Doctoral Dissertation

Matters of Measure: Applied Econometrics in the African and Asian Education Context

BENJAMIN KANE BLEVINS

Graduate School for International Development and Cooperation
Hiroshima University

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BENJAMIN KANE BLEVINS

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We hereby recommend that the dissertation by Mr. BENJAMIN KANE BLEVINS entitled "Matters of Measure: Applied Econometrics in the African and Asian Education Context" be accepted in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY.

Committee on Final Examination:

Yuichiro Yoshida, Professor
Chairperson

Shinji Kaneko, Professor

Keshav Lall Maharjan, Professor

Daisaku Goto, Associate Professor

Keisuke Kawata, Associate Professor
Institute of Social Science, The University of Tokyo

Date: 2019. July. 11

Approved:

Baba Takuya, Professor
Dean

Date: August 30. 2019

Abstract

Education has remained at near the top of the global development agenda since declared a fundamental human right with the signing of the Universal Declaration of Human Rights in 1948. The focus of this dissertation is education in low- and middle-income countries, where children generally have the least access to quality education and where specific subsets of the population may be disproportionately disenfranchised from the education system. The subjects of each chapter include both students and teachers and vary in outcome variables from test scores to preferences. The motivation to study education in these countries stems from understanding the role of education in advancing human development, and by extension, economic and political development. The aim of this dissertation, widely shared, is that by studying education, progress in poverty alleviation and gender equality can be more rapidly advanced through policies that support smarter resource allocation.

This dissertation combines five separate studies, set as chapters, into one body of work. The first two chapters use cross-sectional secondary data, where the final three chapters feature primary, short panel data collected by the author and his co-authors. Each chapter features one or two econometric methods to address endogeneity within the given sample populations. Some of these methodologies are rudimentary to the field of applied econometrics, such as ordinary least squares regression and difference in difference regression, while others, such as the double lasso regression and partitional clustering, represent contemporary developments in the field of machine learning.

The structure of the dissertation is as follows: Chapter 1 discusses the impact of orphanhood on test scores, driven primarily by the HIV-AIDS crisis in southern and eastern Africa. Chapter 2 investigates the correlation between more gender equal countries and the associated gender gap between boys' and girls' test scores. Chapter 3 is an experimental study comparting the use of simulations, comparted with traditional hardware, in physics education in Thailand. Chapter 4 is a collaborative study with other members of the TAOYAKA program which ran a randomized controlled trial to compare the effects of information and communication technology (ICT) against traditional teaching methods on learning outcomes for climate change awareness in Myanmar. Lastly, Chapter 5 studies the revealed preferences of teachers on the characteristics of job placements for rural schools in Myanmar.

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1 The Orphan Impact: HIV-AIDS and Student Test Scores from Sub-Saharan Africa[1]

1.1 Abstract

In sub-Saharan Africa over 52 million children are living with the death of one or both parents. Drivers of this parental mortality include afflictions at levels endemic to the region, including: HIV; malaria and other parasites; lower respiratory infections; diarrheal illnesses; and road accidents, among others (WHO, 2017). This paper examines the impact of orphanhood on learning outcomes among girls and boys in sub-Saharan Africa. By analyzing test scores for approximately 60,000 pupils in 14 countries, this we estimate the effect on student test scores by comparing paternal, maternal, and double orphans to non-orphans in the sample, specifically for the subjects of reading, mathematics, and HIV-AIDS knowledge. No previous study has analyzed how orphanhood might influence learning by using student test score data, making this paper's approach unique in the literature. This study employs two estimation techniques: Coarsened exact matching, following King et al. (2016), calculating the sample average treatment effect on the treated, while matching on students' family structure, household wealth, school resources, and geographic location; and double lasso (DL) regression, following Urminsky & Hansen (2016), applying machine-learning for variable selection with high-dimensional controls for regional and school identifiers, school location, and student age. Our results show both CEM and DL consistently report a significant negative impact of orphanhood on test scores among specific countries, especially those which faltered in addressing the HIV-AIDS crisis.

1.2 Introduction

In southern and eastern Africa, the high prevalence adult mortality has been attributed to causes ranging from: diseases, including HIV-AIDS; poor infrastructure, including roads and hospitals; and armed conflicts. Each of which has contributed to orphaning over 26 million children, a figure that has risen year to year (UNICEF, 2008, 2015).[2] Family networks in Africa are known to provide strong support to children who have lost a parent, however the scale of the orphan crisis has put considerable strain on these networks (Abebe & Aase, 2007; Kuo, Fitzgerald, Operario, & Casale, 2012; Ssewamala, Karimli, Han, & Ismayilova, 2010), leaving children open to physical, social, economic, and psychological vulnerabilities, in addition to an increased exposure to HIV infection (Foster, 2000; Ansell & Young, 2004; UNAIDS, 2015). Children who lose one or both parents are additionally less likely to obtain the same level of schooling than a child with both parents (Lloyd & Blanc, 2006; UNICEF, 2014), despite that schools can buffer the turmoil of orphanhood by providing psychosocial support and stability in the short term in addition to education that imparts important tools for improving lifetime earnings, health, and political participation (Bachman DeSilva et al., 2012; Ha, Salama, & Gwavuya, 2015; Ntinda, Maree, Mpofu, & Seeco, 2014; Urassa et al., 1997).

Numerous studies have sought to quantify orphans' education outcomes. They have done so by measuring indicators such as years of schooling, or other access related questions such as enrolment or attendance, details of which can be found in the next section. Unlike the previous studies which focused on school access and attainment, this paper, using the SACMEQ III dataset, is the first to estimate the effect orphanhood on education through an

[1] Authors: Blevins, Benjamin K.; Kawata, Keisuke

[2] This figure represents a subset of the 52 million orphans living in the whole of sub-Saharan Africa.

analysis of student test score data in southern and eastern Africa, including reading, mathematics, and an HIV-AIDS knowledge test.

To evaluate orphanhood on learning outcomes we first review the literature in section II, which focuses on the extent to which orphans are enrolling in school and their rates of attendance and lifetime years of formal education. In section III we present the data and the variables of interest for this study. In section IV the methodologies used, including ordinary least squares (OLS) regression, coarsened exact matching (CEM), and double lasso regression (DL), are detailed along with their limitations. Section V presents the results of the study, with section VI offering a conclusion to this paper with implications for future studies and policy.

1.3 Previous Literature

The death of one or both parents in childhood represents a tremendous loss to a child's wellbeing and opportunities, both short and long-term. The resulting trauma likely extends beyond the immediate changes (which may include the loss of the main income earner, relocation, change of the primary caregiver, or stigma), but may also include short-term effects such as: reduced school enrolment (Gertler, Levine, & Ames, 2004; Hampshire et al., 2015; Roby, Erickson, & Nagaishi, 2016; Smith-Greenaway & Heckert, 2013); reduced school attainment (Ardington & Leibbrandt, 2010; Shimamura, 2010); and poorer diet/clothes/shelter and child labor/abuse (Kidman & Palermo, 2016; Nyamukapa et al., 2010); and intermediate and long-term effects such as: fewer qualifications/skills and risky behaviors with sex/drugs/alcohol (Birdthistle et al., 2009; Mkandawire, Tenkorang, & Luginaah, 2013); and illness and poverty (Cluver, Gardner, & Operario, 2007; Crea et al., 2015; Meinck, Cluver, & Boyes, 2015). If resulting from an epidemic such as HIV-AIDS, widespread orphanhood can lead to a spillover effect disrupting human capital development throughout a given community (Beegle, de Weerdt, & Dercon, 2010; Bryant & Beard, 2016; Evans & Popova, 2015).

A significant driver of parental mortality generating the orphan crisis in this region is from HIV-AIDS (WHO, 2015). High rates of death also occur from traffic injuries and violence, especially for males, and in childbirth for females, leaving no demographic unaffected. However as many of the countries in the region collect only limited information on vital statistics of their populations, with unfortunately, much of it flawed (Jamison DT, Feachem RG, Makgoba MW, 2006).[3] Detailed, reliable, and comprehensive statistics on adult mortality in southern and eastern Africa remain in short supply leading to a degree of uncertainty in analyses, especially covering individuals of childbearing age, roughly from 15 to 44 years old (Masquelier, Reniers, & Pison, 2014; Rao, Lopez, & Hemed, 2006). With this understanding in mind, we approach the data seeking to control for covariates and confounding factors that is known to correlate with higher or lower learning outcomes, as controls for parental mortality do not feature in the literature.

[3] Examining the rates of paternal versus maternal mortality, the SACMEQ data contains on average 2.5 times the paternal mortality compared to maternal, with a low ratio of 1.8 (Namibia) and a high of 3 times (Kenya). This is consistent with other scholars' estimations using Demographic and Health Survey (DHS) data (1995-2000) on a slightly younger cohort (0 - 15 years old), closely matching the ratio of roughly double the rate of paternal to maternal mortality in seven of the fourteen SACMEQ countries (Ainsworth & Filmer, 2006; Bicego, Rutstein, & Johnson, 2003). These high rates of paternal mortality are not reflected in national health statistics of the World Bank, which shows an average rate of male mortality at only 1.1 times that of female mortality (World Bank, 2012). However the World Bank data address adult mortality (between 15 and 60 years of age) and therefore include adults who are no longer rearing their own children, and as such would not be reflected in the SACMEQ data. This suggests that paternal mortality is high when children are young enough to be enrolled in primary school, with maternal mortality 'catching up' later in the child's life.

Measuring the influence of orphanhood on learning outcomes can be divided into two related categories: 1) The extent to which orphans are accessing the classroom compared to non-orphans, that is, are the children in question enrolled in or attending school? 2) The learning gap between orphans and non-orphans in the classroom, that is, is there a significant difference in test scores between orphans and non-orphans? To date, the academic literature has largely focused on the former category, that is, orphan access to the classroom, measured in terms of enrolment or attendance (Lloyd & Blanc, 2006; Mkandawire et al., 2013; Nyamukapa et al., 2010; Shimamura, 2010; Urassa et al., 2013). This assertion is substantiated by Guo et al. (2012), who surveyed 23 peer reviewed studies related to orphans and schooling, specifically critiquing the absence of school performance data (for example, test scores), especially from researchers focusing on the African continent, a gap which this paper aims to address. Nevertheless, the studies noted above provide useful insight into the context of orphanhood in southern and eastern Africa; those of which that are especially relevant to this paper are discussed later in this section.

Prominent studies have unpacked orphan absenteeism in the classroom from associated covariates, highlighting other determinants. Case, Paxon, and Ableidinger (2004) affirm that after controlling for household wealth and the relatedness of their primary caregiver, orphans continue to face a significant disadvantage in school enrolment, that is, the more distant the relation to their caregiver, the greater the negative impact, with no significant difference observed in enrolment between boy and girl orphans.[4] That evidence is supported by more recent research (Ariyo, Mortelmans, & Wouters, 2019; Roby et al., 2016). Roby et al. (2016) studied five sub-Saharan countries and found that children living with non-relatives, including orphans, had the lowest school attendance rate. Ariyo et al. (2019) found similar evidence identifying socioeconomic status and the relatedness of the caregiver, among a metanalysis of studies, estimating well-being among children in foster care, including orphans. Ainsworth and Filmer (2006) find that despite substantial variation in orphan versus non-orphan enrolment between countries in southern and eastern Africa, few countries demonstrate any statistically significant enrolment disadvantage for orphans after controlling for economic and household characteristics. Where enrolment gaps were identified, these were significant on the axis of rich/poor rather than on the axes of boy/girl or orphan/non-orphan.[5] As a result, Ainsworth and Filmer recommend policies to support enrolment for poor children, rather than orphan-specific interventions. Hampshire et al. (2015) take a slightly different position when examining two countries (Ghana and Malawi), noting that cultural practices of foster case greatly impact orphan school attendance outcomes, where orphans living in very supportive communities (e.g., Ghana) can have better schooling outcomes than non-orphans living with non-relatives. Lastly, Spaull and Taylor (2015) in a study that included ten of the SACMEQ countries, indicate that between boys and girls, urban and rural schools, and wealthy and poor families, the strongest determinant of enrolment was wealth.[6]

Another important factor of parental mortality's influence on enrolment/attendance for the single orphaned child is the sex of the surviving parent. Two key studies are in agreement that paternal orphans are unlikely to experience significantly negative effects to their schooling, whereas a significantly negative impact is measured for maternal orphans. Evans and Miguel

[4] The study reviewed nearly 20 cross-sectional demographic and health survey (DHS) data from ten countries in sub-Saharan Africa, examining the enrollment rates of orphans adjusting for proximity of relatedness among their primary guardians.

[5] Cross-sectional data were used from over 100 household surveys representing over 50 countries spanning from 1992 to 2003, primarily from sub-Saharan Africa.

[6] Malawi, Zambia, Namibia, Lesotho, and Uganda each displayed significant gaps in enrollment between the first and fifth wealth quintile.

(2007) show a strong and significant decrease in school participation (defined as a combination of attendance and enrolment) with maternal orphans and no statistically significant decline among paternal orphans.[7] This impact on school participation was detectable in the immediate years preceding and following the mother's death, in the case of mortal illness. The findings of Evans and Miguel additionally demonstrate that children with lower academic achievement prior to being orphaned face lower school participation than students with high academic scores prior to parental death. Similarly, Beegle et al. (2010) in their study of children in Tanzania find no statistically significant effect on schooling for paternal orphans, however the impact of maternal mortality is clearly demonstrated to have an impact on children lasting into adulthood. The study observes a statistically significant negative causal effect on maternal orphans' educational access (and height) after controlling for covariates associated with learning outcomes using household and child characteristics.[8] As will be discussed further in the subsequent section on data and methodology, these finding, at least for Kenya and Tanzania, suggest a potential or endogenous selection bias for maternal orphans.

For both orphans and non-orphans, a child's capacity to access school remains highly relevant to education research and development policy in the African context. School access and quality are important issues affecting rural and urban areas alike, which supersedes the targeted needs of orphans and vulnerable children (V. E. Lee, Zuze, & Ross, 2005; Zhang, 2006). Noteworthy studies on orphans and education have sought to assess indicators such as years of schooling, attendance, and enrolment (Ardington & Leibbrandt, 2010; Beegle, De Weerdt, & Dercon, 2009; Evans & Miguel, 2007; Ha et al., 2015; Lloyd & Blanc, 2006; Nyambedha & Aagaard-Hansen, 2010). Test scores, in contrast, have not been included in this discussion, however with the information contained in the SACMEQ III dataset, this paper aims to target this most precise measure of student learning outcomes for orphans, albeit limited to the 6th grade cohort. As will be demonstrated, once these examples are adequately controlled for, we can demonstrate that among various countries, a substantial negative impact is measured for orphan scores.

1.4 Data

1.4.1 SACMEQ III

SACMEQ is a consortium of ministries of education founded in 1995 with the stated aim of assessing the quality of education in and among the participating African countries and realizing the Dakar Framework in Education for All (in part) through collaboration on data collection and dissemination between education ministries (Saito, 2011c).[9] Data for this study are drawn from the third SACMEQ (III) assessment, completed in 2011,[10] comprising information from 14 countries (including 15 ministries of education) and 61,396 pupils. The SACMEQ dataset focuses on pupils attending the 6th grade, irrespective of age, and includes

[7] The study accessed a panel dataset from rural Kenya covering approximately 20,000 children over a five-year period (1998-2002).

[8] Panel data were used from Tanzania consisting of two surveys (the first where 718 non-orphans were interviewed between 1991-1994, and the second survey where the same children, as adults, interviewed in 2004).

[9] The ministries of Botswana, Kenya, Lesotho, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland (Eswatini), Tanzania (Mainland), Tanzania (Zanzibar), Uganda, Zambia, and Zimbabwe.

[10] SACMEQ I (1995), included seven Ministries of Education (MoEs). The assessment captured reading test scores from approximately 20,000 learners; 3,000 teachers and 1,000 school principals. SACMEQ II (2000), included fourteen MoEs; assessing reading and mathematics for 40,000 learners; 4,000 teachers; and 2,000 school principals.

information on pupil background and school environment in addition to testing on reading, mathematics, and an HIV-AIDS knowledge test (hereafter HAKT).[11] Two of the ministries of education data were dropped (Seychelles and Mauritius) from the analysis due to the low prevalence of orphanhood, reducing the total number of children in the dataset to 56,392. For detailed figures on the number of children by orphan category by country, see Table 1.

[11] The reading test includes 55 questions, testing pupils' ability to read narrative prose, expository prose, and documents, ranging in difficulty from Level 1 (pre-reading) to Level 8 (critical reading). Mathematics includes 49 questions on numbers, measurements, and spatial data, ranging from Level 1 (pre-numeracy) to Level 8 (abstract problem solving). HIV-AIDS awareness includes 86 test questions including diagnosis/treatment, and myths and misconceptions.

Table 1. Number and percent of orphans by country in dataset

Country	Boy								
	Paternal		Maternal		Double		Non-orphans		Sub-total
Botswana	334	17.4%	109	5.7%	172	9.0%	1,300	67.9%	1,915
Kenya	327	14.2%	96	4.2%	148	6.4%	1,727	75.2%	2,298
Lesotho	364	19.8%	154	8.4%	260	14.1%	1,064	57.8%	1,842
Malawi	210	14.8%	97	6.8%	105	7.4%	1,005	70.9%	1,417
Mauritius	80	4.4%	33	1.8%	5	0.3%	1,682	93.4%	1,800
Mozambique	315	17.7%	103	5.8%	135	7.6%	1,227	68.9%	1,780
Namibia	452	14.7%	213	6.9%	290	9.4%	2,125	69.0%	3,080
Seychelles	21	2.8%	6	0.8%	1	0.1%	727	96.3%	755
South Africa	609	13.6%	253	5.6%	418	9.3%	3,200	71.4%	4,480
Swaziland	418	20.7%	158	7.8%	227	11.3%	1,214	60.2%	2,017
Tanzania (mainland)	289	14.0%	89	4.3%	96	4.6%	1,594	77.1%	2,068
Tanzania (Zanzibar)	324	12.3%	140	5.3%	163	6.2%	2,001	76.1%	2,628
Uganda	219	14.8%	96	6.5%	107	7.2%	1,057	71.5%	1,479
Zambia	91	7.3%	40	3.2%	15	1.2%	1,095	88.2%	1,241
Zimbabwe	262	19.9%	97	7.4%	152	11.5%	806	61.2%	1,317
	4,315	14.3%	1,684	5.6%	2,294	7.6%	21,824	72.5%	30,117

Table 1 *(continued)*

Country	Girl								
	Paternal		Maternal		Double		Non-orphans		Sub-total
Botswana	310	15.9%	90	4.6%	180	9.2%	1,373	70.3%	1,953
Kenya	265	12.4%	84	3.9%	128	6.0%	1,661	77.7%	2,138
Lesotho	506	21.1%	160	6.7%	304	12.7%	1,428	59.5%	2,398
Malawi	185	13.6%	86	6.3%	103	7.6%	990	72.6%	1,364
Mauritius	62	3.6%	16	0.9%	7	0.4%	1,639	95.1%	1,724
Mozambique	233	14.7%	110	7.0%	73	4.6%	1,164	73.7%	1,580
Namibia	473	14.3%	264	8.0%	340	10.2%	2,241	67.5%	3,318
Seychelles	19	2.6%	2	0.3%	1	0.1%	703	97.0%	725
South Africa	676	14.7%	252	5.5%	415	9.0%	3,248	70.7%	4,591
Swaziland	467	23.2%	175	8.7%	212	10.5%	1,159	57.6%	2,013
Tanzania (mainland)	328	15.4%	105	4.9%	87	4.1%	1,606	75.5%	2,126
Tanzania (Zanzibar)	349	13.0%	130	4.9%	152	5.7%	2,048	76.4%	2,679
Uganda	223	15.7%	90	6.4%	100	7.1%	1,003	70.8%	1,416
Zambia	120	7.7%	60	3.9%	14	0.9%	1,356	87.5%	1,550
Zimbabwe	311	18.3%	101	5.9%	192	11.3%	1,100	64.6%	1,704
	4,527	14.5%	1,725	5.5%	2,308	7.4%	22,719	72.6%	31,279

Source: Author's calculation based on SACMEQ III data.

Comparing SACMEQ III with UNICEF data on orphan rates in southern and eastern Africa yields the following distinctions:

- SACMEQ includes both over-age and under-age grade 6 students in the sample selection, corresponding to UNICEF data on national gross enrolment ratios (GER).
- GER is greater than 100% for the uppermost majority of countries from 2007 to 2017. This implies that children who are out of school during one school-year will likely have participated in previous years and/or will return in future years. This information is captured by SACMEQ through variables such as student grade repetition (37% of all students reported repeating at least one grade) and frequency of dropping-out (84% of

all students reported dropping out of school "sometimes" or "often"), allowing this paper to control for those variables.

- Orphans are over-represented in SACMEQ III compared with national statistics provided by UNICEF (see Appendix A), and, on average, are significantly poorer and have lower test scores than their non-orphan counterparts (See Table 2).

Important factors to address when analyzing SACMEQ are: 1) the data are cross-sectional and thereby do not provide information on the included children either before or after this particular slice of time. 2) the data is likely to be representative of 6th grade classrooms in the region, however, despite the abundance of over-age children in the sample, the data is not necessarily representative of all primary or secondary school children for the included countries. 3) the data were collected using a two-stage sampling design,[12] in effect, nesting the student data within the school/district/region/country. The resulting data points cannot therefore be treated as independent as unobservable characteristics (error terms) of respondents may be correlated with the student's geographic location, making standard OLS analysis untenable. To select methods for analysis, other studies of SACMEQ have used hierarchical linear modeling (Gee, 2015; Gustafsson, 2007; V. E. Lee et al., 2005), also known as multilevel modeling, however, given its limitations (Bryan & Jenkins, 2016; Gelman, 2006), this method this paper chooses coarsened exact matching (CEM) and double-lasso regression (DL), detailed in the methodology section.

This paper seeks to address the test score differences between orphans and non-orphans while controlling for covariates and potential confounding factors such as family wealth, school facilities, and existing gender differences, among others (Saito, 2011a). With this gap in the literature noted, the existing studies provide insights into the specific vulnerabilities experienced in countries in southern and eastern Africa.

Outcome variables

Comprising the outcome variables include individual boy and girl student test scores for the subjects of reading, mathematics, and HAKT.

Treatment variables

Following the literature and organizations such as UNICEF, three, mutually exclusive, types of orphan-status have been defined as the treatment variables: a child who has lost a father only ("paternal orphan"); a mother only ("maternal orphan"); or both parents ("double orphan"); with a reference category represented by a child with both parents living classified as ("non-orphan"). Children who reported not knowing the vital status of his or her father/mother/or both were classified as orphans, respective of the unknown parent's biological sex.

In this dataset of 56,392 children, 28,830 (51.1%) are girls. Of the total children, 27% are orphans, based on the definitions listed above. Individual countries show statistics for paternal and double orphans with rates above 20% and 10%, respectively. Furthermore, the dataset reports rates of orphanhood for either boys or girls at approximately 30% or greater for Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Uganda, and Zimbabwe.[13]

Dummy variables were separately created for boys and for girls to ensure that the results were purely disaggregated by sex, for example, under the category "girl maternal orphan," each girl who reported having a father who was living and a mother who was either deceased or

[12] The first stage identified schools in the target frame, with larger schools given a higher probability of inclusion. At this stage, pupil weights were applied to the inverse of the selection probability for each student. The second stage selected 25 students from the 6th grade classroom using computerized randomization (Murimba 2005).

[13] In 2018 Swaziland was renamed *Eswatini*, however this study will continue with *Swaziland* for consistency with the SACMEQ III dataset.

whose vital status was unknown was coded '1' where all other girls were coded '0', with all boys omitted.

1.4.2 Control Variables For CEM

Orphans in SACMEQ III are, on average, in a demonstrably poorer condition, both academically and materially, compared with their non-orphan counterparts. Hence, the control characteristics selected for CEM, listed in Table 2, are shown to correlate with both the outcome variable (test scores) and the treatment variable (orphan status), noted in the literature (Lee et al., 2005; Zhang, 2006; Lee & Zuze, 2011; Spaull, 2013).[14]

[14] Student/household characteristics include continuous, binary (dummy), and categorical variables, inclusive of: the child's age (in years); number of siblings; the parents' mean level of education represented by years of schooling (inclusive of the deceased parent); the number of selected pupil possessions (for example, radio, computer, study desk, etc.); the student's place of stay (home with family); whether the student speaks English at home (never, sometimes, most of the time, all of the time); whether the student receives extra tuition (yes/no); the frequency of homework given (1-2/month, 1-2/week, most days); whether the student has dropped out of school (never, sometimes, often); and if the student has repeated grades (never, once, twice, three or more years). The students' school-level characteristics include: the total school resources (a maximum of 22, for example: chairs, desks, workbooks, library, chairs, pencils, etc.); school location (isolated/rural, small town, city); and the student's school building condition (needs rebuilding/some major repairs, "poor"; some minor repairs/good condition, "good").

Table 2. Summary statistics for treatment variables by control variables for CEM

	Boy orphan			Girl orphan		
Control variables	Paternal	Maternal	Double	Paternal	Maternal	Double
Student/household characteristics						
Difference from mean						
Reading	-17.48***	-29.20***	-29.02***	-18.40***	-28.10***	-31.43***
Mathematics	-16.03***	-26.99***	-27.55***	-18.21***	-23.84***	-30.36***
HAKT††	-2.076	-9.324***	-14.24***	-2.711	-8.060**	-14.02***
Age (in years)	-0.423***	-0.578***	-0.606***	-0.303***	-0.462***	-0.466***
Number of siblings	-0.0485	-0.0306	-0.346***	-0.140**	-0.0426	-0.432***
Parents' mean education	-0.482***	-0.381***	-0.529***	-0.359***	-0.263***	-0.412***
Pupil possessions (0-13)	-0.984***	-0.728***	-0.946***	-0.873***	-0.664***	-0.828***
Live with family	-0.0144**	-0.0520***	-0.124***	-0.0147***	-0.0319***	-0.116***
Pupil dropout (never)	-0.0692***	-0.0842***	-0.106***	-0.0628***	-0.0814***	-0.0924***
Sometimes	0.0371***	0.0623***	0.0918***	0.0505***	0.0536***	0.0839***
Often	0.0322***	0.0219*	0.0147	0.0122	0.0278**	0.00842
Extra tuition (no)	0.0709***	0.0598***	0.0983***	0.0679***	0.0888***	0.0983***
Homework given (no)	0.00524	-0.00315	0.00557	0.00116	0.000759	0.00193
1-2/month	0.00909	0.0201**	0.00731	0.0148**	0.0154*	0.0150*
1-2/week	0.0188*	0.00733	0.00979	0.0320***	0.0185	0.00773
Most days	-0.0332***	-0.0243	-0.0227*	-0.0479***	-0.0346**	-0.0246*
Repeated grades (never)	-0.0654***	-0.0903***	-0.0824***	-0.0768***	-0.0931***	-0.0897***
Once	0.0374***	0.0458***	0.0387***	0.0521***	0.0699***	0.0479***
Twice	0.0198***	0.0323***	0.0316***	0.0217***	0.0135*	0.0245***
Three or more years	0.00825**	0.0122**	0.0122**	0.00304	0.00974**	0.0173***
Speak English at home (never)	0.0183**	0.0245*	0.0290***	0.0259***	0.0250**	0.0480***
Sometimes	0.0061	-0.00529	0.0263*	0.0168*	0.00446	0.0436***
Most of the time	0.00541	0.00156	-0.00644	-0.0189***	-0.00656	-0.0219***
All of the time	-0.0298***	-0.0207*	-0.0488***	-0.0238***	-0.0229**	-0.0697***
Home quality (4-16)	-0.887***	-0.781***	-0.897***	-0.729***	-0.768***	-0.750***
School characteristics						
Total school resources (0-22)	-1.064***	-1.043***	-0.754***	-1.007***	-0.913***	-0.510***
School location (rural/isolated)	0.0547***	0.0648***	0.0588***	0.0466***	0.0605***	0.0551***
Small town	-0.0159*	-0.00958	-0.00437	-0.0156*	-0.0208*	-0.0073
City	-0.0388***	-0.0552***	-0.0544***	-0.0310***	-0.0397***	-0.0478***
School building contition (good)	-0.0530***	-0.0372**	-0.0741***	-0.0509***	-0.0559***	-0.0468***
N	26,139	23,508	24,118	27,246	24,444	25,027

Note: the table presents figures for orphans against non-orphans using the t-test. Author's calculation.
† $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$
†† HIV-AIDS Knowledge Test

The coefficients in table 2 portray the mean difference between orphans compared with non-orphans in the following ways: lower test scores; their parent(s) (living or deceased) who achieved fewer years of education; having fewer personal possessions; are less likely to live with family; are more likely to have dropped-out of school; are less likely to have received extra tuition; are less likely to receive daily homework; are more likely to have repeated a grade; are less likely to speak English at home; are more likely to live in poor quality homes; and are more likely to attend schools with fewer resources, in rural or isolated settings, that are in need of total rebuilding or major repairs.

