		Press Freedom (O)
4	Socially Oriented Public Value	Rule of Law (O)
		Control of Corruption (O)
5	Education	Adult Literacy Rates (O)

DEA is a well-known non-parametric linear programming method for measuring the relative efficiency (Thanassoulis et al., 2011; Bankole et al., 2011a). DEA is a data-oriented method for evaluating the performance (efficiency) of entities known as Decision Making Units (DMUs) (Bankole et al., 2011a) which uses input-output data to compute an efficient production frontier produced by the most efficient DMU's (Bollou, 2006; Oyerinde & Bankole, 2018). DEA, unlike a parametric method, is context specific with respect to the interpretations of the results of the analysis, which are restricted to the sample and should not be generalized beyond the sample (Samoilenko & Osei-Bryson, 2017b). DEA, therefore, can then be viewed as a multiple-criteria evaluation methodology where DMUs are alternatives, and DEA inputs and outputs are two sets of performance criteria where one set (inputs) is to be minimized and the other (outputs) is to be maximized (Cook et al., 2014). In DEA, these multiple criteria are generally modelled as in a ratio form, e.g., the CCR ratio model (Charnes et al., 1978; Cook et al., 2014) which is expressed as:

Maximise:

$$h_0 = \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i x_{i0}}$$

Subject to:

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1$$

Where:

$$j = 1, \ldots, n, v_r v_i \geq 0; r = 1, \ldots, s; i = 1, \ldots, m.$$

where x_{ij} and y_{rj} represents DEA inputs and outputs of the jth DMU, and u_r ,$v_i \geq 0$ are unknown variable weights to be determined by the solution of the problem (Charnes et al., 1978).

Table 24: Regional Data Collected

Region	Year	Individuals Using Internet	Individuals Using Mobile Phones	Households with Computers	Voice and Accountability	Governance Effectiveness	Press Freedom	Rule of Law	Control of Corruption	Adult Literacy Rates
Arab States	2010	0.2439	0.8789	0.2900	-1.0666	-0.3043	0.3071	-0.3255	-0.3537	0.7059
	2011	0.2648	0.9921	0.3282	-1.0467	-0.3548	0.3343	-0.3880	-0.3918	0.7236
	2012	0.3012	1.0540	0.3480	-0.9841	-0.3941	0.3343	-0.3891	-0.3936	0.7351
	2013	0.3282	1.1044	0.3853	-1.0119	-0.4057	0.3262	-0.4144	-0.3966	0.7378
	2014	0.3628	1.1037	0.4164	-1.0109	-0.4291	0.3176	-0.4193	-0.4566	0.7437
	2015	0.3966	1.0931	0.4298	-1.0270	-0.4478	0.3043	-0.4557	-0.4672	0.7481
	2016	0.4180	1.0713	0.4326	-1.0200	-0.4970	0.2957	-0.5030	-0.4817	0.7525
Europe	2010	0.6657	1.1502	0.7190	0.7002	0.7306	0.6796	0.6940	0.5829	0.9913
	2011	0.6777	1.1693	0.7423	0.6877	0.7333	0.6776	0.6968	0.5891	0.9920
	2012	0.6998	1.1863	0.7605	0.6958	0.7588	0.6736	0.6983	0.6093	0.9922
	2013	0.7174	1.1982	0.7764	0.6840	0.7765	0.6690	0.7042	0.6131	0.9924
	2014	0.7381	1.1885	0.7776	0.6826	0.8077	0.6628	0.7752	0.6207	0.9925
	2015	0.7533	1.1817	0.7849	0.6905	0.7945	0.6582	0.7404	0.6241	0.9927
	2016	0.7791	1.1802	0.7959	0.6630	0.7832	0.6548	0.7249	0.6316	0.9930
Sub-Saharan Africa	2010	0.0665	0.4540	0.0545	-0.5488	-0.7880	0.4267	-0.7171	-0.6346	0.5942
	2011	0.0820	0.5248	0.0611	-0.5507	-0.7552	0.4258	-0.7079	-0.6459	0.6104
	2012	0.1004	0.5910	0.0672	-0.5764	-0.7618	0.4221	-0.7073	-0.6753	0.6211
	2013	0.1214	0.6555	0.0700	-0.5720	-0.7704	0.4214	-0.7084	-0.6788	0.6260
	2014	0.1453	0.7078	0.0793	-0.4987	-0.8009	0.4226	-0.6550	-0.6818	0.6333
	2015	0.1759	0.7637	0.0868	-0.4843	-0.7922	0.4195	-0.6603	-0.6657	0.6389
	2016	0.1989	0.7457	0.0964	-0.4883	-0.8050	0.4119	-0.7059	-0.6733	0.6462
World	2010	0.3371	0.9062	0.3793	-0.0195	-0.0029	0.5264	-0.0114	-0.0005	0.8456
	2011	0.3635	0.9569	0.4085	-0.0202	-0.0012	0.5283	-0.0137	-0.0065	0.8460
	2012	0.4042	0.9998	0.4345	-0.0200	-0.0010	0.5257	-0.0130	-0.0065	0.8536
	2013	0.4303	1.0454	0.4589	-0.0196	-0.0007	0.5226	-0.0130	-0.0067	0.8549
	2014	0.4595	1.0703	0.4780	0.0084	-0.0065	0.5178	-0.0084	-0.0058	0.8581
	2015	0.4916	1.0824	0.4922	0.0084	-0.0062	0.5142	-0.0082	-0.0057	0.8602
	2016	0.5171	1.0899	0.5045	0.0084	-0.0061	0.5090	-0.0083	-0.0055	0.8625

Malmquist Productivity Index (MPI) measures the productivity changes along with time variations and can be decomposed into changes in efficiency and technology with DEA like nonparametric approach. Productivity decomposition into technical change and efficiency catch-up necessitates the use of a contemporaneous version of the data and the time variants

of technology in the study period. The MPI can be expressed in terms of distance function (E) as Equation (1) and Equation (2) using the observations at time t and t+1.

$$MPI_I^t = \frac{E_I^t(x^{t+1}, y^{t+1})}{E_I^t(x^t, y^t)} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

$$MPI_I^{t+1} = \frac{E_I^{t+1}(x^{t+1}, y^{t+1})}{E_I^{t+1}(x^t, y^t)} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

where I denotes the orientation of MPI model.

The geometric mean of two MPI in Equation (1) and Equation (2) gives the Equation

$$MPI_I^G = (MPI_I^t MPI_I^{t+1})^{1/2}$$
$$= [\left(\frac{E_I^t(x^{t+1}, y^{t+1})}{E_I^t(x^t, y^t)}\right).\left(\frac{E_I^{t+1}(x^{t+1}, y^{t+1})}{E_I^{t+1}(x^t, y^t)}\right)]^{1/2} \dots\dots\dots\dots\dots\dots\dots\dots (3)$$

The input oriented geometric mean of MPI can be decomposed using the concept of input oriented technical change (TC) and input oriented efficiency change (EC) as given in the Equation

$$MPI_I^G = (EC_I).(TC_I^G)$$
$$= \left(\frac{E_I^{t+1}(x^{t+1}, y^{t+1})}{E_I^t(x^t, y^t)}\right).\left[\left(\frac{E_I^t(x^t, y^t)}{E_I^{t+1}(x^t, y^t)}\right).\left(\frac{E_I^t(x^{t+1}, y^{t+1})}{E_I^{t+1}(x^{t+1}, y^{t+1})}\right)\right]^{1/2} \dots\dots (4)$$

The first and second terms represent the efficiency change (EC) and the technology change (TC) respectively. MPI given by Equation (3) and Equation (4) can be defined using DEA like distance function. That is, the components of MPI can be derived from the estimation of distance functions defined on a frontier technology. Färe et al. (1994) provided the formal derivation of MPI and it is the most popular method among the various methods that have been developed to estimate a production technology (Coelli et al., 2005; Thanassoulis, 2001). By utilizing both CRS and VRS DEA frontiers to estimate the distance functions in Equation (4), the TC can be decomposed into scale efficiency (SC) and pure technical efficiency (PC) components. SC is given in equation (5) and PC is given in equation (6) (Lee et al., 2011).

$$SC = \left[\frac{E_{vrs}^{t+1}(x^{t+1}, y^{t+1})/E_{crs}^{t+1}(x^{t+1}, y^{t+1})}{E_{vrs}^{t+1}(x^{t}, y^{t})/E_{crs}^{t+1}(x^{t}, y^{t})} \cdot \frac{E_{vrs}^{t}(x^{t+1}, y^{t+1})/E_{crs}^{t}(x^{t+1}, y^{t+1})}{E_{vrs}^{t}(x^{t}, y^{t})/E_{crs}^{t}(x^{t}, y^{t})}\right]^{1/2} \quad \ldots\ldots(5)$$

$$PC = \frac{E_{vrs}^{t+1}(x^{t+1}, y^{t+1})}{E_{crs}^{t}(x^{t}, y^{t})} \ldots\ldots\ldots\ldots\ldots(6)$$

Conceptually, however, the mechanism for estimating changes in a DMU using DEA is intuitive as the position of a DMU changes over time and is thus measured by means of MI. The change in the position of a DMU, and the corresponding value of MI, is comprised of two components, the changes in Efficiency (EC) and changes in Technology (TC). With regards to the changes in MI, a value equal to 1 means no change in productivity, while a value of greater than 1 or less than 1 reflects a growth or decline in productivity respectively (Samoilenko & Osei-Bryson, 2017b).

8.4 Analysis

The Input-Oriented Data Envelopment Analysis has been carried out to determine the relative efficiencies using the KonSi Malmquist Index Software. The Analysis has been run for each year to determine the relative efficiency for each of the DMU's. Table 25 shows the average efficiency results for the time period, 2010-2016, where:

t-1 – Base time moment

t – New time moment

CRS (t-1) – CRS efficiency in base moment relative to base frontier

CRS (t) – CRS efficiency in analyzed moment relative to new frontier

CRSMix (t,t-1) – CRS efficiency in analyzed moment relative to base frontier

CRSMix2 (t-1,t) – CRS efficiency in base moment relative to new frontier

VRS (t-1) – VRS efficiency in base moment relative to base frontier

VRS (t) – VRS efficiency in analyzed moment relative to new frontier

Table 25: Average Efficiency Results

REGION	CRS(t-1)	CRS(t)	CRSMix(t,t-1)	CRSMix2(t-1,t)	VRS(t-1)	VRS(t)
Arab States	0.8359	0.8246	0.7759	0.9101	0.8591	0.8418
Europe	1.0000	1.0000	1.0280	1.0521	1.0000	1.0000
Sub-Saharan Africa	1.0000	1.0000	1.0892	1.2949	1.0000	1.0000
World	1.0000	1.0000	0.9548	1.0751	1.0000	1.0000

The choice of an Input-Oriented model is based on the emphasis here on value creation with the utilization of ICT's. The input-oriented models have been adopted in measuring the efficiency of ICT utilization with respect to its desired outputs as evidenced by Mimbi & Bankole (2016a); Oyerinde & Bankole (2018). See DEA Table in Appendix C for more detailed results.

The Malmquist Index Analysis has been carried out using the KonSi Malmquist Index Software. Table 26 shows the average productivity values for the time period, 2010-2016, for the more detailed results see MI Table in Appendix C. For this research the Adjacent base method is used. This method assumes that each time moment is selected as the base moment and the moment next to base is considered as the analysed time moment. Each moment is subsequently selected as the base moment and the one next to it the analysed moment and so on. Calculations are performed for the following time moment pairs:

t_1 *and* t_2

t_2 *and* t_3

…

t_{n-1} *and* t_n

Which can further be represented as:

$MI(t_1t_2)\ MI(t_2t_3)\ \ldots\ MI(t_{n-1}t_n)$

Table 26: Average Productivity Results

REGION	EC	PC	SC	TC	MI
Arab States	0.9836	0.9746	1.0100	0.9282	0.9130
Europe	1.0000	1.0000	1.0000	0.9910	0.9910
Sub-Saharan Africa	1.0000	1.0000	1.0000	0.9188	0.9188
World	1.0000	1.0000	1.0000	0.9418	0.9418

In investigating the productivity, the classic Malmquist Index calculation model is used defined by Färe et al., (1994) and expressed as:

$MI = EC * TC = PC * SC * TC$

where:

MI - Malmquist Index

EC – Efficiency Change

TC - Technical Change

PC - Pure efficiency Change

SC - Scale efficiency Change

8.5 Discussion and Limitations

From the results of the analysis, it can be inferred that public value is being created, albeit not at optimal efficiency, with respect to Arab States. This is deduced from the average relative efficiency scores obtained and shown in Table 25. However, with regards to productivity assessments of the public value created, on the average all regions are in a state of decline of productivity and as such there is room for improvement in utilizing their ICT infrastructure with respect to public value creation. However, regardless of its efficiency, from this research it can be seen that ICT shows a potential in public value creation as suggested by many scholars (Bannister & Connolly, 2014; Jaeger & Bertot, 2010; Mimbi & Bankole, 2016). This makes a contribution to the ongoing discussion as to the impacts and effects of ICT with regards to ICT4D. This research has been able to show that regions are relatively efficiently

at creating PV with respect to education, although there is room for improvement with regards to productivity over the time period researched. This finding can provide useful information for government officials and policy makers with regards to ICT implementation and policy directions.

The main limitations to this study were the lack of data for some countries in their respective regions. Where data was unavailable, the research made up for this by means of extrapolation. However, in attempting to mitigate against this, ITU data was collected in the regional aggregates subsequently used to represent each DMU. While it has been possible to provide credible results using DEA and MI to measure efficiency and productivity in this study, there may be no concrete performance evidence with relation to the different regions due to the unavailability of complete data to carry out intra-regional analyses.

An area of future research would be to also incorporate the effect(s) of soft ICT infrastructure in the efficiency and productivity analysis with respect to public value creation and not just the hardware infrastructure used. This may broaden the scope of the research as well as provide more insights useful to drawing of conclusions of public value creation using ICT infrastructure with respect to education.

8.6 Conclusion

The present study set out to investigate the efficiency and productivity of ICT utilization in public value creation with respect to Adult Literacy Rates. The research showed the relative efficiencies and productivity of ICT infrastructure in education with respect to PV creation. For over 3 decades, development actors have been involved in public sector reforms geared towards improved services. These reforms have been linked to the New Public Management paradigm, which emphasises public value creation in the public sectors, one of which is education. With governments developing policies and implementation of ICTs for the enhancement of educational quality, there is a need to understand the value created by government in this public service.

The next chapter, chapter 9 seeks to critically investigate this policy direction as regards ICT infrastructure developmental outcomes. It does that to determine whether or not any PV is created and what objectives are at the root of these policy direction documents. This policy

direction initiatives and corresponding implementation and impact has proven to be a major discussion point within the ICT4D discourse with opinions of scholars in this field falling on both sides of the argument.

8.7 References

Arjomandi, A., Salleh, M. I., & Mohammadzadeh, A. (2015). Measuring productivity change in higher education: an application of Hicks–Moorsteen total factor productivity index to Malaysian public universities. *Journal of the Asia Pacific Economy*, *20*(4), 630–643. https://doi.org/10.1080/13547860.2015.1045323

Anand, S., & Ravallion, M. (1993). Human Development in Poor Countries: On the Role of Private Incomes and Public Services. *The Journal of Economic Perspective*, *7*(1), 133–150.

Bankole, F. O., Shirazi, F., & Brown, I. (2011a). Investigating the impact of ICT investments on human development. *The Electronic Journal of Information Systems in Developing Countries*, *48*(1), 1-19.

Bankole, F. O., Osei-Bryson, K. M., & Brown, I. (2011b). ICT infrastructure utilization in Africa: Data envelopment analysis based exploration. In *Proceeding of special interest group on ICT and global development at Americas Conference on Information System (AMCIS) Workshop, Detroit, USA*.

Bankole, F.O (2015). ICT Infrastructure and Its' Impact on National Development: A Research Direction for Africa Using Analytics. *In Proceedings of SIG GlobDev 2015 Pre-ECIS Workshop, Munster, Germany, May 26, 2015.*

Bankole, F., & Assefa, Z. (2017). Improving the Quality of Education and Research Output In Africa A Case of Ethiopian Education and Research Network (ETHERNET). *The Journal of Applied Global Research, 10(24), 31-51.*

Bankole Dr, F., & Mimbi, L. (2017). ICT Infrastructure and It's Impact on National Development: A Research Direction for Africa. *The African Journal of Information Systems*, *9*(2), 1.

Bannister, F., & Connolly, R. (2014). ICT, public values and transformative government: A framework and programme for research, *Government Information Quarterly* (31)1, 119-128.

Blaug, R., Horner, L., & Lekhi, R. (2006). Public value, politics and public management A literature review." www.theworkfoundation.com

Bollou, F. (2006). ICT Infrastructure Expansion in Sub-Saharan Africa: An Analysis of Six West African Countries from 1995 to 2002. *The Electronic Journal of Information Systems in Developing Countries*, *26*(1), 1-16.

Brewer, G. A., Neubauer, B. J., & Geiselhart, K. (2006). Designing and Implementing E-Government Systems Critical Implications for Public Administration and Democracy, *Administration & Society* (38)4, 472-499

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision-making units. *European journal of operational research*, *2*(6), 429-444.

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). *An introduction to efficiency and productivity analysis*. Springer Science & Business Media.

Cook, W. D., Tone, K., & Zhu, J. (2014). Data envelopment analysis: Prior to choosing a model. *Omega*, *44*, 1-4.

Desai, M. (1991). Human development. *European Economic Review*, *35*(2-3), 350–357. doi:10.1016/0014-2921(91)90136-7

Easton, L., Murphy, D. J., & Pearson, J. N. (2002). Purchasing performance evaluation: with data envelopment analysis, *European Journal of Purchasing & Supply Management* (8)3, 123-134

Färe, R., Grosskof, S., Norris, M., & Zhang, Z. (1994). Productivity Growth, technical progress and efficiency change in industrial countries. *Am Econ Rev.* 84(1): 66-83.

Gauld, R., Goldfinch, S., & Horsburgh, S. (2010). Do they want it? Do they use it? The 'Demand-Side'of e-Government in Australia and New Zealand, *Government Information Quarterly* (27)2, 177- 186.

ITU: International Telecommunications Union. (2006). World telecommunications development report 2006: Measuring ICT for social and economic development. Geneva, Switzerland: International Telecommunications Union.

Jaeger, P.T., & Bertot, J.C. (2010). Transparency and technological change: Ensuring equal and sustained public access to government information, *Government Information Quarterly* (27)4, 371-376.

Kayisire, D., & Wei, J. (2016). Information Technology for Development ICT Adoption and Usage in Africa : Towards an Efficiency Assessment, *1102*. https://doi.org/10.1080/02681102.2015.1081862

Kelly, G., Mulgan, G., & Muers, S. (2002). Creating Public Value: An analytical framework for public service reform. *London: Strategy Unit, Cabinet Office*.

Lee, K. R., Leem, B., Lee, C. W., & Lee, C. (2011). Malmquist Productivity Index using DEA frontier in Stata. *Stata Journal*, *2*(2), 1-9.

Mimbi, L., & Bankole, F. (2016a). ICT and public service value creation in Africa: Efficiency assessment using DEA approach. *Proceedings OfThe 27th Australasian Conference on Information Systems*, 1–13.

Mimbi, L., & Bankole, F. O. (2016b). Factors influencing ICT service efficiency in curbing corruption in Africa: A bootstrap approach. *Proceedings of the Annual Conference of the South African Institute of Computer Scientists and Information Technologists* (p. 25). ACM.

Moore, M. (1995). *Creating public value: Strategic management in government.* Cambridge, MA: Harvard University Press

Neely, A., Gregory, M., & Platts, K. (1995). Performance measurement system design: a literature review and research agenda, *International Journal of Operations & Production Management* (15:4), pp 80-116.

Ott, J. C. (2010). Good governance and happiness in nations: Technical quality precedes democracy and quality beats size, *Journal of Happiness Studies* (11)3, 353-368

Oyerinde, Y. & Bankole, F. (2018). Influence of Constant Returns to Scale and Variable Returns to Scale Data Envelopment Analysis Models in ICT Infrastructure Efficiency Utilization. *In Proceedings of the 11th Annual Pre-ICIS SIG GlobDev Workshop, San Francisco, USA, Thursday December 13, 2018*

Oyerinde, Y. & Bankole, F. (2019). Measuring Efficiency and Productivity of ICT Infrastructure Utilization. *Accepted to 24th UK Academy for Information Systems International Conference, St Catherine's College, University of Oxford, 9th-10th April, 2019.*

Pang, M. S., Lee, G., & DeLone, W. H. (2014). IT resources, organizational capabilities, and value creation in public-sector organizations: a public-value management perspective, *Journal of Information Technology* (29)3, 187-205

Samoilenko, S., & Osei-Bryson, K. M. (2017a). An analytical framework for exploring context-specific micro-economic impacts of ICT capabilities. *Information Technology for Development*, *1102*, 1–25. https://doi.org/10.1080/02681102.2017.1336072

Samoilenko, S. V., & Osei-Bryson, K. M. (2017b). *Creating Theoretical Research Frameworks Using Multiple Methods: Insight from ICT4D Investigations*. Auerbach Publications.

Saranga, H., & Moser, R. (2010). Performance evaluation of purchasing and supply management using value chain DEA approach, *European Journal of Operational Research* (207)1, 197-205

Thanassoulis, E. (2001). *Introduction to the theory and application of data envelopment analysis*. Dordrecht: Kluwer Academic Publishers.

Thanassoulis, E., Kortelainen, M., Johnes, G., & Johnes, J. (2011). Costs and efficiency of higher education institutions in England: A DEA analysis. *Journal of the Operational Research Society, 62*, 1282–1297.

