The Malawi Priorities Project

Cost-benefit analysis: Improving the quality of primary school education in Malawi - Technical Report

National Planning Commission Report with technical assistance from the Copenhagen Consensus Center and the African Institute for Development Policy

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Disclaimer
This report was prepared independently by Christopher Cotton, Bahman Kashi, Jay MacKinnon, Ardyn Nordstrom, Lindsay Wallace, and Brad Wong, with input from Jonathan Makuwira and Ivy Chauya. The authors have no conflicts of interest.

Malawi Priorities: Background

Malawi Priorities is a research-based collaborative project implemented by the National Planning Commission (NPC) with technical assistance from the African Institute for Development Policy (AFIDEP), and the Copenhagen Consensus Center (CCC) to identify and promote the most effective interventions that address Malawi's development challenges and support the attainment of its development aspirations. The project seeks to provide the government with a systematic process to help prioritize the most effective policy solutions so as to maximize social, environmental and economic benefits on every kwacha invested. Cost-benefit analysis is the primary analytical tool adopted by the project. Cost-benefit analysis will be applied to 20-30 research questions of national importance. Research will take place over the course of 2020 and 2021.

Research questions were drawn from the NPC's existing research agenda, developed in September 2019 after extensive consultation with academics, think tanks, the private sector and government. This sub-set was then augmented, based on input from NPC, an Academic Advisory Group (AAG) of leading scholars within Malawi, and existing literature, particularly previous cost-benefit analyses conducted by the Copenhagen Consensus Center. The research agenda was validated and prioritized by a Reference Group of 25 prominent, senior stakeholders. The selection of interventions was informed by numerous consultations across the Malawian policy space, and one academic and two sector experts provide peer review on all analyses.

Cost-benefit analyses in Malawi Priorities consider the social, economic and environmental impacts that accrue to all of Malawian society. This represents a wider scope than financial cost-benefit analysis, which considers only the flow of money, or private cost-benefit analysis, which considers the perspective of only one party. All benefit-cost ratios (BCRs) reported within the Malawi Priorities project are comparable.

The cost-benefit analysis considered in the project is premised on an injection of new money available to decision makers, that can be spent on expanding existing programs (e.g. new beneficiaries, additional program features) or implementing new programs. Results should not be interpreted as reflections on past efforts or the benefits of reallocating existing funds.

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Contents

Acronyms

3ie	International Initiative for Impact Evaluation Inc
AAG	Academic Advisory Group
BCR	Benefit-cost ratio
CBA	Cost-Benefit Analysis
CCC	Copenhagen Consensus Center
DFID	Department for International Development UK
EYOS	Equivalent years of schooling
GDP	Gross Domestic Product
LIC	Low-income country
MGDS III	Third Malawi Growth and Development Strategy
MWK	Malawian Kwacha
NPC	National Planning Commission
PPP	Purchasing Power Parity
PTR	Pupil to teacher ratio
SACMEQ	Southern and Eastern African Consortium for Monitoring Educational Quality
SD	Standard deviation
SDG	Sustainable Development Goal
TAL	Technology-assisted learning
TARL	Teaching at the right level
TPD	Teacher professional development
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
USD	United States Dollar

1. Introduction and context

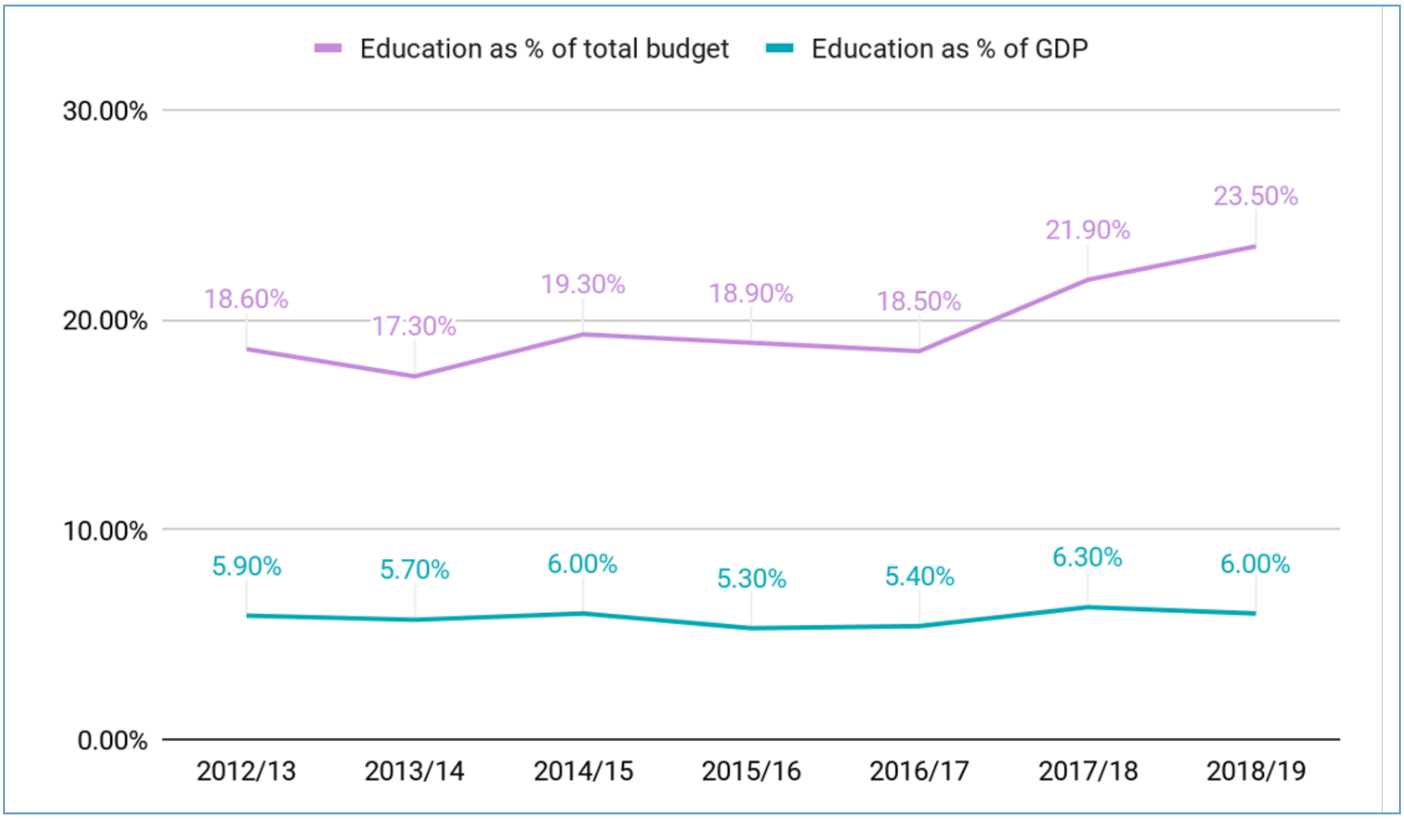
Since making primary education free to all students in 1994, Malawi has made significant progress in improving student enrolment, with over 88% of primary school students enrolled in school before the pandemic (UNICEF, 2019). Despite this, students in Malawi consistently have worse learning and progression outcomes than students in other Southern and Eastern African Countries (World Bank, 2016). This is in part due to the significant challenges that the Malawi education system faces in the form of insufficient infrastructure, inadequately trained or unqualified teachers, and a lack of resources (including teachers) in schools (Ravishankar et al. 2016). At the primary school level, overcrowded classrooms are common, with the pupil-to-teacher ratios ranging between 50 and 160 across districts, and over a quarter of classes being held outdoors in many primary school grades (Ravishankar et al. 2016). These conditions are associated with poorer learning outcomes and contribute to poor education quality at the primary level.

1.1 Education Sector in Malawi

Malawi has made great strides in primary education, which was made free to all students in 1994. This has encouraged many children to attend school. Enrollment rates for primary school[1] students were at 97% in 2009 (UNESCO Statistics, 2020) and 98% in 2015/16 (UNICEF, 2019). The latest enrollment figures show that only 88% of students (87% of boys and 89% of girls) were enrolled in primary education in 2017 (UNICEF, 2019). Although these rates are still relatively high, this recent and rapid decrease is a cause for concern.

As part of the Third Malawi Growth and Development Strategy (MGDS III), the government of Malawi identified education and skills development as one of its five priorities (UNICEF, 2019). This involves a framework to improve access, equity, quality, and relevance at all stages of education as part of Malawi's commitment to Sustainable Development Goal (SDG) 4, which targets inclusive and equitable quality education for all by 2030. In the recently released Vision 2063 document, improving education quality is highlighted as a key aim under Enabler 5: Human Capital Development (NPC, 2020). Government spending on education is above average compared to other low-income countries (LIC) and has been steadily increasing since 2002. As shown in Figure 1.1, this has led to 23.5% of the government's budget spending being dedicated to education, making education the largest allocation in the government's budget (UNICEF, 2019).

Figure 1.1: Education Spending as a Share of Total Budget and GDP (Source: UNICEF, 2019)



Despite this large and growing expenditure on education, education outcomes for students have not improved. Some of the reasons for this are discussed below, but the distribution of spending is one contributing factor. Malawi's teachers have one of the highest entry-level salaries in the region (PPP adjusted). The majority of the education budget is spent on teacher salaries (for example, 84% of all primary school expenditures is spent on teacher remuneration) and the relative size of teacher salaries within education spending limits the government's ability to allocate funds to other education inputs (such as classrooms, schools, textbooks, or curriculum development) or to recruit new teachers (Ravishankar et al., 2016).

[1] Note that primary school refers to Standards 1 -8 while secondary school refers to Forms 1 -4.

Though the education sector receives a relatively high proportion of the government budget, youth in Malawi are failing to progress to secondary school in large numbers and consistently do poorly compared to other Southern and Eastern African Consortium for Monitoring Educational Quality (SACMEQ) countries on literacy and math. The main barriers to education in Malawi, include

- Infrastructure challenges
- Teaching quality and quantity
- Traditional gender norms and early marriage

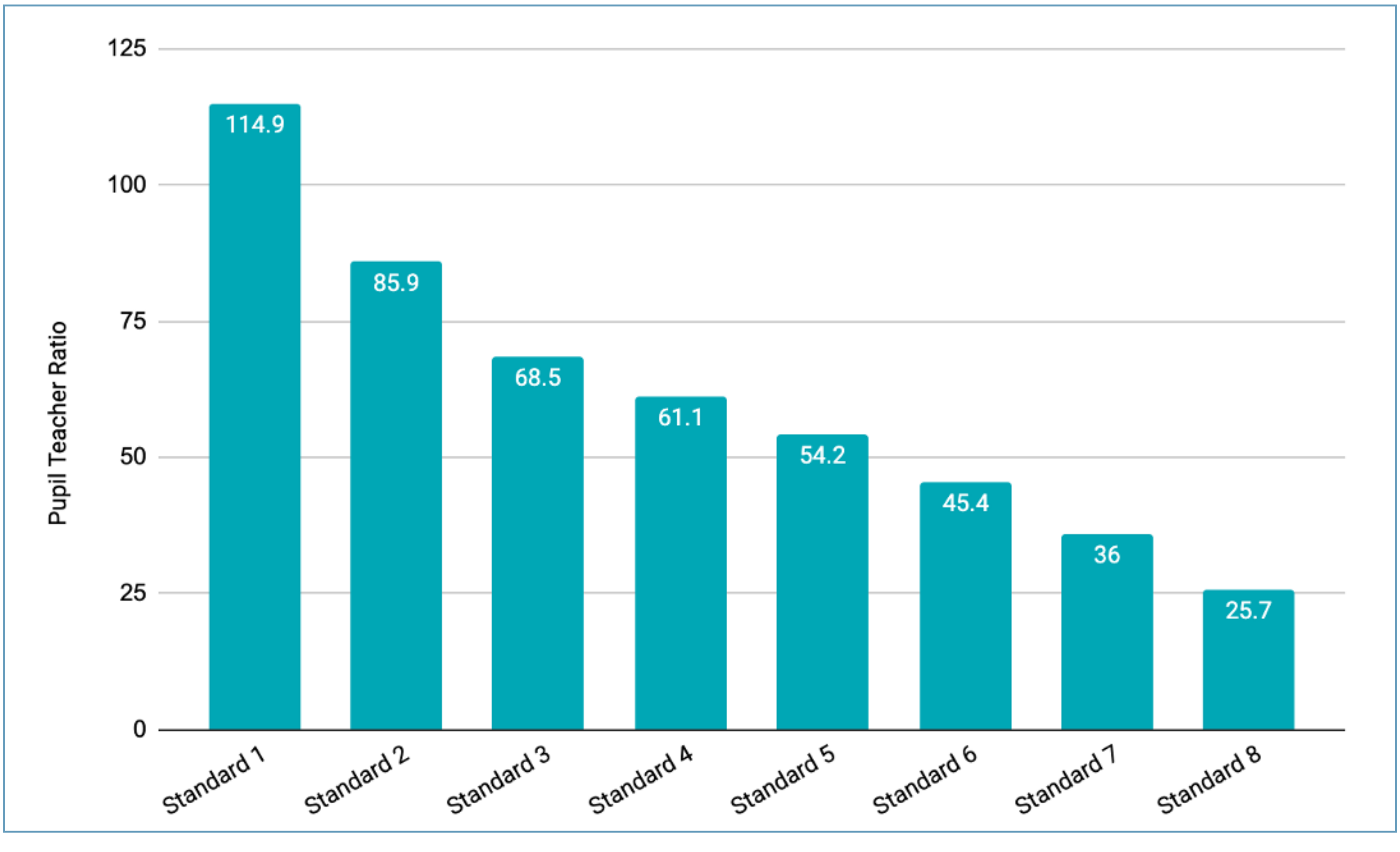
These barriers have significant impacts on education outcomes.