1.5 Methodology

1.5.1 Coarsened Exact Matching (CEM)

CEM, developed by Iacus, King, and Porro (2012), offers a robust estimation technique by optimizing covariate balance prior to estimating the treatment effect for treatment and control groups by exactly matching observation units on a set of predetermined covariates.[15] The included covariates should be based on units that predict changes in the outcome variable. Categorical variables can be matched exactly without researcher intervention, yet for continuous variables, matching takes place after these have been "coarsened" into substantively similar "bins." Each covariate bin is provided a numerical value, organized into strata containing at least one treatment unit and one control unit. The weighted values for each student in a stratum are calculated based on the total number of treatment and control units and the total number of matched control and treatment units. Unmatched units receive a weight of 0, thereby "pruning" them from the sample. After the matching, a weighted regression is applied to calculate the difference in means between the treated and control groups. Compared to various other matching methods, CEM benefits from reduced estimation error, mean square error, imbalance, and bias.[16] Table 3 provides the exact number of matches for each treatment category.

Table 3. Number of matched orphans using CEM

	Paternal orphans		Maternal orphans		Double orphans	
	0	1	0	1	0	1
All	45,152	8,449	50,349	3,252	49,042	4,559
Matched	15,512	5,169	9,962	1,982	18,608	3,488
Unmatched	29,640	3,280	40,387	1,270	30,434	1,071

Note: "0" implies non-orphan, and "1" implies orphan.

Table 3 indicates the number of matched orphans in the coarsened exacted matching (CEM) model used in this study.

[15] The observed characteristics included are: biological sex (male/female); age (10- to 27-years-old, measured in two-year increments), pupils' number of brothers and sisters (0-60, measured in two-unit increments); homework given (none/ 1-2 month/ 1-2 week/ most days); repeated grades (never/ once/ twice/ three or more); pupil home quality (lower-/ middle-/ upper-tercile); extra tuition (no/yes); speak English at home (never/ sometimes/ most of the time/ all the time); dropout of school (never/ sometimes/ often); parents' mean education (2-12 years, in two-year increments); living with family (no/yes); pupil possessions (0-13 items, measured in three-unit increments); school resources (0-22 items, measured in four-unit increments); and the school location (isolated or rural/ small town/ city).

[16] In contrast to other matching methods, such as Mahalanobis distance matching (MDM) and propensity score matching (PSM). For both MDM and PSM, the balancing of covariates occurs *after* the pruning of unmatched sample units, discarding valuable sample information. Compared to MDM- and PSM-type estimators (Iacus et al., 2012; King & Nielsen, 2016; King, Nielsen, Coberley, & Pope, 2011).

1.5.2 Double Lasso Regression

To evaluate robustness for the CEM results, we use a double lasso regression, following Urminsky and Hansen (2016) to "choose" which of the 2,317 variables in SACMEQ III to include in the estimation. With many variables correlating with both the outcome and treatment variables, biased parameter estimates are likely to occur through under- or over-selection of covariates. Omitted variables can artificially inflate the significance of the coefficient (Heckman, 2006) or produce a suppression effect (David, Jennifer, & Chondra, 2000). To support research integrity (Simmons, Nelson, & Simonsohn, 2014), DL regression automates the inclusion of covariates, reducing bias.

Building on the lasso-type[17] method that selects variables to improve robustness for treatment level (independent) effects (Belloni, Chernozhukov, & Hansen, 2013; Tibshirani, 1996), the double lasso additionally selects for covariates of the outcome (dependent) variable. As described in Urminsky and Hansen (2016): 1) The first lasso regression (Eq. 1) identifies and keeps non-zero coefficients for variables that predict the outcome variable.

$$Y_i = \alpha_0 + \alpha_1 W_{i1} + \ldots + \alpha_K W_{iK} + \varepsilon_i \quad (1)$$

2) The second lasso regression (Eq. 2) keeps non-zero coefficients for variables that predict the focal treatment variable.

$$X_i = \delta_0 + \delta_1 W_{i1} + \ldots + \delta_K W_{iK} + \varepsilon_i \quad (2)$$

3) Using the identified covariates in the first and second lasso (W_{ik}), the model fits a linear regression (Eq. 3) from the outcome variable on the focal treatment variable, with *A* representing the combination of non-zero coefficients.

$$Y_i = \beta_0 + \beta_1 X_{i1} + \Sigma_{k \in A} \beta_{K+1} W_{ik} + \varepsilon_i \quad (3)$$

Using STATA's *pdslasso* command to operate the DL regression, we include the following high-dimensional covariates a priori: a region identifier; a school identifier; the school location (rural, small town, and city); and the student age.[18]

1.6 Results

This section includes findings for both CEM and DL regression. Interpretations will be offered at the end of the section after providing a description of the results.

[17] Or LASSO: least absolute shrinkage and selection operator. The single lasso extends the standard linear regression by introducing a penalty term for variables that are uncorrelated with the outcome variable, minimizing their influence. Using the single lasso alone can introduce bias by the under-estimation of non-zero coefficients.

[18] The double lasso requires continuous predictors to be normalized as = (X–mean(X))/S.D.(X), with X equal to the student's age in months.

1.6.1 Coarsened Exact Matching Results

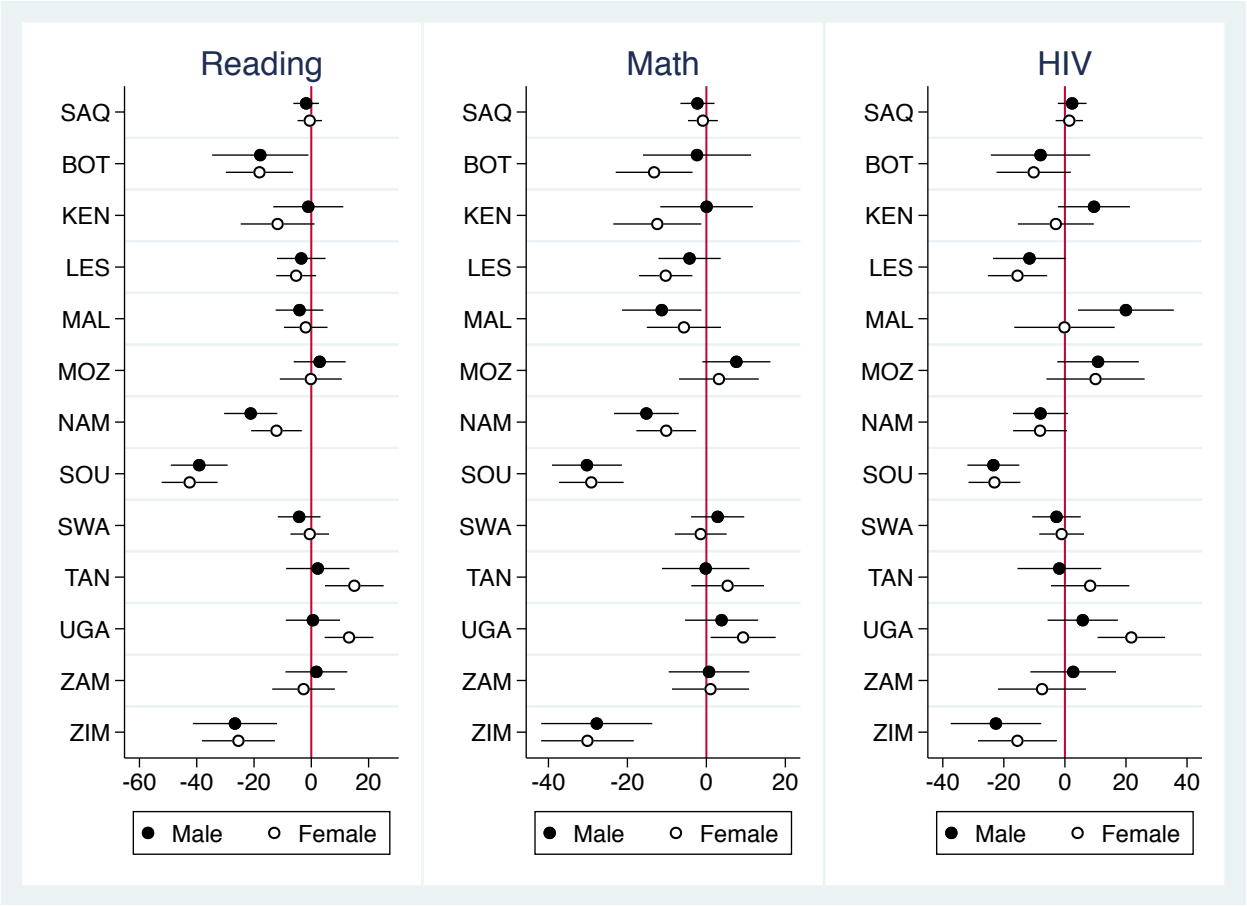

Fig. 1 Paternal orphan test scores compared against non-orphan scores displaying the sample average treatment effect on the treated (SATT) after controlling for covariates including student-, household-, and school-level characteristics using CEM. Error bars show 95% confidence intervals.

For paternal orphans (Figure 1) we observe statistically significant (higher) scores across all three subjects only among girls in Uganda. Countries in which orphans demonstrate negative disparities across all subjects include South Africa and Zimbabwe. For the subjects of reading and mathematics, significantly negative results are observed for Botswana (girls) and Namibia (both sexes).

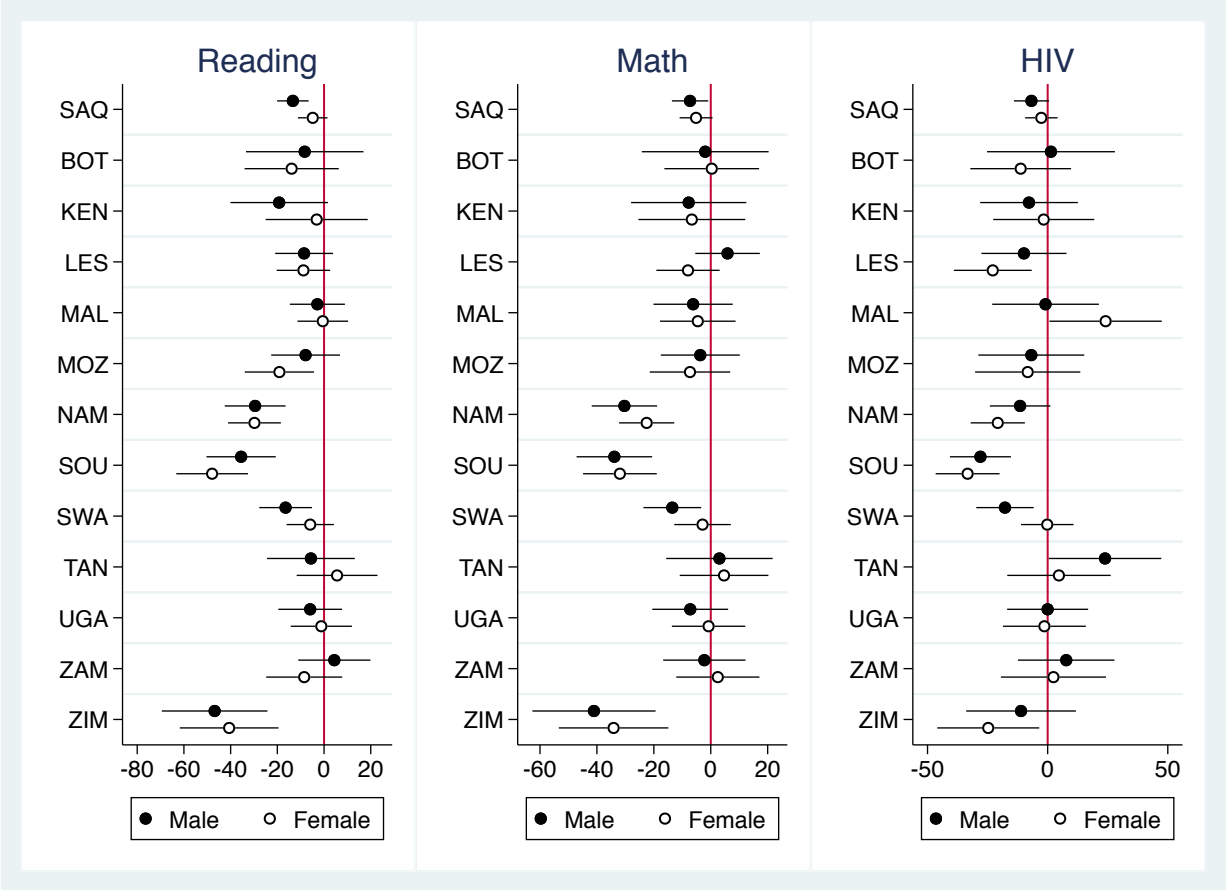

Fig. 2 Maternal orphan test scores compared against non-orphan scores displaying the SATT after controlling for covariates including student-, household-, and school-level characteristics using CEM. Error bars show 95% confidence intervals.

For maternal orphans (Figure 2), significantly below average results are demonstrated across the three subjects in Namibia, South Africa, and Zimbabwe (both sexes),[19] and in Swaziland (boys).

[19] For maternal orphan boys in Namibia and Zimbabwe, the HAKT point estimators are below average, however they do not meet the requirements for statistical confidence.

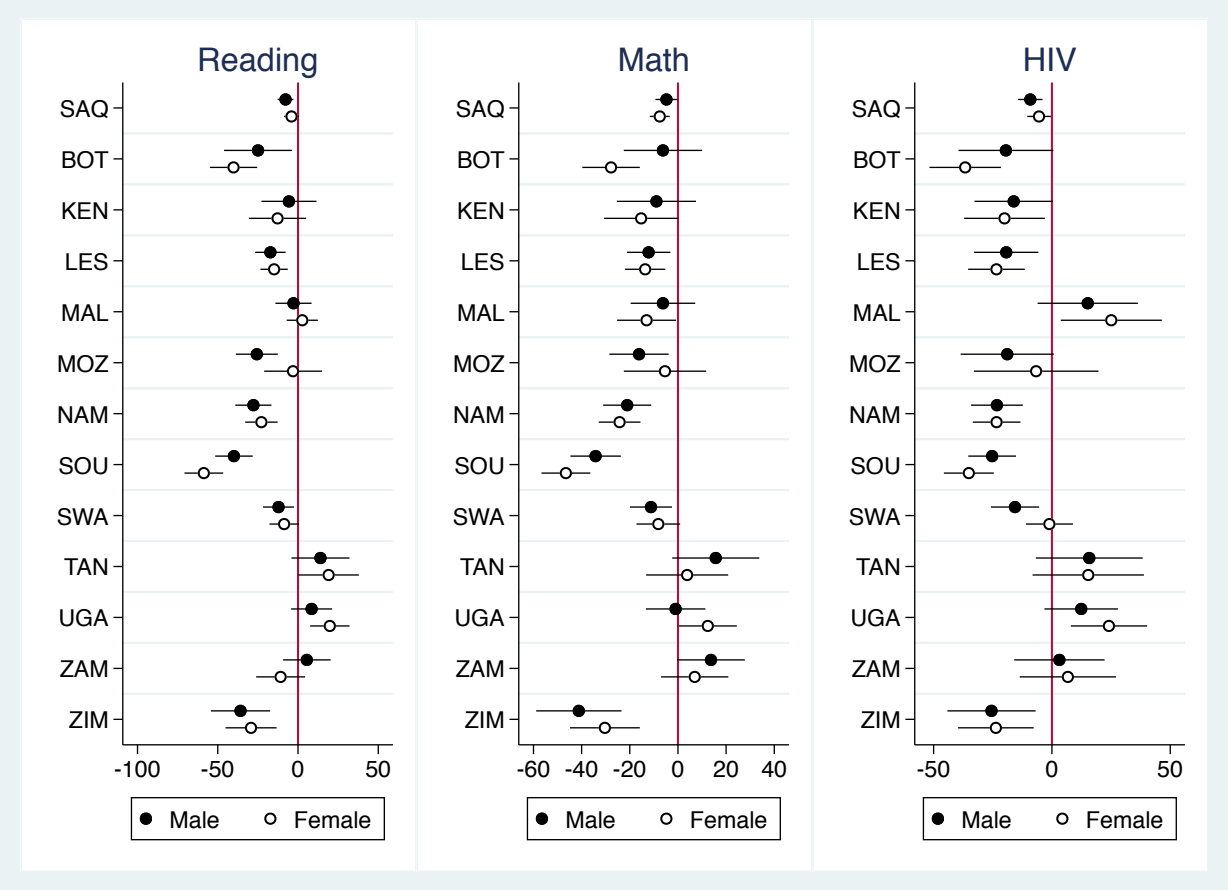

Fig. 3 Double orphan test scores compared against non-orphan scores displaying the SATT after controlling for covariates including student-, household-, and school-level characteristics using CEM. Error bars show 95% confidence intervals.

Consistent with the CEM results in Figures 1 and 2, double orphans (Figure 3) show frequent below average results across the three subjects: Botswana (girls); Lesotho (both sexes); Namibia (both sexes); South Africa (both sexes); Swaziland (boys); and Zimbabwe (both sexes). In most cases the point estimators are below average with the confidence intervals consistently narrower compared with the results from the paternal and maternal orphan CEM results, implying a higher degree of certainty.

1.6.2 Double Lasso Regression Results

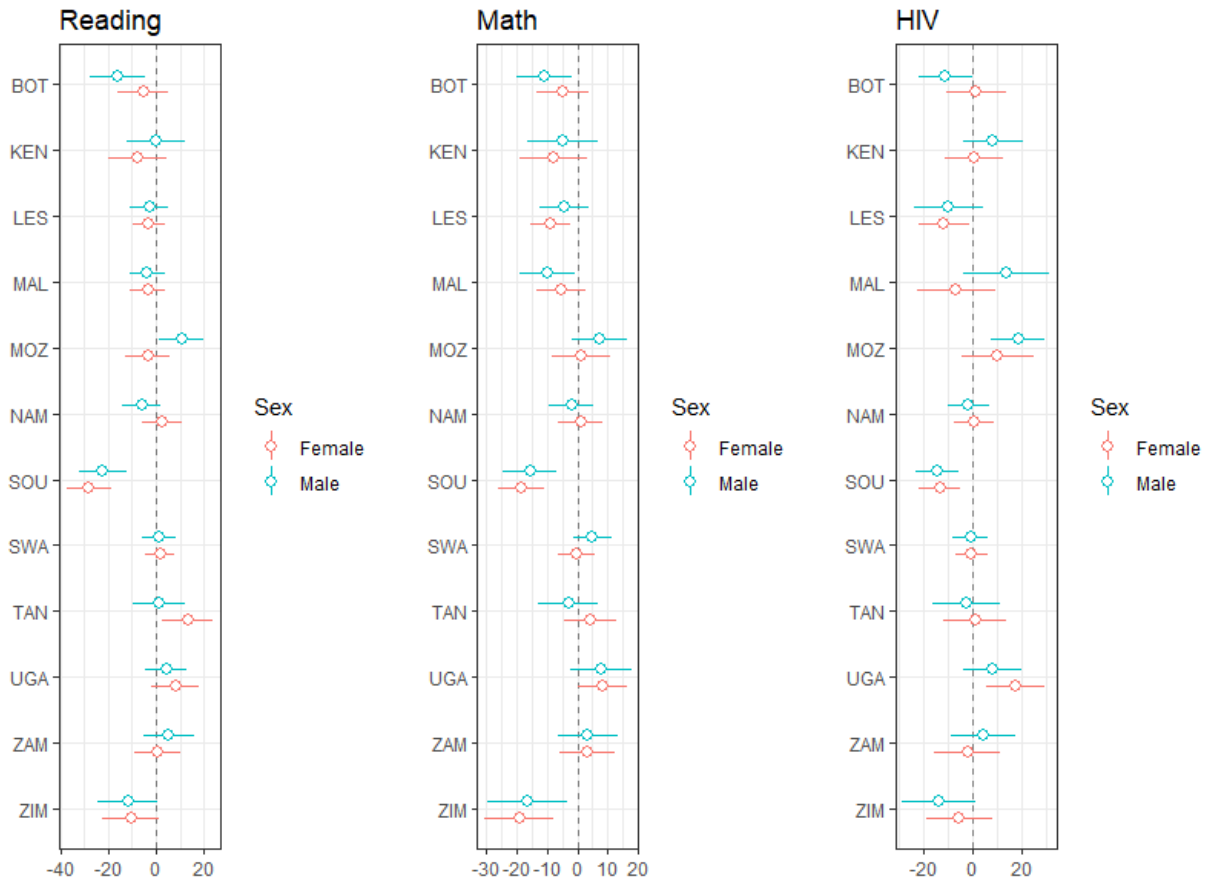

Fig. 4 Paternal orphan test scores compared against non-orphan scores displaying the average effect after using double lasso regression. Error bars show 95% confidence intervals.

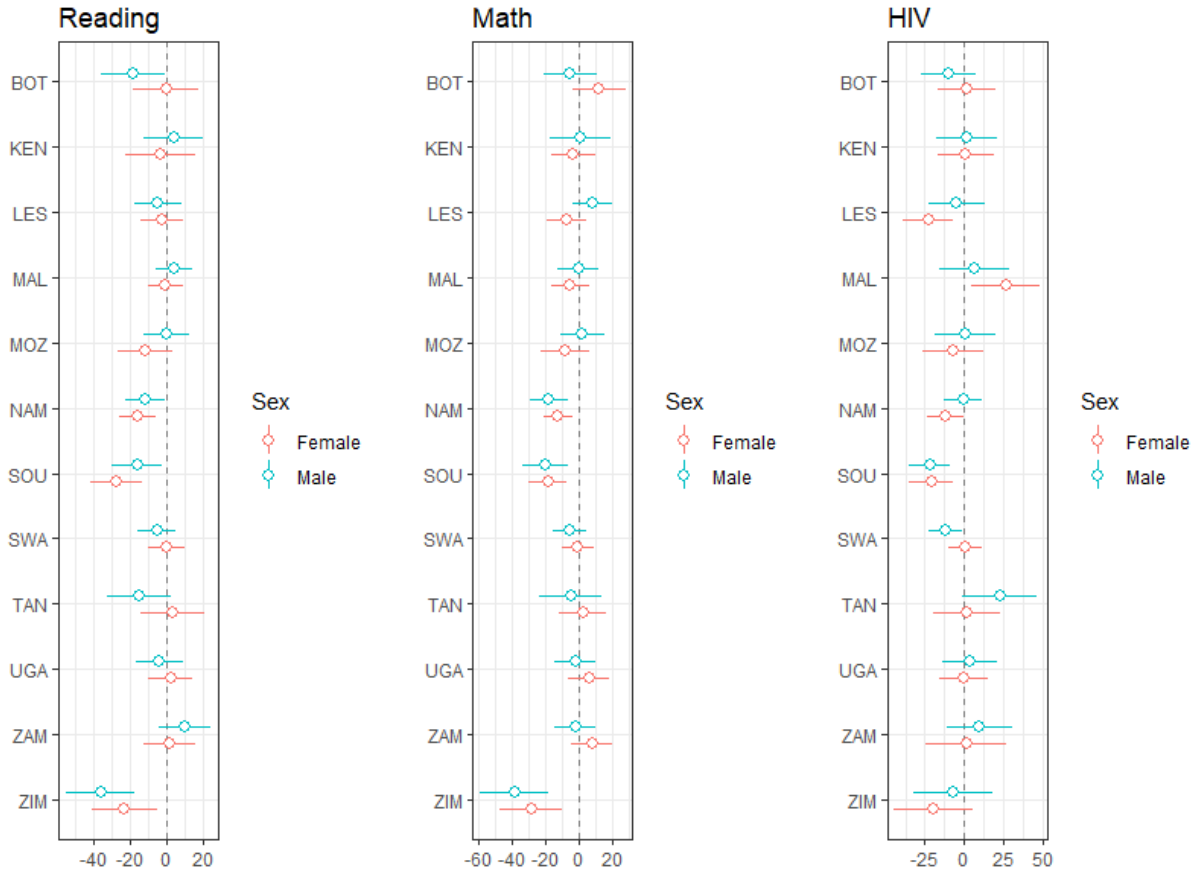

Fig. 5 Maternal orphan test scores compared against non-orphan scores displaying the average effect after using double lasso regression. Error bars show 95% confidence intervals.

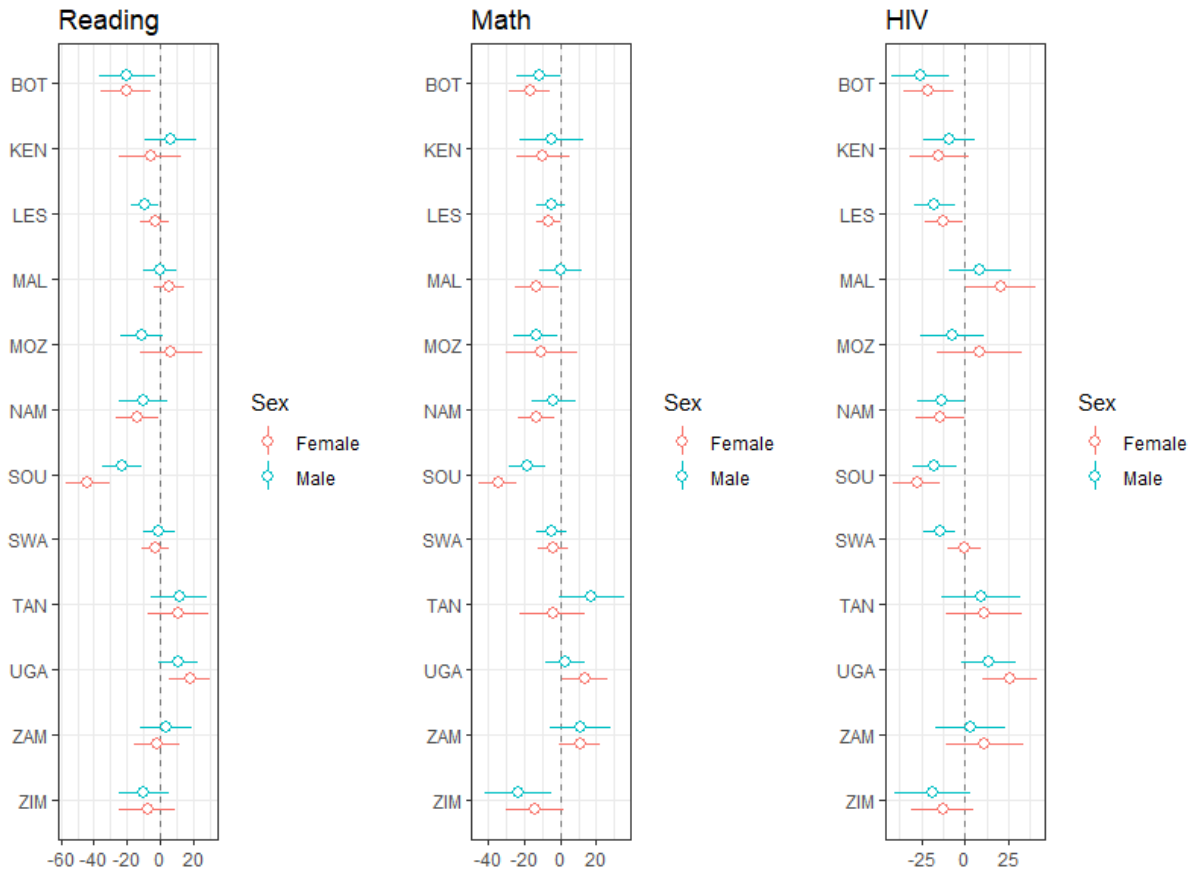

Fig. 6 Double orphan test scores compared against non-orphan scores displaying the average effect after using double lasso regression. Error bars show 95% confidence intervals.

