THE WELFARE IMPACTS OF ENGINEERS WITHOUT BORDERS IN WESTERN KENYA

by

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ABSTRACT

The undergraduate chapter of Engineers Without Borders at Montana State University (EWB-MSU) work towards improvement of student welfare by providing bore hole wells and composting latrines to primary schools in Khwisero, Kenya. These projects seek to improve the safety of drinking water at the school, increase school attendance and performance and decrease time spent collecting water in these communities. Data were collected from 776 households in Khwisero in order to measure the organization's impact. Instrumental variable methods are used to analyze EWB-MSU's impact on health outcomes, while fixed effect analysis is used to investigate the impact on education and time-use outcomes. No impact is detected on student health or education due to EWB-MSU projects but households surrounding EWB-MSU water projects spend almost one minute fewer, on average, traveling to their primary water source relative to other households.

INTRODUCTION

Unsafe or inaccessible water and sanitation has consequences for individual welfare in developing countries. The WHO estimates that 6% of all deaths in 2004 were attributable to water, sanitation or hygiene (WSH) practices [27]. Over *half* of these deaths, or approximately 3% of annual deaths, are caused by diarrheal disease from enteric infections.[1] Children are especially vulnerable. Of the 1.5 million deaths related to diarrhea reported in 2004, the majority were children [27]. Further, inaccessible water may have an opportunity cost for household members, most often women and children.[2] The time required to collect water may keep children from school, decrease female labor force participation, or generally reduce welfare outcomes of women and children. Engineers Without Borders-Montana State University (EWB-MSU), an undergraduate organization, seeks to mitigate these consequences by improving the safety and accessibility of water and sanitation at primary schools in Khwisero sub-county, Kenya.[3] Examination of the impact of this organization is the purpose of this thesis.

Between 2004 and 2014, EWB-MSU has constructed 11 deep bore hole wells and 13 composting latrines at 20 schools in Khwisero.[4] One expected result of increasing drinking water safety is subsequent improvement in primary student health outcomes. In turn, improvement of these health outcomes is expected to lead to improvement in academic performance. Another expected result of the construction of EWB-MSU water projects in particular is increasing water accessibility for nearby households. In turn,

[1]Enteric infections are caused by viruses and bacteria that enter the body through the mouth or intestinal system, primarily as a result of eating, drinking and digesting contaminated foods or liquids [36].

[2]Looking at three African countries: Malawi, Rwanda and Uganda; Koolwal & Van de Walle (2013) find about 60 – 80% women, 50 – 60% of girls and 20 – 60% of boys report collecting water for the household (see Table 2) [17]. In contrast, only about 10 – 40 % of men report doing so.

[3]Other EWB-MSU goals include the reduction of time students spend collecting water during school, increasing school crop yield with human waste compost, increasing the aspirations of Khwisero students and community members and deriving experiential benefit from the exposure of college students living in a more-developed country to people living in a less-developed country, and vice versa.

[4]EWB-MSU also implemented a rainwater catchment system at one school that is included in this analysis.

shorter trips to collect water may reduce the labor burden on household children, allowing them to attend more school.

Studies of similar water and sanitation interventions confirm three impacts worth highlighting. First, both water and sanitation source interventions lead to improvements in health outcomes [1, 9, 11, 12, 14, 31, 33, 34]. However, the impact of water source on child health may be conditional on household wealth and parental education [16, 19, 20]. Second, water source interventions reduce the amount of time household members spend collecting water. Women do not typically use this saved time towards increased labor force participation but rather for non-market household production or leisure. [7, 8, 29]. Third, water source interventions decrease child labor and increase school attendance [17, 24]. This analysis is unique within the literature because EWB-MSU's projects are specifically implemented at primary schools. It contributes by examining whether child health, education and household time-use outcomes improve when water and sanitation projects are implemented at a school.

This analysis uses data collected from 776 households in Khwisero, Kenya during the Summer of 2014. In addition, time-series data for all Khwisero primary schools are used to test the robustness of EWB-MSU's academic impact. Intrinsic to determining EWB-MSU's impacts are two selection bias problems. First, EWB-MSU projects are implemented in communities that the organization deems most in need. As a result, EWB schools and surrounding communities likely experienced lower welfare than other communities in the first place. The fixed effect estimator is used to capture this form of community endogeneity. Second, Khwisero students are able to transfer between schools and may do so in response to EWB-MSU project implementation. Students who transfer may have characteristics that yield better welfare outcomes. Their attendance at an EWB-MSU project school may increase the average welfare outcomes for students at that school. The fixed effect estimator is used to control for time-invariant individual characteristics when time-series data are available. The instrumental variables estimator is also used to control for individual endogeneity when time-series data are unavailable.

The subsequent analysis does *not* find evidence that EWB-MSU projects affect primary student health or education outcomes. Evidence is found to support a time-use impact. Households in communities surrounding primary schools with EWB-MSU water projects save approximately one minute on average traveling to their primary water source. For households actually using the water projects, the time savings are much larger: between 40 minutes to an hour in the dry and wet seasons respectively. Unfortunately, only an estimated 25 households are using the water projects, all in a single community. Their time savings aggregate to approximately 30 hours of labor saved every day for approximately 15% of the population of this community or approximately 3% of the total population surrounding EWB-MSU water projects.

This thesis consists of five additional sections. Section one reviews evidence from the development literature linking water and sanitation interventions to health, education and time-use outcomes. Section two describes household survey data and other data sources used in the subsequent empirical analysis. This section compares welfare outcomes of interest between the groups with and without EWB-MSU projects. Further, the section compares other measures not expected to be impacted by EWB-MSU projects in order to evaluate how these groups differ in observed characteristics. Section three explains the empirical methods used and how they handle the selection bias threats to identification. Section four details and summarizes the results from the methodological approaches to testing EWB-MSU's welfare impact. Section five summarizes findings, presents potential explanations for those findings, and offers future recommendations for EWB-MSU based on the given findings and explanations.

LITERATURE REVIEW

The impacts of water and sanitation projects on health, education and time-use are well analyzed in the literature. The findings of the following studies provide a backdrop with which to compare the estimated outcomes of EWB-MSU projects. The review is separated into two sections that investigate what is understood about the impacts of water and sanitation projects. First, water access intervention impacts on health, time-use and education are examined. Second, the impact of sanitation access intervention on health is examined. Primary students are the target population of EWB-MSU projects and so children are the focus of this review of the literature.