1.1.1 Infrastructure challenges

The education system in Malawi faces significant challenges in the form of insufficient infrastructure, inadequate supply of qualified teachers, and a lack of resources available to schools. At the primary school level, overcrowded classrooms are common, with the pupil to teacher ratios (PTR) ranging between 50 to 160 across districts. This has many potential implications for learning. For example, at least four students share each textbook in all grades, with up to 12 students sharing a textbook in some grades and subjects (Ravishankar et al., 2016). Classroom infrastructure is a primary reason cited for absenteeism and attrition of students (Ravishankar et al., 2016).

PTR also varies significantly by grade, with the youngest primary school grades having the highest PTRs, as shown in the following figure. These high pupil-teacher ratios are in part due to the significant increase in primary school students enrolled in school after primary schooling was made free nationwide.

Figure 1.2: Pupil-teacher ratio by standard in Malawi (Source: Ravishankar, 2016)



Class size is an important constraint in the Malawi education system given the high PTR. However, there is also evidence that the effectiveness of current teachers could also be improved. Evidence from the Quality Service Delivery survey delivered by the World Bank and the United Kingdom's Department for International Development (DFID),[2] as well as the World Banks's School surveys, found that teachers did not have the knowledge necessary to teach problem solving and critical reading skills above a standard 6 level (Ravishankar, 2016). This likely contributes to 75% of students reporting they do not feel like they learned much in class. On average, teachers spend less than four hours teaching per day and spend approximately 20% of instructional time off-task (Ravishankar et al., 2016).

Chronic teacher absenteeism is a major issue in Malawi. Although the reasons for this do vary, the distance from teachers' homes to their school is a primary concern reported by teachers and students alike (Ravishankar et al., 2016).

Outdoor classrooms

In addition to having high pupil-teacher ratios, many schools have large portions of their classes held outside, particularly in the early grades, which can have serious negative impacts on learning as students are forced to learn in poor weather or other harsh conditions (Tolani and Davis, 2017). In one out of 3 schools in Malawi, lower-primary grades are taught in open air resulting in cancellation of

[2] Now the Foreign, Commonwealth and Development Office (FCDO)

classes due to rain and heat (Ravishankar et al. 2016). Most times, outdoor classes tend to be allocated to the younger years (grade 1-4), with more senior grades having indoor classes. This could be because enrollment is higher in lower primary school grades (1-4), making it more difficult to fit them into classrooms and also because senior students are prioritized to prepare for national exams.

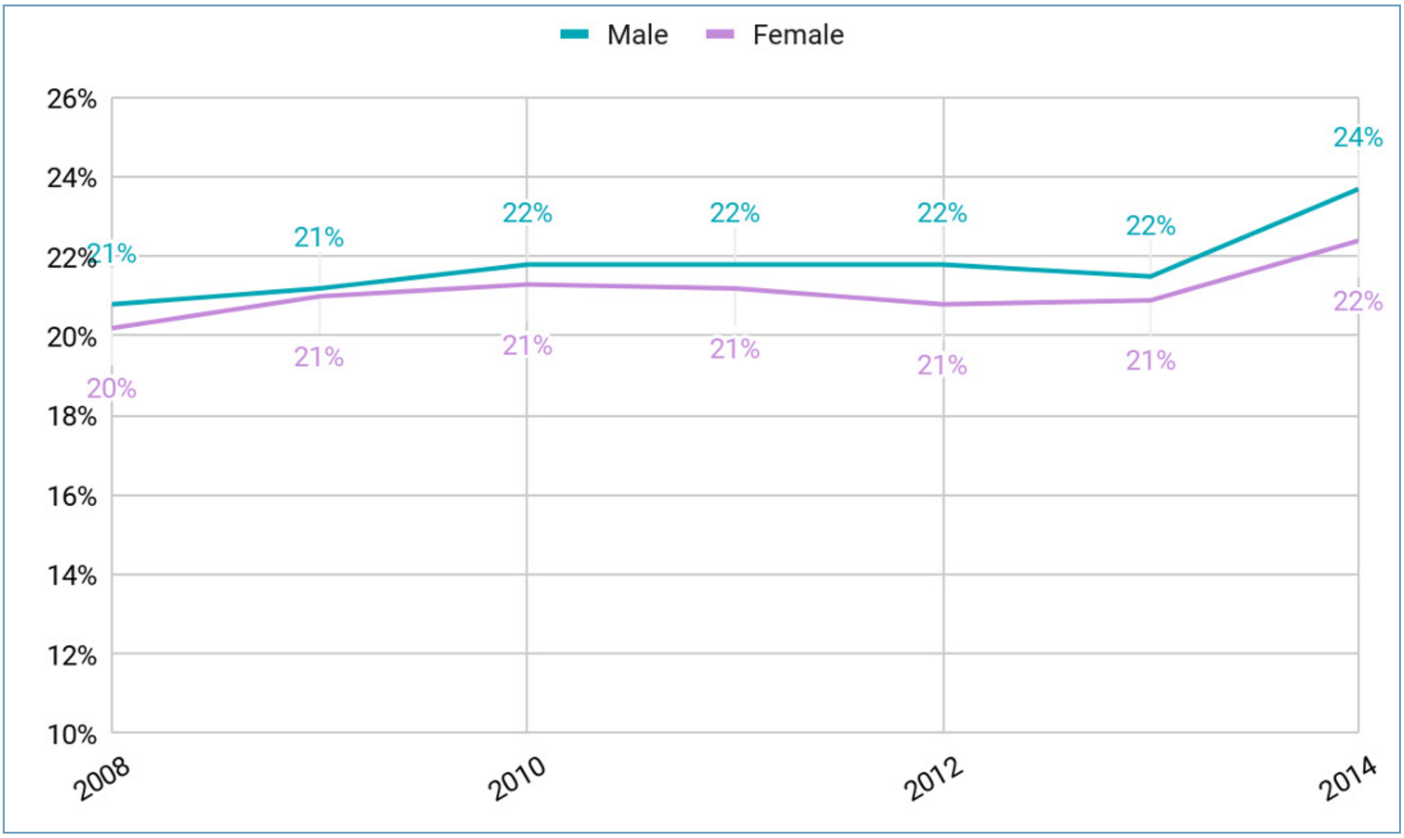
Rainfall is a challenge for outside learning in Malawi. The rainy season in Malawi typically spans the period December to March, which overlaps with the end of the first term and completely with the second term of schooling.[3] If it starts to rain, children may leave school early. If it rains in the morning they may not come to school at all. Besides rain, heat and exposure to other elements such as wind and dust creates less than optimal learning environments. Outdoor classes also generate other distractions including dealing with visitors, additional tasks of carrying the learning materials (portable boards, text books, teachers chair and table etc.) from and to the classrooms where they are kept as they cannot be left outside after learning.

Much of the available evidence for the impacts of classrooms on learning in Malawi comes from cross-sectional regressions of school and pupil data. Dunga (2013), regressing test scores from SACMEQ II on school and pupil attributes notes a 0.093 s.d. reduction in test scores from outdoor learning. Ravishankar et al. (2016), using the QSD survey data and EMIS data for 170 Malawian schools demonstrates that a unit reduction in pupil-classroom ratio increases the promotion rate from standard 1 by 0.039 percentage points. World Bank (2010) finds a 4 percentage point reduction in retention rates associated with having an open-air classroom. Being derived from cross-sectional regressions, these results have the usual concerns about the causal direction of effects. Nevertheless, the broad finding that learning outcomes improve with infrastructure enhancements is supported by studies that use more robust methodologies for inferring causation (Kazianga et al., 2013; Bagby et al., 2016; Kazianga et al., 2019).[4] In this analysis, we adopt the effect from Dunga (2013) applying a 0.093 increase in test scores from learning inside.

1.1.2 Implications for education outcomes

In light of all these barriers, students in Malawi have poor learning outcomes, on average. Like many low-income countries, repetition rates are particularly high in Malawi. For both boys and girls, repetition rates are above 20% on average and remained relatively steady up to 2014, as shown in the following figure. These high rates of repetition likely contribute to the low enrollment and high dropout rates discussed above. High repetition rates also place an additional cost burden on the education system.

Figure 1.3: Repetition rates for Standards 1-4 (Source: World Bank, 2016)



In addition to low participation, students in Malawi schools on average do poorly in learning assessments. Fewer than 25% of students could pass English assessments, even in Standard 7 (Ravishankar, 2016). Performance in mathematics was better, with 40%, 55%, and 37% of students passing in standards 2, 4, and 7, respectively. However, compared to Southern and Eastern African Consortium for Monitoring Educational Quality (SACMEQ) countries, Malawi performs very poorly on both literacy and mathematics, coming in last and second last, respectively, in 2012 assessments (World Bank, 2016).

Following consultations with education experts and reviews of academic and grey literature, this report proposes several intervention options that can mitigate some of the barriers to high-quality primary education that currently exist in Malawi. It presents the findings of a cost-benefit analysis that models the impact of each of these interventions.

[3] Based on pre-COVID schooling year of three terms.

[4] Another strand of literature on expanding school infrastructure has focused on settings and historical periods where the counterfactual scenario was the complete absence of a school (e.g. Duflo, 2004; Burde and Linden, 2013; Deschênes and Hotte, 2019). The aim of building more schools in these contexts was to increase access and participation in formal education. This is clearly different from current day Malawi, where primary school enrolment rates are already high, and the relevant counterfactual is learning outdoors.

1.2 Research process

This research has been conducted in response to the Malawi National Planning Commission's (NPC) Malawi Priorities project. The National Planning Commission (NPC), with technical support from AFIDEP, and the Copenhagen Consensus Center (CCC) is conducting the Malawi Priorities project across 2020 and 2021. The project is a research and advocacy exercise which uses cost-benefit analysis (CBA) to identify cost-effective solutions to some of Malawi's biggest development challenges. The aim is to determine both short-term and long-term development priorities for the country, acknowledging that there are insufficient resources to address all of Malawi's challenges and that maximizing outcomes requires careful, evidence-based consideration of the costs and benefits of all policies.

The starting point of all research questions is the NPC's existing research agenda, structured around the six thematic areas of Sustainable Agriculture, Sustainable Economic Development, Human Capital and Social Development, Sustainable Environment, Demography, Governance, Peace, and Security, and Human Capital and Social Development.

The NPC's research agenda was developed by the Commission in September 2019 after extensive consultation with academics, think tanks, the private sector, and the government. Consequently, the Commission's research agenda, prima facie, contains questions of national importance. As a first step, Malawi Priorities drew questions from the NPC research agenda that could be answered using a cost-benefit methodology. Additional research questions were added based on input from NPC, an Academic Advisory Group (AAG) of leading scholars within Malawi, and existing literature, particularly previous cost-benefit analyses conducted by the Copenhagen Consensus Center. This process of identifying research questions for investigation generated a total of 38 potential research questions across all 6 thematic areas.

The research agenda was validated and prioritized by a Reference Group of 25 prominent, senior stakeholders from government, civil society, and the private sector. The outcomes of the Reference Group exercise were used to inform which research questions to prioritize and which interventions to focus on within those 38 potential research questions. The validation process finished in July 2020.

In September 2020, this research team began the investigation on primary education quality, which was ranked 4.9 out of 5 on a scale ranking its importance as a national priority by the Reference Group. This was the highest rating given to any of the questions reviewed in the Malawi Priorities survey, and is highly relevant given Malawi's long-term visions for education, and the broader Vision 2063 of an inclusively wealthy and self-reliant nation. Improving human capital today will mean a more productive and knowledgeable workforce in the future.

To start the research process, the research team consulted with experts on Malawi education quality to identify the main barriers to education in the context, and to get insights into possible solutions. The list of experts consulted included experts from USAID Malawi, the Malawi University of Science and Technology, and the Centre for Educational Research and Training at the University of Malawi. After consulting with these experts, the research team conducted a thorough review of the academic and grey literature to identify or confirm the existing barriers and gaps in the education sector. This also included a review of the evidence base for the performance of interventions that have tried to address these gaps in similar contexts or within Malawi.

The findings of these interviews and the literature review were summarized in the research plan, which was used to inform the development of a CBA model. The findings of the research plan and the CBA model are summarized in this report.

2. Literature review and intervention selection

The research team has included ten different education interventions in this review, which can be broadly categorized as being either teacher, infrastructure, or student-focused. Each of these interventions is effective at mitigating the relevant barriers discussed in section 1 in either Malawi specifically, or in similar contexts.

Initially, the Malawi Priorities research questionnaire identified teacher quality and quantity; infrastructure quality and quantity; and improved learning materials as possible intervention options. The list of intervention options was then expanded by reviewing the literature, which included previous studies conducted for CCC, as well as the evidence map completed by International Initiative for Impact Evaluation (3ie) Education which summarizes the existing evidence on education interventions, among other sources identified during the literature review.

Table 2.1: Barriers to education quality in Malawi and possible interventions

Barrier	Possible Interventions
Instructor quality and quantity issues	• In-service teacher professional development • Qualified teacher recruitment and pre-service training • Performance-based incentives for teachers • Focusing on foundational skills
Infrastructure shortages	• Classroom and school construction • Textbook and resource investments • Technology-assisted learning • Double or multiple-shift schools
Poverty and food insecurity	• School feeding programs • Cash transfers (conditional and unconditional)

2.1 Intervention Options

This section describes the interventions that have been implemented to address the barriers described in the sector background section that have been rigorously evaluated. This includes a summary of the main beneficiaries and impacts of each intervention considered, as well as a summary of some of the existing evidence on these interventions.