Largely consistent with the estimates from CEM, the double lasso regression, presented in Figures 4, 5, and 6, finds high impacts on test scores for orphans across many of the SACMEQ countries. For both CEM and DL, estimates for South Africa show test scores that are well below average for each treatment category. Botswana, Lesotho, Namibia, and Zimbabwe similarly have between 40% and 50% of their treatment categories with significantly negative average scores. In contrast, Kenya and Zambia register no impact while Uganda reports several higher average scores among orphans.

To account for the negative impact on orphans in South Africa compared to the positive scores in Uganda, one might address first how governments in the region responded to the HIV-AIDS epidemic. While not all children are orphaned by HIV-AIDS, it represents a significant driver of mortality in these countries with significant carryover effects to families and communities. Comparing the rates and duration of HIV-AIDS with the respective country's test scores for orphans, an imprecise yet plausible causal relationship appears.

Data from 2008 to 2018 indicate that South Africa, with 12% of its population infected with HIV, has maintained the highest prevalence rate of HIV-AIDS in the world. Of the 3.8 million South African orphans, half were the result of HIV-related deaths (UNICEF, 2015). Among the countries of eastern and southern Africa in 2018, South Africa accounts for 29% of AIDS related deaths and 33% of new infections (UNAIDS, 2008, 2018).

Historically and politically, South Africa was ill-prepared to cope with the challenge of HIV. The disease was first reported in the country during the final decade of apartheid rule. This period was rife with civil unrest, social discrimination, distrust, and superstition. Each of which interfered with a cogent response to arrest the spread of the disease (Mills, Singh, Nelson, & Nachega, 2006; Skinner & Mfecane, 2004). The post-apartheid government, however, was similarly unresponsive to the crisis and reluctant to accept direct aid from foreign governments and non-governmental organizations, instead preferring to channel aid through government bureaucracies (Schneider & Stein, 2001). South African politicians wavered in accepting the gravity of the crisis and the requisite response. Characterizing the failure, one Minister of Health proposed treating HIV-AIDS through a combination of beetroot and garlic (Kapp, 2007). Contemporary studies indicate that, despite improvements, South Africa is unlikely to meet its 2020 HIV testing, treatment, and reduction goals (Naidu et al., 2017), further exacerbating parental mortality and orphanhood.

Policies directed by the South African government to support orphans have included: the Child Support Grant (1998), giving cash grants to caregivers (Motha, 2018); and the National Action Plan for Orphans and Children Made Vulnerable by HIV and AIDS (2009-2012), which offered family and community support. Given the scale of the HIV-AIDS epidemic in South Africa, these policies, while achieving numerous successes (Pillay, 2018), have evidently not managed to mitigate the impact on learning outcomes.

Uganda also reported its first cases of HIV in the early 1980s and was similarly slow to respond due to political upheavals. By the mid-1980s political stability was attained, yet by the end of the decade Uganda was considered among the worst HIV-AIDS affected countries in the world (Allen & Heald, 2004). Unlike the response in South Africa, the government in Uganda, including a very vocal president, was focused on arresting the advance of the disease (Parkhurst, 2012). Non-governmental organizations were encouraged to enter the country to provide direct support, encouraging open discussion to reduce stigmatization and promote behavior change by sensitizing its citizens on measures such as sexual monogamy, condom usage, and sterile needles for intravenous injections (Bessinger, Katende, & Gupta, 2004; Takada et al., 2014).

In addition to keeping parents alive through informed government policy, Uganda has also directed programs for the education for orphans and vulnerable children (OVC). Uganda has implanted the National OVC Policy, in 2004, among others. While still lacking, policies such as these have ensured that 90% of orphans have at least intermittent access to education (Olanrewaju, Jeffery, Crossland, & Valadez, 2015). A further contribution to the higher scores of paternal and double orphan girls in Uganda (Figures 2 and 3) may be found in Yamano et al. (2006) in that orphaned children were more likely to live in women-headed households, especially with women who have higher means to support additional children. This study also found that orphaned children in Uganda of primary school age were not found to be under-enrolled in school compared to non-orphan children, a feature the researchers attributed the successful implementation of Universal Primary Education.

In the middle of the spectrum for both lower orphan test scores and HIV-AIDS mortality, are Namibia and Botswana. Both countries' test scores for orphans were largely below average compared with non-orphans. For Botswana the lower scores clustered mainly around paternal and double orphans and, for Namibia, with maternal and double orphans. At the outset of the HIV epidemic, both countries seemed to be well positioned to fight the spread of the disease due to being middle income countries with relatively small, homogenous populations (UNAIDS, 2008). Social stigma, discouraging open discussion of the disease, and negative associations with prevention measures, such as condom usage, hampered effective

prevention efforts leading to high mortality and HIV prevalence in both countries (Allen & Heald, 2004; R. A. Smith & Niedermyer, 2009).

Namibia acted to support orphan school attendance through the National Plan of Action (2006-2010), led by the Ministry of Gender Equality and Child Welfare, with over 50,000 children receiving monetary aid and over 100,000 accessing school feeding programs (Biemba, Walker, et al., 2009). Evidence suggests that such efforts supported low school attrition among orphans and other vulnerable children (Coneus, Mühlenweg, & Stichnoth, 2014), despite remaining gaps (Mushaandja & Ashton, 2013).

Policies implemented by Botswana to support orphans include: The Short-Term Plan of Action for the Care of Orphans (1999); and the National Guidelines on the Care of Orphans and Vulnerable Children (2008), among others.

Estimates for Kenya and Zambia show no significant impact on test scores due to orphan status. Research on orphans and vulnerable children in these countries provide explanatory evidence: Kenya, with 3% of the population living with HIV, reports that over 90% of children surveyed have attended school,[20] with conditional cash transfers and other instruments supporting orphans and vulnerable children to stay in school (V. C. Lee et al., 2016). Zambia, with 6% of the population living with HIV, has similarly enacted several policies directly targeting aid to orphans and vulnerable children, with education a key component of the support (Biemba, Macwan'gi, et al., 2009).

Lastly, in Swaziland, test scores for orphans are significantly below average for girls (maternal and double orphans, for all subjects) under CEM and for boys (maternal and double orphans, only for HAKT scores) with DL regression. While these methods have captured an impact, given the very high prevalence rates of HIV and the associated adult mortality (van Schalkwyk et al., 2013), the impact on orphan grades is likely suppressed due to an omission bias. Paternal orphans represent 20% of the Swaziland orphans in SACMEQ III yet for the years 2005 and 2010, female mortality and HIV prevalence was significantly higher than men, suggesting that the measured impact would be greater were these unobserved children included (UNAIDS, 2018).

1.7 Conclusion

Using data from the Southern and Eastern Africa Consortium for Monitoring Education Quality (SACMEQ III) we use coarsened exact matching (CEM) and double lasso (DL) regression to identify the impact of orphanhood on student test scores for paternal, maternal, and double orphans compared to non-orphans. Each of these methodologies offers a unique and robust counter to spurious correlations. Under CEM, discretely matched variables included student-, household-, and school-level characteristics to estimate the sample average treatment effect on the treated. For DL regression we employ STATA's *pdslasso* algorithm to automatically select from all possible covariates included in the dataset. Using only the high-dimensional controls of school-identifier, region-identifier, school location, and student age, the technique minimizes covariate selection bias.

This paper finds a noteworthy, and arguably causal, link between orphanhood and lower average test scores. Across SACMEQ III, double orphans have the lowest average score gap for both boys and girls, followed by maternal and paternal orphans. Numerous cases demonstrate significantly lower mean test scores across all three test subjects (reading, mathematics, and HIV-AIDS awareness). These results correspond closely with the respective

[20] For double orphans, 96.3%; single orphans, 93.9%; and vulnerable children, 90.6%.

country's HIV-AIDS response from the outset of the disease in the early 1980s through the first decade of the 2000s. For South Africa, where HIV-AIDS is still not under adequate control, grades for orphans are especially below average. In contrast, Uganda has implemented a largely successful campaign to suppress new transmissions and to provide support to those with HIV and those affected, including orphans and other vulnerable children. This corresponds closely with the lack of below average test scores among Ugandan orphans and partially explains the higher than average scores among some female orphans. In the middle of spectrum, in terms of the success in countering the spread of HIV and the diminished grades among orphans, are countries such as Botswana and Namibia. Each county appeared well positioned to resist the advancing of the HIV epidemic due to relatively prosperous, organized, and homogeneous societies, yet they struggled to arrest the advance of the disease. Future studies can evaluate how student test scores, especially among orphans, have changed in relation the progress made against the HIV virus.

1.8 Author contribution

The first author (Blevins) analyzed the data and wrote the paper. The second author (Kawata) assisted in the selection of the methodology and provided comments on the text.

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2 Social Gender Inequality and the Gender Gap in the Classroom: Evidence from Sub-Saharan Africa[21]

The gender gap in education is not limited to the subject of mathematics or only to be found in high-income countries, and its repercussions can have generational consequences. Previous literature has sought to explain why the gender gap persists in most high- and middle-income countries vis-à-vis social gender inequality without drawing from similarly comprehensive data from African context with its very unique gender gap landscape. This paper examines the correlation between more gender-equal countries and the gender gap in student test scores for reading, mathematics, and HIV-AIDS awareness in southern and eastern Africa. We use ordinary least squares and quantile regression to analyse student information from the SACMEQ III dataset in comparison with measurements of social gender inequality such as the Gender Inequality Index and the Global Gender Gap Index. As such, this analysis draws on data from roughly 60,000 African students, and includes test scores from reading comprehension and HIV-AIDS awareness, a unique subject that is critical for health, wealth and wellbeing on the continent. Our study finds that in each subject at every quantile, the gender gap displays a robust inverse relationship with more gender-equal countries, specifically demonstrating higher educational performance among girls. With youthful populations and burgeoning economies, these countries in Africa have much to gain from addressing the gender gap in education. These findings encourage policymakers to consider how the social condition of gender-equality might influence the academic performance of students, especially for girls.

[21] Authors: Blevins, Benjamin K.; Kawata, Keisuke

2.1.1 Introduction

Closing the classroom gender gap for both girls and boys is a persistent challenge to educators and policymakers internationally despite that equal rights to education for all children has remained near the top of global development priorities since declared a fundamental human right.[22] In addition, the United Nations 2015 Millennium Development Goals and the subsequent 2030 Sustainable Development Goals both share strong language linking the empowerment of women and the promotion of gender equality as integral to achieving basic human rights and creating a development paradigm that is sustainable. The World Bank's World Development Report reiterates this point adding that gender based inequalities not only affect women and girls, but affect society as a whole, impeding the overall achievement of global development goals (World Bank, 2012).

While some scholars (e.g., Fryer Roland G. and Levitt, 2010; Guiso et al., 2008) have tested the degree to which social gender inequality, at the national level, correlates with the student-level gender gap, this research is limited to two datasets (PISA and TIMSS)[23] originating from mainly high and middle income countries and largely overlooks the African context, which displays remarkably different trends in gender-based learning outcomes compared to OECD countries. Furthermore, the outcomes of these studies have not lead to consensus and have thus motivated this paper to explore the theme using student-level data from southern and eastern Africa's SACMEQ III dataset.[24]

This study contributes to the existing literature through focusing on more than a dozen sub-Saharan countries where the gender gap has received less attention despite the severity of the problem (e.g., Bedard & Cho, 2010; Dickerson, McIntosh, & Valente, 2013; Ellison & Swanson, 2010; Filmer, 2005; Glick, 2008; Pope & Sydnor, 2010). Education is strongly correlated with wealth, health, and political engagement (E. A. Hanushek & Woessmann, 2008). Therefoer reducing the gender gap in these African countries, with youthful populations and broad potential for economic development, stands to improve, both socially and economically, the long-term achievements for much of the population.

Important studies have compared student test scores to national social gender inequality indexes (see, for example, Fryer & Levitt, 2010; Guiso, Monte, Sapienza, & Zingales, 2008). This paper takes a further step by estimating the effects of social gender inequality on a wider range of the test score distribution by using both ordinary least squares (OLS) regression and quantile regression, following Koenker & Bassett (1978). In our results we obtain the conditional quantile effects of social gender inequality on student test scores. To reduce sample selection bias, the main advantage of our methodological approach is that it reduces sample selection bias. This is achieved through region-level fixed effects that account for the wide variation of test scores within a given regions, as well as student-level (such as parental education and household possessions) school characteristics (such as teacher training and learning materials) included as covariates.

The outcome variables in our analysis are taken from the SACMEQ III dataset. This dataset provides internationally comparable cross-sectional test score data for approximately 60,000 6th grade students from 14 countries covering reading, mathematics, and HIV-AIDS

[22] For instance, the United Nations Declaration of Human Right (United Nations General Assembly, 1948); Dakar Framework for Action (UNESCO, 2000); the Incheon Declaration (which states a commitment to equitable quality education for all (UNESCO, 2015)

[23] The Organization for Economic Cooperation and Development's (OECD) Programme for International Student Assessment (PISA) and the National Education Center for Education Statistics' (NCES) Trends in International Mathematics and Science Study (TIMSS).

[24] The Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ).

awareness; it also includes detailed background information regarding students and their schools. A detailed description of the SACMEQ data can be found in Section 3.1. The treatment variables of interest for this study are two measures of social gender inequality at the country level provided by the Gender Inequality Index (GII), elaborated upon in Section 3.2, developed by the United Nations Development Programme, and as a robustness check, the Global Gender Gap Index (GGGI) created by World Economic Forum, with more information in Section 3.3. As will be shown in Section 4, this heterogeneity of the academic landscape offers fertile ground for analysis of the country-level gender inequality ranking and the performance of the children vis-à-vis the gender gap.

The remainder of this study is laid out as follows: Section 2 presents the literature review, Section 3 describes the data and methodology, Section 4 explains the summary statistics and the estimation results, and Section 5 concludes the study.

2.2 Key issues from the literature

Studies examining the gender gap in education for sub-Saharan African countries are a relatively recent addition to the literature (V. E. Lee & Zuze, 2011; Lewin & Little, 2011; Spaull & Taylor, 2015; Taylor & Spaull, 2015), while middle and high income countries have been the subject of analysis (especially in mathematics) for decades (Ackerman, 2006; Goldin, 1990; Reilly, Neumann, & Andrews, 2015; Spelke, 2005). Research exploring correlations between social gender inequality at the national level and the school-level gender gap have contributed a novel perspective to the field by positing the influence that societal standards of gender equality might have on learning outcomes, studies that are, to date, limited to middle and high income counties (e.g., Fryer & Levitt, 2010; Guiso et al., 2008). This present study aims to extend the questions posed by Guiso et al. (2008) and Fryer and Levitt (2010) to the context of sub-Saharan Africa.

2.2.1 Changing trends in gender gap attribution

Previous scholars have contributed greatly to dispelling many myths associated with the gender gap. In doing so, compelling evidence has been brought to light as to why a gender gap exists and persists in varying dimensions across societies and within academic subjects (mainly reading and mathematics). The theories behind the gender gap have ranged from the micro to the macro, including: the biological sex of the student; the classroom environment; and the culture of the society. Of those drivers, explanations deriving from the former may have been the most contentious given the difficulty in parsing out societal influences. While evidence to date cannot support that biology impacts primary school-level learning outcomes, the debate has thus shifted to how biology might affect older test takers such as those at the secondary and tertiary levels of education, leaving the cause of the gender gap in primary education open to other factors (Spelke, 2005).

Without sufficient evidence for the gender gap found in biology, the student's personal environment and factors at the societal level became plausible explanatory sources. At the household or school levels, research from middle and high income countries, such as the United States, have produced studies suggesting the gender gap may result from micro-level gender stereotyping (Kiefer & Sekaquaptewa, 2007; Schmader, 2002; Spencer, Steele, & Quinn, 1999; Van Loo & Rydell, 2013). Others have considered macro-level sociocultural factors, such as women's roles and access in society (Hyde & Mertz, 2009; Nollenberger, Rodríguez-Planas, & Sevilla, 2016). Societal explanations –at the centre of this paper's thesis– have received much scholarly attention, presenting evidence both for and against correlation with the gender

gap. However this conclusion is without consensus, and thus new hypotheses continue to be offered (Dickerson et al., 2013; Ellison & Swanson, 2010; Fryer & Levitt, 2010; Guiso et al., 2008; Hyde & Mertz, 2009; Pope & Sydnor, 2010; Stoet & Geary, 2013).

2.2.2 Country-level gender equality indexes and student test scores

Two relevant studies (Fryer & Levitt, 2010; Guiso et al., 2008) analysed the PISA dataset, containing test scores from students in high and middle income countries, to determine whether evidence exists of a positive relationship between social gender inequality (as measured by the GGGI) and the gender gap in mathematics test scores.[25] Guiso et al. (2008) used the PISA 2003 database to present evidence for a strong correlation between high GGGI index rankings and a lower gender gap between boys and girls. Across the 40 OECD countries in the study where GGGI scores were high (indicating greater gender equality), the gender gap in mathematics was low, if not eliminated or reversed. In the most gender-equal countries, such as Iceland, girls outperformed boys in both reading and mathematics. Girls outperformed boys in reading in all countries and had a higher comparative advantage in more gender-equal countries.

Fryer and Levitt's later research was able to match the findings when examining only the PISA 2003 data; however the results no longer held when expanding the data to include data from the Trends in International Mathematics and Science Study (TIMSS, 2003).[26] The TIMSS scores included many Middle Eastern countries that scored poorly on gender equality, but exhibited little to no gap in mathematics performance. Indeed, in countries such as Bahrain, Iran, Jordan, Palestine, and Saudi Arabia, girls had higher math scores than boys. An alternative hypothesis posed by Fryer and Levitt pointed to the high prevalence of same-sex classrooms (only secondary school was noted) in those Middle Eastern countries with higher-performing girls, indicating that such an environment might be especially conducive to girls' learning.[27] However, all of the Middle Eastern countries included also performed well below the international average for countries participating in the TIMSS assessment.[28] While perhaps surprising or even laudable that these countries can provide environments (such as same-sex classrooms) where girls can overachieve relative to boys within their respective countries, the absolute figures indicate that when compared internationally, these same girls are well behind.

[25] The Organisation for Economic Co-operation and Development (OECD)'s Programme for International Student Assessment (PISA)

[26] Established by the International Association for the Evaluation of Educational Achievement, the Trends in International Mathematics and Science Study (TIMSS) collects math and science scores from 4th and/or 8th grade boys and girls from 46 countries, excluding some European OECD countries and including many Middle Eastern and some north African countries.

[27] A later study noted that 4th grade is rarely segregated by sex in these Middle Eastern countries, where 8th grade will be mixed-sex if the country is more liberal and same-sex if more conservative (Ezzine, Thacker, & Chamlou, 2011).

[28] TIMSS 2003 reported 8th grade girls in Bahrain, Jordan, and the Palestinian National Authority outperforming their within-country boys by 33, 27, and 8 points, respectively, however underperforming compared to the girls international average by 50, 29 and 73 points, respectively. TIMSS 2007 echoed this pattern with additional Middle Eastern countries such as Oman, Qatar, Palestinian National Authority, Saudi Arabia, Bahrain, and Jordan with 8th grade girls outperforming within-country boys by 54, 38, 36, 23, 32, and 20 points, respectively, and the same girls underperforming compared to the international girls average by 54, 128, 68, 112, 39, and 15 points, respectively, Based on the author's calculation based on TIMSS 2003 and 2007 data.

2.2.3 The gender gap in sub-Saharan Africa

Unlike the gender gap patterns in many high-income countries, sub-Saharan Africa redefines how achieving equity for children's education might be attainable. Learning outcomes in core subjects such as reading and mathematics vary widely for boys and girls between national borders, urban and rural areas, post-conflict and emerging economies, with certain combinations seeming to promote learning for boys and/or girls, with other circumstances very much detracting from those desired outcomes. Scholars have identified many characteristics of the learning landscape to improve outcomes including understanding the impact of HIV/AIDS on families and young learners, the unequal distribution of school resources between urban and rural areas and between boys and girls, the impact of traditional and/or customary practices that favour the learning advancement of one gender over the other, and others (V. E. Lee & Zuze, 2011; V. E. Lee et al., 2005; Lewin & Little, 2011; Richardson et al., 2014; Saito, 2011b; Spaull & Taylor, 2015; Taş, Reimão, & Orlando, 2014; Taylor & Spaull, 2015; UNICEF, 2014). The official SACMEQ working paper on gender differences and learning outcomes (Saito, 2011a) highlighted some of the variables commonly associated with learning inequalities. Influential factors include the student's socio-economic status, school location (urban versus rural), access to resources both at home and in school, family structure, etc. In section 3 of this paper, many of these factors are included in a basic analysis to differentiate gender disparities that differ significantly from zero. One aspect that has not undergone analysis prior to this present study is the relationship between social-gender equality at the national level, and the gender gap among children at the individual level following Fryer and Levitt (2010) and Guiso et al., (2008).

Both the studies by Fryer and Levitt (2010) and Guiso et al., (2008) raise interesting questions as to what a similar analysis would produce when focused on very different societal conditions present in the African countries assessed by SACMEQ. As Section 4.1 demonstrates, the gender gap in Africa has both strong similarities and differences when compared to the PISA and TIMSS data; Where in PISA and TIMSS one typically finds boys excelling in mathematics and girls in reading, in SACMEQ some countries display similar results while other show the inverse. These differences offer compelling reasons for exploring the hypotheses set out by the previous studies with this African dataset, while adding new dimensions by way of subjects, social gender inequality indexes, and quantile analysis.

2.3 Data and Methodology

2.3.1 SACMEQ III

Data for this study were drawn from the third SACMEQ assessment,[29] released in 2007, encompassing test scores on reading, mathematics, and HIV-AIDS awareness for roughly 60,000 students, organized by 15 ministries of education—the ministries of Botswana; Kenya; Lesotho; Malawi; Mauritius; Mozambique; Namibia; Seychelles; South Africa; Swaziland; Tanzania (Mainland and Zanzibar); Uganda; Zambia; and Zimbabwe.[30] The focus of

[29] SACMEQ I (1995), included seven Ministries of Education (MoEs). The assessment captured reading test scores from approximately 20,000 learners; 3,000 teachers and 1,000 school principals. SACMEQ II (2000), included fourteen MoEs; assessing reading and mathematics for 40,000 learners; 4,000 teachers; and 2,000 school principals.

[30] To ensure compatibility with the 2008 GII (and the 2007 GGGI for robustness) our study excludes the Seychelles (GII and GGGI), Swaziland (GGGI), and Tanzania (GII) reducing the sample to approximately 57,000 students.

SACMEQ data collection is on students enrolled in the 6th grade, irrespective of age, including detailed information on each student's home life and school environment.

As a representative sample of the participating populations, SACMEQ III reflects the heterogeneity of the student enrolment and attendance ratios. As SACMEQ does not limit inclusion in test participation to a particular age, the gross enrolment statistics, rather than net enrolment, stands to be the more relevant reference, which, with the exception of Mozambique, is greater than 100% for all of the SACMEQ countries (UNICEF, 2008).[31] Despite gross enrolment being predominantly above 100%, other student characteristics may influence exclusion from school enrolment, such as: gender; location of residence (rural or urban); and or familial wealth. Spaull and Taylor (2015) found that in many of the SACMEQ countries, wealth was the strongest determinant of enrolment, more so than location of residence or gender, with only Lesotho (with higher girl enrolment) and Malawi (with higher boy enrolment) displaying significant differences by gender.[32]

[31] The enrollment rate is the percentage of children enrolled, regardless of age, divided by the population of the official age group corresponding to it.

[32] Malawi, Zambia, Namibia, Lesotho, and Uganda each displayed significant gaps in enrollment between the first and fifth wealth quintile.

