African Statistical Journal
Journal statistique africain

Supplementary Edition

Volume 15 – August / août 2012

African Development Bank Group

Groupe de la Banque africaine de développement

African Development Bank Group
Temporary Relocation Agency (TRA)
13 rue de Ghana
BP 323, 1002 Tunis Belvédère
Tunis, Tunisia
Tel: (216) 71 102 342
Fax: (+ 216) 71 103 743
Email: ASJ-Statistics@afdb.org
Internet: http://www.afdb.org

Groupe de la Banque africaine de développement
Agence temporaire de relocalisation (ATR)
13 rue de Ghana
BP 323, 1002 Tunis Belvédère
Tunis, Tunisie
Tel: (216) 71 102 342
Fax: (216) 71 103 743
Courriel: ASJ-Statistics@afdb.org
Internet: http://www.afdb.org

ISSN: 2233 2820

Design/layout by Phoenix Design Aid A/S, Denmark. ISO 14001/ISO9000 certified and approved CO_2 neutral company. Website: www.phoenixdesignaid.dk.

African Statistical Journal
Journal statistique africain

Volume 15
August / août 2012

Contents

Table des matières

Editorial

We welcome readers to Volume 15 of the *African Statistical Journal*. The value of the Journal has been proven by the number of papers that continue to be submitted for publication and the comments we receive on the published papers. Because of the many publishable submissions we have received, the Editorial Board decided to publish an extra volume this year. This volume contains six papers.

The first paper is "Revising GDP Estimates in Sub-Saharan Africa: Lessons from Ghana." The upward revision of Ghana's GDP, announced in November 2010, attracted considerable attention in the media, in the development community and from development scholars. This paper explains what motivated the revision and discusses how it was carried out. The paper also offers a perspective on how the media and popular opinions are best managed through a careful and transparent process. It, therefore, provides guidance for many countries that have outdated base years and do not make full use of available data.

The second paper, "Comparative Analysis of Economic Lifecycle Deficits in Kenya and Nigeria: Some Estimation Results," uses the National Transfer Accounts approach to estimate and compare the sources and size of economic lifecycle deficits in Nigeria and Kenya, which have similar consumption and labor income. The approach offers a framework for analyzing and interpreting the relationship between population age structure and wealth flows, and for understanding how societies use different mechanisms to allocate resources across age groups. The paper shows that public consumption expenditures on health and education are higher in Kenya and lower in Nigeria relative to the mean income of the reference age, and that both countries have economic lifecycle deficits that cannot be offset by labor income. It concludes that individuals must rely on asset income and intergenerational transfers to finance the deficits.

"Determinants of Learning Outcomes for Primary Education: A Case for Uganda" examines factors associated with learning outcomes in primary schools using a Generalized Method of Moments estimation technique. Although a rich literature exists on the determinants of learning outcomes at the primary level, their estimation has proceeded under a strict assumption of policy exogenity. This paper relaxes that assumption and exploits the first panel dataset to have been constructed on Uganda's primary schools. The study shows that: some of the traditional educational inputs yield the expected positive influence on learning outcomes; the magnitude of the influence on learning outcomes differs across government and private schools; and software inputs have a stronger positive impact on learning outcomes than do hardware educational inputs.

"A Comparative Assessment of Selected Approaches in Modeling Completion Dynamics of Graduate Programs" observes that investigating factors related to student persistence in graduate programs can be problematic when: a considerable number of students have not completed the program at the time of data collection; enrolment and completion figures are low; a normal distribution of completion time is assumed; and a detailed assessment of non-completion is required. These problems can be solved using a time-to-event approach in a Cox model, and a multinomial logistic. The analysis of administrative data for the 295 PhD students at Makerere University in the 2000 to 2005 enrolment cohorts illustrates the suitability of these approaches for the analysis of education data with low enrolment and completion figures, a situation characteristic of doctoral studies in many African universities.

The fifth paper, "Technical Efficiency in Uganda's Primary Education System: Panel Data Evidence," estimates the technical efficiency and its determinants for Uganda's primary education system using parametric models based on a panel data set on performance index and educational inputs of various categories of primary schools for the 2001-2008 period. The results show that generally, all primary schools in Uganda are technically inefficient, but private and urban schools are relatively more so than government-aided and rural schools. It concludes that it is feasible to improve learning outcomes without increasing spending on primary education for private schools, where a 56% improvement might be expected. For government-aided and rural schools, efficiency gains on the basis of current funding will result in a mere 1% improvement in learning outcomes. Improvements in learning outcomes for government-aided schools will require increased resources.

According to the results of the final paper, "Predicting Zimbabwe's Annual Rainfall Using the Southern Oscillation Index: Weighted Regression Approach," a negative Southern Oscillation Index for September is associated with below-normal annual rainfall in the coming year, and a positive Southern Oscillation Index for September with above-average annual rainfall.

We trust that you will find this volume of the *Journal* interesting and stimulating. As usual, comments or debate on the content of the articles published will be gratefully received.

Dr. Charles Leyeka Lufumpa
Co-Chair, Editorial Board
Director, Statistics Department
African Development Bank Group
Tunis, Tunisia
Email: c.lufumpa@afdb.org

Professor Ben Kiregyera
Co-Chair, Editorial Board
International Statistical Consultant
Kampala, Uganda
Email : bkiregyera@yahoo.com

Éditorial

C'est avec plaisir que nous vous invitons à lire le volume 15 du *Journal statistique africain*. Le nombre d'articles qui ne cessent de nous parvenir pour publication et les commentaires que nous recevons au sujet des articles publiés témoignent de la valeur du journal. En raison du grand nombre de manuscrits publiables que nous avons reçus, le Comité de rédaction a décidé de publier un volume supplémentaire cette année. Dans ce volume, nous publions six articles.

Le premier article est intitulé Revising GDP estimates in Sub-Saharan Africa: Lessons from Ghana (*Révision des estimations du PIB en Afrique subsaharienne : enseignements tirés du Ghana*). Annoncée en novembre 2010, la révision à la hausse du PIB du Ghana a bénéficié d'une attention particulière dans les médias, la communauté de développement et chez les spécialistes du développement. Cet article apporte un éclairage sur les raisons qui sous-tendent cette révision et la manière dont elle a été effectuée. L'article offre également une perspective sur la meilleure manière de gérer les médias et l'opinion publique dans un processus méticuleux et transparent. Il est donc riche en enseignements pour de nombreux pays ayant des années de base obsolètes et qui n'exploitent pas pleinement les sources de données.

Le deuxième article, Comparative Analysis of Economic Lifecycle deficits in Kenya and Nigeria: Some Estimation Results (*Analyse comparative des déficits du cycle de vie économique au Kenya et au Nigéria : quelques résultats estimatifs*), adopte l'approche des Comptes de transferts nationaux pour estimer et comparer les sources et la taille des déficits du cycle de vie économique du Nigéria et du Kenya, les deux pays ayant des taux de consommation et des revenus de travail similaires. L'approche offre un cadre permettant d'analyser et d'interpréter la relation entre la pyramide des âges et le flux des richesses ainsi que de comprendre la manière dont les sociétés exploitent divers mécanismes pour l'allocation des ressources aux différents groupes d'âge. L'article démontre que les dépenses de consommation publique en matière de santé et d'éducation sont plus élevées au Kenya et moins élevées au Nigéria par rapport au revenu moyen de l'âge de référence, et dans les deux pays, les déficits du cycle de vie économique ne peuvent pas être comblés par le revenu du travail. L'article conclut que, pour financer les déficits, les particuliers doivent compter sur le revenu de l'actif et les transferts intergénérationnels.

« Determinants of Learning Outcomes for Primary Education: A Case for Uganda » (*Les déterminants des résultats d'apprentissage pour l'enseignement primaire: un plaidoyer pour l'Ouganda*), examine les facteurs associés avec des résultats d'apprentissage dans les écoles primaires en utilisant la technique

d'estimation, de la Méthode Généralisée des moments. Malgré l'abondante documentation qui existe sur les facteurs déterminants des résultats d'apprentissage au primaire, l'estimation de ces derniers a été faite sous l'hypothèse d'exogénéité politique. L'article assouplit cette hypothèse et exploite le premier ensemble de données de panel recueillies pour les écoles primaires ougandaises. Il ressort de cette étude que certains intrants éducatifs traditionnels produisent l'incidence positive escomptée sur les résultats d'apprentissage ; l'ampleur de l'incidence sur les résultats d'apprentissage n'est pas la même dans les écoles publiques et privées ; et les intrants éducatifs immatériels a une incidence positive plus forte sur les résultats d'apprentissage que l'investissement dans les intrants matériels.

« A Comparative Assessment of Selected Approaches in Modeling Completion Dynamics of Graduate Programs » (*Evaluation comparative de quelques approches dans la modélisation des tendances observées dans l'achèvement des programmes d'études supérieures*), révèle que l'analyse des facteurs liés à la persévérance des étudiants dans les programmes d'enseignement supérieur, peut poser problème lorsque : i) un nombre élevé d'étudiants n'ont pas achevé leur programme au moment de la collecte des données ; ii) les taux d'inscription et d'achèvement des programmes d'études sont faibles ; iii) l'hypothèse d'une distribution normale pour les délais d'achèvement est retenue ; et iv) une évaluation détaillée du non-achèvement est exigée. Ces problèmes peuvent être résolus à l'aide d'une approche de type temps-évènement dans le modèle de Cox et au moyen d'une logistique multinomiale. À l'Université de Makéréré, l'analyse des données administratives des 295 doctorants inscrits entre 2000 et 2005 montre que ces approches sont adaptées à l'analyse de données sur l'éducation, avec des taux d'inscription et d'achèvement peu élevés, caractéristique typique des études doctorales dans bon nombre d'universités africaines.

Le cinquième article, ''Technical Efficiency in Uganda's primary education system : Panel Data Evidence '' (*Efficacité technique dans le système d'enseignement primaire en Ouganda : faits découlant des données de panel*), évalue l'efficacité technique et ses facteurs déterminants pour le système d'enseignement primaire ougandais. Cette évaluation est effectuée à l'aide de modèles paramétriques tirés d'un ensemble de données de panel sur l'indice de performance et les intrants éducatifs de diverses catégories d'écoles primaires en Ouganda entre 2001 et 2008. L'article démontre que toutes les écoles primaires ougandaises sont, de manière générale, techniquement inefficaces, mais que les écoles privées et urbaines le sont un peu plus que les écoles rurales ou celles subventionnées par l'État. L'article conclut que les résultats d'apprentissage peuvent être améliorés sans pour autant que

cela n'entraîne la hausse des dépenses de l'enseignement primaire pour les écoles privées, où une amélioration de 56 % peut être attendue. Pour les écoles rurales et celles subventionnées par l'État, les gains d'efficacité sur la base du financement actuel ne permettront qu'une amélioration de 1 % des résultats d'apprentissage seulement. Pour l'amélioration des résultats dans les écoles subventionnées par l'État, il faudra plus de ressources.

D'après le dernier article intitulé Predicting Zimbabwe's annual rainfall using the Southerm Oscillation Index : Weighted regression approach (*Prédire les précipitations annuelles du Zimbabwe à l'aide de l'Indice d'oscillation australe : Approche de la régression pondérée*). un Indice d'oscillation australe négatif pour le mois de septembre est associé à des précipitations au-dessous de la normale pour l'année suivante, alors qu'un Indice d'oscillation australe positif pour le mois de septembre est associé à des précipitations annuelles au-dessus de la normale.

Nous esperons que vous trouverez ce volume du Journal intéressant et stimulant. Comme d'habitude, les commentaires ou le débat autour du contenu des articles publiés sont les bienvenus.

Dr Charles Leyeka Lufumpa
Coprésident, Comite de rédaction
Directeur, Département de la statistique
Group de la Banque africaine de développement
Tunis, Tunisie
Courriel: c.lufumpa@afdb.org

Professeur Ben Kiregyera
Coprésident, Comite de rédactions
Consultant international en statistiques
Kampala, Ouganda
Courriel: bkiregyera@yahoo.com

Editorial Board

Le comité de rédaction

Acknowledgments

The Editorial Board would like to express its appreciation to all authors who submitted papers for publication in the journal and to the following reviewers for their expert assistance:

Michel Mouyelo-Katoula	Global Manager, International Comparison Program, Development Data Group, the World Bank
Rosalia Katapa	Professor of Statistics, University of Dar es Salaam, Tanzania
Georges Bresson	Professeur, Université Paris II / Sorbonne Université, Paris, France
Régis Bourbonnais	Maitre de Conférences, Université de Paris-Dauphine, Paris, France
László Kónya	Honours Coordinator, Senior Lecturer, School of Economics, La Trobe University, Victoria , Australia
Abdoulaye Adam	International Consultant, Statistics Department, African Development Bank Group

Remerciements

Le comité de rédaction voudrait exprimer sa gratitude à tous les auteurs qui ont soumis des articles pour la publication dans ce journal et aux personnes suivantes qui composent le comité de lecture des articles pour cette édition:

Michel Mouyelo-Katoula	Coordonnateur Mondial, Programme de Comparaison Internationale, Development Data Group, Banque Mondiale
Rosalia Katapa	Professeur en Statistiques, Université de Dar es Salaam, Tanzanie
Georges Bresson	Professeur, Université Paris II / Sorbonne Université, Paris, France
Régis Bourbonnais	Maitre de Conférences, Université de Paris-Dauphine
László Kónya	Honours Coordinator, Senior Lecturer, School of Economics, La Trobe University, Victoria 3086 Australia
Abdoulaye Adam	Consultant international en statistique, Banque Africaine de Développement

1. Revising GDP estimates in Sub-Saharan Africa: Lessons from Ghana

Morten Jerven[1] and Magnus Ebo Duncan[2]

Abstract
The upward revision of GDP in Ghana, announced in November 2010, attracted considerable attention in the media, in the development community, and from development scholars. This paper clarifies what caused this upward revision and discusses how the revision was handled. Many other countries have outdated base years and do not utilize data sources fully. They can learn from the Ghanaian experience and improve the accuracy of the most important metric for macroeconomic evaluations. This paper also offers a perspective on how the media and popular opinions are best managed in a careful and transparent process.

Key words: *National Income Accounting, Rebasing, Data Quality, Statistical Capacity*

Révision des estimations du PIB en Afrique subsaharienne : enseignements tirés au Ghana

Résumé
La révision à la hausse du PIB du Ghana, annoncée en novembre 2010, a suscité une attention considérable dans les médias et parmi les acteurs et chercheurs du développement. Le présent article apporte un éclairage sur les causes qui sous-tendent cette révision à la hausse et examine comment elle a été gérée. De nombreux autres pays s'appuient sur des années de base caduques et n'exploitent pas pleinement les sources de données. Ils peuvent tirer des enseignements de l'expérience ghanéenne et accroître la précision de l'indicateur le plus important des évaluations macro-économiques. L'article donne également son point de vue sur la meilleure manière de gérer les médias et l'opinion publique, avec prudence et transparence.

Mots clés : *comptabilité nationale, rebasement, qualité des données, capacité statistique*

1 Assistant Professor, School for International Studies, Simon Fraser University, Vancouver, Canada mjerven@sfu.ca

2 Director, Economic and Industrial Statistics Group, Ghana Statistical Service, Accra, Ghana. Magnus.duncan@statsghana.gov.gh

1.0 INTRODUCTION

In November 2010, the Ghana Statistical Service announced an upward revision of the country's total GDP by more than 60%.[3] In current US dollars, GDP per capita rose from about $550 to about $1,100. The revision was widely discussed in the media and internet forums across Ghana (Moss 2010). Internationally, it was reported by news agencies such as Reuters (Kpodo 2010), and soon attracted comment from development scholars (Kenny and Sumner 2011) and the international financial community (Devarajan 2011). The revision is now official, and in the new world income tables, Ghana is recognized as a lower-middle-income country rather than a poor country as it had previously been classified (World Bank 2011). Ghana's example is important, as a similar GDP revision is pending in Nigeria (Ohuocha 2011).

This paper reviews some of the controversy that the revision caused in development circles and clarifies the reasons for the revision. Also, an explanation of how the process was handled by Ghana Statistical Service in collaboration with major national and international stakeholders is provided. Finally, the paper draws general lessons from the Ghanaian experience that may assist other statistical offices in Africa in conducting future GDP revisions through a careful and transparent process.

2.0 MEDIA REACTION

On November 5, 2010, the Ghana Statistical Service announced that the country's GDP for 2010 was 44.8 billion cedi, compared with the previous estimate of 25.6 billion cedi.[4] This meant an increase in the income level of Ghana by about 60%. Ghana moved from being classified as a low-income to a middle-income country overnight (Ghana Statistical Service 2010).

On the Center of Global Development blog pages, African development expert, Todd Moss, observed: "Boy, we really don't know anything" (2010). Given this margin of error in the GDP estimate for Ghana (arguably, the most studied country on the continent), he raised doubt about economic statistics from other African countries. Adding further to the sense of bewilderment, the revision prompted the World Bank Chief Economist for Africa, Shantayanan Devarajan, to declare Africa a statistical tragedy (2011).

3 For 2006, 60% refers to the increase in the share in total "new" GDP. If the percentage change is measured as a share of the "old" GDP, the increase is closer to 100%.

4 Provisional estimates for 2010; the 60% revision in the press release refers to the base year of 2006.

The news was met with equal confusion in Ghana. According to the local media, the Resident Coordinator for the United Nations Development Programme dismissed the new classification as a statistical hypothesis, and contended that, in terms of its progress toward achievement of the Millennium Development Goals, Ghana should still be classified among the poorest countries in the world (*Enquirer* 2011).

The question of whether the upward revision of GDP was politically motivated might arise. During his 2008 campaign, John Atta Mills, the current president, promised to take Ghana to middle-income status by 2020. However, no evidence suggests that the revision was a result of political tampering. According to the World Bank, the revision was done according to global standards of national accounting. The World Bank also reported that the rebased national accounts followed a review of the underlying statistical methodology by International Monetary Fund (IMF) advisors. On July 1, 2011 the World Bank approved the revised estimates, and Ghana was officially reclassified as a low-middle-income country (World Bank 2011a).[5]

Upward revisions stemming from changes in outdated base years are common in developed countries such as the United States (Runkle 1998). In retrospect, what was surprising was about Ghana's GDP revision was that it was well-publicized, widely discussed, and conducted in a transparent manner. The 60% increase and the shift from a poor to a middle-income country are certainly remarkable, but not unique. A recent survey by Statistics South Africa found that a majority of Sub-Saharan African economies have base years that are more than a decade old,[6] many of them older than Ghana's previous base year of 1993. Therefore, similar revisions in other countries may reasonably be expected in the near future. To explore this possibility, the causes of Ghana's revision are examined more closely.

3.0 WHAT CAUSED THE UPWARD REVISION?

In his keynote address to the IARIW-SSA conference on "Measuring National Income, Wealth, Poverty and Inequality in African Countries," Shantayanan Devarajan, World Bank Chief Economist for Africa, stated that the main cause for the revision was the upgrade from the 1968 version of the System of National Accounts (SNA) to the 1993 version (Devarajan 2011). This, is, however, only

5 A status it was granted simultaneously with Zambia.

6 The survey used the term, "base year' was used. The term, "benchmark year," is often used instead to distinguish it from "reference year" (which refers to the base for prices); "base year" refers to the base for volume estimates.

part of the story; the major increase in the estimates came from the inclusion of new data and a rebasing of sector weights' contribution to GDP, thereby taking account of structural changes in the Ghanaian economy since 1993.[7]

Before the revision, the Ghana Statistical Service had evidence that GDP was substantially underestimated. The collapse of many state-owned enterprises and the divesture of others meant that the registry of businesses was out of date and that the national accounts failed to update the base year index to capture the output of new companies. Results of the 2003 National Industrial Census showed that published GDP estimates for the manufacturing sector were far lower than the estimates yielded by the Census,[8] and lower than the numbers derived from value added tax (VAT) receipts. Additionally, many activities in the services sector (for example, community and personal services, recreation, media activities, professional services) were simply not covered. Finally, there was cause to suspect underestimation at the aggregate level. Ratios such as revenue/GDP, tax/GDP and expenditure/GDP were far higher for Ghana than for most sub-Saharan African countries, indicating that the GDP estimate was too low.

The changes implemented in the rebasing exercise can be grouped into: (a) change in conceptual treatment; (b) change in methodology; (c) improvements and revisions in data sources; and (d) updating classification. While the first two receive considerable attention in national accounting manuals and handbooks,[9] for Ghana, it was the availability of new data that mattered.

The revision of the national accounts estimates incorporated a considerable amount of data from surveys conducted in and around the reference year, each of which provided recent input-output details for different economic activities. The main sources of new data are the 2003 National Industrial Census, the 2005/2006 Ghana Living Standards Survey (GLSS 5), and the small-scale 2007 road and lake transport survey.[10] Thus, these new sources improved coverage, paving the way for more disaggregated national accounts. Furthermore, use of VAT data (an important source of economic statistics worldwide), consolidated profit and loss accounts from the banking industry, outbound and inbound call volumes from the telecommunica-

7 "Rebasing" refers to a change in the base year for volume estimates, which may cause changes in growth (depending on how the index number problem is handled). "Revision" implies that the estimates are upgraded with new data. In this case, both took place simultaneously.

8 Unpublished internally circulated calculations based on the 2003 Census.

9 As in the OECD handbook, *Measuring the Non-observed Economy*, Paris, France, 2002.

10 This transport survey was conducted expressly for the rebasing and has not been published.

tion companies, etc. contributed to improvement in the quality of data for national accounts estimation.

Classification of the services sector, which was based on the 1968 SNA, was brought in line with the 1993 SNA's recommendations, and revision 4 of the International Standard Industrial Classification was adopted. This update allowed for wider coverage of activities previously not taken into account. Rebasing also allowed for inclusion of preparatory activities involved in crude oil production (including the exploration and development of oil wells).

Table 1: Percentage share of GDP (at basic prices), by sector, 2006 to 2010

	Old series			New series (rebased)		
Year	Agriculture	Industry	Services	Agriculture	Industry	Services
	%	%				
2006	38.8	28.3	32.9	30.4	20.8	48.8
2007	37.6	28.2	34.2	29.1	20.7	50.2
2008	37.0	28.3	34.7	31.0	20.4	48.6
2009	37.7	27.2	35.1	31.7	18.9	49.5
2010*	35.6	28.3	36.1	30.2	18.6	51.1

Source: Table 4, Ghana Statistical Service (2010), *Information Paper on Economic Statistics: Rebasing of Ghana's National Accounts to Reference Year 2006*, November 10.

*Provisional

The revision meant not only overall expansion in all sectors of the economy, but a shift in the relative economic importance of the sectors (Table 1). In the old series, from 2006 to 2010, agriculture accounted for 35.6% to 38.8% of the economy, but in the new series, this sector accounted for 29.1% to 31.7%. The old series showed agriculture to be the largest sector of the economy in every year but one. By contrast, the new rebased accounts show the service sector to be dominant. This structural shift, which was emerging in the old accounts, is more visible in the new accounts. In retrospect, it is plausible that service sector growth has been strong, but that its contribution to economic growth was underreported in the old series.

The opposite dynamics emerge for the industry sector, which is less important in the new than the old series. Moreover, slow growth in this sector probably contributed more to the slow aggregate growth estimates than did correction of its weight.

Table 2: Comparison of value added, old and new estimates, 2006

Rebased (new) series		**Old series**	
New classification	**Value added**	**Old classification**	**Value added**
Agriculture			
Crop production (including cocoa)	3,793.70	Crops and livestock	2,371.62
Cocoa only	537.20	Cocoa production and marketing	842.19
Livestock production	437.10		
Forestry	736.00	Forestry and logging	432.20
Fishing	448.30	Fishing	511.66
Agriculture GDP	5,415.03		4,157.66
Industry			
Mining and quarrying	497.40	Mining and quarrying	594.85
Manufacturing	1,823.48	Manufacturing	988.59
Production and distribution of electricity	142.70	Production and distribution of electricity, gas and water	364.69
Water and sewerage	224.40		
Construction	1,016.30	Construction	1,082.52
Industry GDP	3,704.30		3,030.60
Services			
Trade; Repair of vehicles, household goods	1,140.70	Wholesale and retail trade; Hotels and restaurants	533.98
Hotels and restaurants	894.08		
Transport and storage	2,357.20	Transport, storage and communications	824.06
Information and communications	483.00		
Financial Intermediation	472.86	Finance, insurance, real estate	519.59
Real estate services	391.40		
Business and other service activities	522.53		
Public administration and defence; Social security	862.14	Government services	1,255.83
Education	654.96	Community, social and personal services	204.11

Rebased (new) series		Old series	
New classification	**Value added**	**Old classification**	**Value added**
Health and social work	249.84	Producers of private non-professional services	69.31
Other community, social and personal service activities	661.62	Other services	282.70
Services GDP	8,690.38		3,690.00

A direct comparison of the old and new sector estimates for each year is not possible, but the two price estimates for 2006 can be compared. Because the 2006 rebasing also meant a new nomenclature consistent with the methodology update, a sector-by-sector comparison is not possible. Nonetheless, Table 2 illustrates where the revision originated.

Most of the revision (72%) originated in the service sector; 10% was due to increases in the industry sector; and the remaining 18% came from the agriculture sector. The relatively minor share of the revision originating in the industry sector is, of course, a reflection of its small share of the economy. And while the estimate for manufacturing almost doubled, the estimates for construction, water and electricity, and mining and quarrying were largely unchanged. Within the agriculture sector, non-cocoa crop production accounted for most of the increase.

The major change in the new estimates is the increased role of services, particularly for Trade/Repair of vehicles, household goods; Hotels and restaurants; Transport and storage; and Information and communications. Value added in these sectors is now almost five times higher than in the old aggregation of Wholesale and retail trade/Hotels and restaurants and Transport, storage and communications. In fact, these two former sectors alone made up 50% of Ghana's total GDP increase. New data from the Industrial Census, VAT records, the Ghana Living Standards Survey, and other ad hoc surveys account for the classification of Ghana as a middle-income rather than a poor country.

4.0 THE REVISION PROCESS

The possibility that Ghana's GDP was underestimated has been an issue for some time. In 2004, a public debate arose about the estimate of per capita income. At that time, the World Bank reported the figure to be US$380,

whereas President Kufuor stated that the correct figure was US$600, and Finance Minister Wiredu put it closer to US$1,000. President Kufour stated that the Ghana Statistical Service lacked the resources to calculate these statistics (Ghanaian Chronicle 2005).

At the Ghana Statistical Service, work toward a rebasing of the national accounts had begun in 2002, when the IMF contracted one of its advisors to undertake the exercise. However, by 2006, the outcome was not conclusive, as large discrepancies existed between the results of the production, expenditure and income approaches used to compile GDP estimates. The IMF advisor cited lack of data as the cause of the discrepancies, and the IMF terminated the contract.