2.1.1 Teacher-focused interventions

In-service teacher professional development: Interventions targeted towards teacher professional development can involve either pre-service training (which refers to training delivered to teachers before they have begun teaching) or in-service training (which refers to training active teachers receive while teaching). Types of professional development interventions vary widely in terms of content and delivery methods, however here the analysis will be limited to in-service training focused on specific subject areas (literacy, mathematics, gender-based teaching methods, etc.) as qualified teacher recruitment has been separated into its own intervention category. When teachers are better qualified, they have the potential to positively impact student's test scores and overall life outcomes (Popova et al., 2018). This is promising, however in 2018-19, the Government of Malawi did not allocate any of their education budget to in-service teacher training or continuous professional development for primary or secondary teachers (UNICEF, 2019). While there is some coverage by organizations like USAID who have provided periodic teacher training support, such as through the National Reading Strategy Program which ran between 2015 and 2016, there is still considerable room for investment at a national level.

Qualified teacher recruitment and pre-service training: In 2014, UNESCO estimated that Malawi would need to increase its number of qualified teachers by 15% to achieve universal primary education. As discussed above, this goal of universal primary education was nearly achieved in the mid-2010s, there has been a reversal in progress towards this goal in recent years. Evidence suggests that increasing the number of qualified teachers in schools can have a significantly positive impact on students' learning, which highlights the need to provide adequate pre-service training for potential teachers. Teacher recruitment interventions can also improve existing teachers' job satisfaction if PTR is significantly reduced (Snilstveit et al., 2016; Kremer and Holla, 2009). However, these interventions are typically challenging to implement, particularly if the government attempts to recruit contract teachers who may be less expensive. Hiring more female teachers has also been emphasized as an important intervention in Malawi (World Bank, 2016). One possible avenue for attracting additional qualified teachers (particularly female teachers) would be to provide adequate housing for teachers in rural areas (Mulkeen, 2006). Indeed there have been recent modest improvements in the resources allocated to pre-service training of primary school teachers by the Government of Malawi in recent years (UNICEF, 2019).

Performance-based incentives for teachers: These interventions tie teacher compensation to education outcomes. While this can increase teacher attendance and improve scores on tests that teachers' compensation was evaluated on (Glewwe et al., 2011), there has been limited evidence to show this improves the overall quality of students' education or learning.

2.1.2 Infrastructure-focused interventions

Classroom and school construction: These interventions involve constructing additional classrooms at existing schools as well as constructing new schools. These interventions can increase learning directly while also improving learners' expectations about school, which can increase participation in education. Infrastructure investments also have the added benefit of attracting and retaining qualified teachers to these schools as their work environment becomes more attractive (Levy et al., 2009; Snilstveit et al., 2016). Investments in school infrastructure can also decrease the distance to schools, or make existing schools safer for vulnerable groups (including girls), which can both decrease gender-based violence (Snilstveit et al., 2016).

Textbook and resource investments: Providing new or additional textbooks and learning materials such as blackboards or notebooks to schools is intended to support instructors' ability to effectively teach. Although limited or poor quality in-school resources are often cited as a major barrier to student learning, evidence suggests that interventions providing resources to teachers in students do not lead to improved learning (Snilstveit et al., 2016). This may be attributable to the fact that these resources tend to be disconnected from the curriculum, not targeted to students at the right level, or cannot be integrated into a teacher's methods or lesson plan (Snilstveit et al., 2016).

Technology-assisted learning: Providing software or hardware to students to facilitate learning and student engagement is becoming an increasingly popular intervention around the world. Providing these tools can offer students more targeted lessons based on their knowledge, and can offer more interactive lessons in environments where PTRs are high. It can also reduce teaching burdens for teachers. These types of interventions are effective in improving learning, particularly in math, in small-scale interventions in Malawi and abroad (Pitchford et al., 2019; Haßler, Major, and Hennessy, 2015; Herodotou, 2018; Outhwaite et al., 2017). However, these types of interventions can negatively impact learning if they are used to replace in-person lessons altogether, and are particularly difficult to administer at a larger scale when electricity, internet access, and technological skills may be lacking. Based on the literature, the team would recommend the adoption of tablet-based interventions that provide students with time to practice curriculum linked mathematics and literacy skills with lessons tailored to their individual learning level (Pitchford, 2015; Outhwaite et al., 2017; Levesque et al. 2020; Rodriguez-Segura, 2020). This would be similar to the interventions described in Pitchford (2015), Outhwaite et al. (2017) and Levesque et al. (2020) which allowed students to practice specific skills that were related to the curriculum and provided them with immediate feedback.

Double or multiple-shift schools: Multiple shift school policies involve having different groups of students attend schools at separate times of the day to reach more students with the same limited infrastructure resources (Arceo et al., 2016; Bray, 1990). This is a cost-effective way to increase the number of students who can attend existing schools and was recommended by Unicef in 2019 as a possible solution to Malawi's infrastructure challenges. While these types of interventions are effective at improving school participation rates, there is limited evidence that double shifting policies positively impact learning outcomes as well so their ability to improve overall school quality may be limited. These interventions will also be less effective if there is no school within a reasonable distance to potential students to begin with, which is a barrier in Malawi.

2.1.3 Student-focused interventions

Focusing on foundational skills: These types of interventions assess student abilities and group pupils based on their learning level instead of their age or grade to teach to student's specific levels. This includes the "Teaching at the Right Level" initiative and similar interventions, which can involve training in-service teachers to incorporate learning methods that focus on the foundational skills students need to be given their learning level for part of the school day (Banerjee et al., 2015). These methods have been effective at improving learning when students' foundational skills are low (as is the case in many Malawi primary schools) and are relatively low-cost to implement.

School feeding: These widespread interventions involve providing some kind of nutritious food to students at the schools they attend and are associated with improved learning and overall education outcomes (Gelli et al., 2011). This is particularly true in contexts where food insecurity is highest. In light of these successes, these interventions have been implemented in almost every country in some form. Although these interventions have not been implemented nationally in Malawi, NGOs and private organizations such as Marys Meals and the World Food Programme delivered meals to 24% of all schools in Malawi in 2013 (International Labour Organization, 2013). More recent figures suggest these programs have each reached at least 30% of primary schools in Malawi (WFP Malawi, 2018; Mary's Meals International, 2016), which suggests a majority of primary schools are already beneficiaries of some sort of school feeding program in Malawi.

Cash or in-kind transfers: Conditional cash transfers are "targeted to the poor and made conditional on certain behaviors of recipient households" (Fiszbein et al., 2009). In the case of education interventions, these are typically conditional on attendance or enrolment. Unconditional cash transfers do not come with these types of requirements but can remove financial barriers that affect educational outcomes. These interventions have different types of impact, depending on the outcomes of interest (Buchmann et al., 2018). Overall, cash transfer programs are effective for improving school participation (both enrolment and drop-out rates), but not always effective for also improving learning (Baird et al., 2011). However, conditional cash transfer programs have effectively improved learning as well as school participation and SRH outcomes in Malawi specifically. Merit-based scholarships also offer significant promise in incentivizing students towards positive educational outcomes. However, the existing evidence on merit-based scholarships is lacking and often imprecise (Snilstveit et al., 2016).

2.2 Selection Criteria

The research team used several criteria to screen and select a subset of interventions to include in the feasibility analysis. These criteria have been applied to other CCC pre-feasibility research projects as well.

Sector expert priority: The intervention is identified by sector experts as important and relevant to the local context. Experts can provide input through several channels: the Reference Group questionnaire, inferences from the NPC research agenda, the academic advisory group, and during individual interviews.

High benefit-cost ratio (BCR) or cost-effectiveness in similar previous research: The purpose of the Malawi Priorities project is ultimately to identify interventions of outsized benefits relative to costs. Input into this factor is determined from the economics literature, particularly previous research conducted by the Copenhagen Consensus Center. In the Center's experience, BCRs above 15 are among the highest across all interventions. Due consideration is given to contextual differences between previous research and the current situation in Malawi in determining the effect of this criterion.

Addresses a problem of sufficient size – some interventions could be considered highly effective but only address a small percentage of a given problem, limiting the overall net benefits of the approach. To avoid focusing on solutions that are too small, each intervention must have the potential to address a significant problem.

A significant gap in current levels of intervention coverage – all analysis conducted in Malawi Priorities focuses on marginal benefits and costs. Therefore, if an intervention already has high coverage rates, then additional resources provided towards that intervention are unlikely to be effective or will suffer from the 'small-size' problem.

Availability of crucial data or credible knowledge of impact – due to time and resource constraints, all analyses conducted by Malawi Priorities are based on secondary data, confirmed by sector expert conversations No primary research is conducted, such as field experiments or trials. Therefore, each intervention is constrained by the availability of data. In many cases, one key constraint is knowledge concerning the impact of a given intervention. It is typical to formally deal with uncertainty via sensitivity analyses. However, in some cases, the uncertainty is so great that it precludes even researching the intervention at all.

The following table summarizes each of the interventions along these criteria, based on the existing evidence. Note that, as discussed above, some interventions increase enrollment or school participation without a corresponding improvement in overall learning. To align with the other research questions in the Malawi Priorities portfolio, which focus on improving education quality, not just quantity, interventions that improve both learning and enrolment have been prioritized over those that only improve enrolment.

Table 2.2: Selection criteria

Interventions Covered	Sector expert priority	BCR or Cost Effectiveness	Addresses a problem of sufficient size	A gap in current coverage	Availability of data	Recommended Priority
Teacher-focused						
In-service teacher professional development	Yes	High	Yes	High	Moderate	✓
Qualified Teacher recruitment and pre-service training	Yes	High	Yes	Moderate	Moderate	✓ (Recruitment)
Performance-based incentives for teachers	No	Mixed	No	Low	High	
Infrastructure-focused						
Classroom construction	Yes	High	Yes	High	Moderate	✓
Textbook and resource investments	Yes	Low	No	High	High	
Technology-assisted learning	Yes	High	Yes	High	High	✓
Double Shifting	No	Mixed	Yes	High	Low	
Student-focused						
Focusing on foundational skills	No	High	Yes	High	Moderate	
School feeding	Yes	High	Yes	Moderate	Moderate	✓
Cash transfers	No	Moderate	Yes	Moderate	Moderate	

Based on these selection criteria, the team identified classroom and school construction, in-service teacher professional development, teacher recruitment, technology-assisted learning, and school feeding as interventions for cost-benefit research. The next sections present the findings of a cost-benefit analysis that models the potential impact of each of these interventions.

The results show that there is large variance in the cost-effectiveness of the identified strategies, with benefit-cost ratios (BCR) spanning three orders of magnitude. The intervention with the highest BCR is technology assisted learning, with a return on investment around 100 kwacha per kwacha spent at an 8% discount rate. This result is based on pupil-level randomized controlled study of a specific type of tablet-based learning implemented in two schools in Malawi for 8 months (Levesque et al. 2020). The intervention with the next highest BCR is in-service teacher training with a BCR of 22. Both of these interventions represent excellent value-for-money, in comparison to alternative investments in education and other sectors. The results of additional analyses show that the remaining interventions have expected BCRs of 3 for classroom construction, 1.2 for hiring teachers and 10 for school feeding.

The main policy implication of the analysis is that Malawian decision makers should strongly consider marshalling additional funds to gradually expand, test and refine a technology-assisted learning program similar to the type documented in Levesque et al. (2020), which is currently being implemented in 112 schools nationally (private correspondence, Yesani Kapana). Importantly, as demonstrated by previous reviews (McEwan, 2015; Snilstveit et al. 2015; Evans and Mendez Acosta, 2021) technology per se is not a panacea to the challenges of poor learning in low-resource settings. Levesque et al. (2020) is about a particular type of application that allows individual students to determine their own pace of learning. There is increasing and robust evidence that more individualized pedagogy – either through technology or grouping students of similar ability – can have substantial impacts on learning (Muralidharan, Singh and Ganimian, 2019; Banerjee et al; 2015; Rodriguez-Segura, 2020). Beyond the individualized element, technology assisted learning also standardizes and ensures a higher quality of teaching. In short, technology assisted learning has the potential to address two key constraints in the Malawian education system simultaneously: very large pupil-teacher ratios and the variable quality of teaching.

A natural question arises whether this type of intervention can be realistically deployed at scale across the country with the well documented infrastructure constraints such as lack of electricity, internet and classrooms. These are genuine concerns which should be given careful consideration in any future scale up. It is likely that not all schools would be able to implement the intervention. That said, the experimental design and our analysis includes costs for classroom construction and rooftop solar electricity for charging. The intervention is designed such that it does not require constant internet connectivity. Relatedly, it is worth noting that the two schools in Levesque et al. (2020) appear to face challenges that are characteristic of many Malawian schools. Neither school had electricity (besides the rooftop solar) and each had class sizes in excess of 100. Implementation suffered from various external and internal factors (election unrest, natural disasters, teacher absenteeism) that meant students received only 53 out of the expected 90 hours of technology-assisted instruction time. Twelve percent of children did not attend for at least half the days of the experiment. The effect size we draw from Levesque et al. – 0.34 s.d. – embeds all of these imperfections, making it a reasonable estimate of the impacts of a larger rollout.[5] This impact on learning is within the range noted in other technology assisted interventions focusing on self-learning from other contexts (Rodriguez-Segura, 2020).

An important caveat of the analysis is that it assumes that the government will undertake the necessary investments to maintain the status quo going forward, as the primary-school-age population grows. This means that the government of Malawi will continue to construct classrooms and hire teachers to maintain the current class sizes and pupil-teacher ratios. These efforts are not reflected in the marginal costs. This report estimates the cost-effectiveness of additional spending in education beyond the **additional** spending that is already necessary to maintain the status quo. As such, one should not misinterpret the results to argue that budgets for future school construction can be allocated to technology-assisted learning instead. Significant investments in classroom construction and new teachers are required to maintain the status quo, which serves as the counterfactual against which gains are compared. If additional funds are found, however, the analysis suggests that technology-assisted learning would be the most effective use of these funds, followed by in-service teacher training.