Van Dooren, W., Bouckaert, G., & Halligan, J. (2015). *Performance management in the public sector.* Routledge

WPSR: World Public Sector Report (2015). Responsive and Accountable Public Governance. *Department of Economic and Social Affairs*. United Nations, New York, 2015

CHAPTER 9

9.0 Is There Any Public Value in ICT Developmental Outcomes? A Discourse View

9.1 Introduction

Information and Communication Technology (ICT) policy adoption has been a central issue in the recent discourse of ICT for Development (ICT4D) to guide countries in planned and strategic intervention of ICT, in order to accelerate socio-economic development (Hasan, 2016). As a result, many developing countries have been steadily progressing over the years in implementing ICT-based applications and initiatives in the hope that it would lead to an increase in efficiency in the public sector, thereby providing public value and ultimately promoting socio-economic development (Hanafizadeh et al., 2019). Consequently, many international bodies and organisations have taken strong positions on the development and utilization of varying ICT policies with the aim of aiding socio-economic development and growth because, as Ayogu (2006) succinctly postulated, policymaking that is informed by careful research can promote efficiency by narrowing the scope for bad decisions. These bodies include the International Development Research Center (IDRC) (IDRC, 1999; Rathgeber, 2000); The Organization for Economic Cooperation and Development (OECD) (OECD, 1992; Marcelle, 2000); The World Bank (WB); The International Telecommunication Union (ITU) (Nulens & Van Audenhove, 1999) and the United Nations via its United Nations Development Program (UNDP) Human Development Reports (HDR) which have been running annually since 1990.

Many countries, having realized the critical role of ICT in socio-economic development promoted by a technocentric development effort (Hanafizadeh et al., 2019) and mostly guided by a number of international development organizations, have expected ICT to enable a series of positive effects with respect to human, national and economic development. This has

resulted in many countries and international organisations drawing up ostentatious ICT documents and policies which, for various reasons, have found adoption a serious challenge (Dabla, 2004; Brown & Brown, 2008; Stahl, 2008; Baqir et al., 2009). The result therefore has been that the actual outcomes have usually fallen short of these expectations. This has led to discussions about the reasons for this failure, as seen in (Heeks, 2002; Dada, 2006; Hasan, 2016). Despite the well acknowledged importance of policy assessment as a powerful monitoring tool for providing valuable guidance required in further policy making and implementation (Kim et al., 2015), some authors have highlighted a lack of research on evaluating the outcome of ICT policies especially in developing countries (Mansell, 2014; Choi, 2016) and because of this lack there is a limited understanding as to how ICT policies have or have not shaped these outcomes.

Governments, the world over, have clearly understood the need and importance of public sector reform in socio-economic development as well (Oyerinde & Bankole, 2019a). ICT has been touted to have the potential to create public value (Bannister & Connolly, 2014) and as such has been implemented as an enabler of public sector reforms, intended for reinventing governments for improved performance (Gauld et al., 2010; Bannister & Connolly, 2014). Since inception, the primary objectives of public sector reforms have been geared towards innovative and productive ways of bringing about socio-economic development (Mimbi & Bankole, 2016a) which has led to governments defining specific policies that show an emphasis on creating supporting mechanisms for ICT infrastructure utilization (Hinostroza, 2018).

International bodies and researchers have also recognised the importance of ICT in public administration with respect to creating public value. For example, the World Public Sector Report (WPSR) produced by the United Nations emphasises that ICT should be harnessed in public services to achieve socio-economic development (Oyerinde & Bankole, 2019a). Importantly, it emphasises that ICT should be a tool for creating public value (WPSR, 2015). Despite all these efforts, questions arise with respect to whether this increasing use of ICT brings any corresponding value to the public and to the rendering of public service. Whatever the answers to these questions, it is clear that ICT is becoming an ever more common factor in public interactions and public service rendering.

In this research, a Critical Discourse Analysis (CDA) is carried out on international policies for human and socio-economic development to determine how much if any, public value

these policies create. This is done from a critical theorist's perspective using qualitative content analysis with an aim to contribute to this on-going global discourse. The CDA is operationalized by Habermas' (1984) Theory of Communicative Action (TCA). The TCA is, as a theoretical background, widely applied in Information Systems (IS) research (Klein & Huynh, 2004). The two main directions of its application are: To develop more socially informed theories and methods through the critique of existing research methods and approaches (Lyytinen, 1992); and to use Habermas' discourse theory to inform practice, which is closely aligned with the critical intention of changing current practices and to emancipate the users of IS (Stahl, 2008). In IS research, this framework can be used in exploring the impacts of ICT on communication and development issues (Ess, 1996; Heng & De Moor, 2003; Stahl, 2008), as well as for defining the field of IS and factors to be considered in progressing IS development processes (Hirschheim & Klein, 2003). The CDA is carried out on the UNDP HDRs from 2010 to 2016.

The rest of the chapter is organized as follows: section 9.2 provides the overview of the literature, section 9.3 discusses the theoretical approach, section 9.4 provides the research methodology, section 9.5 provides the analysis, section 9.6 provides the discussion of findings, section 9.7 the conclusion and future work.

9.2 Overview of the Literature

9.2.1 ICT and Public Value

The concept of public value (PV) can be traced back to the inception of the new public service theory. PV has been influential in public services reform initiatives since the mid-nineties. This concept is linked to the seminal work of Moore (1995), the discussion of public value management by Stoker (2006) and the various contributions in Bennington & Moore (2010). Public value refers to value that citizens and their representatives seek in relation to strategic outcomes and experience of public services (Moore, 1995). Public value also refers to the value created by government through services, laws regulation and other actions (Kelly et al., 2002). Kelly et al. (2002) propose a typology of public value as services, outcomes and trust. This typology has been adopted by a number of scholars, for example by Castelnovo & Simonetta (2007) in their examination of public value in Lombardy and by Kearns (2004) in his discussion of public value and e-government. Public value focuses on performance

evaluation of public organisation in the delivery of services (social outcomes) as desired by the collective (Mimbi & Bankole, 2016b). Brewer et al. (2006) argue that ICT public value creation, as a priority, refers to embracing the information revolution as a means of improving governance and enhancing the democratic process. It therefore focuses on the wider notions of valued public services and efficiency, that call for more accountability of public managers (Blaug et al., 2006). However, for these to be meaningful in the context of ICT, values must therefore be convertible into some behavioural form that ICT has the potential to modify or transform (Bannister & Connolly, 2014). Therefore, ICT is expected to impact on the three dimensions related to public value: duty oriented public value, service oriented public value and socially oriented public value (Bannister & Connolly, 2014; Mimbi & Bankole, 2016b).

9.2.2 ICT and Socio-Economic Development

The promotion of the use of ICT towards attaining social and economic development gained prominence after World War II when seminal works regarding the role and importance of ICT utilization for achieving modernization and socio-economic development began to emerge (Dabla, 2004). Consequently, modernization theory has placed an emphasis on changing people's attitudes and beliefs and on promoting institutional change at the political, economic and social levels, and has advocated the use of information and communication technologies to achieve these aims (Bernstein, 1971; Tipps, 1973; Dabla, 2004). Schmandt et al. (1989) have stated that developing modern economies require a commitment to the development of advanced communication systems and to the building of information services, and technologies that could be used to effectively manage and add value to economic activity and simultaneously increase employment opportunities. Hanna et al. (1995) have viewed information and communication sectors as providing the infrastructure for the whole information economy, facilitating market entry, improving customer service, reducing costs, and increasing productivity. Kenny et al. (2001) have stressed that the promotion of information and communication sectors leads to hitherto disenfranchised people being able to benefit from: health information; distance education dissemination and technical education; better access to services. To them, being able to participate and to make better informed decisions in the economic realm; having an input in government decisions; and being able to bridge distances to interact with remote communities, markets and government agencies. A number of econometric studies also suggest that there is a positive and significant link

between the communications infrastructure, the rate of technology investment, and economic growth (Hardy, 1980; Norton, 1992; Roller & Waverman, 1994; Kraemer & Dedrick, 1994; Zhu, 1996; Canning, 1999). Within this economic framework, emphasis is placed on promoting information technology and communication sectors to expedite connections with global markets, promote economic growth, and facilitate social development.

9.2.3 ICT and the Human Development Index (HDI)

In order to consider different aspects of life when measuring human development, the United Nations Development Program (UNDP) has introduced the Human Development Index (HDI). The HDI is a composite index of socio-economic indicators that reflect three major dimensions of human development: longevity, knowledge and standard of living (Despotis, 2005). The index has been published since 1990 in the UNDP's Human Development Reports (HDRs) (UNDP, 1990). The HDI aims not only to monitor human development, but to encourage countries to take actions that promote it (Ravallion, 2010). This is usually achieved by being a guide for development policy debates and designs (UNDP, 1990). Central to the theory behind the development of the HDI is the concept of national development. Over the last three decades, research into national development has expanded to include certain intervening variables and social factors such as education and some other aspects of human welfare (Desai, 1991; Anand & Ravallion, 1993; Bankole & Mimbi, 2017). Educational attainment is clearly seen as being one of the core indices for measuring a nations HDI (UNDP, 2006; Bankole et al., 2011) and as such has found its way into Learning Analytics (LA) research (Oyerinde & Bankole, 2019b). This has been facilitated on the premises that increased investments in ICT will lead to improvements in productivity and other aspects of development at the organizational and national levels (Samoilenko & Osei-Bryson, 2017) and that ICT infrastructure utilization can greatly increase both average literacy rates and educational attainment levels in developing economies, as ICT facilitates, improves and promotes a positive attitude to learning (Oyerinde & Bankole, 2018). However, it is important to note that with regards to ICT for national development, the adoption of ICTs not only has the potential to empower communities and countries but it can also lead to imbalances and inequalities if there is a lack of ICT adoption, access and usage (Bankole, 2015).

9.2.4 ICT and the Global Discourse on Policy Making

Research into the role of global discourse in shaping ICT policies has shown that, in many cases, assumptions embedded in global ICT policy are completely different from the reality in developing countries (Thompson, 2004; Mansell, 2014). According to Avgerou (2010), a group of those who have studied ICT policy in a developmental context consider the nature of the ICT innovation processes as diffusion in the hope of progressive transformation. The predominant assumption is that enhancing diffusion and increasing the adoption rate, will result in a reaping of the oft-assumed benefits of ICT.

Models and frameworks developed in this literature have found their way into assessments of ICT policies in the developing countries (Shin & Kweon, 2011). This is perhaps most clear in the literature aiming at bridging the digital divide, where often the basic assumption is that the beneficial and positive impacts of ICT hinges upon ensuring widespread diffusion and adoption of ICT through designing policies aimed at enhancing technical competency, lowering the cost of access, and stimulating demand (Kumar & Best, 2006; Trkman & Turk, 2009). Consequently, research has highlighted the role of discourse, the language that is used and the role it plays, in shaping policies and practices (Whitley & Hosein, 2005). Explicitly expressing assumptions and interpretations in these policies is important (Yanow, 1996) as particular understandings and approaches have an effect on policy making, which also shapes the ways of using technology, many of which are often not made explicit in the policy process (Fischer, 2003). While these studies, and more, have generated many insights into the assumptions of the dominant discourse about ICT and its influence on the policies of developing countries, not much attention has been paid to the governmental approach to ICT policy making and the way objectives have been defined. Moreover, these studies stop short of tracing the influence of global discourses on the actual outcomes of ICT policies in developing countries.

Faced with the evidence of the gap between expectations (e.g. achieving economic growth and enhancing services for all) and actual outcomes, some researchers have sought to identify contextual barriers which may militate against achieving desired development outcomes, by rejecting the causal relationship concept between ICT diffusion and outcomes, in favour of a more nuanced understanding of the unique context (Osman & Dawson, 2007; Hayes &

Westrup, 2012; Avgerou, 2017; Adu et al., 2018). Although the importance of context is also recognized in some recent publications by the international development institutions, such as the World Bank (Peña-López, 2016), these reports, like many before, often incorporate the main assumptions of diffusion and adoption models and make unwarranted assumptions about the benefits of ICT vis a vis policy implementation and national development (Avgerou, 2008). It is in considering the importance of these documents and reports in shaping the perceptions and expectations of policy makers in the developing countries, and within the context of the ongoing Global Discourse on ICT4D and its resultant effects/impacts on socio-economic development, that this research is carried out to determine how much, if any, public value is created or derived from these policies and their implementations.

9.3 Theoretical Approach

Research on ICT4D requires the combination of multiple theoretical strands. Central among them are the foundational theories on technology, on context, and on socio-economic development. In addition, ICT4D research draws from middle range theories, which shed light on specific topics of ICT related phenomena in the context of a developing world (Avgerou, 2017). Consequently, this research is founded upon the Theory of Communicative Action (TCA) as developed and postulated by Habermas (1984). The TCA combines multiple concepts: rationality, ideal speech situation, validity claims and the notion of three worlds, which are linked to the social use of language directed to reaching understanding, with a special focus on the justification of the validity claims offered by actors in performing social action through communication.

Habermas has postulated that people communicate to "reach a common understanding and to coordinate actions by reasoned argument, consensus, and cooperation rather than strategic action strictly in pursuit of their own goals" (Habermas, 1984; Bolton, 2005) which is evident when people (speakers) engage in consensual communication. He has gone on further to state that speakers implicitly make four validity claims in every statement, namely truth (veracity), legitimacy (rightness), sincerity (authenticity), and clarity. These claims are often called (i) communication competence (truth, legitimacy, sincerity), and (ii) linguistics competence (clarity), which in their turn are related to the notion of three worlds: the objective world,

subjective world and social world (Lyytinen & Hirschheim, 1988; Stahl, 2008). Each of these worlds, which are essential for understanding social action, reflect a specific type of claim. The objective world holds the universal truth, the subjective world contains the internal beliefs of a person, and the social world states desirable actions, i.e. the normative truth.

In this research, the TCA is approached from a Critical Realist's Epistemological perspective based on the principles of Critical Research as proposed by Myers & Klein (2011). They believe that critical research can challenge prevailing assumptions; the critical perspective reminds researchers of the constantly changing potential of humans who need not be confined by their immediate circumstances (Orlikowski & Baroudi, 1991). Orlikowski & Baroudi (1991) classify research as critical where a critical stance is taken toward taken-for-granted assumptions about organizations and information systems, and where the aim is to critique the status quo "through the exposure of what are believed to be deep-seated, structural contradictions within social systems".

Alvesson & Deetz (2000) suggest that critical research is comprised of three elements. namely insight, critique, and transformative redefinition. Central to this perspective is the belief that, in conducting critical research, it might neither be practical nor desirable to completely separate these three elements from each other; they are all, to some extent, interconnected and present in a critical study. Myers & Klein (2011) have subsequently proposed a set of principles for the conduct of critical field research in information systems. Their principles, however, are concerned solely with the two elements of critique and transformation. This is because the first element of insight is virtually identical to the kind of insight that is provided by interpretive research.

9.4 Research Methodology

The research methodology employed in this study is the Critical Discourse Analysis (CDA). Critical Discourse Analysis is concerned with understanding and interpreting meaning as it is produced in the social context. This allows researchers to establish an association between language and context, by showing that discourse i.e. language use by social actors in specific social contexts (Bankole et al., 2010; Hanafizadeh et al., 2019) is constitutive of social reality and as such, not only has demonstrable effects but also plays an important role in power relations within the society (Chouliaraki & Fairclough, 1999). Critical Discourse Analysis

also provides an integrated notion that allows the construction and communication of a coherent interpretation of reality presented in a text. It is applied when drawing a critical conclusion about texts, the methods of their production and their effects within a certain social context. The method also applies to developing a theoretical understanding of different types of discursive practice (Hasan, 2016).

Here CDA is employed because, as Yanow (1996) has argued, it can clarify the frame of reference that policy makers use by exposing assumptions and interpretations embedded in policies. Furthermore, it can be used to shed light on the social process through which meaning is explained and fixed, thereby becoming naturalized and part of the common sense (Hanafizadeh et al., 2019). In order to justify communicative validity of the policy documents analysed, a modification of the framework developed by Hasan (2016) is used which is based on the framework introduced by Cukier et al. (2004) and presented in table 27. This framework is grounded on Habermas' (1984) four validity claims: truth, legitimacy, sincerity, and clarity, together with the concept of public value represented by accountability, government effectiveness, transparency (freedoms), and rule of law, postulated by Bannister & Connolly (2014) and operationalized by Mimbi & Bankole (2016a).

Table 27: Critical Discourse Analysis Framework

Competence	World	Claim	Key Factors for Justification of Claim	Explanation
Communication	Objective	Truth	Definition & Description; Benefits & Challenges; Ideological Stance; Distortion	Utterance should match the case in reality. The theme should be properly stated, pros and cons discussed, presented from an ideological perspective and void of distortion
	Subjective	Sincerity	Metaphors; Connotative Words	Checks the Intentions of the Speaker Cannot be observed, only inferred. Use of metaphors of connotative words should not be deceptive and present a false situation.
	Social	Legitimacy	Form of Legitimization; Dominant Speaker; Assumptions in ICT	Utterance should be in accordance with socially accepted norms and from a recognized source. Prevalent Assumptions on ICT to be stated and legitimized from practice or validated research.
Linguistics		Clarity	Ambiguity; Unexplained Terms	Utterance should be clear in terms of syntax & Semantics, devoid of ambiguity and all terms used properly defined

Qureshi (2017) has provided a theoretical lens through which researchers can view ICT's with respect to their intended developmental outcomes. This lens helps researchers to focus

solely on the particular actors with which their research is concerned and is presented in figure 26. Within the context of this theoretical lens and using the framework presented in table 27, the analysis is done by reading through the policy document several times and picking out claims. All identified claims are noted down in a conventional data sheet, and the evaluations are done and presented through an analytical explanation.

The HDR has been published by the UNDP since 1990 as independent, analytically and empirically grounded discussions of major development issues, trends and policies (UNDP, 2016) and as such is accepted internationally as a valid policy direction document. Therefore, this CDA has been carried out using these validated research discussions.

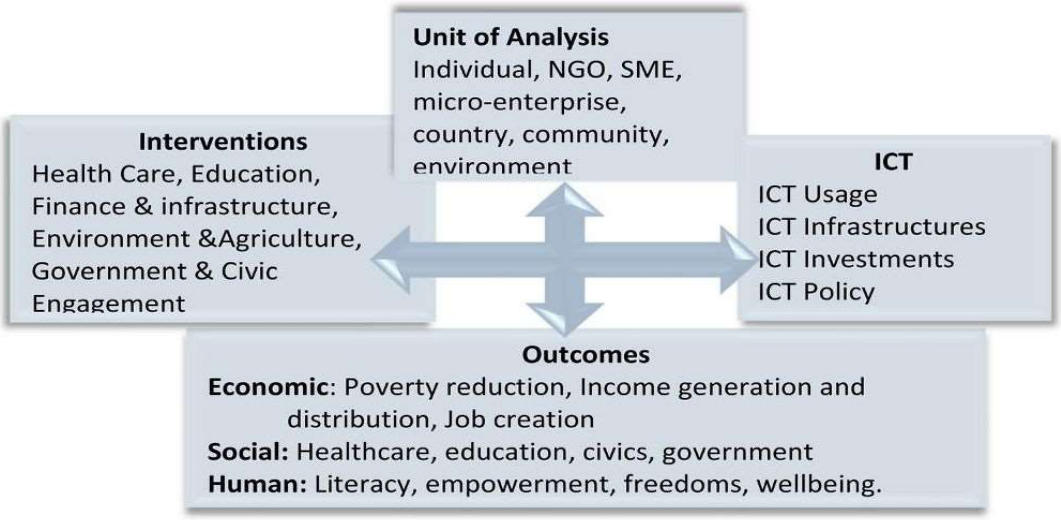

Figure 26: Theoretical Lens for Investigating Development Outcomes – Adapted from Qureshi (2017)

Therefore, in line with the scope and focus of this research and using the theoretical lens as a guide, developmental outcomes of this study are defined in table 28. This is in order to critically investigate whether public value is created from ICT and policy interventions on the educational component of the HDI.

Central in this theoretical perspective is the view that investment in ICT and its effective use do matter for the economic development of a country (Mann, 2003). It is however acknowledged that ICT needs to be accompanied by organizational or national restructuring, as the case may be, to deliver productivity gains (Dedrick et al., 2003; Draca et al., 2007)

which although evident in policy documents, need to be substantiated. Here the UNDP's Human Development Reports (HDRs) from 2010 to 2016 are analyzed.

Table 28: Research Developmental Outcomes

S/N	Indicator	Index
1	Unit of Analysis	International (Country)
2	ICT	ICT Infrastructure, ICT Policy
3	Outcomes	Social: Education, Government Human: Literacy, Freedoms
4	Interventions	Education, Government & Civic

9.5 Analysis

In doing the analysis the research has been carried out using the developmental outcomes explained in Table 28, and the outcomes are presented in Table 29 and 30. Table 29 focuses on the ICT indicator while Table 30 focuses on the Outcomes and Interventions indicator. The analysis has been carried out on UNDP HDRs from 2010 to 2016. As expected, many themes within the reports were repeated but for the sake of presentation, the most current version of the theme has been selected.