In 2007, a supply and use table with reference year 2004 was constructed to aid the building of a social accounting matrix for Ghana under the Transport Sector Programme Support sponsored by the Danish International Development Agency. The supply and use table employed all data that were available in 2006.

In 2008, the estimates from this supply and use table exercise were reviewed with newly available data (for example, for crude oil and reforestation) and updated to include 2006 as a reference year. A draft of rebased GDP estimates with 2006 as the base year was prepared. The IMF was invited to review the rebasing process. The IMF report endorsed the methodology used, but recommended further investigation of the estimates for some activities. All comments were incorporated, and in September, 2008, another request for f review was made to the IMF. In 2009, an expert identified additional areas of concern and recommended further review. A final review by this expert in October, 2010 concluded that the rebasing work was complete. The rebasing and upward revision were announced in November, 2010.

Thus, the revision extended over a long period. Initial calculations and moves toward a rebased national accounts series were made as early as 2002, but at that time, the data needed for a complete revision were not available. President Kufuor's statements to the press in 2004 indicate that the political leadership and the bureaucracy were aware that the GDP estimates did not reflect economic realities in Ghana, but that they were dependent on: a) resources being made available for data collection, and b) experts from international organizations to give credibility to the new methods of estimation.

Although the revision was made official in November, 2010, news of the impending change had circulated among stakeholders before this date. In his

report to the IMF after the review of the rebased estimates, the IMF expert indicated the possibility of a substantial change in the GDP—information that was posted on the IMF website. The Ghana Statistical Service also prepared a paper for the Minister of Finance and Economic Planning on the need to rebase and on what the macroeconomic indicators would look like under the assumption of a 50% increase in GDP.

5.0 LESSONS FROM GHANA

What is the likelihood of similar GDP revisions in Sub-Saharan Africa in the immediate future? A recent survey of 48 countries (13 did not respond) found that 19 of them have a base year within the last decade (2001 or later) (Jerven 2011a; Jerven 2011b). According to the IMF Statistics Department, the international best practice is to rebase every fifth year, but only 7 countries (Burundi, Ghana, Malawi, Mauritius, Niger, Rwanda and Seychelles) have followed this recommendation. Most statisticians in national accounts agencies replied affirmatively to the question: "Do you think that GDP is underestimated today?" Out of 23 countries surveyed, only Lesotho and Namibia were satisfied that GDP estimates covered the whole economy; representatives from 18 countries responded that GDP was underestimated.

Media reports indicate that a revision on the scale of Ghana's is underway in Nigeria (Ohuocha 2011). However, as illustrated in Ghana, the road from official acknowledgement of underestimation to official World Bank approval of revised GDP estimates can be long. Moreover, it is essential that the process not be undertaken hastily, and that it be the result of independent evaluation and consultation. Similar endeavours in Liberia and Burundi have not succeeded in getting official endorsement from the World Bank or IMF data groups (Duncan 2011).[11]

In conclusion, similar revisions should and will probably be undertaken across Sub-Saharan Africa in the immediate future. The case of Ghana is unique in that the revision was well-documented and widely discussed.

While Deverajan characterized the revision as a "Statistical Tragedy" (2011), it could be argued that the real tragedy is that the causes underlying the revision have been misunderstood and obscured in some discussions following the announcement. In fact, the revision is "good news," particularly for Ghana.

11 Personal communication with the Institut de Statistiques et d'Études Économiques, Burundi, February, 2011.

The bad news is that it may confuse data users who depend on comparable income tables for Sub-Saharan Africa. A ranking of African economies by GDP levels cannot be taken at face value. Current income tables reflect an uneven application of statistical methods, data availability, and country level. The most recent country level estimates reported in international databases are, in large part, automatic data permutations, and the differences are as likely to reflect statistical methodology as economic reality.

Thus, the problem arising from this revision is comparability across time and geography. The addition of new information changed past growth dynamics in the Ghanaian dataset, but where and when this large increase in GDP occurred remains unresolved—challenging analyses lie ahead for economic historians (Jerven 2012). Economists must exercise caution in using series that have been spliced together (Jerven 2010a). When similar revisions took place in Tanzania, mistakes that were made were carried into statistical tables used by econometricians (Jerven 2011c). Similarly, comparisons of country-level per capita estimates are unlikely to be useful (Jerven 2010b); without knowledge of the methods and data underlying the estimates, such comparisons are misleading. Ghana points the way forward in GDP revisions.

The main lesson for other GDP revisions across Sub-Saharan Africa is that data matter more than methods. Complete and meaningful revisions can take place only when data availability is improved. Many countries can use consumption information from new household budget surveys and living standard surveys. Ideally, such data should be complemented by industrial and agricultural surveys. However, as demonstrated by Ghana, statistical offices can make good use of VAT receipts.

The priority in a revision is, of course, numerical validity—getting the new estimates right. But the validity of a new GDP estimate goes beyond accuracy to involve credibility of the numbers that are produced. In the case of Ghana, an open and transparent process fostered this outcome, particularly in explaining why the revision took place.

REFERENCES

Devarajan, S. (2011), "Africa's Statistical Tragedy," *Africa Can… End Poverty Blog*, October 6. Accessed March 18, 2012.

Devarajan, S. (2011),"Measuring National Income, Wealth, Poverty and Inequality in African Countries," *IARIW-SSA Conference on Measuring National Income, Wealth, Poverty, and Inequality in African Countries*, Cape Town, South Africa, September 28 to October 1. Available at: http://www.youtube.com/watch?v=rLkWDcOfMSo.

Duncan, M.E. (2011), "The Nightmare of Estimating the National Accounts of a War Torn Country," *IARIW-SSA Conference on Measuring National Income, Wealth, Poverty, and Inequality in African Countries*, Cape Town, South Africa, September 28 to October 1.

Enquirer (2011), "Middle Income Status Is Just Statistical Hypothesis," *Enquirer*, April 4.

Ghana Statistical Service (2010), *Information Paper on Economic Statistics: Rebasing of Ghana's National Accounts to Reference Year 2006*. Accra: Ghana Statistical Service.

Ghana Statistical Service (2006), *2003 National Industrial Census Report*. Accra: Ghana Statistical Service.

Jabbah, S.L. (2005), "Ghana: Conundrums," *Ghanaian Chronicle*, August 17. Available at: http://allafrica.com/stories/200508170707.html. Accessed March 18, 2012.

Jerven, M. (2012), *Future Challenges in Measuring Africa's Past: Lessons from estimating GDP for the Gold Coast, 1891-1954*, Paper presented at the Economic History Seminar, Universidad Carlos III de Madrid, May 24, 2012.

Jerven, M. (2011a), "Counting the Bottom Billion: Measuring the Wealth and Progress of African Economies," *World Economics*, vol. 12, no. 4, pp. 35-52.

Jerven, M. (2011b), *Poor Numbers! What Do We Know about Income and Growth in Sub-Saharan Africa?* Paper presented at the Center for Global Development Presentation, Washington D.C. November 2012. Forthcoming as Poor Numbers: Facts, Assumptions and Controversy in African Development Statistics, Cornell University Press.

Jerven, M. (2011c), "Growth, Stagnation or Retrogression? On the Accuracy of Economic Observations, Tanzania, 1961-2001," *Journal of African Economies*, vol. 20, no. 3, pp. 377-394.

Jerven, M. (2010a), "The Relativity of Poverty and Income: How Reliable Are African Economic Statistics?," *African Affairs*, vol. 109, no. 434, pp. 77-96.

Jerven, Morten (2010b), "Random Growth in Africa? Lessons from an Evaluation of the Growth Evidence on Botswana, Kenya, Tanzania and Zambia, 1965–1995," *Journal of Development Studies*, vol. 46, no. 2, pp. 274-294.

Kenny, C. and A. Sumner (2011),"How 28 Poor Countries Escaped the Poverty Trap," *Poverty Matters Blog*, July 12. Available at: http://www.guardian.co.uk/global-development/poverty-matters. Accessed March 18, 2012.

Kpodo, K. (2010), "Data Overhaul Shows Ghana's Economy 60 pct Bigger," *Reuters*, November 5. Available at: http://af.reuters.com/. Accessed March 18, 2012.

Moss, T. (2010), "Ghana Says: Hey, Guess What? We're Not Poor Anymore!" *Blog of Global Development: Views from the Center*, November 5. Available at: http://blogs.cgdev.org/globaldevelopment/. Accessed March 18, 2012.

Ohuocha, C. (2011), "Nigeria GDP Rebasing may See Big Upwards Revision – Stats Chief," *Reuters*, November 10. Available at: http://af.reuters.com/article/currenciesNews/. Accessed March 18, 2012.

Runkle, D.E. (1998), "Revisionist History: How Data Revisions Distort Economic Policy Research," *Federal Reserve Bank of Minneapolis Quarterly Review*, vol. 22, no. 4, pp. 3-12.

World Bank (2011a), "Changes in Country Classification," *World Bank News Online*, July 1. Available at: http://data.worldbank.org/news/2010-GNI-income-classifications. Accessed March 18, 2012.

2. Comparative analysis of economic lifecycle deficits in Kenya and Nigeria: Some estimation results

Adedoyin Soyibo[1], Germano Mwabu[2], Olanrewaju Olaniyan[3], Moses Muriithi[4]

Abstract

This paper used the National Transfer Accounts (NTA) approach to estimate and compare the sources and size of economic lifecycle deficits of Nigeria and Kenya. The approach offers a framework for analyzing and interpreting the relationship between age structure and wealth flows, and for understanding how societies utilize different mechanisms to allocate resources across age groups. Consumption and labor income in Kenya and Nigeria have similar features. Public consumption expenditures on health and education are higher in Kenya and lower in Nigeria relative to the mean income of the reference age. Both countries have economic lifecycle deficits that cannot be offset by labor income. Therefore, individuals must rely on asset income and intergenerational transfers to finance the deficits.

Key words: *National transfer accounts (NTA), child dependency, economic lifecycle deficits, Kenya, Nigeria*

Analyse comparative des déficits du cycle de vie économique au Kenya et au Nigéria : quelques résultats d'estimations

Résumé

Le présent article se fonde sur l'approche des comptes de transfert nationaux (CTN) pour estimer et comparer les sources et l'ampleur des déficits du cycle de vie économique au Nigéria et au Kenya. Cette approche fournit un cadre pour analyser et interpréter la relation entre la pyramide des âges et les flux de richesse et pour comprendre comment les sociétés utilisent différents mécanismes pour distribuer leurs ressources selon les tranches d'âge. La consommation et le revenu du travail au Kenya et au Nigéria présentent des caractéristiques similaires. Les dépenses de consommation publique dans le domaine de la santé et de l'éducation sont plus élevées au Kenya et moins élevées au Nigéria par rapport au revenu moyen de l'âge de référence. Les deux pays enregistrent des déficits du cycle de vie économique que le revenu du travail ne parvient pas à combler.

1 Health Policy Training and Research Programme, Department of Economics; University of Ibadan, Nigeria; Email: doyinsoyibo@yahoo.com

2 School of Economics, University of Nairobi, Kenya; Email: gmwabu@gmail.com

3 Health Policy Training and Research Programme, Department of Economics, University of Ibadan, Nigeria; Email: lanreolaniyan@yahoo.co.uk, o.olaniyan@ui.edu.ng

4 School of Economics, University of Nairobi, Kenya; Email: mkmuriithi@unonbi.ac.ke

Par conséquent, les populations doivent se tourner vers le revenu du capital et les transferts intergénérationnels pour financer ces déficits.

Mots clés: *Comptes de transferts nationaux (CTN), dépendance infantile, déficits du cycle de vie économique, Kenya, Nigéria*

An earlier version of this paper was presented at Western Economic Association International Conference, held at Sheraton Hotel, Waikiki, Honolulu, Hawaii, June 29-3 July 2008. We acknowledge the financial support of the John D. and Catherine T. MacArthur Foundation and Canada's International Development Research Centre (IDRC,) as well as the encouragement and support of Andrew Mason and Karen O. Mason, Sang-Hyop Lee and Amonthep "Beet" Chawla, all of University of Hawaii on earlier versions of the paper. However, we are solely responsible for any errors in the paper.

Corresponding author: Olanrewaju Olaniyan, *Health Policy Training and Research Programme (HPTRP), University of Ibadan, Nigeria.* Tel: +234-802-325-5741. Email: o.olaniyan@mail.ui.edu.ng; lanreolaniyan@yahoo.co.uk

1.0 INTRODUCTION

Every country faces the problem of optimal population to balance production and consumption activities. Population structure is such that while some are productive, others are dependent. Most basically, children and the elderly are typically dependent—children because they are either too young to engage in productive activities or because they are still acquiring the skills and knowledge needed to be productive; the elderly because of retirement or because the higher prevalence of health disability at older ages prevents them from engaging in economically productive activities. Both groups must rely on people in the productive age range to finance their consumption. If the labor income of those in the productive age range in a given country is sufficient to finance their own consumption and that of the dependent age groups, that country enjoys an economic lifecycle surplus; if not, that country is in economic lifecycle deficit (Lee and Mason 2011).

Depending on their stage of demographic transition, countries undergo shifts in the age structure of their population. For instance, in many parts of the world, changes in the total fertility rate and the infant mortality rate have increased the potential labor force and improved labor productivity. In Africa, however, high fertility combined with declining mortality has resulted in one of the youngest age structures in the world. In economies with high

youth dependency ratios, families tend to be heavily burdened with health and education expenditures. And because these human capital investments must be spread over a large number of children, spending per child is low. Governments in such societies face the dual challenges of investing in the human capital of future generations, and the immediate, short-term need to invest in the physical capital required for economic growth.

Changes in population age structure enable countries to experience rapid economic growth in the period when youth dependency ratios have fallen, but old age dependency ratios are still relatively low. The economic gain associated with the changing phases of demographic transition, usually measured in terms of a higher growth rate, is known as the demographic dividend. The relatively high percentage of young age groups in African populations and the substantial declines in fertility and mortality in some parts of the continent suggest that Africa is well-positioned to reap the demographic dividend. This, however, is not an automatic consequence of completion of the demographic transition; policy-makers must create the right environment. At the moment, little empirical basis exists for understanding how population dynamics might affect contemporary African populations, because no evidence is available on resource flows across age groups or on how these flows operate to create human capital in various sectors, particularly education and health. The system of the National Transfer Accounts (NTA) offers a framework for analyzing and interpreting the relationship between age structure and wealth flows, as well as the sources of data for understanding how societies allocate resources across age groups. This paper presents and discusses some preliminary results of the estimation of NTAs of Kenya and Nigeria.

Kenya and Nigeria have similar demographic experiences. Fertility declined significantly over the past three decades, particularly in Kenya (Table 1), but in both countries, the decline was below the average decrease for the continent. Both countries faced a reduction in life expectancy; the decline in Kenya was sharper than that in Nigeria, mainly due to the effects of HIV/AIDS. But despite this decline, Kenya's life expectancy is above the African average, which rose only marginally over the past three decades.

The two countries are important in their sub-regions. Kenya has the largest economy in East Africa, and Nigeria has the largest in West Africa. Both countries currently face challenges in meeting the Millennium Development Goals (MDGs), particularly poverty reduction and improvements in human capital. Understanding their population profiles and how they affect economic growth is important. Individuals pass from dependency during

childhood into a stage of surplus during their productive years, and then end in dependency during old age. The policy challenge is whether the surplus income generated during the productive years can cover the deficits of the two dependency periods.

This paper estimates lifecycle deficits for Kenya and Nigeria. This study analyzes the underlying reasons for the size and structure of these deficits.

Table 1: Demographic indicators, Kenya, Nigeria and Africa, selected years, 1975 to 2005-10

Geography	Fertility		Life expectancy		Ageing index		Dependency ratios			
							60+/Total		Old age dependency ratio (OADR)*	
	1975-80	2005-10	1975-80	2005-10	1975	2007	1975	2000	1975	2000
Kenya	7.6	5.0	56.2	50.3	9.9	9.6	4.9	4.1	6.8	5.1
Nigeria	6.9	5.3	44.5	44.2	10.9	11	4.8	4.8	5.7	5.7
Africa	6.6	4.7	48.7	49.9	11.1	12.9	5.0	6.2	6.0	6.2

Source: United Nations (2007)

Note: OADR = 60+/Age (15-59)

The paper is organized as follows. Section 2 contains a literature review. Section 3 explains the methodology and describes the National Transfer Accounts (NTA) approach, which attempts to estimate National Income and Production Accounts (NIPA) by age groups. Section 4 presents the estimates of economic lifecycle deficits for Nigeria and Kenya. Section 5 is a discussion of the results. Section 6 contains a conclusion and policy implications.

2.0 LITERATURE REVIEW

Lifecycle deficit is the difference between labor income and consumption over the life course. The economic lifecycle is the cross-sectional age pattern that shows the age at which individuals reach economic independence or fall back into dependency (Lee et al 2006). It measures how consumption, labor productivity, and hence, economic dependency, vary with age. The theory underlying lifecycle deficits postulates a long period of child dependency and long life during which elders support the young (Chu and Lee

2006). Despite assumptions that the elders also become dependent in old age, studies have shown that they remain net producers until death (Lee and Mason 2011), which enables them to transfer surplus output to the young. However, Becker and Lewis (1973) and Willis (1987), among others, argue that parents' altruism toward their children is often limited by the parents concern for their own consumption. As a result, parents balance their own lifetime consumption with that of their children.

This is a refinement of the assumptions of Samuelson (1958) who described how consumption might be sustained throughout the lifecycle via a distribution between generations. In his overlapping generations model (1958), an individual's lifee consists of two periods—the productive worker phase and the unproductive retiree phase (Bengtsson and Scott 2011). Those in the productive period finance the consumption of those in the unproductive period. Arthur and McNicoll (1978) expanded Samuelson's two-generation model to include the entire population, not only workers and retirees, but also, children.

Building on this model, the National Transfer Accounts (NTA) approach estimates age profiles of consumption and production from age 0 to 90 (Mason et al 2011a). Because the approach introduces age estimates into a country's national income accounts, NTA estimates must be compatible with the National Accounts of the country (Mason et al 2009). The NTA approach has been used to quantify the surplus and/or deficit throughout the lifecycle, and has been calculated for more than 30 countries (Lee and Mason 2008 and Lee and Mason 2011b).

As individuals age, they pass through a deficit-surplus-deficit cycle. This can be depicted by age curves of consumption and production (labor income). The lifecycle deficit illustrates the importance of age structure in the economic development of any country (Lee, Mason, and Miller 2003). Lifecycle deficits must be financed from the surplus period. The intergenerational transfer is such that funds are transferred from the surplus period to the deficit periods. The direction of this transfer depends on the age profile of a particular country. In many developing countries, the direction of intergenerational transfer is mainly downward to finance children's consumption. However, in some rich nations, the direction is also upward to finance elderly people's consumption (Lee and Mason 2011b). As old age dependency grows in such countries, it is possible that the system of public transfer to the elderly might not be fiscally sustainable. However, many African countries must still find innovative ways of financing child dependency, which accounts for more than 70% of their lifecycle deficit (Soyibo 2010).

3.0 DATA AND METHODS

The data and methods employed in this paper are from the estimates of the National Transfer Accounts of Kenya and Nigeria (Soyibo et al 2008 and Muriithi and Mwabu 2009). The methodology is explained in Lee and Mason, 2011 and NTA 2011. The aggregate NTA figures are estimated to be consistent with figures of the National Accounts. Construction of the NTA is illustrated by Equation (1). This is a summary expression obtained by rearranging the basic inflows = outflows identity:

$$\underbrace{C - Y_l}_{\text{Lifecycle deficit}} = \underbrace{\underbrace{\underbrace{Y_A - S}_{\text{Asset-based reallocations}} + \underbrace{\tau_g^+ - \tau_g^-}_{\text{Net public transfers}} + \underbrace{\tau_f^+ - \tau_f^-}_{\text{Net private transfers}}}_{\text{Net transfers}}}_{\text{Age reallocations}} \qquad (1)$$

In Equation (1), the key variable of interest is $C\text{-}Y_l$ and is defined as the lifecycle deficit (the difference between consumption and labor earnings at each age). Inflows to individuals of any given age consist of labor income (Y_l), income from assets (Y_A), and transfer inflows from the public sector (τ_g^+) and the private sector (τ_f^+). Outflows consist of consumption (C), investment (I) in capital, credit and land, and transfer outflows to the government (τ_g^-) and to the private sector (τ_f^-). To obtain Equation (1) by rearranging terms in the basic *Inflows = Outflows* identity, saving (S) is set equal to investment (I). Thus, Equation(1) states that the difference between consumption and production, that is, the *lifecycle deficit (LCD),* must equal *age reallocations* made up of *asset-based reallocations* and *net transfers.*

The method introduces age into the National Accounts figures. The starting point is the age profile of the National Accounts figures associated with the consumption and labor income in the two countries. To estimate the age profile of labor income, individuals are identified based on whether they generate income. Income is calculated as earnings from wage and salaries, including fringe benefits. Self-employment income is also included. To incorporate self-employment income in the national aggregate, two-thirds of the mixed income in the National Accounts is used, according to the standard NTA approach, which assumes that the remaining third accrues to property or capital. The age profile of the labor income is derived from survey data in the two countries, and together with population, is adjusted so as to be consistent with the totals in the countries' National Accounts.

For the consumption age profile, total consumption is divided into private consumption and in-kind public consumption. Because of the importance of human capital to the development of any nation, both education and health consumption are identified: *private* education and health consumption as reported in household surveys, and *public* health and education consumption from government spending on these two sectors. As is done for labor income, estimated private expenditure for health, education and other consumption is adjusted to be consistent with the totals in the national income account. NTA is constructed to be compatible with the National Income and Production Accounts (NIPA), meaning that the per capita NTA figures for each age group are the counterfactual amounts that would be obtained if the NIPA per capita figure (for example, per capita compensation of employees) was disaggregated by age.

Estimates of consumption, incomes, asset-based reallocation and transfer inflows and outflows obtained from different sources are adjusted to ensure that they are equal to aggregate totals in NIPA (the control totals). The NIPA of the country for which NTA is being estimated must contain enough detail to provide estimates such as aggregate consumption of public and private education, health, and housing. In addition, NIPA estimates using the income approach must have details such as compensation of employees, operating surplus, mixed income, and indirect and direct taxes.

The currency units in the two countries differ. To make the shapes of the age schedules of income, consumption and lifecycle deficits comparable, the levels were adjusted by dividing the average level of labor income across ages 30 to 49. This age range was chosen because it is the least affected by educational enrolment and early retirement, and because for most countries that have estimated NTAs, it is the period when incomes peak (Bixby, 2011; Lee and Mason 2011a). Thus, the graphs are plotted as ratio to average labor income at ages 30 to 49. In essence, the figures use a monetary scale of one income unit equals average labor income at ages 30 to 49. Details of the methodology are provided in Soyibo et al (2008) and Mwabu and Muriithi (2009).

This study used both primary and secondary data sources. Primary sources played a dominant role in the estimation of age profiles for incomes and consumption, asset re-allocation, and public and private transfer. For Kenya, the primary data source is the Welfare Monitoring Survey of 1994; for Nigeria, the Nigeria Living Standard Survey conducted in 2004. Secondary data sources include Central Bank of Kenya, Kenya Annual Report and Statement of Accounts, Central Bank of Nigeria Annual Reports and Statement of Ac-

counts, Government Budget documents in both countries, publications of the statistics bureaus of both countries, and NIPAs for Kenya and Nigeria.

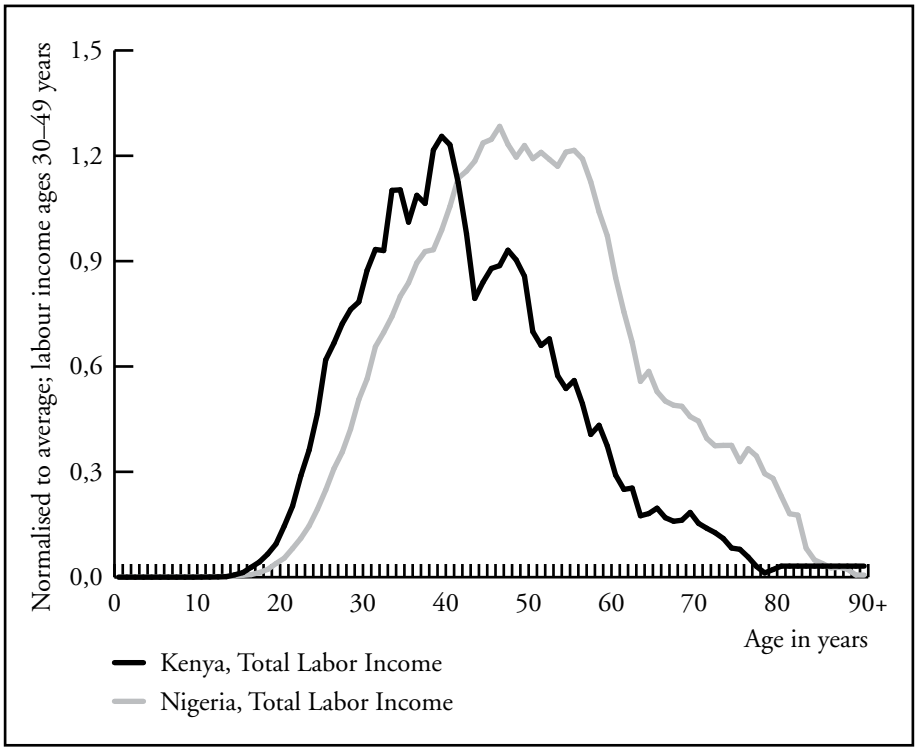
4.0 RESULTS

The results examine the two components of the lifecycle deficits: consumption and income. The relationship between them indicates the surplus or deficit age span, which, when aggregated, yields either lifecycle deficit or surplus.

4.1 Profile of labor income

Figure 1 shows the normalized components of labor income, where the reference is the 30 to 49 age group. In Kenya, average labor income rises sharply during the late teens and early twenties, reaching a peak at age 40. In Nigeria, labor income does not start to increase does not start until the early twenties, and peaks at age 46. Thereafter, average labor income falls in both countries, but remains relatively high well into old age, reflecting the traditional sectors in which older people continue to work. This contrasts with the profile in developed countries, where labor income drops sharply after age 60. In accordance with the practice in the literature, the means for these variables were normalized for comparison purposes using the average labor income of prime age adults (30 to 49).