[5] Given the very large BCR, there is ample room for deterioration in benefits that would still render the investment very cost-effective.

3. Methodology

This section describes the methodology for valuing costs and benefits associated with primary education interventions. The objectives and summary of the model are described in the following table.

Table 3.1: Scope of the model

Objectives of the analysis	
This document summarizes the methodology behind cost-benefit analyses of five interventions to address the following research question: **How does Malawi most effectively improve the quality of education in primary schooling?** This document details the calculations used in modeling of the following interventions: 1. A. Indoor classes via classroom construction B. Reduced class sizes 2. In-Service Teacher Training 3. School Feeding Programs 4. Technology-Assisted learning	
Other information	
Main currency	MWK
Other currencies	USD
Timeframe	**Intervention 1A -Indoor Classes via classroom construction** Intervention implemented year 1 Benefits accrue year 1-20 **Intervention 1B -Reduced Class Sizes** Intervention implemented year 1-20 Benefits accrue year 1-20 **Intervention 2 - In-Service Teacher Training** Intervention implemented year 1-3 Benefits accrue year 3 **Intervention 3 - School Feeding Programs** Intervention implemented year 1 Benefits accrue year 1 **Intervention 4 - Technology-assisted learning** Intervention implemented year 1 Benefits accrue year 1

3.1 Benefits, Costs, and Stakeholders

The CBA conducted here considers multiple intervention options, which each has its own benefits and costs. These costs and benefits are experienced by different stakeholders. For example, while school feeding programs benefit learners, the costs of these interventions are covered by the government of Malawi and by development partners. The following table lists the benefits and costs for each intervention and indicates the stakeholders that are impacted.

Table 3.2: Benefits, costs, and stakeholders in Malawi primary education quality interventions

Intervention	Impact	Learners	Government of Malawi	Donors
1A. Classroom Construction	B1 - Increased Lifetime Earnings from Learning Indoors	X		
	C1 - Classroom Construction Cost		X	X
1B. Reduced Class Sizes	B1 - Increased Lifetime Earnings from Reduced Class Size	X		
	C1 - Reduced Class Size Cost		X	X
2. In-Service Teacher Training	B1 - Increased Lifetime Earnings from improved learning	X		
	C1 - Teacher Training Costs		X	X
3. School Feeding Programs	B1 - Increased Lifetime Earnings from improved learning	X		
	C1 - School Feeding Costs		X	X
4. Technology-assisted learning	B1 - Increased Lifetime Earnings from improved learning	X		
	C1 - Technology Assisted Learning Costs		X	X

The following sections go through each of these interventions and describe how each of these benefits and costs can be valued.

3.2. Intervention 1A - Classroom Construction

3.2.1 Intervention Description

Indoor classrooms shelter students and teachers from harsh weather conditions, and studies have shown investment in classroom infrastructure to be important in improving learning (Dunga 2016; Tolani and Davis, 2017). The intervention proposes building 1,000 additional classrooms to ensure more students are able to learn with a roof over their head, thereby reducing the amount of students learning outside, which will result in improved learning outcomes.

We assume that the difference between total teachers hired and the number of classrooms constructed is indicative of the number of teachers teaching outside. We also assume that class sizes are on average the same size, so therefore the total number of students outside is the percentage of outdoor teacher's times the total number of students. This estimate is calculated for a scenario where additional classrooms are constructed as well as a counterfactual. The difference in students is the estimated number of beneficiaries each period.

Timing Assumption: The analysis assumes that the benefits of reducing moving students indoors sizes will occur over the lifespan of the constructed schools. The model currently assumes a twenty-year life for the asset. Although the timeframe of benefit accumulation is the lifetime of beneficiaries, the benefits are discounted to their present value in the period the beneficiary experiences the improved learning benefit for simplicity.

3.2.2 Classroom Construction Costs

The cost of bringing classes indoors is the cost of constructing additional classrooms (compared to the projected counterfactual scenario where classroom construction increases at historical rates, 1.3% per annum). We assess the BCR of several scenarios of classrooms constructed.

Fixed costs are incurred in year 1, based on the expectation that the average classroom lifespan is 20 years. Our estimates for classroom costs come from a 2009 project that designed a "Low-cost school building" prototype for Malawi, from the engineering firm Arup. An alternative estimate for school construction cost is from a 2010 UNESCO report, which is significantly lower and based on global averages. We currently use the higher estimate of $ 25,410 per classroom to avoid underestimating costs. The full cost calculation details can be found in Table A.1 in Annex A.

3.2.3 Classroom Construction Benefits

Improved learning outcomes are estimated in terms of test scores improvements for each beneficiary following Dunga (2016). These estimated improvements in test scores are converted to equivalent years of schooling (EYOS) using the methodology found in Evans and Yuan (2019). We then convert years of schooling to expected lifetime earnings (LTE) via a Mincerian estimate of returns to schooling in Malawi conducted by CCC in anticipation of this exercise (Turkson et al., 2020). The estimated wage premium from every additional year of schooling is 13.2%. The full calculation details can be found in Table A.2 in Annex A.

3.3 Intervention 1B - Reduced Class Sizes

3.3.1 Intervention Description

Class sizes in Malawi are large enough that learning is negatively impacted, exceeding both regional and international averages as well as government-defined targets. It is not uncommon for a class to have more than 100 children, which negatively impacts learning and imposes various administrative issues. This intervention proposes building 1,000 additional classrooms and hiring 1,000 more teachers. The additional classrooms constructed will allow schools to divide students into smaller classes and maintain or improve the average number of students in each class to meet the education standards for a growing population.

In the base period, there were more than seventy thousand primary school teachers, but roughly forty thousand classrooms in Malawian primary schools. In such a case, increasing the supply of additional teachers will only reduce the average pupil teacher ratio if more classes occur outside. This is not recommended since indoor classrooms shelter students and teachers from harsh weather conditions and have been shown to be an important factor in improving learning.

Timing Assumption: The analysis assumes that the costs and benefits of reducing class sizes will occur over the entire duration of the intervention. The model currently assumes a twenty-year intervention,although longer could also be possible if ongoing government support is provided. Although the timeframe of benefit accumulation is the lifetime of beneficiaries, the benefits are discounted to their present value in the period the beneficiary experiences the improved learning benefit for simplicity. Costs- are annualized for ease of scaling reasons.

3.3.2 Reduced Class Sizes Cost

The cost of reducing class sizes will be the cost of additional teachers hired (compared to the projected counterfactual scenario) and the cost of constructing additional classrooms (compared to the projected counterfactual scenario).

Fixed costs are incurred in year 1, based on the expectation that the average classroom lifespan is 20 years. The estimates for teacher salaries are based on a 2016 World Bank report. The average teacher cost per year is estimated at MWK 2,206,499. The estimates for classroom costs come from a 2009 project that designed a "Low-cost school building" prototype for Malawi, from the engineering firm Arup. An alternative estimate for school construction cost is from a 2010 UNESCO report, which is significantly lower and based on global averages. The higher estimate of $ 25,410 per classroom is to avoid underestimating costs, but other values are considered in the sensitivity analysis. The full calculation details can be found in Table A.3 in Annex A.

3.3.3 Reduced Class Sizes Benefits

The benefit of reduced class sizes is observed via improvements to overall academic performance. The literature on class size in similar contexts suggests a significant impact on academic performance in response to a shift towards smaller class sizes. We will utilize an analysis conducted in a 2017 paper by Mulera et al. as a foundation for the estimate of the marginal impact of pupil-teacher ratio (PTR) shifts on test scores. The Mulera paper estimates the relationship between class sizes and The Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ) test scores in standard six (Malawi's sixth year of primary). Because the standard six students are likely benefitting from the effects of lower class sizes in the five years preceding the data collection, this estimate can be interpreted as the cumulative effect of 6 years of lower class sizes. The effects of one year are assumed to be six times less. Different values of this effect size are considered in the sensitivity analysis.

These estimated improvements in test scores are converted to equivalent years of schooling (EYOS) using the methodology found in Evans and Yuan (2019). We then convert years of schooling to expected lifetime earnings (LTE) via a Mincerian estimate of returns to schooling in Malawi conducted by CCC in anticipation of this exercise (Turkson et al., 2020). The estimated wage premium from every additional year of schooling is 13.2%. The full calculation details can be found in Table A.4 in Annex A.

3.4 Intervention 2 - In-Service Teacher Training

3.4.1 Intervention Description

Types of professional development interventions vary widely in terms of content and delivery methods, however here the focus is limited to only in-service training focused on specific early grade foundational mathematics skill instruction, which has not been the primary focus of previous interventions. The focus on in-service training is particularly relevant considering 48% of teachers in Malawi are not professionally qualified to teach (Mkandawire, Luo, and Maulidi, 2018). When teachers are better qualified, they have the potential to positively impact student's test scores and overall life outcomes (Popova et al., 2018). Considerable investment has been made into improving literacy instruction through existing training interventions, including training provided through the on-going Early Grade Reading Activity implemented in Malawi (Mattos and Sitabkhan, 2016).

The intervention involves a three-year activity that will provide teachers with lesson plans and training on foundational numeracy skill instruction for primary school students, reaching 50,000 students for a given year. This ongoing, subject-specific approach will follow best practices for teacher professional development (Popova et al., 2018), while addressing a gap in the existing training programs in Malawi.

Timing Assumption: The model as mentioned earlier assumes a program that lasts three years, obtaining cost estimates from the EGRA program that lasted for this duration. Thus, costs are incurred over three years. The benefits are delayed until the final year of the program to avoid overestimation, although other benefit timing scenarios are conceivable.

3.4.2 Cost of In-Service Teacher Training

To estimate the cost of better-trained teachers, estimates of per teacher training costs are used from similar reading programs like the EGRA program, implemented in Malawi in 2013-2016. Cost estimates are based on average teacher costs across four modules (Quality Reading Instruction, Teaching and Learning Materials, Parental and Community Involvement, and Improving Policy Environment.) Average teacher training costs will vary according to the specifics of implementation and should be analyzed for sensitivity. The average cost per teacher used in the analysis is MWK 434,768.

The number of teachers trained is computed as a function of the number of beneficiaries, under the assumption that pupil-teacher ratios will continue to increase based on historical trends. The full calculation details can be found in Table A.5 in Annex A.

3.4.3 In-Service Teacher Training Benefits

Improved learning outcomes, measured in SD improvements in standardized tests, are estimated in multiple sources. In the initial estimates, the more conservative McEwan (2015) estimates of treatment effect are used. Higher estimates, like those found in Yoon (2007) are included as part of the sensitivity analysis.

These estimated improvements in test scores are converted to equivalent years of schooling (EYOS) using the methodology found in Evans and Yuan (2019). We then convert years of schooling to expected lifetime earnings (LTE) via a Mincerian estimate of returns to schooling in Malawi conducted by CCC in anticipation of this exercise (Turkson et al., 2020). The full calculation details can be found in Table A.6 in Annex A.

3.5 Intervention 3 - School Feeding

3.5.1 Intervention Description

School feeding, like most other social protection interventions in Malawi, is not entirely implemented centrally by the government, but rather consists of a medley of programs implemented by various NGOs and development partners. The current coverage is estimated at 30% of all primary school children in Malawi according to the National Nutrition Policy (2018). There are many districts in the country with no program in place. The school feeding intervention is an expansion of school feeding programs, modelled as a 1-year intervention benefitting 50,000 students.

Timing Assumption: The model assumes a program that lasts one year, as is the case in similar programs like that found in Afridi et al. (2019). Costs are incurred over one year. The benefits are also assumed to accrue in this period.

3.5.2 Cost of School Feeding

School feeding costs are based on average per-student costs found in other interventions. These include the cost of the food itself, as well as overhead costs like transportation and administration. It is assumed that the meals will be distributed during regular school hours so there is no additional opportunity cost.

Our cost estimates per student come from a cost-benefit analysis document by Dunaev & Corona (2018) which estimated the costs and benefits of a school feeding program in Ghana. This estimate of annual costs per student includes the cost of all food, transportation, personnel (cooks), water, and firewood necessary to operate the intervention. The full calculation details can be found in Table A.7 in Annex A.

3.5.3 Benefits From School Feeding

These widespread interventions involve providing some kind of nutritious food to students at the schools they attend and are associated with increased participation, attendance, as well as improved math and literacy assessment results. This is particularly true in contexts where food insecurity is highest. We use estimates of treatment effects from Snilstveit et al. (2016) for calculating the average change in test scores (measured in standard deviations (SD)) expected for each beneficiary.

These estimated improvements in test scores are converted to equivalent years of schooling (EYOS) using the methodology found in Evans and Yuan (2019). We then convert years of schooling to expected lifetime earnings (LTE) via a Mincerian estimate of returns to schooling in Malawi conducted by CCC in anticipation of this exercise (Turkson et al., 2020). The full calculation details can be found in Table A.8 in Annex A.

3.6 Intervention 4 - Technology-Assisted Learning

3.6.1 Intervention Description

The intervention is a particular type of Technology Assisted Learning (TAL) that uses tablets to deliver the curriculum to students. Students engage individually with high quality education software, can proceed through the curriculum at their own pace and are guaranteed an indoor learning environment when using the software. The intervention requires a specially built classroom with a solar charging panel and locked storage space for tablets. Students use the software in this classroom during a dedicated part of the day, with an individualized account that allows for progression through the curriculum at the student's desired pace. The software does not require internet connectivity for use. This particular TAL intervention addresses three major constraints of the education system simultaneously: high pupil-teacher ratios, variable teacher quality and lack of infrastructure.

Timing Assumption: The model assumes a program that lasts only one year, depicting average lifecycle costs per student, benefitting 50,000 students per year. This is similar to the Levesque et al. (2020) study from which the costs were estimated. The benefits are also assumed to accrue in this period.