Table 29: Analysis of ICT Developmental Outcomes

Validity Claim	Accountability	Government Effectivenes	Freedoms
Truth	Vast increases in literacy and educational attainment, aided by the proliferation of and access to ICTS such as mobile telephony and internet access, have strengthened peoples abilities to make informed choices and hold governments accountable.	New Technologies has changed the ways government interact with their citizens increasing reach and efficiency of public service delivery	Human development is also about people's active engagement in shaping development, equity and sustainability, intrinsic aspects of freedoms people have to create value in the lives they lead. People with skills and resources to use tech and create value can thrive in today's digital world.
Legitimacy	94.1% of population in developing countries own mobile phones. 40.1% of this population have access to internet.	Mobile phones used to extend basic social services like health and education to difficult to reach populations	Smartphones and Social media present opportunities for people to express themselves freely.
Sincerity	ICT has allowed civil societies to gather across borders and share ideas. The more a country's telecommunications infrastructure is developed, the more likely the existence of mechanisms for civil society participation in public and political life.	Estimates put the internets contribution to GDP at $4.2t	The dramatic increases in Internet coverage and mobile telephone use have occurred despite structural constraints. Globalization has propelled domestic issues onto the international stage. One expression of this trend is the upsurge of global and transnational civil society: the number of international organizations increased more than fivefold from 1970 to 2010, to an estimated 25,000. New forms of public and civic societies participation especially through social networks with global reach are increasingly important in policy making
Clarity	Internet has enabled sharing of information more than any form of communication has	Technology and social media have mobilized grassroots activism ensuring public social value.	Internet has enabled acts such as crowdfunding which have enabled donors to fund projects that affect civic and social institutions. The exponential spread of ICT along with rising education and literacy rates has provided individuals with new tools for inclusive participation.

In analyzing the HDRs focusing on the ICT indicators as shown in table 28, the documents have been read through using the framework defined in Table 27. Claims validated in the HDRs that have focused on ICT infrastructure and its utilization as well as ICT policy within the theoretical lens employed have been extracted and subjected to the 4 validity claims as explained in Table 27 and subsequently presented in Table 29. The same method has been used for the analysis presented in Table 30 with claims that focused on education/literacy, government, freedoms and civic oriented outcomes and interventions. The indices of Outcomes and Interventions overlap and therefore these findings are combined in Table 30.

All claims critically analyzed and presented in the tables using the framework presented in Table 27 have been picked verbatim from the HDRs.

Table 30: Analysis of Outcomes & Interventions

Validity Claim	Accountability	Government Effectivenes	Freedoms
Truth	Use of these technologies is very high in developed countries—by 2008, 70 percent of people were using the Internet, and phone subscriptions had reached 1.5 per capita—but still low in low HDI countries. However, growth over the past decade has been striking: in low HDI countries Internet use soared more than 4,000 percent, and the share of people with phone subscriptions by close to 3,500 percent. Inexpensive and reliable access to internet is crucial for high quality education. Biggest challenge is the cost. 47% of entire world population uses the internet. Only 25% of people in sub-Saharan Africa are users and 42% of people in Asia & the Pacific and Arab states. 66% of people in the Americas and CIS are users and 79% of people in Europe.	Global literacy rates up to 91% in 2015. Advances in Tech have led to major advances in education and other developmental outcomes. Increased inclusion and adoption of the Internet and web-based data gathering systems have supported the explosion in data and public sector activities and performance in both developed and developing economies This has allowed for a better understanding of the links between inputs, outputs and impacts of public sector activities. Improved information and analysis have informed policy discussions, debates, and decisions about government's priorities albeit the data constraints remain large.	The technological revolution coupled with globalization has transformed the political landscape. The proliferation of cell phones and satellite television, alongside widening access to the Internet, has vastly increased the availability of information and the ability to voice opinions. Voice and Autonomy as parts of freedom of agency and freedom of well being are integral to human development. Modern ICT's offer major opportunites for successful implementations of major future related agendas e.g 2030 Agenda as young people are active users of ICT.
Legitimacy	Improvements and advances in ICT have shown to have a potential to greatly increase quality of education which in turn improves HDI. Many have made gains in access to education but improvement in quality have not kept pace. Therefore, developmental policies must be based on the local context and sound overarching principles. As with education and other aspects of development, numerous problems associated with these go beyond the capacity of individual states and require democratically accountable global institutions	Striving for universal free Wi-Fi may be needed to help bridge digital-divide and make accessibility possible as cost of internet access is still relatively high in many regions. Telecommunication infrastructure and online participation tools are positively correlated	Right to information of social institutions. This requires freedom to form public opinions and call governments to account. ICT's provide new tools to monitor the commitments and results of multilateral institutions. Survey evidence suggests that most people around the world feel free to make choices and are satisfied with this freedom. Reported trends in freedom of choice, available for 66 countries, suggest general improvement over time.
Sincerity	Fundamental contextual factors—most important, the vast increases in literacy and educational attainment in many parts of the world—have strengthened people's ability to make informed choices and hold governments accountable. Holding social institutions publicly and mutually accountable, especially in protecting the rights of excluded segments of the population, requires explicit policy interventions. One major instrument in accomplishing this is the right to information and use of ICT.	Mere availability of services or even access to them is not enough; the effective use of these services is what is of utmost importance and requires affordability and adaptability. Human capital is an asset and differences in educational attainment, one aspect of this asset, prevent poor people from becoming part of the high productivity growth process.	There has been wide ranging democratization and an increase in people's perceived freedom to choose. At the national level we see the spread of formal procedural democracy, and at the subnational level the rise of local participatory processes in different forms—with greater possibilities for accountability. A free press, vibrant civil society and political freedoms guaranteed by a constitution underpin inclusive institutions and human development. The Facebook broadcast of police attacks on pro-democracy demonstrating was instrumental in 2011 Arab spring.
Clarity	Educational attainment is a central mechanism for perpetuating socio-economic stratification across generations. Knowledge expands people's possibilities, promotes creativity and imagination. Progress in education has been substantial and widespread, reflecting improvements in quality and equity of access as a direct result of state involvement via policy direction and public spending.	New technology can give voice to marginalized people, though some contend that such innovations consolidate the power of people who already have some resources. However, universal internet access combined with high quality education could greatly increase opportunities and reduce inequalities everywhere.	A country's preconditions affects which policies are conducive to human development. For example, a regime with strong institutions (measured using a composite index of corruption, rule of law, quality of bureacracy, investment profile, internal conflicts), higher government spending on wages and goods and services, is conducive for faster progress in HDI

9.6 Discussion of Findings

The 1990 HDR began with a clear definition of human development as a process of "enlarging people's choices", emphasizing the freedom to be healthy and educated and to enjoy a decent standard of living (UNDP, 1990). This has remained a recurring theme throughout all the HDRs published since. However, it has also acknowledged that human development and well-being has gone far beyond these dimensions and now encompasses a much broader range of capabilities, including political freedoms, human rights, inclusions and abilities to live without shame – all components of public value (UNDP, 2010). The concept of human development has three components of capabilities as shown in figure 27. These are related to people's opportunities; process freedoms (affecting people's ability to shape their lives); and key principles of justice that shape processes and outcomes across space and time. Human development is also about sustaining these developmental outcomes steadily over fixed periods of time. With freedoms, justice and equity central to the concept of public value, the human development concept is centred around public value creation.

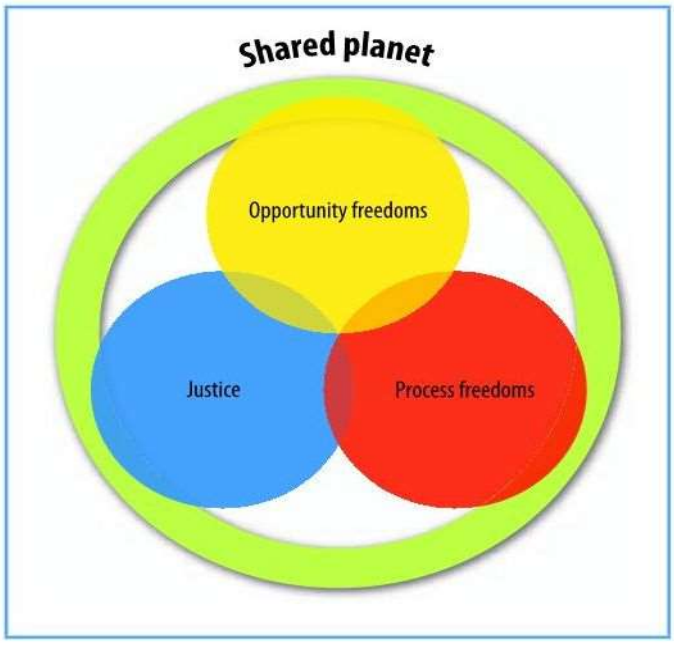

Figure 27: Concept of Human Development – Adapted from UNDP (2010)

The 2016 HDR states that HDI has improved worldwide, although the rate of progress has slowed down since 2010. This reflects important advances, not only in income, as evidenced by a $4.2t contribution to GDP with digital currencies (crypto currencies) making a considerable contribution, but in health and education as well. This is evidenced by the fact that global literacy rates are up to 91% as of 2015 (UNDP, 2016). Focus has therefore shifted from quantity (access) to quality of education with the aid of improvements and advances in ICT, which are shown to have the potential to greatly increase educational quality. Therefore, educational policies can now be drawn up to focus more on the factors which will affect the quality of education going forward rather than those that affect access to education. The biggest challenge to this is not the availability of the technology itself, but the high cost of access to the technology. The cost of Internet connectivity is relatively high costing more in developing economies than in developed ones and costing the most in the least developed economies, as shown in figure 28. Policies also have to be made to bring the benefits of ICT, especially Internet connectivity, to all. There is therefore a strong call for governments and international institutions alike to make provisions for free universal WI-FI.

A My World global survey conducted by the United Nations in support of the 2030 Agenda has assessed developmental issues that matter to most people. With over 9 million responses, good education, better health care and better job opportunities are the top three priorities from 16 available options, with good education being the overall top priority across all surveyed human development groups. This, therefore, further accentuates the relevance of attaining quality education with educational attainment, being a central mechanism required for perpetuating socio-economic stratification across generations. The 2016 HDR further goes on to stress this point by unambiguously stating that universal Internet access combined with high quality education has the potential to greatly increase opportunities and reduce inequalities everywhere.

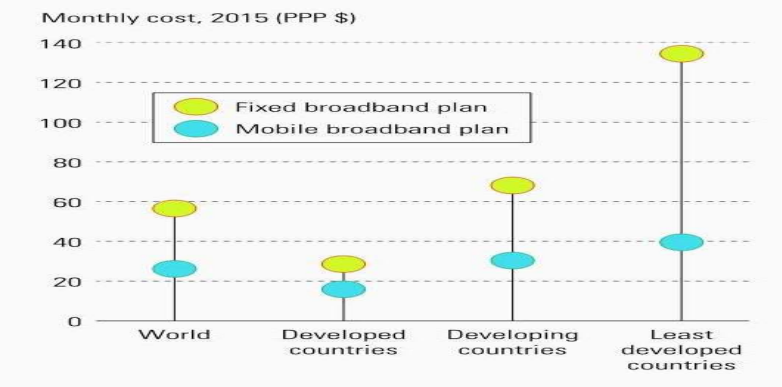

Figure 28: Internet Connectivity Cost, 2015 – Adapted from ITU (2016)

The HDRs also stress that holding social institutions publicly and mutually accountable, especially in protecting the rights of excluded segments of the population, requires explicit policy interventions. One major instrument to accomplish this is the right to information. It has been globally acknowledged that the Internet has done more for the sharing of information than any other form of communication has in history. Examples abound, ranging from how the Internet and social media have helped donors fund projects that affect civic and social interests via crowdfunding, to how a Facebook broadcast of police attacks during pro-democracy demonstrations has been instrumental in the Arab spring of 2011. Activists and civic groups are now able to gather support from millions of people over a broad range of geographic and demographic strata within a short period of time and at limited costs, one example of which is via the signing of online petitions. This has enabled activists to have an impact on public and political life which hitherto would have been extremely difficult if not impossible. However, while pursuing policies that will further provide equal access of technology (Internet), there must be a mechanism to protect people from misinformation (fake news) and online violence (cyberbullying).

9.7 Conclusion and Future Work

The impacts of HDRs over the years have illustrated that policy thinking and direction can be informed by deeper explorations into key dimensions of development. An important element of this is a rich and diverse agenda of research analyses. This research has been able to show that public value is indeed being created and is at the root of policy direction being called for in the 2010 to 2016 HDRs. This can be seen from tables 29 and 30 where critical stances are

being taken and presented in the report with regards to the three indices representative of the concept of public value: accountability; government effectiveness; and freedoms. This information has been extracted from the report using the theoretical lens for viewing ICT developmental outcomes postulated by Qureshi (2017) and subjecting same to the four validity claims postulated by Habermas (1984).

With the literature of ICT and Public Value awash with research evaluating impact and efficiency (Blaug et al., 2006; Benington & Moore, 2010), this research has also been able to inform theory and practice on the use of CDA for public value assessment. This has been done from a Critical Theorist's perspective using Critical Research. In doing so, this research has been able to contribute to the ongoing global discourse on ICT4D with respect to policy directions of ICT interventions and their resultant impact on socio-economic development and public value creation, using a hitherto unfamiliar interpretivist approach within the e-government literature.

Considering findings from the studies in the previous chapters, we can see that the relatively efficient utilization of ICT infrastructure and its corresponding productivity levels in education aid in the creation of public value and is in tandem with policy calls seen in the UNDP HDRs. This research has been able to utilize insights and findings from LA research methods for decision making, fusing them with policy formulation documents analysis to contribute to the global discourse in ICT4D.

A limitation of this research, however, is the scope of the study. An area of future research, to build upon this, would be to carry out a CDA of not only HDRs but other policy direction documents and reports, that have been shown to impact policy direction, especially with respect to ICT interventions for socio-economic development, such as WPSR from 2010-2016.

Another limitation of this study is within the discourse itself. Much of the developmental discourse tends to seek uniform policy prescriptions that can be applied across the vast majority of countries, assuming that economic growth is indispensable to achievements in areas such as health and education. It is now widely accepted that the results suggest that this is not the case, largely due to the fact that development processes and possibilities facing

developing economies today are quite different from those that the now developed economies once faced (UNDP, 2010). Development therefore is not so much about having a one-size-fits-all solution based on experiences of developed economies, as it is about finding new paths to progress in today's world. Therefore, the shortcomings and limitations of this research and discourse are acknowledged.

9.8 References

Adu, K. K., Patrick, N., Park, E. G., & Adjei, E. (2018). Evaluation of the implementation of electronic government in Ghana. *Information Polity*, *23*(1), 81-94.

Alvesson, M., & Deetz, S. (2000). *Doing critical management research*. Sage.

Anand, S., & Ravallion, M. (1993). Human Development in Poor Countries: On the Role of Private Incomes and Public Services. *The Journal of Economic Perspective*, *7*(1), 133–150

Avgerou, C. (2008). Information systems in developing countries: a critical research review. *Journal of information Technology*, *23*(3), 133-146.

Avgerou, C. (2010). Discourses on ICT and development. *Information Technologies & International Development*, *6*(3), pp-1.

Avgerou, C. (2017). Theoretical framing of ICT4D research. In *International Conference on Social Implications of Computers in Developing Countries* (pp. 10-23). Springer, Cham.

Ayogu, M. (2006). Infrastructure development in Africa: Prospect and challenges. *Paper on economic development in the millennium AERC-AfDB Project on Africa's development, Tunis 22–24 November 2006*.

Bankole, O. O., Bisimwa, K., van Vuuren, I. J., Onumajuru, P. U., & Chigona, W. (2010). The SEACOM Undersea Fibre Optic Cable Project: A Critical Discourse Analysis. *In Proceedings of International Development Informatics Association IDIA2010 Conference.*

Bankole, F. O., Shirazi, F., & Brown, I. (2011). Investigating the impact of ICT investments on human development. *The Electronic Journal of Information Systems in Developing Countries*, *48*(1), 1-19.

Bankole, F.O (2015). ICT Infrastructure and Its' Impact on National Development: A Research Direction for Africa Using Analytics. *In Proceedings of SIG GlobDev 2015 Pre-ECIS Workshop, Munster, Germany, May 26, 2015.*

Bankole Dr, F., & Mimbi, L. (2017). ICT Infrastructure and It's Impact on National Development: A Research Direction for Africa. *The African Journal of Information Systems*, *9*(2), 1.

Bannister, F., & Connolly, R. (2014). ICT, public values and transformative government: A framework and programme for research, *Government Information Quarterly* (31)1, 119-128.

Baqir, M. N., Palvia, P., & Nemati, H. (2009). Evaluating government ICT policies: An extended design-actuality gaps framework. In *Proceedings of Second Annual SIG GlobDev Workshop*.

Benington, J., & Moore, M. H. (Eds.). (2010). *Public value: Theory and practice*. Macmillan International Higher Education.

Bernstein, H. (1971). Modernization theory and the sociological study of development. *The Journal of Development Studies*, *7*(2), 141-160.

Blaug, R., Horner, L., & Lekhi, R. (2006). Public value, politics and public management A literature review." www.theworkfoundation.com

Bolton, R. (2005). Habermas's theory of communicative action and the theory of social capital. *Association of American Geographers, Denver, Colorado, April*, *2*.

Brewer, G. A., Neubauer, B. J., & Geiselhart, K. (2006). Designing and Implementing E-Government Systems Critical Implications for Public Administration and Democracy, *Administration & Society* (38)4, 472-499

Brown, W., & Brown, I. (2008). Next generation ICT policy in South Africa: Towards a human development-based ICT policy. In *IFIP International Conference on Human Choice and Computers* (pp. 109-123). Springer, Boston, MA.

Canning, D. (1999). *A Database of World Infrastructure Stocks, 1950 95*. The World Bank.

Castelnovo, W., & Simonetta, M. (2007). The Evaluation of e-Government projects for Small Local Government Organisations. *Electronic Journal of e-Government*, *5*(1).

Choi, H., Park, M. J., Rho, J. J., & Zo, H. (2016). Rethinking the assessment of e-government implementation in developing countries from the perspective of the design–reality gap: Applications in the Indonesian e-procurement system. *Telecommunications Policy*, *40*(7), 644-660.

Chouliaraki, L., & Fairclough, N. (1999). *Discourse in Late Modernity: Rethinking Critical Discourse Analysis (Critical Discourse Analysis EUP)*. Edinburg, UK: Edinburg University Press.

Cukier, W., Bauer, R., & Middleton, C. (2004). Applying Habermas' validity claims as a standard for critical discourse analysis. In *Information systems research* (pp. 233-258). Springer, Boston, MA.

Dabla, A. (2004). The role of information technology policies in promoting social and economic development: The case of the State of Andhra Pradesh, India. *The Electronic Journal of Information Systems in Developing Countries*, *19*(1), 1-21.

Dada, D. (2006). The failure of e-government in developing countries: a literature review. *The Electronic Journal of Information Systems in Developing Countries*, *26*(1), 1-10.

Dedrick, J., Gurbaxani, V., & Kraemer, K. L. (2003). Information technology and economic performance: A critical review of the empirical evidence. *ACM Computing Surveys (CSUR)*, *35*(1), 1-28.

Desai, M. (1991). Human development. *European Economic Review*, *35*(2-3), 350–357. doi:10.1016/0014-2921(91)90136-7

Despotis, D. K. (2005). A reassessment of the human development index via data envelopment analysis. *Journal of the operational research society*, *56*(8), 969-980.

Draca, M., Sadun, R., & Van Reenen, J. (2007) Productivity and ICTs: A review of the evidence. In R. Mansell, C. Avgerou, D. Quah, & R. Silverstone (Eds.), *The Oxford handbook of information and communication technologies* pp. 100–147. Oxford: Oxford University Press.

Ess, C. (1996). Introduction: Thoughts along the I-way: Philosophy and the emergence of computer-mediated communication. *Philosophical perspectives on computer-mediated communication*, 1-12.

Fischer, F. (2003). *Reframing public policy: Discursive politics and deliberative practices*. Oxford University Press.

Gauld, R., Goldfinch, S., & Horsburgh, S. (2010). Do they want it? Do they use it? The 'Demand-Side'of e-Government in Australia and New Zealand, *Government Information Quarterly* (27)2, 177- 186.

Habermas, J. (1984). *The theory of communicative action* (Vol. 2). Beacon press.

Hanafizadeh, P., Khosravi, B., & Badie, K. (2019). Global discourse on ICT and the shaping of ICT policy in developing countries. *Telecommunications Policy*, *43*(4), 324-338.

Hanna, N., Guy, K., & Arnold, E. (1995). The diffusion of information technology: experience of industrial countries and lessons for developing countries. The World Bank.

Hardy, A. P. (1980). The role of the telephone in economic development. *Telecommunications policy*, *4*(4), 278-286.

Hasan, Z. (2016). Evaluation of a government ICT policy document from a communicative action perspective: A case of Bangladesh. *The Electronic Journal of Information Systems in Developing Countries*, *73*(1), 1-14.

Hayes, N., & Westrup, C. (2012). Context and the processes of ICT for development. *Information and organization*, *22*(1), 23-36.

Heeks, R. (2002). Information systems and developing countries: Failure, success, and local improvisations. *The information society*, *18*(2), 101-112.

Heng, M. S., & De Moor, A. (2003). From Habermas's communicative theory to practice on the internet. *Information Systems Journal*, *13*(4), 331-352.

Hinostroza, J. E. (2018). New Challenges for ICT in Education Policies in Developing Countries: The Need to Account for the Widespread Use of ICT for Teaching and Learning Outside the School. In *ICT-Supported Innovations in Small Countries and Developing Regions* (pp. 99-119). Springer, Cham.

Hirschheim, R. & Klein, H. K. (2003). Crisis in the IS Field? A Critical Reflection on the State of the Discipline. *Journal of the Association for Information Systems*, *4*(1), 10.