Figure 1: Normalized components of per capita labor income, Kenya (1994) and Nigeria (2004)



4.2 Components of consumption

Figures 2 and 3 show the age profile of public and private consumption in Kenya and Nigeria. No age group in either country has a mean consumption expenditure that exceeds the mean income of the reference age group (30 to 49). In both countries, the pattern of per capita total consumption is similar to that of other countries studied under the global NTA project (Mason et al 2008).

Consumption rises steeply in childhood and remains relatively stable among working-age adults. Among the elderly, however, relative to the mean income of the reference age group, consumption is higher in Nigeria than in Kenya. In Kenya, the ratio of per capita public (government) consumption to the mean income of the reference age group is elevated, particularly for education, which, at its highest point, is about six times the corresponding ratio for Nigeria (Figure 2). By contrast, the ratio of per capita private consump-

tion is much higher in Nigeria than in Kenya, particularly with respect to health care (Figure 3). At its highest point, the ratio for private education consumption in Nigeria relative to the mean income of the reference age group, is about four times the corresponding ratio for Kenya.

Government spending on health is relatively higher in Kenya than in Nigeria. The Kenyan government spends more than 6.2% of average labor income on health, compared with 1.8% by the Nigerian government.

Figure 2: Composition of per capita public consumption in health and education, Kenya (1994) and Nigeria (2004)

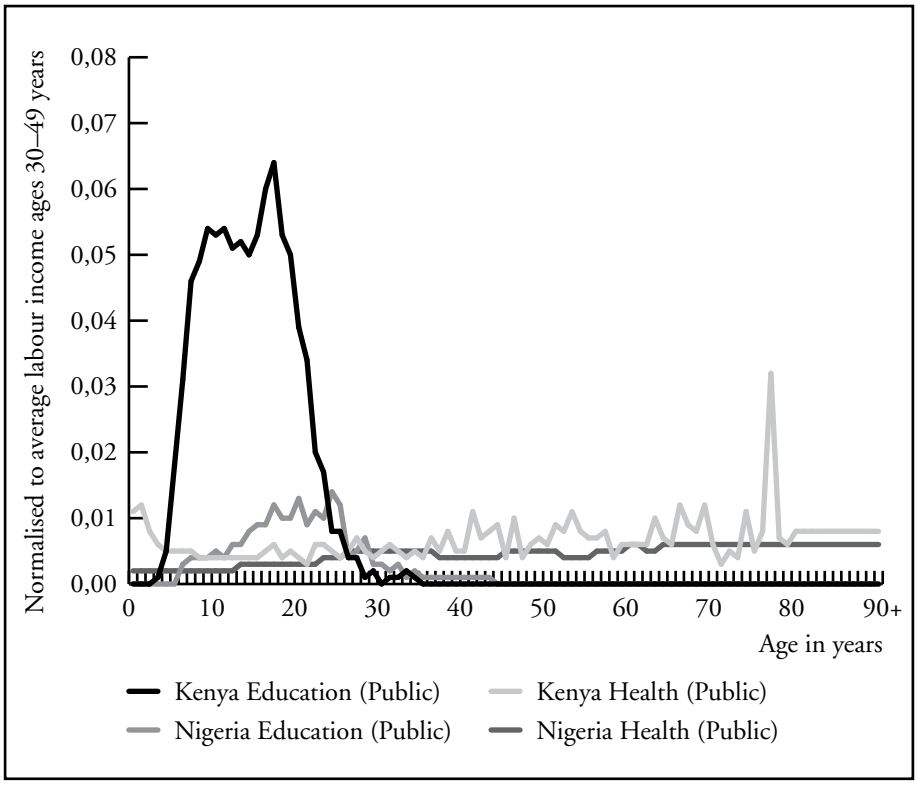
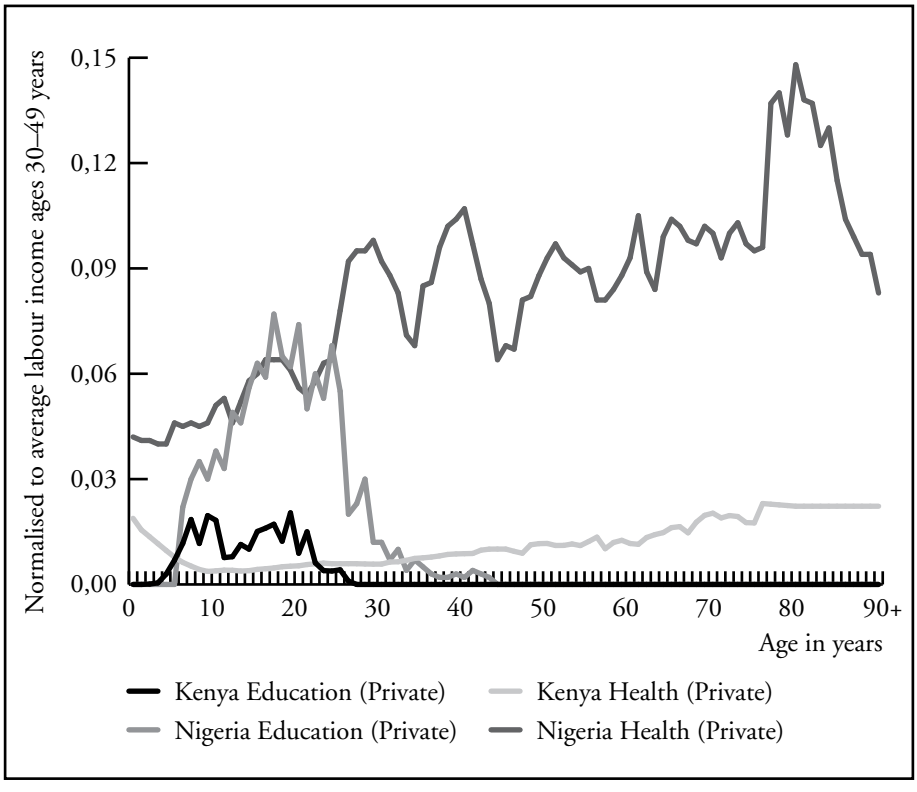


Figure 3: Composition of per capita private consumption in health and education, Kenya (1994) and Nigeria (2004)



The private sector accounts for most of the spending on human capital in Nigeria. At the peak, private consumption on education in Nigeria accounts for 7.9% of average labor income, compared with 2% in Kenya. And while private spending on health continues to rise over the lifecycle, it peaks at more than 14% in Nigeria, compared with around 2% in Kenya.

4.3. Economic lifecycle

The Lifecycle Deficit (LCD)—the difference between consumption and labor income at each age—indicates when child dependency ends and old age dependency begins. Figure 4, which compares the LCDs of Kenya for 1994 and Nigeria for 2004, shows that child dependency ends at age 24 in Kenya and at age 31 in Nigeria. Old age dependency begins at age 59 in Kenya and at age 62 in Nigeria.

The positive values in Figure 4 indicate the ages during which more is consumed than is produced; hence, there is a deficit at those ages. The negative values indicate the ages when more is produced than is consumed; hence, there is surplus at those ages.

Figure 4: Profile of lifecycle deficit, Kenya (1994) and Nigeria (2004)

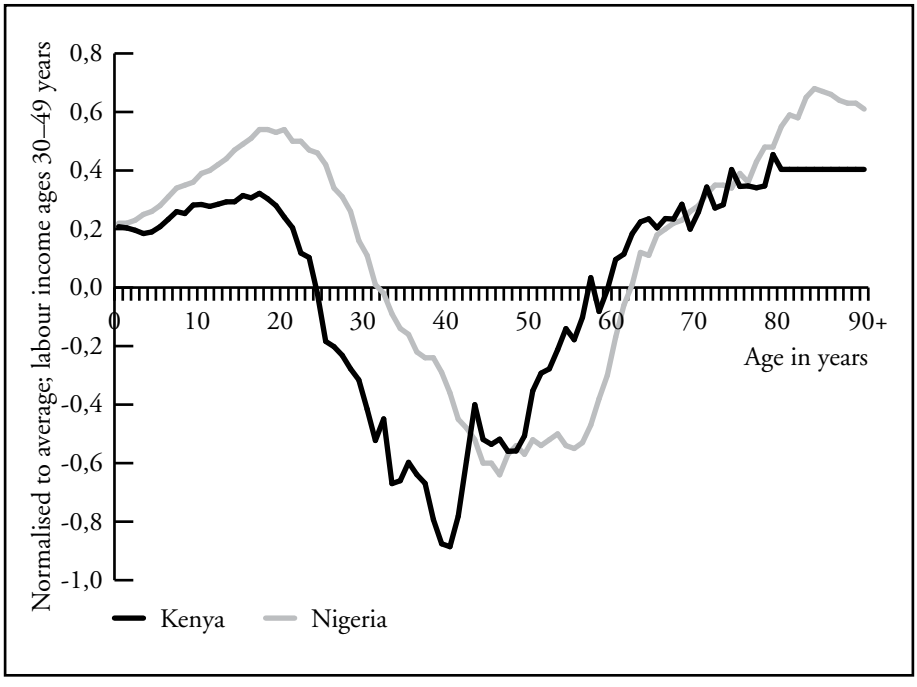


Table 2 shows the per capita NTA flows of Kenya in 1994 and Nigeria in 2004. Kenya's LCD is financed mainly by surpluses generated by people in the 20 to 29, 30 to 49, and 50 to 64 age groups; Nigeria's LCD is financed by surpluses generated by the 30 to 49 and 50 to 64 age groups. Although per capita labor income is higher in Nigeria than in Kenya, consumption expenditure is also higher, which explains Nigeria's greater lifecycle deficit: about $180 per person versus $25 per person in Kenya. This is the result of the shorter surplus age range—30 to 64— in Nigeria. In Kenya, the surplus period is ten years longer: 20 to 64.

Table 2: Per capita National Transfer Accounts (NTA) flows (US$), Nigeria (2004) and Kenya (1994)

	Age group (years)					
	0-19	**20-29**	**30-49**	**50-64**	**65+**	**Total**
U.S. dollars						
Nigeria						
Life cycle deficit (+)/ surplus (-) (*consumption minus labor income*)	322.97	311.25	-255.54	-329.88	291.69	180.29
Consumption	326.45	507.72	604.03	606.16	650.55	446.06
Labor income	3.48	196.47	859.57	936.04	358.85	265.76
Kenya						
Lifecycle deficit (*consumption minus labor income*)	155.25	-43.64	-368.64	-44.70	180.93	24.55
Consumption (public and private)	161.14	232.20	245.04	231.92	253.43	198.51
Labor income	5.90	275.85	613.67	276.61	72.50	173.96

5.0 DISCUSSION

The age profile of labor income in Kenya and Nigeria has the typical inverted-U shape, with productivity concentrated among working-age adults. Labor income peaks at age 39 in Kenya and at age 46 in Nigeria. This compares with the average labor income peak, estimated at around age 40 in the low-income countries and 50 in the high- income countries for which the NTA has been computed (Lee and Mason 2011). In both Kenya and Nigeria, people older than 70 still generate substantial labor income. This contrasts with other NTA countries, notably, Spain, Germany and China, where labor income is almost zero around age 70 (Mason et al 2007; Kluge 2008) .

Kenya and Nigeria have common economic features. Self-employment is a major source of income for the young and the elderly, and formal employment is a source of wage income mainly for people in the prime working age range. Some differences are also evident. In Kenya, earnings are the dominant form of income, whereas in Nigeria, self-employment dominates wage income. Also, on average, youth in Kenya start working at an earlier age than do Nigerian youth (this difference could be due to greater avail-

ability of data on child labor in Kenya than in Nigeria). Total labor earnings peak earlier in Kenya than in Nigeria.

Children and elderly in the two countries are a net economic burden to their families—the economic transfers they receive from their families exceed the amounts they transfer to their families. On average, child dependency lasts 33 years in Nigeria, compared with 24 years in Kenya. However, old age dependency starts four years earlier in Kenya (age 59) than in Nigeria (age 63). Kenyans enjoy a longer lifecycle surplus than do Nigerians: 35 years versus 30 years. In both countries, the surplus "age span"' is within the range for many other developing countries, which extends from 18 years in Mexico to 38 years in Uruguay (Rosero-Bixby 2011). Nonetheless, most of the lifecycle of a typical Kenyan or Nigerian is spent in economic deficit. Based on life expectancy in the two countries, Nigerians, on average, live more years in deficit than do Kenyans.

This study reveals that the total lifecycle surplus in the two countries is inadequate to cover the lifecycle deficits. Thus, both countries have net lifecycle deficits. The lifecycle surplus can cover 28% of the total deficit in Nigeria, and 76% in Kenya. For example, if the entire surplus was used for child dependency, it would cover 29% of the child LCD in Nigeria and 81% in Kenya. Moreover, this still leavers elderly dependents, for whom 13% and 8% of the surplus is needed in Nigeria and Kenya, respectively. The implication is that the deficits must be covered from sources other than labor income, such as asset income and other transfers.

The lack of social welfare provisions in the two countries has implications for the economic well-being of the elderly. Both countries are in the midst of economic transition, which means that the senior population will continue to grow. As population aging progresses, the need to raise productivity will increase. Unemployment, which has raised the age at which Nigerians attain surplus, will have to be tackled, and child in-kind transfers will have to be implemented

6.0 CONCLUSION AND POLICY IMPLICATIONS

High dependency ratios in Nigeria and Kenya have resulted in economic lifecycle deficits. The government in Kenya spends more, on average, on the human capital of children, than does Nigeria, where the burden lies more on the household. Relative to the mean income of the reference age group, public consumption expenditures on health and education are higher in

Kenya and rather low in Nigeria. However, because labor income in the two countries cannot pay for consumption at all ages, the excess consumption must be financed through asset incomes and transfers. Public transfers in both countries seem to be of the in-kind variety, although cash transfers can have a much greater impact in reducing poverty, particularly among the elderly. In Nigeria, private consumption is relied upon to finance children's education, and the health of both children and the elderly. This suggests the need for more government welfare measures that would initiate in-kind and cash transfers to assist dependent age groups.

REFERENCES

Becker, G., and H.G. Lewis (1973), On the interaction between the quantity and quality of children. *Journal of Political Economy*,Vol. 84, No. 2, pt. 2.

Bergston, T., and K. Scott (2011), Population aging and the future of the welfare state: The example of Sweden. *Population and Development Review*, Vol. 37, supplement, pp. 158-172

Bloom, D., J. Finlay, S. Humair, A.Mason, O. Olaniyan, and A. Soyibo (2010), *Prospects for Economic Growth in Nigeria: A Demographic Perspective*. Paper presented at the IUSSP Seminar on Demographics and Macroeconomic Performance. Paris, France. Accessed June 22, 2011 from www.ntaccounts.org/doc/repository/BFHMOS2010.pdf .

Bloom, D.E., and J.G. Williamson (1998), Demographic transitions and economic miracles in emerging Asia. *World Bank Economic Review*, Vol. 12, No. 2, pp. 419-456.

Chu, C.Y., and R. Lee (2006), The co-evolution of intergenerational transfer and longevity: An optimal life history approach. *Theoretical Population Biology*, Vol. 69, No. 2, pp. 193-201.

Kelley, A.C., and R.M. Schmidt (2001), Economic and demographic change: A synthesis of models, findings, and perspectives. In: N. Birdsall, A.C. Kelley, and S.W. Sinding (eds). *Population Matters: Demographic Change, Economic Growth, and Poverty in the Developing World*. Oxford: Oxford University Press. pp. 67-105.

Kluge, F.A. (2008), *National Transfer Accounts for Germany*. Paper presented at the Workshop on Population and Policy: A Follow-Up Workshop. Honolulu, Hawaii, June 20.

Lee, R., and A. Mason (2008), *Fertility, Human Capital, and Economic Growth over the Demographic Transition*. Working Paper. Accessed April 10 from http://www.schemearts.com/proj/nta/show/Working%20Papers.

Lee, R., and A. Mason (2011a), Generational economics in a changing world. *Population and Development Review*, Vol. 37, supplement, pp. 115-142.

Lee, R., and A. Mason (eds.) (2011b), *Population Aging and the Generational Economy: A Global Perspective*. Cheltenham, United Kingdom: Edward Elgar.

Lee, R., A. Mason, and T. Miller (2003), From transfers to individual responsibility: Implications for savings and capital accumulation in Taiwan and United States. *Scandinavian Journal of Economics*, Vol. 105, No. 3, pp. 339-357.

Mason A. (2008), *Lectures and Presentations at the Seminar on Population, Development and Policy: A Follow-Up Workshop*, 39th Summer Seminar on Population and Development, East-West-Centre, Honolulu, Hawaii. 3 June-3 July

Mason, A. (2001), *Population Change and Economic Development in East Asia: Challenges Met, Opportunities Seized*. Stanford: Stanford University Press.

Mason, A., et al. (2007), *The Economic Life Cycle and Population Age Structure*. Substantive Report of Work Accomplished during the 38th Summer Seminar on Population Workshop on Population, Development and Policy: The Economic Payoff of Population Change.

Mason, A., R. Lee, A.-C. Tung, M.-S. Lai, and T. Miller (2005), Population aging and Intergenerational Transfers: Introducing Age into National Accounts. In D.Wise (ed.), *Developments in the Economics of Aging*. National Bureau of Economic Research: University of Chicago Press.

Muriithi, M. and G. Mwabu (2008), *Estimation of National Transfer Accounts for Kenya Using 1994 Data: Selected Results and Discussion of their Policy Implications*. Paper submitted for consideration for presentation at IUSSP Marrakech, Morocco, September/October, 2009.

NTA (2011), Available at: http://www.ntaccounts.org/web/nta/show/Documents/Methods, Accessed May 14, 2011.

Olaniyan, O., A. Soyibo, and O. Lawanson (2011), Consumption and income over the lifecycle in Nigeria. *African Population Studies* Vol. 25, No. 1.

Rosero-Bixby, L. (2011), Generational transfers and population aging in Latin America. *Population and Development Review*, Vol. 3, supplement, pp. 143-157.

Samuelson, P. (1958), An exact consumption loan model of interest with or without the social contrivance of money. *Journal of Political Economy*, Vol. 66, pp. 467-82.

Soyibo, A., O. Olaniyan, and O. Lawanson (2008), *National Transfer Accounts of Nigeria, 2004*. Draft Research Report Submitted to the East West Centre, Honolulu Hawaii.

United Nations (2007), *World Population Ageing 2007*. New York: United Nations.

Willis, R.J. (1987), Externalities and population. In: D.G. Johnson and R.D. Lee (eds.), *Population Growth and Economic Development: Issues and Evidence*. Madison: University of Wisconsin Press. pp. 106-138.

3. Determinants of learning outcomes for primary education: A case of Uganda

Joseph Muvawala[1]

Abstract
The paper examines determinants of learning outcomes in primary schools using a Generalized Method of Moments (GMM) estimation technique. Although there is rich literature on the determinants of learning outcome at the primary level, its estimation has proceeded under a strict assumption of policy exogenity. Studies that have employed the production function technique to estimate the influence on learning outcomes of expenditures on "traditional" educational inputs fail to yield the expected positive influence. This paper relaxes the strict assumption of policy exogenity and exploits the first panel dataset to have been constructed on Uganda's primary schools. The study shows that some of the traditional educational inputs actually yield the expected positive influence on learning outcomes, notably, provision of textbooks, inspection frequency, teacher houses, teacher numbers, teacher training, and the proxy for school environment. The magnitude of the influence on learning outcomes differs across government and private schools. Evidence from the study also indicates that investing in software inputs has a higher positive impact on learning outcomes than do hardware educational inputs.

Key words: *Learning outcomes, primary schools, GMM, panel data, panel estimation techniques*

Facteurs déterminants des résultats d'apprentissage ans l'enseignement primaire : l'exemple de l'Ouganda

Résumé
Le présent article utilise la Méthode des moments généralisée (GMM en anglais) pour examiner les facteurs déterminants des résultats d'apprentissage dans les établissements d'enseignement primaire. Si la littérature ne manque pas en l'espèce, l'estimation de ces facteurs s'est jusqu'ici basée sur une hypothèse d'exogénéité stricte des politiques. Les études qui utilisent la méthode de la fonction de production pour estimer l'impact des dépenses relatives aux intrants éducatifs « traditionnels » sur les résultats d'apprentissage ne parviennent pas à faire ressortir l'impact positif attendu. Le présent article assouplit l'hypothèse d'exogénéité stricte des politiques et exploite le premier ensemble de données de panel à avoir été constitué sur les établissements d'enseignement primaire en Ouganda. L'étude montre que certains intrants éducatifs traditionnels ont effectivement l'impact positif

1 Joseph Muvawala is a Chief Country Economist with the African Development Bank. The views and conclusions in this paper do not represent the position of the African Development Bank.

attendu sur les résultats d'apprentissage, notamment la fourniture de manuels scolaires, la fréquence des inspections, l'offre de logements aux enseignants, le nombre d'enseignants, la formation des enseignants et l'indicateur du milieu scolaire. L'ampleur de l'impact sur les résultats d'apprentissage varie selon qu'il s'agit d'établissements publics ou privés. Les données de l'étude montrent en outre qu'un investissement dans les intrants éducatifs immatériels a une incidence positive plus forte sur les résultats d'apprentissage que l'investissement dans les intrants matériels.

Mots clés : *Résultats d'apprentissage, établissements d'enseignement primaire, GMM, données de panel, méthode d'estimation sur données de panel*

1.0 INTRODUCTION

A general consensus has emerged in the literature that in most developing countries the relationship between increased resource allocation to the education sector and improved education outcomes is fairly weak (Pritchett and Filmer 1999). A major finding is that "traditional" education inputs fail to yield the expected positive influence.

The standard conceptual approach usually entails specification of a technical relationship in the form of production functions (Evans et al., 2000), whereby an institution (such as a primary school) is seen as analogous to a firm, transforming inputs into outputs through a production process. Typical inputs in the education production function at the primary level include government expenditures on teaching and the learning atmosphere, especially where the major output is defined in terms of pupils' numeracy and literacy (Kirjavainen and Loikkanen 1998). Christiansen et al. (2002) argued that where the relationship exists and can be quantified, policy can be constructed to maximize a preferred conceptual outcome. Indeed, considerable empirical research in this area has focused on identifying this technical relationship.

Nonetheless, the literature points to the failure of education production functions to identify the purported/perceived relationship between key policy variables (such as resource spending) and educational achievement (Mayston 1996). Two explanations for the failure of education production functions have been proposed: 1) the validity of the educational production function framework itself and the possibility of econometric misspecification, and 2) the possibility that public policy may not have a measurable impact on educational outcome. Deller and Rudnicki (1997), for instance,

contended that innate ability combined with socio-economic background, may be more important in the educational production process. Nonetheless, Kremer (commenting on Hanushek's article, 1995) maintained that specific inputs, such as provision of textbooks and use of educational radio, have had a demonstrable impact on learning outcomes.

Others have sought to define various dimensions of quality education. For example, the World Bank's Primary Education Policy Paper (1990), using a comprehensive review of research, identified five principal contributors to primary education effectiveness: curriculum, learning materials, instructional time, classroom teaching, and students' learning ability. This review assesses how the research, especially since 1990, has addressed the importance of these and others factors, and offers insight into the circumstances under which the various factors make a difference. However, this paper is not conclusive, as the variables examined are not the only determinants of education outcomes.

Moreover, despite agreement in educational circles that hardware factors are perceived as being key determinants of education outcomes, some ambiguity in the importance of this factor exists. This may be partly explained by evidence suggesting that the quality of facilities may be more important in disadvantaged settings. At any rate, growing evidence suggests that the variability of hardware factors may not diminish their determinant potential.

The role of teachers is generally accepted as crucial to learning outcomes. In most countries, developing and industrialized, teacher salaries account for half to three-quarters of education expenditures, rising as high as 90% in some African countries (World Bank 2002). Given the magnitude of this investment, it is important to know if it affects students' learning outcomes. Beyond that, most studies agree that time spent on teaching is an important condition for learning (Fuller 1986). Another characteristic of high-quality schools is assignment and correction of homework.

At the international level, debate continues about the relevance of class size. Hanushek (1998) summarized the available evidence as inconclusive, and warned against placing too much emphasis on the issue given the high costs involved. Others, however, claim that gains in educational quality will be realized by reducing class size, particularly in the early grades (Biddle and Berliner, 2002). Whatever the results of these studies, which predominantly consider industrialized countries, a negative effect of student numbers might be expected in Africa where the average class size in primary schools is two to three times that in Europe or the United States.

Finally, children's personal characteristics and background affect their persistence and attainment. These variables include the child's health and nutritional status, gender and age, and parents' or caregivers' attitudes and experience with school. Prior schooling such as early childhood/pre-school programs will shape the child's response to school.

The literature is not definitive. Different conclusions drawn by different researchers applying different methodologies demonstrate the difficulty of identifying determinants of learning outcomes *a priori*. Even so, developing countries are spending heavily on inputs, based on the perception that they improve learning. Hence, more research that employs different methodologies and datasets is needed to try to establish which inputs have a positive influence on learning outcomes.

2.0 COUNTRY CONTEXT

In January 1997, the Government of Uganda implemented the Universal Primary Education program. This followed the Education Strategic Investment Plan (ESIP) 1998-2003, which offered a framework for education development in Uganda. ESIP's priorities included "access and equity in education, improvement in quality, delivery of education services, and capacity development." (Hallak et al 2000). The objective of the UPE program is to provide the minimum facilities and resources needed to complete primary education. Under the program, the State provides "free" primary education for all school-age children.

Attempting to achieve the objectives of the UPE program has been costly to the government, but the results, especially with regard to the quality of education, have been less than satisfactory. The percentage of the national budget allocated to education grew from 15% in 1998/99 to 24 % in 2006/07. And as a percentage of the total education budget, the share devoted to the primary level averaged more than 60% from 2000 to 2008; it has declined to about 50%. Government efforts to increase resources to primary education have resulted in six key achievements:

- Primary enrolment rose from about 2.5 million in 1997 to 8.0 million in 2011, with near parity in enrolment of girls and boys.
- Teacher training programs have been developed—the percentage of with a diploma was 89% in 2010.
- Massive teacher recruitment reduced the pupil-teacher ratio to a national average of 49:1 in 2010.

- An increase in classrooms reduced the average number of pupils per classroom from 96 in 2000 to 58 in 2010.
- Pupil-textbook ratios have been reduced.
- Curriculum review for the primary level has been completed.

However, despite these improvements in quality enhancement indicators, learning outcomes, especially numeracy and literacy, have been less than satisfactory. National Assessment of Progress in Education studies (2003 to 2008) conducted by the Uganda National Examinations Board report literacy rates at P3 and P6 of 41.8% and 36.2%, respectively, and corresponding numeracy rates of 49.3% and 35.7%. The UPE program has faced challenges with regard to completion rates and the quality of graduates, which raise questions about both the technical and allocative efficiency of its implementation. Also questioned are the policy assumptions made by the government during the 13 years of implementing the UPE program and spending on selected inputs, on the basis of perception rather than empirical research. Table 1 shows trends in spending on primary education (in billions of UGX) over the nine years from 2000/01 to 2008/08, by expenditure category.