Table 1
Average difference of covariates across all countries in dataset

Variable	Boys	Girls	Difference	Variable	Boys	Girls	Difference
Mother alive				1	0.27	0.26	0.01**
Dead	0.13	0.13	0	2	0.23	0.22	0.01*
Alive	0.87	0.87	0	3	0.15	0.15	0
Don't know	0.01	0.01	0	4	0.09	0.09	0
Father alive				5	0.04	0.05	-0.01**
Dead	0.2	0.2	0	6	0.02	0.03	-0.01**
Alive	0.78	0.78	0	>7	0.01	0.02	0
Don't know	0.02	0.02	0	Home possession			
Travel time to school				Newspaper	0.43	0.44	-0.01
<0.5km	0.29	0.28	0.01*	Magazine	0.36	0.37	-0.02*
>0.5 km	0.17	0.17	0	Clock	0.78	0.77	-0.01
Travel mode				Piped water	0.46	0.47	-0.01
Walk	0.85	0.87	-0.02**	Borehole	0.29	0.27	0.02**
Bicycle	0.03	0.01	0.02**	Table to study	0.74	0.76	-0.02**
Car	0.06	0.06	0	Bed	0.8	0.82	-0.02**
Bus/Truck/Van	0.05	0.05	0	Private study area	0.36	0.34	0.02**
Train	0	0	0	Bicycle	0.49	0.42	0.07**
Other	0.01	0.01	0	Horse cart	0.16	0.16	0
Birth year				Car	0.26	0.27	-0.01
1988	0.01	0	0.01**	Motorcycle	0.12	0.1	0.02**
1989	0.01	0.01	0	Tractor	0.08	0.07	0.01**
1990	0.04	0.02	0.02**	Electricity	0.47	0.46	0.01
1991	0.06	0.04	0.02**	Refrigerator	0.35	0.35	0.01
1992	0.13	0.1	0.03**	Air conditioner	0.1	0.1	0.01*
1993	0.17	0.16	0.01**	Electric fan	0.24	0.23	0.01
1994	0.22	0.22	0	Washing machine	0.18	0.17	0.01
1995	0.24	0.3	-0.06**	Vacuum cleaner	0.12	0.11	0.01*
1996	0.11	0.15	-0.03**	Computer	0.14	0.13	0.01*
1997	0	0	0	Internet	0.1	0.09	0.02**
Number of brothers				Radio	0.87	0.87	0.01
None	0.2	0.2	0	TV	0.48	0.48	0.01
1	0.26	0.28	-0.02**	Video tape player	0.26	0.24	0.02**
2	0.22	0.24	-0.02**	Video disc player	0.33	0.31	0.02**
3	0.15	0.15	0	Audio disc player	0.33	0.3	0.03**
4	0.09	0.08	0.01**	Audio cassette player	0.38	0.34	0.04**
5	0.06	0.04	0.02**	Ordinary camera	0.2	0.19	0
6	0.03	0.02	0.01**	Digital camera	0.13	0.11	0.02**
>7	0.02	0.01	0.01**	Video camera	0.14	0.13	0.02**
Number of sisters				Telephone	0.65	0.67	-0.02**
None	0.2	0.21	-0.01	Number of books	16.02	16.91	-0.89

** p<0.01, * p<0.05

Table 1 (cont.)
Average difference of covariates across all countries in dataset

Variable	Boys	Girls	Difference	Variable	Boys	Girls	Difference
Mother's education				School type			
No School, Some Adult Education	0.08	0.07	0.01**	Non-government school	0.83	0.81	-0.02*
No School, Some Adult Education	0.04	0.04	0	Government school	0.18	0.2	-0.02*
Completed Some Primary	0.14	0.13	0	School head age level	47.51	47.7	-0.19*
Completed All Primary	0.17	0.17	0	School head years of professional training	2.84	2.88	-0.04**
Some Training After Primary	0.05	0.05	0	Teacher/Student ratio	44.19	43.23	0.96**
Completed Some Secondary	0.11	0.11	0	Ratio of teachers with tertiary education	0.09	0.09	0.00
Completed All Secondary	0.12	0.12	0	Average staff years of training	2.42	2.44	-0.02**
Completed Training After Secondary	0.07	0.08	0	Ratio of Girls/Boys	0.49	0.5	-0.01**
Completed Some University	0.04	0.04	0	Teacher's gender			
Completed University Degree	0.07	0.07	0	Male	0.62	0.6	0.02**
I Do Not Know	0.13	0.14	-0.01**	Female	0.39	0.41	-0.02**
I Do Not Have a Father	0.04	0.04	0	Teacher employment status			
Father's education				Permanent Government	0.85	0.85	0
No school, no adult education	0.1	0.08	0.02**	Permanent, Not-government	0.03	0.03	0
No School, Some Adult Education	0.05	0.05	0	Temporary, Government	0.09	0.09	0
Completed Some Primary	0.17	0.17	0	Temporary, Not-government	0.05	0.05	0
Completed All Primary	0.2	0.21	0	Teacher's education			
Some Training After Primary	0.05	0.04	0	T_education1	0.12	0.12	0
Completed Some Secondary	0.13	0.14	-0.01*	Junior Secondary	0.08	0.07	0.01
Completed All Secondary	0.11	0.11	0	Senior Secondary	0.43	0.42	0
Completed Training After Secondary	0.06	0.07	-0.01*	A-Level	0.24	0.24	0
Completed Some University	0.03	0.03	0	First Degree	0.16	0.17	-0.01**
Completed University Degree	0.05	0.05	0	Teacher training			
I Do Not Know	0.09	0.09	0	None	0.05	0.05	0
I Do Not Have a mother	0.02	0.02	0	<1 YR TT	0.03	0.03	0
Source of light				1 YR TT	0.05	0.05	0
Fire	0.05	0.04	-0.01*	2 YRS TT	0.39	0.36	0.03**
Candle	0.2	0.2	0	3 YRS TT	0.26	0.27	-0.01**
Paraffin/Oil	0.32	0.33	-0.01*	>3 YRS TT	0.26	0.27	-0.01**
Gas	0.03	0.03	0	Years of teaching	12.99	12.88	0.11
Electric	0.42	0.41	0.01*	Teacher trained: English	0.66	0.66	0
No lighting	0.01	0.01	0	Teacher trained: Maths	0.85	0.85	0
				Teacher trained: Sciences	0.73	0.73	0
				Teacher trained: Social sciences	0.6	0.6	0
				Number of observations	24481	25380	

** p<0.01, * p<0.05

Similarly, Table 1 shows some of the characteristics of the heterogeneity within the dataset. When comparing mean differences of male and female background characteristics, statistically significant differences are revealed (definitions of these characteristics can be found in Table A-1 of the Appendix). We can observe that approximately one-third of the students are ages 11 and 12 (and are significantly more likely to be girls); another third are between ages 14 to 20 (significantly more likely to be boys); and the final third are ages 20 and older (significantly more likely to be boys). Put differently, despite that SACMEQ III has roughly equal amounts of boys and girls; the ages of the students are not equally distributed between the genders. For ages 10-13, girls comprise roughly 55%, while for ages 14 and above girls comprise 43% of the sample population.[33]

Given these characteristics of these data, is likely that girls with parents having little to no formal education are overly excluded from the sample, possibly having either never enrolled or having dropped out before the 6th grade. This would leave a larger portion of the girls who are closer to, or within, the 'normal' age-range for 6th grade, also coming from relatively wealthier households and having more educated parents.[34] Further evidence for this can be

[33] Based on the author's calculation.

[34] A second point of interest is the effect of classrooms comprised primarily of younger girls and older boys. While the effects of mixed-aged classrooms are outside the scope of this research, as age-appropriate girls constitute a minority within the classroom (at the aggregate level) this could indicate that an undesirable effect on grades is occurring despite the girls' relatively better household circumstances.

seen in Table 1, indicating that boys are more likely to have mothers and fathers with formal schooling at or below the primary school level, whereas girls are more likely to have mothers and fathers with formal schooling at or above secondary school, including tertiary levels. Regarding household wealth, boys are more likely to come from households with only fire for lighting, where girls are more likely to come from households that used paraffin or oil for lighting and are more likely to come from households with more electric appliances. As both parental education and household wealth are positively correlated with higher test scores for children (Dubow, Boxer, & Huesmann, 2009; D Filmer & Pritchett, 1999), we can postulate why many of the SACMEQ countries display exceptionally high test score high test score data for girls relative to their male counterparts.

2.3.2 SACMEQ Characteristics: Average and Quantile Differences of Test Scores

Before applying more sophisticated analysis to the SACMEQ data (such as OLS and quantile regression in section 4), a simple difference-in-means test is useful to understand where and to what degree gender gaps exist in these data. As will be apparent, analysing the gender gap based simply on differences in averages between the test scores of boys and girls yields results that are illuminating yet inconclusive. As a basis for comparison, in the following two tables we determine the difference in average test scores in each subject for boys and girls at the country level (Table 2), in addition to conducting comparisons at the 25th, 50th, and 75th percentiles (Table 3). Positive numbers in Table 2 and 3 denote girls' scores exceeding that of boys, while negative numbers denote boys' scores exceeding that of girls.

Table 2
Test score difference for females compared with boys by quartile

Country	Discipline	Ave.	25th q.	50th q.	75th q.	Country	Discipline	Ave.	25th q.	50th q.	75th q.
BOT	Reading	536	43.9**	34.6**	19.8**	NAM	Reading	502	18.41**	8.584**	17.84**
	Mathematics	521	0	12.9**	12.5**		Mathematics	475	0	0	-12.94**
	HIV/AIDS	501	25.8**	19.3**	11.8*		HIV/AIDS	503	8.696**	9.581**	11.64**
Obs.		3868				Obs.		6398			
KEN	Reading	548	-8.679*	0	-10.40*	SOU	Reading	497	9.729**	34.91**	36.91**
	Mathematics	562	-13.28**	-12.49**	-37.58**		Mathematics	496	15.53**	0	0
	HIV/AIDS	515	-8.991*	-10.17**	-25.06**		HIV/AIDS	501	17.39**	9.728**	24.02**
Obs.		4436				Obs.		9071			
LES	Reading	466	0	17.84**	8.584**	TAN	Reading	580	-18.31**	-20.22**	-12.88**
	Mathematics	474	0	0	0		Mathematics	555	-27.23**	-25.77**	-25.77**
	HIV/AIDS	463	8.254*	8.696**	9.875**		HIV/AIDS	576	-21.08**	0	-17.69**
Obs.		4240				Obs.		4194			
MAL	Reading	433	0	-9.252**	-8.870**	UGA	Reading	478	0	0	-8.679*
	Mathematics	447	0	-14.85**	-13.50**		Mathematics	479	-15.53**	-13.95**	-12.83**
	HIV/AIDS	508	-25.94**	-20.19**	-26.38**		HIV/AIDS	487	-8.549*	-9.728**	-11.79**
Obs.		2781				Obs.		5307			
MAU	Reading	570	43.49**	36.91**	12.69*	ZAM	Reading	434	0	-9.538**	-17.64**
	Mathematics	619	25.77**	25.20**	14.96*		Mathematics	435	0	-15.53**	-13.95**
	HIV/AIDS	450	17.83**	18.87**	21.37**		HIV/AIDS	490	-25.35**	-19.01**	-11.64**
Obs.		3524				Obs.		2895			
MOZ	Reading	477	-10.68**	-10.01*	0	ZIM	Reading	506	18.79**	8.584*	9.347
	Mathematics	484	-14.85**	-13.61**	-12.94**		Mathematics	517	0	0	0
	HIV/AIDS	505	-25.35**	-19.46**	-12.23**		HIV/AIDS	475	16.80**	9.286*	0
Obs.		3360				Obs.		3021			

Note: positive scores indicate girls have a higher score than boys
** p<0.01, * p<0.05

As the above tables and preceding sections suggest, learning outcomes are wide-ranging and do not exhibit a systematic or consistent gender bias favouring either boys or girls. The following paragraphs will detail where significant gender gaps exist based on the subject

of the test scores. Unlike scores from PISA or TIMSS where boys usually score higher in mathematics and girls usually score higher in reading, in several of the SACMEQ countries girls are the top scorers in all subjects, while boys clearly lead in achievement.

For the reading scores in several countries (e.g., Mauritius, Botswana, and Zimbabwe), girls not only over-perform within their country but also have scores that are above the SACMEQ average. Overall, the top-performing readers in terms of national average are Tanzanian boys; Tanzania also has the largest gender gap in reading (although Tanzanian girls perform very well, ranking third overall). In terms of the top quantile, Mauritian boys and girls tie for the highest scores, while Malawi and Zambia not only have the lowest country scores among the SACMEQ countries but also exhibit a significant gender gap.

In mathematics, girls from six countries (Mauritius, Kenya, Tanzania, Botswana, Zimbabwe, and South Africa) score above the SACMEQ average (500 points). Boys in five of these countries had scores that are above the SACMEQ average for boys; South African boys do not make the cut. Most remarkable in terms of ability are Mauritian girls, who score the most points of any gender group across the SACMEQ in mathematics, in addition to out-performing the boys of Mauritius, who rank second overall. In Botswana and South Africa, girls also outperform boys by a small yet statistically significant margin.

Regarding national average scores on the HIV-AIDS awareness section, only in Tanzania and Kenya do both boys and girls score above the mean; Tanzanian boys and Tanzanian girls occupy the first and second positions overall, respectively, with a minor gender gap of five points existing between them. By contrast, Kenya exhibits a much more serious gap in favour of boys. In several countries (Malawi, South Africa, Mozambique, Botswana, and Zambia) there are substantial gender gaps with only one gender achieving scores above the SACMEQ average. Although they generally exhibit small gender gaps, the least encouraging results were those from Uganda, Zimbabwe, and Lesotho; these countries exhibit the lowest average test scores and have national HIV-AIDS prevalence rates of 7%, 17%, and 23%, respectively. Again, the outlier is Mauritius, which has the largest gender gap favouring girls. In addition, both boys and girls score at the bottom of the HIV-AIDS awareness test results. Although, as Mauritius is a remote island nation with an HIV-AIDS prevalence rate of less than 1%, it is perhaps less critical than if the poor test results occur on the mainland of Africa.

2.3.3 Gender Inequality Index

The Gender Inequality Index (GII), launched in 2010 by the United Nations Development Programme (UNDP), seeks to quantify the human capital loss due to gender-based inequities. Although developed recently, scholars have used it to test the relationship between social gender inequality and the achievement of development goals (Brinda, Rajkumar, & Enemark, 2015; Ferrant, 2010, 2011; Gressard et al., 2015; UNDP, 2011; Wells, Marphatia, Cole, & McCoy, 2012). Closely modelled after the UNDP's Human Development Index, the GII aims to improve upon what was viewed as deficiencies with other indexes such as the Global Gender Gap Index, among others (Gaye, Klugman, Kovacevic, Twigg, & Zambrano, 2010). The GII captures inequality along three dimensions: the first accounts for both the ratio of representation in government and education, the second includes labour force participation, and the third reflecting ideals for women's health (detailed below). The normative position integrated into the index sought to favour countries in which men and women were treated equally regardless of levels of human development, in addition to measuring any inequalities between the three dimensions. These dimensions include: 'reproductive health', including adolescent fertility and maternal mortality; 'empowerment', measuring educational attainment (years of schooling for secondary and above) and parliamentary representation; and 'labour

market', addressing labour force participation. Following the HDI, the GII seeks to reflect the cost of gender inequality to human development by assigning a score ranging from zero (indicating zero inequality) to one (indicating total inequality). Unlike the Global Gender Gap Index, the GII exhibits a positive correlation with the HDI.

In the subsequent regression model, the outcome variables (student test scores in reading, mathematics, and HIV-AIDS awareness) and the treatment variables (the Gender Inequality Index and Global Gender Gap Index) both include education related components. This combination could present a problem of endogeneity. However, in the case of the GII, "education attainment" is measured by the number of years of school for boys and girls at the secondary and tertiary schooling levels, not individual test scores at the primary schooling level. According to UNICEF statistics on primary school attendance spanning ten years (2002-2012) for the countries included in SACMEQ, girls out-attend boys by an average of two per cent. The exceptions to this are in Mozambique and Uganda, where boys out-attend by a small margin. The gap was six per cent and one per cent for the 2002-2007 sample, respectively, though this was narrowed to effectively zero in the 2008-2012 sample (UNICEF, 2008, 2014). In contrast, SACMEQ data is equally comprised of boys and girls.

2.3.4 Global Gender Gap Index

To evaluate the robustness of our findings using the Global Inequality Index, we also employ the Global Gender Gap Index (GGGI). The GGGI features prominently in many recent studies related to social gender inequality and education (Dickerson et al., 2013; Fryer Roland G. & Levitt, 2010; Guiso et al., 2008; Hyde & Mertz, 2009; Nollenberger et al., 2016) though not always with effectual correlation. The GGGI was created by the World Economic Forum (WEF) in 2006 to target and measure gendered inequality among state actors.[35] The GGGI has four sub-indexes: economic participation and opportunity, which calculates labour force participation rates, gender-based remuneration gaps, the ratio of women in government and business leadership, etc.; educational attainment, which captures adult female over male literacy rate, and the sex enrolment ratios in primary, secondary, and tertiary education; health and survival, which measures the "missing women" phenomena prominent in countries with strong male-child preferences, life expectancy, etc.; and political empowerment, which collects data on the ratio of women to men in government, etc.

Similar to studies comparing within-country gender gaps, the GGGI measures gaps rather than absolute achievements. For this it has received criticism as certain indicators, such as income and life expectancy, could be better served by using absolute figures, expressing more poignantly the status of men and women in that country. This structure results in lower-income countries, such as Lesotho or Belarus, with relatively limited socioeconomic opportunities for its citizens (regardless of gender), being ranked above developed countries, such as the United States, Switzerland, France, or Luxembourg (Gaye et al., 2010). For other indicators (such as literacy, labour force participation, seats in parliament, and school enrolment) the use of ratios aptly captures the particular country's gender situation. Contrary to the GII, the GGGI assigns a score of 0 to countries with a total lack of gender parity, and a score of 1 for perfect parity.

For the GGGI, "education attainment" poses little risk of endogeneity as adult literacy ratios and sex ratios of student enrolment do not directly correspond with learning outcomes such as mathematics and HIV-AIDS awareness. Furthermore, in a study of ten SACMEQ

[35] WEF is a Swiss-based not-for-profit foundation that utilizes public data from the International Labour Organisation, the UNESCO Institute for Statistics, and the US Central Intelligence Agency, among others.

countries measuring the effectiveness of education for enrolled students, Spaull and Taylor (2015) state that performing at grade-level is somewhat rare, with the majority of enrolled students performing below grade level, and with a sizeable minority functionally illiterate and innumerate.

2.4 Methodology

The following population model is employed to estimate the coefficient representing the gender-based difference in test scores for each subject:

(1) $$E[Test\ score_{irc}|Gender_{irc}, GII_c, X_{irc}] = \beta_0 + \beta_1 Gender_{irc} + \beta_2 Gender_{irc} * GII_c + \boldsymbol{\beta} X_{irc} + f_r$$

The model controls for covariates associated with learning outcomes at the individual level known to influence gender-based school performance, such as the location of the student, household wealth, parental education, and school resources. $Test\ score_{irc}$ is the test score of student *i* in the region *r* of country *c*; $Gender_{irc}$ is a gender dummy variable, equal to one if a girl and equal to zero if a boy; GII_c is the Global Inequality Index, a continuous variable ranging from zero to one; $Gender_{irc} * GII_c$ is a cross-term between the student's gender and her/his country's GII score; X_{irc} refers to covariates including household and school characteristics, as shown in Table 3, and finally f_r captures the country's region-level fixed effects through a 'region' dummy variable, to control for unobserved heterogeneity.

As SACMEQ uses stratified sampling, student data becomes 'nested' within the school, region, and country. Given this structure, a possibility arises that unobservable characteristics (error terms) of respondents may be correlated with the student's location. To avoid the bias from such correlation in the error terms, we cluster robust standard errors at the region level in the OLS regressions.[36]

Our parameter of interest in equation (1) is β_2, capturing the relative effect of the GII on girls' test scores. Given the hypothesis that in a more gender-equal society the girls' relative test scores would be better, β_2 is expected to have a positive and statistically significant value. With increases in the value of the GII between 0 and 1, the β_2 value is considered to represent the effect of social gender inequality on girls' test scores.

Secondly, we estimate the effect of GII on girls' test scores at the 25th, 50th, and 75th percentiles. A linear model is also assumed in regard to the conditional quantile of students' test scores:

(2) $$Q_q[Test\ score_{irc}|Gender_{irc}, GII_c, X_{irc}] = \alpha_{q0} + \alpha_{q1} Gender_{irc} + \alpha_{q2} Gender_{irc} * GII_c + \boldsymbol{\alpha_q} X_{irc} + f_r$$

The model specified above allows for differences in the coefficients between quantiles. Our parameter of interest in equation (2) is α_{q2}. We hypothesize that GII will remain positive and statistically significant at the noted quantile. However, as seen in the differences in test scores across the SACMEQ countries, significant variation may exist between quantile results; therefore, variation in α_{q2} is expected.

[36] An alternative approach is to employ hierarchical linear modeling (Cameron and Miller, 2015; Moulton, 1990; Primo et al., 2007).

2.5 Results

2.5.1 OLS regression results

Table 3
Average effects for GII and GGGI

Variables	Reading	Math	HIV	Reading	Math	HIV	Reading	Math	HIV
Global Inequality Index (GII)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Female*GII	149.1**	109.3**	134.3**	130.4**	93.67**	117.9**	128.8**	92.81**	112.9**
	(17.87)	(11.61)	(20.67)	(16.98)	(11.38)	(19.51)	(17.31)	(11.59)	(18.88)
Region dummy	YES	YES	YES	YES	YES	YES	YES	YES	YES
Household characteristics	NO	NO	NO	YES	YES	YES	YES	YES	YES
School characteristics	NO	NO	NO	NO	NO	NO	YES	YES	YES
Observations	52,931	52,434	49,649	52,853	52,359	49,584	52,804	52,312	49,533
Global Gender Gap Index (GGGI)	(10)	(11)	(12)	(14)	(12)	(15)	(16)	(17)	(18)
Female*GGI	150.3**	119.4**	249.3**	138.3**	117.3**	244.2**	132.3**	118.4**	226.3**
	(27.95)	(27.12)	(29.85)	(25.19)	(25.34)	(28.76)	(26.72)	(27.49)	(30.23)
Region dummy	YES	YES	YES	YES	YES	YES	YES	YES	YES
Household characteristics	NO	NO	NO	YES	YES	YES	YES	YES	YES
School characteristics	NO	NO	NO	NO	NO	NO	YES	YES	YES
Observations	53,095	53,018	52,968	52,580	52,506	52,458	49,696	49,632	49,580

Note: We use sampling weights and robust standard errors, in parentheses. In rows with Region dummy, Household characteristics, and School characteristics, "YES" implies controled, and "NO" implies non-controled.
** p<0.01, * p<0.05

Table 3 shows the main estimation results from equation (1) and (2); more detailed results are shown in Table A.2 in the Appendix. Columns (1), (2), and (3) show that an increase in GII positively and strongly correlates with higher girls' scores when the region dummies are controlled, as captured by the β_2 parameter. For results from each of the three sections of the assessment, the effect of social gender inequality was statistically significant at the 1% level. Columns (4), (5), and (6) show that even when controlling for household characteristics at the region level, the coefficients remained significant at the 1% level. Column (7), (8), and (9) show that after controlling for school characteristics, the coefficients remained significant at the 1% level.

By this estimation, we can robustly observe that the effect of social gender inequality is strong for each of the three SACMEQ assessment scores, the effect of social gender inequality was found to be statistically significant at the 1% level. Columns (4) to (9) indicate that this coefficients on the covariates of interest remain robust and statistically significant at the 1% level even when controlling for household and school characteristics at the regional level.

To evaluate the robustness the GII, we run the same estimation for the Global Gender Gap Index. Columns (10) to (12) indicate that the GGGI strongly and positively correlate with higher reading, mathematics and HIV-AIDS awareness scores. Under this specification we observe that HIV-AIDS awareness scores increase nearly twice as much as for the other two subjects under the hypothetical scenario of perfect social equality.

2.5.2 Quantile regression results

Table 4
Quantile effects for the Global Inequality Index (GII)

Variables	0.25	0.5	0.75	0.25	0.5	0.75	0.25	0.5	0.75
Reading	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Female*GII	165.2**	173.2**	169.3**	161.0**	153.1**	114.1**	157.4**	153.3**	127.4**
	(17.33)	(15.40)	(14.68)	(8.86)	(9.72)	(9.13)	(9.04)	(9.84)	(9.14)
Region Dummy	YES	YES	YES	YES	YES	YES	YES	YES	YES
Household Characteristics	NO	NO	NO	YES	YES	YES	YES	YES	YES
School Characteristics	NO	NO	NO	NO	NO	NO	YES	YES	YES
Observations	52,931	52,434	49,649	52,931	52,434	49,649	52,931	52,434	49,649
Variables	0.25	0.5	0.75	0.25	0.5	0.75	0.25	0.5	0.75
Mathematics	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Female*GII	135.9**	124.5**	105.1**	131.2**	105.4**	90.72**	126.6**	103.7**	89.65**
	(12.50)	(12.23)	(18.73)	(8.73)	(10.28)	(10.95)	(10.30)	(10.26)	(10.66)
Region Dummy	YES	YES	YES	YES	YES	YES	YES	YES	YES
Household Characteristics	NO	NO	NO	YES	YES	YES	YES	YES	YES
School Characteristics	NO	NO	NO	NO	NO	NO	YES	YES	YES
Observations	52,853	52,359	49,584	52,853	52,359	49,584	52,853	52,359	49,584
Variables	0.25	0.5	0.75	0.25	0.5	0.75	0.25	0.5	0.75
HIV-AIDS knowledge	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Female*GII	125.9**	143.1**	156.1**	131.8**	127.5**	120.5**	128.3**	132.1**	114.8**
	(10.31)	(10.92)	(15.47)	(8.22)	(10.19)	(9.33)	(8.89)	(10.46)	(10.48)
Region dummy	YES	YES	YES	YES	YES	YES	YES	YES	YES
Household characteristics	NO	NO	NO	YES	YES	YES	YES	YES	YES
School characteristics	NO	NO	NO	NO	NO	NO	YES	YES	YES
Observations	52,804	52,312	49,533	52,804	52,312	49,533	52,804	52,312	49,533

Note: We use sampling weights and robust standard errors, in parentheses. In rows with Region dummy, Household characteristics, and School characteristics, "YES" implies controled, and "NO" implies non-controled.
** p<0.01, * p<0.05

Table 4 shows the quantile estimation results for reading, mathematics, and HIV-AIDS awareness (detailed results are shown in the Appendix in Tables A.3, A.4, and A.5). As in the results for equation (1), the estimation results for our interest variable α_{q2} in equation (2) show that as the GII index decreases from 1 to 0, girls' scores increase across each subject in every quantile with 1% statistical significance. Reviewing the outcomes with each of the three controls reveals a marginal decrease in points when moving from the 25th to the 75th quantile. As the GII measures gender equality across countries, these diminishing returns at the upper quantiles may simply indicate that the top-performing female students will see a smaller return on greater gender equality, within their respective countries, compared with females with lesser academic abilities.

Table 5
Quantile effects for the Global Gender Gap Index (GGGI)

Variables	0.25	0.5	0.75	0.25	0.5	0.75	0.25	0.5	0.75
Reading	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Female	-25.19	-104.6**	-167.5**	-48.19**	-127.7**	-147.1**	-40.84**	-122.4**	-160.4**
	-23.13	-12.8	-20.58	-11.1	-12.01	-11.3	-10.98	-13.1	-13
Female*GGI	49.33	161.4**	251.6**	75.86**	188.6**	213.7**	66.12**	179.9**	233.1**
	-32.86	-18.69	-30.36	-16.3	-17.57	-16.63	-16.04	-19.1	-19.06
Region Dummy	YES	YES	YES	YES	YES	YES	YES	YES	YES
Household Characteristics	NO	NO	NO	YES	YES	YES	YES	YES	YES
School Characteristics	NO	NO	NO	NO	NO	NO	YES	YES	YES
Observations	53,095	53,095	53,095	52,580	52,580	52,580	49,696	49,696	49,696
Variables	0.25	0.5	0.75	0.25	0.5	0.75	0.25	0.5	0.75
Mathematics	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Female	0	-123.3**	-133.8**	-73.87**	-102.1**	-136.1**	-66.82**	-103.3**	-158.1**
	-110.4	-23.19	-22.82	-10.64	-12.86	-12.33	-13.99	-13.9	-14.3
Female*GGI	0	171.4**	186.0**	99.72**	138.5**	182.3**	91.21**	140.4**	214.5**
	-161.3	-34.88	-34.36	-15.6	-18.9	-18.09	-20.42	-20.23	-20.66
Region Dummy	YES	YES	YES	YES	YES	YES	YES	YES	YES
Household Characteristics	NO	NO	NO	YES	YES	YES	YES	YES	YES
School Characteristics	NO	NO	NO	NO	NO	NO	YES	YES	YES
Observations	53,018	53,018	53,018	52,506	52,506	52,506	49,632	49,632	49,632
Variables	0.25	0.5	0.75	0.25	0.5	0.75	0.25	0.5	0.75
HIV-AIDS knowledge	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Female dummy	-169.2**	-174.7**	-202.8**	-158.2**	-143.2**	-167.6**	-146.7**	-152.5**	-153.3**
	-13.72	-12.15	-20.55	-13.79	-14.15	-13.44	-13.43	-15	-15.86
Female*GGI	247.7**	256.0**	296.0**	231.0**	207.9**	240.6**	214.3**	220.5**	219.8**
	-20.4	-17.93	-30.13	-20.19	-20.75	-19.78	-19.74	-21.9	-23.2
Region dummy	YES	YES	YES	YES	YES	YES	YES	YES	YES
Household characteristics	NO	NO	NO	YES	YES	YES	YES	YES	YES
School characteristics	NO	NO	NO	NO	NO	NO	YES	YES	YES
Observations	52,968	52,968	52,968	52,458	52,458	52,458	49,580	49,580	49,580

Note: We use sampling weights and robust standard errors, in parentheses. In rows with Region dummy, Household characteristics, and School characteristics, "YES" implies controled, and "NO" implies non-controled.
** p<0.01, * p<0.05

The estimation results for reading, mathematics, and HIV-AIDS awareness are checked for robustness in Tables 5 (with detailed results to be found in the Appendix under Tables B.3, B.4, and B.5). Similar to the results from the GII, the results for equation (2) when incorporating the GGGI data into our interest variable α_{q2}, we observe an equally strong increase in test scores in every quantile, however, only in the middle and upper quantiles are the results significant at the 1% level; HIV-AIDS awareness scores were unique in that the influence of social engender inequality was significant at 1% for all quantiles. For the reading and mathematics scores, it was determined that GGGI had no significant effect on the 25th quantile when only the covariate for the region dummy was incorporated in X_{irc}. In contrast with the GII results in Table 4, under the fully controlled scenario of columns (7) to (9), we observe an increasing margin of points gained between the 25th and 75th quantile. The marginal increase in points at the upper quintiles is a likely manifestation of the index comparing the within-country gender gap as opposed to the absolute gender gap reflected in the GII.