3.6.2 Technology Assisted Learning Costs

Technology-Assisted Learning costs include the cost of tablets, instructor staffing, construction and some solar infrastructure to support charging.

The costs per beneficiary are estimated by the non-profit "onebillion" in a document shared with the team and are equal to $15 per student per year. While the team are not necessarily claiming that the onebillion platform should be the basis for all of Malawi's TAL, the use of a proprietary platform would add additional costs such as design and coding which could reduce cost-efficiency. The full calculation details can be found in Table A.9 in Annex A.

In the process of doing due diligence on this particular intervention, the team noted that the $15 per student per year represented an average annualized cost per student over the lifetime of the intervention investments (classrooms, tablets, solar panels, staff). While it is appropriate to utilize this figure for the purposes of determining the benefit-cost ratio in a 1-year model, from an implementation perspective it is necessary to also understand the actual cost profile that needs to be incurred to deliver the intervention over multiple years. This additional analysis is presented in Annex C with results that are similar to the 1-year model.

3.6.3 Technology-Assisted Learning Benefits

Interactive software has been shown to improve learning outcomes for students in sub-Saharan Africa. Moreover, interventions that provide students with tablets for at least 30 minutes per day to work on mathematical skills in Malawi proved to have significant positive impacts on student learning in math in primary school.

These estimated improvements in test scores are converted to equivalent years of schooling (EYOS) using the methodology found in Evans and Yuan (2019). We then convert years of schooling to expected lifetime earnings (LTE) via a Mincerian estimate of returns to schooling in Malawi conducted by CCC in anticipation of this exercise (Turkson et al., 2020). The full calculation details can be found in Table A.10 in Annex A.

3.7 Timing and flags

The timing of benefits and costs for each intervention is important. The model uses "flags", a modelling shortcut used to specify relevant time periods where formulas from the benefits and costs apply. The following table describes the time periods and flags that will be applied to each of the benefit and cost calculations.

The timing assumptions for each intervention are given in full detail in Table A.11 in Annex A.

3.8 Analytical Sensitivity

All models are based on assumptions, and an important step in assessing a model's usefulness is testing how sensitive the results are to these assumptions. The results of the model include sensitivity analyses, where results are presented across a range of different inputs. The inputs that are included as part of this sensitivity analysis are identified as crucial parameters that are either decision factors (for example, the number of classrooms constructed to reduce class sizes) or are a vulnerability (for example, all benefits are based on the critical assumption that improvement in test scores is associated with a certain equivalent years of schooling). The parameters that will be included in the sensitivity analysis, the interventions they affect, and the range of values considered are summarized in the following table.

Table 3.2: Benefits, costs, and stakeholders in Malawi primary education quality interventions

Intervention	Impact	Discount rate	Estimated wage premium from additional year of schooling	Increase in EYOS per one SD improvement on standardized test	Intervention 2 benefits length
1A. Classroom Construction	B1 – Increased Lifetime Earnings from learning indoors	X	X	X	
	C1 – Classroom Construction Cost	X			
1B. Reduced Class Sizes	B1 – Increased Lifetime Earnings from Reduced Class Size	X	X	X	
	C1 – Reduced Class Size Cost	X			
2. In-Service Teacher Training	B1 – Increased Lifetime Earnings From In-Service Teacher Training	X	X	X	X
	C1 – Cost of In-Service Teacher Training				
3. School Feeding Program	B1 – Increased Lifetime Earnings From School Feeding	X	X	X	
	C1 – Cost of School Feeding				
4. Technology-Assisted Learning	B1 – Increased Lifetime Earnings From Technology-Assisted Learning	X	X	X	
	C1 – Technology Assisted Learning Costs				
Range for Sensitivity Analysis		5%/ 8%/ 14%	0 to 30%	4.7 to 6.8	½/3 years

3.9 Limitations

The methodology employed is subject to some limitations, including the reliance on secondary data, and the inference of class size effects.

3.9.1 Reliance on secondary data

These primarily stem from the fact that the analysis relies on secondary data and analyses from other projects and contexts that may not be perfectly comparable. Of the interventions considered, only technology-assisted learning effect size estimates were derived from studies based in Malawi and show causal evidence of impact. Some of the evidence for intervention one is sourced from administrative data (not specifically collected for causal inference), and the evidence for teacher training and school feeding comes from meta-analyses of international studies of other low-income countries. The evidence is also based on gains that are observable only a short time after the interventions that were studied, so it is unclear how long the benefits of each intervention type persist. For these reasons, all effect sizes are included in the sensitivity analysis. The conclusions of the results remain consistent even when the input values are changed to be much more pessimistic, suggesting the results of the CBA model are robust to changes in these inputs that pose as potential vulnerabilities.

Additionally, the logic behind all of these findings is based on the findings of Evan and Yuan's 2019 paper, which converts improved test scores to equivalent years of schooling using international data. They use data from two Sub-Saharan Africa countries: Kenya and Ghana, but not Malawi. The value of EYOS is considered in the sensitivity analysis, and the results appear to be robust to changes in this input as well.

3.9.2 Inference of class size effects

In estimates of classroom construction impacts, this analysis has estimated the educational impact of reduced class sizes as equivalent to Mulera et al.'s coefficient for pupil-teacher ratios in a regression of SACMEQ III test scores in Malawi. Their study is not designed to estimate causal impacts. However, this value is likely close to a causal approximation of the impact of smaller class sizes since the authors use a large number of controls in their regression, and their findings are large in magnitude and highly significant (with a p-value below 0.001). As to the assumption that class sizes and pupil-teacher ratio are equivalent, Achilles et al. (1998) discuss that class size is what is relevant to education outcomes, as opposed to aggregate pupil-teacher ratio. If this is the case then it is reasonable to assume that the PTR estimate in Mulera et al is actually capturing the more important class-size effects.

The final assumption underpinning the impact estimate is that a class requires both one teacher and one classroom. Although it is true that if classes can be held outdoors even if there are more teachers without adding classrooms, it is improper to assume they are producing the same results as classes inside as outdoor classrooms are often cited as contributing to poor learning conditions (Tolani and Davis, 2017). There are approximately 1.6 teachers for every classroom in Malawi, which suggests that it is reasonable to estimate the benefits of adding additional classrooms without adding additional teachers given the large deficit between staff and infrastructure that currently exists. This means that in this context, it is classroom construction that influences class sizes, not teacher recruitment. The impact of changes in class size is considered in the sensitivity analysis.

4. Results

This section presents and discusses the results of the CBA modeling, including the sensitivity analysis.

4.1 Primary CBA Results

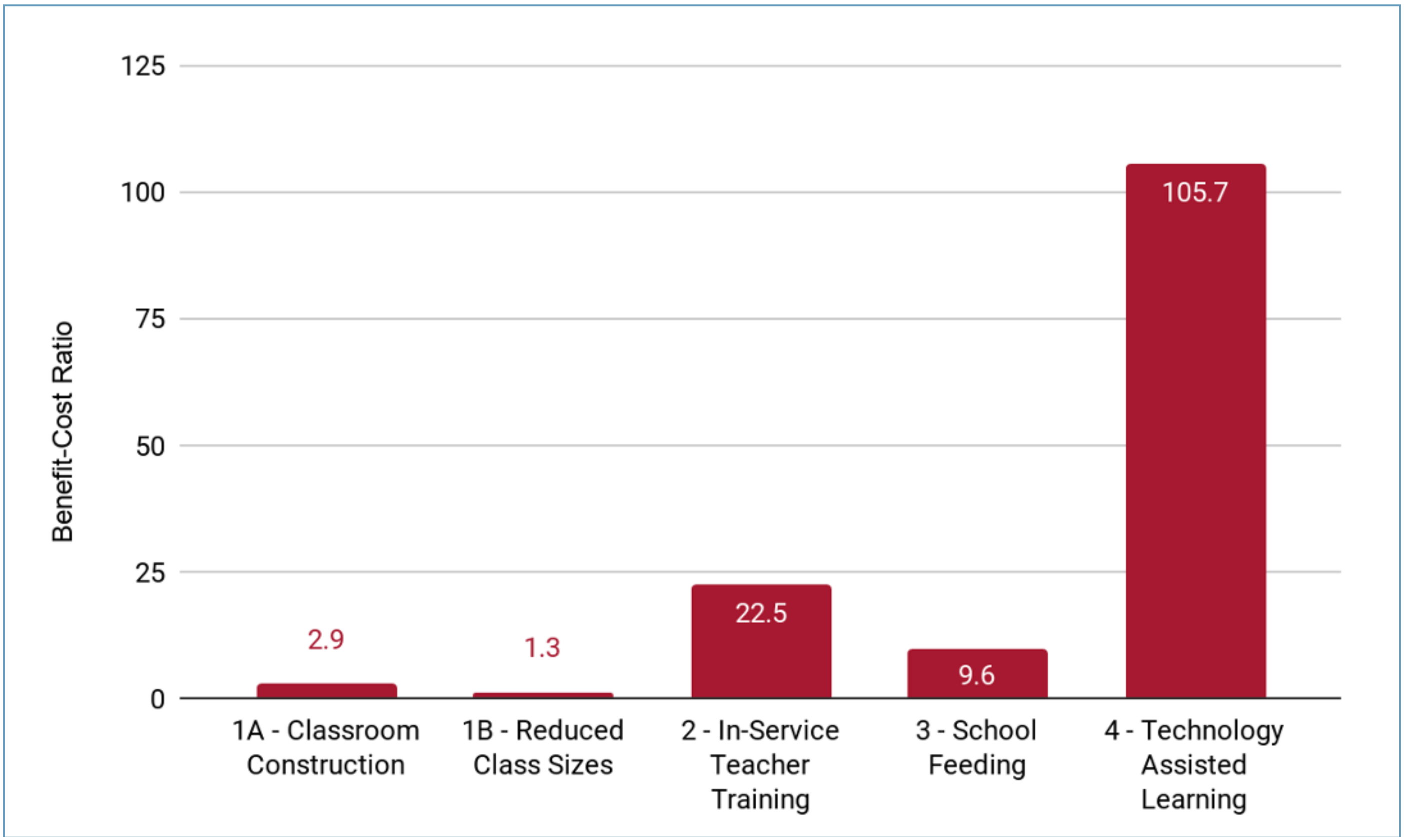
4.1.1 Benefit Cost Ratios

In the base case scenario (8% discount rate) all of the interventions proposed have expected benefit-cost ratios above one. However, there is substantial variance in results with BCRs spanning three orders of magnitude. The discount rate has a large bearing on the BCR – this is unsurprising given that all of the benefits accrue 10 years into the future. School construction and reduced class size do not pass a benefit-cost test at a 14% discount rate, but do at 5% and 8% levels. BCRs for technology-assisted learning and in-service teacher training are very large and represent excellent value-for-money in the base case.

Table 4.1: Intervention benefit-cost ratios

Intervention	Benefit-Cost Ratio		
	5% Discount Rate	8% Discount Rate	14% Discount Rate
Intervention 1A: School Construction	7.10	2.87	0.64
Intervention 1B: Reduced class size	2.75	1.28	0.34
Intervention 2: In-Service teacher training	44.22	22.47	7.13
Intervention 3: School feeding	18.38	9.62	3.23
Intervention 4: Technology-assisted learning	201.99	105.73	35.56

Figure 4.1: BCR by intervention (8% discount rate)



The technology-assisted learning intervention has a BCR of more than four times the second-best intervention (teacher training) and more than 10 times that of school feeding, reduced class sizes, and school construction interventions. The results suggest that if additional funds are available, they should be directed towards a technology-assisted learning program similar to that documented in Levesque et al. (2020), followed by in-service training. This intervention involves some level of classroom construction but the majority of funds, on a per child per year basis, are directed towards software and hardware.

One caveat of this is that the baseline scenario of all interventions assumes some growth in classroom and teachers to maintain status quo levels of pupil-teacher ratios and pupil-classroom ratios. Therefore, the results should not necessarily be interpreted as a recommendation to shift budgets from classrooms to teacher assisted learning or another intervention. Rather the results demonstrate the most cost-effective use of funds for additional resources beyond keeping the status quo levels. Additionally, it seems unlikely that Malawi will be able to reach its education goals without building substantially more classrooms.

The research team has identified several reasons for why the benefit-cost ratios for some interventions are so high. First, the benefits in each case are calculated by applying educational gains, measured via equivalent years of schooling, to earnings calculations across a long period. A small wage increase is significant when it is assumed to hold across the majority of a beneficiary's working life.

A second reason the BCRs are so high is that costs are relatively low for some of the interventions. The interventions proposed are all relatively cheap at a per-student level when implemented at scale. For example, the training of one teacher can lead to educational gains for an average of 70 or more students simultaneously since class sizes are so large, which makes it potentially very cost-effective. This is most pronounced for the technology assisted learning interventions, which have an expected cost per student of only $15 USD per year. While this is supported by empirical evidence, these cost estimates are based on some assumptions about the distribution of costs that may be overly optimistic. However, even with significantly more pessimistic assumptions, the results indicate in the sensitivity analysis that the BCR would still be very high.