Table 1: Trend analysis of primary education budget (UGX billions), by spending category and financial year, 2000/01 to 2008/09

Spending category	**2000/1**	**2001/2**	**2002/3**	**2003/4**	**2004/5**	**2005/6**	**2006/7**	**2007/8**	**2008/9**
	UGX (billions)								
UPE grant	41.3	46.7	41.5	41.5	33.5	33.5	32.8	33.5	33.5
SFG	50.2	72.1	68.3	59.8	54.1	51.0	16.4	16.4	23.7
Primary wages	141.8	153.7	185.0	208.0	230.2	254.0	342.5	354.5	354.3
Primary textbooks	8.5	5.93	14.8	16.3	16.3	12.1	8.64	7.7	6.9
Teacher training	5.6	5..9	6.0	5.4	6.2	4.7	4.6	4.6	4.6
Inspection funds	-	-	-	-	-	-	-	-	2.5
TOTAL	**247.4**	**284..5**	**315.8**	**331.0**	**340.2**	**355.3**	**405.0**	**416.7**	**425.5**

Source: Researcher computation based on the MTBF for the education sector

Other issues exacerbate the challenges to UPE. Funding to primary education has not kept pace with population growth and inflation. Hence, the allocation of funds to the sector has not increased (and will not increase) in real terms. Increasingly, the focus is on secondary, business, technical/vocational and higher education. The share of the education budget devoted to the primary level fell from 66.8% in 1998/99 to 58.8% in 2008/09, and is projected to decline to 49.6% in 2013. Moreover, the shrinking share the national budget allocated to education overall (from 24% in 2000 to just over 16% in 2008) signals the need to do things differently, which involves a deliberate, objective process that ensures efficient allocation of the limited funds.

3.0 DETERMINANTS OF LEARNING OUTCOMES ANALYSIS

3.1 Conceptual framework

This analysis employs a production function framework to estimate determinants of learning outcomes. Although schools are not profit-maximizing firms, the framework treats them as production units on the supply side. Production function studies have been used extensively to identify factors that "produce" good learning outcomes.

Education economists recognize that the production function theory needs modification when applied to schools, but generally believe that the basic idea of using capital, labor, and other inputs to produce specific outputs can be valuable. The result is a theoretical economic model of the behavior of schools that yields observations and hypotheses related to school organization, management and governance, which are important to the delivery of quality education services (Boissiere 2004). This framework specifies a level of achievement, usually measured by students' test scores, as the typical output, and characteristics of the teaching and learning environment as typical inputs (Todd and Wolpin 2003).

3.2 Estimation technique

The primary estimation technique employed in this analysis is the generalized method of moments (GMM). This method is considered to be superior to other dynamic panel estimation techniques, because of its ability to deal with large samples and the existence of endogenity in education production functions. The GMM produces consistent and efficient estimates, the latter of which are particularly critical for policy inference.

3.3 Model specification and estimation procedure

A multivariate analysis procedure is applied on a set panel data. The learning outcome relationship is indicated as a Performance Index model. The Performance Index of school in period is specified to be a function of educational inputs, which consist of school and students' characteristics. In particular, the random effects multivariate regression specification is used.

Why random effects Regression?
Random effects regression was preferred over fixed effects. First, the use of several variables in the model created the possibility of multi-co-linearity, which random effects modeling is best suited to deal with. Second, the use of cross-sectional observations and time series observations necessitates modifications to the assumptions underlying the error term in the initial specification, which is possible only under the random effects regression specification. Third, the number of cross-sectional units was much larger than the number of time periods. When this is the case, the Random Effects Regression specification produces more efficient estimators. Fourth, the units in the sample were regarded as random samples from a larger universe (the national population of primary schools), making the random effects regression specification more appropriate.

Random effects regression specification
Given a vector of purchased schooling inputs (X_i) and Learning outcomes (PI_i), and following Monk (1992)*, the Performance index of school i, in period t, was specified as:

$$PI_{it} = X_{it}\beta + u_{it} \tag{1}$$

Where (X_{it}) is a vector on observations on school characteristics and students' background characteristics. β, is a vector of parameters such that:

$$\beta = \beta_{1i}, \beta_{2i} \ldots \beta_{ki} \tag{2}$$

To write the model in (1) as a random effects regression model, β_{1i} was treated as a random variable with mean β_1, so that the intercept value for an individual school would be expressed as:

$$\beta_{1i} = \beta_1 + e_i \tag{3}$$

where e_i is a random error term and that: e_i, $i = 1 \ldots n$.

Considering equations (1) and (3), the random effects Performance Index regression equation became:

$$PI_{it} = X_{it}\beta + e_i + u_{it} \tag{4}$$

Letting $\varepsilon_{it} = e_i + u_{it}$ (5)

the model in (4) was specified as:

$$PI_{it} = X_{it}\beta + \varepsilon_{it} \tag{6}$$

where β is such that: $\beta' = \beta_1, \beta_{2i} \ldots \beta_{ki}$; ε_{it} is a composite error term. The composite error term ε_{it} consists of two components, ε_i which is individual (school) specific, and u_{it} which is the combined time series and cross-section error component. The following assumptions were considered to hold the model error terms:

$$\begin{aligned}
&\varepsilon_i \sim N(0, \delta_\varepsilon^2),\ u_i \sim N(0, \delta_u^2);\\
&E(\varepsilon_i, u_{it}) = 0,\ E(\varepsilon_i, \varepsilon_j) = 0;\ i \neq j;\\
&E(u_{it}, u_{is}) = E(u_{it}, u_{jt}) = E(u_{it}, u_{js}) = 0;\ t \neq s
\end{aligned} \tag{7}$$

X_{it} is matrix on observations on school characteristics and students' background, including socio-economic indicators. The observations on school characteristics were the pupil-teacher ratio (PTR), the pupil-textbook ratio (PTXR), the pupil-classroom ratio (PCR), teachers' houses (TH), inspection frequency (INSP), head teacher's experience (HTEXP), and state of ownership and location of the school (OWN). The observations on socio-economic indicators captured in the X_{it} matrix included the average monthly incomes of the households where the pupils lived.

Parameters included in the model were selected through the process of obtaining a congruent GMM model. In estimating the GMM, the analysis applies lagged dependent variables as instruments, since they are exogenous. Location (rural versus urban) and ownership (private versus government) were used as controls. The GMM model applied is specified in linear log form.

3.4 Derivation of PLE Performance Index

For this study, a performance index (PLE Performance Index) that mitigates the bias of school size was computed. In each grade, candidates were weighted so that passing with the best grade carried high weight, and failure

was given zero weight. The actual weight was summed and expressed as a ratio of the expected maximum weight attained by multiplying the highest weight with the number of candidates who took exams.

4.0 RESULTS

The factors (inputs) associated with learning outcomes in primary schools in Uganda vary, depending on ownership (government or private) and location (urban or rural).

4.1 Dynamic panel estimates for all categories

Dynamic panel estimates for all categories of primary schools indicate that eight of the eleven factors in the model are significant at 5%, and therefore, are associated with learning outcomes: lagged dependant variable, a proxy for passing culture, pupil-textbook ratio, pupil-classroom ratio, pupil-desk ratio, teacher training, teacher houses, and inspection frequency.

However, the influence of these factors on learning outcomes is relatively weak. A 1% improvement in input will influence learning outcomes by 0.05% for pupil-teacher ratio; 1.1% for pupil-textbook ratio; 1% for teacher training; 0.09% for teacher houses; 0.04% for pupil-desk ratio; 0.02% for pupil-classroom ratio; and 0.84% inspection frequency.

4.2 Dynamic panel estimates, by ownership

Government-owned schools
Dynamic panel estimates for government-owned schools show that eight inputs in the model are significant at 5%, and therefore, are associated with learning outcomes: lagged dependent variable, proxy for passing culture, pupil-teacher ratio, pupil-textbook ratio, pupil-desk ratio, teacher training, teacher houses and inspection frequency. In this case, too, the influence of these on learning outcomes is small. A 1% improvement in input will influence learning outcomes by 0.04% for pupil-teacher ratio; 1.4% for pupil-textbook ratio; 1% for teacher training; 0.08% for teachers' houses; 0.039% for pupil-desk ratio; 0.02% for pupil-classroom ratio; and 0.89% for inspection frequency.

Private schools
For private schools, only three factors are significant at 5%: teacher training; pupil-textbook ratio; and pupil-desk ratio. A 1% improvement in input

will influence learning outcomes by 1.2% for teacher training; 2.3% for pupil-textbook ratios; and 1.2% for pupil-desk ratio.

4.3 Dynamic panel estimates, by location

Rural schools

For schools in rural areas, seven factors are significant at 5%: lagged dependent variable, proxy for passing culture, pupil-teacher ratio, pupil-textbook ratio, teachers' houses, pupil classroom ratio, teacher training, pupil-desk ratio, and inspection frequency. A 1% improvement in input will influence learning outcomes by 0.04% for pupil-teacher ratio; 1.0% for pupil textbook ratio; 1% for teacher training; 0.08% for teachers' houses; 0.02% for pupil classroom ratios; and 0.81% for inspection frequency.

Urban schools

For schools in urban areas, five factors are significant at 5% and 10%: lagged dependent variable, pupil-teacher ratio, teacher training, teacher houses, inspection, and head teachers' experience. A 1%, change in input will influence learning outcomes by 0.06% for pupil-teacher ratio; 1.4% for pupil-textbook ratio; 0.1% for teachers' houses; 0.15% for head teacher experience; 0.6% for inspection frequency; and 0.5% for teacher training.

The GMM estimates reveal that the factors associated with learning outcomes depend on ownership and location. Hence, analyzing learning outcomes without taking these factors into account may result in erroneous inferences. Table 2 summarizes the factors that are significant overall and by school ownership and location.

Table 2: Summary table: Significant inputs, by school ownership and location of schools

Ownership/ Location of schools	Teacher training	L1	Pupil-teacher ratio	Pupil-class-room ratio	Pupil-text book ratio	Pupil-desk ratio	Teach-ers' houses	Head Teacher experi-ence	Inspec-tion fre-quency	House-hold expendi-ture on Education	Spouse literay
All categories	*	*	*	*	*	*	*		*		
Government	*	*	*	*	*	*	*		*		
Private	*				*	*					
Rural	*	*	*		*		*		*		
Urban	*	*	*		*		*	*	*		

* Significant at $p<0.05$.

5.0 CONCLUSIONS AND POLICY IMPLICATIONS

The results of this analysis demonstrate that an appropriate estimation technique enhances the robustness of the education production function estimates, and empirically illustrate a positive influence of some of "traditional" education inputs on learning outcomes. Hence, policy-based traditional education inputs can be effective in providing quality education if the right combination of input and thresholds is achieved. The question that policy-makers must answer is, "What works?"

This paper does not consider new child-focused teaching methodologies. Because of resource constraints, they are not institutionalized in education delivery in Africa. Thus, traditional input will predominate for a long time to come, so this limitation does not reduce the value of the findings especially in the context of African education systems. Moreover, no datasets on these methodologies exist in Uganda or in other African countries.

The government's education policy and budget allocation have targeted traditional educational inputs that have a positive influence on learning outcomes. But the amounts spent on the various inputs have not matched the degree of influence they have on learning outcomes. Specifically, inputs with the highest returns, such as teacher training, inspection and textbook procurement, have not been allocated resources commensurate with their impact on learning outcomes. The results of the present study show that investments in software have a higher pay-off in terms influencing learning outcomes than do investments in hardware. The implications of these results are that:

(i) There is a need for the government to shift its spending priorities toward inputs such as textbooks, inspection, and teacher recruitment and training.

(ii) The quality crisis in education in Uganda may not be the result of misapplication of government resources per se, but rather, failure to achieve the right balance, that is, the right "dose."

Consequently, blanket appraisals of the UPE program as failing to achieve quality may not be justified. It may be a case of blaming the medicine for not curing a disease when the right dose was not administered. For example, treating acute malaria with half a dose of quinine will not cure the disease, but it cannot be argued that the medication has no value in treating malaria. The value of the medication is apparent only when enough is taken to be effective.

This analogy is applicable to education. A comparison of per capita spending in private and government schools reveals a wide disparity: the average expenditure per pupil in private schools is more than 30 times that in government schools. As well, private schools spend proportionately more on teaching and learning support: 40% versus 10%. The average pass rate in private schools is 54%, compared with 44% in government schools. These statistics suggest that less-than-adequate funding in government and rural primary schools may be a reason for their less-than-average performance. It is clear from the evidence that although government financing through the UPE program was intended to play a supplementary and complementary role, it has turned out to be a substitute for the parental contributions that existed before the program was implemented. Parents in rural areas have abandoned their responsibility to pay other costs required of them by the policy.

This study does not answer the question, "What is the right dose (adequate level of spending per input) required to remedy the quality problem?" This question can be answered only by government investments in randomized experiments, applying different combinations and doses of inputs based on pay-offs that are studied over time. In sum, policy-makers have to use empirical techniques to determine the right doses. Hence, the policy and research functions of education ministries, and their capacity to perform high-level quantitative and qualitative analysis, must be prioritized to ensure effective allocation of limited funds.

The determinants of and the impact on learning outcomes in government and private schools differ to some extent. For example, textbook provision to private primary schools would have the highest pay-off, but at the primary level, the government does not provide textbooks to private schools. To enhance the effectiveness of policy-based inputs, the government should consider providing textbooks to private schools and formulating policy that takes differences ownership and location into account.

A passing culture has a major impact on performance—82% for all schools. This lends credence to the argument that it is difficult to improve learning outcomes in schools that have had a poor passing culture. By contrast, pupils' social background was not significantly associated with their performance. This implies that in a setting where earnings are relatively low, the school environment matters as an agent of social transformation.

Head teacher experience is not associated with learning outcomes in government schools and rural schools. This finding challenges the practice of

paying head teachers almost three times the salary of classroom teachers. It also suggests that devolution of instructional leadership to lower levels particularly the teacher's scheme of service may be more effective. In fact, inspections have revealed that the majority of head teachers in Uganda, especially in rural and government schools, are absent from the schools, and therefore, have failed to provided instructional leadership. This may justify the government in institutionalizing customized performance contracts and reinforcing inspection. Nonetheless, the effectiveness of customized performance contracts will be seriously compromised by the less-than-adequate capitation allocated to schools.

REFERENCES

Aragon, Y., A. Daouia and C. Thomas-Agnan (2005), "Nonparametric Frontier Estimation: A Conditional Quantile-based Approach," *Econometric Theory*, vol. 21, no. 2, pp. 358-389.

Barrow, M. (1991), "Measuring Local Education Authority Performance: A Frontier Approach," *Economics of Education Review*, vol. 10, no. 1, pp. 19-27.

Bates, J.M. (1997), "Measuring Predetermined Socioeconomic 'Inputs' When Assessing the Efficiency of Educational Outputs," *Applied Economics*, vol. 29, no. 1, pp. 85-93.

Biddle, B. J. and D.C. Berliner (2002), "Unequal School Funding in the United States," *Educational Leadership*, vol. 59, no. 8, pp. 48.

Boissiere, M., J.B. Knight, and R.H. Sabot (1985), "Earnings, Schooling, Ability and Cognitive Skills," *American Economic Review*, vol. 75, no. 5, pp. 1016-1030.

Burney, N.A. and M. Irfan (1991), "Parental Characteristics, Supply of Schools and Child-School Enrolment in Pakistan," *The Pakistan Development Review*, vol. 30, no. 1, pp. 21-62.

Deller, S.C. and D.R. Rudnicki (1993), "Production Efficiency in Elementary Education: The Case of Maine Public Schools," *Economics of Education Review*, vol. 12, pp. 45-57.

Evans, D.E., A.Tandon, C.J.L.Murray, et al. (2000), *The Comparative Efficiency of National Health Systems in Producing Health: An Analysis of 191*

Countries, Global Programme on Evidence for Health Policy, Discussion Paper No.29. Geneva, Switzerland: World Health Organization.

Farrell, M.J. (1957), "The Measurement of Productive Efficiency," *Journal of the Royal Statistical Society*, vol. 120, no. 3, pp. 253-290.

Hanushek, E.A. (1998), *The Evidence on Class Size*, W. Allen Wallis Institute of Political Economy Occasional Paper, No. 98-1. Rochester, New York: University of Rochester.

Kirjavainen, T. and H.A. Loikkanen (1998), "Efficiency Differences of Finnish Senior Secondary Schools: An Application of DEA and Tobit Analysis," *Economics of Education Review*, vol. 17, no. 4, pp. 377-394.

Kremer, M. (1995), "Research on Schooling: What We Know and What We Don't: A Comment on Hanushek," *World Bank Research Observer*, vol. 10, no. 2, pp. 247-54.

Mayston, D.J. (1996), "Educational Attainment and Resource Use: Mystery or Econometric Misspecification?" *Education Economics*, vol. 4, no. 2, pp. 127-142.

Pritchett, L. and D. Filmer (1999), "What Production Functions Really Show: A Positive Theory of Education Expenditures," *Economics of Education Review*, vol. 18, no. 2, pp. 223-239.

Rivkin, G., E.A. Hanushek, and J.F. Kain (2005), "Teachers, Schools, and Academic Achievement," *Econometrica*, vol. 73, no. 2, pp. 417-458.

Robert, K. (2010), *Education in Uganda*, 21st Century Schoolhouse Online.

Sengupta, J.K. and R.E. Sfeir (1986), "Production Frontier Estimates of Scale in Public Schools in California," *Economics of Education Review*, vol. 5, no. 3, pp. 297-307.

Tan, J., J. Lane, and P.Coustere (1997), "Putting Inputs to Work in Elementary Schools: What Can Be Done in the Philippines?" *Economic Development and Cultural Change*, vol. 45, no. 4, pp. 857-881.

Teskey, G. and R. Hopper (1999), *Uganda Education Strategies Investment Programme: Case Study*. Nairobi, Kenya: Department for International Development.

UNESCO (2002), *Education for All: Is the World on Track*, EFA Global Monitoring Report. Paris: UNESCO.

UNESCO (2006), *Literacy for Life*, EFA Global Monitoring Report. Paris: UNESCO.

Verspoor, A.M. (2003), *The Challenge of Learning: Improving the Quality of Basic Education in Sub-Saharan Africa*, Summary, Discussion Paper prepared for the ADEA Biennial Meeting. Paris: Association for the Development of Education in Africa.

Ward, H. and H. Craig (1995), *Schools Count: World Bank Project Designs and the Quality of Primary Education in Sub-Saharan Africa*, World Bank Technical Paper No. 303. Washington, D.C.: The World Bank.

White, H. (2004), *Books, Buildings, and Learning Outcomes: An Impact Evaluation of World Bank Support to Basic Education in Ghana*. Washington, D.C.: The World Bank.

The World Bank (1990), *World Bank's Primary Education Policy Paper*. Washington, D.C.: The World Bank.

Wright, C. and R. Govinda, (eds.) (1994), *Three Years after Jomtien: EFA in the Eastern and Southern Africa Region*. Paris: UNESCO, International Institute for Educational Planning.

Zellner, A. and N.S. Revankar (1969), "Generalized Production Functions," *Review of Economic Studies*, vol. 36, no. 106, pp. 241-250l.

4. A comparative assessment of selected approaches in modeling completion dynamics of graduate programs

Robert Wamala,[1,2] Joseph C. Oonyu[3] and Bruno Ocaya[4]

Abstract

As the higher education landscape changes, factors related to student persistence in graduate programs are being examined by a growing number of researchers. Their investigations, however, can be problematic when: i) a considerable number of students have not completed the program at the time of data collection; ii) enrolment and completion figures are low; iii) a normal distribution of completion time is assumed; and iv) a detailed assessment of non-completion is required. A time-to-event approach in a Cox model, which uses enrolment time as censored for students who have not completed by the time of the study and makes no assumption about the distribution of completion time, solves the first three problems. A multinomial logistic, allowing for at least three outcomes of doctoral candidature, solves the fourth problem. This is illustrated by an analysis of administrative data for the 295 PhD students at Makerere University in the 2000 to 2005 enrolment cohorts. The total elapsed time from first enrolment to submission of final thesis copy was adopted as a measure of completion time. The findings underscore the suitability of these approaches for the analysis of education data with low enrolment and completion figures, a situation characteristic of doctoral studies in many African universities.

Key words: *Student success in graduate programs, completion and non-completion of doctoral studies, Makerere University.*

Évaluation comparative de quelques méthodes de modélisation de la dynamique d'achèvement des programmes de troisième cycle

Résumé

Alors que le paysage de l'enseignement supérieur est en pleine évolution, un nombre croissant de chercheurs étudient les facteurs liés à la persévérance des étudiants

1 Robert Wamala, School of Statistics and Applied Economics, Makerere University, Uganda. Email: rwamala@isae.mak.ac.ug

2 Correspondence concerning this paper should be addressed to Robert Wamala, School of Statistics and Applied Economics, Makerere University, P. O. Box 7062, Kampala, Uganda E-mail: rwamala@isae.mak.ac.ug, Mobile: +256-772-623-100.

3 Dr.Bruno Ocaya, School of Statistics and Applied Economics, Makerere University, Uganda. Email: bocaya@isae.mak.ac.ug

4 Dr. Joseph Oonyu, School of Education, Science and Technical Education Department, Makerere University, Uganda. Email: joonyu@educ.mak.ac.ug

dans les programmes de troisième cycle. Ces recherches peuvent néanmoins être problématiques si : i) un nombre considérable d'étudiants n'a pas achevé le programme au moment de la collecte des données ; ii) les taux d'inscription et d'achèvement sont faibles ; iii) l'hypothèse de départ est celle d'une répartition normale du temps d'achèvement ; et iv) une évaluation détaillée des cas d'abandon s'impose. Les trois premiers problèmes peuvent être résolus à l'aide d'une approche de type temps-évènement selon le modèle de Cox reposant sur la date d'inscription censurée des étudiants n'ayant pas achevé le programme au moment de l'étude et n'émettant aucune hypothèse quant à la répartition du temps d'achèvement. Le quatrième problème peut être résolu grâce à une modélisation de type logit multinomial prévoyant au moins trois résultats possibles pour les candidatures doctorales. L'analyse des données administratives relatives aux 295 étudiants doctorants de l'Université Makerere figurant dans les cohortes des années 2000 à 2005 en est une illustration. Le temps total écoulé entre la première inscription et la présentation de la copie finale de la thèse a été retenu pour mesurer le délai d'achèvement. Les résultats montrent que ces méthodes sont adaptées à l'analyse des données relatives à l'éducation lorsque les taux d'inscription et d'achèvement des études sont peu élevés, ce qui est une caractéristique des études doctorales dans nombre d'universités africaines.

Mots clés : *Accès des étudiants aux programmes de troisième cycle, achèvement et abandon des études doctorales, Université Makerere.*

1.0 INTRODUCTION

Consensus is lacking about the statistical methods that should be used to determine factors associated with the length of time taken to complete a doctoral degree. Studies may not present adequate diagnostics to support the choice of method (univariate, bivariate or multivariate) or the results obtained. In a 2002 review, Osborne and Waters observed the lack of testing of assumptions that underpin the methods on which researchers rely on when drawing conclusions. For a substantial number of results, conclusions and assertions, no statistical rationale for the approaches used in the analyses is provided.

Owing to the skewed nature of completion time for doctoral studies, the median rather than the mean elapsed time has been adopted as a descriptive measure (Bourke, Holbrookand Lovat 2004; Wamala, Oonyu and Ocaya 2011). Because the data are skewed, the assumed normality of the total time elapsed (completion time) in the OLS multiple linear regression adopted by Bourke et al (2004) could be unreasonable. By ignoring violation of

the distributional assumptions, application of a multiple regression to the data could distort associations and significance tests, thereby resulting in a Type I or Type II error (Osborne and Waters 2002). Cleves et al (2010) also demonstrate the skewed nature of time-to-event data, a perfect example of which is completion time for graduate studies. They argue that the distribution of the variable is non-symmetric, and that linear regression is not robust to these violations.

Another complication is that when a study of completion time is conducted, not all students who are enrolled have completed their degree. Ignoring the candidature status and total elapsed time of these individuals means loss of data in the analysis, and could distort the statistical significance of associations. Given the availability of methodologies that take censored data into account, evaluating the total elapsed time as a categorical outcome has been suggested (Wamala et al 2011). This makes it possible to model data with nominal outcome variables (Hosmer and Lemeshow 2000; Hilbe 2009). The question, however, is whether to model the outcome variable with two or more candidature outcomes. Although either approach could yield meaningful results, a number of factors associated with non-completion or completion time (for example, extended candidature) may not be examined.

This paper assesses several techniques methods for investigating the completion and non-completion dynamics of doctoral studies. Variation in the results generated is also examined.

2.0 DATA AND METHODS

The assessment is based on administrative data for the 295 doctoral students registered across all academic units and/or disciplines at Makerere University in the enrolment cohorts from 2000 to 2005. The total elapsed time from first enrolment to submission of a final thesis or dissertation copy, after a VIVA or public defense, was adopted as the measure of completion time. The enrolment time for students who had not graduated when the time the study was conducted was estimated by the time of data collection—November 2010.

First, an OLS Multiple Linear Regression (MLR) was used to estimate completion time dynamics. Completion time will be positive ($[0,\infty)$). The methodology is based on the formula:

$$Y_i = \beta_0 + \beta_1 X_{\mathbf{1}} + \beta_2 X_{\mathbf{2}} + \ldots + \beta_k X_{\mathbf{k}} + \varepsilon_i \qquad (1)$$

where Y is completion time of doctoral studies, and $\beta_1, \beta_2, ...\beta_k$ are the regression coefficients of the predictors $X_1, X_2, ..., X_k$, respectively.

Second, time-to-event (survival) analysis methodology according to the Cox Proportional Hazard Regression was used:

$$h_i(t \mid \mathbf{X}) = h_0(t)\exp(\beta_1 X_1 + \beta_2 X_2 + ... + \beta_k X_k). \quad (2)$$

where $h_i(t \mid \mathbf{X})$ is the resultant hazard at time t (months); $h_0(t)$ is baseline hazard; and $\beta_1, \beta_2, ...\beta_k$ are exponentiated regression coefficients of the predictors $X_1, X_2, ..., X_k$, respectively. A failure variable is generated and takes a binary form for completion and non-completion:

$$Failure \text{ var } iable = \begin{cases} 1 & if\ completed\ at\ time\ t_i,\ \forall t_i \text{ int } eger: t_i > 0 \\ 0 & Otherwise \end{cases}$$

Third, with a binary logistic regression, the outcome variable was modeled using categorical outcomes. The likelihood of completion of doctoral studies at a particular point in time is given by the formula:

$$\ln\left[\frac{P_i}{1-P_i}\right] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_k X_k \quad (3)$$

where P_i is the probability that a candidate has completed a doctorate, and $\beta_1, \beta_2, ...\beta_k$ are the coefficients of the predictors $X_1, X_2, ..., X_k$, respectively.