2.6 Conclusion

In this paper, we present new evidence demonstrating a statistically robust inverse correlation between social gender equality and the gender gap at the lower, middle, and upper quantiles.

These results were obtained after controlling for household and school characteristics in addition to fixed effects through clustered standard errors. The findings contribute to the research of education and development scholars, specifically in the eastern and southern African context. This study applied OLS regression and quantile analysis to the gender gap within the subjects of mathematics, reading, and HIV-AIDS knowledge and awareness, compared with social gender inequality metrics from the Global Inequality Index (GII) and Global Gender Gap Index (GGGI). We additionally aimed to limit the possibility of endogeneity bias by including both the GII and GGGI, which capture similar but different indicators (especially those related to adult education levels) of social gender inequality for each of the countries included. Using either index the results consistently correlated countries with less social gender inequality and a lower gender gap in all three subjects with higher test scores from girls.

We need to, however, note several limitations of the findings. First, the data is cross-sectional. Without panel data, the analysis does not account for the trajectory of the countries' policy choices and social attitudes, nor the scholastic performance of these children over time. This scenario is unlikely to change in the forthcoming surveys from SACMEQ given the regular addition of new countries into the consortium and the ambitious sample size of the dataset. Individual counties in this region have produced panel data in limited amounts. Given the interest of this study is to compare between countries, no data to date contains both the standardized testing and student background characteristics in a panel format.

The secondary limitation derives from characteristics of the students' school and household life that are incomplete or not included in the SACMEQ data. While detailed information regarding teacher qualifications, years of experience, class size and gender ratio are included in the analysis, qualitative factors such as teacher motivation are not. Likewise, parental attitudes, including the beliefs about gender, distribution of assets among the household members, the origin and means of income generation and priorities of expenditures, among others, are not included in the data. Each of these variables exerts an influence on the child's learning environment and are thus important controls when measuring social gender equality against children's learning outcomes. Without these more nuanced data, inferring causality will be challenging, which may impact the potency of the policy implications. Future studies may benefit from improved datasets which include more qualitative features that influence student performance, or by indexes of social gender inequality that are more accurate in representing the state of a given society, perhaps by including variation of social gender inequality within specific regions of a country. This might include comparable panel data containing covariate information such as teacher skill and parental motivation and income, to further reduce the known sources of bias associated with the dependent variables.

Despite these limitations it is our aim that these findings will serve to further support policy that seeks to improve women's societal empowerment in southern and eastern Africa, given its strong association with a reduced gender gap and higher grades for girls in primary education. Scholars have already elucidated the myriad reasons policymakers ought to support women's access to equality in society (e.g., Duflo, 2012; Taş et al., 2014), for policies that invest in human capital, such as reducing the classroom gender gap, ensure dividends to last generations.

2.7 Author contribution

The first author (Blevins) analyzed the data and wrote the paper. The second author (Kawata) assisted in the selection of the methodology and provided comments on the text.

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3 Substituting the Practical Teaching of Physics with Simulations for the Assessment of Practical Skills: An Experimental Study [37]

3.1 Abstract

Practical skills in science education, defined as those developed through the observation, demonstration, manipulation, and application of scientific principles, valued in both academia and industry, feature conspicuously in curriculums the world over. Efficiently imparting such skills to students necessitates access to scientific equipment of sufficient quantity and quality, often a limiting factor in low-income schools. This study compares the learning outcomes of practical skills in an experimental setting in preparing 12-13-year-old students for an assessment on the properties of light after two weeks of instruction, here after 'one unit.' The treatment classroom used physics simulations while the control classroom used hands-on equipment. All students completed tests demonstrating practical skills on the physics of light, both at the start and at the end of the unit, providing pre- and post-unit test data. Individual student scores were analysed using a difference-in-differences (DID) linear regression model. Results show no statistically significant difference between the simulation and hands-on groups, suggesting simulations' suitability to substitute in this scenario, especially at schools without the resources to invest in physical equipment for physics instruction, such as in low-income countries. The concluding remarks include the advantages and disadvantages of simulations and the limitations of the study.

3.2 Introduction

Practical science work at school is an essential part of science education (Ofqual, 2014; Score, 2008). Likewise, many governments around the world have incorporated practical work into their curriculums, although to varying degrees (Abrahams et al., 2013). The effective delivery of practical science teaching is often hindered by poor quality or the complete absence of necessary physical equipment despite schools' admirably high expectations for students (Radulovic et al., 2016; McKagan, 2010; Smetana and Bell, 2012; Falode and Gambari, 2017).

In the absence of equipment, virtual educational simulations potentially offer a convenient and cost-effective alternative to physical hardware. The delivery of 'virtual' science could be significantly aided by policies such as Thailand's 'One Tablet per Child' (Yamwagee, 2012) and Rwanda's 'One Laptop per Child' (Anon, 2018) that provide large numbers of secondary school students with internet-enabled devices, consequently allowing access to troves of freely available online physics simulations.

Numerous studies compare traditional 'hands-on' physics learning (henceforth referred to as hands-on) to simulations. Hands-on skills are those conducted in school science laboratories with physical equipment, for example conducting a 'law of reflection' practical lesson using ray boxes and mirrors in a darkened room. However, few studies specifically research how adequately simulations compare to hands-on instruction when preparing students for the assessment of practical skills, seen on standard testing such as in the International General Certificate of Secondary Education (IGCSE).

As a result, this study aims to assess, through an experiment, the suitability of simulations compared to physical equipment in the assessment of practical skills. This study

[37] Authors: Wood, Benjamin K.; Blevins, Benjamin K.

focuses on a cohort of year-eight (12-13-year-old) students studying physics (reflection and refraction) in a Thai-British school in May 2018.

3.3 Methods

Located in Bangkok, Thailand, the school hosts approximately 1,200 students, aged 3-18. The students are mostly Thai nationals with English as a second language. The school is both bi-lingual (English and Thai languages) and bi-curricular (following the Thai National curriculum and an English and Welsh National curricula equally divided within the timetable).

The school's Year 7-9 (aged 11-14) students follow the Cambridge Secondary 1 Science curriculum. As a physics subject specialist, the author (Wood) selected the physics of light as the unit of work for the study for its short duration and suitable simulations. The authors verified that the students had not previously studied the content with the school as the Thai curriculum runs concurrently with the English/Welsh curricula.

Although the students could not be randomly allocated into classes due to timetable complications, the students were randomly distributed at the start of the school year (a month before the study commenced) resulting in mixed ability classes. From these classes, two classes were randomly selected using the flip of a coin, with one class being assigned as the hands-on control group, and the second class assigned as the treatment simulation group.

One teacher would teach both classes, removing any teaching bias. However, the classes would therefore, be taught at separate times, with the potential for students from each class to discuss the work throughout, potentially diminishing the effect of the experiment.

3.3.1 Selection of Data Collection Methodologies

Without a ‘fit for purpose' test available, the author (Wood) developed one using examples from various standardised examinations found in the United Kingdom.[38] The resulting exam contained six questions. The skills tested include: drawing and labelling ray diagrams; drawing correctly set up apparatus and measured angles; measuring angles of reflection and incidence; identifying anomalous results; writing conclusions; correctly reading a line of best fit; identifying different rays of reflection and refraction; carefully following a sequence of instructions and measuring length of lines accurately. The pre and post-unit tests were adapted to have subtle differences. Both tests were allocated 40 minutes for students to complete.

3.3.2 Selection of Simulations

Referring to the categories of simulations outlined by Quellmalz et al. (2009), ‘Virtual Laboratory' simulations, which attempt to replicate virtually, that of a real lab, were most suitable. The refraction simulation chosen was that of a PhET simulation. It allows for manipulation and exploration of all the pieces of equipment, is a standalone programme, and the representation is 2D and clear, without being overly simplified (Trindade et al., 2002; Wieman et al., 2008).

The search for an appropriate reflection simulation, however, was more challenging. Many of the simulations found were overly simplified, without adequate manipulation of the virtual equipment, which would have resulted in overly scaffolded learning (Lee et al., 2006).

[38] These were the Key Stage 3 end of unit examinations, IGCSE Alternative to Practical examinations, and Cambridge Checkpoint Examinations.

The researchers and school administrators decided on a combination of two simulations in sequence to be the most suitable option to achieve ‘an optimum level of simplification' that is easy to understand, but strong enough to support later progression (Taber et al., 2006). The first[39] is restrictive and overly-simplified, with crude divisions on the protractor. However, it allows for students to observe the correct positioning of the equipment and ‘Normal line', yet still allowing for data to be independently collected. It was anticipated that students would complete and progress from this simulation rapidly. The more scaffolded nature of this simulation would then allow for progression to the next simulation. This second simulation is a ‘sandbox' simulation for light rays in general, with far greater manipulation allowed (Clark et al., 2009). Although the representation of the components is different to that of the first simulation, this allows for natural curiosity and ‘play time' prior to the data collection occurring, enabling students to familiarize themselves with the more complex components. Over the course of the unit, the students in this study group had exposure to three very different simulations, all representing the hands-on equipment in very different ways.

3.3.3 Delivery of Content

The classroom teacher facilitated the pre-testing in the week before the commencement of the unit of work. During this period, each class had a total of six lessons, each lasting 40 minutes. Of these six lessons, there were two double lessons (80 minutes in total) and two single lessons (of 40 minutes). Due to these double and single lessons not running sequentially for each class, this unit of work must be considered as six individual lessons of 40 minutes. The final lesson for each class involved the 40-minute post-test.

The classroom teacher is a biology specialist, however, has also been teaching chemistry and physics to years 7-9 (aged 11-14) for three years previous to the start of this study. The teacher stated feeling comfortable and knowledgeable teaching this level of physics content. The teacher has been practising at the school for a period of one year at the time of this study and had taught the same cohort of students, who are the focus of this study, in the previous year.

3.3.4 Ethical Considerations

The ethical considerations in this study adhered to the guidelines specified by the British Educational Research Association (BERA). As this study took place in a school with young participants, a number of ethical considerations were raised and fully considered, as outlined below. In advance of any research taking part, the final proposal for the study was presented to the school Principal hosting the research, including ethical considerations.

As the participants in this study are students under 16 years of age, student and parental consent were required. Both parents and students received consent and information forms in both Thai and English. It was made clear that participants had the right to withdraw from the research at any time. Any data collected would remain on a single password-protected laptop, with subsequent data fully anonymised. A member of staff also accompanied the researcher at all times over the course of the research period.

3.4 Results

For each student, two points of test score data were collected, one for the pre-unit test and one for the post-unit test. The treatment and control groups each had 22 students, 44 students total. With two points of data for each student, the total data points are 88. The software STATA 15 was utilised in the analysis of this data and production of subsequent tables.

Table 3-1. Displays the difference-in-difference results comparing the control and treatment groups.

DIFFERENCE-IN-DIFFERENCES ESTIMATION RESULTS

Number of observations in the DIFF-IN-DIFF: **88**

	Before	After	
Control:	**22**	**22**	44
Treated:	**22**	**22**	44
	44	44	

Outcome var.	total	S. Err.	|t|	P>|t|
Before				
Control	**5.273**			
Treated	**10.000**			
Diff (T-C)	**4.727**	**1.634**	**2.89**	**0.005*** **
After				
Control	**15.136**			
Treated	**18.864**			
Diff (T-C)	**3.727**	**1.634**	**2.28**	**0.025** **
Diff-in-Diff	**-1.000**	**2.310**	**0.43**	**0.666**

R-square: **0.49**

* Means and Standard Errors are estimated by linear regression

**Inference: *** p<0.01; ** p<0.05; * p<0.1

Table 1 indicates that there were significant differences in the abilities between the treatment and control groups both for the pre-unit test and post-unit test. However, there was only a difference of one point between the groups, which is not statistically significant, indicating no difference in the outcome of the two teaching methods.

3.5 Discussion

The results showed that there was no statistically significant difference between the cohort of students employing the simulations to those of the hands-on group, reflecting results in similar studies (Riess and Mischo, 2010; Kiboss, 2004; Grmek, 2014; Sarabando et al., 2014; Zacharia and Olympiou, 2011; Finkelstein, Adams, et al., 2005; Keller et al., 2006). Consequently, it may be concluded that simulations prove to be an adequate substitute for hands-on equipment when preparing students for assessment of practical skills.

This study focussed on a specific unit of work, for a small cohort of young learners. It is with caution any conclusions should be wholly accepted as results may fail to extrapolate to further populations. Although adequate simulations were available for this unit of work, there may not currently be the same availability covering the breadth of subjects seen in many school physics curricula. This study also allowed both cohorts of students to access physical protractors to develop their measuring skills. Although protractors are arguably a standard piece of equipment found in a student's possession, they were nonetheless also replicated in the simulations, possibly giving an advantage to this group of students.

One advantage of simulations is the ability to improve the efficiency of practical work as they are quick to set up, operate the simulation itself, make repeats of data and pack away compared with the hands-on equivalent (Yildiz and Atkins, 1996). This is, however, assuming there are no technical issues with regards to the devices running the software, as was witnessed at times in this study. The simulations also proved effective during teacher demonstrations as light rays and their effects were far easier for the whole class to see on the whiteboard, than the hands-on equivalent.

The value of 'exploration time' prior to data collection by students was evident and would be recommended in the future use of simulations (Moore et al., 2013; Perkins et al., 2012; Wieman et al., 2008; McKagan, 2010; Bryan and Slough, 2009).

Another successful teaching strategy was that of the critiquing of the strengths and weaknesses of simulations by the whole class to develop an understanding of how simulations differ to their equivalents (Taber et al., 2006; Harrison and Treagust, 2000).

However, a number of shortcomings in the simulations were also reported. The oversimplification or enhanced functions of simulations may result in simulations being either too easy or complicated for students, and so the selection of appropriate simulations and differentiated activities requires significant planning. A final disadvantage is that of poor group dynamics, as some students feeling isolated during groupwork were seen to work independently with the simulations with no communication occurring between members.

Limitations to Study

A specific challenge of this study was in the planning of lessons and resources due to the researchers located remotely to the study location. With no prior experience of the class dynamics, or the classroom teacher's style of teaching, activities and lessons may have varied to that normally seen in the classroom teacher's lessons. This may have created a slightly artificial learning environment to that normally delivered. The teaching also naturally diverged from that of the plan at times as the teacher addressed learning considerations as they arose. The limited time period of each lesson (40 minutes) led to the researcher overestimating lesson content coverage due to loss of time at the start and end of lessons and so two additional, 40-minute lessons were required for each of the classes to ensure the content was fully covered. This resulted in the observer missing each class's final lessons.

Finally, due to the students studying in year-eight, there were no current suitable examination papers available, which assessed the required content of this study. Therefore, researcher-produced papers were utilised, without thorough suitability or errors within the paper being tested in advance.

Undoubtedly, the utilisation of simulations for this purpose is not expected to be universally adopted by all teachers. Nonetheless, in some scenarios, they may prove valuable. In particular, those classrooms which have adequate computer facilities, yet, lack the equipment and space required for quality hands-on practical work to be undertaken, as seen in some developing countries (Radulovic et al., 2016; McKagan, 2010; Smetana and Bell, 2012; Falode and Gambari, 2017)ts

3.6 Author contribution

This chapter originated as the master's thesis of Benjamin K. Wood, in which the author (Blevins) was a minor contributor to the drafting and editing, and the lead contributor to the methodology and analysis. The version presented in this chapter was published in the journal *Physics Education* (Wood & Blevins, 2019), for which the author (Blevins) led the revision.

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4 An Experimental Approach to ICT for Climate Change Awareness in Myanmar [40]

4.1 Abstract

The study explores the introduction of information and communication technology (ICT) into the classroom by conducting a randomized controlled experiment (RCT) among secondary schools in urban Myanmar. Using a lecture on climate change awareness, 942 students in five schools in Yangon and Mandalay participated in the experiment. For treatment groups, the lecture was video-based, with the teachers simply providing support to the contents of the video. In contrast, the teachers in the control groups presented the content of the video lecture without the video-aid. Student learning outcomes for those in the treatment group resulted in a mixture of outcomes divided on gender lines. The study suggest that ICT can simultaneously benefit certain students while impeding others, and thus should not be treated as a panacea to improve learning outcomes.

4.2 Introduction

Education and technology have an inseparable history in an increasingly globalised society and yet one that is asymmetric in contributions to one another. Although education is the gateway to all technologies, either through self-study or formal education, technologies do not readily facilitate advancements in pedagogy. Information and communication technology (ICT) in the form of computers, the internet, and digital media, are now central to the globalized economy and yet their integration into education, especially at the primary and secondary school levels is often awkward or incomplete. The phenomenon is noteworthy for schools in countries with growing economies, transitioning from low- to middle-income status, such as in the Republic of the Union of Myanmar, hereafter Myanmar, with recent access to stable electricity, computers, and internet, but which have not yet applied the strengths of ICT to enhance the pedagogy of the student curriculum.

To test how ICT might play a role in the enhancement of learning outcomes, the paper presents the finding of a series of experiments conducted at five secondary schools in Yangon and Mandalay, Myanmar in 2017. The experiment used freely available internet content, including videos and translation software to develop a lecture on climate change awareness. The experiment presented a lecture on climate change to two groups of students, with the treatment group receiving a teacher-supported video lecture, while the control group received the content of the video lecture, presented solely by a teacher. The selection of climate change awareness for the lecture stemmed from two considerations: first, it was not included in the school's existing curriculum. The choice allowed the researchers to present a topic with rich scientific literature that was simultaneously relevant to the students' lives, with overlapping themes in economics, politics, and the environment. Secondly, Myanmar will likely be disproportionately affected by climate change, given both its geographic position and its more limited economic resources to dedicate to climate change mitigation and adaption (Burke et al., 2016; Colenbrander et al., 2016; Springmann et al., 2016). The results of the experiment suggest a difference in results based on gender with measured improvements to boys scores in the treatment group and measurably worse outcomes for girls in the treatment group.

[40] Authors: Blevins, Benjamin K.; Nye Nye Htwe; Maharjan, Shree Kumar; Kaneko, Shinji

4.3 ICT for education

In recent decades, ICT has been integrated into virtually every sector of the modern economy including health, agriculture, business, infrastructure development, education, and tourism (Leu, Kinzer, Coiro, & Cammack, 2004; Livingstone, 2004; Roberts, 2000; R Silverstone & Haddon, 1996; Roger Silverstone & Hirsch, 1992). The power of ICT is due to its overwhelming ability to preserve, analyse, present, and share information more efficiently, affordably, and faster than any previously time in human history. As the benefits of ICT integration in education can be significant, various researchers have sought to track its progress from the primary school level to universities (Hepp, Hinostroza, Laval, & Rehbein, 2004; Leu et al., 2004; Volman, Van Eck, Heemskerk, & Kuiper, 2005; Wastiau et al., 2013). As examples, the use of ICT in education helps to enrich the knowledge and understanding of students and teachers such as by allowing self-paced learning, learning by trial and error, and by accessing a wide range of teaching-learning materials, all of which enhances direct and indirect/online interactions and active participation of the students and teachers.

Considering the potential benefits for the enhancement of the teaching-learning process by integration of ICT, it is no surprise that computers are now found in schools worldwide. Yet, as with any technology, special skills are often required before the benefits of the technology can be felt. Before the requisite skills are gained, interested parties may feel disenchanted or disappointed as the benefits of ICT are not so easily acquired. This can also be true for the application of ICT into the classroom. Studies have reported that without the proper training, computers can sit idle or may not be brought to the fullest potential for aiding learners, often through insufficient teacher training on how to access the benefits of the new technology (Bridge & Tisdell, 2004; Livingstone, 2012; Martinovic & Zhang, 2012). Indeed, some scholars have noted the negative impacts of ICT in the classroom (Hermans, Tondeur, van Braak, & Valcke, 2008; Zain, Atan, & Idrus, 2004). As with any new technology, the benefits of adoption can also be accompanied by negative externalities. These externalities need to be factored into the cost-benefit equation either at the level of the individual schools or with the policy makers.

The situation of underutilized ICT in the classroom is precisely what the authors of this paper encountered for the schools visited in Myanmar. In each school, computers and other equipment such as video projectors and sound equipment were available, and yet sat idle during most of the school year. Both the principals and teachers were interested in exploiting the benefit of ICT but did not know what was available freely on the internet and how to incorporate this knowledge into the classroom.

4.4 Education in Myanmar

The role of education in present day Myanmar is deeply entwined with the rich and complex history of the territory. From the outer edge of the greater Himalayan mountain range in the north, to the Ayeyarwady Delta in the south, are over 135 ethnic groups speaking over 100 languages. The Bamar people comprise roughly 70 percent of the population and have dominated the political and economic landscape from the age of dynastic kingdoms in the ninth century of the common era to the present day. Other major ethnic groups include the Chin, Kachin, Kayah, Karen, Mon, Rakhine, and Shan, each of which have clashed with the Bamar majority seeking greater independence and autonomy. The only major disruption to the Bamar rule came from the British imperial forces in the mid 19th century to the mid 20th century. A century of British rule brought with it dramatic reforms and new social and political hierarchies, which still shape the country to the present day. Following the ousting of the British,

Myanmar's military forces took control of the country forming a political junta. Decades of mostly peaceful struggle from the civil and monastic communities ensued, culminating in major reforms in 2011 that transferred most government function from the military junta to a civilian government.

Constitutionally, all children in Myanmar are guaranteed the right to free and compulsory primary education, consisting of the first five years of education. However, due to insufficient government funding, universal basic education is not yet achieved with roughly 10 percent of boys and girls still not attending school, and for secondary school, the rates are around 40 percent (UNICEF, 2015). Three types of schools are found in Myanmar: monastic, government, and private. Government schools comprise the vast majority of the primary and secondary schools, with private and monastic schools catering to a small percentage of the population. Monastic schools cater to three percent of the school-age children (Tin & Stenning, 2015), usually among the most economically disadvantaged, but given their long historical presence, these schools are also important politically and culturally. These schools primarily teach the national curriculum along with after-hours Buddhist teachings. They rely on a combination of charitable donations and government funds to support their operational costs, however, these funds are often insufficient (Tin & Stenning, 2015). The primary consequence of this lack of funding in Monastic schools is low teacher retention. When teachers have gained enough competence to pass the national exam, these teachers often leave for teaching positions in government schools which offer better payment. Of the 1,500 monastic schools in Myanmar, 70 percent are primary schools and the remaining 30 percent is secondary schools. In contrast, private schools exist over 45,000 across the country and they are primarily providing education to secondary school students.

There are different focuses of ICT integration in education, however the primary interest of this paper is to measure the effectiveness of video supported lectures on student learning. The video chosen for this study is on how climate change impacts biodiversity, which was downloaded from the internet and was translated and subtitled into the Myanmar language and presented in the selected schools.

4.5 Methodology

4.5.1 Selecting the subject

Prior to data collection, in order to gain the schools' support, the aims and methodology of the project was explained to whom? in the local language, in addition to the identification and hiring of the research support personnel at each target school. Furthermore, both teachers and students were sensitized with the purpose and requirements of their participation in the data collection process for this study.

4.5.2 Preparing the contents of analysis

The video selected was a short movie clip, 12 minutes in length, about the global warming and climate change, designed for secondary-school children. As this study focuses on climate change awareness, content was selected based on the suitability for the secondary-level students. As the purpose of this study is to test content that could be accessed by teachers for their lessons, the video on climate change was obtained using free content on the internet, including the software for subtitling the video into Burmese. In contrast, a customized video may have delivered stronger results, but the possibility of replication by local teachers for

various subjects, would be quite unlikely and therefore not appropriate for this paper. Ideally, teachers should be able to duplicate the type of video-lecture used in this case study to enhance the learning experience of their students. For all the schools in Myanmar, at least one teacher had a high level of English language ability, enabling the school in question to access the content online and to produce the learning material by adding subtitles for the students as part of their regular curriculum.

4.5.3 Preparation of survey questionnaires

The survey questionnaires were divided into two parts: part one consists of ten questions capturing information on student characteristics, and part two contains 30 questions measures the students' level of comprehension about the lecture, including six memorized questions. The memorization questions were designed to measure how effectively the students retained short-term information from the lecture, with and without the video aid. The personal and socio-economic questions were included I the questionnaire in order to provide control variables for later analysis, such as age, gender, and family background. To address the internal consistency of the questionnaire, the Cronbach's alpha test was run, with all questions scoring higher than 0.70. As this coefficient represents the threshold for acceptable inter-correlation in social science research , the research team proceeded with the experiment (Sijtsma, 2009).

Surveys were conducted at four schools in Yangon and one in Mandalay, selected at random from a Ministry of Education (MOE) master-list. In total, data from 942 students were collected (47 percent female). The four schools in Yangon are publicly operated as basic education high schools (BEHS) while the fifth one in Mandalay is a monastery school.[41] However, all the schools are taught the same curriculum under the guidelines and national curriculum of the MOE.

The respondents (students) were required to take two tests, a pre-test and post-test, comprising identical questions, to compare the efficiency of two different teaching techniques. After the pre-test, the students were randomly divided into two groups to form a treatment group and a control group. Each group received the same lecture using different methods, as described in the section on methodology in this paper. After taking the respective lectures, held simultaneously, both treatment and control groups took a post-test. The rationale for the simultaneous lectures was to avoid any spill over effects from treated or controlled students sharing their experience of the given lecture, which would potentially bias the results of the test. To minimize the error in the estimation a clustered random sampling approach was applied by dividing students into treatment and control groups according to their pre-test scores. This was done after the pre-test scores were analysed, by randomly assigning students to treatment and control groups from the bottom, middle, and upper third strata of the test-score distribution.

4.5.4 Randomized control trials

Starting in the 1990s then rapidly gaining popularity, randomized control trials (RCTs) have become established for utility in the evaluation of empirical research (Grossman, 1997; Iritani et al., 2016; Piper, Jepkemei, & Kibukho, 2015; Piper, Zuilkowski, & Mugenda, 2014). Each of these studies using RCT was aiming to access the benefit of random assignment, a concept that was made clear by statisticians in the early part of the 20th century (Fisher, 1925; Jerzy

[41] The sampled schools were: BEHS 1, Shwe Pyi Thar, Yangon; BEHS 4, North Okkala, Yangon; BEHS 1, Kyee Myin Dine, Yangon; BEHS 6, North Okkala, Yangon; and Monastric High School, Phaung Daw Oo, Mandalay.