The Impacts of Water Access & Safety

The literature on water access and safety provides three general conclusions about the impact of water source interventions on welfare outcomes. First, introducing an improved water source decreases the likelihood of contracting all enteric diseases.[1] Improvements in water safety are shown to improve child health [9, 11, 14, 31, 33, 34]. However, the effects on children may be conditional on wealth and parental education [16, 19, 20]. Second, women who experience decreases in time requirements for water collection are *not* observed to substitute greater time participating in the work force. Instead, they use extra time to conduct other non-market household production or enjoy leisure [7, 8, 17]. Third, a decrease in resource gathering activities, including water collection, will increase a child's attendance at school [17, 23, 24, 28]. Contrary to intuition, the impact is not significantly different between boys and girls.

Water Safety & Enteric Disease Contraction

Several studies consider the relationship between water access and health [9, 11, 14, 31, 33, 34]. This literature broadly addresses whether an increase in water safety causes a decrease in disease morbidity. Specifically, diarrhea morbidity is of great interest among several other water borne illnesses.

The relationship between water access and disease is found to be relatively weak compared with sanitation facilities or hygiene habits. Nevertheless, it is agreed upon that water source interventions negatively impact disease contraction. Access to ground water is an improvement over surface water and piped water is superior to both. Wang, Shepard, Shu, Cash, Zhao, Zhu & Shen (1989) find that randomized implementation of bore hole well tap water in Chinese communities decreases the incidence of enteric diseases [34].[5] Esrey, Potash, Roberts & Shiff (1991) examine 144 water and sanitation access studies and how they impact health. They find a consensus that improved water facilities generally reduces morbidity in many common diseases. However, water safety improvements are less important than improved sanitation facilities. Interestingly, simultaneous interventions in water, sanitation and hygiene (WSH) areas are not significantly more effective in reducing morbidity than interventions that focus on one of the three. The majority of WSH-related deaths are due to diarrhea, a symptom of enteric disease.[6] Fewtrell, Kaufmann, Kay, Enanoria, Haller & Colford (2005) conclude that all WSH interventions, including water source interventions, form a significant negative relationship with diarrhea morbidity [11].

Water Safety & Child Health

As indicated in the introduction, children appear more vulnerable to enteric diseases than adults. Much of water safety research focuses on child morbidity, as these diseases more severely affect young children [1, 4, 16, 18–22]. These studies are highlighted here because they are most directly comparable to the focus of this thesis. Three studies indicate the relationship between water access and child health outcomes is conditional on parental education and household wealth. Lee, Rosenzweig & Pitt (1997) use the semi-parametric maximum likelihood (SML) estimator as well as simultaneous

[5] These diseases included bacillary dysentery, viral hepatitis A, El Tor cholera, and acute watery diarrhea.
[6] See Table 1 from Pruss-Ustun and WHO [27].

equations with data collected in rural Bangladesh to conclude that water safety has an insignificant impact on child survivability, conditional on parental education and wealth [19]. Further, Lee et al. find that child health is strongly correlated with parental wealth and education level. Similarly, Jalan & Ravallion (2003) find that health benefits associated with piped water access are conditional on household income and mother's education using propensity score matching methods on a cross section of households from India [16]. Mangyo (2007) follows with evidence that children in Chinese households who receive water access within their own compound have improved health, only if the mother is educated. The effect is insignificant otherwise [20].

Another set of studies find positive impacts of water source on child health even after controlling for household wealth and parental education. Tumwine, Thompson, Katua-Katua, Mujwajuzi, Johnstone & Porras (2002) find that the use of surface water has a significant positive relationship with child diarrheal disease using data from 33 East African sites [31]. They use a logistic regression for whether a child had diarrhea in the past week and control for community and household variables. Mutunga (2007) uses the 2003 Kenya Demographic and Health Survey (DHS) dataset to estimate a hazard function for child mortality controlling for mother's education and household assets [22].[7] The hazard ratio estimation indicates that environmental factors, including access to water, have a significant impact on the probability of child survival.[8] Adewara & Visser (2011) use the 2008 Nigeria DHS dataset to relate water safety with better child health compared to unimproved sources [1]. Balasubramaniam (2010) finds that both water access and sanitation have significant negative relationships with stunting and malnutrition using a cross section of data from Indian households. She also finds that sanitation facilities are more strongly related to child health than water source safety [4]. Adewara & Visser (2011), Balasubramanian (2010) and Tumwine et al. (2002) include child characteristics

[7] The Demographic and Health Survey (DHS) is conducted by USAid in developing countries around the world [32].

[8] Hazard Ratio: The probability of dying within the next day given survival for *t* days.

such as age, birth order, and gender as well as household characteristics such as assets and parental education in their models. These studies rely on the conditional independence of water access improvements from health outcomes when using a control variable conditioning set. However, as Lee et al. (1997) argue, the allotment of resources to child health may be endogenous due to unobserved characteristics of households that have safer and closer water sources. Further, there is a possibility of omitted household or individual characteristics that may bias these results.

Some of the literature on water access and child health questions the beneficial relationship of water infrastructure and child health [10, 16, 19, 20]. Instead these studies point to parental or maternal education level as a necessary condition for child health impacts. Lee et al. (1997) make the argument that reduced form estimates may underestimate the impact on child health due to endogeneity of resource allocation towards child health in households with improved infrastructure [19]. Though Mutunga (2007) may successfully address household endogeneity with a hazard rate function, other literature does not mention this potential concern. Nevertheless, more recent literature finds that water infrastructure is significantly related with child health, controlling for child and household characteristics. The relationship between water safety and child health outcomes appears mixed.

Water Access & Time-Use

Studies of water source interventions indicate such projects save time for household members, especially women, who are the most frequent contributers to household water collection.[9] Ilahi & Grimard (1991) find that as water access decreases, female labor hours increase [15]. They use a system of equations on household data from Pakistan. Costa, Hailu, Silva & Tsukada (2009) find that increases in the number of community water sources causes a decrease the total labor burden for women in the household [6]. They use data from Ghana with two stage least squares to deal with the

[9] See Koolwal & Van de Walle (2013), Table 2 [17].

suspected endogenous relationship between communities with water and time women spend collecting water. Koolwal and Van de Walle (2013) use a cross-section of households from 9 countries and fixed effects to link increased water access with decreased overall labor burden for women [17]. Each of these studies finds insignificant relationships between water collection time and female labor force participation, however women do spend their saved time productively in non-market activities in the household or at leisure.