Fourth, the outcome variable (Y) was modeled using categorical outcomes following a Multinomial Logistic Regression; that is, with more than two outcomes. For example, at a particular point in time, three outcomes may be evaluated—completed, still enrolled, and withdrawn. The coding of items is:

$$Enrolment\ \ time(Y) = \begin{cases} 1 & if\ completed \\ 2 & if\ still\ enrolled \\ 3 & if\ withdrawn \end{cases}$$

Thus, given the independent variables, the likelihood that a candidate completed a doctorate rather than having withdrawn is expressed by the formula:

$$\ln\left[\frac{P(Y=1 \mid \mathbf{X})}{P(Y=3 \mid \mathbf{X})}\right] = \beta_{10} + \beta_{11} X_1 + \beta_{12} X_2 + ... + \beta_{1k}\ X_k \quad (4)$$

and the likelihood that a candidate is still enrolled rather than having withdrawn is:

$$\ln\left[\frac{P(Y=2\,|\,\mathbf{X})}{P(Y=3\,|\,\mathbf{X})}\right]=\beta_{20}+\beta_{21}X_{\mathbf{1}}+\beta_{22}X_{\mathbf{2}}+\ldots+\beta_{2k}\,X_{\mathbf{k}} \tag{5}$$

where $P(Y=1\,|\,\mathbf{X})$ represents the probability that a candidate has completed a doctorate at a particular time; $P(Y=2\,|\,\mathbf{X})$ represents the probability that a candidate is still enrolled; and $P(Y=3\,|\,\mathbf{X})$ represents the probability that a candidate has withdrawn (base category). $\beta_1,\beta_2,\ldots\beta_k$ are coefficients of the predictors $X_{\mathbf{1}},X_{\mathbf{2}},\ldots,X_{\mathbf{k}}$, respectively.

3.0 RESULTS

The individuals examined in this study were full-time students at Makerere University. They were predominantly Ugandan (94.2%), registered in thesis-based studies (81.4%), male (76.6%), and married (90.9%). The majority (63.9%) had earned their bachelor's and/or master's degrees at Makerere University. Their median age when they began doctoral studies was 37 years (ranging from 24 to 61). Close to two-thirds (63%) were in the 2003 to 2005 enrolment cohorts.

Table 1 presents results of analysis using the methodologies assessed in this study.

Table 1: Completion and non-completion estimates of doctoral studies, by methodological approach

Variable	Cox[a]	MLR[b]	Binomial	Multinomial	
			Completion[c]	Completion[d]	Enrolled[e]
Age					
41 or older†	…	…	…	…	…
31 to 40	0.69**	-8.93	1.26*	1.35**	0.15
30 or younger	1.38**	-12.57*	2.04**	2.02*	-0.01
Doctoral registration					
Research†	…	…	…	…	…
Coursework and research	-0.36	-1.70	-0.43	-0.40	0.05
Year of enrolment					
2000 to 2002†	…	…	…	…	…
2003 to 2005	-0.66**	-12.52**	-0.54	-0.75	-0.33
Marital status					
Single†	…	…	…	…	…
Married	…	0.41	-0.37	-0.55	-0.20
Prior schooling					
Makerere University†	…	…	…	…	…
International university	…	-1.22	-0.19	-0.20	-0.01
Nationality					
Ugandan†	…	…	…	…	…
Non-Ugandan	1.06**	-8.87	1.63*	1.48*	-0.30
Sex					
Male†	…	…	…	…	…
Female	-0.37	3.33	-0.37	-0.24	0.18
Financial assistance					
No assistance†	…	…	…	…	…
Assistance held	-0.05	4.64	0.03	0.87	1.21**
Broad field of study					
Science	…	…	…	…	…
Arts	-0.67**	6.09	-0.69	-1.03*	-0.62*

Note: † *represents reference category*; ** $p < 0.01$, * $p < 0.05$; … *not applicable*

[a] Cox regression of completion time (N = 218); the variables considered satisfied a selection criterion – all predictors with probability value less than 0.25 in the Log-rank test at the bivariate stage.

[b] OLS Multiple Linear Regression with assumed normality of completion time (N = 89)

[c] Likelihood of completion, five years after initial enrolment (N = 284)

[d] Likelihood of completion rather than withdrawal, five years after initial enrolment (N = 284)

[e] Likelihood of extended candidature rather than withdrawal, five years after initial enrolment (N =284)

3.1 Regression diagnostics

Without verifying that the data meet the assumptions underlying the methodology adopted, the results may be misleading. Thus, the following diagnostics were performed for the various approaches presented in Table 1.

In a recent study employing a Cox-proportional hazard model to examine completion time dynamics for doctoral studies at Makerere University, Wamala et al. (2011) presented four diagnostic tests: the global and detailed proportionality assumption, the overall model fit evaluated using Cox-Snell residual (Cox and Snell 1968), specification errors link function and disproportionate effect of outliers and influential cases (Collet 2003). The assumptions for the Cox methodology were satisfied.

In an analysis using a Multinomial Logistic Regression (MNR) model with "withdrawal" as the base category, Wamala et al. (2011) performed the following diagnostic tests: sample size requirements of MLR (Hosmer and Lemeshow 2000), goodness-of-fit based on Pearson and Deviance Statistics, classification accuracy of model, as well as effects of outliers and influential cases using standardized residuals and Cook's distance. The assumptions of the MNR were satisfied.

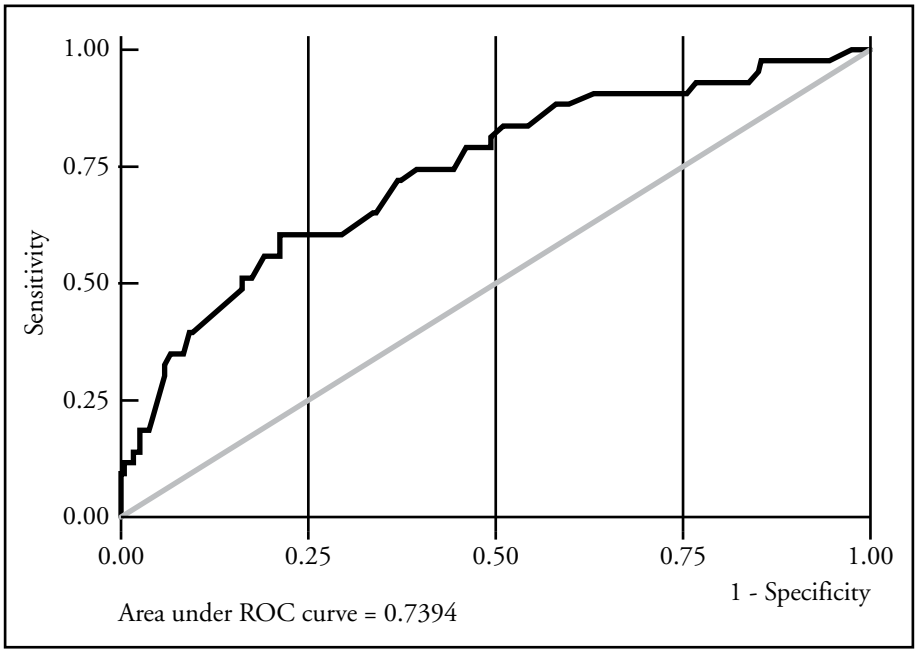
In the binary logistic regression analysis, the following diagnostic tests were performed: specification errors, classification accuracy, and chi-square goodness-of-fit (Hosmer and Lemeshow 2000). Results of specification errors in Table 2 show that the model was well specified as predicted by the hat-statistic ($p < 0.05$); the hat-square statistic shows that no additional variables were significant ($p > 0.05$). In other words, results of the specification test show that the logit transformation is a correct functional form for the outcome variable. Figure 1, the Receiver Operating Characteristic (ROC) curve, shows that logistic regression has acceptable discriminatory power (AUC = 0.739). The Hosmer and Lemeshow Chi-square test shows that the model is a good fit ($\chi^2 = 88.1,\ p = 0.8158$), and 86% of the observations were correctly classified. Thus, the results and conclusions made were unquestionable.

Table 2: Specification Error of Link Function

Link Function	Coeff.	Std. Err	p-value
Logit Function			
_hat	1.836	0.576	0.001
_hatsq	0.240	0.146	0.101

Note: Results relate to the logistic model in Table 1.

Figure 1: Receiver Operating Characteristic Curve following a logistic model in Table 1



Following the application of the OLS in a multiple linear regression, the normality assumption of residuals necessary for the validity of hypothesis tests was supported adopting the Shapiro-Wilk W test ($W = 0.98$, $p = 0.308$)). Similarly, results of the Breusch-Pagan/Cook-Weisberg test for homogeneity of variance of the residuals support the homoscedasticity assumption ($x^2 = 1.87$, $p = 0.171$). The results of the specification error of link function presented in Table 3 reveal that the model is not well specified as predicted by the hat statistic ($p > 0.05$). This could imply any of the following: i) the identity function is not a correct specification for the completion time of studies—the outcome variable; ii) the linear combination of the predictors is not sufficient; and iii) the identity function in MLR is not a linear combination of the predictors—candidate, candidature and institutional factors.

Table 3: Specification error of link function

Model	Coefficient	Standard error	p-value
Normal/Identity			
_hat	-0.717	2.140	0.738
_hatsq	0.014	0.017	0.423

Note: Results relate to the MLR model in Table 1

3.2 Summary

In the results of a Cox regression that excluded candidates who recorded no load on their doctoral candidature (N = 69), significant associations with the hazard of completion emerged for age at commencement, nationality, broad discipline, and enrolment cohort ($p < 0.05$). Specifically, completion rates were higher for candidates at younger ages of commencement, international students, those in science disciplines, and in the 2000 to 2002 enrolment cohorts.

In a Multinomial Logistic Regression with "withdrawal" as the base category, significant associations with the likelihood of completion, rather than withdrawal, five years after initial enrolment were noted for age at commencement, nationality, discipline, and financial assistance ($p < 0.05$). Doctoral completion was more likely among younger candidates, international students, and those in science-related disciplines. The likelihood of extended candidature beyond five years, rather than withdrawal, was significantly associated with the receipt of financial assistance and enrolment in science disciplines.

In the results of an OLS Multiple Linear Regression with assumed normality of completion time, and modeled using doctoral candidates who had completed by the time of the study (N = 89), significant associations emerged with age at commencement and enrolment cohort ($p < 0.05$). Specifically, completion time was shorter for candidates who were younger than 30 when they began their studies and those in the 2000 to 2002 enrolment cohorts.

4.0 DISCUSSION AND CONCLUSIONS

The various methodologies presented have implications for data requirements, precision, and the significance of associations. Time-to-event analysis and the binomial and multinomial logistic methodologies require both com-

pletion and non-completion data, but the OLS linear regression requires only completion data. Consequently, a number of differences in statistically significant associations emerged between results based on methods that require data only on students who had completed a doctorate (N=89) and results based on methods that also require enrolment data (N = 195). Moreover, the statistical significance of the associations observed using methodologies with unsatisfied diagnostic tests is debatable. In particular, the OLS multiple linear regression pertains to only 89 of the 295 doctoral students who were enrolled across disciplines at Makerere from 2000 to 2005. The low output of doctorates at the University (Mugimu et al 2009; Wamala et al 2011), and the low enrolment in doctoral studies are typical of the situation in many countries.

Although normality and homoscedasticity assumptions of the OLS linear regression were supported in the diagnostic tests, the differences in data requirements compared with the Cox regression resulted in variations in the statistical significance of associations. Specifically, associations with discipline and nationality that were significant in the Cox regression were not significant when OLS linear regression was used. With regard to the superiority of Cox regression over OLS for analyzing survival data, Cleves et al. (2010) noted: "Survival analysis is concerned with nothing more than making a substitution for the normality assumption characterized by OLS with something more appropriate for the problem at hand." Although OLS would be a reasonable model to use in some instances, it may not be appropriate for analyzing the dynamics of doctoral completion time in institutions with low enrolment and completion numbers, which is the case for many African universities.

Analysis based on binary logistic regression reveals a number of associations, but compared with the Multinomial Logistic Regression, it provides a less detailed picture of the non-completion dynamics of doctoral studies. Modeling completion dynamics using a binary outcome (completed versus not completed) in a logistic regression ignores the influences of financial assistance and discipline area on extended candidature, which emerged in the analysis using the Multinomial Logistic Regression. That is, analyzing the likelihood of completion of doctoral studies using a binary outcome fails to account for potential predictors of extended candidature rather than withdrawal.

The findings of the present study suggest that evaluating the completion dynamics of doctoral candidature with more than two outcomes is the preferable approach, because it offers the ability to discriminate between

extended candidature and attrition. In light of these results, Cox-PH regression and multinomial logistic regression are the most satisfactory methodologies for investigating the completion and non-completion dynamics of doctoral studies, particularly for institutions where graduate enrolment and completion are low.

REFERENCES

Bourke, S., A. Holbrook, and T. Lovat (2004), *Attrition, Completion and Completion Time of Ph.D Candidates*, The AARE Annual Conference, Adelaide, Australia.

Cleves, M., W. Gould, R. Gutierrez, and Y.V. Marchenko (2010), *An Introduction to Survival Analysis Using Stata, Third Edition*. College Station, Texas: StataCorp LP.

Collett, D. (2003), *Modelling Survival Data in Medical Research, Second Edition*. London: Chapman and Hall/CRC.

Cox, D. R. (1972), "Regression Models and Life Tables (with Discussion)," *Journal of the Royal Statistical Society, Series B (Methodological),* vol. 34, no. 2, pp. 187-220.

Cox, D.R. and D. Oakes (1984), *Analysis of Survival Data*. London: Chapman and Hall.

Cox, D.R. and E.J. Snell (1968), "A General Definition of Residuals (with Discussion)," *Journal of the Royal Statistical Society, Series B (Methodological),* vol. 34, no. 2, pp. 248-275.

Hilbe, Joseph M. (2009), *Logistic Regression Models*. London: Chapman and Hall/CRC Press.

Hosmer, D.W. and S. Lemeshow (2000), *Applied Logistic Regression, Second Edition*. New York: Chichester, Wiley.

Mugimu C.B., M.G. Nakabugo, and R.E. Katunguka (2009), *Exploring Factors Affecting Staff Research Output and Completion Rates of Graduate Students in Makerere University*, Status Report as of 21 November 2010. Kampala: Makerere University.

Osborne, J. and E. Waters (2002). "Four Assumptions of Multiple Regressions that Researchers Should Always Test." *Practical Assessment, Research and Evaluation*, vol. 8, no. 2.

Wamala, R., J. Oonyu, and B. Ocaya (2011), "Likelihood of Completion and Extended Candidature of a Ph.D. A Five-year Analysis of Studies at Makerere University," *Proceedings of the 8th PhD Seminar Series at Makerere University. Deputy Vice-chancellor (AA).* Retrieved from http://mak.ac.ug/documents/8thPhDDissemAbstractRobertWamala.pdf.

Wamala, R., J. Oonyu, and B. Ocaya (2011), "Completion Time Dynamics of Doctoral Studies at Makerere University: A Hazard Model Evaluation," *Journal of International Education Research (JIER),* vol. 7, no. 3, pp. 49-58.

5. Technical efficiency in Uganda's primary education system: Panel data evidence

Joseph Muvawala[1] and Eria Hisali[2]

Abstract
This paper estimates the technical efficiency and its determinants for Uganda's primary education system using parametric models based on a panel data set on performance index and educational inputs of various categories of primary schools for the 2001-to-2008 period. Generally, all primary schools in Uganda are technically inefficient, but private and urban schools are relatively more so than government-aided and rural schools. Hence, it is feasible to improve learning outcomes without increasing spending on primary education for private schools, where a 56% improvement might be expected. For government-aided and rural schools, efficiency gains on the basis of current funding will result in a mere 1% improvement in learning outcomes. Improvements in learning outcomes for government-aided schools will require increased resources.

Key words: *panel data, parametric, primary schools, stochastic frontier, technical efficiency*

Efficacité technique du système éducatif primaire en Ouganda : indications des données de panel

Résumé
L'article évalue l'efficacité technique du système éducatif primaire ougandais et des facteurs déterminants de cette efficacité à l'aide de modèles paramétriques sur la base d'un ensemble de données de panel relatives à l'indice de la performance et aux intrants éducatifs dans diverses catégories d'établissements d'enseignement primaire, de 2001 à 2008. Si, de manière générale, tous les établissements d'enseignement primaire en Ouganda sont inefficaces du point de vue technique, les établissements privés et urbains le sont relativement plus que ceux qui bénéficient d'un financement public ou sont situés en zone rurale. Il est donc possible d'améliorer les résultats d'apprentissage sans pour autant augmenter les dépenses de l'enseignement primaire privé, qui pourrait enregistrer une amélioration de 56 %. En ce qui concerne les établissements ruraux et bénéficiant de fonds publics, les gains en matière d'efficacité entraîneront une amélioration de 1 % seulement des résultats d'apprentissage, s'i l'on s'en tient à l'enveloppe actuelle. L'amélioration des résultats d'apprentissage dans les établissements publics nécessitera des ressources accrues.

1 Joseph Muvawala is a Chief Country Economist at the African Development Bank Group, email: j.muvawala@afdb.org

2 Eria Hisali is with the School of Economics, Makerere University, P.O. Box 7062 Kampala, Uganda, email: mhisali@yahoo.co.uk.

Mots clés : *Données de panel, paramétrique, établissements d'enseignement primaire, frontière stochastique, efficacité technique*

1.0 INTRODUCTION

The last decade has witnessed increased resource allocation to the education sector in Uganda. From 1996 to 2007, the allocation averaged 20% of total government spending, placing Uganda's education expenditures 6 percentage-points above the sub-Sahara African average. About 60% of the country's total education expenditures have been devoted to the primary school level. Primary education requirements are projected to grow fourfold over the current Education Sector Strategic Plan (ESSP) period (GoU 2006). However, the primary education budget is projected to fall by about 50% between 2009 and 2015 (GoU 2006), as a result of competing demands from the secondary school and other levels of education. Moreover, resource constraints are likely to worsen because of high population growth. These trends justify an examination of the efficiency with which allocated resources are transformed into outcomes in Uganda's primary education subsector.

Generally, an efficient production system yields higher output for a given set of inputs, or conversely, uses fewer inputs to yield a given output (Kumbhaker and Lovell 2000). A number of researchers have studied the relationship between resource allocation and the degree to which they contribute to optimal outcomes (Kirjavainen and Loikkanen 1998; Grosskopf and Valdmanis 1987; Evans et al 2000; Ruggiero 1998). These studies reveal considerable inefficiency in the provision of education. Grosskopf et al (1997), for instance, suggest that education spending in most countries could be reduced by up to 30%, yet still achieve the same outcomes, if the schools were operated efficiently.

This study analyzes the relationship between resource allocation and the observed outcomes in Uganda's primary education subsector. This is especially important because of the heavy public sector involvement in the provision of primary education, which may create incentives for schools operate as semi-monopolies.

This paper is organized as follows: Section 2 provides an anecdotal analysis of inefficiencies in primary education provision in Uganda; Section 3 explains the methods used in estimating technical efficiency of primary schools; Section 4 presents the results; and Section 5 discusses the empirical results and concludes the paper.

2.0 PRIMARY EDUCATION DELIVERY AND INTERNAL INEFFICIENCY IN UGANDA: AN ANECDOTAL ANALYSIS

In January 1997, the Ugandan government formalized its commitment to primary education with implementation of Universal Primary Education as part of a wider framework for education development under the Education Strategic Investment Plan (ESIP) 1998-2003. The main priorities of the ESIP included expanding access and equity in education, improving quality delivery of education services, and capacity development (Hallak et al 2000). Under the UPE program government and other stakeholders seek to provide the minimum facilities and resources needed for completion of primary school education.

Since the introduction of the UPE program, progress in education has been remarkable. For example, the net enrolment ratio has risen to more than 90%. But despite this progress, only a few children complete the primary cycle of schooling and even fewer attain the minimum competencies needed to become literate and numerate. This situation raises questions about efficiency.

Six probable sources of inefficiency affect primary education in Uganda: 1) leakage of resources between the central government and the school, through ghost teachers, misuse of UPE and grants to district governments; 2) leakage of resources within the school, mainly attributable to high rates of pupil, teacher, and head teacher absenteeism; 3) deployment of teachers both across and within districts; 4) allocation of resources within government schools, where class sizes are largest in the early grades and smallest in the later grades; 5) use of education policy as a means of accessing donor financing, and the speed at which the UPE policy was introduced; and 6) inherent inefficiencies in the decentralization of primary education.

With regard to leakage within the system, based on expenditure and personnel audits and evaluations, the estimated leakages of recurrent expenditures between the Ministry of Finance, Planning and Economic Development and the schools is UGX 16 billion, or 6% of total budgeted recurrent primary education expenditures (Annual Budget Performance Report, 2005/06). The single largest source of government-to-school leakage is the UPE grant, estimated at 16% of total UPE grants, or UGX 5 billion (Winkler 2007).

In addition to leakage, a two-month delay separated the release of UPE grants by the central government and their arrival at schools. The cost of this delay is not always included in surveys undertaken by MoES. Although questionable expenditures have not been quantified at the district level, a

number of problems adversely affect the use of resources and constitute "questionable expenditures." These include delays and uncertainty in funding, which make it difficult to plan and spend efficiently; inadequate supervision of construction projects; delays in receiving and damage to textbooks; and teachers' and students' failure to use textbooks in the classroom.

The implications of these losses are important. Given the very low ratio of books to students (about 1:3), loss of and failure to use textbooks may have considerable consequences, such as grade repetition and dropout. This affects the cost to government of enrolling primary students. For instance, the unit cost of an enrolled student in Uganda is UGX 50,534. A student who successfully completes primary school without repeating any grades would cost UGX 353,738 (Winkler 2007). However, the average cost of a primary school graduate, including repetition and dropout, is UGX 923,833, or 2.6 times what it would be if there was no grade repetition or dropout.

In addition, an examination of the data reveals low completion rates. This is mainly the result of high drop-out rates in P 1 and from P 5 to P 7. Grade repetition rates range from 12% to 15%, with the highest in P7. Drop-out rates in lower grades are generally below repetition rates, suggesting that non-compliance with automatic promotion at this level has little impact on the completion rate. However, from P5, drop-out rates rise substantially above repetition rates, indicating that some pupils who repeat grades may subsequently drop out. Rising repetition rates have a number of implications. One implication has been overcrowding, which has raised costs. Therefore, grade repetition is key to improving overall efficiency and attaining equity.

The target of actions taken through the UPE program was a 54% primary completion rate. However, results from UNEB show a completion rate of 49.4% in 2007, once again raising the question of education efficiency. The persistently high drop-out rates and low completion rates are evidence that the resources committed to primary education are not resulting in the expected outcomes.

Another concern is the percentage of the national wage bill devoted to primary education. The current national mean wage bill is UGX 39,259 per student, but this varies across districts and schools. For example, the mean wage bill is UGX 50,526 per student for the top-spending quintile of schools, almost double the mean of UGX 26,585 for the bottom-spending quintile (Winkler 2007). The question is whether these variations are a result of explicit MoES policy or of policies and practices that have nothing to do with effective delivery of education.

The inefficiencies can also be attributed to the rapid implementation of the UPE program, which, in the short run, meant larger class sizes, a higher percentage of unqualified teachers, and fewer resources for the delivery of education services. In other words, the UPE program itself may be a cause of the inefficiencies the primary education system, mainly as a result of large numbers and inadequate financing.

Another issue for Ugandan education policy is the trend toward liberalization and decentralization. In a case study of Uganda's ESIP, Teskey and Hooper (1999) observed that the 1995 Constitution provides for political devolution and administrative decentralization of most public services, including primary education. Hence, decentralization is important to the ESIP, which must take into account a fundamental shift of power and responsibility from central to local government. The central government is now responsible for the "policy formulation and planning, inspection and management" of national programs, but districts have final authority over "personnel matter, district plans, budgets and tendering" (Hallack et al 2000). Thus, restructuring of the primary education system has had major implications for policy formulation and for efficient and effective use of resources.

In addition to local and central governments, international agencies have committed large amounts of aid to Ugandan education. Such aid does not come without the donors influencing policy formulation. For instance, according to a press release from the IMF on February 8, 2000, "enhanced HIPC assistance would be provided as soon as Uganda finalized a poverty reduction strategy paper—in a participatory process with civil society—with broad endorsement by the Boards of the World Bank and IMF."

Furthermore, it is probable that Ugandan decision-makers formulate policy with the intention of attracting aid, but without being cognizant of the socio-economic characteristics of Ugandans. These characteristics, however, have been among the principal causes of inefficiency in the system. Havelock and Huberman (2007) concluded that inadequate planning and failure to make provision for the systems into which the innovation is being introduced contributed to internal inefficiencies in the education sector.

In consideration of these shortcomings, the national government and other stakeholders have taken steps to improve the UPE program. Efforts have been made to monitor administration, and additional funding has been provided to deal with limitations associated with the lack of resources.

3.0 METHODS

The parametric technique of the Stochastic Frontier Analysis (SFA) introduced by Aigner Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977) is employed to measure technical efficiency of primary schools in Uganda.

A parametric approach was chosen for three reasons. First, the production process, especially in education, is characterized by stochastic elements (Millimet et al 2004; Pascoe and Herrero 2001). Second, data envelopment methodology requires that the number of decision-making units evaluated must be less than the total number of inputs and outputs (Thomas 2000). However, the sample for the present study (primary schools in various districts in Uganda) is larger than what can be appropriately handled by the DEA, as the DMUs (primary schools) exceed the total number of inputs and outputs in the primary school production function specified. Third, the stochastic approach makes a marginal effect analysis possible (Bravo-Ureta and Pinheiro 1993; Coelli 1995).

3.1 Analytical framework and model specification

The education production function is used to explain how institutions generate outcomes from a flow of inputs (Clive 2000). The specification relates education outcomes (students' achievement measured by the pass rate) to education inputs plus a composite error term for both public and private schools. The composite error term consists of a term to capture a random element and another to capture technical inefficiency. Each school is considered to be a decision-making unit that operates under the assumption of variable returns to scale. Therefore, a primary school stochastic frontier model is formulated within the generalized production framework of Zellner and Revankar (1969) and Zellner and Ryu (1998). This framework is convenient for parsimonious modeling of a production function with variable returns to scale (William et al 2005). An alternative is made to introduce the stochastic inefficiency term and the stochastic error in the primary school production relationship. This is because the initial production function is linear in form, and thus, need not be solved for the log of output before the stochastic terms are added.