Splawa-Neyman, D. M. Dabrowska, 1990). By randomly distributing the treatment, no unobservable characteristics of the treated participants would be linked to their assignment, enabling researchers to be certain that the difference in outcomes between the treated and controlled groups would be the effect of the treatment.

4.5.5 Validity and limitations

Despite offering a powerful tool to test a given treatment on a population sample, RCT is only as effective as the degree to which the randomization encompasses the target population, any deviation from which increases the error and the validity of the experiment. As is the case for this study, the randomization was conducted within a limited number of schools rather than among the entire school-going population of Myanmar. Therefore, the students attending the selected schools likely share characteristics that may be particular to their school, a form of endogeneity bias. Furthermore, RCT alone cannot account for the appropriateness of the treatment given the duration of the experiment. For example, this study is a cross-sectional research experiment that was implemented in a short timeframe, hence reducing the total cost requited, but it was limited in measuring effects that may be better captured over a longer duration in time.

Questions of validity also pertain to the findings of the experiment and what they might reveal about both the participants within the sample frame and the target population outside of the sample frame, respectively accounting for the internal and external validity of the experiment. Internal validity represents the measurable, verifiable link between this study's cause and effect (Anderson-Cook, 2005). For instance, in the case of this paper, if ICT on climate change knowledge was introduced into the classroom by way of a video supplement to a lecture, would test scores on the subject be systematically affected? Ideally, this question would be posed by framing the introduction of one variable into a treatment group that was excluded from the control group. This treatment variable would therefore be the only possible explanation for the difference in treatment and control group test differences, assuming that the sample size in both groups was adequately large enough to form a normal distribution of test scores. This is therefore a question of the study's efficacy within the study population, without explicitly verifying how the effect of the study would relate to populations outside the study frame.

External validity, in contrast, seeks to gauge if the results of the study can be applied generally, to other populations or circumstances. However, external validity cannot be guaranteed (Banerjee & Duflo, 2017). This is true both in the case of RCTs and for observational studies. In the case of this study, external validity would be confirmed if the findings of this paper were reliably duplicated across schools with similar characteristics. However, as the results of this paper will attest, results between schools varied substantially. As such, we can only speculate as to the true effect of the usage or application of video-based lecture aids in the classroom.

4.6 Results

Table 1

Summary statistics of Myanmar study

Gender	Control	Treatment	Total
Male	243	259	502
Female	230	210	440

Total score	Overall	Pre-test	Post-test	Control group		Treatment group	
				Pre-test	Post-test	Pre-test	Post-test
Max	27	25	27	25	27	25	26
Min	7	7	16	8	16	7	17
Average	20.43	18.32	22.53	18.23	22.41	18.36	22.61
Standard Deviation	3.49	3.275	2.053	2.914	2.035	2.699	1.643
n	942	469	473	236	237	233	236

Table 1 shows the summary statistics of the survey conducted in Myanmar for this paper. The study shows both groups are not different before the experiment. The similarity of two groups after the pre-test results encourage the use of the difference-in-differences method for the analysis. In general, the average score of treatment group is slightly better than the controlled group. However, since the total score is 27, the difference of two average scores is 0.2 means 0.74% of total test score which is less than one percent which means no greater significance. The one important thing can be seen from Table 1 is that the standard deviation is smaller for the post-test for the treatment group which suggests that more students are getting middle-level scores. This summary analysis leads us for further advance statistical analysis.

4.6.1 Difference –in difference (DID) results

The analysis was conducted using a difference-in-differences method (DID) for all observations within schools. DID is only slightly more sophisticated than a difference-in-means test, however DID has the added advantage to analyse the statistical significance of a change of with-in group populations. In the case of this paper, DID was used to measure the differences for the scores of boys and girls in both the treated and control groups, for each school, and for each type of question. As such, it can be observed if any of these sub-groups experienced an impact that may have been overlooked when comparing the whole sample.

Table 2
Difference-in-differences estimation results, overall and BEHS 1, Kyee Myin Dine, Yangon (school 3)

	Coefficient	S.E	P-Value
Overall DID result (n=942)	0.073	0.31	0.813
Girls	-0.422	0.41	0.299
Boys	0.493	0.45	0.274
Girls' estimation result for school 3 (n= 71)	-1.864	1	0.068*
Boys' estimation result for school 3 (n=107)	2.277	0.84	0.008***

*** p < 0.01; ** p < 0.05; * p < 0.1

For the full sample (n=942), the results in Table 2 show that girls in the treatment group scored somewhat worse than the girls in the control group. For the boys, the result was the opposite, with slightly higher scores. As the size of the impacts was small and the results were statistically insignificant, a subset of questions were examined in the test scores. In looking at the memorized questions, a significant result was found. In this subset, boys in the treatment group performed better than the boys in the control group, with statistical significance at (95% CI).[42] From here, further analysis was conducted which showed that if the individual schools might reveal more details. At BEHS 1, Kyee Myin Dine, Yangon it was observed that girls in the treatment group preformed worse than the girls in the control group (significant at 90% CI), and boys in the treatment group performed better than those in the control group overall (99% CI).

The results of the experiment demonstrate different outcomes for female and male students at BEHS 1, Kyee Myin Dine, Yangon. For female students, those that participated in the treatment group had significantly worse outcomes than those in the control group. For male students in the treatment group, the scores were significantly better than those in control group. Potential causal factors for these results include a difference in learning approaches but can also include endogenous variables that might result despite random assignment.

4.7 Conclusion

This paper presents the findings on the introduction of information and communication technologies (ICT) bay way of video-aided lectures on climate change awareness by randomized controlled trials (RCT) in secondary schools in Myanmar. By developing content for classrooms using freely available videos from the internet, in addition to freely available subtitling software, this study tested schools with tools that could be developed on their own accord, adjusted to their particular needs. While urban schools are likely better equipped than rural schools, each of the schools in this study already possessed the hardware necessary for the experiment, including video projectors and audio equipment. However, this might not be the case in rural schools that may lack the same level of resources.

[42] CI refers to confidence interval.

As this study was conducted at multiple schools at different locations in the country, uniformity of the experimental setting was the highest priority to ensure comparability between schools. However, inevitable variations in the experimental setting, including, as examples, teacher and head master commitment to the study, time of day, and overall classroom anomalies such as acoustics and students' desk placement, each represent an added element of statistical error into the experimentation parameters. Despite the effort to minimize variation in the experimental setting, the presented results may be under or over reported and will require a longer period of experimentation to reduce the error effect.

4.8 Author contribution

This chapter was published in the *Asian Journal of Education and Social Studies* (Blevins, Htwe, Maharjan, & Kaneko, 2018). Blevins led the drafting, contributed to the methodology and analysis, and aided in the data collection. Nye Nye Htwe contributed to the analysis and led the data collection. Maharjan contributed to the text and aided in the data collection. Kaneko supervised the study.

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5 Revealing Preferences for Teachers in Rural Myanmar

5.1 Abstract

In November 2010, Myanmar[43] began a process of significant democratic reform ending a half century of authoritarian rule by military junta. Rural education, having long suffered from a lack of qualified teachers in poorly equipped, overcrowded schools, has received little attention from empirical scholarship aimed at informing policymakers. This article pilots a direct survey of university students entering into the teaching profession, producing clear priorities to support teachers, especially in rural areas. Survey data was gathered at the Yangon University of Education using an improved conjoint analysis. Survey attributes were completely and independently randomized then analysed by ordinary least squares regression and the Sarafidis and Weber partitional-clustered regression with unobserved fixed effects. Out of many competing priorities, the analysis reveals that secure housing is at the highest priority for respondents, with secondary and tertiary preferences varying based on group clusters. This study aims to inform teacher placement policy by demonstrating methodologically how observed and unobserved characteristics of the respondents and the teaching environment influence teacher retention. Given the present challenges facing teachers in rural areas, better meeting the preferences of teachers can have long-term educational benefits for children in these areas.

5.2 Introduction

"To welcome the advice of expertise, non-governmental educational organizations, representatives selected by parents, teachers and students when the ministry and respective ministries formulate the education policies."
-2nd policy agenda (Ministry of Education, 2019)

The period of military rule in Myanmar was characterised by political oppression, ethnic conflict, and state corruption (Walton, 2013). An educated populace, once perceived by the ruling elite as a threat to power, has since transmuted to the new economic engine, primed to power national redevelopment for the benefit of all citizens (Krueger & Lindahl, 2000). The Ministry of Education (MOE) leads this effort to arrive at substantive change in the policy and practice of education (Esson & Wang, 2018).[44] However, during the decades of imposed isolation, sparse collaboration existed between the international community (such as development practitioners and academia) and the MOE, leaving little precedence for cooperation measures (Carr, 2018).

Post-2011 studies revealed the formidable scale of rehabilitating education services. Myanmar's population, 70 per cent rural, is distributed across the largest land area of Southeast Asia. Most communities lack access to basic services and infrastructure including roads, public transportation, and electricity. National teacher to pupil ratios for secondary schools average 1:37 (Tanaka, Spohr, & D'Amico, 2015), among the highest in Southeast Asia. In rural schools, overcrowding and 'double shift' classrooms are common, giving teachers little opportunity to

[43] Officially, the Republic of the Union of Myanmar

[44] The Comprehensive Education Sector Review (2012), was the first critical assessment of the state of education in Myanmar in two decades (Goodman, 2013; Higgins, Maber, Lopes Cardozo, & Shah, 2016; Salem-Gervais & Metro, 2012). This was followed by the National Education Sector Plan (2016-2021), acknowledging the "immediate need [to] strengthen teacher recruitment, deployment and retention." (Ministry of Education, 2016), and the Myanmar Sustainable Development Plan 2018-203.

provide for students' individual learning needs (Lall, 2011; Lorch, 2008). Nationwide, these factors contribute to low net enrolment (60 per cent) for secondary school students (Ministry of Education, 2015).

To ameliorate the teacher shortage in rural areas, the MOE mandates that teachers graduating with Bachelor of Education (B.Ed.) degrees from the leading universities work in a rural community for a minimum of two years (or one in the case of hardship or conflict areas). This policy aims to establish and maintain a desirable student/teacher ratio. However, the incentives provided to teachers have yet to reverse the trend of teachers leaving as soon a feasible from these rural areas. Some teachers reported the use of bribes to MOE officials to secure transfers to more comfortable schools, or to avoid the rural areas all together. After the mandatory service, a majority of teachers find means to return either to major cities (such as Yangon or Mandalay) or to urban areas of their home region. As stated earlier, this unwillingness among teacher to remain in rural areas leaves schools and students with a shortage of trained and motivated teaching staff, degrading the quality of the learning and creates a disincentive for students (and their parents) to continue the pursuit of formal education.

Teachers interviewed for this study cited key concerns related to teaching in rural areas including: a lack of safe, appropriate, and/or affordable housing; overcrowded classrooms; poor salaries and professional support; and sexual violence, especially against female teachers. However, teachers simultaneously expressed motivation to work in rural areas with the hope of contributing to the betterment of children living in disadvantaged areas and to experience some of Myanmar's many distinct cultures. This contradictory sentiment, desiring to serve and daunted by the level of adversity, reflects an attitude shared by teachers around the world when working in rural communities (Goodson & Hargreaves, 2003; Whiteside, Bernbaum, & Noble, 1969), one that research has long aimed to ameliorate given the benefits of providing education to children in underserved areas (Nias, 1981; Sass, Seal, & Martin, 2011). This study aims to address to what degree the stated preferences of those entering the teaching profession can inform retention in rural areas of Myanmar.

Evidence of teacher preferences can aid policymakers in creating informed decisions on the priorities to support the MOE goals. This paper pilots a conjoint experiment to simultaneously measure the impact of seven workplace attributes on job selection preferences. Having provided the key issues affecting teachers in rural Myanmar in the **introduction**, the **literature review** will provide readers with more details on the role of surveys in education policy, with emphasis on the conjoint analysis. In the **methodology and data** section, a detailed discussion will be given on: the conjoint analysis, how it differs from previous approaches by the same name, the attributes and levels chosen, and the required assumptions; partitional clustering analysis; and the data collection. The **results** section provides: a general overview of the survey experiment; a sub-analysis of male and female differences in preferences; and lastly an algorithm derived division of the respondents based on shared preference characteristics. Lastly, the **conclusion** section will express the limitations of the study in addition to implications for future research.

5.3 Literature review

5.3.1 Preferences and teaching in rural areas

Rural teachers do not hold homogeneous interests or motivations. Preferences vary among teachers, including value orientations (Ennis & Chen, 1995), what incentives might influence

retention in rural areas (McEwan, 1999), and how these preferences can change over time and through experience (Heeralal, 2014). What these and other studies exemplify is the importance of including the input of teacher preferences when considering creating or amending policy to improve outcomes in rural schools. As rural areas, by definition, have a smaller pool of qualified educators compared with urban areas, it is especially important to understand how the state can best facilitate these professionals to succeed in rural localities (Gagnon & Mattingly, 2015). The methodology espoused in this study utilizes surveys of teacher preferences, organized in the form of a conjoint analysis, to statistically rank the relative importance of the stated preferences. This ranking approach has several advantages, detailed in the subsequent sub-section.

5.3.2 Conjoint analysis

Teacher preference surveys have substantial history in academic literature as they provide unique insights into the aggregated personal and professional demands of these individuals (Beghetto, 2007; Dabach, 2011; Webb, 1993). In addition, they have applications for producing recommendations for policy change (Grosh, 1991; Stapleton, 2011). The use of CA in surveys is also well established. With its origin in market research, CA has found consequential applications in the medical, political, and social sciences (Chrzan, 1994; Hainmueller, Hopkins, & Yamamoto, 2014; Veisten, 2007). In the education sector, CA has contributed to the revelation and examination of teacher and student preferences, primarily in high-income countries (Horng, 2009; Kuzmanovic, Savic, Andric Gusavac, Makajic-Nikolic, & Panic, 2013).

Given the breadth and impact of research conducted using CA (Grunert, Hieke, & Wills, 2014; Masini & Menichetti, 2012), the limited number of studies using the methodology for education research is likely due, in part, to the formal constraints of traditional CA. Developed in the 1960s and 1970s (Green & Rao, 1971; Luce & Tukey, 1964), traditional CA demonstrates the causality of choice when ranking (non-parametric) multivariate outcomes requiring the synchronised use of behaviour models (such as utility maximization) and statistical models, often recommending a smaller, selected set of attributes for profiles, usually to output a unidimensional or agglomerated results. In professions, such as teaching, where job satisfaction incorporates a multitude of variables, traditional CA likely poses too many unnatural constraints to satisfactorily address ordinal preferences. The following section will introduce a new approach to CA, used in this study.

5.4 Methodology and data

5.4.1 Improved conjoint analysis

Hainmueller et al. (2014) provides significant improvements to the traditional conjoint analysis, as evidenced by recent scholarship (Bansak, Hainmueller, & Hangartner, 2016; Bechtel & Scheve, 2013; Grimmer, Messing, & Westwood, 2017). The improved CA offers high internal validity when obtaining the average marginal component effect (AMCE), our causal quantity of interest, provided that the model's three assumptions are met:

(1) Stability and no carry-over effect. This assumption implies that the respondent's choice is stable given that they are presented with an identical choice-set and would not be

affected by the combinations presented in previous choice-sets. To illustrate, if a respondent was asked to choose between *A versus B*, then *C versus D*, and finally *E versus F*, their preference of *D* over *C* was not affected by their choice of *A* over *B*, for example. For this study, a carry-over effect is highly unlikely as the respondents were informed of the number of rounds in the choice experiment and only asked to choose between the pairs of job profiles provided. Additionally, as the pairs of choice-sets were accessed by scrolling down the tablet, hence being partially visible, there would be no indication that a choice in the first round would affect the choice options in the subsequent rounds. As such, respondents would be very unlikely to carry-over their choice in one round with the idea of altering subsequent pair options.

(2) No profile-order effects: That is, if the order of the profiles were rearranged, there would be no impact on the final choice of the respondent. Another illustration provides that *A versus B*, then *C versus D*, and finally *E versus F*, would be equal in outcomes to *F versus E*, *C versus D*, and lastly *B versus A*, for example. With only two choice profiles per round, as opposed to experiments with three or more choice profiles per round, the likelihood of a profile-order effect is negligible.

(3) Randomization of the profiles: with attributes assigned by completely independent randomization, the outcomes become statistically independent of the profiles. The estimation strategy, given the previous assumptions, is therefore greatly simplified allowing for a basic linear regression estimator to yield the AMCE. For this study, all profiles were completely randomized for each choice profile. However unlikely, there was a possibility to have two identical profiles in a choice-set. As expected, this did not occur.

To choose the attributes and levels of the hypothetical teaching profiles, informal discussions were conducted with YUOE faculty and serving teachers based on what might affect a teacher's decision to stay or leave a rural teaching position, establishing the attributes and levels for the study, see Table 1. The table includes seven attributes, having two to four levels per attribute. Multiplying the attribute/level combinations by each other[45] produces the approximately 3,000 possible profile combinations that a respondent may encounter. Details for these attributes and levels are further addressed below.

Table 1

Attributes and levels included in the conjoint analysis survey

Attributes	Levels
Secondary income allowed	Yes (O); No (X)
Salary (Kyat per month)	150,000; 200,000; 250,000; 300,000
Travel home (per month)	half-day; one day; four days
Daily classes	25-35 pupils, one class; 25-35 pupils 3-4 classes
	50-60 pupils, one class; 50-60 pupils 3-4 classes
Community size	Large city; Small city; Large village; Small village
Secure housing	Yes (O); No (X)
State/Region	Ayeyarwady; Bago; Mon; Yangon

[45] $(4^4 \times 2^2 \times 3^1 = 3{,}072)$

5.4.2 Attributes and levels

CA attributes were selected through consolations with teachers and university staff, who deemed what was relevant to influencing teacher retention in rural areas. These characteristics of the workplace profile would not be unfamiliar with teachers in other countries, as demonstrated by the literature. These are: Access to a secondary income, or 'moonlighting', by means of offering private tuition (Molyneaux, 2011; Parham & Gordon, 2006; Robert M. Maninger, William Edgington & Samuel S. Sullivan, 2011); Access to higher salaries (Clotfelter, Glennie, Ladd, & Vigdor, 2008; E. Hanushek, Kain, & Rivkin, 1999); Duration of home-leave (Edelfelt, 1986; Odland & Ruzicka, 2009); Class frequency and size (Klassen & Chiu, 2010; M. L. Smith & Glass, 1979); Secure housing to prevent theft and sexual violence (Planty, Langton, Krebs, Berzofsky, & Smiley-McDonald, 2013); and the school location in either a village (small or large) or city (small or large) (Sharplin, 2002; White, 2008). Additional attributes were added to nuance the context specific to Myanmar. These were 1) the Region or State where the hypothetical teaching post would be located and 2) whether or not this Region or State was the same as the respondent's home region, labelled in the Tables as "Same home".

The ability to offer private tuition (secondary income) was stated as important by teachers as the government salary was deemed insufficient to support a family. In the major urban centres of Yangon and Mandalay, this salary level forces many teachers to rely on family or a spouse to cover the remaining living costs. Private tutoring is the primary source of secondary income for teachers, especially in areas where parents have enough disposable income to provide additional support for their child's education. However, some governmental authorities prohibit teachers from offering private tuition as parents who are unable to pay for their child's extra tuition may find that their child is neglected by their teacher or unscrupulous teachers may use this service to solicit money for grades (i.e., corruption). From the teacher interviews, the statute against allowing teachers to obtain secondary incomes through private tuition is not codified (or perhaps enforced) nationwide. This results in a patchwork of legal and illegal zones, arbitrarily shaping the educational landscape. For the choice set, respondents were presented with a binary choice, either access to secondary incomes through extra tuition was allowed (O), or not (X).

With a base salary of 150,000 Kyat ($112), the Ministry of Education (MOE) in Myanmar does acknowledge the role of increased salaries to encourage support for teachers in difficult areas. Several territories within Myanmar's frontier (e.g., Rakhine, Shan, and Kachin) experience either sustained or intermittent conflict between local and government forces, making living conditions for teachers all the more difficult. In these locations MOE are reported to provide 300,000 Kyat ($225) per month in addition to reducing the required length of service from two years to one. With the understanding that the MOE is capable to allocate additional salary as an incentive to teachers serving in hardship, the range of choice set was set from 150,000 up to 300,000 Kyat.

With a majority of the newly graduated teachers unmarried and young, the ability to return home frequently was stated during the interviews as a motivation for placements near home or in the teacher's home state. Three levels were chosen, with one half-day, one day, and four days per month as options. In practical terms this would convert to one day every other month, one day per month, and one day per week, respectively. As Myanmar is a large country with high variations in the quality and accessibility of transportation infrastructure, these options for the number of leave days would translate into a much wider range of realistic home leave options. For example, one day every other month would be easy to spend if commuting along the major national highways. However, in a mountainous zone in the country, simply

getting out of the village and on to the first paved road could take longer than one day, and hence the teacher would need to accumulate far more days of home leave in order to exercise the right.

As many teachers would attest, class size (the number of pupils per class) and class frequency (the number of classes per day) can strongly affect the wellbeing of a teacher given the additional workload in and out of the class as the class size and frequency increases. Levels for this attribute were set with both variations on class size and frequency: 25-35 students and one class per day; 25-35 students and 3-4 classes per day; 50-60 students with one class per day; and 50-60 students with 3-4 classes per day. As stated in the introduction, pupil teacher ratios can be very high, leaving teachers and learners at a major disadvantage in respect to achieving the learning targets. Despite knowing that this extreme had been reported, it was unclear to the author how frequent this situation occurs and as such the choice set range was placed with a less extreme range, considered closer to the median teacher experience.

For both women and men interviewed, security ranked as a high priority. Many teachers placed in communities with differing ethnic and linguistic traditions and/or in remote locations. Respondents reported feeling that, as outsiders, they would be more vulnerable to assault especially as housing was often rudimentary and insecure from intruders. To date, only anecdotal evidence is available as to whether or not these fears are warranted, as the frequency of assault, whether in the form of physical or sexual violence, is not publicly available information. Furthermore, records that might be made public would likely suffer from an underreporting bias. Respondents were presented with a binary choice, either (O) indicating that the housing was secure, or (X) if not.

With only two cities representing major urban areas (Yangon and Mandalay) the criteria for community size attribute had to be set with levels that would not be overly ambiguous. For example, the Yangon Region comprises both the most populous urban agglomeration, but also sparsely populated rural villages. To avoid confusion, the levels were set as: small village; large village; small city; and large city. This definition for the communities was easy to differentiate by the students to accurately measure preferences. Place names could have provided more accurate descriptions of the respondent's choice preference; however, the CA should not offer too many levels as each successive level will decrease the likelihood that the level will be selected, diminishing the basis for a statistical comparison. Similarly, the interest of the question is to offer a greater external validity to the questions and thereby would be narrowed if place names were added.

Myanmar's administrative divisions are principally divided into States and Regions: States have greater autonomy than Regions and primarily comprise distinct ethnic minority groups; whereas Regions are comprised largely of the Myanmar (Burman) ethnic group. In deciding which States/Regions would be included in the attribute levels, the primary factor was the level of similarity. Myanmar has various levels of on-going conflict in the country, especially along the borders. As this adds an unwanted dimensionality to the analysis, States/Regions were chosen that are similarly pacific, these being: Ayeyarwady Region, Bago Region, Mon State, and Yangon Region.

5.4.3 Partitional clustering

In addition to comparing the preference outcomes on the observable characteristic of the biological sex of the respondents in Figure 2, the author sought to explore whether unobservable characteristics might reveal motivations based on the stated preferences. By using a partitional clustering algorithm, further explained below, groups with common

preference patters can be identified, see Figure 3. While partitional clustering can, in theory, identify any number of clusters, more clusters generally need larger sample sizes to retain statistical significance (Liu, Hayes, Nobel, & Marron, 2008). Further complexity arises from each additional cluster, in that the inter-cluster characteristics must be identified or interpreted by the researcher. Given these constraints, the data was segmented into two clusters with common intra-cluster preference patters.

Partitional clustering is an "exploratory data analysis approach" to identify groups with shared unobserved fixed effects based on the K-means clustering algorithm (Christodoulou & Sarafidis, 2017; Sarafidis & Weber, 2015). Using STATA's xtregcluster command, the panel data generated by the CA can be divided to identify individuals with shared slope parameters along the multiple cross-sections. The partitional clustering does not require a priori information for group membership, instead forming clusters by minimizing the residual sum of squares under partially heterogeneous restrictions, grouping respondents with shared preference patterns. Interpreting the characteristics of the two groupings is discussed in the results section.

5.4.4 Data collection

Data were collected at the YUOE campus on 25 February 2017. To select participants in the days prior to the survey, the university's Acting Rector (Dr. Aye Aye Myint) assigned staff to randomly draw names from a master list of enrolled students. After the witnessed informed consent was obtained, the respondents included 105 students (41 men) from the final year of the five-year Bachelor of Education (B. Ed.) course (population, 351). Two students opted not to participate in the study. Explanations for opting out were not requested. Despite high levels of English competency among the respondents, student aids were on hand during the data collection to clarify responses or on how to complete the survey (see an example survey in Appendix A). Participants were not explicitly informed on the mechanisms of the conjoint analysis to reduce statistical bias.

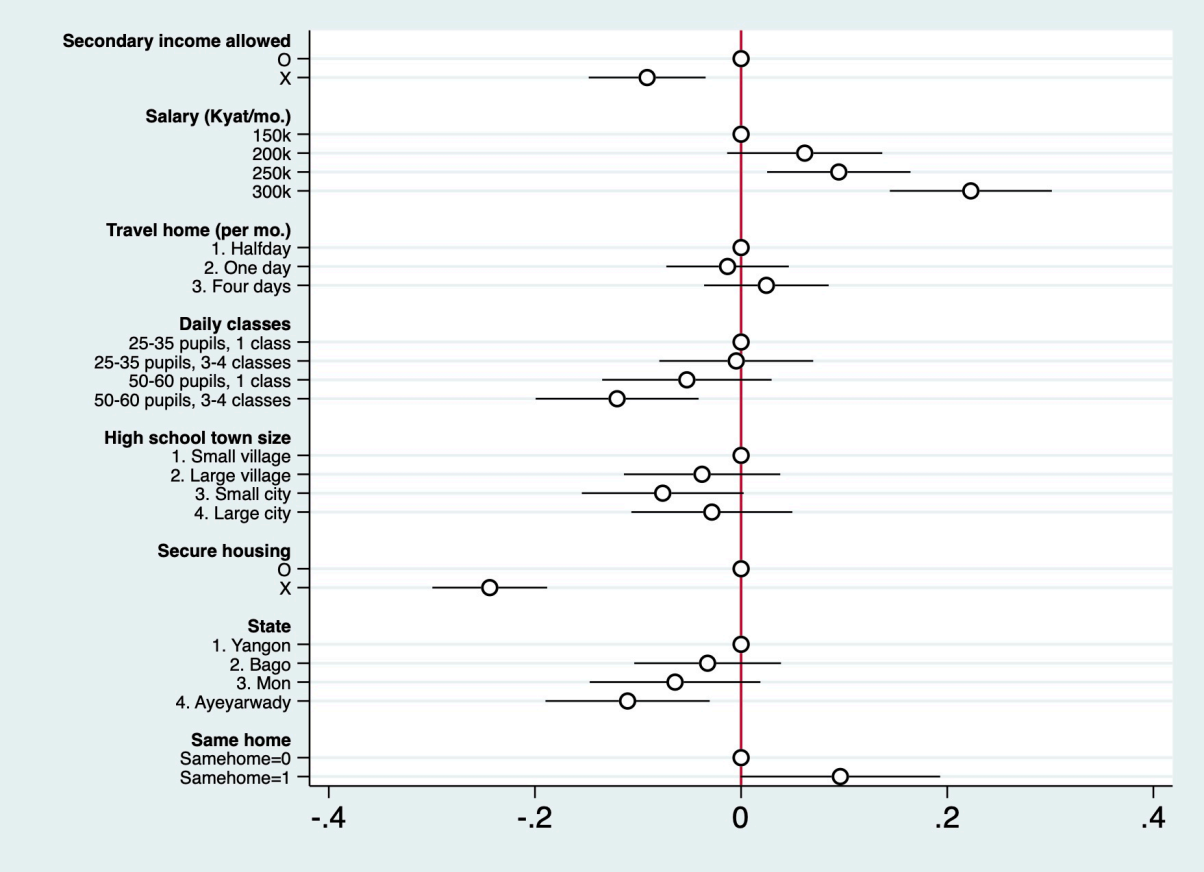
Respondents input choice preferences using electronic tablets equipped with a Microsoft Excel-generated Macros interface, which provided the randomisation of the levels and attributes for the CA. The subsequent ordinary least squares regression was done using STATA. Each respondent was presented with two choice alternatives over either six or ten rounds (with weighting applied to the final number of rounds per student). The respondents were grouped in batches of ten students. After one batch of students completed the survey, another batch would be invited to take the survey until all 105 students had finished. Out of the 3,072 possible profiles, 1,422 profiles were randomly combined into 712 choice-pairs, from which respondents selected their preference. The results are summarized in Figures 1, 2, and 3, in the results section.