Water Access & Education

One concern regarding water access is that time spent collecting water may take away from a child's educational attainment. Further concerning is the possibility that girls may bear a larger responsibility for collection relative to boys in the household, thus suffering academic losses disproportionately. Early research on the impact of household labor and education was conducted by Psacharopoulos (1997). He finds that child labor hours have a negative relationship with education attainment as well as a positive relationship with grade repetition. He used a tobit model and household survey data from Bolivia and Venezuela [28]. More recently, Nankhuni & Findeis (2003) evaluated the effect of child labor on school attendance in Malawi using a multinominal logit regression. They find that hours spent on resource collection reduces the probability of school attendance. They hypothesize that households are affected by the trade off between the child's education and household resource needs [23].[10]

Nauges & Strand (2013) are the first to find evidence in Africa that decreases in the time spent collecting water increases the portion of girls 5 to 15 years of age attending school using four rounds of DHS data in Ghana [24]. Interestingly, the effect is insignificant when collection times are below 20 minutes one-way. This suggests to the authors the existence of a threshold effect caused by *discretionary* household time

[10]The variable *resource collection* in Nankhuni and Findeis's 1997-8 Malawi Integrated Household Survey (IHS) dataset refers to collection of firewood, another necessary household task in poor households.

available for water collection. They argue households may not recognize the effects on their time budget constraints until the amount of time required to collect water increases beyond 20 minutes, at which point children are kept home from school. Interestingly, they find no significant difference between girls and boys in the effect on attendance after controlling for other household and community characteristics. They estimate that a 50% reduction in haul time leads to an average increase of 2.4% in school attendance for both sexes, with stronger average effects in rural communities. They make the explicit assumption that endogeneity of water access arises at the individual-level, *not* the community-level. Thus, community averages for school attendance are expected to wash out in individual fixed effects. However, heterogeneous communities may have unobserved characteristics that correlate with both water access and education and, thus, explain some of the variation.

Koolwal & Van de Walle (2013) also look at the effect of water access on school attendance across multiple countries [17]. They find a positive and significant impact of increasing water access on girls and boys attendance but only in non-African countries. They posit the equal impact on boys and girls may be due to a small attendance gender gap along with room for improvement in attendance for both sexes. This gender-neutral result concurs with the results of Nauges & Strand (2013). Koolwal & Van de Walle hypothesize that a lack of significant estimates relating water collection to school attendance in African countries may be explained by overall higher attendance rates relative to other developing countries.

Studies of child labor estimate a negative relationships with education. Specifically, estimates of the relationship between water access and education suggest that as haul times decrease, school attendance increases. Contrary to intuition, there is no significant difference between this effect on boys and girls.

The Impacts of Sanitation Access

The impact of sanitation facilities on health outcomes is well studied in the literature. There is general accordance that increased or improved sanitation facility access decreases disease contraction. Frisvold, Mines & Perloff (1988) find that a lack of field sanitation facilities for agriculture workers increased the likelihood of contracting a gastrointestinal disorder by 60% [12]. They use a probit model with data from Tulare County, California. In a meta analysis mentioned previously, Esrey et al. (1991) conclude that sanitation facilities, as well as improved water sources, generally reduce morbidity of several enteric infections [9]. They further conclude that sanitation facilities are more important in treating diarrheal disease than water sources. Another meta analysis by Fewtrell et al. (2005) also indicates sanitation interventions improve health outcomes [11]. In contrast, Pradhan & Rawlings (2002) find no impact on health outcomes for *public* investment in sanitations facilities using data from Nicaragua [26]. They used propensity score matching to create control and treatment groups. Nevertheless, it appears well established that improvement of sanitation facilities leads to better health outcomes in most circumstances.

Sanitation Access & Child Health

Examinations of the impacts of sanitation on children often specifically focus on child mortality as a consequence of enteric infection. Sanitation facilities are further linked with reductions in child mortality rates. Aly & Grabowski (1990) find that sanitation facilities were relatively more important for child survival than parental education using data from Egypt and probit methods [3]. Watson (2006) uses data from sanitation infrastructure investment on US Indian reservations and county fixed effects to estimate that a 10% increase in homes with a US government funded sanitation improvement led to a decrease in infant mortality by 0.5 per 1000 [35]. In an analysis of 31 Sub-Saharan African countries, Shandra, Shandra & London (2011) find sanitation improvements decrease child mortality after controlling for year and country fixed effects [30]. Günther & Fink (2013) find similar results in 40 countries using logistic regression on the probability of a child dying [13].

Other studies link sanitation to non-fatal health outcomes. Begum, Ahmed & Sen (2011) show with propensity score matching and data from Bangladesh that improved sanitation facilities reduce the incidence of diarrhea in children, but only when paired with water interventions [5]. Adewara & Visser (2011) connect improved sanitation sources, in addition to improved water sources to better child health outcomes, measured in morbity rates for several diseases [1].

How This Thesis Contributes to the Literature

In addition to this study's value to the EWB-MSU organization, it is valuable as a member of a very small set of studies that examines the impact of water and sanitation interventions specifically at primary schools. This researcher is aware of only one other similar study. Adukia (2013) investigates the impact of government implemented sanitation facilities at Indian schools. She finds that these projects increase enrollment using difference in differences [2]. Further, the effect is not significantly different for boys than it is for girls, except pubescent girls, who require a sex-specific sanitation facility to see increases in enrollment. EWB-MSU's program is an opportunity for further research on the impacts of water and sanitation access and safety at primary schools. This thesis will test for the health effects observed elsewhere of both types of interventions. It may go further than Adukia's study by measuring the effect of these projects on academic performance as well as enrollment. This thesis will also test for time-use impacts from water access interventions at primary schools but it is unable to distinguish what saved-time is used for, as other studies have done.