As adopted by Pascoe et al. (2003), a general stochastic primary school production frontier model can be given by:

$$Y_j = f(\ln X) + v_j - u_j \qquad (1)$$

where Y_j is the output produced by school j measured by the pass rate of school j; X is a vector of factor inputs; v_j is the stochastic error term; and is the estimate of the technical inefficiency of school j. Both v_j and u_j are assumed to be independently and identically distributed (iid), with variance δ_v^2 and δ_u^2, respectively. The empirical primary school production frontier is specified and identified in the form of a typical Battese and Coelli (1992) model as follows:

$$Y_{it} = X'_{it}\beta' + z \tag{2}$$

Where $z = v_j - u_j$;

$\beta' = (\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_6, \beta_7, \beta_8, \beta_9)$;
$X' = (XTR, NTRB, NCR, TH, SR, SR, E, HE)$ such that:

XTR is the number of teachers.
NTB is the number of textbooks.
NCR is the number of classrooms.
TH is the number of teachers' houses per school.
SF is supervisor frequency.
HE is head teacher experience.
Y is the performance index of candidates from a given primary school who sit the Primary Leaving Examination (PLE).

The dependent variable (performance index[3] of candidates at primary level P7) is preferred because education is a value-added product (that is, theoretically, every year of school increases the knowledge level of pupils). Education outcomes can be measured using the knowledge test and the competency test. The knowledge test gauges knowledge, whereas the competency test determines mastery of certain competencies such as numeracy and literacy. Competency tests have been administered by the Uganda National Examinations Board (UNEB), but these have been diagnostic rather than continuous in that different respondents are tested each time. The only continuous dataset available is the knowledge test at P7, compiled annually by the UNEB. This study used a school-level panel on the performance of government and private primary schools for the 2001-to-2008 period.

3 To calculate PLE Performance Index , candidates in each grade are weighted such that passing with the best grade carries high weight, and failure is given zero weight . The weights are summed and expressed as a ratio of the expected maximum weight, which is estimated by multiplying the highest weight by the number of candidates who sat exams.

The SFA technique was used to obtain maximum-likelihood estimates of the parameters of the stochastic frontiers of education production functions of a sample of rural, urban, private, government-aided and district schools to measure their technical efficiency.

In estimating the frontiers, the study used pooled panel data. The inefficiency term was specified as partially normal, while the symmetric idiosyncratic term was specified as absolutely normal. Pooled panel data were used because preliminary analyses revealed that using unpooled panel observations on private schools and urban schools yielded infinite iterations and failed to achieve convergence.

The SFA model was specified in linear-log form. Hence, the data of all independent variables were in log terms, while the dependent variable is an index. The estimate of the inefficiency term is taken as a measure of the percentage by which the particular observation (the school and/or the district) fails to achieve the frontier, that is, the ideal performance index (Green 2008).

4.0 RESULTS

4.1 Summary statistics of the performance index

A statistical summary of the performance index data for government-aided and private school is presented in Appendix Table 1. The low overall mean performance index (44%) is strongly influenced by government-aided schools, which constitute the overwhelming majority (97.3%) of schools. The mean performance index of the small number of private schools is 53%. However, the coefficient of kurtosis of the distribution of the performance index for private schools is comparable to that of government-aided schools, and it exhibits a low peak in the distribution.

4.2 Ownership: Government-aided versus private schools

The models for government-aided and private schools indicate non-zero values of the estimated percentage standard deviations of the inefficiency error. This suggests that neither type of school operates along their respective frontiers. That is, they do not achieve their expected ideal performance rates, and thus, exhibit technical inefficiency. As well, the percentage standard deviation (56%) by which a given private school fails to achieve the frontier is much greater than the percentage standard deviation (0.32%) by which a given government-aided school fails to achieve the frontier.

These results imply that government-aided schools make use of inputs with more technical efficiency than do private schools. Thus, private schools seem to be more technically inefficient[4] than government-aided schools.

As well, unlike private schools, all the estimated partial elasticities for government-aided schools were significant at the 5% test level. This could indicate that the determinants of technical efficiency included in the frontier specification for government-aided schools are different from the determinants of technical efficiency for private schools (Appendix Table 2).

4.3 Location: Rural versus urban

Frontier estimates for rural and urban schools are similar to those of government-aided and private schools, respectively, reflecting the fact that most government-aided schools are in rural areas, and most private schools are in urban areas. The results[5] indicate that the standard percentage of deviation by which a given urban school fails to attain the frontier is 52%, compared with 0.25% for a given rural school. The implication is that both rural[6] and urban schools are inefficient (Appendix Table 3).

The frontier output showed that all the estimated partial elasticities for rural and urban schools were significant and insignificant, respectively, at 5%. This may indicate that the determinants of technical efficiency included in the frontier specification for rural schools could be much different from the determinants of technical efficiency for urban schools.

4.4 Administrative unit controls: Districts

Measurement of technical efficiency for districts was deemed crucial to avoid over-generalization and to account for the fact that the delivery of primary education in Uganda is a function of district authorities. The frontier esti-

4 The Likelihood Ratio (LR) test rejects the hypothesis that there is no technical inefficiency component in the model for private schools and fails to reject (with maximum probability) the hypothesis that there is no technical inefficiency component in the model for government-aided schools.

5 The Likelihood Ratio (LR) test rejects the hypothesis that there is no technical inefficiency component in the model for urban schools and fails to reject (with maximum probability) the hypothesis that there is no technical inefficiency component in the model for rural schools.

6 The estimated total errors are smaller for rural (22.7%) than urban schools (27.1%). The frontier estimates also show that the estimated percentage ratio of the standard deviation of the inefficiency component to the standard deviation of the idiosyncratic component (λ) is far greater for urban than rural schools.

mate for 52 districts[7] countrywide indicates that all districts are technically inefficient, with the level of inefficiency ranging from 21.8% off the frontier (Hoima district) to 0.1% (Iganga) (Appendix Table 4).

The results show that, generally, all schools and districts are inefficient, and that private schools are relatively more inefficient than government-aided schools. These findings are consistent with recent surveys indicating that the cost of producing a primary graduate, without considering learning achievement, is Shs. 492 per student. This is more than twice the Shs. 189 that would be needed to produce a primary graduate if Uganda's education system was perfectly efficient. Furthermore, the annual unit cost of a graduate achieving a specific minimum knowledge is Shs. 2,424, almost thirteen times the efficient standard for Uganda.

4.5 Determinants of technical efficiency

A further analysis examined determinants of technical efficiency, using ownership and location as controls. The residualisation[8] methodology was used to determine which independent variables significantly enter into the residual model. Variables with coefficients that were statistically significant in the residual model were deemed irrelevant in the determination of technical efficiency of a particular school category. Appendix Table 5 indicates the results of the residualisation process for government-aided and private schools.

Textbooks, teachers and desks are significant at 5% test level in the residual model for government-aided schools, and therefore, do not enter into the inefficiency error term. Thus, textbooks, teachers and desks are not associated with technical inefficiency or efficiency for government-aided schools. On the other hand, teacher houses, classroom space and inspection are statistically insignificant,[9] and therefore, enter into the inefficiency error term,

7 The variables used for each district are the same, and the same specification of the stochastic frontier as was used under urban and rural schools and government and private schools was considered. The same distribution assumptions of the two error terms were considered and pooled panel data were used.

8 Procedure: Technical efficiency models were run for different school categories. Technical efficiency parameters were estimated and used to generate the residuals. The residuals were regressed on the independent variables to determine which independent variables significantly enter into the residual model.

9 The F-statistic reported indicates that on the whole, the included factors are insignificant in residual model for Government aided schools and this further confirms they enter into the inefficiency error term.

implying that they are associated with technical efficiency or inefficiency (Appendix Table 5).

Teacher's houses, classrooms, textbooks, inspection, teachers and desks are significant at 5% test level in the residual model for private schools, and therefore, do not enter the inefficiency error term. This implies that none of the factors included in the frontier are associated with inefficiency in private schools. This result is further supported by the F-statistic, which indicates that, on the whole, the factors included are significant in the residual model for private schools, confirming that they do not determine efficiency.

These results clearly demonstrate that the determinants of technical efficiency differ for private and government-aided schools. Based on this finding, government authorities cannot adopt one-size-fits-all policy interventions to reduce inefficiencies in education. Individual factors like teachers' houses, classrooms, inspection and desks are associated with technical efficiency for government-aided schools, but not for private schools.

5.0 DISCUSSION AND CONCLUSIONS

The results of this study validate the hypothesis that technical inefficiency in education delivery exists for all categories of primary schools in Uganda. Urban and private schools are more technically inefficient than are rural and government-aided schools. Hence, it is possible to improve learning outcomes without increasing spending on primary education in private schools whose percentage deviation from their production frontier is 56%. The results for private school are consistent with Grosskopf et al (1997), who suggest that if schools were operated efficiently, education spending in most countries could be reduced by up to 30% and still achieve the same outcomes.

For government-aided and rural schools, it is not possible to significantly increase learning outcomes with the same resource allocation, because their percentage deviation from their production frontier is only 1%.

Hence, efficiency interventions introduced in the context of current resource allocations to primary education would result in a mere 1% improvement in learning outcomes. The message is that without resource increases, efficiency interventions alone will not improve learning outcomes in Uganda.

This analysis provides evidence that governments cannot increase learning outcome through mass access reforms without substantially increasing

funding to education. Moreover, at current levels of funding, even those efficiency interventions that are implemented are insufficient to achieve the learning outcomes agenda. In many mass access reform programs like UPE in Uganda and Tanzania, governments have not been able to provide funding commensurate with the increased enrolment stemming from high population growth and from the policy itself. In Uganda, for example, government spending amounts to less than $0.10 per child per day to support teaching and learning at the school level. This is clearly inadequate and will continue to impede effective teaching and improved learning outcomes.

But while the evidence shows an association between technical efficiency and learning outcomes, the association is not causal. It is not surprising that studies which apply simple ratio analysis to measure efficiency have concluded that urban and private schools are efficient because their average pass rate at the P7 level exceeds 50%. This conclusion is valid if the cost of achieving the over-50% pass rate is not taken into account. However, recent studies in Uganda have established that the average annual amount invested per student in urban/private schools is Shs. 426,789, which is 17 times that of rural/government-aided schools Shs. 24,936.

The findings raise questions about the sequencing of government interventions. For example, should governments make efficiency a top priority or should they focus on achieving learning outcomes and make efficiency a second-tier priority? In other words, does the cost of achieving a certain level of learning outcomes matter in the initial stages of mass access reforms like UPE? A number of studies on what determines learning outcomes have concluded that a passing culture has a positive and significant influence. Based on this, in the initial stages of a mass education program, the government should make improving learning outcomes the first priority, and efficiency, the second.

This study demonstrates that determinants of efficiency depend on the location and ownership of schools. This finding sends an important message to education policy-makers: expenditures on inputs influence the efficiency level of rural, but not urban schools. Policy-makers should, therefore, avoid one-size-fits-all interventions. While policy for government-aided and rural schools should emphasize expenditure inspection, classroom construction, textbooks and teachers' houses, policy for private schools should target the households of pupils. This is beyond the mandate of the education sector and calls for integrated planning by the government as a whole.

REFERENCES

Aigner, D.J., C.A.K. Lovell and P. Schmidt (1977), "Formulation and Estimation of Stochastic Frontier Production Functions," *Journal of Econometrics*, vol. 6, pp. 21-37.

Battese, G.E. and T.J. Coelli (1992), "Frontier Production Function, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India," *Journal of Productivity Analysis*, vol. 3, pp. 153-169.

Bravo-Ureta, B.E., and A.E. Pinheiro (1993), "Efficiency Analysis of Developing Country Agriculture: A Review of the Frontier Function Literature," *Agricultural and Resource Economics Review*, vol. 22, pp. 88-101.

Coelli, T. (1995), "Estimators and Hypothesis Tests for a Stochastic Frontier Function: A Monte Carlo Analysis," *Journal of Productivity Analysis*, vol. 6, pp. 247-268.

Evans, D.E., A. Tandon, C.J.L.Murray, et al. (2000), *The Comparative Efficiency of National Health Systems in Producing Health: An Analysis of 191 Countries*, Global Programme on Evidence for Health Policy Discussion Paper No. 29. Geneva: World Health Organization.

Grosskopf, S. and V. Valdmanis (1987), "Measuring Hospital Performance: A Non-Parametric Approach," *Journal of Health Economics*, vol. 6, no. 2, pp. 89-107.

Grosskopf, S., K.J. Hayes, L.L. Taylor, and W.L. Weber (1997), "Budget-constrained Frontier Measures of Fiscal Equality and Efficiency in Schooling," *Review Economics and Statistics*, vol.79, pp. 116-124.

Hanushek, E.A. (2002), "Publicly Provided Education," in A.J. Auerbach and M. Feldstein (eds.) *Handbook of Public Economics*. Amsterdam: Elsevier, pp. 2045-2141.

Hayami, Y. and V.W. Ruttan (1970), "Agricultural Productivity Differences Among Countries," *American Economic Review*, vol. 60, pp. 895-911.

Kirjavainen, T. and H.A. Loikkanen (1998). "Efficiency Differences of Finnish Senior Secondary Schools: An application of DEA and Tobit Analysis," *Economics of Education Review*, vol. 17, no. 4, pp. 377-394.

Kumbhakar, S.C. and C.A.K. Lovell (2000), *Stochastic Frontier Analysis*, Cambridge: Cambridge University Press.

Meeusen W., and J. van den Broeck (1977), "Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error," *International Economic Review*, vol. 18, pp. 435-444.

Pascoe, S., J.E. Kirkley, D. Greboval, and C.J. Morrison-Paul (2003), *Measuring and Assessing Capacity in Fisheries. Issues and Methods*, FAO Fisheries Technical Paper. No. 433/2, Rome: Food and Agriculture Organization.

Pascoe, S., J.L. Andersen, and J.W.de Wilde (2001), "The Impact of Management Regulation on the Technical Efficiency of Vessels in the Dutch Beam Trawl Fishery," *European Review of Agricultural Economics*, vol. 28, no. 2, pp. 187-206.

Ruggiero J. (1998), "A New Approach for Technical Efficiency Estimation in Multiple Output Production," *European Journal of Operational Research*, vol. 111, pp. 369-380.

Williams, T., M. Kirst, E. Haertel, et al. (2005), *Similar Students, Different Results: Why Do Some Schools Do Better? A Large-scale Survey of California Elementary Schools Serving Low-income Students*, Mountain View, California: EdSource.

Zellner, A. and N.S. Revankar (1969), "Generalized Production Functions," *Review of Economic Studies*, vol. 36, no. 106, pp. 241-250.

Zellner, A. and H. Ryu (1998), "Alternative Functional Forms for Production, Cost and Returns to Scale Functions," *Journal of Applied Econometrics*, vol. 13, pp. 101-127.

APPENDIX: MODEL RESULTS

Table 1. Performance index descriptive statistics

	All schools	Government-aided schools	Private schools
Number of observations	37,516	36,502	1,014
Mean	0.4471658	0.444587	0.5399952
Maximum	1	1	1
Minimum	0	0	0.0044643
Standard deviation	0.191532	0.1890551	0.4951767
Skewness	0.0762815	0.0571257	-.1375758

Source: author computations

Table 2. Technical efficiency estimates of government-aided and private Schools

	Government aided Schools		Private Schools	
Parameter	**Estimate**	**Standard Error**	**Estimate**	**Standard Error**
δu	0.0032386	.0962995	0.5608038	.0172087
δv	0.4736384	.0022036	4.66e-09	4.92e-07
$\delta 2$	0.2243439	.0021127	0.314501	.0193014
Λ	0.0068377	.0965635	1.20e+08	.0172087
	LR test of $\delta u=0$: Pr>chibar2=1.000		LR test of $\delta u=0$: Pr>chibar2= 0.000	
	Convergence achieved after 20 iterations		Convergence achieved after 34 iterations	

Source: author computations

Table 3. Technical efficiency estimates for rural and urban schools

	Rural schools		Urban schools	
Parameter	**Estimate**	**Standard error**	**Estimate**	**Standard error**
δu	0.0025782	0.0621834	0.5205847	0.0068881
δv	0.4762601	0.0023243	1.41e-09	1.19e-07
δ2	0.2268303	0.0022203	.2710084	0.0071716
Λ	0.0054135	0.0623489	3.70e+08	0.0068881
	LR test of δu=0: Pr>chibar2=1.000		LR test of δu=0: Pr>chibar2= 0.000	
	Convergence achieved after 21 iterations [10]		Convergence achieved after 36 iterations	

Source: author computations

Table 4. Technical efficiency estimates for district primary schools, by reverse order of inefficiency

		sigma_u	
S/n	**District**	**Estimate**	**Standard error**
1	Hoima	0.2184035	0.0237951
2	Bugiri	0.2026792	0.0335642
3	Kabalore	0.1932331	0.0293291
4	Wakiso	0.1859553	0.0227506
5	Katakwi	0.1790658	0.017204
6	Moroto	0.169529	0.0211958
7	Kumi	0.1658609	0.0115826
8	Kampala	0.1638588	0.0147741
9	Kasese	0.1627969	0.0143555
10	Pader	0.1526437	0.0471574
11	Bundibugyo	0.1523177	0.0341951
12	Ntungamo	0.1519698	0.0215283
13	Busia	0.1491074	0.0234781
14	Masindi	0.144346	0.0144527

10 The number of iterations to reach convergence for urban schools was almost twice the number needed to reach convergence for rural schools.

		sigma_u	
S/n	**District**	**Estimate**	**Standard error**
15	Kotido	0.1373249	0.0134086
16	Mbarara	0.1329552	0.0319553
17	Bushenyi	0.1309502	0.0156676
18	Kamwenge	0.1216501	0.0803263
19	Arua	0.1173438	0.0110651
20	Mayuge	0.113142	0.0710257
21	Rukungiri	0.0972764	0.0176954
22	Moyo	0.0774199	0.0877537
23	Lira	0.0574149	0.0973155
24	Luwero	0.0384884	0.2107887
25	Soroti	0.0072493	0.1395926
26	Nakasongola	0.006502	0.2169421
27	Jinja	0.0061448	0.1768772
28	Kitgum	0.0055819	0.1698236
29	Kibale	0.0051148	0.14883
30	Nebbi	0.0048293	0.1252742
31	Sembabule	0.0045685	0.1463209
32	Yumbe	0.0042813	0.1296088
33	Kisoro	0.0037297	0.1128824
34	Kapchorwa	0.0037028	0.1459768
35	Kiboga	0.0034673	0.1174921
36	Masaka	0.003398	0.1218017
37	Mubende	0.0028082	0.0908931
38	Rakai	0.0027087	0.0931505
39	Sironko	0.0027083	0.1170402
40	Gulu	0.0026264	0.1017922
41	Adjumani	0.0026242	0.1088244
42	Mpigi	0.0024449	0.1415568
43	Kyenjojo	0.0023322	0.1030255
44	Mukono	0.0022722	0.1067389
45	Tororo	0.0021912	0.0858374
46	Pallisa	0.002182	0.0848793
47	Kayunga	0.0021209	0.1011802
48	Mbale	0.0020003	0.0894958

		sigma_u	
S/n	**District**	**Estimate**	**Standard error**
49	Apac	0.0017747	0.0965903
50	Kabale	0.0014674	0.1052241
51	Kamuli	0.0012497	0.0598043
52	Iganga	0.0010649	0.0562925

Source: author computations

Table 5

Residual model estimates for government-aided and private schools

Government-aided schools				Private schools		
res.	**Coef.**	**Std. Err.**	**P>|t|**	**Coef.**	**Std. Err.**	**P>|t|**
Logth	.0007345	.0012665	0.562	-.0395869	.0012665	0.000
Logcr	-.0002351	.0031164	0.940	.0287474	.0031164	0.000
Logtx	-.004898	.0019391	0.012	.004317	.0019391	0.026
Loginsp	-.0033034	.0029411	0.261	.0658625	.0029411	0.000
Logtrs	.0073052	.0036777	0.047	-.0416009	.0036777	0.000
Logtdesk	-.0016269	.0013844	0.240	-.0032179	.0013844	0.020
Cons.	.0154818	.0131404	0.239	-.3582373	.0131404	0.000
Prob > F = 0.1399				Prob > F = 0.0000		

Source: author computations

6. Predicting Zimbabwe's annual rainfall using the Southern Oscillation Index: Weighted regression approach

Delson Chikobvu[1] and Retius Chifurira[2]

Abstract
In this paper, weighted linear regression is used to predict Zimbabwe's annual rainfall based on the Southern Oscillation Index value for September of the previous year. Results show that a negative Southern Oscillation Index for September is associated with below-normal annual rainfall in the coming year, and a positive Southern Oscillation Index for September, above-average annual rainfall.

Key words: *September Southern Oscillation Index, previous year, simple least square regression, variability.*

Prévoir les précipitations annuelles au Zimbabwe à l'aide de l'indice d'oscillation australe : le modèle de régression linéaire pondérée

Résumé
Dans le présent article, la régression linéaire pondérée est utilisée pour prédire les précipitations annuelles au Zimbabwe à partir de la valeur de l'indice d'oscillation australe du mois de septembre de l'année précédente. Les résultats montrent qu'un indice négatif en septembre est associé à des précipitations annuelles inférieures à la norme l'année suivante, et qu'un indice positif en septembre est associé à des précipitations annuelles au-dessus de la moyenne.

Mots clés : *Indice d'oscillation australe de septembre, année précédente, régression simple, méthode des moindres carrés, variabilité.*

1.0 INTRODUCTION

Zimbabwe, a land-locked country in Southern Africa, is situated between latitudes 15°30" and 22°30" just south of the equator and between longitudes 25° and 33°10" east of the Greenwich Meridian.

Agriculture, upon which more than 80% of the population depends, is the main driver of the economy. Thus, Zimbabwe is vulnerable to annual rainfall.

1 Dr D. Chikobvu is a lecturer in the Department of Mathematical Statistics and Actuarial Science, University of Free State, Box 339, Bloemfontein 9300, South Africa. Email: chikobvu@ufs.ac.za

2 Mr. R. Chifurira is a Phd student in the same Department.

Over 50% of Zimbabwe's gross domestic product (GDP) is derived from rain-fed agriculture (Jury 1996). The impact of unreliable rainfall is severe, because the country lacks the resources and technology to harness water during good rainfall seasons. The climatic challenges include droughts, floods, cyclones, and more recently, high seasonal rainfall variability (Washington and Preston 2006). Droughts are frequent and severe.

During the 1991 to 1992 rainy season, Zimbabwe experienced the worst drought in living memory (Zimbabwe Central Statistical Office Report 1994), and in 2000, the country was ravaged by cyclone Eliñe. From 2001 to 2003, Zimbabwe had rain only in the first half of the rainy season; a dry spell in the second half resulted in severe drought in some parts of the country. From 2004 to 2008, rainfall was average in the north of the country, but other areas received very little or no rain. In the 2009-2010, rainfall was below average in the first half of the rainy season and above average in the second half (Zimbabwe Central Statistical Office Report 2010). These sharp fluctuations make the prediction of rainfall for a given year a matter of paramount importance. For agriculture-dominated economies like Zimbabwe's, it is imperative that a simple tool be developed to predict rainfall patterns as early and as accurately as possible. Reliable predictions assist farmers with planning for each season, for instance, in terms of crops suitable for the expected amount of rain.

This study proposes a model of the relationship between the Southern Oscillation Index (SOI), a climatic determinant, and Zimbabwe's annual rainfall.

1.1 Zimbabwe's rainfall

Rainfall in Zimbabwe is associated with the behaviour of the Intertropical Convergence Zones (ITCZs), whose oscillations are influenced by changing pressure patterns to the north and south of the country (Buckle 1996).

Zimbabwe lies in the South West Indian Ocean zone, which is often affected by tropical cyclones. Tropical cyclones are low pressure systems that, in the Southern hemisphere, have well-defined clockwise wind circulations spiralling toward the centre where the winds are strongest and rains are heaviest. Cyclones that develop over the western side of the Indian Ocean occasionally affect the rainy season—the amount and intensity of rainfall during a given wet spell is enhanced by the passage of upper westerly waves of mid-latitude origin (Smith 1985; Buckle 1996).

1.2 Southern Oscillation Index (SOI)

The Southern Oscillation Index is a measure of the strength and phase of the difference in sea level air pressure of the area between Tahiti (in the mid-Pacific) and Darwin (Australia). A strong and consistent negative SOI pattern is related to El Niño, and a deep and consistent positive SOI pattern, to La Niña. El Niño is usually associated with below-normal rainfall; La Niña is associated with above-normal rainfall.

El Niño is the abnormal warming of surface ocean water in the eastern tropical Pacific Ocean, while La Niña is the cooling of those surface ocean waters. If El Niño occurs in the eastern tropical Pacific Ocean (Northern Hemisphere), La Niña will occur simultaneously in the western tropical Pacific Ocean. Changes in the temperature of the water affect surface air pressure in the Pacific Ocean, a phenomenon known as the Southern Oscillation. The Southern Oscillation is the see-saw pattern of reversing surface air pressure between the eastern and western tropical Pacific Ocean: when the surface pressure is high in the eastern tropical Pacific Ocean, it is low in the western tropical Pacific Ocean, and vice versa.

Because ocean warming and pressure reversal are usually simultaneous, the phenomenon is called El Niño/Southern Oscillation (ENSO). ENSO refers to both El Niño and La Niña (National Weather Service: Climate Prediction Centre). ENSO is more about the positive and negative phases of Southern Oscillation, but it is difficult to separate it from the SOI. This study uses monthly SOI values to predict annual rainfall.

2.0 EARLIER RESEARCH

A number of studies have investigated the relationship between Zimbabwean rainfall and the SOI. Significant differences in rainfall amount and in temporal and spatial distributions were observed between opposite extremes of the phases of ENSO (Matarira 1990). Matarira found that during the warm phase of ENSO, rainfall tends to be low across much of the country, whereas the converse is true for the cold phase. Using an average of the SOI during the preceding 12 months (January to December), Matarira found a positive correlation of +0.42 with total rainfall for the wet season (November to April). Matarira and Unganai (1994) reported a peak correlation of +0.56 with November to January rainfall in the southeastern part of the country, using the SOI one to two months earlier. They concluded

that SOI can explain up to 30% of the annual variance in summer rainfall in some parts of the country.