5.5 Results

This study presents the results in three sub-sections displaying choice outcomes based on a basic linear regression with attribute-level dummy variables using robust standard errors clustered by respondent: the full sample (Figure 1); sex differentiated findings observing differences between male and female respondents (Figure 2); and partitional clustering (Figure 3). Starting with the full sample, the results will be provided in brief, suppling an overarching perspective of the findings before moving deeper into the sub-section analyses. For each

Figure, reference categories are indicated by dots without error bars. Horizontal markers represent likelihood for the preference selection from zero to one, with one representing 100 per cent likelihood. For example, in Figure 1, the second line ("X") under "Secondary income allowed" implies that respondents are -9.1 per cent less likely (SE = .029) to select communities that do not allow for secondary incomes.

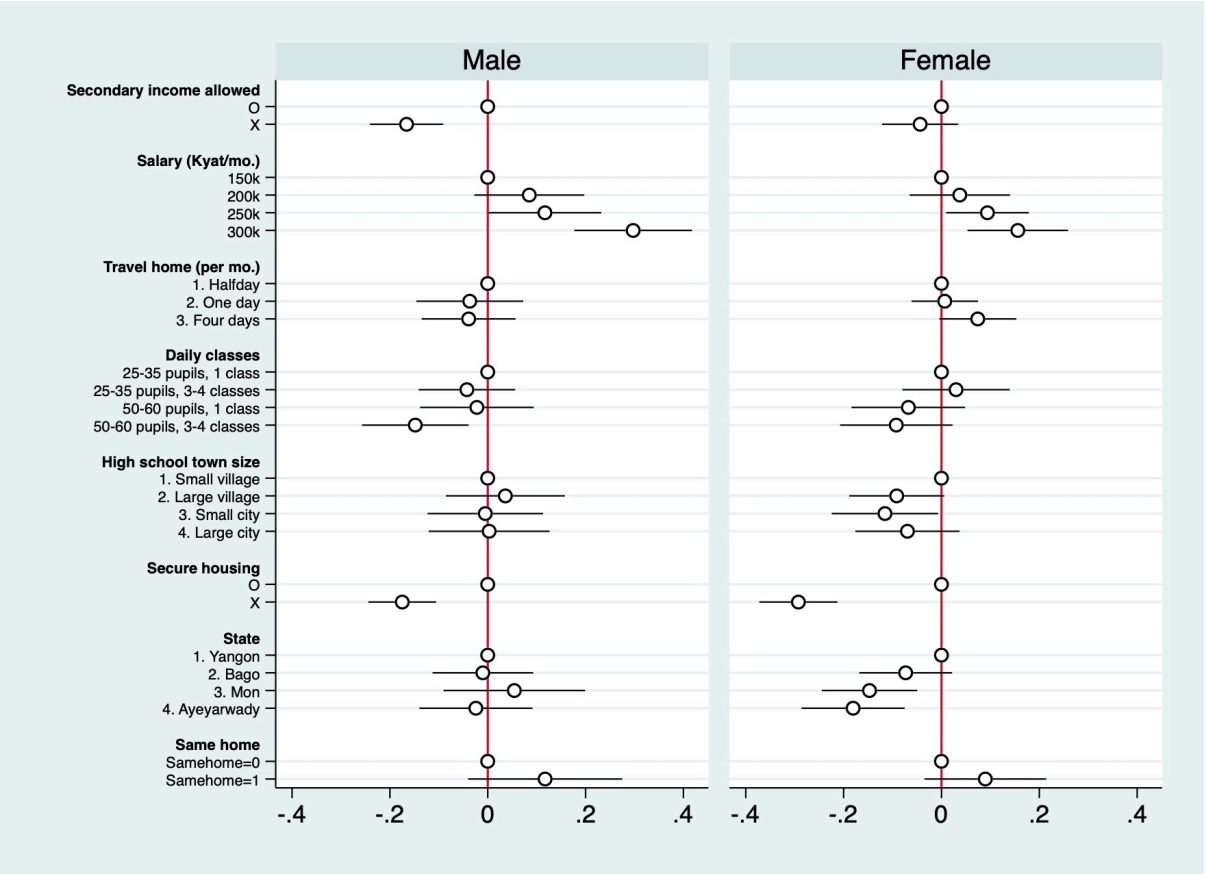
5.5.1 Full sample



The initial analysis combining all respondent results gives AMCE results that might be expected: the access to secondary incomes, higher salaries, smaller class sizes, secure housing, working in the main commercial region (Yangon), and a bias toward one's home region. If one were to stop the analysis here, the key message is that teachers want higher incomes and secure housing. The highest income bracket increases the likelihood for preference 22 per cent more compared to the reference category with a standard error (SE) of 0.039. Similar in strength of preference is secure housing with the largest coefficient among attribute levels (insecure housing is 24 per cent less likely to be selected (SE = 0.028).

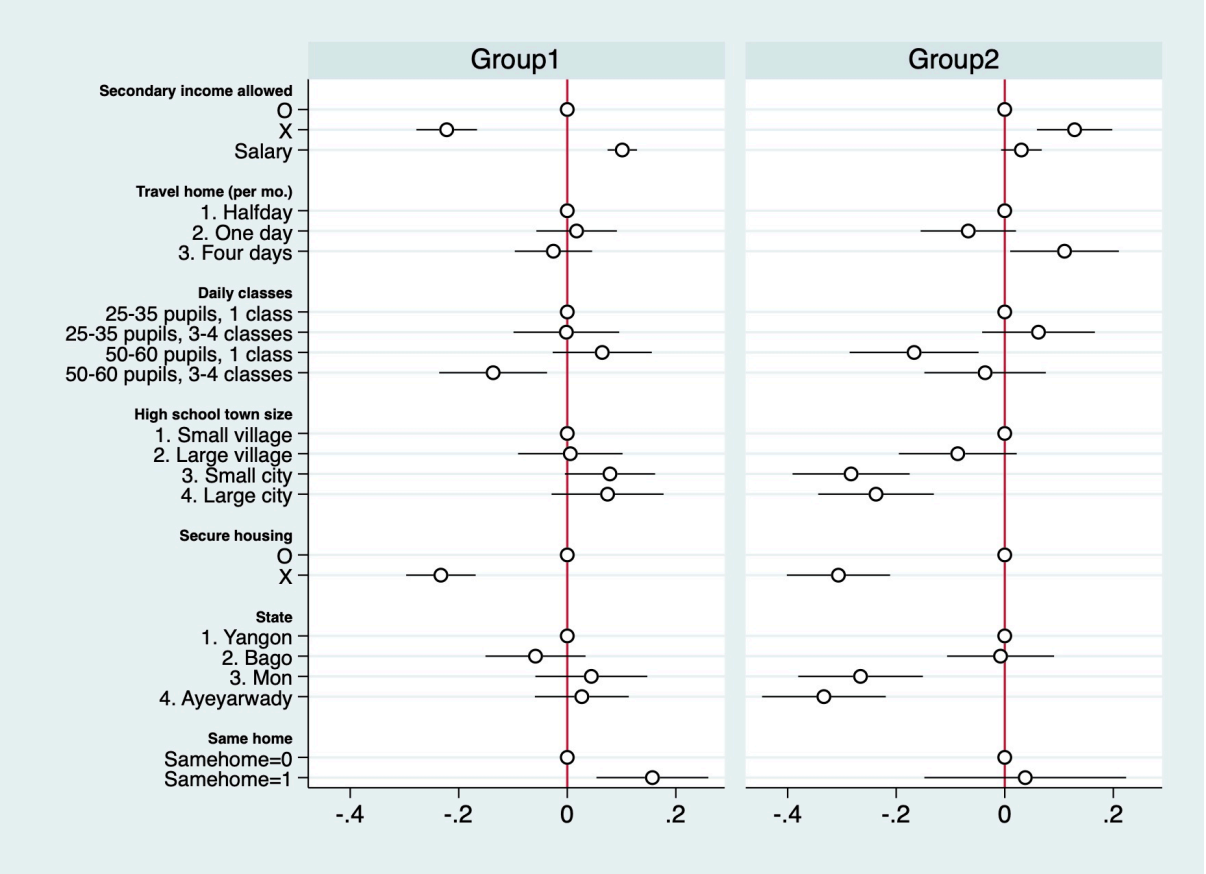
More nuance emerges as the analysis moves to the sex differentiated findings in the next sub-section.

5.5.2 Sex differentiated



Here, sex specific results are provided. Access to secondary incomes are most important for men, given that communities that prohibit secondary incomes are 16 per cent less likely to be selected compared with profiles where secondary incomes are allowed (SE = 0.03). Salaries, perhaps unsurprisingly, receive greater preference as the values increase in comparison with the baseline. When comparing magnitudes of importance, men prefer the highest salary 29 per cent more likely over baseline (SE = 0.05), where for women the preference is 15 per cent more likely over baseline (SE = 0.05). For men and women, home leave, despite expressing it as an important perquisite of a job in the informal interviews, did not prioritise it when forced to make compromises among the given attributes of the job profile choices. It should be noted that women did express a seven per cent increase in likelihood preference for posts with four days per month of leave, however the threshold for statistical significance was not met (SE = 0.039). The busiest of class schedules was rejected by men 14 per cent compared with the baseline schedule (SE = 0.05). Again, an aversion to the busiest of schedules appeared for women too, yet with no level of resounding statistical significance. The community size variable, with the 'small village' as the baseline unit, garnered no preferential response among men, and among women the point estimators indicated a general preference for the 'small village'. The absence of secure housing received the lowest levels of preference for both men and women. Women chose this feature 29 per cent less likely compared to profiles with secure housing (SE = 0.039), and for men the estimator was 17 per cent less likely (SE = 0.034). The State/Region did not affect preferences among men, yet with women the baseline location (Yangon Region) was preferred.

Partitional clustering with unobserved fixed effects



After partitional clustering into two group: Group 1, which includes 70 per cent of the males (29 individuals) and 48 per cent of the females (31 individuals), demonstrates a strong preference for access to secondary incomes (communities not allowing secondary incomes were preferred less by 23 per cent, SE = 0.029) and continuously higher salaries above the baseline (for the group analysis, the salary attribute was converted from a dummy variable to a continuous variable, reflecting the preference for higher pay: ten per cent less likely to be selected (SE = 0.013); this group is indifferent to the duration of home-leave and shows a bias towards city-based teaching positions; all but the busiest class schedule is preferred; insecure housing is rejected by 23 per cent (SE = 0.03); and lastly, this groups prefers to work in their home State/Region by 15 per cent (SE = 0.05).

In contrast, Group 2 is most clearly defined by what it rejects: Preferring not to access to secondary incomes by a likelihood of 15 per cent (SE = 0.034) and only a marginal preference for higher pay (statistically insignificant); a four-day home-leave is desired at 11 per cent (SE = 0.049); the only class size to be rejected was the one-per-day class with 50-60 students; small-village-based teaching positions significantly outweigh city based posts; insecure housing is one of the most strongly rejected attributes among either group at 30 per cent (SE = 0.047); placements in either Yangon Region or Bago Region are strongly preferred to those in Ayeyarwadi Region or Mon State; and lastly, those in Group 2 express no preference to be placed in their home State/Region.

While this pilot study does not purport to solve the challenge of securing teachers in rural secondary schools of Myanmar, the results of this study, in conjunction with the literature,

suggest interpretations and ways forward to accommodate teacher motives into improved school outcomes for students. The profession of teaching can be likened to that of medicine (e.g., physicians or nurses) or public safety (e.g., police or firefighters), as these careers can attract individuals with altruistic/idealistic personalities (Brown 1992; Serow 1993; Bastick 2000; Krecic 2005). Similarly, teaching can be viewed as either a 'job' or a 'profession' (Martinez, Desiderio, & Papakonstantinou, 2010). Group 1 may view teaching as a 'job' or a means to achieve an end, without the high-minded goal of providing education to children. These individuals demonstrate a preference to work in their home state with higher incomes (either from primary or secondary activities) and to have a secure residence. In contrast, those in Group 2 may see teaching as a 'profession' or a 'calling', expressing an altruistic interest in the characteristics of the profession including: modest salaries; working in small villages; the desire for a secure residence; and a four-day per month home-leave.

While this paper does not provide specific policy suggestions, understanding how teacher motivation may influence retention is a valuable first step. Teacher retention strategies suggested by the literature, such as performance-based pay incentives (Sundararaman 2011; Dolton 2011) might motivate teachers interested solely in increased pay, though they may not be as effective for teachers driven by more altruistic aims.

5.6 Conclusion

This study conducted an improved conjoint analysis, following Hainmueller et al. (2014), to reveal the non-parametric preferences of final-year teaching students at the Yangon University of Education as a means to address the reported challenges faced by teachers serving in the rural areas of Myanmar. Analysis was conducted along three sections using ordinary least squares regression: the dataset in full; sex-disaggregated; and partitional clustering algorithm, following Sarafidis and Weber (2015).

The study was designed to pilot the identification of factors that most contribute to the high attrition rates for rural area teachers. The evidence provided could inform policymakers on ways-forward to address this issue. The discrete choice experiment presented the respondents with multiple job profiles to reveal how attributes of the hypothetical teaching location incentivized or dis-incentivized the selection of that community. Arranged in pairs, each profile contained seven multi-level attributes, each independently and completely randomized, reflecting the traits of a rural teaching position. By selecting their preferred option over repeated rounds, the respondents revealed a statistically robust set of data with high internal validity: the average marginal component effect (AMCE) of each attribute-level. This technique combines the relative importance of choosing an outcome variable with the avoidance of direct questioning, giving a more realistic representation of the participant's preference.

The sample population represents the key limitation for this study. While the respondents for this study are representative of young graduates of YUOE, external validity may vary with age and professional experience. Future studies would also do well to broaden the sample frame to include teachers from the more than one hundred ethnic groups in Myanmar.

The average and sex-specific effects revealed similarities in preferences for higher salaries, secure housing, and smaller class sizes. The partitional clustering, however, revealed the appearance of two groups with distinct underlying motivations: those labelled Group 1 demonstrated a preference for higher salaries, access to secondary income, a bias towards larger communities, an aversion to insecure housing, and a preference to remain in their home region. This group, comprising almost half of the females and 70 per cent of the males, could

be labelled as those who see teaching as a "job" rather than a "profession." In contrast, those in Group 2 demonstrated preferences for job communities including: those without secondary incomes; modest salary increases; four-days per month of home-leave; small communities; secure housing; and a strong aversion to placements in either Ayeyarwady or Bago Regions. The Group 2 respondents present characteristics of the "professional" teacher, those who are following a calling to educate children. This study thereby demonstrates to policymakers that incentivising teachers to remain in rural schools will require an approach that accounts for differing teacher motivations and preferences.

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6 Concluding remarks

Each chapter in this dissertation aimed to provide new insights, both in African and Asian countries, to the field of education research. The outcome variables of interest, with the exception of the revealed preferences of student-teachers in Myanmar, were the result of student test scores. The empirical utility of testing, and hence the evaluation of test-scores, is only limited to the degree to which the text mirrors the knowledge or skills being tested. Despite this constraint, each chapter provided evidence to aid policy decisions to benefit either children or their teachers using the evidence at hand.

In the case of children orphaned in eastern and southern Africa, despite the advances in arresting the propagation of HIV, orphanhood continues to increase. This is in part due to a growing population in the region, but it is also a signal as to the troubling state of health and safety outcomes of many communities. Even in the most advances economies of the region, maternal mortality, road accidents, and crime, continue to leave children without the essential support of one or both parents. For less developed countries, armed conflict and famines add to the loss and suffering.

To better isolate which policies can most effectively address the needs of these effected children, advanced econometrics can aid in the separation of covariates influencing orphanhood and learning outcomes, as was the objective in Chapter 1. This research benefited from recent advances in machine learning techniques to select the weight of controlled covariates for both the outcome and treatment variables, further reducing bias. Combined, the countries in which orphans are most disadvantaged are identified to aid policy interventions. Chapter 2 utilized a similar technique for examining the effect of gender on learning outcomes between countries in the region using the same dataset.

Improving teaching techniques can also benefit from experimental models. In Chapter 3, primary school physics students in Thailand agreed to be divided into two classrooms with slightly different pedagogical approaches over the course of a taught unit. For this chapter, the research aimed to address a concern for all schools, that of cost. This experiment compared teaching physics with hardware, which can be expensive, to learning using freely available software. The design of the study was narrow in scope, implying that the results cannot necessarily be valid across the subject, however no significant differences were found. This provides an important implication for saving on costs without losing on the quality of the instruction. Chapter 4 similarly reported the results of an experimental study on information and communication technology (ICT) for learning climate change awareness in the classroom in Myanmar. As was the case in Thailand, the effects were not significant, implying that both lecture-based and ICT-based techniques are equivalent approaches to teach the subject.

Lastly, Chapter 5 sought to capture the preferences of teachers when considering the tradeoffs of working in rural Myanmar. This study piloted a conjoint analysis that can serve as a model for future studies. The importance of sampling teacher preferences is relevant in all national contexts but especially so in a country such as Myanmar, due to its long isolation from the global marketplace of business and ideas. Now that the country is rapidly expanding its social and economic horizons, it can benefit from understanding how these dynamic changes are affecting the teachers of its future leadership and workforce. If the government fails at addressing the needs of its teachers, the future productivity of the country will be at risk given that the children will likely have not received the education needed to thrive. This study applied a contemporary conjoint analysis using randomized attribute levels to isolate the influence of the attributes on the workplace preference. A secondary analysis used partitional clustering to differentiate preferences based on unobservable motives of the participants, further informing policymakers how to tailor the needs of teachers in challenging rural schools.

This dissertation is just one small affirmation for the contribution of data analytics in evidence-based development policy.

7 Appendix

7.1 Appendix to Chapter 1

Appendix A. Estimated number of children orphaned in southern and eastern Africa, including primary school net and gross enrollment figures for all children

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Children orphaned by AIDS (thousands) 2007 estimate	Children orphaned due to all causes (thousands) 2007 estimate	Orphan school attendance ratio (%) 2002-2007*	Primary school gross enrollment ratio (%), male 2002-2007*	Primary school gross enrollment ratio (%), female 2002-2007*	Primary school net enrollment ratio (%), male 2002-2007*	Primary school net enrollment ratio (%), female 2002-2007*	Primary school net attendance ratio (%), male 2002-2007*	Primary school net attendance ratio (%), female 2002-2007*
Botswana	95	130	99	108	106	83	85	83	86
Kenya	-	2500	95	107	104	75	76	79	79
Lesotho	110	160	95	115	114	71	74	82	88
Malawi	550	1100	97	117	121	88	94	86	88
Mauritius	<0.5	21	-	102	102	94	96	-	-
Mozambique	400	1400	80	113	97	79	73	63	57
Namibia	66	110	100	107	107	74	79	91	91
Seychelles	-	-	-	126	125	99	100	-	-
South Africa	1400	2500	-	108	103	88	88	80x	83x
Swaziland	56	96	97	110	102	78	79	83	86
Tanzania	-	2600	-	112†	109†	99†	97†	71	75
Uganda	1200	2500	96	116	117	-	-	83	82
Zambia	600	1100	103y	118	116	90	94	55	58
Zimbabwe	1000	1300	95	102	101	87	88	91	93
	2013 estimate	2013 estimate	2009-2013*	2009-2012*	2009-2012*	2009-2013*	2009-2013*	2008-2013*	2008-2013*
Botswana	96	130	-	112.1	108.1	86.7	87.9	85.5	88.2
Kenya	1100	2500	-	114.6	112	83.5	84.5	72.4	75
Lesotho	150	220	98	104.8	101.4	73.6	76.4	87.2	91.2
Malawi	790	1200	97	138.5	144.1	-	-	84.3	86.2
Mauritius	-	-	-	-	-	-	-	-	-
Mozambique	810	2100	91	116.3	105.4	92.1	87.6	77.2	77.1
Namibia	96	150	100x	107.6	106.1	83.8	88.5	91.4	92.8
Seychelles	-	-	-	112.6	113.1	-	-	-	-
South Africa	2400	3600	101x	103.9	99.5	89.7	90.9	-	-
Swaziland	73	100	100x	121.3	108.9	-	-	96	97
Tanzania	1200†	3100†	95x	92.2	95.1	98.5	98	78.9	81.9
Uganda	1000	2400	87	112.2	114.2	92.5	95.2	81.3	81.1
Zambia	600	1400	92	117.7	117	96.1	98.4	81.3	81.8
Zimbabwe	890	1100	95x	-	-	-	-	87.5	88.8

Note: This data is adapted from UNICEF's State of the World's Children (SOWC) reports from 2009, 2015, and www.unicef.org/infobycountry/. The orphan school attendance ratio is defined as: the percentage of children (aged 10 to 14) who have lost both biological parents and who are currently attending school as a percentage of non-orphaned children of the same age who live with at least one parent and who are attending school. However, the definition for 'orphan' used in SACMEQ and in this paper included both single- and double-parent orphans and includes ages 10 to 27. Using the definition of orphan from SACMEQ, attendance ratios must be significantly higher than those provided by UNICEF.

* Data refer to the most recent year available during the period specified in the column heading.
x: Data refer to years or periods other than those specified in the column heading.
y: Data differ from the standard definition or refer to only part of a country.

7.2 Appendix to Chapter 2

Table A-1 Covariates inclueded in the regression model including student- and school-level characteristics

Variable name	Description	Variable type
Female	Student's gender dummy	(Reference: Male)
Female*GII	Cross term between female and Gender Inequality Index (GII)	Continuous
	Student characteristics	
Mother alive	Surviving status of mother	(Reference: Deceased)
Father alive	Surviving status of father	(Reference: Deceased)
Travel time to school	Time to travel to school from student's home	(Reference: <0.5 km)
Travel mode	How to travel to school from student's home	(Reference: Walk)
Birth year	Student's birth year	(Reference: 1981)
Number of books	-	Continuous
Household possession	Possession of each good	(Reference: Don't have)
Number of brothers	-	(Reference: None)
Number of sisters	-	(Reference: None)
Mother's education	-	Reference: No school, no adult education
Father's education	-	Reference: No school, no adult education
Source of light	Main source of lighting in student's home	(Reference: Fire)
	School characteristics	
School type	Government school or Non-government school	(Reference: Government school)
School head age	Age of school head	Continuous
School head, years of professional training	Professional training year of school head	Continuous
Pupil-teacher ratio	Ratio of students over teachers in student's school	Continuous
Ratio of teachers with tertiary education	Ratio of tertiary educated teacher over whole teachers in student's school	Continuous
Average staff years of training	Average training year of staff in student's school	Continuous
Ratio of girls/boys	Ratio of girl students over boy students in student's school	Continuous
Teacher's sex	Gender of teacher in student's class	(Reference: Male)
Teacher's age	Age of teacher in student's class	Continuous
Teacher employment status	Employment contract of teacher in student's class	(Reference: Permanent Govt.)
Teacher qualification	Academic education of teacher in student's class	(Reference: Primary)
Teacher training	Professional training of teacher in student's class	(Reference: No training)
Years of teaching	Year of professional training of teacher in student's class	Continuous
Teacher trained: English	English-specific training of teacher in student's class	(Reference: No training)
Teacher trained: Math	Mathematics-specific training of teacher in student's class	(Reference: No training)
Teacher trained: Sciences	Science-specific training of teacher in student's class	(Reference: No training)
Teacher trained: Social sciences	Social science-specific training of teacher in student's class	(Reference: No training)

Note: under column tile 'Variable type', all categories are categorical, with the reference category included. Unless noted otherwise, the variable is continuous.

7.3 Appendix to Chapter 3[46]

A: Pre-test

Reflection & Refraction Test

Score: ____ / 25

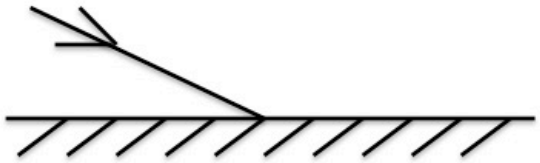
Student Name_____

Class: _____

[46] The tests presented in this appendix were produced by the co-author (Wood).

1.

The diagram below shows a ray of light reaching a mirror



On the diagram above, draw and label:

- The normal line
- The angle of incidence
- The reflected ray (3)

The IGCSE class is investigating the reflection of light by a plane mirror. Fig. 1.1 shows a student's ray-trace sheet.

2.

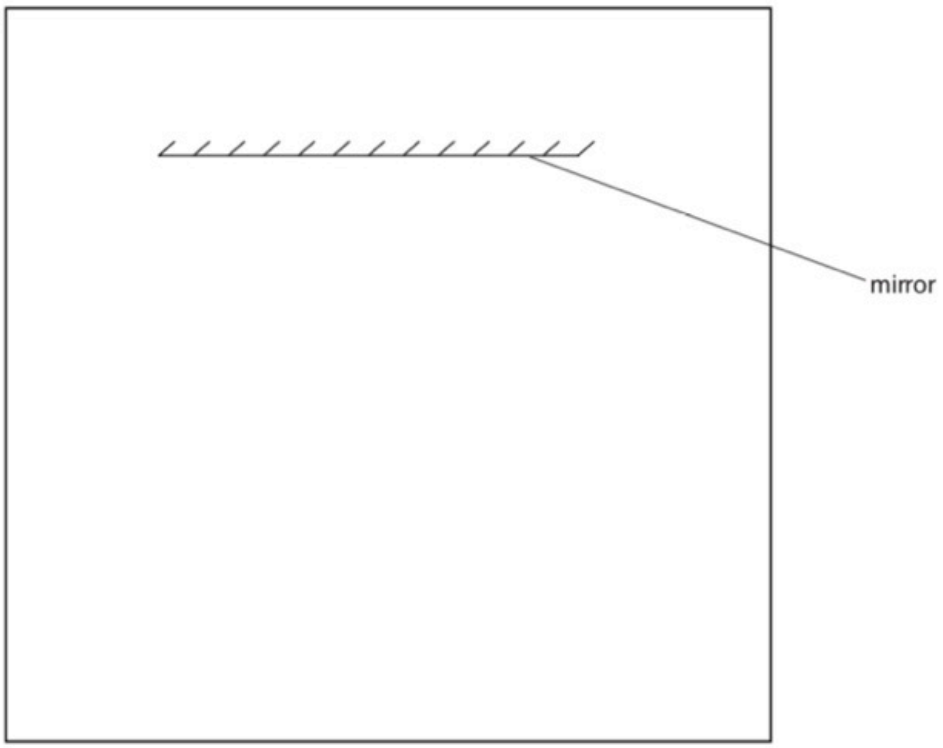


Fig. 1.1

(a) On Fig. 1.1, draw a normal to the centre of the mirror. [1]

(b) On Fig. 1.1, draw an incident ray at 30° to the normal and to the left of the normal. [1]

(c) Fig. 1.2 shows a diagram of a ray box.