International Development Research Center (IDRC) (1999). The Acacia Initiative. IDRC, Ottawa, ON, Canada. www.idrc.ca/acacia

ITU: International Telecommunications Union. (2016). "ICT Facts and Figures 2016." Geneva. www.itu.int/en/ITU-D/Statistics/Documents/facts/ ICTFactsFigures2016.pdf

Kearns, I. (2004). *Public value and e-government*. London: Institute for Public Policy Research.

Kelly, G., Mulgan, G., & Muers, S. (2002). Creating Public Value: An analytical framework for public service reform. *London: Strategy Unit, Cabinet Office*.

Kenny, C., Navas-Sabater, J., & Qiang, C. (2001). Information and Communication Technologies and Poverty. *TecKnowLogia, 3 (4)*, 7-11.

Kim, H., Shin, D. H., & Lee, D. (2015). A socio-technical analysis of software policy in Korea: Towards a central role for building ICT ecosystems. *Telecommunications Policy*, *39*(11), 944-956.

Klein, H. K., & Huynh, M. Q. (2004). The critical social theory of Jürgen Habermas and its implications for IS research. *Social theory and philosophy for information systems*, 157-237.

Kraemer, K. L., & Dedrick, J. (1994). Payoffs from investment in information technology: Lessons from the Asia-Pacific region. *World Development*, *22*(12), 1921-1931.

Kumar, R., & Best, M. L. (2006). Social impact and diffusion of telecenter use: A study from the sustainable access in rural India project. *The journal of community informatics*, *2*(3).

Lyytinen, K., & Hirschheim, R. (1988). Information systems as rational discourse: An application of Habermas's theory of communicative action. *Scandinavian Journal of Management*, *4*(1-2), 19-30.

Lyytinen, K. (1992). Information systems and critical theory. *Critical management studies*, 159-180.

Mann, C. L. (2003). Information technologies and international development: conceptual clarity in the search for commonality and diversity. *Information Technologies & International Development*, *1*(2), pp-67.

Mansell, R. (2014). Power and interests in information and communication and development: exogenous and endogenous discourses in contention. *Journal of international development*, *26*(1), 109-127.

Marcelle, G. M. (2000). Getting gender into African ICT policy: A strategic view. *Gender and the Information Revolution in Africa*, 35-84.

Mimbi, L., & Bankole, F. (2016a). ICT and public service value creation in Africa: Efficiency assessment using DEA approach. *Proceedings Of The 27th Australasian Conference on Information Systems*, 1–13.

Mimbi, L., & Bankole, F. O. (2016b). ICT Efficiency in Creating Public Value, 2005-2014: A Cross-National Enquiry of BRICS Countries. *GlobDev 2016*.

Moore, M. (1995). *Creating public value: Strategic management in government.* Cambridge, MA: Harvard University Press

Myers, M. D., & Klein, H. K. (2011). A set of principles for conducting critical research in information systems. *MIS quarterly*, *35*(1).

Norton, S. W. (1992). Transaction costs, telecommunications, and the microeconomics of macroeconomic growth. *Economic Development and Cultural Change*, *41*(1), 175-196.

Nulens, G., & Van Audenhove, L. (1999). An information society in Africa? An analysis of the information society policy of the World Bank, ITU and ECA. *Gazette (Leiden, Netherlands)*, *61*(6), 451-471.

Organisation for Economic Co-operation and Development (OECD) (1992). New Technologies: opportunities and policy implications for the 1990s. OECD, Paris, France

Orlikowski, W. J., & Baroudi, J. J. (1991). Studying information technology in organizations: Research approaches and assumptions. *Information systems research*, *2*(1), 1-28.

Osman Shereif Mahdi, M., & Dawson, P. (2007). The introduction of information technology in the commercial banking sector of developing countries: voices from Sudan. *Information Technology & People*, *20*(2), 184-204.

Oyerinde, Y., & Bankole, F. (2018). Influence of Constant Returns to Scale and Variable Returns to Scale Data Envelopment Analysis Models in ICT Infrastructure Efficiency Utilization. *In Proceedings of the 11th Annual Pre-ICIS SIG GlobDev Workshop, San Francisco, USA, Thursday December 13, 2018*

Oyerinde, Y., & Bankole F. (2019a). Creating Public Value Using ICT: An Efficiency And Productivity Assessment Approach. *In Proceedings of the International Conference on Information Resources Management (Conf-IRM 2019), Auckland, New Zealand, May 27th – 29th, 2019.*

Oyerinde, Y., Bankole F. (2019b). Investigating the Efficiency of ICT Infrastructure Utilization: A Data Envelopment Analysis Approach. *In: Nielsen P., Kimaro H. (eds) Information and Communication Technologies for Development. Strengthening Southern-Driven Cooperation as a Catalyst for ICT4D.* ICT4D 2019. IFIP Advances in Information and Communication Technology, vol 551. Springer, Cham

Peña-López, I. (2016). World development report 2016: Digital dividends.

Qureshi, S. (2017). The forgotten awaken: ICT's evolving role in the roots of mass discontent. *Information Technology for Development,* 23:1, 1-17, DOI: 10.1080/02681102.2017.1293963

Rathgeber, E. M. (2000). Women, men and ICTs in Africa: Why gender is an issue. *Gender and the information revolution in Africa*, 17-34.

Ravallion, M. (2010). Troubling tradeoffs in the human development index. The World Bank.

Roller, L. H., & Waverman, L. (1994). The impact of telecommunications infrastructure on economic growth and development. *OECD ICCP Draft Working Paper, Paris, France*.

Samoilenko, S., & Osei-Bryson, K. M. (2017). An analytical framework for exploring context-specific micro-economic impacts of ICT capabilities. *Information Technology for Development*, *1102*, 1–25. https://doi.org/10.1080/02681102.2017.1336072

Schmandt, J., Williams, F., & Wilson, R. H. (1989). Telecommunications policy and economic development: The new state role. Praeger Publishers.

Shin, D. H., & Kweon, S. H. (2011). Evaluation of Korean information infrastructure policy 2000–2010: Focusing on broadband ecosystem change. *Government information quarterly*, *28*(3), 374-387.

Stahl, B. C. (2008). Empowerment through ICT: A critical discourse analysis of the Egyptian ICT policy. In *IFIP international conference on human choice and computers* (pp. 161-177). Springer, Boston, MA.

Stoker, G. (2006). Public value management: a new narrative for networked governance?. *The American review of public administration*, *36*(1), 41-57.

Thompson, M. P. (2004). ICT, power, and developmental discourse: A critical analysis. *The Electronic Journal of Information Systems in Developing Countries*, *20*(1), 1-25.

Tipps, D. C. (1973). Modernization theory and the comparative study of national societies: A critical perspective. *Comparative studies in society and history*, *15*(2), 199-226.

Trkman, P., & Turk, T. (2009). A conceptual model for the development of broadband and e-government. *Government Information Quarterly*, *26*(2), 416-424.

UNDP: United Nations Development Programme. (1990). Human Development Report 1990. Oxford University Press, New York.

UNDP: United Nations Development Programme. (2006). The Millennium Development Goals. *UNDP*.

UNDP: United Nations Development Programme. (2010). Human Development Report 2010. The Real Wealth of Nations: Pathways to Human Development

UNDP: United Nations Development Programme. (2016). Human Development Report 2016. Human Development for Everyone.

Whitley, E. A., & Hosein, I. (2005). Policy discourse and data retention: The technology politics of surveillance in the United Kingdom. *Telecommunications policy*, *29*(11), 857-874.

WPSR: World Public Sector Report (2015). Responsive and Accountable Public Governance. *Department of Economic and Social Affairs*. United Nations, New York, 2015

Yanow, D. (1996). How does a policy mean: Interpreting policy and organizational actions. Georgetown University Press.

Zhu, J. (1996). Comparing the effects of mass media and telecommunications on economic development: a pooled time series analysis. *Gazette (Leiden, Netherlands)*, *57*(1), 17-28.

CHAPTER 10

10.0 Research Summary

This chapter provides a comprehensive summary of the individual studies and how they relate to the complete research. The chapter is organized as follows: section 10.1 provides the summary, section 10.2 explains how the research questions were answered and section 10.3 explains how the individual studies link to each other.

10.1 Summary

This section provides a brief and concise summary of the five essays in this thesis as follows:

Essay 1: Predicting Students' Academic Performances – A Learning Analytics Approach using Multiple Linear Regression

Learning Analytics is an area of Information Systems research that integrates data analytics and data mining techniques with the aim of enhancing knowledge management and learning delivery in education management. This essay has sought to operationalize LA, within a case study context, for decision making using predictive analytics. The research has proposed a framework to administer the prediction of Student Academic Performance, which in turn can be used for appropriate planning and decision making within the department and/or institution using archival educational data. Multiple Linear Regression has been used with the aid of the Statistical Package for Social Sciences (SPSS) analysis tool. Statistical Hypothesis testing has then been used to validate the model with a 5% level of significance. Results have shown a viable and working model which has achieved the aim set out in its development. An effective prediction model has been developed and tested on identified dependent and independent variables. Results have also shown the viability of using LA for decision-making, albeit at a micro institutional scale.

Essay 2: Investigating the Efficiency of ICT Infrastructure Utilization: A Data Envelopment Analysis Approach

The second essay investigates the relative efficiency in ICT infrastructure utilization, and the association of ICT infrastructure with educational attainments and adult literacy rates. A lot of research has been done in the field of Information and Communication Technology for Development (ICT4D) investigating and measuring the impact of Information and Communication Technology (ICT) investments on Human Development. Education is a major component of the Human Development Index (HDI) which affects the core of Human Development. This research has investigated the relative efficiency of ICT infrastructure utilization with respect to the educational component of the Human Development Index (HDI). A Novel conceptual model is proposed, and the Data Envelopment Analysis (DEA) methodology is used to measure the relative efficiency of the components of ICT infrastructure (Inputs) and the components of education (Outputs). An OLS regression analysis has also been carried out to determine the effect of each of these inputs on each of the outputs. Results show a strong positive correlation of this ICT infrastructure with educational attainment and literacy rates. Results also provide a theoretical support for the argument of increasing ICT infrastructure to provide an increase in human development, especially within the educational context, as those regions with significantly lower educational attainment and literacy rates are utilizing their significantly lower ICT infrastructure with relative efficiency.

Essay 3: Measuring Efficiency and Productivity of ICT Infrastructure Utilization

The third essay seeks to measure and determine the relative efficiency and productivity of ICT infrastructure utilization with respect to human development vis a vis the educational component of the HDI. Several pieces of research have been carried out with respect to ICT Infrastructure Investments made by nations, in a bid to bridge the digital divide and improve quality of life and the Human Development Index (HDI). With a strong argument being made in the literature for continued investments in ICT Infrastructure, this research has investigated the relative efficiency and productivity of ICT Infrastructure Utilization in Education. The research has employed the Data Envelopment Analysis (DEA) and Malmquist Index (MI) non-parametric research methodology, with Arab States, Europe, Sub-Saharan Africa and World regions forming the Decision-Making Units. An OLS regression analysis has been carried out to determine the effect of each of the ICT infrastructure indicators on adult literacy rates with Data collected from the United Nations Educational, Scientific and

Cultural Organization (UNESCO) and the International Telecommunications Union (ITU). Findings show a relatively efficient utilization and steady increase in productivity for the regions, but with only Europe and the Arab States currently operating in a state of positive growth in productivity. Individuals with access to Internet have the most positive correlation with adult literacy rates, while surprisingly, households with Internet had the strongest negative correlation with adult literacy rates.

Essay 4: Creating Public Value Using ICT: An Efficiency and Productivity Assessment Approach

The fourth essay sets out to determine how public value can be created using ICT by means of an efficiency and productivity assessment of ICT infrastructure utilization. For over three decades, development actors have been involved in public sector reforms geared towards improved services. These reforms have been linked to the New Public Management paradigm, which emphasises public value creation in the public sectors, one of which is education. This research sets out to investigate the efficiency and productivity of ICT utilization in public value creation, with respect to adult literacy rates. The research has employed the Data Envelopment Analysis (DEA) and Malmquist Index (MI) non-parametric research methodology, with Arab States, Europe, Sub-Saharan Africa and World regions forming the Decision-Making Units. Findings show a relatively efficient utilization of ICT in public value creation, but an average decline in productivity levels over the years.

Essay 5: Is There Any Public Value in ICT Developmental Outcomes? A Discourse View

Finally, the fifth essay in this thesis seeks to critically investigate whether public value is being created or is at the core of ICT policy directions, with respect to socio-economic developmental outcomes. This research provides a contribution to the ongoing global discourse on ICT4D with respect to ICT developmental outcomes and its impacts on socio-economic development. There has been a lot of focus on policy formulations from governments and international institutions over the years aimed at improving Human Development with respect to the HDI. With many of these policies providing optimism for socio-economic growth resulting from increased ICT investments and usage, the resultant effects have not been as promising as anticipated and sometimes they have not been evident at all. In this research, a Critical Discourse Analysis has been carried out on the UNDP Human Development Research Reports (HDRs), from 2010 to 2016, to determine if any public value is created or derived from the policy directions being put forward and their

subsequent implementations. This research is founded on Habermas Theory of Communicative Action approached from a Critical Theorist's epistemological perspective and falls within the progressive perspective of ICT-enabled development. In doing so, this research has been able to contribute to the ongoing global discourse on ICT4D with respect to policy directions of ICT interventions and their resultant impact on socio-economic development and public value creation, using a hitherto unfamiliar interpretivist approach within the e-government literature. Findings show that indeed public social value is created which is at the core of policy directions that are being called for in these reports.

10.2 How Research Questions were Answered

This thesis sets out to seek answers to a set of research questions and objectives clearly articulated in chapter 1. The array of 5 essays duly presented and published, have dutifully addressed each of these questions and the outcome is summarized below.

The principal research question asked in this thesis is: is any public value being created in ICT infrastructure utilization in education, and what are its resultant effect(s) on socio-economic development? In answering this principal research question, the specific research questions have been answered and the findings show that public value is indeed being created in ICT infrastructure utilization in education. It is also at the root and center of policy direction discussions within the ICT4D discourse. With education identified by the UNDP as a major component of the HDI, there is therefore a positive effect on socio-economic development.

Is there any Public Value being created in ICT infrastructure utilization in education? The specific research questions are:

- How can Learning Analytics be operationalized for decision making? (In answering this question, multiple linear regression is used to test a framework proposed for predictive analytics. In chapter 5 there is the proposal that students' academic performance in computer science courses can be predicted based on past performances in mathematics courses using archival data collected from the Department of Computer Science in a University in Nigeria. In this research, LA has been used for

prediction purposes, albeit in a local context. Having established its viability, the scope has been extended, as shown in chapters 6 and 7).

- What is the effect of ICT infrastructure utilization in education on socio-economic development? (Here OLS regression is used in determining the answer to this question, in chapters 6 and 7. Archival data has been collected from the ITU for ICT infrastructure indicators, World Bank and UNESCO for educational attainment and adult literacy rate indicators. Data has been collected for 2010 to 2016. Chapter 6 results show a strong positive correlation of the ICT indicators, predominantly individuals with Internet with the educational attainment and adult literacy rate indicators. However, in chapter 7 it can also be seen that the households with Internet has a significantly negative relationship with adult literacy rates. This is an interesting finding and can prove useful to donors and policy makers, as well as bring up interesting discussions within the ICT4D discourse).

- What are the relative efficiencies and productivity of ICT infrastructure utilization in education and its effect on socio-economic development? (This question is answered by findings in chapter 7. DEA has been used to measure the relative efficiency of ICT infrastructure utilization, with ICT indicators obtained from ITU as inputs and Adult literacy rates obtained from UNESCO as outputs. Data has been collected from 2010 to 2016. The regional groupings from the UNESCO data, Arab States, Sub-Saharan Africa, Europe and World have served as the DMU's. Malmquist Productivity Index has then been used to determine the productivity. Results have shown that Arab States have the least relatively efficient scores amongst the DMU's, although there has been a steady increase in relative efficiency from year to year in all regions. With regards to productivity, there is still opportunity for continuous growth, as the average values show that all regions are still operating in a declining state of productivity. However, Arab states and Europe have moved into a state of growth in productivity from 2013).

- What are the relative efficiencies and productivity of ICT infrastructure utilization in creating public value with respect to education? (This question is addressed in chapter 8. In addition to the ICT indicators and adult literacy rates data collected from ITU and UNESCO respectively, data is also collected on the key indicators of PV as established in the literature. These are control of corruption, government effectiveness,

regulatory quality and rule of law. These have been collected from the World Bank and serve as additional outputs in the efficiency and productivity assessment analysis, using the DMUs already introduced in chapter 7. Answers to this question can be found in Tables 22 and 23 where the relative efficiency and productivity scores respectively can be seen. Here it is possible to infer that public value is being created, albeit not at optimal efficiency with respect to Arab States. However, with regards to productivity assessments of the public value created, on average, all regions have productivity in a state of decline and as such there is room for improvement in the utilization of their ICT infrastructure in education, with respect to public value creation).

- Is any Public Value being created from ICT infrastructure policy formulation and calls, with respect to education in the UNDP HDRs? (This question is addressed in chapter 9. Here a CDA, operationalized by Habermas' TCA, is carried out on UNDP HDR's from 2010 to 2016. The CDA framework is implemented using a theoretical lens, postulated by Qureshi 2017, for viewing ICT related developmental outcomes in the ICT4D discourse. The research has been able to show that public value is indeed being created and is at the root of policy direction being called for in the 2010 to 2016 HDRs. This can be seen from tables 26 and 27 where critical stances are being taken and presented in the report with regards to the three indices representative of the concept of public value: accountability; government effectiveness; and freedoms).

In answering these questions, it has also been possible to achieve the main desired objectives which are:

- To inform practice on the viability of Learning Analytics in international ICT policy direction. This objective has been achieved in chapters 6 and 7.

- To assess the relative efficiency and productivity of ICT infrastructure utilization in education with respect to national development. This objective has been achieved in chapters 6 and 7.

- To investigate the efficiency and productivity of ICT Infrastructure utilization in public value creation with respect to education. This objective has been achieved in chapter 8.

- To determine if any public value is being created from ICT in education policy directions and interventions within the ICT4D global discourse. This objective has been achieved in chapter 9.

10.2 How Individual Studies Are Linked

The first study set out to operationalize learning analytics for decision making. The framework proposed and tested showed that indeed learning analytics is capable of aiding in decision making. This is consistent with the literature and emphasizes the benefits of analytics within the education domain, albeit at a micro level. Having shown that LA can be used for decision making, the second study set out to mitigate the major limitation of the first study, its scope. Also, the robustness of LA, being the ability to utilize various analytical tools and methods, was also investigated, hence, the use of a different analytical method in the second study from that used in the first study. Subsequently, with the viability of LA in relative efficiency analytics on a global (macro) scale determined from the results of the second study, the third study goes further by introducing productivity analytics. Using a well known and established econometric theory, the relevance to developmental economics within the ICT4D research area is also established in the third study. Furthermore, having met its set objectives, the fourth study introduces the public value concept to show that value is being created from use of LA in ICT4D research. This is done using the efficiency and productivity analytical methods used in the second and third studies. It brings in the public value dimension of ICT4D research into the established viable LA research. Finally, the fifth study sought to critically determine if public value is truly being called for and at the core of policy directions for developing economies. This is done introducing a hitherto unfamiliar method within the literature for public value determination and e-government. The fifth study also offers a major contribution to the ongoing global discourse in ICT4D, drawing from the outputs of the previous 4 essays and using a qualitative methodology to critically seek out relevant information from which this conclusion can be drawn. The data sources used for all the essays are internationally accepted data used for research and policy determination purposes.

CHAPTER 11

11.0 Conclusion and Recommendations

This chapter concludes this thesis. Contributions, limitations, and recommendations are presented here. It is important to state that this research does not seek to investigate the conditional impacts of ICT with respect to human development, but rather seeks to incorporate a new dimension of LA into the ICT4D discourse by illustrating how LA can be used for decision making aimed at improving socio-economic development. The chapter is organized as follows: section 11.1 provides the contributions to IS reseach, section 11.2 discusses the limitations and section 11.3 provides recommendations for future work.

11.1 Contributions to IS Research

This thesis has made some contributions, both in theory and in practice, to the ICT4D discourse and IS in general. These contributions are presented chapter by chapter and are as follows:

- Chapter 5 – This essay makes a contribution to practice by operationalizing predictive LA within an African educational institutional perspective. The essay proposes a framework for predicting student academic performances, and operationalizes same, using a local case study and showing how this framework can be used for decision making in the traditional context of LA. This contribution is even more relevant considering, that at the time the research was carried out and published, it was the first and only published research on the adoption and/or practice of LA being used in Africa, outside South Africa (Prinsloo, 2018). It was necessary to first establish the viability of LA in a developing economy's institutional perspective by localizing and operationalizing it for decision making before extending the scope and methodology for macro-economic applications. As LA and its constituent analytics methods and applications are still not predominant, in the global south especially, extending its application areas would not have been feasible without first of all establishing its

viability within the local context. This essay makes a strong contribution to the practice of LA research.

- Chapter 6 – This essay makes a contribution to both theory and practice by implementing LA for decision making in a macro-economic perspective. The research uses methods predominant in Operations Research literature to establish the relative efficiency of ICT infrastructure utilization within the educational context. This research enables decision making, by donors, funders and government, major players in Academic Analytics (AA), on determining how and where to focus resource utilization for efficient educational attainment and adult literacy rates, so as to have a positive effect on national development. It contributes to theory by determining a positively significant correlation of ICT infrastructure with educational attainment and adult literacy rates. This significant correlation shows a strong relationship between ICT infrastructure utilization with socio-economic outcomes within the educational component of the HDI, when assessing relative efficiency of ICT utilization, world-wide.