In a comparison of SOI anomalies with Zimbabwean seasonal rainfall, Torrance (1990) found that the positive values of the SOI coincided with amounts that were 101% to 125 % of normal. Negative SOI values were generally associated with below-normal rainfall. Torrance's study focused on correlations between SOI values and rainfall. He grouped positive SOI levels into a positive phase, and negative SOI levels into a negative phase. By contrast, this paper aims to identify a particular month and lag whose SOI value explains total annual rainfall in Zimbabwe; that is, it seeks to identify the explanatory variable at a time lag of at least one year in advance.

Makarau and Jury (1997) found an association between ENSO phases and extreme rainfall. Specifically, when the SOI is within one standard deviation of the long-term mean, the probability is high that rainfall in Zimbabwe will be within 10% of the mean. Based on a 41-year time series and using the average of August to October SOI values, the correlation between the SOI and Zimbabwean summer rainfall was +0.44.

Rocha (1992) found that southeast Zimbabwean rainfall correlated significantly with the SOI (+0.4), with a lead time of four to five months.

Using precipitation data from 68 meteorological sites with least 20 years of complete records, Waylen and Henworth (1995) investigated the association between monthly precipitation totals and the SOI throughout Zimbabwe. Simple lag cross-correlations between the SOI and annual precipitation totals, both annual and monthly, were used to determine significant associations. The authors revealed positive correlations, with almost 30% of the stations at lag zero. They found a negative correlation at lag -1 (month). The periods with the strongest positive association were the months of the rainy season from October to April, which were correlated to synchronous values of the SOI and those in the preceding June-to-September period. March precipitation was found to be positively correlated with the SOI value of the same month. More than 70% of the stations in the study reported significant correlations between March precipitation and the SOI in the preceding July, and at least 25% of the stations reported similar associations with monthly SOI in the preceding May (lag -10) to February (lag -1). The correlation was found to extend through the end of the rainy season into April and May. November and December precipitation were less strongly correlated with the SOI values in the same period. January and February precipitation were not correlated with monthly SOI.

With contingency tables, Mason and Goddard (2001) investigated the influence of extreme ENSO phases on global precipitation anomalies. Precipitation anomalies that were weakly positive or negative were considered near-normal and were not counted in the climate impacts. For a total of n years, of which b are "dry," and from which r years are selected at random (the strongest El Niño years, for example), letting the number of dry years that are selected (denoted by X) be equal to x [where $0 \leq x \leq \min(r, b)$], the authors assumed a total of *r El Niño* years, and x of them dry. The significance probability is defined as the probability of selecting x or more dry years in a random sample of r years. This probability is equivalent to the right tail area of the hypergeometric distribution (Agresti 1996) and is given by:

$$P_x(X \geq x) = H(x; r, b, n) = \sum_{k=x}^{\min(r,b)} \frac{\binom{b}{k}\binom{n-b}{r-k}}{\binom{n}{r}}$$

Manatsa et al. (2007) used correlation analysis to identify the period lags for which the SOI and Darwin pressure anomalies are significantly correlated with the Zimbabwean summer precipitation index. Manatsa et al. (2007) found that lagged four months moving averages of Darwin pressure and also the four months moving averages of the SOI are correlated with the Zimbabwean summer precipitation.

Table 1: Correlations between SOI, Darwin pressure and Zimbabwe's summer precipitation index

	JFMA	FMAM	MAMJ	AMJJ	MJJA	JJAS	JASO	ASON	SOND
SOI	0.184	0.247	0.237	0.269	0.333	0.366	0.394	0.420	0.398
Darwin	-0.198	-0.293	-0.326	-0.303	-0.300	-0.297	-0.312	-0.341	-0.320

Source: Manatsa et al. (2007)

JFMA - *January, February, March, April;* FMAM - *February, March, April, May;*
MAMJ- *March, April, May, June ;* AMJJ - *April, May, June, July;*
MJJA - *May, June, July, August;* JJAS - *June, July, August, September;*
JASO- *July, August, September, October;* ASON- *August, September, October, November*
SOND- *September, October, November, December*

Although considerable attention has focused on predicting Zimbabwean rainfall using the SOI, those studies determined correlations between rainfall and the SOI values. This paper departs from previous research by attempting to model annual rainfall in Zimbabwe by incorporating the effect of the SOI

using the weighted regression method. The paper also aims to determine a particular month and time lag whose SOI value explains mean annual rainfall in Zimbabwe, that is, it seeks to identify the explanatory variable at a lag of at least one year.

3.0 DATA AND METHODOLOGY

3.1 Data Sources

Annual rainfall data for 1974 to 2009 were obtained from the Zimbabwe Department of Meteorological Services. Mean annual rainfall was calculated by averaging the monthly totals for the summer period (October through March).

The SOI data were obtained from http://www.longpaddock.qld.gov.au. The SOI is calculated from monthly or seasonal fluctuations in the air pressure difference of the area between Tahiti (mid-Pacific) and Darwin (Australia). The SOI is a measure of the strength and phase of the difference in sea-level pressure between the two locations, expressed as an index. A strong negative value usually indicates that the oscillation has entered an *El Niño* phase; a strong positive value usually indicates a *La Niña* phase.

SOI is calculated (Australian Bureau of Meteorology) using the formula:

$$SOI = 10\left(\frac{Pdif - Pdiffav}{SD(Pdif)}\right)$$

where:

Pdiff = (average Tahiti mean sea-level pressure for the month) – (average Darwin mean sea-level pressure for the month)

Pdiffav = Long-term average of Pdiff for the month in question

SD(Pdiff) = Long-term standard deviation of Pdiff for the month

Multiplication by 10 allows the value of the SOI to be expressed as a whole number, usually and +35.

3.2 Weighted least squares regression

The simple least squares method weighs each observation equally in determining the estimates of the parameters. Because all data are treated equally, less precise measured points have more influence than is warranted, and highly precise points have less influence. By contrast, the weighted least squares weighs some observations more heavily than others, thereby giving data points different amounts of influence over the parameter estimates, which maximizes the efficiency of parameter estimation. Weighted least squares regression reflects the behaviour of random errors in the model.

Parameter estimates $\hat{\beta}_0$ and $\hat{\beta}_1$ for the model $y_t = \beta_0 + \beta_1 x_{t-1} + \varepsilon$ are required:

To find these parameters of the weighted least square method minimize:

$$WSSE = \sum_{t=1}^{n} w_t (y_t - \hat{y}_t)^2 \tag{3.1}$$

$$= \sum_{t=1}^{n} w_t \, (y_t - \hat{\beta}_0 - \hat{\beta}_1 x_{t-1})^2 \tag{3.2}$$

where w_t is the weight assigned to the t^{th} observation. The weight w_t is the reciprocal of the variance of that observation's error term, σ_t^2, that is,

$$w_t = \frac{1}{\sigma_t^2} \tag{3.3}$$

Observations with larger error variances receive less weight (and hence, have less influence on the analysis) than observations with smaller error variances. The estimates are:

$$\hat{\beta}_0 = \frac{\sum_{t=1}^{n} y_t w_t}{\sum_{t=1}^{n} w_t} - \hat{\beta}_1 \frac{\sum_{t=1}^{n} x_{t-1} w_t}{\sum_{t=1}^{n} w_t} \tag{3.4}$$

and

$$\hat{\beta}_1 = \frac{\sum_{t=1}^{n} y_t x_{t-1} w_t - \frac{(\sum_{t=1}^{n} y_t w_t)(\sum_{t=1}^{n} x_{t-1} w_t)}{\sum_{t=1}^{n} w_t}}{\sum_{t=1}^{n} x_{t-1}^2 w_t - \frac{(\sum_{t=1}^{n} x_{t-1} w_t)^2}{\sum_{t=1}^{n} w_t}} \tag{3.5}$$

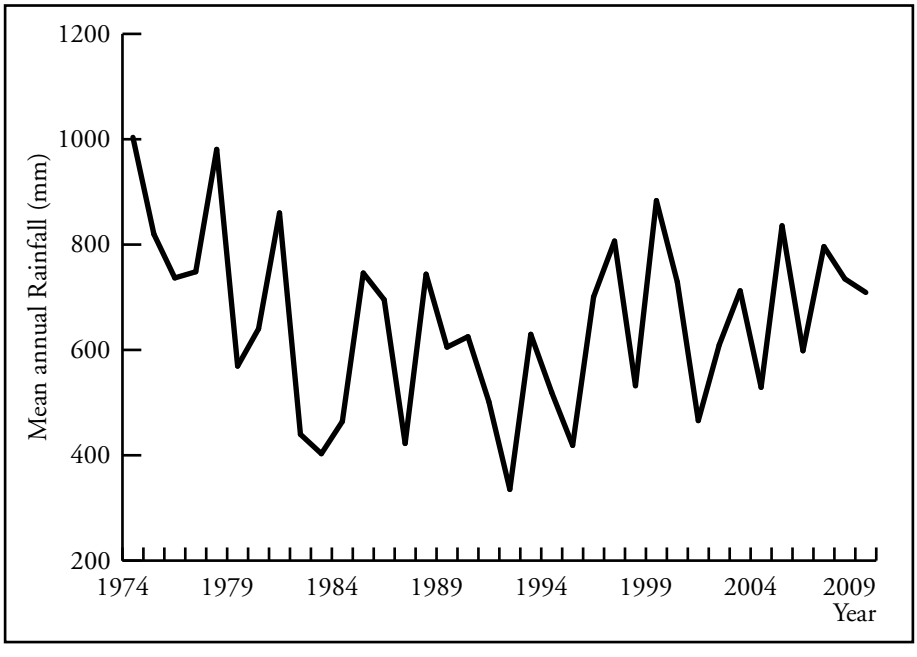
The major disadvantage of weighted least squares regression is that it assumes that the weights are known exactly, which is almost never the case in real applications, where estimated weights are used instead (Carrol and Ruppert 1988).

4.0 RESULTS

4.1 Zimbabwean mean annual rainfall patterns and the Southern Oscillation

Figure 1 shows Zimbabwe's mean annual rainfall from 1974 to 2009. The highest amount was in 1974, and the smallest, in 1992 (the worst drought in the country's history). The Department of Meteorological Services in Zimbabwe categorizes annual rainfall of less than 473 mm as a meteorological drought.

Figure 1. Zimbabwean mean annual rainfall, 1974 to 2009



The highest correlation between the monthly SOI and mean annual rainfall is +0.45, based on the April and January SOI values of the same year. The lowest correlation is +0.23, which is obtained between mean annual rainfall and the February SOI values of the same year. September SOI values of the same year have a +0.33 correlation with mean annual rainfall.

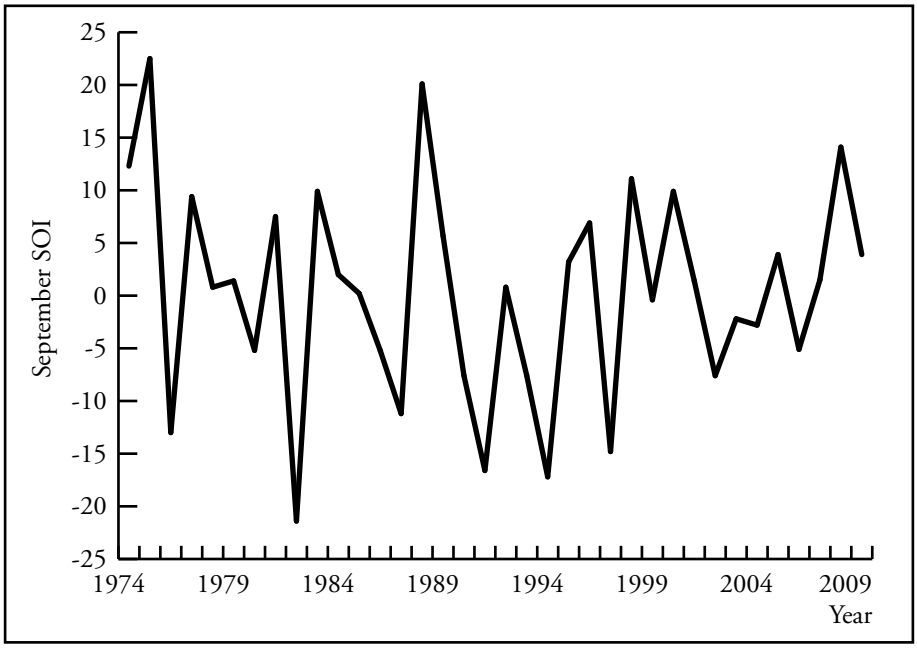
However, the aim of this analysis is to identify a particular month's SOI that is highly correlated with mean annual rainfall **at a lead time of a year**

or more. The SOI value should provide a prediction of total mean annual rainfall at least a year ahead. This is a clear departure from other research.

The highest correlation between annual Zimbabwean rainfall and SOI values in the previous year is with September, at +0.36. Correlations between annual rainfall and SOI values more than a year earlier are not significant.

Figure 2 shows the September SOI values from 1974 to 2009.

Figure 2: September Southern Oscillation Index, 1974 to 2009



4.2 Relationship between the SOI and mean annual rainfall

Table 1 shows the results of an ordinary least squares approach to predicting Zimbabwean mean annual rainfall patterns.

The ordinary least squares linear regression model is:

$$\hat{y}_t^* = \hat{\beta}_0^* + \hat{\beta}_1^* x_{t-1} \tag{4.1}$$

where is the predicted annual rainfall, x_{t-1} is the September SOI value for the previous year. The parameter estimates are $\hat{\beta}_0^*$=643.1394 and $\hat{\beta}_1^*$=5.525738.

Table 2: Simple ordinary least squares regression model

Explanatory variable	Coefficient	p value
$SOI_{sept(-1)}$	$\widehat{\beta}_0^* = 643.1394$	0.0000
	$\widehat{\beta}_1^* = 5.525738$	0.0311

The model suggests that if the September SOI of the previous year is zero, mean annual rainfall is an estimated 643.1 mm. Predicted rainfall increases by 5.5 mm for a unit increase in the September SOI of the previous year.

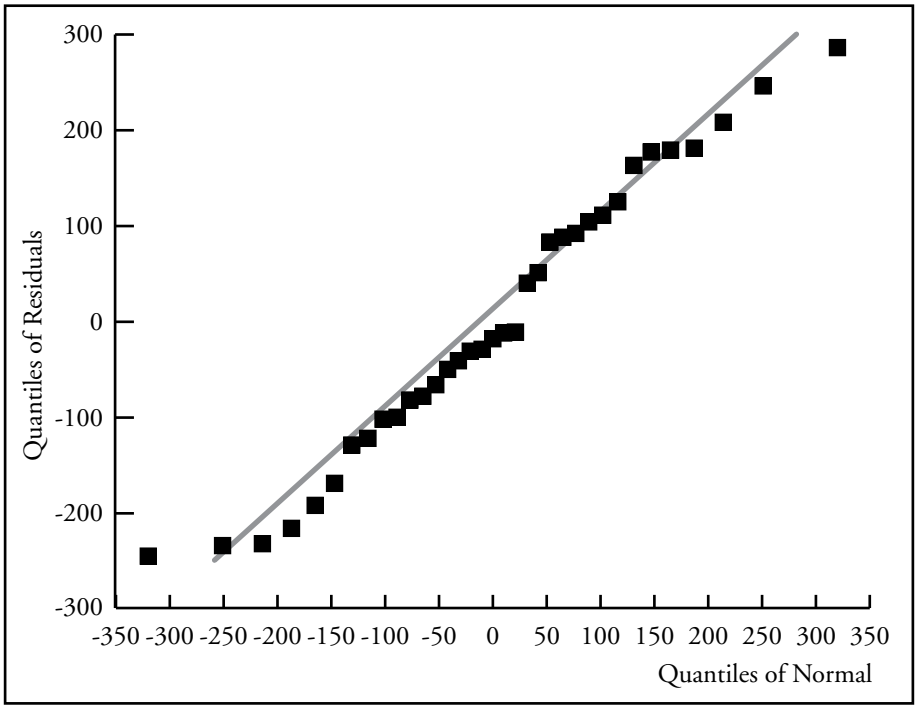
Checking model assumptions

The ACF and PACF correlogram (Appendix 2) shows that the residuals are independent. The Durbin-Watson statistic is 2.1748, indicating that the residuals are independent.

Testing for normality of residuals

Figure 3 shows the normal probability Q – Q plot of the residuals from the ordinary least squares model.

Figure 3: Normal Q – Q plot of residuals for simple least squares regression model

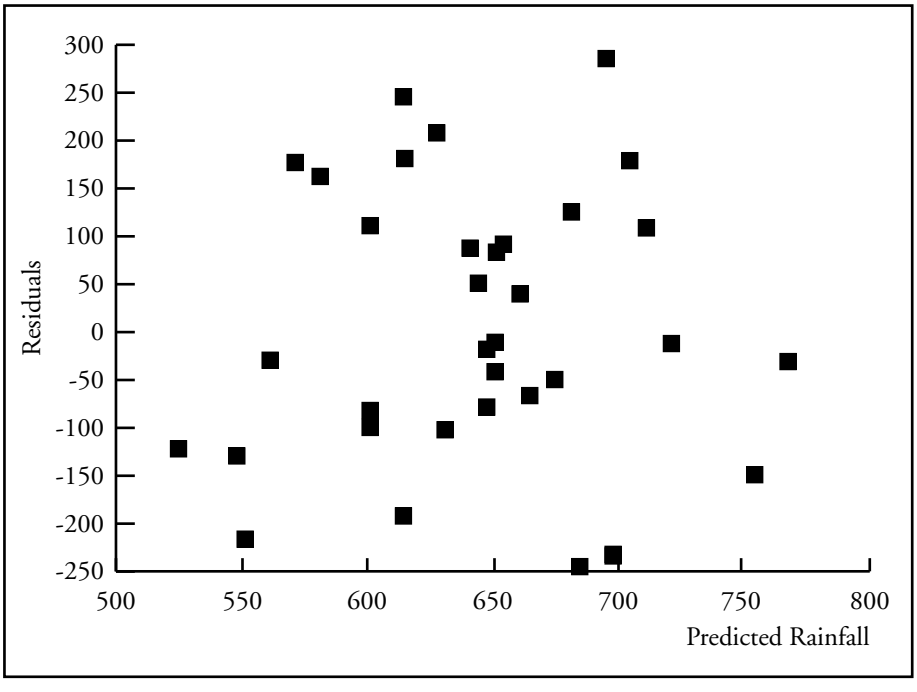


The normal probability plot of the residuals is an almost straight line, suggesting that the residuals are normally distributed. Thus, the model thus does not violate the normality assumptions.

Testing for constant variance

Figure 4 shows the scatter plot of residuals against predicted mean annual rainfall from the ordinary least squares regression model. The plot of residuals against predicted values indicates clustering, which suggests that the model violates the assumption of constant variance. This means that the model can be improved by stabilizing the variance using the weighted least squares method.

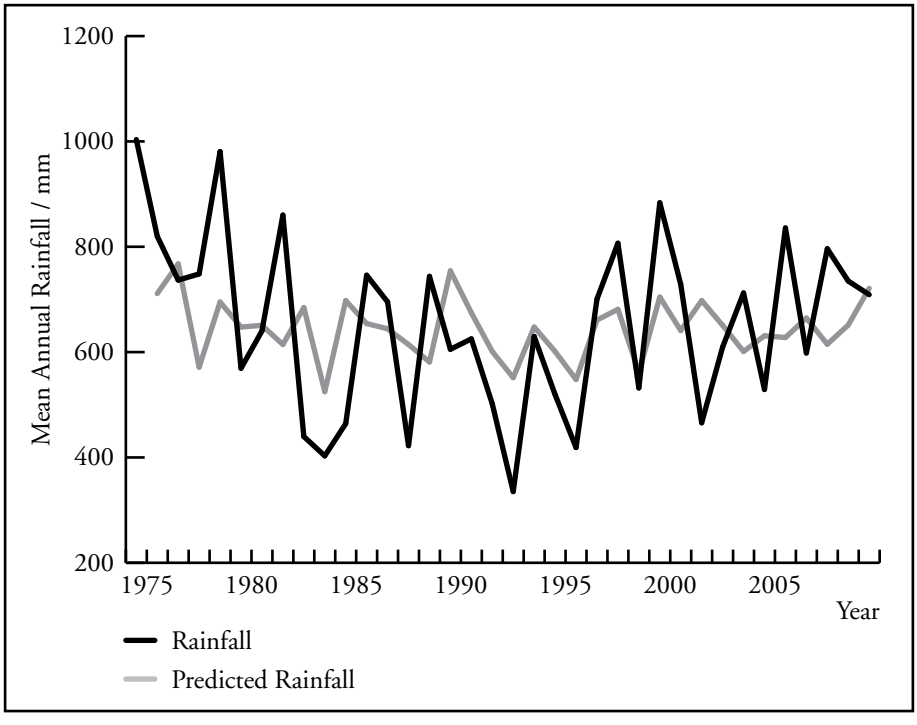
Figure 4: Residuals versus predicted values for simple least squares regression model



4.3 Rainfall versus predicted rainfall using simple least squares regression model

Figure 5 shows predicted and observed mean annual rainfall from 1974 to 2009. The model fails to capture the variability in the observed values, and therefore, needs to be improved.

Figure 5: Predicted and observed rainfall, 1974 to 2009 (simple least squares model)



4.4 Weighted regression model

To address the heteroscedacity in the data, weighted regression is used. Table 4.2 shows the weighted linear regression models results for rainfall y_t, with SOI for September of the previous year as an explanatory variable. The model is:

$$\hat{y}_t = \hat{\beta}_0 + \hat{\beta}_1 x_{t-1} \tag{4.2}$$

where x_{t-1} is SOI for September of the previous year. Various weights are considered in arriving at estimates $\hat{\beta}_0$ and $\hat{\beta}_1$ using weighted regression (equations 3.4 and 3.5).

Table 3: Weighted regression models

Explanatory variable	Weight	Coefficients $\widehat{\beta}_0$ $\widehat{\beta}_1$	p value	AIC	BIC
$SOI_{sept(-1)}$	SOI_{sept}	672.3622 10.87731	0.0000 0.0182	13.14399	13.24356
	$\frac{1}{SOI_{sept}}$	708.7970 5.483862	0.0000 0.0367	12.62942	12.72900
	SOI_{sept}^2	701.0582 16.76346	0.0000 0.0000	11.59687	11.68584

The model with SOI_{sept}^2 as the variance stabilizing weight was selected, because it is the model with the least AIC and BIC. The model is significant for both parameters. The estimates of β_0 and β_1 are 701.0582 and 16.76346 respectively.

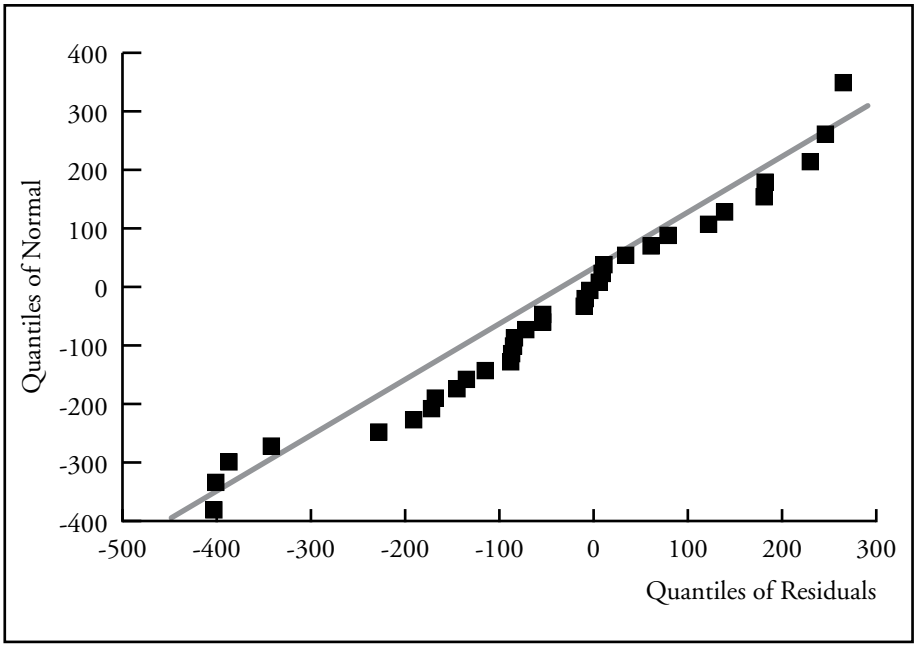
Checking model assumptions

The ACF and PACF correlogram (Appendix 3) shows that the residuals are independent. The Durbin-Watson statistic is 2.2742, indicating that the residuals are independent.

Testing for normality of residuals

Figure 6 shows the normal probability Q – Q plot of the residuals from the weighted least squares model.

Figure 6: Normal Q – Q plot of residuals for weighted regression model



The normal probability Q – Q plot of residuals is linear, suggesting that the residuals are almost normally distributed. The model thus does not violate the assumption of normality.

Testing for constant variance

Figure 7 shows the scatter plot of residuals against the predicted mean annual rainfall from the weighted least squares regression model.