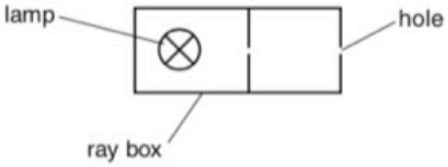


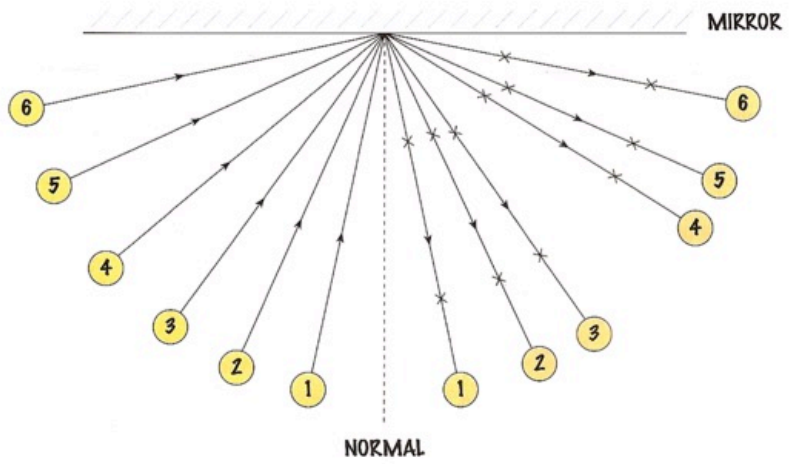
Fig. 1.2

On Fig. 1.1, draw the ray box in a suitable position to produce the incident ray that you have drawn. [1]

(d) On Fig. 1.1, draw a reflected ray in the position you would expect it to be using the incident ray that you have drawn. [1]

3. What are the Rules of Reflection?

Two year 7pupils decided to investigate whether there was a link between a ray of light that hits a mirror and its reflected ray. Using a ray box and slit, the pupils shone a ray of light along 6 previously drawn incident rays. In each case the reflected ray was marked and drawn in.



1. Using a protractor complete the table opposite by writing in the angle of incidence and angle of reflection for each ray.

Ray	Angle of Incidence	Angle of Reflection
1		
2		
3		
4		
5		
6		

(6)

2. What conclusion can you draw from their results?

.....

.....

(1)

4. James set up a different experiment as shown below.

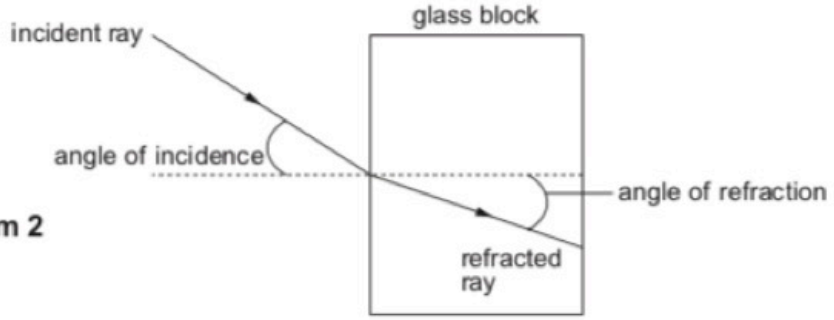
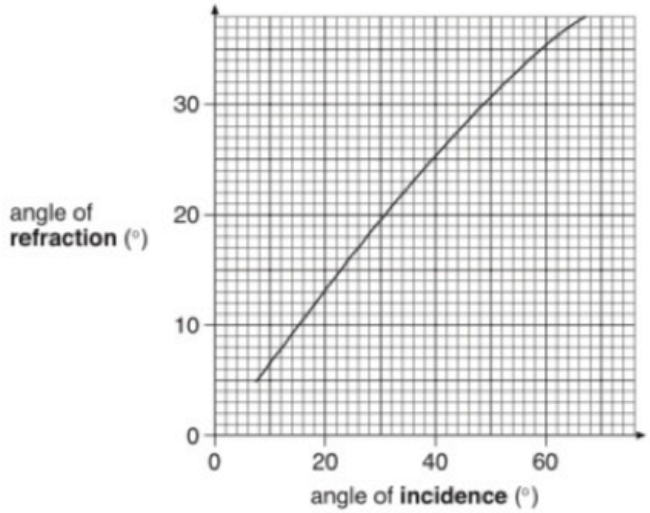


diagram 2

He measured the angle of **refraction** for different angles of incidence.
His results are shown in the graph.



Use the graph to answer the questions below.

(i) When the angle of **refraction** is 20°, what is the angle of **incidence**?

_____°

(1)

(ii) What conclusion could James draw from his graph?
Complete the sentence below.

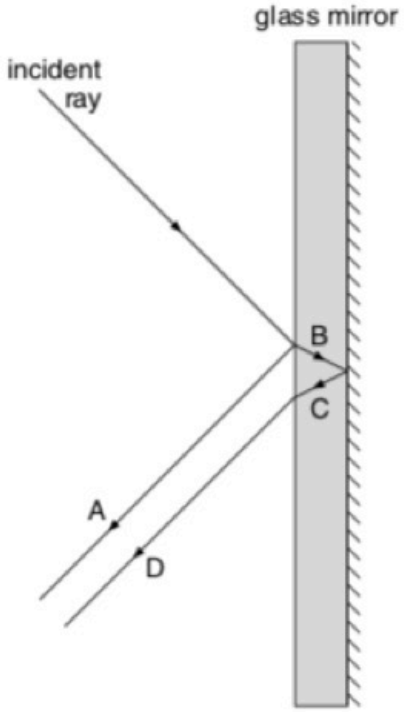
When light passes from air into glass, the angle of **incidence** is

always _____ the angle of **refraction**.

(1)

5. **On diagram 2, on the opposite page**, draw a line to continue the refracted ray as it leaves the glass block.

The diagram shows a ray of light hitting the surface of a mirror made from thick glass.
The incident ray is both reflected and refracted.



(a) (i) Give the letters of the **two** reflected rays.

_____ and _____ (2)

(ii) Give the letter of **one** refracted ray.

_____ (1)

(b) The incident ray is brighter than ray A.
Give **one** reason for this.

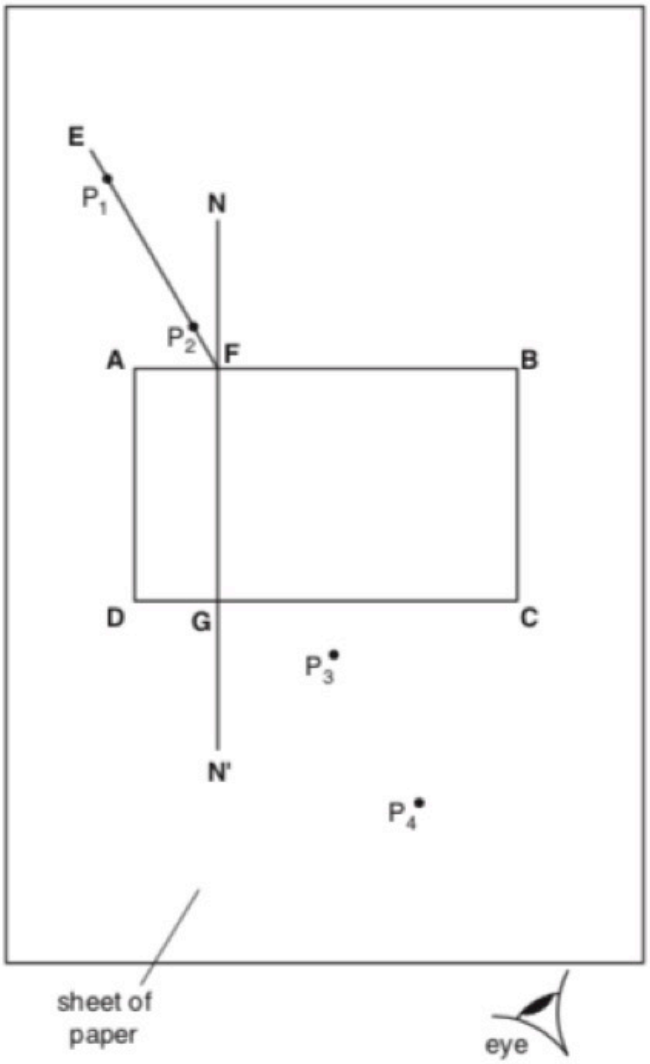
(1)

_____

The IGCSE class is investigating the refraction of light through a transparent block.

Fig. 4.1 shows a student's ray trace sheet. It is not drawn full size.

6.



(a) The student places a transparent block, largest face down, on a sheet of plain paper and draws the outline **ABCD** of the block. She removes the block and draws the normal **NN'** to side **AB**. She then draws the line **EF** at an angle of incidence *i*.

On Fig. 4.1, measure the angle of incidence *i*.

i = ...[1]

(b)

The student notices the light exits the block. She marks these points where the light exits P_3 and P_4.

(i) On Fig. 4.1, draw a line joining the positions of P_3 and P_4. Continue the line until it meets **CD**. Label this point **H**.

(ii) Measure and record the length *a* of the line **GH**.

a = ...

(iii) Draw the line **HF**. (2)

(iv) Measure and record the length *b* of the line **HF**.

b = ...

(2)

Appendix B: Post-test

Reflection & Refraction Test

Score: ____ / 25

Student Name_____

Class: _____

Please choose your top three school subjects. Choose from: Art, Drama, PE, Humanities, English, Science, DT, Chinese, Maths.

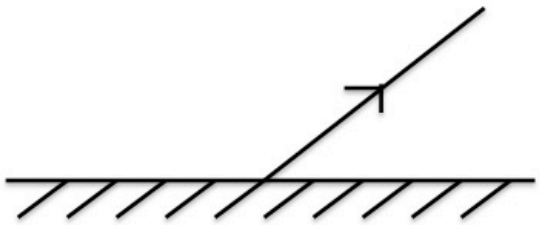
1. _____

2. _____

3. _____

1.

The diagram below shows a ray of light reaching a mirror



On the diagram above, draw and label:

- The normal line
- The angle of reflection
- The incidence ray (3)

The IGCSE class is investigating the reflection of light by a plane mirror. Fig. 1.1 shows a student's ray-trace sheet.

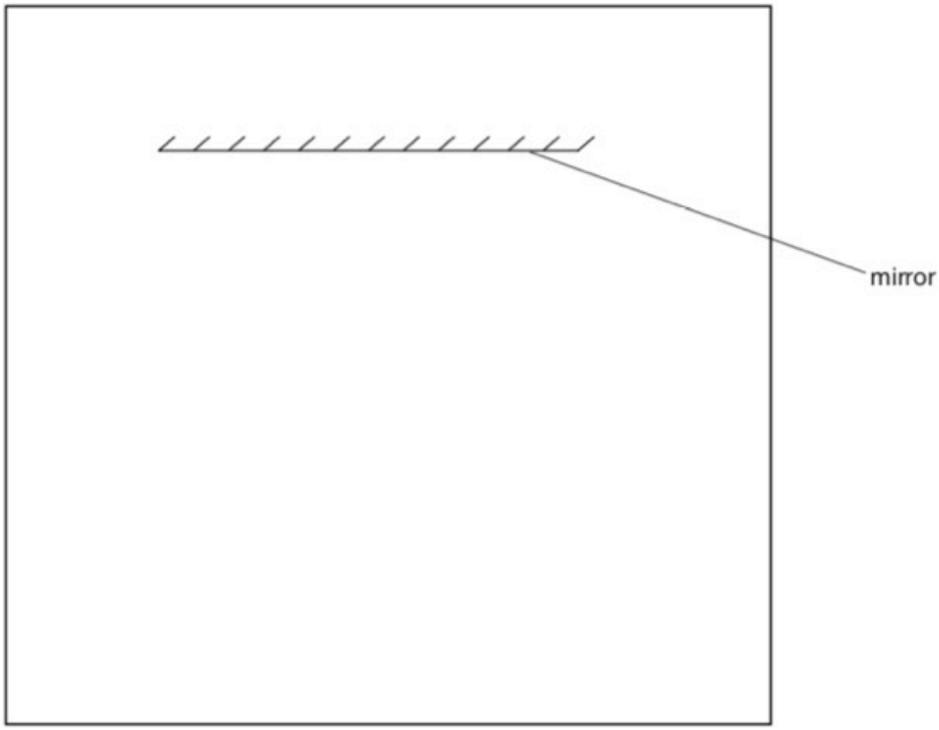


Fig. 1.1

(a) On Fig. 1.1 draw a normal to the centre of the mirror (1)

(b) on Fig. 1.1, draw an incident ray at 25° to the normal and to the right of the normal (1)]

(c) Fig. 1.2 shows a diagram of a ray box.

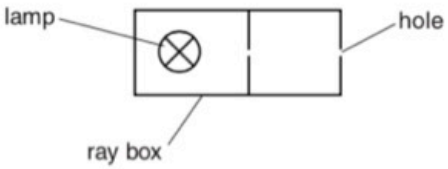


Fig. 1.2

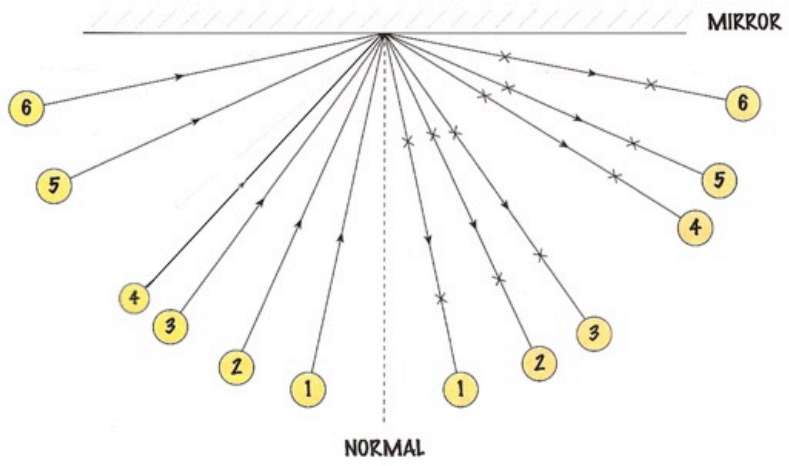
On Fig. 1.1, draw the ray box in a suitable position to produce the incident ray that you have drawn. [1]

(d) On Fig. 1.1, draw a reflected ray in the position you would expect it to be using the incident ray that you have drawn. [1]

What are the Rules of Reflection?

Two year 7pupils decided to investigate whether there was a link between a ray of light that hits a mirror and its reflected ray. Using a ray box and slit, the pupils shone a ray of light along 6 previously drawn incident rays. In each case the reflected ray was marked and drawn in.

3.



1. Using a protractor complete the table opposite by writing in the angle of incidence and angle of reflection for each ray.

Ray	Angle of Incidence	Angle of Reflection
1		
2		
3		
4		
5		
6		

(6)

2. What conclusion can you draw from their results?

.....

.....

(1)

(b) James set up a different experiment as shown below.

4.

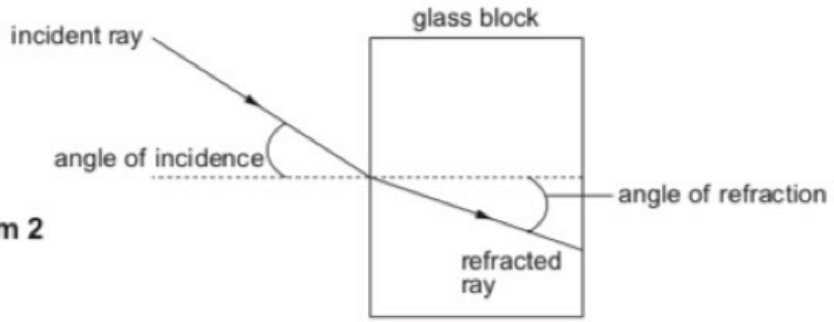
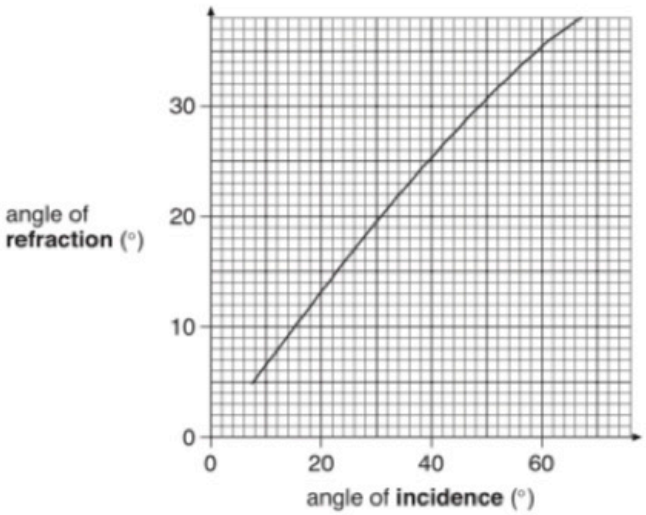


diagram 2

He measured the angle of **refraction** for different angles of incidence.
His results are shown in the graph.



Use the graph to answer the questions below.

(i) When the angle if incidence is 30° what is the angle of refraction?

_____°

(1)

(ii) What conclusion could James draw from his graph?
Complete the sentence below.

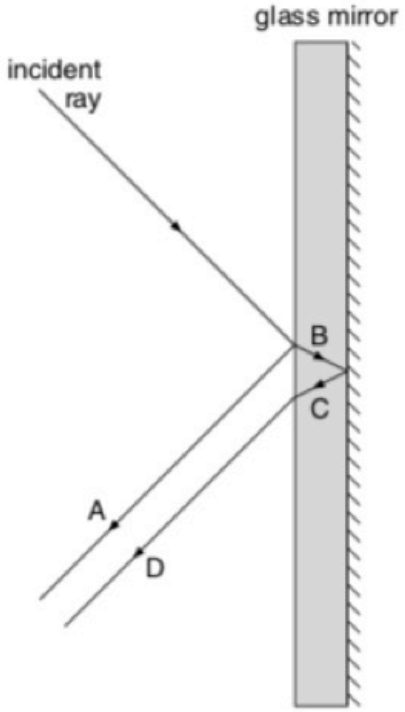
When light passes from air into glass, the angle of refraction is

always _____ the angle of incidence.

(1)

5.

The diagram shows a ray of light hitting the surface of a mirror made from thick glass.
The incident ray is both reflected and refracted.



(a) (i) Give the letters of the **two** refracted rays.

_____ and _____ (2)

(ii) Give the letter of **one** reflected ray.

_____ (1)

(b) The incident ray is brighter than ray A.
Give **one** reason for this.

(1)

_____

6. The IGCSE class is investigating the refraction of light through a transparent block.

Fig. 4.1 shows a student's ray trace sheet. It is not drawn full size.

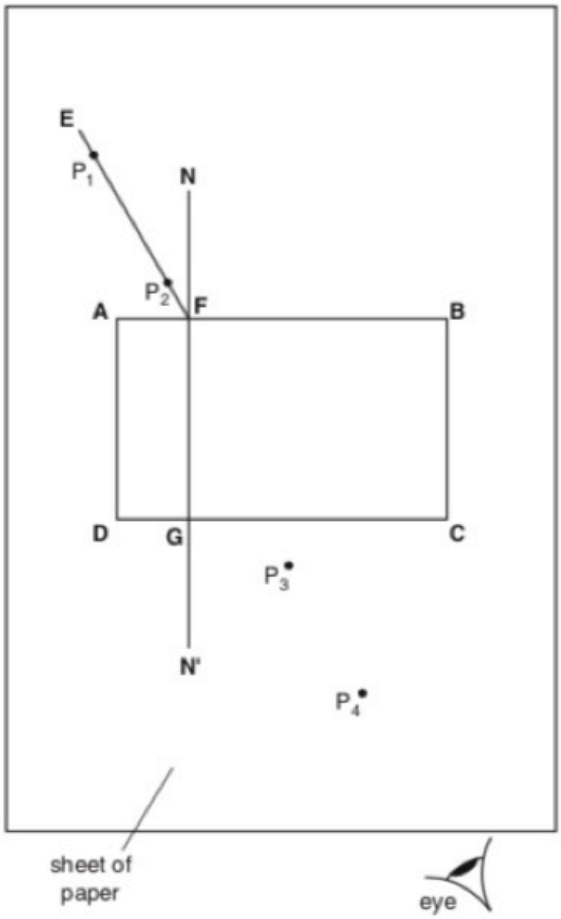


Fig. 4.1

(a) The student places a transparent block, largest face down, on a sheet of plain paper and draws the outline **ABCD** of the block. She removes the block and draws the normal **NN'** to side **AB**. She then draws the line **EF** at an angle of incidence *i*.

On Fig. 4.1, measure the angle of incidence *i*.

i = ...[1]

(b)

The student notices the light exits the block. She marks these points where the light exits P_3 and P_4.

(i) On Fig. 4.1, draw a line joining the positions of P_3 and P_4. Continue the line until it meets **CD**. Label this point **H**.

(ii) Measure and record the length *a* of the line **GH**.

a = ...

(iii) Draw the line **HF**. (2)

(iv) Measure and record the length *b* of the line **HF**.

b = ...

(2)

7.4 Appendix to Chapter 4

Questionnaire

ID: _____

Basic Information

Grade

Gender

Male	Female

Birth Year

Do you live with your parents?

(a) Yes, both of them.	(b) One of them (Father/Mother)
(c)No, live with grand parents	(d) No, live with relatives
(e) Others (specify)	

Do you know education of your parents?

(a) Illiterate	(b) Elementary School	(c) Middle School
(d) High School	(e) Graduate	(f) Don't know

Occupation of your parents

Father	**Mother**
(a) Farming	(a) Farming
(b) Trading	(b) Trading
(c) Construction	(c) Construction
(d) Factory worker	(d) Factory worker
(e) Self-employed	(e) Self-employed
(f) Other (Specify)	(f) Other (Specify)

Total family members

Type of the house you live.

(a) Concrete built	(b) Wooden built	(c) Tent
(d) Temporary	(e) Others (specify)	

Do you have access to electricity in your home?

(a) Yes	(b) No

Do you know what carbon dioxide is?

(a) Yes	(b) No

Questions concerning the lecture

Have you ever heard about greenhouse gas?

Yes	No

Greenhouse gases are (tick the ones)

(a) Carbon Dioxide (CO_2)	(b) Ozone (O_3)
(c) Oxygen (O_2)	(d) Hydrogen peroxide (H_2O_2)

Do you think Greenhouse gases are main sources of global warming?

(a) Yes	(b) No

Burning fossil fuels increased the amount of CO_2 in the atmosphere which consequently raised the sea level.

(a) Yes	(b) No

The world's carbon dioxide concentration is stable since thousands of years ago.

(a) Yes	(b) No

Arctic and Antarctica are covered by ice bergs.

(a) Yes	(b) No

What will happen if the average temperature of earth increased 5°C?

(a) People will die	(b) All water will dehydrate
(c) Ocean level will raise	(d) Nothing will happen

Most of the carbon dioxide in our surroundings is absorbed by plants.

(a) Yes	(b) No

Plants can absorb all carbon dioxide emitted.

(a) Yes	(b) No

Increased carbon dioxide in the atmosphere can severely damage the earth including plants and animals.

(a) Yes	(b) No

Using nitrogen fertilizers will increase greenhouse gases.

(a) Yes	(b) No

Do you think local activities have global effects?

(a) Yes	(b) No

Light rays from sun come to the earth as Short wavelength radiation or longer wave length radiation?

(a) short wave length	(b) long wave length
(c) both	(d) neither of

What is the difference between atmospheric greenhouse gas effect and gardener's green house?

(a) same	(b) more CO_2 in Atmosphere
(c) more CO_2 in Gardeners house	(d) More hot in Gardener's house

What is the main problem of greenhouse gases now?

(a) No problem at all	(b) The problem of rate of CO_2

What is the trend of CO_2 emissions in the atmosphere over the years?

(a) Increasing	(b) Decreasing	(c) Up and Down	(d) Stagnated

What is the CO_2 emission in recent years?

(a) Same as before	(b) Increasing drastically	(c) Up and Down	(d) decreasing

Have you heard of Climate Change before?

(a) Yes	(b) No

What is the full form of IPCC?

(a) Intergovernmental Panel on Climate Change	(b) International Program on Climate Change
(c) International Program on Children's Care	(d) Interested People of Climate Change

As per IPCC, the average global temperature on earth is increased by

(a) 1.1 to 2.9^oC	(b) 2 to 5.2^oF	(c) None of them	(d) both of them

What is the worst-case scenario of CO_2?

(a) 2.4 to 6^oC	(b) 4.3 to 11.5^oF	(c) None of them	(d) both of them

What is the main cause of global sea level rise?

(a) Melting of ice	(b) Rise in temperature	(c) None of them	(d) both of them

The main effect of sea level rise is/are

(a) Disappearance of low lying countries like Maldives	(b) Occurrence of floods, hurricanes, typhoons, storms	(c) Loss of endemic species and their habitats	(d) All of above

Every species has its own optimal habitat and tolerance ranges of temperate?

(a) True	(b) False

Because of sea level rise and increase in temperature,

(a) Species and habitats become endangered and rare	(b) New species are emerged
(c) Species adapt or move to the cooler places	(d) All of above
(e) None of Above	

Impacts of sea level rise and increase in temperature is more in

(a) Marine ecosystem	(b) Terrestrial ecosystems	(c) None of them	(d) both of them

Atmospheric CO_2 is absorbed by

(a) Plants	(b) Animals	(c) None of them	(d) both of them

Atmospheric CO_2 is absorbed through the process of

(a) Photosynthesis	(b) Sequestration	(c) Fixation	(d) all of above	(e) None

Is it true or false that some places are getting warmer and some places are getting colder to the increase in temperature and climate change?

(a) True	(b) False

What do we need to do to save our earth?

7.5 Appendix to Chapter 5

Question Number

1 <=max. 1024

START

The 1st trial

		Choice A Choice Code 179	Choice B Choice Code 3013
Attribute 1	Secondary income	Allowed	Not-allowed
Attribute 2	District/State of High School	Ayeyarwady	Bago
Attribute 3	You can travel home	Once per month	Once per two months
Attribute 4	Housing	Secure housing	Not-secure housing
Attribute 5	Monthly salary	150,000	300,000
Attribute 6	Teaching environment	25-35 students, 3-4 subjects per day	50-60 students, 1 subjects per day
Attribute 7	Size of High School community	Small city	Small village
	Your Choice (insert "Y") ==>		

The 2nd trial

		Choice A Choice Code 2497	Choice B Choice Code 2858
Attribute 1	Secondary income	Allowed	Not-allowed
Attribute 2	District/State of High School	Bago	Yangon
Attribute 3	You can travel home	Once per month	Once per month
Attribute 4	Housing	Secure housing	Secure housing
Attribute 5	Monthly salary	300,000	300,000
Attribute 6	Teaching environment	50-60 students, 1 subjects per day	25-35 students, 3-4 subjects per day
Attribute 7	Size of High School community	Small village	Large village
	Your Choice (insert "Y") ==>		