DATA

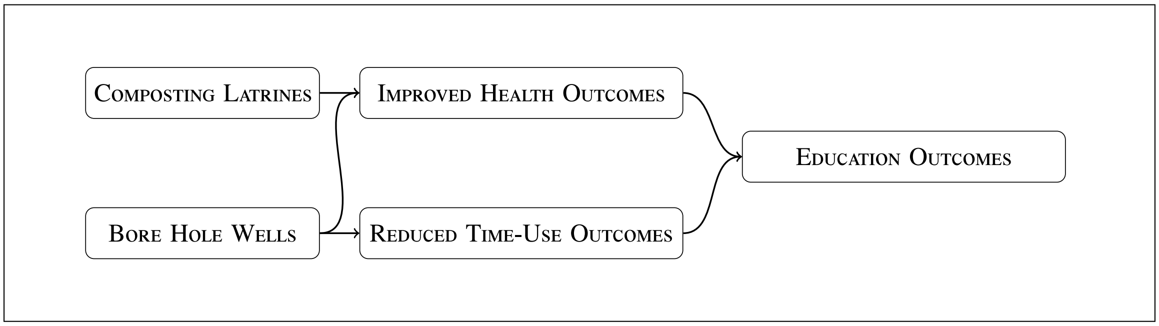
The data described here were collected in Khwisero, Kenya beginning the 16th of June, 2014 and ending the 5th of August, 2014. The data were collected for Engineers Without Borders-Montana State University (EWB-MSU) using the 2014 Impact Evaluation Survey. The survey was developed at MSU by Kirkwood Donavin, Master's candidate in Applied Economics, and undergraduates researchers Jacob Ebersole, Elesia Fasching, Colin Gaiser, Niel Liotta, and Alexander Paterson. These are members of the EWB-MSU Research Team advised by Dr. Sarah Janzen, Assistant Professor of Economics at MSU. The survey was primarily designed to assess the impact of EWB-MSU's water and sanitation projects on health, education and time-use. Additional data were collected from Khwisero government sources that measure school-level outcomes. These data include all Khwisero primary school enrollment from 2004 to 2014 and national exam averages from 2004 to 2013.

Welfare Outcomes of Interest

EWB-MSU projects have many potential impacts. Three welfare outcomes have been selected that are subsequently used to test EWB-MSU's impact with the empirical methods described in the Methodology section. These welfare outcomes include health, education and time-use and were selected because they are both expected outcomes of EWB-MSU projects and readily measurable with cross-sectional data collected in the 2014 household survey.

As is depicted in Figure 1, EWB-MSU projects are each expected to improve health outcomes through the enhancement of the students' drinking water source as well as through provision of improved sanitation facilities. EWB-MSU bore hole wells enhance students' drinking water source by providing deeper, less contaminated drinking water. EWB-MSU composting latrines enhance drinking water by preventing human waste contamination of the ground water through a concrete seal in the base of the

Figure 1: EWB-MSU's Anticipated Welfare Impacts



structure. Additionally, composting latrines are safer than the school's previous sanitation facility, which is further expected to benefit student health. Health outcomes may be observed in decreased individual symptoms of enteric disease, such as diarrhea, vomiting, fever or number of days spent home sick.

In addition to providing clean water access to students at school, another EWB-MSU goal is to provide this access to nearby households. It is expected that some of these households will save time collecting water at an EWB-MSU water project because the project is closer than prior water sources (see Figure 1). Time use outcomes are measured by the amount of time households spend collecting drinking water from their primary source over a five year period.

EWB-MSU is expected to impact primary student education outcomes indirectly through beneficial impacts on health or time-use (see Figure 1). If students are healthier because they use an EWB-MSU composting latrine or bore hole well, they may also be able to attend more days of school and become better educated. Alternatively, if household labor requirements for water collection decrease due to an EWB-MSU water project, then the labor required of students in the household may decrease as well, allowing increased school attendance. Education outcomes may be observed in increased grade point averages, school enrollment or school average performance on national exams, all measured over time.

What Was Collected

This project's target population is primary school children in Khwisero, Kenya. To gather data on these children, households were randomly sampled using parent lists acquired from 16 Khwisero primary schools (see Table 16 in Appendix A). Eight of these schools are tentatively the location of the next eight EWB-MSU projects to be implemented after survey. The remaining eight schools are the location of the eight most recent EWB-MSU projects. Four of these schools received composting latrines and the other four received EWB-MSU water projects, most of which were bore hole wells.[11] The community sample size was chosen with respect to cultural, administrative and monetary limitations. In particular, these communities were selected because it was presumed that the eight most recent EWB-MSU communities would be characteristically similar to the next eight EWB-MSU communities. The EWB-Khwisero Board created the project order by ranking school applications based on need.[12] It is expected that communities that are near each other in need-rank are also characteristically more similar than other schools in Khwisero. If this is true, it mitigates a concern that differences in welfare outcomes are driven by prior differences in community characteristics.

Microsoft Excel's random number generator was used to create a sample of households from each school's parent list. The target sample size for most schools was 48 households. The actual sample size ranged between 47 and 60 households. 60 households were sampled from two schools because of their relatively larger population size (See Table 16 in Appendix A). These samples represented between 16.6% and 32.6% of each school's household population, with a mean of 24.2% of households. Some sampled households were not found during survey. This occurred for 0% to 14.0% of households

[11] One of the four EWB-MSU water projects observed in the household survey is a rain catchment and filtration system rather than a bore hole well. This project, located at Ekatsombero, is similar to a bore hole well in terms of safety and convenience of access. It does have the drawback of relying on rainfall, which can be infrequent during the dry season, but is generally plentiful during the remainder of the year.

[12] The EWB-Khwisero Board is made up of nine leaders from the overall Khwisero community representing the Ministry of Education, the Ministry of Health, and the Ministry of Water, as well as several head teachers from schools in Khwisero.

and usually transpired because children from, or familiar with the household were not located at the primary school being surveyed.