- Chapter 7 – This essay makes a further contribution to practice adding to the contributions made in chapter 6. This is done by further assessing productivity of ICT infrastructure utilization over a specific time period, to determine how productive the relative efficient utilization of ICT infrastructure in socio-economic development is with respect to education. This is done on world-wide data using established UNESCO regional groupings as the DMUs. This chapter also determines the significantly positive correlation of ICT infrastructure indicators with adult literacy rates directly. In this instance, it informs theory by providing a theoretical and empirical basis for the prevailing assumptions regarding ICT infrastructure utilization within the general ICT4D discourse. Here the research establishes an empirical evidence of a strong predominantly positive relationship of ICT, in this case individuals with Internet, on adult literacy rates and interestingly establishes that households with computers has a strong negative relationship with adult literacy rates. These findings can have diverse and ranging effects on policy directions and implementations.

- Chapter 8 – This essay contributes to practice by fusing the concepts of Public Value within the IS literature with efficiency and productivity assessment methods, to determine how Public Value can be created from ICT infrastructure utilization within the educational sector. With IS generally being a field drawing from various theories and methodologies, this contribution towards PV practice within the general IS literature focuses on ICT infrastructure utilization within the educational sector.

- Chapter 9 – This essay makes a strong contribution to both theory and practice within the global discourse on ICT4D developmental outcomes. It makes a theoretical contribution by operationalizing a CDA on Habermas' TCA to critically investigate a major policy direction and research discussion, the UNDP HDRs, in order to determine if any PV is created or has a place at the root of these discussions, with respect to educational developmental outcomes. With the majority of PV research within the e-government literature focusing on efficiency and productivity assessments, this research uses a hitherto unfamiliar theoretical approach to carry out the CDA, thereby making a strong contribution to the global ICT4D discourse and e-government literature. In practice, this research makes a contribution by using a theoretical lens postulated by Qureshi (2017), for viewing ICT developmental outcomes, and to define the developmental context on which the critical investigation is focused.

Overall, this thesis makes a general contribution to IS by employing multi-method mixed methods research from a Critical Theorists epistemological perspective. Considering that the IS domain draws from multiple research theories and methods, it is however interesting that the use of multi-method research approaches are generally scarce within the IS literature (Mingers, 2001). The use of multiple analytical methods in this thesis has not been done with the aim of triangulation in mind, but rather these methods have been employed with specific research questions and aims to be addressed. Multiple quantitative research methods, and a single qualitative method have been employed in the thesis. The quantitative study has been carried out and the findings have informed the qualitative study, although they are two distinctly separate studies within the same ICT4D domain, and their outcomes are presented accordingly.

11.2 Limitations of the Study

The major limitation in this research is centred around the availability of data. In study 2, data was collected from three different sources. Educational attainment data was collected from UNESCO, adult literacy rates data from World Bank, and ICT infrastructure data from ITU. Data for many countries were not readily available for some or all of the indices required, and the process of extrapolation had to be employed during the data cleaning and sorting stage. The data was then sorted into regional groupings; Sub-Saharan Africa, Northern Africa, Europe and North America, and World which in turn formed the DMUs. Although averages for the regional groupings were used, the lack of availability of complete data for certain countries made it statistically impossible to carry out intra DMU efficiency analysis. In study 3, the author tried to mitigate against this limitation by collecting data from just UNESCO and ITU. The adult literacy rates data collected from UNESCO had already been cleaned and sorted into the following regional groupings; Arab States, Europe, Sub-Saharan Africa, and World. These regional groupings then formed the DMU's with ICT infrastructure data collected from ITU and sorted in a similar way. However, complete data for some constituent countries within these groupings were still not readily available and hence intra-DMU analyses could not be carried out.

Another major limitation of this study is related to the scope of the research and is evident in Studies 1 and 5. In Study 1, the scope of the research is scaled down significantly to a single department in a University in Nigeria. As this research proposes a framework for the application of predictive analytics for decision making, there is a need for further testing and implementation of this framework in a larger population, as there are not enough empirical metrics for significant extrapolation. In Study 5, the scope of the study is limited to UNDP HDRs from 2010 to 2016. Although the HDRs are widely accepted policy direction and verified research discussion documents, they are not the only documents that are used for these purposes. Extending the CDA to these other widely accepted documents, such as the World Public Sector Reports (WPSR), would increase the validity of the research and strengthen the position presented in the discourse.

Finally, the major limitation to this study is in the ICT4D discourse itself. Much of the developmental discourse within ICT4D tends to seek and promulgate uniform policy prescriptions that can be applied across the vast majority of countries, assuming that economic growth is indispensable to achievements in areas such as health and education. A

standardized metric of assessment of these developmental outcomes are then applied and reports generated as to how countries rank amongst themselves. It is, however, evident and now widely accepted, that the results suggest that this is not the case, largely due to the fact that development processes and possibilities facing developing economies today are quite different from those that the now developed economies once faced (UNDP, 2010). Development therefore is not so much about having a one-size-fits-all solution based on experiences of developed economies, as it is about finding new paths to progress in today's world. Therefore, the shortcomings and limitation of this research and discourse is acknowledged.

11.3 Recommendations for Future Work

Some areas for future research work can be derived from the limitations presented in the previous section. One of these areas would be to implement the proposed framework introduced in chapter 5 on a larger scale as well as incorporate other salient factors that may be contributory factors to students academic perfomance. As more LA implementations and adoptions crop up, more data will be readily available. This will be of interest to educational managers and executives. Another direction for future work would be to investigate the extent to which each of the constituent ICT infrastructure indices individually and collectively affect educational attainment and adult literacy rates. The levels of interaction between these variables may have varying ranges of effects on the educational attainment indices and this could bring up interesting findings and discussions. Also, in future research, the perspectives of what constitute ICT infrastructure can be broadened to include soft ICT components such as capacities, skills and ICT Human Resources. This will add another dimension to the models in chapters 6, 7 & 8.

Another direction for future work will be to incorporate more policy direction and research discussion documents into the CDA. Also, the scope of the CDA can be expanded to include more developmental outcomes identified by Qureshi (2017). This will enable a more comprehensive critical analysis of the discourse and bring forth more robust discussions within the context of ICT4D. The practical outcomes of ICT implementations on national and international development, still remains a contentious topic within the ICT4D discourse. Many prevailing assumptions about ICT effects and impacts have definitely not been the case, and the reasons why have been well discussed amongst researchers in the literature (Heeks, 2002; Dada, 2006; Hasan, 2016). Critically investigating ICT developmental

outcomes and policy directions, across all sectors, through the lens introduced by Qureshi (2017), will make for a clearer understanding of implementing ICT interventions and could serve as a valuable tool for policy makers, funders and donors, as well as government agencies responsible for improving socio-economic development (Mansell, 2014; Choi et al., 2016).

11.4 References

Choi, H., Park, M. J., Rho, J. J., & Zo, H. (2016). Rethinking the assessment of e-government implementation in developing countries from the perspective of the design–reality gap: Applications in the Indonesian e-procurement system. *Telecommunications Policy*, *40*(7), 644-660.

Dada, D. (2006). The failure of e-government in developing countries: a literature review. *The Electronic Journal of Information Systems in Developing Countries*, *26*(1), 1-10.

Hasan, Z. (2016). Evaluation of a government ICT policy document from a communicative action perspective: A case of Bangladesh. *The Electronic Journal of Information Systems in Developing Countries*, *73*(1), 1-14.

Heeks, R. (2002). Information systems and developing countries: Failure, success, and local improvisations. *The information society*, *18*(2), 101-112.

Mansell, R. (2014). Power and interests in information and communication and development: exogenous and endogenous discourses in contention. *Journal of international development*, *26*(1), 109-127.

Mingers, J. (2001). Combining IS Research Methods: Towards a Pluralist Methodology. *Information Systems Research, 12 (3), 240-259.*

Prinsloo, P. (2018). Context Matters: An African Perspective on Institutionalizing Learning Analytics. *Include us All*, 24.

Qureshi, S. (2017). The forgotten awaken: ICT's evolving role in the roots of mass discontent. *Information Technology for Development,* 23:1, 1-17, DOI: 10.1080/02681102.2017.1293963

UNDP: United Nations Development Programme. (2010). Human Development Report 2010. The Real Wealth of Nations: Pathways to Human Development

Bibliography

Abbott, M., & Doucouliagos, C. (2003). The efficiency of Australian universities: a data envelopment analysis. *Economics of Education review*, *22*(1), 89-97.

Adomavicius, G., & Tuzhilin, A. (2005). Toward the next generation of recommender systems: A survey of the state-of-the-art and possible extensions. *IEEE Transactions on Knowledge & Data Engineering*, (6), 734-749.

Adu, K. K., Patrick, N., Park, E. G., & Adjei, E. (2018). Evaluation of the implementation of electronic government in Ghana. *Information Polity*, *23*(1), 81-94.

Afonso, A., & Aubyn, M. S. (2005). Non-parametric approaches to education and health efficiency in OECD countries. *Journal of applied economics*, *8*(2), 227-246.

Afonso, A., & Aubyn, M. S. (2006). Cross-country efficiency of secondary education provision: A semi-parametric analysis with non-discretionary inputs. *Economic modelling*, *23*(3), 476-491.

Afonso, A., & St Aubyn, M. (2006). Relative efficiency of health provision: A DEA approach with non-discretionary inputs. *ISEG-UTL economics working paper*, (33).

Agasisti, T., & J. Johnes. (2009). Beyond Frontiers: Comparing the Efficiency of Higher Education Decision-Making Units Across More Than One Country. *Education Economics* 17: 59-79.

Ahn, T., Charnes, A., & Cooper, W. W. (1988). Efficiency characterizations in different DEA models. Socio-Economic Planning Sciences, 22(6), 253-257

Ahrens, J. (2007). Governance in the process of economic transformation. System Transformation in Comparative Perspective. Affinity and diversity in institutional, structural and cultural patterns, *Munster: LITVerlag*

Akpan, P. (2000) Africa and the New ICTs: Implications for Development. Proceedings of the International Federation for Processing Conference (IFIP TC9), South Africa

Alvesson, M., & Deetz, S. (2000). *Doing critical management research*. Sage.

Anand, S., & Ravallion, M. (1993) Human Development in Poor Countries: On the Role of Private Incomes and Public Services. The Journal of Economic Perspective, *7*(1): 133–150

Angulo-Meza, L., & Lins, M. P. E. (2002). Review of methods for increasing discrimination in data envelopment analysis. *Annals of Operations Research*, *116*(1-4), 225-242.

Anozie, N., & Junker, B. W. (2006). Predicting end-of-year accountability assessment scores from monthly student records in an online tutoring system. Educational Data Mining: Papers from the AAAI Workshop. Menlo Park, CA: AAAI Press.

Apte, C. (2010). The role of machine learning in business optimization. In *Proceedings of the 27th International Conference on Machine Learning (ICML-10)* (pp. 1-2).

Arcelus, F. J., & Coleman, D. F. (1997). An efficiency review of university departments. *International Journal of Systems Science*, *28*(7), 721-729.

Aristovnik, A. (2012) The impact of ICT on Educational Performance and its efficiency in selected EU and OECD countries: a non-parametric analysis. http://dx.doi.org/10.2139/ssrn.2187482

Arjomandi, A., Salleh, M. I., & Mohammadzadeh, A. (2015). Measuring productivity change in higher education: an application of Hicks–Moorsteen total factor productivity index to Malaysian public universities. *Journal of the Asia Pacific Economy*, *20*(4), 630–643. https://doi.org/10.1080/13547860.2015.1045323

Arnold, A., Scheines, R., Beck, J.E., & Jerome, B. (2005). Time and Attention: Students, Sessions, and Tasks. In AAAI2005 Workshop on Educational Data Mining, Pittsburgh, 62-66.

Arsad, P. M., Buniyamin, N., Ab Manan, J. L., & Hamzah, N. (2011). Proposed academic students' performance prediction model: A Malaysian case study. In *Engineering Education (ICEED), 2011 3rd International Congress on* (pp. 90-94). IEEE.

Athanassapoulos, A., & E. Shale. 1997. Assessing the Comparative Efficiency of Higher Education. *Education Economics 5:* 117_134.

Atici, K. B., & Podinovski, V. V. (2015). Using data envelopment analysis for the assessment of technical efficiency of units with different specialisations: An application to agriculture. *Omega*, *54*, 72-83.

Avgerou, C. (2008). Information systems in developing countries: a critical research review. *Journal of information Technology*, *23*(3), 133-146.

Avgerou, C. (2010) Discourses on ICT and development. Information Technologies & International Development, 6(3): 1

Avgerou, C. (2017). Theoretical framing of ICT4D research. In *International Conference on Social Implications of Computers in Developing Countries* (pp. 10-23). Springer, Cham.

Aviv, R., Erlich, Z., Ravid, G., & Geva, A. (2003). Network analysis of knowledge construction in asynchronous learning networks. *Journal of Asynchronous Learning Networks*, *7*(3), 1-23.

Avkiran, N. K. (2001). Investigating technical and scale efficiencies of Australian universities through data envelopment analysis. *Socio-Economic Planning Sciences*, *35*(1), 57-80.

Ayers E., & Junker B.W. (2006). Do skills combine additively to predict task difficulty in eighth grade mathematics? In AAAI Workshop on Educational Data Mining: Menlo Park, 14-20.

Ayogu, M. (2006). Infrastructure development in Africa: Prospect and challenges. *Paper on economic development in the millennium AERC-AfDB Project on Africa's development, Tunis 22–24 November 2006*.

Aziz, A. (2018). *ICT Policy Challenges for Digital Inclusion in Bangladesh* (Doctoral dissertation, Vrije Universiteit Brussel).

Aziz, A. A., Ismail, N. H., & Ahmad, F. (2013). Mining Students' Academic Performance. *Journal of Theoretical & Applied Information Technology*, *53*(3).

Baepler, P., & Murdoch, C. J. (2010). Academic analytics and data mining in higher education. *International Journal for the Scholarship of Teaching and Learning*, *4*(2), 17.

Baker, R., & Yacef, K. (2009). The State of Educational Data Mining in 2009: A Review and Future Visions. *Journal of Educational Data Mining (JEDM)*, 1(1), 3–17.

Baker, R. S. J. D. (2010). Data mining for education. *International encyclopedia of education*. B. McGaw, P. Peterson, and E. Baker, Eds., 3rd ed. Oxford, U.K.: Elsevier, *7*, 112-118.

Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management science*, *30*(9), 1078-1092

Banker, R. D., Cooper, W. W., Seiford, L. M., Thrall, R. M., & Zhu, J. (2004). Returns to scale in different DEA models. *European Journal of Operational Research*, *154*(2), 345-362.

Bankole Dr, F., & Mimbi, L. (2017). ICT Infrastructure and It's Impact on National Development: A Research Direction for Africa. *The African Journal of Information Systems*, *9*(2), 1.

Bankole, F. O., & Bankole, O. O. (2017). The effects of cultural dimension on ICT innovation: Empirical analysis of mobile phone services. *Telematics and Informatics*, *34*(2), 490-505.

Bankole, F. O., Brown, I., & Osei-Bryson, K. M. (2011) The Impact of ICT Infrastructure on Human Development: An Analysis of ICT-Use in SADC Countries. In Proceedings of the 11th International Conference on Social Implications of Computers in Developing Countries, Kathmandu, Nepal, May 2011

Bankole, F. O., Osei-Bryson, K. M., & Brown, I. (2011). ICT infrastructure utilization in Africa: Data envelopment analysis-based exploration. In *Proceeding of special interest group on ICT and global development at Americas Conference on Information System (AMCIS) Workshop, Detroit, USA*.

Bankole, F. O., Osei-Bryson, K. M., & Brown, I. (2015). The impact of information and communications technology infrastructure and complementary factors on Intra-African Trade. *Information Technology for Development*, *21*(1), 12-28.

Bankole, F. O., Osei-Bryson, K. M., & Brown, I. (2015). The impacts of telecommunications infrastructure and institutional quality on trade efficiency in Africa. *Information Technology for Development*, *21*(1), 29-43.

Bankole, F. O., Shirazi, F., & Brown, I. (2011). Investigating the impact of ICT investments on human development. *The Electronic Journal of Information Systems in Developing Countries*, *48*(1), 1-19.

Bankole, F., & Assefa, Z. (2017). Improving the Quality of Education and Research Output In Africa A Case of Ethiopian Education and Research Network (ETHERNET). *The Journal of Applied Global Research*, *10*(24), 31-51.

Bankole, F., & Mimbi, L. (2017). ICT Infrastructure and It's Impact on National Development: A Research Direction for Africa. *The African Journal of Information Systems*, *9*(2): 1

Bankole, F.O (2015). ICT Infrastructure and Its' Impact on National Development: A Research Direction for Africa Using Analytics. *In Proceedings of SIG GlobDev 2015 Pre-ECIS Workshop, Munster, Germany, May 26, 2015*

Bankole, O. O., Bisimwa, K., van Vuuren, I. J., Onumajuru, P. U., & Chigona, W. (2010). The SEACOM Undersea Fibre Optic Cable Project: A Critical Discourse Analysis. *In Proceedings of International Development Informatics Association IDIA2010 Conference.*

Bannister, F., & Connolly, R. (2014). ICT, public values and transformative government: A framework and programme for research, *Government Information Quarterly* (31)1, 119-128.

Baqir, M. N., Palvia, P., & Nemati, H. (2009). Evaluating government ICT policies: An extended design-actuality gaps framework. In *Proceedings of Second Annual SIG GlobDev Workshop*

Barth, K. (2019). *An analysis of semantic data quality deficiencies in a national data warehouse: a data mining approach* (Doctoral dissertation).

Basu, A. T. A. N. U. (2013). Five pillars of prescriptive analytics success. *Analytics magazine*, 8-12.

Beck, J. E., & Woolf, B. P. (2000, June). High-level student modeling with machine learning. In *International Conference on Intelligent Tutoring Systems* (pp. 584-593). Springer, Berlin, Heidelberg.

Benington, J., & Moore, M. H. (Eds.). (2010). *Public value: Theory and practice*. Macmillan International Higher Education.

Berners-Lee, T., Hendler, J., & Lassila, O. (2001). The semantic web. *Scientific american*, *284*(5), 28-37.

Bernstein, H. (1971). Modernization Theory and the Sociological Study of Development. *Journal of Development Studies*, *7*(2), 141–160.

Bertsimas, D., & Kallus, N. (2019). From predictive to prescriptive analytics. *Management Science*.

Bessent, A. M., Bessent, E. W., Charnes, A., Cooper, W. W., & Thorogood, N. C. (1983). Evaluation of educational program proposals by means of DEA. *Educational Administration Quarterly*, *19*(2), 82-107.

Blaug, R., Horner, L., & Lekhi, R. (2006). Public value, politics and public management A literature review." www.theworkfoundation.com

Bollou, F. (2006). ICT Infrastructure Expansion in Sub-Saharan Africa: An Analysis of Six West African Countries from 1995 to 2002. *The Electronic Journal of Information Systems in Developing Countries*, *26*(1), 1-16.

Bolton, R. (2005). Habermas's theory of communicative action and the theory of social capital. *Association of American Geographers, Denver, Colorado, April*, *2*.

Bradley, S., Johnes, G., & Millington, J. (2001). The effect of competition on the efficiency of secondary schools in England. *European Journal of Operational Research*, *135*(3), 545-568.

Bradley, S., Johnes, J., & Little, A. (2010). Measurement and determinants of efficiency and productivity in the further education sector in England. *Bulletin of Economic Research*, *62*(1), 1-30.

Brewer, G. A., Neubauer, B. J., & Geiselhart, K. (2006). Designing and Implementing E-Government Systems Critical Implications for Public Administration and Democracy, *Administration & Society* (38)4, 472-499

Briede, B. (2017) Usage of the Goals for Sustainable Development in Formation of Learning Outcomes in Higher Education. In *Rural Environment. Education. Personality. (REEP).* Proceedings of the International Scientific Conference (Latvia). Latvia University of Agriculture

Brown, W., & Brown, I. (2008). Next generation ICT policy in South Africa: Towards a human development-based ICT policy. In *IFIP International Conference on Human Choice and Computers* (pp. 109-123). Springer, Boston, MA

Bryman, A. (1984). The debate about quantitative and qualitative research: a question of method or epistemology? *British journal of Sociology*, 75-92.

Brynjolfsson, E., & Hitt, L. M. (1996). Productivity, Profit and Consumer Welfare. Three Different Measures of Information Technology's Value. *MIS Quarterly*, 1–23

Bukht, R., & Heeks, R. (2018). Digital economy policy in developing countries (DIODE Working Papers No. 7). Manchester: University of Manchester.

Calvo-Flores, M. D., Galindo, E. G., Jiménez, M. P., & Pineiro, O. P. (2006). Predicting students' marks from Moodle logs using neural network models. *Current Developments in Technology-Assisted Education*, *1*(2), 586-590.

Campbell, J. P., & Oblinger, D. G. (2007). Top-ten teaching and learning issues, 2007. *Educause Quarterly*, *30*(3), 15-22.

Campbell, J. P., DeBlois, P. B., & Oblinger, D. G. (2007). Academic analytics: A new tool for a new era. *EDUCAUSE review*, *42*(4), 40.

Canning, D. (1999). *A Database of World Infrastructure Stocks, 1950 95*. The World Bank.

Carrington, R., T. Coelli, & D.S.P. Rao. (2005). The Performance of Australian Universities: Conceptual Issues and Preliminary Results. *Economic Papers* 24: 145-163.