Figure 7: Residuals versus predicted values

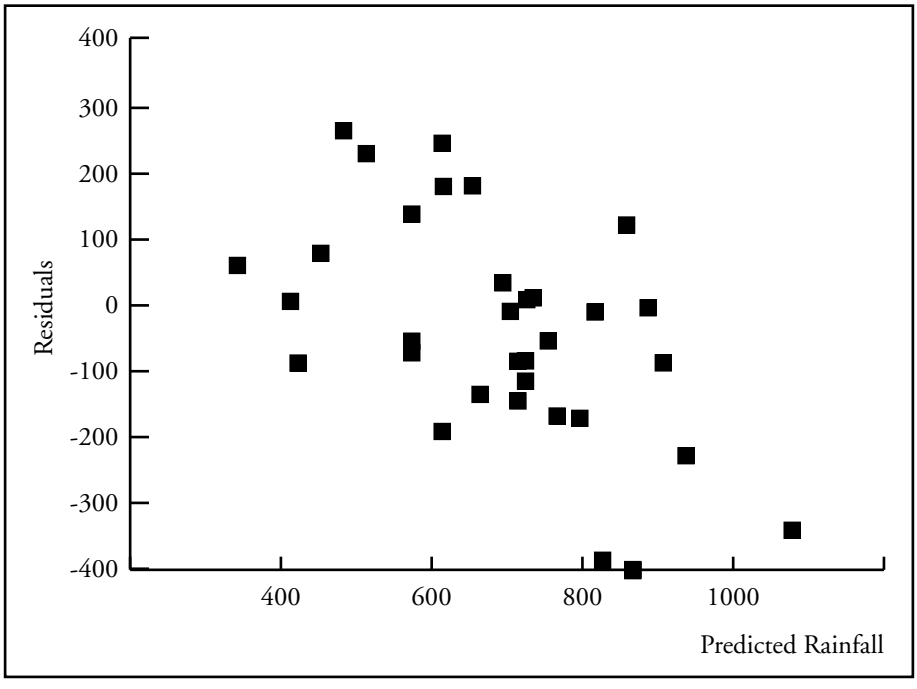
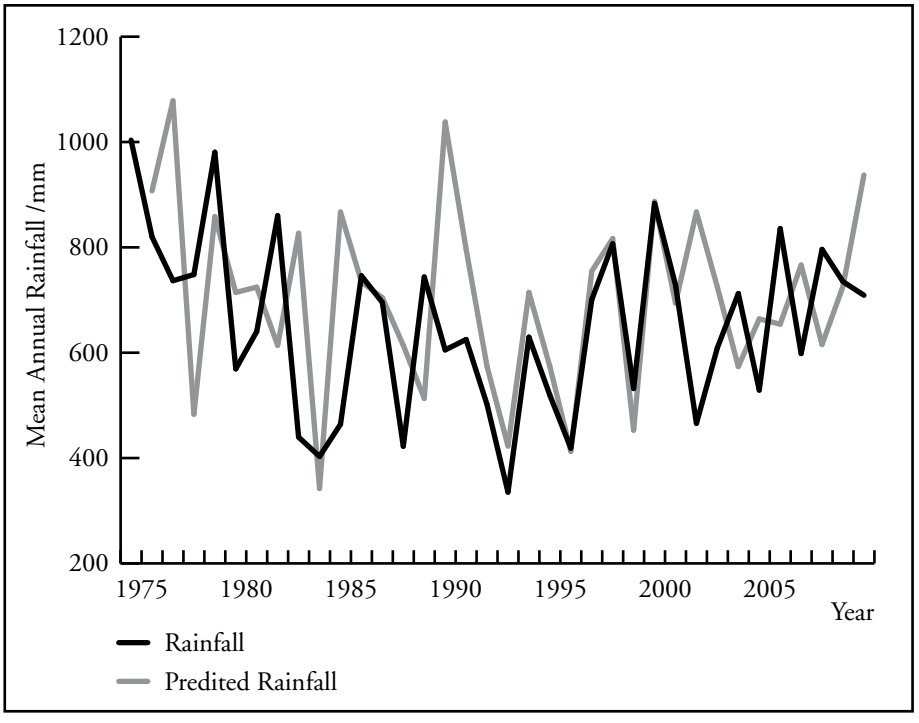


Figure 7 shows that the model almost has a constant variance, and therefore, does not violate the model assumptions grossly. The model can be used to forecast rainfall.

Actual versus predicted rainfall

Figure 8 shows predicted and observed mean annual rainfall from 1974 to 2009, based on the weighted least squares regression model.

Figure 8: Predicted and observed rainfall, 1974 to 2009 (weighted least squares model)



The weighted least squares model captures much of the variation, and therefore, has considerable forecasting power.

5.0 SUMMARY AND CONCLUSIONS

The aim of this paper was to establish the relationship between the Zimbabwean mean annual rainfall patterns and the SOI of a particular month at a maximum lag for effective planning purposes. The results demonstrate that Zimbabwe's annual rainfall and drought patterns can be predicted using the September Southern Oscillation Index value of the previous year. At a lag of one year, the highest correlation of (+0.36) was found between the mean annual rainfall and the SOI for September. Correlations at a lag of more than a year are insignificant.

The weighted regression model using squared SOI for September as a variance-stabilizing weight was found to be significant. The model:

$y_t = 701.0582 + 16.76346x_{t-1}$, where x_{t-1} is the SOI for September of the previous year captured the variability between observed and predicted values. Using the SOI for September 2010 of +25, the model predicts annual rainfall of 1,120 mm for 2011, a figure well above the drought threshold of 473 mm.

If the SOI value for September of the previous year is less than -13, the model predicts an annual rainfall below the drought threshold.

As a follow-up to the results of this study, additional work could include:

- Developing a model to forecast the September SOI such that these models can be used to forecast annual rainfall for Zimbabwe with a lead time of more than a year.
- Applying the Bayesian statistics approach in modeling the relationship between the September SOI and annual Zimbabwean rainfall. Arguably, the Bayesian approach gives more information than the classical approach.
- Based on these findings, modelling annual rainfall patterns by climatic region in Zimbabwe, total annual rainfall varies in different regions.

REFERENCES

Agresti, A. (1996), *An Introduction to Categorical Data Analysis*. London: John Wiley.

Australian Bureau of Meteorology, Available at: http://www.bom.gov.au/climate/glossary/soi.shtml [Accessed on 14 July 2012].

Buckle, C. (1996), *Weather and Climate in Africa*. Harlow, United Kingdom: Longman.

Carroll, R. J. and D. Ruppert (1988), *Transformation and Weighting in Regression*. New York: Chapman and Hall.

National Weather Service: Climate Prediction Centre, Frequently asked questions about El Niño and La Niña. Available at: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensofaq.shtml#ENSO [Accessed on 14 July 2012].

Jury, M. R. (1996), "Regional Teleconnection Pattern Associated with Summer Rainfall over South Africa, Namibia and Zimbabwe," *International Journal of Climatology*, vol. 16, no. 2, pp. 135-153.

Makarau, A. and M.R. Jury (1997), "Predictability of Zimbabwe Summer Rainfall," *International Journal of Climatology* vol. 17, pp. 1421-1432.

Manatsa, D., W. Chingombe, H. Matsikwa, and C.H. Matarira (2007), "The Superior Influence of the Darwin Sea Level Pressure Anomalies over ENSO as a Single Drought Predictor in Southern Africa," *Theoretical and Applied Climatology* D01 10.1007/s00 704 – 007 – 0315 3. www.springerlink.com/index/8703666K421773hpdf

Mason, S. J. and L. Goddard (2001), "Probabilistic Precipitation Anomalies Associated with ENSO," *Bulletin of the American Meteorological Society*, vol. 82, pp. 619-638.

Matarira, C. H. (1990), "Drought over Zimbabwe in a Regional and Global Context," *International Journal of Climatology*, vol. 10, pp. 609-625.

Matarira, C. H, and L.S. Unganai (1994), *A Rainfall Prediction Scheme for Southern Africa based on the Southern Oscillation*. Technical Report. Harare: Southern African Development Community, Regional Early Warning Unit.

Rocha, A.M.C. (1992), *The Influence of Global Sea Surface Temperatures on Southern African Summer Climate*. Phd. Thesis, University of Melbourne.

Smith, S.V. (1985), "Studies of the Effects of Cold Fronts during the Rainy Season in Zimbabwe," *Weather*, vol. 40, pp. 198-203.

Torrance, J. D. (1990), "The Southern Oscillation and the Rainy Season in Zimbabwe," *Zimbabwe Science News*, vol. 24, pp. 4-6.

Washington, R. and A. Preston (2006), "Extreme Wet Years over Southern Africa: Role of Indian Ocean Sea Surface Temperatures," *Journal of Geophysical Research*, vol. 111: D15104. doi:10.1029/2005JD006724.

Waylen, P. and P. Henworth (1996), "A Note on the Timing of Precipitation Variability in Zimbabwe as Related to the Southern Oscillation," *International Journal of Climatology*, vol. 16, pp. 1137-1148.

Zimbabwe Central Statistical Office (2004). *Environmental Statistics Report*. CSO, Harare, Zimbabwe.

Zimbabwe Central Statistical Office (2010). *Environmental Statistics Report*. CSO, Harare, Zimbabwe.

The Long Paddock Available at: http://www.longpaddock.qld.gov.au/seasonalclimateoutlook/southernoscillationindex/soidatafiles/index.php [Accessed on 14 July 2012].

APPENDIX 1

Mean annual rainfall in Zimbabwe and September SOI, 1974 to 2009

Year	Mean annual rainfall (mm)	September SOI	Year	Mean annual rainfall (mm)	September SOI
1974	1003.5	12.3	**1992**	335.2	0.8
1975	819.9	22.5	**1993**	629.6	-7.6
1976	736.7	-13	**1994**	519.3	-17.2
1977	748.4	9.4	**1995**	418.8	3.2
1978	980.7	0.8	**1996**	700.7	6.9
1979	569.3	1.4	**1997**	806.7	-14.8
1980	640.2	-5.2	**1998**	532	11.1
1981	860.1	7.5	**1999**	883.5	-0.4
1982	439.7	-21.4	**2000**	728.6	9.9
1983	403	9.9	**2001**	465.8	1.4
1984	464.1	2	**2002**	609.5	-7.6
1985	746	0.2	**2003**	712.3	-2.2
1986	695.3	-5.2	**2004**	529	-2.8
1987	422.4	-11.2	**2005**	835.7	3.9
1988	743.8	20.1	**2006**	598.4	-5.1
1989	605.3	5.7	**2007**	796.2	1.5
1990	625.1	-7.6	**2008**	734.9	14.1
1991	501.6	-16.6	**2009**	709.1	3.9

APPENDIX 2

Autocorrelation of residuals from least squares model

Included observations: 35						
Autocorrelation	**Partial correlation**		**AC**	**PAC**	**Q-Stat**	**Prob**
.*| . |	.*| . |	1	-0.096	-0.096	0.3487	0.555
. | . |	. | . |	2	0.044	0.035	0.4254	0.808
. |** |	. |** |	3	0.246	0.256	2.8724	0.412
.*| . |	.*| . |	4	-0.167	-0.130	4.0397	0.401
. | . |	. | . |	5	-0.005	-0.061	4.0407	0.544
.*| . |	**| . |	6	-0.163	-0.233	5.2330	0.514
. | . |	. | . |	7	-0.020	0.030	5.2524	0.629
. |*. |	. |*. |	8	0.148	0.197	6.3060	0.613
. | . |	. |*. |	9	0.009	0.157	6.3100	0.709
. | . |	. | . |	10	0.055	-0.017	6.4688	0.774
. | . |	.*| . |	11	0.040	-0.108	6.5544	0.834
. | . |	.*| . |	12	-0.023	-0.097	6.5842	0.884
.*| . |	.*| . |	13	-0.176	-0.193	8.4088	0.816
.*| . |	.*| . |	14	-0.151	-0.111	9.8134	0.776
.*| . |	.*| . |	15	-0.142	-0.106	11.124	0.744
**| . |	.*| . |	16	-0.207	-0.165	14.052	0.595

APPENDIX 3

Autocorrelation of residuals from weighted regression model

Included observations: 35						
Autocorrelation	**Partial Correlation**		**AC**	**PAC**	**Q-Stat**	**Prob**
.*| . |	.*| . |	1	-0.190	-0.190	1.3683	0.242
.*| . |	.*| . |	2	-0.120	-0.161	1.9301	0.381
. | . |	. | . |	3	0.046	-0.011	2.0171	0.569
.*| . |	.*| . |	4	-0.117	-0.136	2.5843	0.630
. |*. |	. |*. |	5	0.189	0.153	4.1338	0.530
***| . |	***| . |	6	-0.415	-0.423	11.830	0.066
. | . |	.*| . |	7	-0.045	-0.170	11.924	0.103
. |*. |	. | . |	8	0.168	-0.039	13.279	0.103
. |*. |	. |*. |	9	0.102	0.195	13.801	0.130
. | . |	. | . |	10	0.052	0.010	13.940	0.176
.*| . |	. | . |	11	-0.103	0.047	14.513	0.206
. |*. |	.*| . |	12	0.090	-0.073	14.972	0.243
. | . |	.*| . |	13	-0.010	-0.094	14.978	0.309
.*| . |	.*| . |	14	-0.101	-0.102	15.608	0.338
.*| . |	. | . |	15	-0.085	-0.001	16.078	0.377
.*| . |	.*| . |	16	-0.126	-0.157	17.156	0.376

African Statistical Journal
Call for Papers

The African Statistical Journal (ASJ) is currently accepting manuscripts for publication in French or/and English. The ASJ was established to promote the understanding of statistical development in the African region. It focuses on issues related to official statistics as well as application of statistical methodologies to solve practical problems of general interest to applied statisticians.

In addition to individual academic and practicing statisticians, the Journal should be of great interest to a number of institutions in the region including National Statistical Offices, Central Banks, research and training institutions and sub-regional economic groupings, and international development agencies.

The Journal serves as a research outlet and information sharing publication among statisticians and users of statistical information mainly in the Africa region. It publishes, among other things:

- articles of an expository or review nature that demonstrate the vital role of statistics to society rather than present technical materials,
- articles on statistical methodologies with special emphasis on applications,
- articles about good practices and lessons learned in statistical development in the region,
- opinions on issues of general interest to the statistical community and users of statistical information in the African region,
- notices and announcements on upcoming events, conferences, calls for papers, and recent statistical developments and anything that may be of interest to the statistical community in the region.

All manuscripts are reviewed and evaluated on content, language and presentation. The ASJ is fully committed to providing free access to all articles as soon as they are published. We ask you to support this initiative by publishing your papers in this journal. Prospective authors should send their manuscript(s) to **ASJ-Statistics@afdb.org**

The ASJ is also looking for qualified reviewers. Please contact us if you are interested in serving as a reviewer.

For instructions for authors and other details, please visit our website – **http://www.afdb.org/en/knowledge/publications/african-statistical-journal/**

Journal statistique africain
Demande de soumission d'articles

Le journal statistique africain (JSA) accepte actuellement des manuscrits pour la publication en anglais ou en français. Le JSA a été établi pour favoriser la compréhension du développement statistique dans la région africaine. Il se concentre sur des questions liées aux statistiques officielles aussi bien que l'application des méthodologies statistiques pour résoudre des problèmes pratiques d'intérêt général pour les praticiens de la statistique.

En plus des universitaires et des statisticiens de métier, le Journal devrait revêtir un grand intérêt pour les institutions de la région, notamment les offices nationaux de statistiques, les banques centrales, les instituts de recherche et les organisations économiques sous-régionaux et les agences internationales de développement.

Le Journal constitue un document de recherche et d'information entre les statisticiens et les utilisateurs de l'information statistique, principalement dans la région africaine. Il publie entre autres:

- des articles sur le plaidoyer en matière de statistique qui démontrent le rôle essentiel des statistiques dans la société, plutôt que de présenter le matériel technique,

- des articles sur les méthodologies statistiques, avec un accent particulier sur les applications,

- des articles sur les meilleures pratiques et les leçons tirées sur le développement de la statistique dans la région,

- des avis sur des questions d'intérêt général pour la communauté statistique et les utilisateurs de l'information statistique dans la région africaine,

- des informations et des annonces sur les prochains événements, les conférences, les appels à contribution pour des papiers, et

- les développements statistiques récents et tout autre aspect susceptible d'intéresser la communauté statistique dans la région.

Tous les manuscrits sont passés en revue et évalués sur le contenu, la langue et la présentation. Le JSA s'engage entièrement à fournir le libre accès à

tous les articles dès qu'ils sont publiés. Nous vous demandons de soutenir cette initiative en publiant vos articles dans ce journal. Les auteurs éventuels devraient envoyer leur manuscrit(s) à **ASJ-Statistics@afdb.org**

Le JSA cherche également les critiques qualifiés. Veuillez nous contacter si vous êtes intéressé à contribuer en tant que critique.

Veuillez visiter notre site Web **http://www.afdb.org/en/knowledge/publications/african-statistical-journal/** pour les instructions aux auteurs et autres détails.

Editorial policy

The African Statistical Journal was established to promote the understanding of statistical development in the African region. It focuses on issues related to official statistics as well as application of statistical methodologies to solve practical problems of general interest to applied statisticians. Of particular interest will be exposition of: how statistics can help to illuminate development and public policy issues like poverty, gender, environment, energy, HIV/AIDS, etc.; development of statistical literacy; tracking national and regional development agenda; development of statistical capacities and effective national statistical systems; and the development of sectoral statistics e.g. educational statistics, health statistics, agricultural statistics, etc.

In addition to individual academic and practicing statisticians, the Journal should be of great interest to a number of institutions in the region including National Statistical Offices, Central Banks, research and training institutions and sub-regional economic groupings, and international development agencies.

The Journal serves as a research outlet and information sharing publication among statisticians and users of statistical information mainly in the African region. It publishes, among other things: articles of an expository or review nature that demonstrate the vital role of statistics to society rather than present technical materials, articles on statistical methodologies with special emphasis on applications, articles about good practices and lessons learned in statistical development in the region, opinions on issues of general interest to the statistical community and users of statistical information in the African region, notices and announcements on upcoming events, conferences, calls for papers, and recent statistical developments and anything that may be of interest to the statistical community in the region.

The papers which need not contain original material, should be of general interest to a wide section of professional statisticians in the region.

All manuscripts are peer reviewed and evaluated on content, language and presentation.

Ligne éditoriale

Le Journal statistique africain a été établi pour favoriser la compréhension du développement statistique dans la région africaine. Il se concentre sur des questions liées aux statistiques officielles aussi bien que l'application des méthodologies statistiques pour résoudre des problèmes pratiques d'intérêt général pour les statisticiens de métier. L'intérêt particulier est de montrer comment les statistiques peuvent aider à mettre en exergue les problèmes de développement et de politique publique tels que la pauvreté, le genre, l'environnement, l'énergie, le VIH/ SIDA, etc.; le développe- ment de la culture statistique ; la prise en compte des questions de développement régional et national; le développement des capacités statistiques et des systèmes statistiques nationaux efficaces; et le développement des statistiques sectorielles comme les statistiques d'éducation, de santé, des statistiques agricoles, etc.

En plus des universitaires et des statisticiens de métier, le Journal devrait revêtir un grand intérêt pour les institutions de la région, notamment les offices nationaux de statistiques, les banques centrales, les instituts de recherche et les organisations économiques sous-régionaux et les agences internationales de développement.

Le Journal constitue un document de recherche et d'information entre les statisticiens et les utilisateurs de l'information statistique, principalement dans la région africaine. Il publie entre autres: des articles sur le plaidoyer en matière de statistique qui démontrent le rôle essentiel des statistiques dans la société plutôt que la présentation des outils techniques, des articles sur les méthodologies statistiques, avec un accent particulier sur les applications, des articles sur les meilleures pratiques et les leçons tirées de la région, des avis sur des questions d'intérêt général pour la communauté statistique et les utilisateurs de l'information statistique dans la région africaine, des informations et des annonces sur les prochains événements, les conférences, les appels à contribution pour des papiers, et les développements statistiques récents et tout autre aspect susceptible d'intéresser la communauté statistique dans la région.

Les articles, qui n'ont pas besoin de contenir du matériel original, devraient intéresser une grande partie des statisticiens professionnels dans la région.

Tous les manuscrits seront passés en revue et évalués sur le contenu, la langue et la présentation.

Guidelines for Manuscript Submission and Preparation

Submissions

Manuscripts in English or French should be sent by email to **ASJ-Statistics@afdb.org**

Title

The title should be brief and specific. The title page should include the title, the author's name, affiliation and address. The affiliation and address should be given as a footnote on the title page. If the manuscript is co-authored, the same information should be given for the co-author(s).

Abstract, Key Words, and Acknowledgments

A short abstract of about 150 words must be included at the beginning of the manuscript, together with up to 6 key words used in the manuscript. These key words should not repeat words used in the title. Acknowledgements, if any, should be inserted at the bottom of the title page.

Sections and Numbering

Major headings in the text should be numbered (e.g. "**1. INTRODUCTION**"). Numbered subheadings (e.g. "**1.1 The establishment of the NSDS**") may be used but thereafter sub-subheadings should be unnumbered. Main body text in the form of paragraphs should not be numbered.

Formatting

Please use minimal formatting as this will facilitate harmonization of all the papers. As your default, keep to "normal" (12 pt. Times New Roman) for main text with a single line space between paragraphs. Do not apply "body text" as an inbuilt style. The levels of heading need to be easily identifiable. We recommend all capitals bold for the first level of heading in the main text (e.g. "**1. INTRODUCTION**"); thereafter bold upper and lower case for subheadings (e.g. "**1.1 The establishment of the NSDS**") and unnumbered bold italic (e.g. "***Creating a culture of cooperation***") thereafter. Please refer to the latest volume of the AJS as a guide.

House Style

The Bank's house style is US rather than British spellings (e.g. "organization" not "organisation"; "program" rather than "programme", "analyse"

etc.). Use % rather than "percent" or "per cent" and double rather than single quotation marks. Dates should be US style (e.g. December 11, 1985 not 11 December 1985).

Tables and Figures

Tables and figures should be numbered and given a title. These should be referred to in the text by number (e.g. "See Table 1"), not by page or indications such as "below" or "above".

Equations

Any equations in the paper should be numbered. The numbers should be placed to the right of the equation.

References

A list of references should be given at the end of the paper (to precede the Annexes, if included). The references should be arranged alphabetically by surname/name of organization. Where there is more than one publication listed for an author, order these chronologically (starting with the earliest). The references should give the author's name, year of publication, title of the essay/book, name of journal if applicable. Use a, b, c, etc. to separate publications of the same author in the same year. Titles of journals and books should be in italic; titles of working papers and unpublished reports should be set in double quotation marks and not italicized.

Examples:

Fantom, N. and N. Watanabe (2008). "Improving the World Bank's Database of Statistical Capacity," *African Statistical Newsletter*, vol. 2, no. 3, pp. 21–22.

Kish, L. (1988a). "Multipurpose Sample Designs," *Survey Methodology*, vol. 14, no. 3, pp. 19–32.

Kish, L. (1988b). *A Taxonomy of Elusive Populations*, Proceedings of the Section on Survey Research Methods, American Statistical Association, pp. 44–46.

Herzog, A. R. and L. Dielman (1985). "Age Differences in Response Accuracy for Factual Survey Questions," *Journal of Gerontology*, vol. 40, pp. 350–367.

World Bank (2006). *Statistical Capacity Improvement in IDA Countries – Progress Report*. Washington, DC: World Bank.

Cross References

In the main body of the article, cross-references should be Harvard-style, e.g. (Kish 1988a; Herzog and Dielman 1985: 351). For cross-references to three or more authors, only the first surname should be given, followed by et al., although the names of all the authors must be provided in the References entry itself. Abbreviations ibid. and op. cit. should not be used in the text or in footnotes.

Instructions pour la préparation et la soumission de manuscrits

Soumission

Les manuscrits en anglais ou en français doivent être envoyés à **ASJ-Statistics@afdb.org**

Titre

Le titre devrait être bref et détaillé. La page de titre doit inclure le titre du papier, le nom de l'auteur, l'affiliation et l'adresse. L'affiliation et l'adresse doivent figurer comme note de bas de page. Si le manuscrit est produit par des coauteurs, la même information doit être donnée pour les coauteurs.

Résumé, mots clés et remerciements

Un résumé court d'environ 150 mots doit être inclus au début du manuscrit ainsi qu'environ 6 mots clés utilisés dans le manuscrit. Les mots clés ne doivent pas répéter les mots utilisés dans le titre. Les remerciements, s'il y en a, doivent être insérés en bas de la page titre.

Section et numérotation

Les principaux titres doivent être numérotés (par exemple "**1. INTRODUCTION** "). Les sous-titres numérotés (par exemple "**1.1 L'élaboration de SNDS**") peuvent être employés mais par la suite les sous sous-titres ne devraient pas être numérotés. Le corps principal du texte sous forme de paragraphes ne devrait pas être numéroté.

Formatage

Veuillez utiliser le formatage minimal car ceci facilitera l'harmonisation de tous les articles. Garder par défaut le format "normal" (12 pt. Times New Roman) pour le texte principal avec l'espace d'une seule ligne entre les paragraphes. Ne pas appliquer le "corps de texte " en tant que modèle intégré. Les niveaux du titre doivent être facilement identifiables. Nous recommandons les majuscules en gras pour le premier niveau titre dans le texte principal (par exemple "**1. INTRODUCTION**") ; ensuite les lettres minuscules en gras pour les sous-sections (par exemple "**1.1 l'élaboration de la SNDS**") et ensuite l'italique en gras sans numérotation (par exemple "***créant une culture de coopération***").Veuillez vous référer au dernier volume du JSA comme guide.

Tableaux et Figures

Les tableaux et les graphiques doivent être numérotés et comporter un titre. Ceux-ci devraient être mentionnés (par exemple "voir Tableau 1") dans le texte par le nombre correspondant, et non par une indication de page ou par d'autres indications telles que "ci-dessous" ou "au-dessus de".

Équations

Toutes les équations dans le papier doivent être numérotées. Les nombres doivent être placés à la droite de l'équation.

Bibliographie

Une liste de références doit être fournie à la fin de l'article (avant les annexes, le cas échéant). Les références doivent être classées par ordre alphabétique selon le nom de l'auteur ou de l'organisation. Là où il y'a plus d'une publication listée pour un auteur, elles doivent être classées chronologiquement (en commençant par les plus récents). Les références doivent donner le nom de l'auteur et l'année de publication, le titre du livre, le nom du journal le cas échéant. Utiliser a, b, c, etc. pour séparer les publications du même auteur au cours der la même année. Les titres des journaux et des livres devraient être en italique ; les titres des documents de travail et des rapports non publiés devraient être placés dans de doubles guillemets et ne pas être imprimés en italique.

Exemples:

Fantom, N. et N. Watanabe (2008). « Improving the World Bank's Database of Statistical Capacity », *African Statistical Newsletter*, vol. 2, no. 3, pp. 21–22.

Kish, L. (1988a). « Multipurpose Sample Designs », *Survey Methodology*, vol. 14, no. 3, pp. 19–32.

Kish, L. (1988b). *A Taxonomy of Elusive Populations*, Proceedings of the Conference on Survey Research Methods, American Statistical Association, pp. 44–46.

Herzog, A. R. et L. Dielman (1985). « Age Differences in Response Accuracy for Factual Survey Questions », *Journal of Gerontology*, vol. 40, pp. 350–367.

World Bank (2006). *Statistical Capacity Improvement in IDA Countries – Progress Report*. Washington DC: The World Bank.

Renvois

Dans le corps principal de l'article, les renvois devraient suivre le modèle de Harvard, par exemple (Kish 1988a ; Herzog et Dielman 1985 :351). Pour des renvois à trois auteurs ou plus, seulement le premier nom de famille devrait être donné, suivi par et al., bien que les noms de tous les auteurs doivent être fournis dans la Bibliographie elle-même. Les abréviations ibid. et op. cit. ne devraient pas être employées dans le texte ou dans les notes de bas de page.

Temporary Relocation Agency (TRA) – Agence Temporaire de Relocalisation (ATR)
13 Rue du Ghana
BP. 323, 1002 Tunis Belvédère
Tunis, Tunisia / Tunisie
Tel: (+216) 71 102 342
Fax: (+216) 71 103 743
Internet: http://www.afdb.org
Email: ASJ-Statistics@afdb.org

ISSN : 2233-2820