The 2014 Impact Evaluation Survey was administered to consenting sampled households. A comprehensive list of measures collected in this survey that are relevant to this analysis is found in Table 17 in Appendix A. To measure the three primary outcomes of interest, respondents provided information on health & education of household members over time, and information on the household's primary drinking water source over time.[13] First, respondents reported household member health measures, including the likelihood of contracting fever, vomiting, diarrhea, malaria and the likelihood of missing school due to illness, all within that last few months. Unlike the other outcomes of interest, these health outcomes were measured in cross-section rather than in time-series. The health measures are summarized for primary students in Table 1. Second, respondents reported household member education data including household members' grade point averages from 2011 to 2013 and parental education levels. These measures are summarized in Table 2. The household survey data measuring education outcomes are supplemented by school-level data on enrollment numbers from 2004 to 2014 and mean Grade 8 Kenya Certificate of Primary Education (KCPE) national examination scores from all 61 schools in Khwisero between 2004 and 2013 (Table 2).[14] Third, respondents reported the household's drinking water source history from 2010 to 2014, including information on water source type, distance and treatment status of the water. These measures are summarized in Table 3. Primary water sources and time-use measurements were collected for the wet and dry seasons separately. This was done because households often switch water sources between rain and alternate sources between the two seasons.[15]

[13]Health measures were recored as totals from the past three months, rather than for multiple points of time like retrospective measures of academic performance and water source. The Research Team decided to measure health only in the current time period because the group speculated that, in general, household respondents would not precisely recall health information for household members from years past.

[14]This community-level data were supplied by the EWB-Khwisero Board representatives for the Kenyan Ministry of Education, Mr. Caleb Musa, and Kenyan Ministry of Health, Mr. Johnstone Aseka.

[15]The correlation coefficient for households between usage of "good" water sources in the wet and the dry seasons is 0.80. This provides evidence that some households are switching water sources between the wet

The Research Team used the survey to collected additional data on parental education (Table 2), orphan rates (Table 8), household wealth measures (Tables 4 & 5), measures of population density (Table 6), household water treatment frequency (Table 3) and household sanitation facilities (Table 7). It is not expected that EWB schools affect this set of outcomes. Thus, these outcomes may be used to determine whether the eight communities without EWB-MSU projects are a proper counterfactual for the eight communities that have received projects.

Data Summary

Throughout this section, summarized data are separated into two groups and the statistical difference between the means is calculated. These groups are labeled the "EWB group" with EWB-MSU projects, and the "non-EWB group" without projects but tentatively scheduled to receive one of the next eight EWB-MSU projects. Further, each group contains observations from one of three levels. First, the individual-level EWB-MSU group label refers to primary school students who are attending an EWB-MSU project school. The comparable individual-level non-EWB group consists of students attending a primary school *without* an EWB-MSU project. Second, the household-level EWB group label refers to those households that have a child in attendance at a primary school with an EWB-MSU project. The comparable household-level non-EWB group label refers to those households with children in primary school but only at those schools *without* EWB-MSU projects. Third, the school-level EWB group label refers to primary schools that have received EWB-MSU projects while the comparable non-EWB group label refers to primary schools that have not.

The purpose of comparing the EWB and non-EWB group is two-fold. First, comparison of primary student health & education outcomes and household time-use outcomes provides descriptive evidence for or against a relationship between EWB-MSU

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and dry seasons.

and welfare in Khwisero. However, causality in this relationship *cannot* be inferred because characteristic differences between the groups may obscure any effect EWB-MSU truly has on health, education and time-use outcomes. For instance, if a relatively unhealthy community is selected for a project based on need, this community may experience improved health outcomes while also remaining less healthy than other communities after project implementation. Analyzing the differences in means in this case, The EWB group would form a *negative* relationship with health outcomes even though the EWB-MSU project *positively* affected health.

Second, comparing other outcomes that are not expected impacts of EWB-MSU projects constructs an image of how equivalent the groups were prior to project implementation. These outcomes include measures of household wealth, parental education, population density, orphan rates, drinking water treatment behavior and household sanitation facilities. It is argued here that these outcomes are not likely to be affected by EWB-MSU within the time-frame of project implementation to observation (2011 to 2014). Analyzing the differences in these other welfare measures provides evidence for whether or not the non-EWB group is an approximate counterfactual for the EWB group. If observed differences exist, it may be inferred that the groups were characteristically different in welfare outcomes of interest from the beginning. That is because health, education and time-use are likely related to wealth, parental education, population density, and other welfare measures examined here. Such an analysis is important for motivating the use of statistical methodology that controls for potential characteristic differences, layed out in the Methodology section.

Welfare Outcomes

Table 1 reports the likelihood of experiencing disease symptoms by primary student group. Likelihood of experiencing fever, vomiting or diarrhea is not significantly different between groups. Fever is the most likely illness to experience in the three months prior to survey, while diarrhea is the least likely. EWB students are approximately 4%

Table 1: Probability of Suffering Illness Symptoms

	Non-EWB Schools	EWB Schools	Difference
Fever[†]	0.356	0.358	-0.002
	(0.479)	(0.480)	(0.021)
Vomit[†]	0.171	0.188	-0.017
	(0.376)	(0.391)	(0.017)
Diarrhea[†]	0.100	0.113	-0.013
	(0.300)	(0.317)	(0.014)
Malaria[††]	0.553	0.596	-0.043*
	(0.497)	(0.491)	(0.022)
Sick Day[††]	0.216	0.254	-0.038**
	(0.412)	(0.435)	(0.019)
Observations	1076	967	2043

means/differences reported above, standard deviations/errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$
Individual health statistics are for students in primary school only.
[†]The student has experienced at least one episodes of this illness symptom in the previous 3 months.
[††]The student has experienced at least one episode of malaria or at least one sick day from school in the previous month.

more likely to experience malaria and to take at least one sick day in the month prior to survey.

The household survey measured primary student performance using annual final grade point averages for 2011 to 2013. There is no significant difference in grades between groups in 2013 (Table 2). The mean final grade was approximately 300 out of 500. It is assumed that students attending an EWB school in 2014 were also doing so between 2011 and 2013. This is excepting years for which students do not have grades, when it is instead assumed the student was not in school. This assumption may create error in the categorization of students into the EWB and non-EWB groups. For example, one student may have attended a non-EWB school between 2011 and 2013 but transfered to an EWB school in 2014. Conversely, another student may have attended an EWB school between 2011 and 2013 but transfered to a non-EWB school in 2014. Both of these students will be mis-categorized into groups. However, the assumption is unavoidable because the dataset does not contain information regarding where students attended school prior to 2014. There is no reason to believe that this assumption is not true for the vast majority of students.