Castelnovo, W., & Simonetta, M. (2007). The Evaluation of e-Government projects for Small Local Government Organisations. *Electronic Journal of e-Government*, *5*(1).

Caves, D., Christensen, L., & Diewert, W. (1982). The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity. *Econometrica*, *50*(6), 1393–1414.

Cecez-Kecmanovic, D., & Janson, M. (1999). Communicative action theory: an approach to understanding the application of information systems. In *ACIS, Australasian Conference on Information Systems*.

Cetintas, S., Si, L., Xin, Y. P., & Hord, C. (2009). Predicting Correctness of Problem Solving from Low-Level Log Data in Intelligent Tutoring Systems. *International Working Group on Educational Data Mining*.

Chan, C. C. (2007). A framework for assessing usage of web-based e-learning systems. In *Second International Conference on Innovative Computing, Informatio and Control (ICICIC 2007)* (pp. 147-147). IEEE.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978) Measuring the efficiency of decision-making units. European journal of operational research, 2(6): 429-444.

Chatti, M.A., Dyckhoff, A.L., Schroeder, U., & Thüs, H. (2012). A reference model for learning analytics. *International Journal of Technology Enhanced Learning*, 4(5/6), 318–331.

Chen, C. M., Chen, M. C., & Li, Y. L. (2007). Mining key formative assessment rules based on learner profiles for web-based learning systems. In *Seventh IEEE International Conference on Advanced Learning Technologies (ICALT 2007)* (pp. 584-588). IEEE.

Chigona, A., & Chigona, W. (2008). MXit it up in the media: Media discourse analysis on a Mobile instant messaging system. *The African Journal of Information and Communication*, *2008*(9), 42-57.

Choi, H., Park, M. J., Rho, J. J., & Zo, H. (2016). Rethinking the assessment of e-government implementation in developing countries from the perspective of the design–reality gap: Applications in the Indonesian e-procurement system. *Telecommunications Policy*, *40*(7), 644-660.

Chouliaraki, L., & Fairclough, N. (1999). *Discourse in Late Modernity: Rethinking Critical Discourse Analysis (Critical Discourse Analysis EUP)*. Edinburg, UK: Edinburg University Press.

Clements, B. (2002). How efficient is education spending in Europe? *European Review of Economics and Finance, 1: 3-26*.

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). *An introduction to efficiency and productivity analysis*. Springer Science & Business Media.

Cook, W. D., & Seiford, L. M. (2009). Data envelopment analysis (DEA)–Thirty years on. *European journal of operational research*, *192*(1), 1-17.

Cook, W. D., Tone, K., & Zhu, J. (2014). Data envelopment analysis: Prior to choosing a model. *Omega*, *44*, 1-4.

Cooper, W. W., Seiford, L. M., & Tone, K. (2000). Data envelopment analysis. *Handbook on Data Envelopment Analysis, 1st ed.; Cooper, WW, Seiford, LM, Zhu, J., Eds*, 1-40.

Cooper, W. W., Seiford, L. M., & Tone, K. (2006). Introduction to data envelopment analysis and its uses. *New York: Springer*.

Cooper, WW, Seiford, LM & Tone, K. (2007). Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software.

Crawshaw, J., & Chambers, J. (1984). *A concise course in A-level statistics*. Nelson Thornes Limited.

Cukier, W., Bauer, R., & Middleton, C. (2004). Applying Habermas' validity claims as a standard for critical discourse analysis. In *Information systems research* (pp. 233-258). Springer, Boston, MA.

Dabla, A. (2004). The role of information technology policies in promoting social and economic development: The case of the State of Andhra Pradesh, India. *The Electronic Journal of Information Systems in Developing Countries*, *19*(1), 1-21.

Dada, D. (2006). The failure of e-government in developing countries: a literature review. *The Electronic Journal of Information Systems in Developing Countries*, *26*(1), 1-10.

Daud, A., Aljohani, N. R., Abbasi, R. A., Lytras, M. D., Abbas, F., & Alowibdi, J. S. (2017). Predicting student performance using advanced learning analytics. In *Proceedings of the 26th international conference on world wide web companion* (pp. 415-421).

Davenport, T., & Harris, J. (2017). *Competing on analytics: Updated, with a new introduction: The new science of winning*. Harvard Business Press.

Dawson, S. (2010). 'Seeing' the learning community: An exploration of the development of a resource for monitoring online student networking. *British Journal of Educational Technology*, *41*(5), 736-752.

De Laat, M., Lally, V., Lipponen, L., & Simons, R. J. (2006). Analysing student engagement with learning and tutoring activities in networked learning communities: A multi-method approach. *International Journal of Web Based Communities*, *2*, 394-412.

De Laat, M., Lally, V., Lipponen, L., & Simons, R. J. (2007). Investigating patterns of interaction in networked learning and computer-supported collaborative learning: A role for Social Network Analysis. *International Journal of Computer-Supported Collaborative Learning*, *2*(1), 87-103.

De Liddo, A., Shum, S. B., Quinto, I., Bachler, M., & Cannavacciuolo, L. (2011, February). Discourse-centric learning analytics. In *Proceedings of the 1st international conference on learning analytics and knowledge* (pp. 23-33). ACM.

de Waal, C. (2001). On Peirce. Belmont, CA: Wadsworth.

Dedrick, J., Gurbaxani, V., & Kraemer, K. L. (2003). Information technology and economic performance: A critical review of the empirical evidence. *ACM Computing Surveys (CSUR)*, *35*(1), 1-28.

Delen, D., & Demirkan, H. (2013). Data, information and analytics as services. *Decision Support Systems,* 55(1), 359–363.

Desai, M. (1991). Human development: concepts and measurement. *European Economic Review*, *35*(2-3), 350-357.

Desmarais, M. C., & Gagnon, M. (2006). Bayesian student models based on item to item knowledge structures. In *European Conference on Technology Enhanced Learning* (pp. 111-124). Springer, Berlin, Heidelberg.

Despotis, D. K. (2005). A reassessment of the human development index via data envelopment analysis. *Journal of the operational research society*, *56*(8), 969-980.

Despotis, D. K. (2005). Measuring human development via data envelopment analysis: the case of Asia and the Pacific. *Omega*, *33*(5), 385-390.

Draca, M., Sadun, R., & Van Reenen, J. (2006). Productivity and ICT: A Review of the Evidence. In R. Mansell, C. Avgerou, D. Quah, & R. Silverstone (Eds.), *The Oxford handbook of information and communication technologies pp. 100–147*. Oxford: Oxford University Press.

Draper, N. R., & Smith, H. (1998). *Applied regression analysis* (Vol. 326). John Wiley & Sons.

Dringus, L. P., & Ellis, T. (2005). Using data mining as a strategy for assessing asynchronous discussion forums. *Computers & Education*, *45*(1), 141-160.

Dutta, A. (2001). Telecommunications and Economic Activity: An Analysis of Granger Causality. *Journal of Management Information Systems*, *17*(4), 71–95

Easton, L., Murphy, D. J., & Pearson, J. N. (2002). Purchasing performance evaluation: with data envelopment analysis, *European Journal of Purchasing & Supply Management* (8)3, 123-134

Eckerson, W. W. (2007). Predictive Analytics. Extending the Value of Your Data Warehousing Investment. TDWI Best Practices Report. Q1 2007.

Emrouznejad, A., & E. Thanassoulis. (2005). A Mathematical Model for Dynamic Efficiency Using Data Envelopment Analysis. *Applied Mathematics and Computation* 160: 363_378

Emrouznejad, A., Banker, R. D., & Neralic, L. (2019). Advances in Data Envelopment Analysis: Celebrating the 40th anniversary of DEA and the 100th anniversary of Professor Abraham Charnes' birthday. *European Journal of Operational Research*, *278*(2), 365-367.

Ess, C. (1996). Introduction: Thoughts along the I-way: Philosophy and the emergence of computer-mediated communication. *Philosophical perspectives on computer-mediated communication*, 1-12.

Etchells, T. A., Nebot, À., Vellido, A., Lisboa, P. J., & Mugica, F. (2006). Learning what is important: feature selection and rule extraction in a virtual course. In *ESANN* (pp. 401-406).

EU Expert Group (2010) Assessing Europe's University-Based Research, European Commission, Brussels, Belgium.

Fairclough, N. (2013). *Critical discourse analysis*. R. Wodak (Ed.). London: Sage.

Färe, B. R., Grosskopf, S., Norris, M & Zhang, Z. (1994). Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries. *The American Economic Review*, *84*(1), 66–88.

Färe, R., Grosskopf, S., Forsund, F. R., Hayes, K., & Heshmati, A. (2006). Measurement of productivity and quality in non-marketable services: with application to schools. *Quality Assurance in Education*, *14*(1), 21-36.

Färe, R.S., Grosskopf, S., & Lovell, C.A.K. (1994). *Production Frontiers*, Cambridge University Press.

Fausett, L. V., & Elwasif, W. (1994, June). Predicting performance from test scores using backpropagation and counterpropagation. In *Proceedings of 1994 IEEE International Conference on Neural Networks (ICNN'94)* (Vol. 5, pp. 3398-3402). IEEE.

Feng, M., Heffernan, N. T., & Koedinger, K. R. (2005, July). Looking for sources of error in predicting student's knowledge. In *Educational Data Mining: Papers from the 2005 AAAI Workshop* (pp. 54-61).

Ferguson, R. (2012). Learning analytics: drivers, developments and challenges. *International Journal of Technology Enhanced Learning*, *4*(5/6), 304-317.

Ferguson, R., & Shum, S. B. (2011). Learning analytics to identify exploratory dialogue within synchronous text chat. In *Proceedings of the 1st International Conference on Learning Analytics and Knowledge* (pp. 99-103). ACM.

Ferguson, R., & Shum, S. B. (2012). Social learning analytics: five approaches. In *Proceedings of the 2nd international conference on learning analytics and knowledge* (pp. 23-33). ACM.

Fielding, D., & Torres, S. (2009). Health, Wealth, Fertility, Education, and Inequality. *Review of Development Economics*, *13*(1), 39–55

Fischer, F. (2003). *Reframing public policy: Discursive politics and deliberative practices*. Oxford University Press.

Flegg, A.T., Allen, D.O., Field, K., & Thurlow, T.W. (2004). Measuring the Efficiency of British Universities: A Multi-Period Data Envelopment Analysis. *Education Economics* 12:, 231-249.

Freyberger, J., Heffernan, N. T., & Ruiz, C. (2004). Using association rules to guide a search for best fitting transfer models of student learning. In *ICITS 2004 Workshop on Analyzing Student-Tutor Interaction Logs to Improve Educational Outcomes*.

Friedman, T. L. (2005). *The world is flat: A brief history of the twenty-first century*. Macmillan.

Ganju, K. K., Pavlou, P. A., & Banker, R. D. (2015) Does information and communication technology lead to the well-being of nations? A country-level empirical investigation

Gauld, R., Goldfinch, S., & Horsburgh, S. (2010). Do they want it? Do they use it? The 'Demand-Side'of e-Government in Australia and New Zealand, *Government Information Quarterly* (27)2, 177- 186.

Gedeon, T. D., & Turner, S. (1993). Explaining student grades predicted by a neural network. In *Proceedings of 1993 International Conference on Neural Networks (IJCNN-93-Nagoya, Japan)* (Vol. 1, pp. 609-612). IEEE.

Ghasemi, M. R., Ignatius, J., & Rezaee, B. (2018). Improving discriminating power in data envelopment models based on deviation variables framework. *European Journal of Operational Research.*

Gilhooly, D. & Ocampo, J. (2005) Creating an Enabling Environment: Toward theMillennium Development Goals, The United Nations Information and Communication Technologies Task Force, New York

Golany, B., & Roll, Y. (1989). An application procedure for DEA. *Omega,* 17(3), 237-250

Golding, P., & Donaldson, O. (2006). Predicting academic performance. In *Proceedings. Frontiers in Education. 36th Annual Conference* (pp. 21-26). IEEE.

Goldstein, P. J., & Katz, R. N. (2005). *Academic analytics: The uses of management information and technology in higher education* (Vol. 8, pp. 1-12). Educause.

Gramsci, A. (1978). Selections from the Political Writings, ed. and trans. Q. Hoare.

Granovetter, M.S. (1973) 'The strength of weak ties', *American Journal of Sociology*, Vol. 8, pp. 1360-1380

Greene, J. C., Caracelli, V. J., & Graham, W. F. (1989). Toward a conceptual framework for mixed-method evaluation designs. Educational Evaluation and Policy Analysis, 11, 255–274.

Gregory, R., & Hicks, C. (1999). Promoting public service integrity: A case for responsible accountability. *Australian Journal of Public Administration*, *58*(4), 1-15.

Grigorescu, A. (2003). International organizations and government transparency: Linking the international and domestic realms. *International Studies Quarterly*, *47*(4), 643-667.

Grosskopf, S., & Moutray, C. (2001). Evaluating performance in Chicago public high schools in the wake of decentralization. *Economics and Education Review, 20, 1–14*.

Gülbahar, Y., (2008) ICT usage in higher education: a case study on preservice teachers and instructors, The Turkish Online Journal of Educational Technology, 7(1): 32-37

Gülbahar, Y., (2008). ICT usage in higher education: a case study on preservice teachers and instructors, *The Turkish Online Journal of Educational Technology, 7(1)*: 32-37.

Gupta, S., & Verhoeven, M. (2001). The efficiency of government expenditure: experiences from Africa. *Journal of policy modeling*, *23*(4), 433-467.

Gurumurthy, A. (2010). From social enterprises to mobiles-seeking a peg to hang a premeditated ICTD theory. *Information Technologies & International Development*, *6*(SE), pp-57.

Haas, P. J., Maglio, P. P., Selinger, P. G., & Tan, W. C. (2011). Data is Dead... Without What-If Models. *PVLDB*, *4*(12), 1486-1489.

Habermas, J. (1984). *The theory of communicative action* (Vol. 2). Beacon press.

Habermas, J. (1987), Théorie de l'agir communicationnel, Tome 1, Rationalité de l'agir et rationalisation de la société, Fayard (L'espace du politique).

Hajkova, A. D., & Hurnik, J. (2007). Cobb-Douglas Production Function: The Case of a Converging Economy. *Journal of Economics and Finance*, *57*, 9–10.

Hämäläinen, W., & Vinni, M. (2006). Comparison of machine learning methods for intelligent tutoring systems. In *International Conference on Intelligent Tutoring Systems* (pp. 525-534). Springer, Berlin, Heidelberg.

Hanafizadeh, P., Khosravi, B., & Badie, K. (2019). Global discourse on ICT and the shaping of ICT policy in developing countries. *Telecommunications Policy*, *43*(4), 324-338.

Hanna, N., Guy, K., & Arnold, E. (1995). The diffusion of information technology: experience of industrial countries and lessons for developing countries. The World Bank.

Hardy, A. P. (1980). The role of the telephone in economic development. *Telecommunications policy*, *4*(4), 278-286.

Hargreaves A., & Braun, H. (2013) Data-driven improvement and accountability. National Education Policy Centre, Boulder, CO. http://co.chalkbeat.org/wp-content/uploads/sites/2/2013/10/PB-LB-DDIA-POLICY-FINAL-EMBARGOED.pdf.

Hasan, Z. (2016). Evaluation of a government ICT policy document from a communicative action perspective: A case of Bangladesh. *The Electronic Journal of Information Systems in Developing Countries*, *73*(1), 1-14.

Hatami-Marbini, A., Saati, S., & Tavana, M. (2010) An ideal-seeking fuzzy data envelopment analysis framework. Applied Soft Computing, 10(4): 1062-1070

Hayes, N., & Westrup, C. (2012). Context and the processes of ICT for development. *Information and organization*, *22*(1), 23-36.

Hays, W. L. (1994). Inferences about population means. *Statistics*, *5*, 311-42.

Hays, W. L. (1994). *Statistics (5th edition)*. Harcourt Brace College Publishers.

Haythornthwaite, C. (2006). Facilitating collaboration in online learning. *Journal of Asynchronous Learning Networks*, *10*(1), 7-24.

Haythornthwaite, C., & De Laat, M. (2010). Social networks and learning networks: Using social network perspectives to understand social learning. In *Proceedings of the 7th international conference on networked learning* (pp. 183-190). Aalborg, Denmark: Lancaster University.

Heeks, R. (2002). Information systems and developing countries: Failure, success, and local improvisations. *The information society*, *18*(2), 101-112

Heeks, R. (2009). IT and the World's' Bottom Billion'. *Communications of the ACM*, *52*(4), 22-24.

Heeks, R. (2010). Do information and communication technologies (ICTs) contribute to development? *Journal of international development*, *22*(5), 625-640.

Heng, M. S., & De Moor, A. (2003). From Habermas's communicative theory to practice on the internet. *Information Systems Journal*, *13*(4), 331-352.

Hien, N. T. N., & Haddawy, P. (2007). A decision support system for evaluating international student applications. In *2007 37th annual frontiers in education conference-global engineering: knowledge without borders, opportunities without passports* (pp. F2A-1). IEEE.

Hinostroza, J. E. (2018). New Challenges for ICT in Education Policies in Developing Countries: The Need to Account for the Widespread Use of ICT for Teaching and Learning Outside the School. In *ICT-Supported Innovations in Small Countries and Developing Regions* (pp. 99-119). Springer, Cham.

Hinostroza, J. E., Isaacs, S., & Bougroum, M. (2014). Information and communications technologies for improving learning opportunities and outcomes in developing countries. *In Learning and education in developing countries: Research and policy for the post-2015 UN development goals* (pp. 42-57). Palgrave Pivot, New York.

Hinostroza, J. E., Jara, I., & Brun, M. (2011) Chapter 6: Case study: Uruguay. In R. B. Kozma (Ed.), Transforming education: The power of ICT policies pp. 125–164. Paris, France: UNESCO

Hirschheim, R. & Klein, H. K. (2003). Crisis in the IS Field? A Critical Reflection on the State of the Discipline. *Journal of the Association for Information Systems*, *4*(1), 10.

Hollingsworth, B., & Smith, P. (2003). Use of ratios in data envelopment analysis. *Applied Economics Letters*, *10*(11), 733-735.

Hollyer, J. R., Rosendorff, B. P., & Vreeland, J. R. (2014). Measuring transparency. *Political analysis*, *22*(4), 413-434.

Howe, K. R. (1992). Getting over the quantitative-qualitative debate. *American Journal of Education*, *100*(2), 236-256.

https://economicpoint.com/production-function/cobb-douglas Cobb Douglas Production Function

Hudson, H. E. (1998). Global connections. International Telecommunications Infrastructure and Policy. *Telecommunications Policy*, *22*(4), 455.

Hutcheson, G. D. (1999). *The multivariate social scientist*.: SAGE Publications, Ltd. doi: 10.4135/9780857028075

Huttunen, R. (2000) *Habermas' Ideal Speech Situation*. http://www.srcf.net/pipermail/theoryfrankfurt-school/2000-October/002820.html

Ibrahim, Z., & Rusli, D. (2007). Predicting students' academic performance: comparing artificial neural network, decision tree and linear regression. In *21st Annual SAS Malaysia Forum, 5th September*.

International Development Research Center (IDRC) (1999). The Acacia Initiative. IDRC, Ottawa, ON, Canada. www.idrc.ca/acacia

Islam, R. (2006). Does more transparency go along with better governance? *Economics & Politics*, *18*(2), 121-167.

ITU: International Telecommunications Union. (2006). World telecommunications development report 2006: Measuring ICT for social and economic development. Geneva, Switzerland: International Telecommunications Union.

ITU: International Telecommunications Union. (2016). "ICT Facts and Figures 2016." Geneva. www.itu.int/en/ITU-D/Statistics/Documents/facts/ ICTFactsFigures2016.pdf

Jaeger, P. T., & Bertot, J. C. (2010). Transparency and technological change: Ensuring equal and sustained public access to government information. *Government Information Quarterly*, *27*(4), 371-376.

Jeremic, V., Markovic, A., & Radojick, Z. (2011). ICT as Crucial Component of Socio-economic Development. *Management (1820-0222)*, (60).

Johnes, J. (2006). Data envelopment analysis and its application to the measurement of efficiency in higher education. *Economics of Education Review*, *25*(3), 273-288.

Johnes, J. (2008). Efficiency and Productivity Change in the English Higher Education Sector from 1996/97 to 2004/5. *Manchester School* 76: 653_674.

Johnes, J., & Li, Y. U. (2008). Measuring the research performance of Chinese higher education institutions using data envelopment analysis. *China economic review*, *19*(4), 679-696.

Johnson, L., Adams, S., & Cummins, M. (2012). NMC Horizon Report: 2012 K-Austin, TX: The New Media Consortium.

Johnson, L., Smith, R., Willis, H., Levine, A., & Haywood, K. (2011). *NMC Horizon Report: 2011 Edition*. The New Media Consortium.

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational researcher*, *33*(7), 14-26

Johnson, R. B., Meeker, K. M., Loomis, E. J., & Onwuegbuzie, A. J. (2004). Development of the philosophical and methodological beliefs inventory. In *annual meeting of the American Educational Research Association, San Diego, CA*.

Kadam, U. (n.d). Impact of Technology in Higher Education.

Kaufmann, D., Kraay, A., & Mastruzzi, M. (2008). *Governance matters VII: aggregate and individual governance indicators 1996-2007*. The World Bank.

Kayisire, D., & Wei, J. (2016). Information Technology for Development ICT Adoption and Usage in Africa : Towards an Efficiency Assessment, *1102*. https://doi.org/10.1080/02681102.2015.1081862

Kearns, I. (2004). *Public value and e-government*. London: Institute for Public Policy Research.