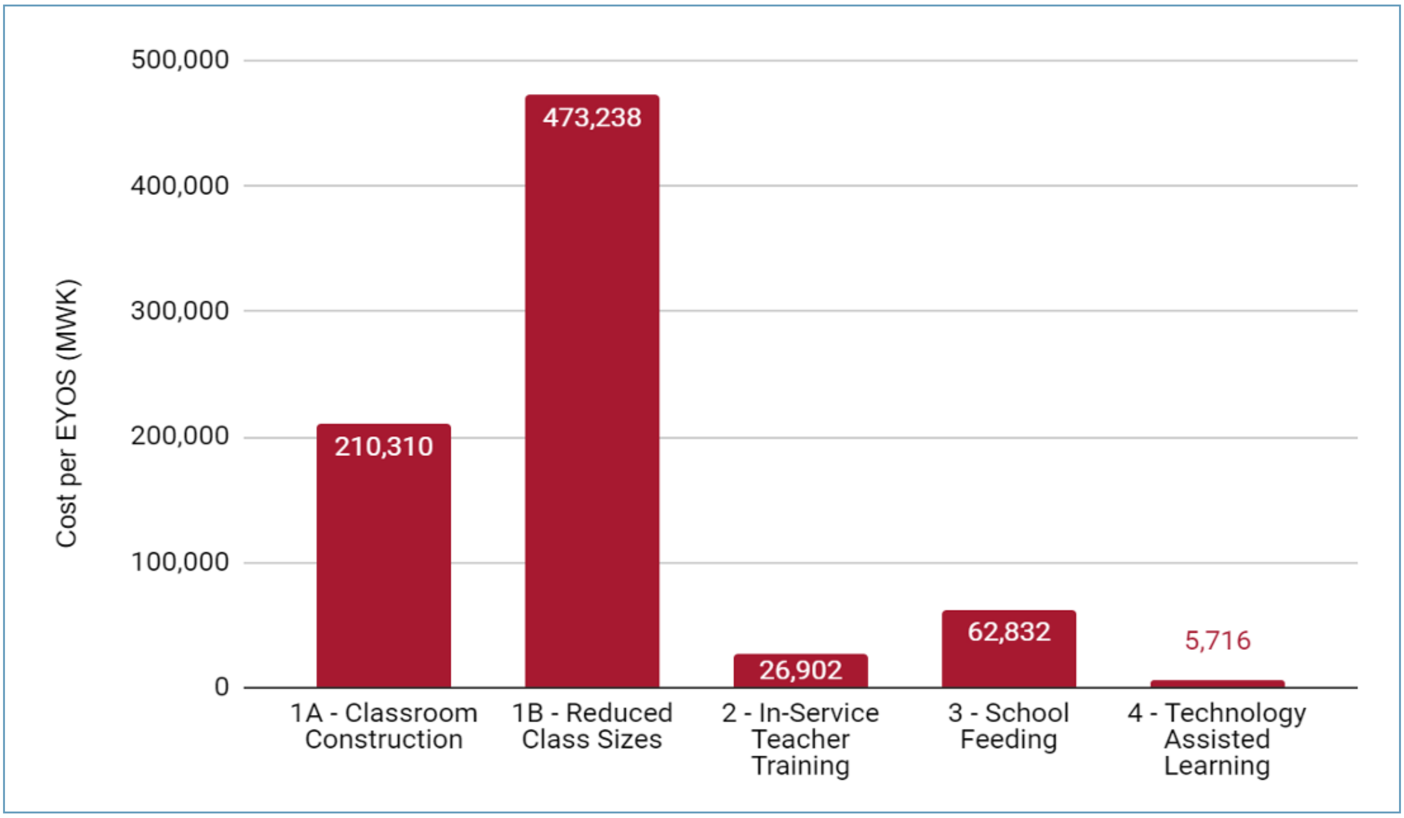
4.1.2 Cost Effectiveness Analysis

This can also be discussed in terms of the cost of achieving the equivalent of an additional year of schooling. Table 4.2 shows that technology-assisted learning is the most cost-effective intervention considered here, with a cost of 5,716 MWK to achieve the equivalent of one additional year of schooling. School feeding is the most expensive of the interventions considered, requiring 62,832 MWK of investment for each additional equivalent year of schooling (EYOS) achieved.

Table 4.2: Cost per EYOS by Intervention

Intervention	Cost per EYOS (MWK @ 8% discount rate)
Intervention 1A: School Construction	210,310
Intervention 1B: Reduced class size	473,238
Intervention 2: In-Service teacher training	26,902
Intervention 3: School feeding	62,832
Intervention 4: Technology-assisted learning	5,716

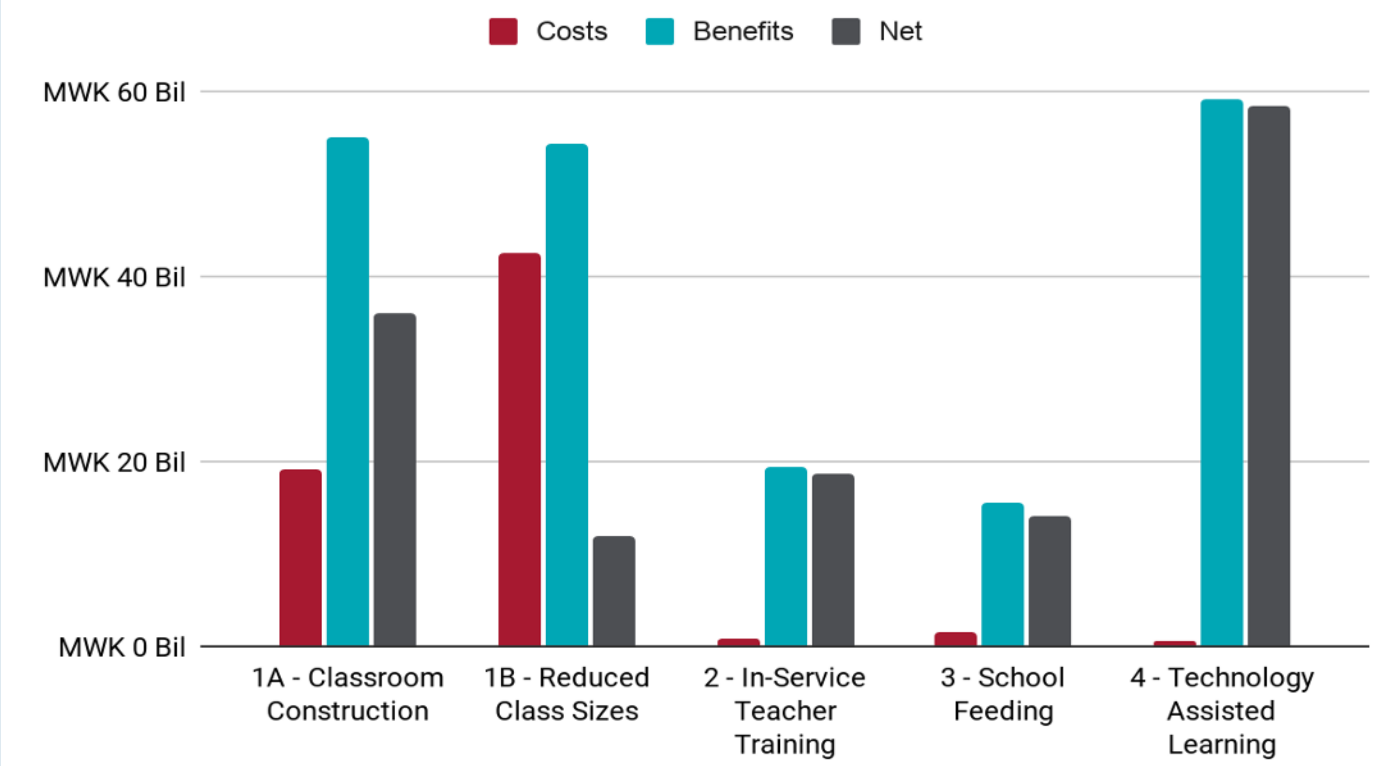
Figure 4.2: Cost per EYOS by intervention (8% discount rate)



4.1.3 Total Costs and Benefit Flows

In the figure below, the total costs and benefits of each intervention are compared to provide a sense of scale.

Figure 4.3: Present Value of Costs and Benefit Flows, by Intervention



The above absolute figures are based on 1000 classrooms constructed (intervention 1A), 1000 teachers hired and 1000 classrooms constructed (intervention 1B) or 50,000 students reached for a given year (interventions 2,3 and 4). For more information see Annex B. Given that the scale of each intervention can be tailored to the needs of policymakers, the absolute benefit and cost flows are generally less important than BCRs.

4.2 Sensitivity Analysis

To identify which assumptions are the most critical to the success of each intervention, the team has conducted some basic sensitivity analyses, which are reported in the following pages. Tables list the BCR or one or more interventions when alternative input values are assumed.

4.2.1 Value of Additional Schooling to Wages

All four interventions rely on estimates of the average impact of an additional year of schooling on wages to determine the impact of educational gains on lifetime earnings. In table 4.3, the BCRs of each intervention are recalculated assuming new values for the increase in wages per EYOS.

Table 4.3: Sensitivity of BCR to wage premium per EYOS

Scenario	ΔWage/ ΔEYOS	Benefit Cost Ratio (8% discount rate)				
		Intervention 1A – School Construction	Intervention 1B – Reduced Class Sizes	Intervention 2 – Teacher Training	Intervention 3 – School Feeding	Intervention 4 – Technology Assisted Learning
Current	11.2%	2.87	1.28	22.47	9.62	105.73
Alternative 1	0.0%	0.00	0.00	0.00	0.00	0.00
Alternative 2	5.0%	1.28	0.57	10.03	4.29	47.20
Alternative 3	10.0%	2.57	1.14	20.06	8.59	94.40
Alternative 4	15.0%	3.85	1.71	30.09	12.88	141.60
Alternative 5	20.0%	5.13	2.28	40.12	17.18	188.80

As expected, the benefit-cost ratios increase as the impact of education on wages increases. When the percentage increase per year is set to zero, the benefits will also be zero, which is one indication that this is a critical assumption. The benefits increase linearly in proportion to this parameter, so the higher this number the better. Even at a five percent value, which is less than half of the estimate found in Turkson et al, the benefit-cost ratio is still above one for all interventions, except hiring teachers. This is a good sign and indicates that even if this parameter has been overestimated, the results of the interventions should still be a net positive.

4.2.2 Additional years of schooling equivalent to improved test scores

At the core of each benefit calculation is an assumption that the improvement in test scores (measured in SD) measured in empirical studies of each intervention can be considered equivalent to some number of additional years of traditional schooling. Evans and Yuan estimate an average equivalency of 5.75 years per SD improvement, or 0.17 SD per additional year. This estimate is derived from meta-analysis of numerous studies, which vary in terms of contextual similarity to Malawi. It is therefore important to consider what alternative estimates imply for the interventions.

Table 4.4: Sensitivity of BCR to EYOS gain per SD improvement in test scores

Scenario	ΔEYOS/ΔSD	Benefit Cost Ratio (8% discount rate)				
		Intervention 1A – School Construction	Intervention 1B – Reduced Class Sizes	Intervention 2 – Teacher Training	Intervention 3 – School Feeding	Intervention 4 – Technology Assisted Learning
Current	5.75	2.87	1.28	22.47	9.62	105.73
Alternative 1	1.00	0.50	0.22	3.91	1.67	18.39
Alternative 2	2.00	1.00	0.44	7.81	3.35	36.78
Alternative 3	4.00	2.00	0.89	15.63	6.69	73.55
Alternative 4	6.00	3.00	1.33	23.44	10.04	110.33
Alternative 5	8.00	4.00	1.78	31.26	13.38	147.10

As seen in the table above, the BCR of each intervention increases linearly with the value of EYOS per SD. Even with the most pessimistic alternatives proposed, the rank order of interventions remains unchanged suggesting the results are highly robust to the model's assumptions. In all scenarios, technology-assisted learning remains an excellent use of resources.

4.2.3 Duration of the wage premium effect

The model requires an estimate of the total number of years that the wage benefit will be accrued to yield the total change in lifetime earnings.

Table 4.5: Sensitivity of BCR to the duration of the wage premium

Scenario	Duration (Years)	Benefit Cost Ratio (8% discount rate)				
		Intervention 1A – School Construction	Intervention 1B – Reduced Class Sizes	Intervention 2 – Teacher Training	Intervention 3 – School Feeding	Intervention 4 – Technology Assisted Learning
Current	30.00	2.87	1.28	22.47	9.62	105.73
Alternative 1	10.00	1.29	0.57	10.17	4.37	47.99
Alternative 2	20.00	2.21	0.98	17.34	7.43	81.68
Alternative 3	30.00	2.87	1.28	22.47	9.62	105.73
Alternative 4	40.00	3.28	1.46	26.16	11.19	123.04

4.2.4 Class size effect in Intervention 1B

The main determinant of improved test scores in intervention one is the impact of a one-unit change in class sizes on test scores. The following table tests the sensitivity of the results to this input.

Table 4.6: Sensitivity of BCR to change in test scores per change in PTR for intervention 1

Scenario	Δ Test Scores/ Δ PTR	BCR (8% discount rate) - Intervention 1
Current	0.19	1.28
Alternative 1	0.00	0.00
Alternative 2	0.05	0.34
Alternative 3	0.10	0.67
Alternative 4	0.15	1.01
Alternative 5	0.20	1.34
Alternative 6	0.30	2.02

As seen in the table above, the BCR increases linearly with the estimate of this relationship, and drops below one when the value is less than 75% of the original value. The results for intervention 1B are relatively sensitive to changes in this parameter.

4.2.5 Classroom construction in Intervention 1B

The number of classrooms constructed for intervention one is a decision that will depend on the available resources and the ambition of the implementer. This decision will also impact the BCR and is thus considered in the table below.

Table 4.7: Sensitivity of BCR to number of additional classrooms constructed in intervention 1

Scenario	# Classrooms Added	BCR (8% discount rate) - Intervention 1
Current	1000.00	1.28
Alternative 1	100.00	1.29
Alternative 2	2,000.00	1.26
Alternative 3	10,000.00	1.17

Notice that the more schools are constructed, the lower the BCR gets. This is because the more classrooms that are constructed, the less impact each additional one has on the student-class ratio. However, even at 100,000 classrooms constructed, the BCR is still positive, which suggests that at more reasonable lower numbers, decreasing returns to scale should not be a major issue.