An alternative performance measure uses annual KCPE exam and enrollment data from all primary schools in Khwisero. Evidence is found that primary schools in Khwisero with EWB-MSU projects perform significantly better on the KCPE exam on average. However, the absolute difference is small, at under 7 out of 500 points in favor of EWB schools. Students must earn at least 150 points to pass this exam and mean scores for both groups are about 100 points above the passing score cut off, indicating the difference does not likely lead to more students passing the test in EWB schools [**hussein˙teenage˙2011**]. However, marginal increases in KCPE exam scores may relate to better secondary school opportunities for students at EWB schools, as secondary schools consider exam scores for student enrollment choices.[16]

For drinking water comparisons across groups, the definition of the "EWB" group is altered to refer *only* to households who have a child in attendance at a primary school with an EWB-MSU *water* project. There is a significant difference in reported water source distance between these alternately defined groups (Table 3).[17] EWB households spend approximately four fewer minutes on average reaching their drinking water source. No significant difference between whether or not households are using "good" water sources is found between groups.[18] Approximately 80% of households in either group are using good sources. As one would expect, only households surrounding schools with EWB-MSU water projects are using a project as their primary water source. They do so at a rate of 3.5% of households in this redefined EWB group. All of these households are

[16]Anecdotal evidence from EWB-MSU's project coordinator, Jackson Nashitsakha, indicates that Class 8 students generally need to score between 200 and 350 on the KCPE exam to attend a county secondary school, and to score above 350 to attend a national secondary school.

[17]Distance to the household primary water source was measured in minutes reported to walk to the source.

[18]"Good" water sources are defined here as protected springs and wells, bore holes, rain water or piped water.

Table 2: Education

	Non-EWB Schools	EWB Schools	Difference
Grades (2013)†	304.9	301.0	3.8
	(90.475)	(86.919)	(4.265)
Fathers < Primary Education††	0.320	0.311	0.009
	(0.467)	(0.463)	(0.024)
Fathers = Primary Education††	0.406	0.473	-0.067***
	(0.491)	(0.500)	(0.026)
Fathers ≥ Secondary Education††	0.273	0.216	0.057**
	(0.446)	(0.412)	(0.022)
Mothers < Primary Education††	0.358	0.402	-0.045*
	(0.480)	(0.491)	(0.023)
Mothers = Primary Education††	0.448	0.468	-0.020
	(0.498)	(0.499)	(0.024)
Mothers ≥ Secondary Education††	0.194	0.130	0.064****
	(0.396)	(0.336)	(0.018)
Observations	1052	948	2000
Enrollment Numbers†††	487.2	518.9	-31.7
	(191.4)	(140.1)	(21.6)
KCPE exam score average†††	253.8	260.3	-6.5*
	(26.5)	(25.5)	(3.4)
Observations	563	85	648

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$
Schools included in "EWB Schools" group in the year a project is implemented and afterwards. means/differences reported above, standard deviations/errors in parentheses
† Grades are out of 500 and from 2013. It is unknown whether the students earned the grades at the school they were observed to be attending in 2014.
††Education level categories are exclusive of other categories. This means, for example, that mothers with a secondary education are not counted with those mothers with a primary education, even though the former group are also required to complete primary school.
†††Calculated with data on all Khwisero primary schools from 2004 to 2013 (2014 for enrollment numbers only). Kenya Certificate of Primary Education (KCPE) exam scores are out of 500 and awarded for a national examination given to Class 8 students.

found to be surrounding Mundaha Primary School, which is only one of the four schools with EWB-MSU water projects in the household survey.

Table 3: Drinking Water

	Wet Season			Dry Season		
Household Group	Non-EWB	EWB	Diff.	Non-EWB	EWB	Diff.
Dist. to Primary Water Source (min.)	16.0	12.2	3.8***	17.0	12.9	4.1****
	(15.5)	(12.6)	(1.2)	(13.8)	(11.9)	(1.1)
Treat Water †	0.583	0.678	-0.095**	0.583	0.678	-0.095**
	(0.493)	(0.468)	(0.040)	(0.493)	(0.468)	(0.040)
Treat Water in House††	0.403	0.467	-0.065	0.403	0.467	-0.065
	(0.491)	(0.500)	(0.041)	(0.491)	(0.500)	(0.041)
Good Water Source†††	0.834	0.869	-0.035	0.768	0.799	-0.031
	(0.372)	(0.338)	(0.030)	(0.423)	(0.402)	(0.034)
Spring (protected)	0.418	0.347	0.072*	0.503	0.447	0.056
	(0.494)	(0.477)	(0.040)	(0.500)	(0.498)	(0.041)
Spring (unprotected)	0.043	0.030	0.013	0.064	0.035	0.029
	(0.204)	(0.171)	(0.016)	(0.245)	(0.185)	(0.019)
Rain	0.217	0.246	-0.029	0.002	0.010	-0.008
	(0.413)	(0.432)	(0.034)	(0.042)	(0.100)	(0.005)
Public Tap	0.099	0.090	0.009	0.156	0.136	0.021
	(0.299)	(0.288)	(0.024)	(0.363)	(0.343)	(0.029)
Household Pipe	0.023	0.090	-0.068****	0.026	0.095	-0.069****
	(0.149)	(0.288)	(0.016)	(0.159)	(0.295)	(0.017)
River/Stream	0.106	0.090	0.015	0.148	0.151	-0.003
	(0.308)	(0.288)	(0.025)	(0.355)	(0.359)	(0.029)
Well (protected)	0.064	0.045	0.019	0.068	0.055	0.012
	(0.245)	(0.208)	(0.019)	(0.251)	(0.229)	(0.020)
Well (unprotected)	0.012	0.010	0.002	0.017	0.015	0.002
	(0.110)	(0.100)	(0.009)	(0.131)	(0.122)	(0.011)
Bore Hole Well	0.012	0.015	-0.003	0.012	0.020	-0.008
	(0.110)	(0.122)	(0.009)	(0.110)	(0.141)	(0.010)
EWB Bore Hole	0.000	0.035	-0.035****	0.000	0.035	-0.035****
	(0.000)	(0.185)	(0.008)	(0.000)	(0.185)	(0.008)
Lake/Pond	0.003	0.000	0.003	0.002	0.000	0.002
	(0.059)	(0.000)	(0.004)	(0.042)	(0.000)	(0.003)
Observations	576	199	775	576	199	775

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

The EWB group is restricted here to households surrounding EWB schools with *water* projects, only. This is done to specifically examine the relationship between EWB-MSU water projects and household water use. Means/differences reported above, standard deviations/errors in parentheses

†indicates the household *always* treats drinking water in house *or* the drinking water is treated at the source.