Kelly, G., Mulgan, G., & Muers, S. (2002). Creating Public Value: An analytical framework for public service reform. *London: Strategy Unit, Cabinet Office*.

Kenny, C., Navas-Sabater, J., & Qiang, C. (2001). Information and Communication Technologies and Poverty. *TecKnowLogia, 3 (4)*, 7-11.

Kenton, W. (2019). Multiple Linear Regression – MLR Definition. Article. Investopedia. https://www.investopedia.com/terms/m/mlr.asp. Accessed on October 2nd 2019

Kiiski, S. K. (2001) Cross country Diffusion of the Internet. UNU/WIDER Discussion paper WDP, 11

Kim, H., Shin, D. H., & Lee, D. (2015). A socio-technical analysis of software policy in Korea: Towards a central role for building ICT ecosystems. *Telecommunications Policy*, *39*(11), 944-956.

Kleesuwan, S., Mitatha, S., Yupapin, P. P., & Piyatamrong, B. (2010). Business intelligence in Thailand's higher educational resources management. *Procedia-Social and Behavioral Sciences*, *2*(1), 84-87.

Klein, H. K., & Huynh, M. Q. (2004). The critical social theory of Jürgen Habermas and its implications for IS research. *Social theory and philosophy for information systems*, 157-237.

Ko, M., & Osei-Bryson, K. M. (2004). Using regression splines to assess the impact of information technology investments on productivity in the health care industry. *Information Systems Journal*, *14*(1), 43-63.

Kotsiantis, S. B., & Pintelas, P. E. (2005). Predicting students marks in hellenic open university. In *Fifth IEEE International Conference on Advanced Learning Technologies (ICALT'05)* (pp. 664-668). IEEE.

Kraemer, K. L., & Dedrick, J. (1994). Payoffs from investment in information technology: Lessons from the Asia-Pacific region. *World Development*, *22*(12), 1921-1931.

Kumar, R., & Best, M. L. (2006). Social impact and diffusion of telecenter use: A study from the sustainable access in rural India project. *The journal of community informatics*, *2*(3).

Lakoff, G. & Johnson, M. (1980). *Metaphors We Live By.* Chicago. University of Chicago Press.

Lakoff, G. & Johnson, M. (1999). *Philosophy in the Flesh.* New York. Basic Books.

Landauer, T. K., Foltz, P. W., & Laham, D. (1998). An introduction to latent semantic analysis. *Discourse processes*, *25*(2-3), 259-284.

Learning Analytics and Knowledge. (2011). *1st International Conference on Learning Analytics and Knowledge 2011.* Retrieved from https://tekri.athabascau.ca/analytics/

Lee, I., & Shin, Y. J. (2018). Fintech: Ecosystem, business models, investment decisions, and challenges. *Business Horizons*, *61*(1), 35-46.

Lee, K. R., Leem, B., Lee, C. W., & Lee, C. (2011). Malmquist Productivity Index using DEA frontier in Stata. *Stata Journal*, *2*(2), 1-9.

Lee, S. Y., & Whitford, A. B. (2009). Government effectiveness in comparative perspective. *Journal of Comparative Policy Analysis*, *11*(2), 249-281.

Liberatore, M., & Luo, W. (2011). INFORMS and the analytics movement: The view of the membership. *Interfaces*, *41*(6), 578-589.

Liu, J. S., Lu, L. Y., Lu, W. M., & Lin, B. J. (2013). Data envelopment analysis 1978–2010: A citation-based literature survey. *Omega*, *41*(1), 3-15

Liu, J. S., Lu, L. Y., Lu, W. M., & Lin, B. J. (2013). A survey of DEA applications. *Omega*, *41*(5), 893-902.

Long, P., & Siemens, G. (2014). Penetrating the fog: analytics in learning and education. *Italian Journal of Educational Technology*, *22*(3), 132-137.

Lyytinen, K. (1992). Information systems and critical theory. *Critical management studies*, 159-180.

Lyytinen, K., & Hirschheim, R. (1988). Information systems as rational discourse: An application of Habermas's theory of communicative action. *Scandinavian Journal of Management*, *4*(1-2), 19-30.

Malmquist, S. (1953). Index Numbers and Indifference Surfaces. *Trabajos de Estadistica y de Investigacion Operativa*, *4*(2), 209–242.

Mann, C. L. (2003). Information technologies and international development: conceptual clarity in the search for commonality and diversity. *Information Technologies & International Development*, *1*(2), pp 67-79.

Mansell, R. (2014). Power and interests in information and communication and development: exogenous and endogenous discourses in contention. *Journal of international development*, *26*(1), 109-127.

Manyika, J. (2011). Big data: The next frontier for innovation, competition, and productivity. *http://www.mckinsey.com/Insights/MGI/Research/Technology_and_Innovation/Big_data_The_next_frontier_for_innovation*.

Marathe, M. V., Mortveit, H. S., Parikh, N., & Swarup, S. (2014). Prescriptive analytics using synthetic information. In *Emerging Methods in Predictive Analytics: Risk Management and Decision-Making* (pp. 1-19). IGI Global.

Marcelle, G. M. (2000). Getting gender into African ICT policy: A strategic view. *Gender and the Information Revolution in Africa*, 35-84.

Martinez, D. (2001). Predicting Student Outcomes Using Discriminant Function Analysis.

Mazza, R., & Dimitrova, V. (2004). Visualising student tracking data to support instructors in web-based distance education. In *Proceedings of the 13th international World Wide Web conference on Alternate track papers & posters* (pp. 154-161). ACM.

Mazza, R., & Milani, C. (2004). Gismo: a graphical interactive student monitoring tool for course management systems. In *International Conference on Technology Enhanced Learning, Milan* (pp. 1-8).

Mcdonald, B. (2004). Predicting student success. *J Math Teach Learn*, *1*, 1-14.

McIntosh, N. E. (1979). Barriers to implementing research in higher education. *Studies in Higher Education*, *4*(1), 77-86.

Meeusen, W., & van Den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composed error. *International economic review*, 435-444.

Mercer, N. & Wegerif, R. (1999). 'Is "exploratory talk" productive talk?', in Light, P. and Littleton, K. (Eds): Learning with Computers: Analysing Productive Interaction, Routledge, London and New York, pp.79–101.

Mercer, N. (2002). *Words and minds: How we use language to think together*. Routledge.

Mimbi, L., & Bankole, F. (2016). ICT and public service value creation in Africa: Efficiency assessment using DEA approach. *Proceedings Of The 27th Australasian Conference on Information Systems*, 1–13.

Mimbi, L., & Bankole, F. O. (2016). Factors influencing ICT service efficiency in curbing corruption in Africa: A bootstrap approach. *Proceedings of the Annual Conference of the South African Institute of Computer Scientists and Information Technologists* (p. 25). ACM.

Mimbi, L., & Bankole, F. O. (2016). ICT Efficiency in Creating Public Value, 2005-2014: A Cross-National Enquiry of BRICS Countries. *GlobDev 2016*.

Mimbi, L., & Kyobe, M. (2017). Public perceptions of the role of IT in resolving governance challenges in a transition state: The case of Tanzania. *The Electronic Journal of Information Systems in Developing Countries*, *78*(1), 1-25.

Mimbi, L., Bankole, F. O., & Kyobe, M. (2011). Mobile phones and digital divide in East African countries. In *Proceedings of the South African Institute of Computer Scientists and Information Technologists Conference on Knowledge, Innovation and Leadership in a Diverse, Multidisciplinary Environment* (pp. 318-321). ACM.

Minaei-Bidgoli, B., Kashy, D. A., Kortemeyer, G., & Punch, W. F. (2003). Predicting student performance: an application of data mining methods with an educational web-based system. In *33rd Annual Frontiers in Education, 2003. FIE 2003.* (Vol. 1, pp. T2A-13). IEEE.

Mingers, J. (2001). Combining IS Research Methods: Towards a Pluralist Methodology. *Information Systems Research, 12 (3), 240-259.*

Mingers, J. (2003). A Classification of the Philosophical Assumptions of Management Science Methods. *The Journal of the Operational Research Society*, *54*(6), 559–570.

Molina, A. (2003) The digital divide: the need for a global e-inclusion movement. Technology Analysis & Strategic Management, 15(1): 137-152

Moore, M. (1995). *Creating public value: Strategic management in government.* Cambridge, MA: Harvard University Press

Moreira, F., Gonçalves, R., Martins, J., Branco, F., & Au-Yong-Oliveira, M. (2017) Learning Analytics as a Core Component for Higher Education Disruption: Governance Stakeholder. In Proceedings of the 5th International Conference on Technological Ecosystems for Enhancing Multiculturality pp. 37. ACM

Morse, J. M. (1991). Approaches to qualitative-quantitative methodological triangulation. *Nursing research*, *40*(2), 120-123.

Myers, M. (1997). Qualitative Research in Information Systems. *MIS*, *1*(6), 241–243.

Myers, M. D., & Klein, H. K. (2011). A set of principles for conducting critical research in information systems. *MIS quarterly*, *35*(1).

Myller, N., Suhonen, J., & Sutinen, E. (2002). Using data mining for improving web-based course design. In *International Conference on Computers in Education, 2002. Proceedings.* (pp. 959-963). IEEE.

Nair, K. S., & White, S. A. (1993). *Perspectives on development communication*. Sage Publ.

Nebot, A., Castro, F., Vellido, A., & Mugica, F. (2006, January). Identification of fuzzy models to predict students performance in an e-learning environment. In *The Fifth IASTED international conference on web-based education, WBE* (pp. 74-79).

Neely, A., Gregory, M., & Platts, K. (1995). Performance measurement system design: a literature review and research agenda, *International Journal of Operations & Production Management* (15:4), pp 80-116.

Neumayer, E. (2001) The human development index and sustainability—a constructive proposal. Ecological Economics, 39(1): 101-114

Ngwenyama, O., & Morawczynski, O. (2009). Factors affecting ICT expansion in emerging economies: An analysis of ICT infrastructure expansion in five Latin American countries. *Information technology for development*, *15*(4), 237-258.

Ngwenyama, O., Andoh-Baidoo, F. K., Bollou, F., & Morawczynski, O. (2006). Is there a relationship between ICT, health, education and development? An empirical analysis of five West African countries from 1997–2003. *The Electronic Journal of Information Systems in Developing Countries*, *23*(1), 1-11.

Nielsen, M. M., & Goderdzishvili, N. (2017). Georgia on my mind: A study of the role of governance and cooperation in online service delivery in the Caucasus. In *International Conference on Electronic Government* (pp. 71-91). Springer, Cham.

Norris, D., Baer, L., Leonard, J., Pugliese, L., & Lefrere, P. (2008). Action analytics: Measuring and improving performance that matters in higher education. *EDUCAUSE review*, *43*(1), 42.

Norris, P. (2000) The worldwide digital divide. In Paper for the Annual Meeting of the Political Studies Association of the UK, London School of Economics and Political Science

Norton, S. W. (1992). Transaction costs, telecommunications, and the microeconomics of macroeconomic growth. *Economic Development and Cultural Change*, *41*(1), 175-196.

Nulens, G., & Van Audenhove, L. (1999). An information society in Africa? An analysis of the information society policy of the World Bank, ITU and ECA. *Gazette (Leiden, Netherlands)*, *61*(6), 451-471.

Ogor, E. N. (2007). Student academic performance monitoring and evaluation using data mining techniques. In *Electronics, Robotics and Automotive Mechanics Conference (CERMA 2007)* (pp. 354-359). IEEE.

Oladokun, V. O., Adebanjo, A. T., & Charles-Owaba, O. E. (2008). Predicting students' academic performance using artificial neural network: A case study of an engineering course. In *Pacific Journal of Science and Technology, 9,1,* 72-79.

Olaniyi, T. K., & Ademola, E.O. (2014) Deployment of Information and Communication Technology in Higher Education Learning Environment of Emerging Nigerian Economy. African Journal of Computer & ICTs, (7)1: 121-126

Orbicom (2005) *From The Digital Divide To Digital Opportunities: Measuring Infostates for Development*, Montreal: Claude-Yves Charron

Organisation for Economic Co-operation and Development (OECD) (1992). New Technologies: opportunities and policy implications for the 1990s. OECD, Paris, France

Orlikowski, W. J., & Baroudi, J. J. (1991). Studying Information Technology in Organizations: Research Approaches and Assumptions. *Information Systems Research*, *2*(1), 1–28.

Osman Shereif Mahdi, M., & Dawson, P. (2007). The introduction of information technology in the commercial banking sector of developing countries: voices from Sudan. *Information Technology & People*, *20*(2), 184-204.

Ott, J. C. (2010). Good governance and happiness in nations: Technical quality precedes democracy and quality beats size. *Journal of Happiness Studies*, *11*(3), 353-368.

Oyerinde, O. D. (2014) A review of challenges militating against successful e-learning and m-learning implementations in developing countries. *International Journal of Science and Advanced Technology, 4(6): 1-5*

Oyerinde, O. D., & Chia, P. A. (2017). Predicting students' academic performances–A learning analytics approach using multiple linear regression. *International Journal of Computer Applications*, *157*(4).

Oyerinde, Y., & Bankole, F. (2018). Influence of Constant Returns to Scale and Variable Returns to Scale Data Envelopment Analysis Models in ICT Infrastructure Efficiency Utilization. *In Proceedings of the 11th Annual Pre-ICIS SIG GlobDev Workshop, San Francisco, USA, Thursday December 13, 2018*

Oyerinde, Y., & Bankole, F. (2019). Investigating the Efficiency of ICT Infrastructure Utilization: A Data Envelopment Analysis Approach. *In: Nielsen P., Kimaro H. (eds) Information and Communication Technologies for Development. Strengthening Southern-Driven Cooperation as a Catalyst for ICT4D.* ICT4D 2019. IFIP Advances in Information and Communication Technology, vol 551. Springer, Cham

Oyerinde, Y., & Bankole, F. (2019). Measuring Efficiency and Productivity of ICT Infrastructure Utilization. *In proceedings of the 24th UK Academy for Information Systems International Conference, St Catherine's College, University of Oxford, 9th-10th April, 2019.*

Oyerinde, Y., Bankole F. (2019). Creating Public Value Using ICT: An Efficiency And Productivity Assessment Approach. *In Proceedings of the International Conference on Information Resources Management (Conf-IRM 2019), Auckland, New Zealand, May 27th – 29th, 2019.*

Pang, M. S., Lee, G., & DeLone, W. H. (2014). IT resources, organizational capabilities, and value creation in public-sector organizations: a public-value management perspective. *Journal of Information Technology*, *29*(3), 187-205.

Papamitsiou, Z., & Economides, A. A. (2014). Learning analytics and educational data mining in practice: A systematic literature review of empirical evidence. *Journal of Educational Technology & Society*, *17*(4), 49-64.

Pardos, Z. A., Heffernan, N. T., Anderson, B., & Heffernan, C. L. (2007). The effect of model granularity on student performance prediction using Bayesian networks. In *International Conference on User Modeling* (pp. 435-439). Springer, Berlin, Heidelberg.

Pardos, Z., Heffernan, N., Ruiz, C., & Beck, J. (2008). The composition effect: Conjuntive or compensatory? an analysis of multi-skill math questions in ITS. In *Educational Data Mining 2008*.

Parker, E. B., & Hudson, H. E. (1995). *Electronic byways: State policies for rural development through telecommunications, 2nd Edition*. Washington DC: The Aspen Institute.

Peña-López, I. (2016). World development report 2016: Digital dividends.

Phillips, D. C. (2004). Is mixed methods research an epistemological oxymoron. In *annual meeting of the American Educational Research Association, San Diego, CA*.

Pick, J. B., & Azari, R. (2011). A Global Model of Technological Utilization Based on Governmental, Business-Investment, Social, and Economic Factors. *Journal of Management Information Systems*, *28*(1), 49–84

Podinovski, V. V., & Thanassoulis, E. (2007). Improving discrimination in data envelopment analysis: Some practical suggestions. *Journal of Productivity Analysis*, *28*(1-2), 117-126.

Podinovski, V. V., Ismail, I., Bouzdine-Chameeva, T., & Zhang, W. (2014). Combining the assumptions of variable and constant returns to scale in the efficiency evaluation of secondary schools. *European Journal of Operational Research*, *239*(2), 504-513.

Pool, I. D. S. (1990). *Technologies without boundaries: On telecommunications in a global age*. Cambridge, MA: Harvard University Press.

Portela, M. C. S., Camanho, A. S., & Borges, D. (2012). Performance assessment of secondary schools: the snapshot of a country taken by DEA. *Journal of the Operational Research Society*, *63*(8), 1098-1115.

Prinsloo, P. (2018) Context Matters: An African Perspective on Institutionalizing Learning Analytics. Include us All! Directions for Adoption of Learning Analytics in the Global South, 24

Prinsloo, P., & Slade, S. (2017) Big data, higher education and learning analytics: Beyond justice, towards an ethics of care. *In Big data and learning analytics in higher education pp. 109-124.* Springer, Cham

Pritchard, D., & Warnakulasooriya, R. (2005). Data from a web-based homework tutor can predict student's final exam score. In *EdMedia+ Innovate Learning* (pp. 2523-2529). Association for the Advancement of Computing in Education (AACE).

Qiang, C. Z. & Pitt, A. (2004). Contribution of Information and Communication Technologies to Growth. T*he World Bank Working Paper, Vol: 24*

Quah, J. S. (Ed.). (2011). *Curbing corruption in Asian countries: An impossible dream?*. Emerald Group Publishing Limited.

Qureshi, S. (2017). The forgotten awaken: ICT's evolving role in the roots of mass discontent. *Information Technology for Development,* 23:1, 1-17, DOI: 10.1080/02681102.2017.1293963

Rathgeber, E. M. (2000). Women, men and ICTs in Africa: Why gender is an issue. *Gender and the information revolution in Africa*, 17-34.

Ravallion, M. (2010). Troubling tradeoffs in the human development index. The World Bank.

Reeves, G. W. (1993). *Communications and the 'Third World'*. Routledge.

Rehman, A. A., & Alharthi, K. (2016). An introduction to research paradigms. *International Journal of Educational Investigations*, *3*(8), 51-59.

Richardson, H., Kvasny, L., Pozzebon, M., Titah, R., & Pinsonneault, A. (2006). Combining social shaping of technology and communicative action theory for understanding rhetorical closure in IT. *Information Technology & People*.

Roberts, P. (1991). Habermas' varieties of communicative action: controversy without combat. *Journal of Advanced Composition*, 409-424.

Roller, L. H., & Waverman, L. (1994). The impact of telecommunications infrastructure on economic growth and development. *OECD ICCP Draft Working Paper, Paris, France*.

Romero, C., & Ventura, S. (2007). Educational data mining: A survey from 1995 to 2005. *Expert systems with applications*, *33*(1), 135-146.

Romero, C., & Ventura, S. (2013). Data mining in education. *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery, 3*(1), 12–27.

Romero, C., Ventura, S., & García, E. (2008). Data mining in course management systems: Moodle case study and tutorial. *Computers & Education*, *51*(1), 368-384.

Romero, C., Ventura, S., Espejo, P. G., & Hervás, C. (2008). Data mining algorithms to classify students. In *Educational data mining 2008*.

Rothstein, B. O., & Teorell, J. A. (2008). What is quality of government? A theory of impartial government institutions. *Governance*, *21*(2), 165-190.

Sachin, R. B., & Vijay, M. S. (2012). A survey and future vision of data mining in educational field. In *2012 Second International Conference on Advanced Computing & Communication Technologies* (pp. 96-100). IEEE.

Sahay, S., & Walsham, G. (2006). Scaling of health information systems in India: Challenges and approaches. *Information Technology for development*, *12*(3), 185-200.

Sahu, S. (2017) Role of ICT in Enhancement of Quality Learning and Teaching in Higher Education

Samoilenko, S. V., & Osei-Bryson, K. M. (2017). *Creating Theoretical Research Frameworks Using Multiple Methods: Insight from ICT4D Investigations*. Auerbach Publications.

Samoilenko, S., & Green, L. T. (2008). Convergence and Productive Efficiency in the Context of 18 Transition Economies: Empirical Investigation Using DEA. *Proceedings of the Southern Association for Information Systems Conference, Richmond, VA, USA. March 13th-15th, 2008* (pp. 1–6)

Samoilenko, S., & Osei-Bryson, K. M. (2013). Using Data Envelopment Analysis (DEA) for monitoring efficiency-based performance of productivity-driven organizations: Design and implementation of a decision support system. *Omega*, *41*(1), 131-142.

Samoilenko, S., & Osei-Bryson, K. M. (2017). An analytical framework for exploring context-specific micro-economic impacts of ICT capabilities. *Information Technology for Development*, *1102*, 1–25. https://doi.org/10.1080/02681102.2017.1336072

Saranga, H., & Moser, R. (2010). Performance evaluation of purchasing and supply management using value chain DEA approach, *European Journal of Operational Research* (207)1, 197-205

Sarker, S., & Valacich, J. S. (2010). An alternative to methodological individualism: a non-reductionist approach to studying technology adoption by groups. *Mis Quarterly*, *34*(4), 779-808.

Sarker, S., Valacich, J. S., & Sarker, S. (2005). Technology adoption by groups: A valence perspective. *Journal of the Association for Information Systems*, *6*(2), 3.

Schiller, H. I. (1992). *Mass communication and American empire*. Boulder.

Schmandt, J., Williams, F., & Wilson, R. H. (1989). *Telecommunications policy and economic development: The new state role*. Praeger Publishers.

Schniederjans, M. J., Schniederjans, D. G., & Starkey, C. M. (2014). *Business analytics principles, concepts, and applications: what, why, and how*. Pearson Education.