4.2.6 Teacher training effect in Intervention 2

The impact of teacher training on their students' education is a central parameter for the estimate of benefits in intervention 2.

Table 4.8: Sensitivity of BCR to SD improvement attributed to teacher training for intervention 2

Scenario	Δ SD from training	BCR (8% discount rate) - Intervention 2
Current	0.12	22.45
Alternative 1	0.00	0.00
Alternative 2	0.05	9.36
Alternative 3	0.10	18.71
Alternative 4	0.20	37.42
Alternative 5	0.30	56.13

As reported in the table above, there is a linear relationship between the BCR and this parameter value. Even parameter estimates less than half of the current value produce BCRs above one.

4.2.7 School feeding effect in intervention 3

The impact of school feeding on test scores is a key parameter for the estimate of benefits in intervention 3. In the following table, we consider different effect sizes (as defined in SD deviation change to test scores).

Table 4.9: Sensitivity of BCR to SD improvement attributed to school feeding for intervention 3

Scenario	Δ SD from school feeding	BCR (8% discount rate) - Intervention 3
Current	0.09	9.62
Alternative 1	0.00	0.00
Alternative 2	0.05	5.34
Alternative 3	0.10	10.69
Alternative 4	0.20	21.38
Alternative 5	0.30	32.06

As shown in the table above, the effect size is directly proportional to the BCR. The effect size can go as low as 0.01 and still produce BCRs above one.

4.2.8 Sensitivity Analysis Conclusions

Through sensitivity analysis, it is observed that while the BCRs are sensitive to a number of parameters, the top interventions such as technology assisted learning maintain positive net benefits even when significantly worse parameter value estimates are employed. The top rated interventions are relatively robust, even if the magnitude of net benefits can vary in response to changes in the model's assumptions.

However, the lower BCR interventions like reduced class sizes and classroom construction are much more likely to dip below the threshold of one, which would imply negative net benefits. However, given that our base parameter estimates are just as likely to be off in either direction, these BCRs could also be higher than our base estimates.

Overall, the relatively low possibility of negative net benefits —even if parameters are not estimated perfectly— increases the team's confidence in endorsing the top interventions. All else equal, the sensitivity analysis shows that most of our estimates react similarly to changes in major variables like discount rate and years of school per SD, and the ordering of our interventions would only change if the effect size of any specific intervention on test scores were significantly different from those we obtain from empirical studies.

5. Discussion and policy implications

Malawi's education system is facing many challenges. Despite a consistently high proportion of the government's budget being allocated to education, youth in Malawi are failing to progress to secondary school in large numbers and consistently do poorly compared to other similar countries assessed on literacy and math skills. This report has proposed several intervention options that can mitigate some of the barriers to high-quality primary education that currently exist in Malawi. This includes five interventions: classroom construction, reduced class sizes, in-service teacher training, school feeding, and technology-assisted learning.

The results of this model show that each of these interventions has an expected benefit-cost ratio above one, the threshold where expected benefits exceed costs. The technology-assisted learning intervention has by far the highest benefit-cost ratio out of the primary-school interventions considered. As stated in the introduction, the results suggest that the Government of Malawi should strongly consider marshalling additional funds to gradually expand, test and refine a technology-assisted learning program similar to the type documented in Levesque et al. (2020). Note that this program also includes some classroom construction elements.

An important caveat of the analysis is that it assumes that the government will undertake the necessary investments to maintain the status quo going forward, as the primary-school-age population grows. This means that the government of Malawi will continue to construct classrooms and hire teachers to maintain the current class sizes and pupil-teacher ratios, and that these efforts are not reflected in the analysis. This report estimates the cost-effectiveness of additional spending in education beyond the additional spending that is already necessary to maintain the status quo. As such, one should not misinterpret the results to argue that budgets for future school construction can be allocated to technology-assisted learning instead. Significant investments in classroom construction and new teachers are required to maintain the status quo, which serves as the counterfactual against which gains are compared. If additional funds are found, however, the analysis suggests that technology-assisted learning would be the most effective use of these funds.

Effective targeting of the greatest potential beneficiaries can further improve the effectiveness of each intervention. For the class size intervention, this means building schools starting in areas with the largest class sizes since the impact on class sizes will be greatest. For teacher training or school feeding, this might mean targeting the districts with lower quality teachers, or where absenteeism is highest. For technology-assisted learning (TAL), the prioritized beneficiaries should be those that stand to gain the most from the content that will be covered by the app installed on the tablets. These types of targeting should further increase the cost-effectiveness of each intervention.

The exact timing or balance of these interventions is not something this model can specifically recommend but there will always be risk associated with projects and adopting a portfolio of these education interventions will still lead to very large benefits.

Primary education quality was the highest-ranked priority by sector experts consulted for the Malawi Priorities study. The findings of this report suggest that education interventions can bring about substantial benefits to the people of Malawi. Based on these findings, a combination of tablet-based technology-assisted learning interventions combined with long-term investments in teacher training and classroom construction should be recommended to governments and development partners looking to invest in Malawi. These interventions will not only improve primary education quality but will also improve the livelihoods of generations of Malawians to come.

Annex A: Methodology Calculations

Table A.1: School construction cost specification

Timeframe					
Costs accrue year 1 (Flag F1AC$_t$)					
Inputs		**Dimensions**	**Estimate**	**Unit**	**Source of verification**
P^C	Classroom construction cost	-	25,410	USD	Arup Engineering Study, 2009
$FX^{MWK/US}_{\square}$	Current Exchange rate of MWK per USD	-	755	MWK	Google Finance, October 22
$T_0^{\square}$	# of teachers in base period	-	66,732	#	MoEST Education Statistics 2014
$C_0^{\square}$	# of classrooms in base period	-	36,682	#	MoEST Education Statistics 2014
Calculation					
Cost:	$C1A_t^{\square} = ACC_t \times Q^C_{\square\square}$				
Where:	**Average classroom cost** $ACC_t = IF(t = 0, FX^{MWK/USD}_{\square} \times P^C_{\square\square}, 0)$ **Classrooms built in intervention** $Q^C_{\square\square} = T_0 - C_0$				

Table A.2: School construction benefit specification

Timeframe
Benefits accrue year 1-20 (Flag $F1AB_t$)

Inputs		Dimensions	Estimate	Unit	Source of verification
α	Increase in test scores per student indoors	-	0.093	SD	Dunga 2013
n^{α}	Number of observations used for test score SE estimate	-	2,589	#	Mulera et al 2017
SE^{α}	Standard error of the mean of test scores in Malawi	-	2.63	SE	SACMEQ Website
β	Increase in EYOS per one SD improvement on standardized test	-	5.75	EYOS	Evans and Yuan 2019
S_0	# of primary students in base period	-	4,670,279	#	MoEST Education Statistics 2014
Q^{C}	# of classrooms constructed for intervention	-	-	#	User Defined
C_0	# of classrooms in base period	-	36,682	#	MoEST Education Statistics 2014
T_0	# of teachers in base period	-	66,732	#	MoEST Education Statistics 2014
g^{S}_{t}	Population growth	Time	See CCC Projections	%	CCC Projections
g^{T}	Annual growth rate of teachers in counterfactual	-	3.20%	%	Ravishankar et al. 2016, Table 2.6
g^{C}	Annual growth rate of classrooms constructed in counterfactual	-	1.33%	%	Ravishankar et al. 2016, pg. xvii
W_t	Base Income Projections	Time	See CCC projections	MWK	CCC projections
Ret	Estimated wage premium from additional year of schooling	-	13.2%	%	Turkson et al 2020
n	Number of years worked with wage premium	-	30	#	Author Assumption
r	Discount rate	-	5%/ 8%/ 14%	%	CCC Defined
d	Delay in benefit accumulation	-	10	Years	Author Assumption

Calculation	
Benefit:	$B1_t = \Delta S_t \times \frac{\alpha}{6} \times \frac{1}{\sqrt{n^{\alpha}} \times SE^{\alpha}} \times \beta \times \gamma_t$
Where:	**Change in the number of students Outdoors** $\Delta S_t = OS^{w/o}{}_t - OS^{w}{}_t = S_t \times \frac{Q^C}{T_t}$ $OS^{w}{}_t = S_t \times \frac{T_t - C_t - Q^C}{T_t}$ $OS^{w/o}{}_t = S_t \times \frac{T_t - C_t}{T_t}$ **Growth of Students, Teachers, Classrooms** $S_t = S_{t-1} \times (1 + g_t{}^{S})$ $T_t = T_0 \times (1 + g^{T})^t$ $C_t = C_0 \times (1 + g^{C})^t$ **Change in discounted life-time earnings per additional year of schooling in year t:** $\gamma_t = \frac{NPV(r, LTE_{t+d} : LTE_{t+d+n})}{(1+r)^{d-1}}$ **Lifetime Earnings Premium Projections** $LTE_t = W_t \times Ret$

Table A.3: Reduced class size cost specification

Timeframe					
Costs accrue year 1-20 (Flag F1BImp$_t$)					
Inputs		**Dimensions**	**Estimate**	**Unit**	**Source of verification**
$Q^{T\&C}$	# of teachers hired and classrooms constructed	-	-	#	User Defined
P^{T}	Average teacher cost per year	-	2,206,499	MWK	Ravishankar et al. 2016
P^{C}	Classroom construction cost	-	25,410	USD	Arup Engineering Study, 2009
$FX^{MWK/US}$	Current Exchange rate of MWK per USD	-	755	MWK	Google Finance, October 22
r	Discount rate	-	5%/8%/14%	%	CCC Defined
Calculation					
Cost:	$C1B_t = Q^{T\&C} \times (P^{T} + ACC_t)$				
Where:	**Average classroom cost** $ACC_t = IF(t = 1, FX^{MWK/USD} \times P^{C}, 0)$				

Table A.4: Reduced class size benefit specification

Timeframe

Benefits accrue year 1-20 (Flag F1BImp$_t$)

Inputs		Dimensions	Estimate	Unit	Source of verification
α	Increase in test scores per one unit decrease in PTR	-	0.19	#	Mulera et al 2017
n^{α}	Number of observations used for test score SE estimate		2,589	#	Mulera et al 2017
SE^{α}	Standard error of the mean of test scores in Malawi	-	2.63	SE	SACMEQ Website
β	Increase in EYOS per one SD improvement on standardized test		5.75	EYOS	Evans and Yuan 2019
S_0	# of primary students in base period	-	4,670,279	#	MoEST Education Statistics 2014
Q^{C}	# of classrooms constructed for intervention		-	#	User Defined
C_0	# of classrooms in base period	-	36,682	#	MoEST Education Statistics 2014
Q^{T}	# of teachers hired for intervention		-	#	User Defined
T_0	# of teachers in base period	-	66,732	#	MoEST Education Statistics 2014
g^{S}_{t}	Population growth		See CCC Projections	%	CCC Projections
g^{T}	Annual growth rate of teachers in counterfactual	-	3.20%	%	Ravishankar et al. 2016, Table 2.6
W_t	Base Income Projections	-	See CCC projections	MWK	CCC Projections
Ret	Estimated wage premium from additional year of schooling		13.2%	%	Turkson et al 2020
n	Number of years worked with wage premium	-	30	#	Author Assumption
r	Discount rate	-	5%/ 8%/ 14%	%	CCC Defined
d	Delay in benefit accumulation		10	Years	Author Assumption

Calculation	
Benefit:	$B1B_t^{\square} = S_t \times \Delta PTR_t \times \frac{\alpha}{6} \times \frac{1}{\sqrt{n^{\alpha}{}_{\square}} \times SE^{\alpha}{}_{\square}} \times \beta \times \gamma_t$
Where:	**Change in pupil teacher ratio:** $$\Delta PTR_{\square t} = \frac{S_t}{T_t} - \frac{S_t}{T_t + Q_{\square}{}^{T}}$$ **Growth of Students, Teachers, Classrooms** $$S_t = S_{t-1} \times (1 + g_t{}^{S}{}_{\square})^{\square}$$ $$T_t = T_0 \times (1 + g^{T}{}_{\square})^{t}$$ **Change in discounted life-time earnings per additional year of schooling in year t:** $$\gamma_t = \frac{NPV(r, LTE_{t+d}: LTE_{t+d+n})}{(1+r)^{d-1}}$$ **Lifetime Earnings Premium Projections** $$LTE_t = W_t \times Ret$$

Table A.5: In-service teacher training cost specification

Timeframe					
Costs accrue year 1-3 (Flag $F2C_t$)					
Inputs		**Dimensions**	**Estimate**	**Unit**	**Source of verification**
Q	# of students benefiting from in-service training	-	-	Student	User Defined
P	Average cost per teacher	-	434,767.60	MWK	EGRA Performance Evaluation 2016, table 27
g_t^S	Population growth	Time	See CCC Projections	%	CCC Projection
g^T	Annual growth rate of teachers in counterfactual	-	3.20%	%	Ravishankar et al. 2016
S_0	# of primary students in base period	-	4,670,279	#	MoEST Education Statistics 2014
T_0	# of teachers in base period	-	66,732	#	MoEST Education Statistics 2014
Calculation					
Cost:	$C1_t = Q \times \frac{T_t}{S_t} \times P$				
Where:	**Change in class sizes:** $S_t = S_{t-1} \times (1 + g_t^S)$ $T_t = T_0 \times (1 + g^T)^t$				

Table A.6: In-service teacher training benefit specification

Timeframe					
Benefits accrue year 3 (Flag $F2B_t$)[6]					
Inputs		**Dimensions**	**Estimate**	**Unit**	**Source of verification**
Q	# of students benefiting from in-service training	-	-	#	User Defined
α	Change in test scores per change in teacher training	-	0.12	SD	McEwan, 2015
β	Change in EYOS per one SD improvement on standardized test	-	5.75	EYOS	Evans and Yuan, 2019
W_t	Base Income Projections	Time	See CCC projections	MWK	CCC Projection
Ret	Estimated wage premium from additional year of schooling	-	11.1%	%	Turkson et al 2020
n	Number of years worked with wage premium	-	30	#	Author Assumption
r	Discount rate	-	5%/ 8%/ 14%	%	CCC Defined
d	Delay in benefit accumulation	-	10	Years	Author Assumption
Calculation					
Benefit:	$B1_t = Q \times \alpha \times \beta \times \gamma_t$				
Where:	**Change in discounted life-time earnings per additional year of schooling in year t:** $\gamma_t = \frac{NPV(r, LTE_{t+d} : LTE_{t+d+n})}{(1+r)^{d-1}}$ **Lifetime Earnings Premium Projections** $LTE_t = W_t \times Ret$				

[6] While it is possible the benefits of a training program would last for more than a year, the evidence from in-service teacher training interventions typically does not measure the impact of the intervention beyond one year after the training so the model lacks sufficient evidence to make that assumption. This is included as a parameter for sensitivity analysis.