††indicates the household *always* treats drinking water in house.

†††"Good" indicates the source is piped, a protected ground source (including bore hole wells) or rain water and excludes any surface or unprotected source.

Other Variables of Interest

The following summarized outcomes are not expected to be impacted by EWB-MSU projects but are likely related to the outcomes of interest: health, education and time-use. As mentioned above, evaluating differences between groups in these dimensions provides evidence regarding whether the non-EWB group is an approximate counterfactual for the EWB group.

Household wealth is measured in various ways in Table 4, including a household asset score, a house construction score, household electricity access and reported wealth statistics. Weighted asset scores and house construction scores are created using the first principal component of a matrix of household assets or of house construction material types. They serve as measures of household wealth. Based on this measure, non-EWB households are significantly wealthier in assets (Table 4). On the other hand, the EWB group reports greater annual income. EWB households claim to be approximately 50,000 KSh ($\approx \$1,500$) richer in annual income on average.[19]

There is reason to suspect the asset and building score is a superior measure of wealth relative to reported income. Income is an awkward topics of discussion in Khwisero, as it is elsewhere. Respondents may not answer questions regarding annual income truthfully or carefully. However, such measurement error *does not* explain why reported income favors the EWB group. It is conceivable that households in this group are disparately tempted to exaggerate reported income in order to give the impression that their community has improved in response to receiving an EWB-MSU project. Nevertheless, it may be assumed that reported income data are likely to contain more measurement error than physical asset reports and building scores. Thus, the principal component scores may be the best indicator of real household wealth. These wealth measures provide evidence that EWB households are poorer on average relative to the

[19]Kenyan Shilling (KES) to US Dollar (USD) conversions based on PPP-adjusted exchange rate of 34 KES/1 USD. This rate was obtained using an approximate nominal exchange rate of 85 KES/1 USD from the summer of 2014, multiplied by the 2014 Price level ratio of PPP conversion factor (GDP) to market exchange rate of 0.4 from the World Bank [25].

Table 4: Household Wealth

	Non-EWB school	EWB school	Diff.
Asset Score†	0.298	-0.286	0.584****
	(2.661)	(2.127)	(0.174)
House Construction Score†	0.381	-0.370	0.752****
	(2.068)	(1.505)	(0.131)
Electricity Access	0.051	0.052	-0.002
	(0.220)	(0.223)	(0.016)
Present Income (KES)††	62455.35	115009.92	-52554.57**
	(95056.44)	(491426.08)	(25571.54)
Present Income (USD)††	1836.92	3382.64	-1545.72**
	(2795.78)	(14453.71)	(752.10)
Observations	384	391	775

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$
Income and assets are self reported and subject to measurement error. Means/differences reported above, standard deviations/errors in parentheses
†Scores calculated with the first principle component of a matrix of assets or primary house construction materials. Assets are numbers of the following: houses, carts, hoes, motorbikes, boats, bicycles, plows, tractors, sewing machines, lanterns or lamps, refrigerators, generators, wheelbarrows, computers, radios, water tanks, video players, chairs, cars, cellphones, sofas, solar panels, beds, cupboards, chest of drawers, dining sets, watches, drums (instrument) and televisions.
††Kenyan Shilling (KES) to US Dollar (USD) conversions based on PPP-adjusted exchange rate of 34 KES/1 USD.

non-EWB group.

Over all households, the most numerously owned assets on average are chairs (6.4), hoes (2.7), houses (2.3), sofas (2.1), and beds (1.9).[20] Households are least likely to own cars, boats, tractors, plows, generators, and computers. Primary house floors are most commonly constructed with earth or clay (nearly 90%)(Table 5). Walls of primary houses are most often built of poles and mud. However, this most common wall construction is significantly more common in EWB households at almost 90% rather than almost 80% for the non-EWB group. Roofs of primary houses are most commonly constructed of corrugated metal sheets. EWB households are significantly more likely to have a metal roof, at over 90% relative to just under 80% for the non-EWB group. Non-EWB

[20]Rate of asset ownership is not reported in a table.

households are significantly more likely to have a tile roof, at about 15% relative to 1.5% for the EWB-group.

A summary of population density measures is found in Table 6. Rather than direct measures of population density, such as the number of individuals per square kilometer, these measures are average distances within groups to a primary school or the nearest clinic. However, assuming the school or clinic used by a set of households is centrally located, average distances are a good proxy measure of population density. This is because, while it measures how far households are likely to be from a population center it also indirectly measures how far households are likely to be from each other.

EWB households report spending significantly *less* time reaching school (~ -4 minutes) and the nearest clinic (~ -10 minutes) compared with the non-EWB group. However, the GPS unit measured distances between households and corresponding schools are not significantly different between groups. Measures of time students spend getting to school and their household distance to that school are both measures of the distance that students need to travel. Thus, it is expected that each measure will tell the same summarized story. The discrepancy in this summary may be related to a disparity between the way in which students travel to school and the way in which GPS coordinate distance is calculated using Euclidean geometry. That is, students may be forced to take round-about paths to school, while coordinate distance calculations ignore possible impassible terrain and find the path "as the crow flies". Putting aside this inconsistency, the EWB group appears to be in more densely populated areas relative to the non-EWB group. If this is true, relative density may be a partial explanation for shorter trips to water sources observed for the EWB group (see Table 3).

Households in the EWB group (water projects only) are significantly more likely to report to drink water that was either treated at the source *or* treated at home all of the time (Table 3).[21] These households are about 10% more likely to claim this is the case, for

[21] "Treat Water" is a dummy variable that indicates the household *always* treats drinking water in house *or* the drinking water is treated at the source.