Schutz, D. (2009). Educational Intelligence: Bringing Schools into the 21st Century. *Available at SSRN 1336243*.

Sechrest, L., & Sidani, S. (1995). Quantitative and qualitative methods: Is There an Alternative? *Evaluation and program planning*, *18*(1), 77-87.

Seiford, L. M., & Zhu, J. (1997). An investigation of returns to scale in data envelopment analysis. *Omega*, *27*(1), 1-11.

Seiford, L. M., & Zhu, J. (1999). An investigation of returns to scale in data envelopment analysis. *Omega*, *27*(1), 1-11.

Sein, M. K., & Harindranath, G. (2004). Conceptualizing the ICT artifact: Toward understanding the role of ICT in national development. *The information society*, *20*(1), 15-24.

Sen, A. (1990). Development as capability expansion. *The community development reader*, 41-58.

Shangping, D., & Ping, Z. (2008, April). A data mining algorithm in distance learning. In *2008 12th International Conference on Computer Supported Cooperative Work in Design* (pp. 1014-1017). IEEE.

Shin, D. H., & Kweon, S. H. (2011). Evaluation of Korean information infrastructure policy 2000–2010: Focusing on broadband ecosystem change. *Government information quarterly*, *28*(3), 374-387.

Sia, C. L., Lee, M. K., Teo, H. H., & Wei, K. K. (2001). Information instruments for creating awareness in IT innovations: An exploratory study of organizational adoption intentions of ValuNet. *Electronic markets*, *11*(3), 206-215.

Sia, C. L., Teo, H. H., Tan, B. C., & Wei, K. K. (2004). Effects of environmental uncertainty on organizational intention to adopt distributed work arrangements. *IEEE Transactions on Engineering Management*, *51*(3), 253-267.

Siemens G (2011) Learning analytics: a foundation for informed change in higher education. http://www.educause.edu/library/resources/learning-analytics-foundation-informed-change-higher-education

Siemens, G. (2012) Learning analytics: envisioning a research discipline and a domain of practice. *In Proceedings of the 2nd international conference on learning analytics and knowledge 4-8. ACM*

Siemens, G., & Long, P. (2011) Penetrating the fog: Analytics in learning and education. EDUCAUSE review, 46(5): 30

Sinuany-Stern, Z., Mehrez, A., & Barboy, A. (1994). Academic departments efficiency via DEA. *Computers & Operations Research*, *21*(5), 543-556.

Solow, R. M. (1994). Perspectives on Growth Theory. *The Journal of Economic Perspective*, *8*(1), 45–54.

Soltanpoor, R., & Sellis, T. (2016). Prescriptive analytics for big data. In *Australasian Database Conference* (pp. 245-256). Springer, Cham.

Sparks, C. (2007). *Globalization, development and the mass media*. Sage.

St. Aubyn, M. (2002). Evaluating efficiency in the Portuguese health and education sectors. *Economia, Vol. 26*. Available at SSRN: https://ssrn.com/abstract=504942

Stahl, B. C. (2008). Empowerment through ICT: A critical discourse analysis of the Egyptian ICT policy. In *IFIP international conference on human choice and computers* (pp. 161-177). Springer, Boston, MA

Stevens, R., Soller, A., Giordani, A., Gerosa, L., Cooper, M., & Cox, C. (2005). Developing a framework for integrating prior problem solving and knowledge sharing histories of a group to predict future group performance. In *2005 International Conference on Collaborative Computing: Networking, Applications and Worksharing* (pp. 9-pp). IEEE.

Stoker, G. (2006). Public value management: a new narrative for networked governance? *The American review of public administration*, *36*(1), 41-57.

Straub, D., Boudreau, M. C., & Gefen, D. (2004). Validation Guidelines for IS Positivist Research. *Communications of the AIS*, *13*(1), 380–427.

Talbot, C. (2008). Measuring Public Value: A Competing Values Approach. *The Work Foundation Research Report*.

Tan, B. H. (2008). Cobb-Douglas Production Function. *Retrieved January 10, 2012 from docente.fe.unl.pt/jamador/Macro/cobb-douglas.pdf.*

Tehranian, M., & Dervin, B. (1990). *Technologies of power*. Greenwood Publishing Group Inc.

Teorell, J. (2009). The impact of quality of government as impartiality: theory and evidence. In *APSA 2009 Toronto Meeting Paper*.

Thanassoulis, E. (2001). *Introduction to the theory and application of data envelopment analysis*. Dordrecht: Kluwer Academic Publishers.

Thanassoulis, E., Kortelainen, M., Johnes, G., & Johnes, J. (2011). Costs and efficiency of higher education institutions in England: A DEA analysis. *Journal of the Operational Research Society, 62*, 1282–1297.

Thanassoulis, E., Portela, M. C., & Despic, O. (2008). Data envelopment analysis: the mathematical programming approach to efficiency analysis. *The measurement of productive efficiency and productivity growth*, 251-420.

Thomas, E. H., & Galambos, N. (2004). What satisfies students? Mining student-opinion data with regression and decision tree analysis. *Research in Higher Education*, *45*(3), 251-269.

Thomason, N. & Rider, Y. (2008). 'Cognitive and pedagogical benefits of argument mapping: L.A.M.P. guides the way to better thinking', in Okada, A. Buckingham Shum, S. and Sherborne, T. (Eds): Knowledge Cartography: Software Tools and Mapping Techniques, Springer, London

Thompson, M. P. (2004). ICT, power, and developmental discourse: A critical analysis. *The Electronic Journal of Information Systems in Developing Countries*, *20*(1), 1-25.

Tipps, D. C. (1973). Modernization theory and the comparative study of national societies: A critical perspective. *Comparative studies in society and history*, *15*(2), 199-226.

Tondeur, J., van Braak, J., & Valcke, M. (2007). Towards a typology of computer use in primary education. *Journal of Computer Assisted Learning, 23,* 197-206.

Tongia, R., Subrahmanian, E., & Arunachalam, V. S. (2004). *Information and Communications Technology for Sustainable Development: Defining a Global Research Agenda* (pp. 1–129).

Trkman, P., & Turk, T. (2009). A conceptual model for the development of broadband and e-government. *Government Information Quarterly*, *26*(2), 416-424.

Tsui, L. S. (1991). The use of new communication technologies in third world countries: A comparison of perspectives. *Gazette (Leiden, Netherlands)*, *48*(2), 69-93.

UNDP: United Nations Development Programme. (1990). Human Development Report 1990. Oxford University Press, New York.

UNDP: United Nations Development Programme. (2006). The Millennium Development Goals. *UNDP*.

UNDP: United Nations Development Programme. (2010). Human Development Report 2010. The Real Wealth of Nations: Pathways to Human Development

UNDP: United Nations Development Programme. (2016). Human Development Report 2016. Human Development for Everyone.

UNDP: United Nations Development Programme. Human development report 2000. (2000). Oxford: Oxford University Press. http://www.undp.org/hdr2000/english/HDR2000.htm

Unwin, T. (Ed). (2009). *ICT4D: Information and Communication Technology for Development*. *Cambridge: Cambridge University Press*.

Van Barneveld, A., Arnold, K. E., & Campbell, J. P. (2012). Analytics in higher education: Establishing a common language. *EDUCAUSE learning initiative*, *1*(1), l-ll.

Van Der Wal, Z., Pevkur, A., & Vrangbaek, K. (2008). Public sector value congruence among old and new EU member-states? Empirical evidence from the Netherlands, Denmark, and Estonia. *Public Integrity*, *10*(4), 317-334.

Van Dijk, T. A. (2001). 18 Critical discourse analysis. *The handbook of discourse analysis*, 349-371.

Van Dooren, W., Bouckaert, G., & Halligan, J. (2015). *Performance management in the public sector.* Routledge

Venkatesh, V., Thong, J. Y., & Xu, X. (2016). Unified theory of acceptance and use of technology: A synthesis and the road ahead. *Journal of the Association for Information Systems*, *17*(5), 328-376.

Veríssimo, D., Vaughan, G., Ridout, M., Waterman, C., MacMillan, D., & Smith, R. J. (2017). Increased conservation marketing effort has major fundraising benefits for even the least popular species. *Biological Conservation*, *211*, 95-101.

Walsham, G. (2017). ICT4D research: reflections on history and future agenda. *Information Technology for Development*, *23*(1), 18-41.

Wang, A. Y., & Newlin, M. H. (2002). Predictors of web-student performance: The role of self-efficacy and reasons for taking an on-line class. *Computers in human behaviour*, *18*(2), 151-163.

Wang, T., & Mitrovic, A. (2002). Using neural networks to predict student's performance. In *International Conference on Computers in Education, 2002. Proceedings.* (pp. 969-973). IEEE.

Whitley, E. A., & Hosein, I. (2005). Policy discourse and data retention: The technology politics of surveillance in the United Kingdom. *Telecommunications policy*, *29*(11), 857-874.

Worthington, A.C., & B.L. Lee. (2008). Efficiency, Technology and Productivity Change in Australian Universities, 1998_2003. *Economics of Education Review* 27: 285-298.

WPSR: World Public Sector Report (2015). Responsive and Accountable Public Governance. *Department of Economic and Social Affairs*. United Nations, New York, 2015

Yanow, D. (1996). How does a policy mean: Interpreting policy and organizational actions? Georgetown University Press.

Yu, C. H., Jannasch-Pennell, A., Digangi, S., & Wasson, B. (1999). Using online interactive statistics for evaluating web-based instruction. *Journal of Educational Media International*, *35*, 157-161.

Zafra, A., & Ventura, S. (2009). Predicting Student Grades in Learning Management Systems with Multiple Instance Genetic Programming. *International Working Group on Educational Data Mining*.

Zaiane, O. (2001). Web usage mining for a better web-based learning environment.

Zheng, Y., Hatakka, M., Sahay, S., & Andersson, A. (2018). Conceptualizing development in Information and Communication Technology for Development (ICT4D), *Information Technology for Development, 24*(1), 1-14, DOI: 10.1080/02681102.2017.1396020

Zhu, J. (1996). Comparing the effects of mass media and telecommunications on economic development: a pooled time series analysis. *Gazette (Leiden, Netherlands)*, *57*(1), 17-28.

Zhu, J., & Shen, Z. H. (1995). A discussion of testing DMUs' returns to scale. *European journal of operational research*, *81*(3), 590-596.

Zorrilla, M., García, D., & Álvarez, E. (2010) A decision support system to improve e-learning environments. In Proceedings of the 2010 EDBT/ICDT Workshops 11. ACM.

Appendix A

Model Summary[c,d]

Model	R	R Square[b]	Adjusted R Square	Std. Error of the Estimate
1	.943[a]	.890	.883	18.208

a. Predictors: mth103, mth204, mth205

b. For regression through the origin (the no-intercept model), R Square measures the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R Square for models which include an intercept.

c. Dependent Variable: cs201

d. Linear Regression through the Origin

ANOVA[c,d]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	126018.412	3	42006.137	126.706	.000[a]
	Residual	15581.588	47	331.523		
	Total	141600.000[b]	50			

a. Predictors: mth103, mth204, mth205

b. This total sum of squares is not corrected for the constant because the constant is zero for regression through the origin.

c. Dependent Variable: cs201

d. Linear Regression through the Origin

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	mth204	.500	.148	.298	3.367	.002
	mth205	.537	.126	.396	4.260	.000
	mth103	.453	.149	.314	3.043	.004

a. Dependent Variable: cs201

b. Linear Regression through the Origin

Appendix B

Python Code for Chapter 6 OLS Regression.

```
#!/usr/bin/python
# -*- coding: utf-8 -*-

print(__doc__)


# Code source: Jaques Grobler
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import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
from sklearn import datasets, linear_model
from sklearn.metrics import mean_squared_error, r2_score

# Load the dataset
data = pd.read_csv('OLS_datasetIFIP.csv')

# independent variables
individuals_using_computers = data['individuals using
computers'].values.reshape(-1, 1)
individuals_using_internet = data['individuals using
internet'].values.reshape(-1, 1)
individuals_using_mobile_phones = data['individuals using mobile
phones'].values.reshape(-1, 1)

# trained independent variables
train_individuals_using_internet = individuals_using_internet
train_individuals_using_computers = individuals_using_computers
train_individuals_using_mobile_phones =
individuals_using_mobile_phones

# test and trained independent variables list
independent_variables = [individuals_using_internet,
individuals_using_mobile_phones, individuals_using_computers]
trained_independent_variables = [train_individuals_using_internet,
train_individuals_using_mobile_phones,
train_individuals_using_computers]

#labels
independent_labels = ['Individuals using Internet', 'Individuals
using Mobile Phones', 'Individuals using Computers', ]


# dependent variables
educational_attainment_short_cycle_tertiary = data['educational
attainment short cycle tertiary'].values.reshape(-1, 1)
educational_attainment_post_sec = data['educational attainment post
sec'].values.reshape(-1, 1)
```

```
educational_attainment_bachelors = data['educational attainment
bachelors'].values.reshape(-1, 1)
literacy_rate = data['adult literacy rates'].values.reshape(-1, 1)

#trained dependent variables
train_literacy_rate = literacy_rate
train_educational_attainment_short_cycle_tertiary =
educational_attainment_short_cycle_tertiary
train_educational_attainment_post_sec =
educational_attainment_post_sec
train_educational_attainment_bachelors =
educational_attainment_bachelors

#test and trained dependent variables list
dependent_variables = [literacy_rate,
educational_attainment_short_cycle_tertiary,
educational_attainment_post_sec, educational_attainment_bachelors]
trained_dependent_variables = [train_literacy_rate,
train_educational_attainment_short_cycle_tertiary,
train_educational_attainment_post_sec,
train_educational_attainment_bachelors]

#list labels
dependent_labels = ['Literacy Rate', 'Educational Attainment Short
Cycle Tertiary', 'Educational Attainment Post Sec', 'Educational
Attainment Bachelors']

# Create linear regression object
regr = linear_model.LinearRegression()

for (dependent_variable, trained_dependent_variable,
dependent_label) in zip(dependent_variables,
trained_dependent_variables, dependent_labels) :
    for (independent_variable, trained_independent_variable,
independent_label) in zip(independent_variables,
trained_independent_variables, independent_labels) :
        regr.fit(trained_independent_variable,
trained_dependent_variable)
        prediction_y = regr.predict(independent_variable)
        plt.figure()
        plt.scatter(independent_variable, dependent_variable,
color='black')
        plt.plot(independent_variable, prediction_y, color='red',
linewidth=3)
        plt.xlabel(independent_label)
        plt.ylabel(dependent_label)
        plt.savefig(dependent_label+' VS '+independent_label+'.png')


plt.xticks(())
plt.yticks(())

plt.show()
```

Python Code for Chapter 7 OLS Regression

```
#!/usr/bin/python
# -*- coding: utf-8 -*-

print(__doc__)


# Code source: Jaques Grobler
# License: BSD 3 clause


import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
from sklearn import datasets, linear_model
from sklearn.metrics import mean_squared_error, r2_score
import itertools

# Load the dataset
data = pd.read_csv('OLS_datasetUKAIS.csv')

# independent variables
individuals_using_internet = data['individuals using
internet'].values.reshape(-1, 1)
individuals_using_mobile_phones = data['individuals using mobile
phones'].values.reshape(-1, 1)
households_with_computers = data['households with
computers'].values.reshape(-1, 1)
households_with_internet = data['households with
internet'].values.reshape(-1, 1)

# trained independent variables
train_individuals_using_internet = individuals_using_internet
train_individuals_using_mobile_phones =
individuals_using_mobile_phones
train_households_with_computers = households_with_computers
train_households_with_internet = households_with_internet

# test and trained independent variables list
independent_variables = [individuals_using_internet,
individuals_using_mobile_phones, households_with_computers,
households_with_internet]
trained_independent_variables = [train_individuals_using_internet,
train_individuals_using_mobile_phones,
train_households_with_computers, train_households_with_internet]

# dependent variables
literacy_rate = data['adult literacy rates'].values.reshape(-1, 1)

#trained dependent variables
train_literacy_rate = literacy_rate

#test and trained dependent variables list
dependent_variables = [literacy_rate]
```

```
trained_dependent_variables = [train_literacy_rate]

#list labels
dependent_labels = ['Literacy Rate']
independent_labels = ['Individuals using Internet', 'Individuals
using Mobile Phones', 'Households with Computers', 'Households with
Internet']

# Create linear regression object
regr = linear_model.LinearRegression()

for (dependent_variable, trained_dependent_variable,
dependent_label) in zip(dependent_variables,
trained_dependent_variables, dependent_labels) :
    for (independent_variable, trained_independent_variable,
independent_label) in zip(independent_variables,
trained_independent_variables, independent_labels) :
        regr.fit(trained_independent_variable,
trained_dependent_variable)
        prediction_y = regr.predict(independent_variable)
        plt.figure()
        plt.scatter(independent_variable, dependent_variable,
color='black')
        plt.plot(independent_variable, prediction_y, color='red',
linewidth=3)
        plt.xlabel(independent_label)
        plt.ylabel(dependent_label)
        plt.savefig(dependent_label+' VS '+independent_label+'.png')


plt.xticks(())
plt.yticks(())

plt.show()
```

Appendix C

Detailed MI Productivity Results

REGION	t-1	t	EC	PC	SC	TC	MI
Arab States	2010	2011	0.9660	0.9140	1.0560	0.9360	0.9040
Europe	2010	2011	1.0000	1.0000	1.0000	0.9720	0.9720
Sub-Saharan Africa	2010	2011	1.0000	1.0000	1.0000	0.9440	0.9440
World	2010	2011	1.0000	1.0000	1.0000	0.9320	0.9320
Arab States	2011	2012	0.9630	0.9470	1.0170	0.8960	0.8620
Europe	2011	2012	1.0000	1.0000	1.0000	0.9920	0.9920
Sub-Saharan Africa	2011	2012	1.0000	1.0000	1.0000	0.8490	0.8490
World	2011	2012	1.0000	1.0000	1.0000	0.9280	0.9280
Arab States	2012	2013	0.9970	1.0020	0.9950	0.9150	0.9120
Europe	2012	2013	1.0000	1.0000	1.0000	0.9860	0.9860
Sub-Saharan Africa	2012	2013	1.0000	1.0000	1.0000	0.9080	0.9080
World	2012	2013	1.0000	1.0000	1.0000	0.9440	0.9440
Arab States	2013	2014	0.9910	0.9960	0.9950	0.9110	0.9030
Europe	2013	2014	1.0000	1.0000	1.0000	1.0350	1.0350
Sub-Saharan Africa	2013	2014	1.0000	1.0000	1.0000	1.0220	1.0220
World	2013	2014	1.0000	1.0000	1.0000	0.9500	0.9500
Arab States	2014	2015	1.0040	1.0180	0.9870	0.9380	0.9410
Europe	2014	2015	1.0000	1.0000	1.0000	0.9760	0.9760
Sub-Saharan Africa	2014	2015	1.0000	1.0000	1.0000	0.9080	0.9080
World	2014	2015	1.0000	1.0000	1.0000	0.9460	0.9460
Arab States	2015	2016	1.0010	1.0140	0.9870	0.9830	0.9840
Europe	2015	2016	1.0000	1.0000	1.0000	0.9700	0.9700
Sub-Saharan Africa	2015	2016	1.0000	1.0000	1.0000	0.8710	0.8710
World	2015	2016	1.0000	1.0000	1.0000	0.9550	0.9550

Detailed DEA Efficiency Results

t-1	t	CRS(t-1)	CRS(t)	CRSMix(t,t-1)	CRSMix2(t-1,t)	VRS(t-1)	VRS(t)
2010	2011	0.8856	0.8551	0.8011	0.9466	0.9563	0.8743
2010	2011	1.0000	1.0000	0.9942	1.0513	1.0000	1.0000
2010	2011	1.0000	1.0000	1.1557	1.2980	1.0000	1.0000
2010	2011	1.0000	1.0000	0.9436	1.0856	1.0000	1.0000
2011	2012	0.8551	0.8233	0.7369	0.9538	0.8743	0.8279
2011	2012	1.0000	1.0000	1.0200	1.0363	1.0000	1.0000
2011	2012	1.0000	1.0000	0.9897	1.3725	1.0000	1.0000
2011	2012	1.0000	1.0000	0.9572	1.1124	1.0000	1.0000
2012	2013	0.8233	0.8209	0.7503	0.8998	0.8279	0.8294
2012	2013	1.0000	1.0000	1.0132	1.0429	1.0000	1.0000
2012	2013	1.0000	1.0000	1.0202	1.2372	1.0000	1.0000
2012	2013	1.0000	1.0000	0.9517	1.0671	1.0000	1.0000
2013	2014	0.8209	0.8137	0.7465	0.9070	0.8294	0.8261
2013	2014	1.0000	1.0000	1.1098	1.0361	1.0000	1.0000
2013	2014	1.0000	1.0000	1.3145	1.2578	1.0000	1.0000
2013	2014	1.0000	1.0000	0.9636	1.0684	1.0000	1.0000
2014	2015	0.8137	0.8170	0.7824	0.8865	0.8261	0.8407
2014	2015	1.0000	1.0000	1.0175	1.0685	1.0000	1.0000
2014	2015	1.0000	1.0000	1.0195	1.2377	1.0000	1.0000
2014	2015	1.0000	1.0000	0.9548	1.0678	1.0000	1.0000
2015	2016	0.8170	0.8175	0.8382	0.8669	0.8407	0.8523
2015	2016	1.0000	1.0000	1.0132	1.0772	1.0000	1.0000
2015	2016	1.0000	1.0000	1.0357	1.3663	1.0000	1.0000
2015	2016	1.0000	1.0000	0.9576	1.0493	1.0000	1.0000