Table A.7: School feeding cost specification

Timeframe					
Costs accrue in year 1 (Flag F3Imp$_t$)					
Inputs		**Dimensions**	**Estimate**	**Unit**	**Source of verification**
Q^F	Number of students benefiting from school feeding	-	-	#	User Defined
P^F	Average annual cost per beneficiary of school feeding	-	32,515.60	MWK	Dunaev & Corona, 2018
Calculation					
Cost:	$C1_t = Q^F \times P^F$				

Table A.8: School feeding benefit specification

Timeframe					
Benefits accrue year 1 (Flag $F3Imp_t$)					
Inputs		**Dimensions**	**Estimate**	**Unit**	**Source of verification**
Q^F	Number of students benefiting from school feeding	-	-	#	User Defined
α	Average change in test scores for school feeding beneficiaries	-	0.09	SD	Snilstveit et al, 2016
β	Change in EYOS per one SD improvement on standardized test	-	5.75	EYOS	Evans and Yuan, 2019
W_t	Base Income Projections	Time	See CCC projections	MWK	CCC Projection
Ret	Estimated wage premium from additional year of schooling	-	11.1%	%	Turkson et al 2020
n	Number of years worked with wage premium	-	30	#	Author Assumption
r	Discount rate	-	5%/ 8%/ 14%	%	CCC Defined
d	Delay in benefit accumulation	-	10	Years	Author Assumption
Calculation					
Benefit:	$B1_t = Q^F \times \alpha \times \beta \times \gamma_t$				
Where:	**Change in discounted life-time earnings per additional year of schooling in year t:** $\gamma_t = \frac{NPV(r, LTE_{t+d}: LTE_{t+d+n})}{(1+r)^{d-1}}$ **Lifetime Earnings Premium Projections** $LTE_t = W_t \times Ret$				

Table A.9: Technology assisted learning cost specification

Timeframe					
Costs accrue year 1 (Flag F4Imp$_t$)					
Inputs		**Dimensions**	**Estimate**	**Unit**	**Source of verification**
Q^{TAL}	Number of technology-assisted learning (TAL) beneficiaries	-	-	Students	User Defined
P^{TAL}	Average annual cost per beneficiary of TAL	-	15	USD	onebillion estimate
$FX^{MWK/US}$	Current Exchange rate of MWK per USD	-	755	MWK	Google Finance, October 22
Calculation					
Cost:	$C1_t = Q^{TAL} \times P^{TAL}$				

Table A.10: Technology assisted learning benefit specification

Timeframe					
Benefits accrue year 1 (Flag F4Imp$_t$)					
Inputs		**Dimensions**	**Estimate**	**Unit**	**Source of verification**
Q^{TAL}	Number of technology-assisted learning (TAL) beneficiaries	-	-	#	User Defined
α	Change in test scores for beneficiaries of TAL	-	0.34	SD	Levesque, 2020
β	Change in EYOS per one SD improvement on standardized test	-	5.75	EYOS	Evans and Yuan, 2019
W_t	Base Income Projections	Time	See CCC projections	MWK	CCC Projection
Ret	Estimated wage premium from additional year of schooling	-	11.1%	%	Turkson et al 2020
n	Number of years worked with wage premium	-	30	#	Author Assumption
r	Discount rate	-	5%/ 8%/ 14%	%	CCC Defined
d	Delay in benefit accumulation	-	10	Years	Author Assumption
Calculation					
Benefit:	$B1_t = Q^{TAL} \times \alpha \times \beta \times \gamma_t$				
Where:	**Change in discounted life-time earnings per additional year of schooling in year t:** $\gamma_t = \frac{NPV(r, LTE_{t+d}: LTE_{t+d+n})}{(1+r)^{d-1}}$ **Lifetime Earnings Premium Projections** $LTE_t = W_t \times Ret$				

Table A.11: Benefit and cost timing and flags

Inputs		Estimate	Unit
Y_0	Start year	2020	Year
$1Imp^{B}{}_{\square}$	Intervention 1 implementation beginning year	2020	Year
$1Imp^{L}{}_{\square}$	Intervention 1 implementation length	20	Years
$2B^{B}{}_{\square}$	Intervention 2 benefits beginning year	2022	Year
$2B^{L}{}_{\square}$	Intervention 2 benefits length	1	Years
$2C^{B}{}_{\square}$	Intervention 2 costs beginning year	2020	Year
$2C^{L}{}_{\square}$	Intervention 2 costs length	3	Years
$3Imp^{B}{}_{\square}$	Intervention 3 implementation beginning year	2020	Year
$3Imp^{L}{}_{\square}$	Intervention 3 implementation length	1	Years
$4Imp^{B}{}_{\square}$	Intervention 4 implementation beginning year	2020	Year
$4Imp^{L}{}_{\square}$	Intervention 4 implementation length	1	Years

Calculation	
Periods:	t is a time index corresponding to the number of complete years elapsed since the start year $Y_t = Y_0 + t$
Flags:	$F1Imp_t = if(Y_t >= 1B^{B}{}_{\square}, if(Y_t < (1B^{B}{}_{\square} + 1B^{L}{}_{\square}),1,0),0)$ $F2B_t = if(Y_t >= 2B^{B}{}_{\square}, if(Y_t < (2B^{B}{}_{\square} + 2B^{L}{}_{\square}),1,0),0)$ $F2C_t = if(Y_t >= 2C^{B}{}_{\square}, if(Y_t < (2C^{B}{}_{\square} + 2C^{L}{}_{\square}),1,0),0)$ $F3Imp_t = if(Y_t >= 3B^{B}{}_{\square}, if(Y_t < (3B^{B}{}_{\square} + 3B^{L}{}_{\square}),1,0),0)$ $F4Imp_t = if(Y_t >= 4B^{B}{}_{\square}, if(Y_t < (4B^{B}{}_{\square} + 4B^{L}{}_{\square}),1,0),0)$

Annex B: Stream of cost flows (millions, MWK)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Classroom construction	19,185									
Reduce class sizes	21,391	2,206	2,206	2,206	2,206	2,206	2,206	2,206	2,206	2,206
In-service teacher training	310	311	312							
School feeding	1,626									
Technology assisted learning *(1-year model, average annualized cost)*	*559*									
Technology assisted learning *(20-year model, detailed cost modelling)*	3,478	165	223	165	1,609	165	223	165	1,609	165

Notes: Classroom construction is based on construction of 1000 classrooms; reduce class sizes is based on construction of 1000 classrooms and hiring of 1000 teachers; In-service teacher training assumes 3 years of training benefiting 50,000 students; school feeding is modelled as a 1-year intervention benefitting 50,000 students; Technology assisted learning is depicted in two ways: a 1-year model depicting average lifecycle costs per student, as well as a 20-year model depicting more detailed costs. Both models depict scenarios benefitting 50,000 students per year.

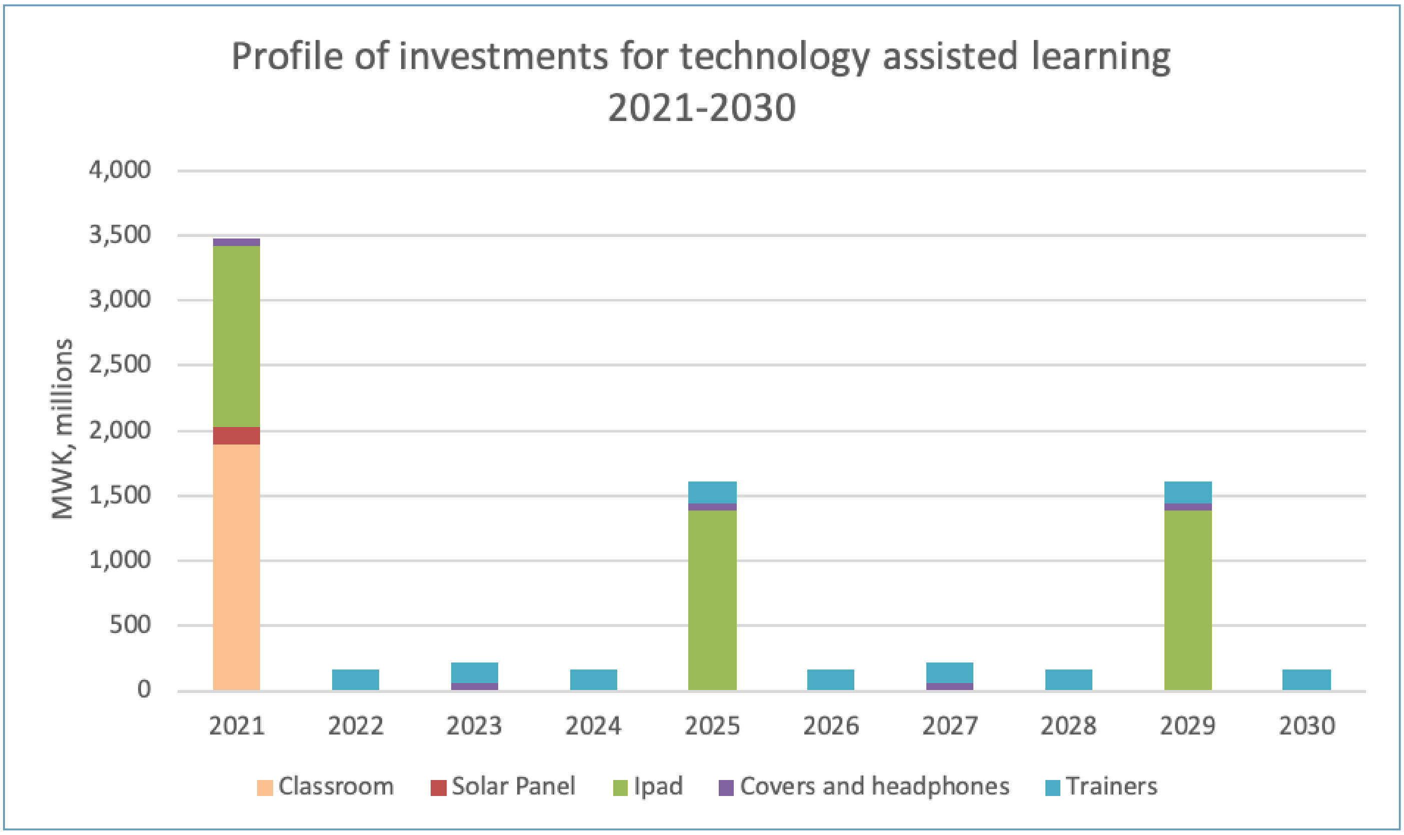
Annex C:20-year model for Technology Assisted Learning

As this analysis was nearing completion, the team undertook extra due diligence on the technology assisted learning intervention due to its very high BCR. During this process we noted that the costs per student per year originally used (USD 15) represented average annualized costs over the life cycle of intervention investments. While this is appropriate for use in a one-year model of costs and benefits to determine the BCR, multi-year modelling is required to inform policy makers about the medium and long-term cost budget implications to actually implement the intervention.

After consultation with onebillion we noted that the following investments were required to rollout the intervention for one school of 500 students.

Cost Category	Value	Assumed lifespan	Notes
Tablet (iPad)	USD 310 per unit 60 units required per school	4 years	Tablets sourced at wholesale prices from African distributor Tablets can last as long as 6 years
Headphones and tablet covers	USD 13 per unit 60 units required per school	2 year	Headphones and covers can last as long as 4 years
Staff	USD 31,000 annual salary One staff member can cover 14 schools	n/a	USD 31,000 represents the cost of an international staff member; local staff members would be less expensive
Classroom	USD 25,400	20 years	In the first 112 schools, onebillion has constructed classrooms to ensure a dedicated learning environment and to store tablets when not in use
Solar charging	USD 1,900	10 years	Tablets are charged via solar panels

Scaling this up to 50,000 students per year would require investments for 100 classrooms every 20 years, 100 solar panels every 10 years, 6000 tablets every 4 years, 6000 headphones and covers every 2 years and roughly 7 additional staff members annually. The profile of these costs is presented in the graph below, shown only until 2030. It is clear that the main investment is in the first year, at almost MWK 3,500 million. Periodic replacement of tablets represents the next most costly element.



Benefits of the intervention were estimated as per the one-year model, assuming the same learning gains and accounting for real growth in benefits as real income grows. The BCRs of this are depicted in the table below and are very similar to the results of the one-year model. Policy implications are unchanged. Any differences in BCRs are primarily driven by income growth over time which are not captured in a single year model.

Intervention	Benefit-Cost Ratio		
	5% Discount Rate	8% Discount Rate	14% Discount Rate
Benefits (MWK, millions)	2,138,575	870,733	194,345
Costs (MWK, millions)	9,375	8,122	6,537
BCR from 20-year model	228	107	30
BCR from one year model	202	106	36

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2021

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