Table 5: House Construction Materials

	Non-EWB School	EWB School	Difference
Floors			
Earth or Clay	0.838	0.871	-0.033
	(0.369)	(0.335)	(0.025)
Cement & Sand	0.103	0.126	-0.023
	(0.305)	(0.332)	(0.023)
Walls			
Mud & Poles	0.706	0.876	-0.170****
	(0.456)	(0.330)	(0.029)
Baked Bricks	0.034	0.062	-0.028*
	(0.181)	(0.242)	(0.015)
Cement Blocks	0.052	0.047	0.005
	(0.222)	(0.211)	(0.016)
Sheet Metal	0.193	0.010	0.182****
	(0.395)	(0.101)	(0.021)
Lime & Stone	0.013	0.000	0.013**
	(0.114)	(0.000)	(0.006)
Thatch	0.003	0.003	0.000
	(0.051)	(0.051)	(0.004)
Wood	0.000	0.003	-0.003
	(0.000)	(0.051)	(0.003)
Roofs			
Corrugated Metal Sheets	0.727	0.936	-0.208****
	(0.446)	(0.246)	(0.026)
Thatch Grass or Palm	0.056	0.049	0.007
	(0.231)	(0.216)	(0.016)
Mud & Straw	0.008	0.000	0.008*
	(0.089)	(0.000)	(0.005)
Tiles	0.201	0.013	0.188****
	(0.401)	(0.113)	(0.021)
Observations	384	389	773

means/differences reported above, standard deviations/errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

Table 6: Population Density

	Non-EWB Schools	EWB Schools	Difference
Time to School (min.)†	23.21	19.27	3.935****
	(22.01)	(12.12)	(0.799)
Observations	1066	966	2032
Distance to Sample School (km)††	1.201	1.034	0.167
	(2.403)	(1.237)	(0.140)
Time to Nearest Clinic (min.)††	39.54	29.17	10.37****
	(23.52)	(19.89)	(1.573)
Observations	390	380	770

means/differences reported above, standard deviations/errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$
†Distance to school is reported at the individual-level for primary students.
††Kilometers to sampled school and time in minutes to the nearest clinic are reported for households.

an overall rate of almost 70%. However, this significant difference disappears when exclusively comparing households that treat their water at home.[22] Approximately 40% of households report always treating their own drinking water. Chlorination is the most common method of treatment in the household while Waterguard is the least common method.[23][24] Curiously, households in the EWB group are over 6% more likely to have household piped water access with an overall rate of almost 10%.

No significant difference between household sanitation facility usage is found between groups (Table 7). Covered pit latrines are the most common household sanitation facility in Khwisero at approximately 90%. Interestingly, three households reported primarily using EWB-MSU composting latrines but none reported doing so from the non-EWB group.

Mothers and fathers of primary students are significantly less educated in EWB

[22]"Treat Water in Household" is a dummy variable that indicates the household *always* treats drinking water in house.

[23]Treatment methods are not shown in any tables.

[24]Water Guard is a company that offers many chemical drinking water treatment methods including Ammonium Hydroxide, Calcium Hypochlorite and Potassium Permanganate. The type used in Khwisero was not specified.

Table 7: Household Sanitation Facilities

	Non-EWB School	EWB School	Difference
Good Facility†	0.063	0.072	-0.010
	(0.242)	(0.259)	(0.018)
Uncovered Latrine	0.029	0.033	-0.005
	(0.167)	(0.180)	(0.012)
Covered Latrine	0.906	0.875	0.032
	(0.292)	(0.332)	(0.022)
Improved Latrine	0.060	0.061	-0.001
	(0.238)	(0.240)	(0.017)
EWB Composting Latrine	0.000	0.008	-0.008*
	(0.000)	(0.087)	(0.004)
Flush Toilet	0.003	0.003	0.000
	(0.051)	(0.051)	(0.004)
No Facility	0.003	0.010	-0.008
	(0.051)	(0.101)	(0.006)
Observations	384	391	775

means/differences reported above, standard deviations/errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$
†"Good" Facility is a dummy variable that indicates the household uses an improved latrine (covered latrine with a vent, sometimes with a screen to catch flies), EWB-MSU latrine or flush toilet.

households (Table 2). Non-EWB households parents are approximately 6% more likely to have a secondary education. Orphans make up almost 5% of children in Khwisero (Table 8). If "orphan" is defined as having no more than one living biological parent, then the overall rate is a bit over 14% of children. Orphan rates not significantly different between groups.

Summary

This section investigates the relationship between EWB groups and the three welfare outcomes of interest: health, education and time use. First, EWB primary students do not suffer greater incidence of diarrhea, vomiting or fever relative to non-EWB primary

Table 8: Orphan Rates

Orphan Rate (1 parent)†	0.163	0.140	0.023
	(0.369)	(0.347)	(0.016)
Orphan Rate (2 parents)†	0.050	0.044	0.006
	(0.218)	(0.205)	(0.010)
Observations	1044	936	1980

means/differences reported above, standard deviations/errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

†"parent(s)" refers to biological parents and excludes adoptive or de facto parents for minors (< 18 years). The "1-parent" rate refers to minors who have at least one deceased parent. The "2-parent" rate refers to the minors with two deceased parents.

students. However, students in the EWB group are *more* likely to experience malaria or to take a sick day from school. Second, the relationship between the EWB group and education is similarly mixed. Grade point averages for 2013 are not different between primary student groups. However, KCPE exam scores are six points higher at EWB schools, on average, relative to non-EWB schools. Third, Household time-use outcomes are significantly better in communities with EWB-MSU well projects. On average, households in the EWB group spend four fewer minutes collecting water than the non-EWB group.

The differences that exist in the welfare outcomes of interest are *not* necessarily caused by EWB-MSU projects. Instead, the differences may partially or completely be caused by other differences in characteristics between the groups. For instance, it is unlikely that EWB-MSU projects are causing greater incidence of malaria contraction or increasing the likelihood that students become too sick to attend school. Rather this observed difference provides evidence that the EWB group was likely less healthy than the non-EWB group from the beginning. If the EWB group is characteristically worse-off relative to the non-EWB group, then these summarizations of the welfare outcomes of interest may under estimate the relationship between EWB-MSU and welfare outcomes.

Thus, the true impacts of the projects are likely entangled with other factors.

This section also investigates the relationship between the EWB group and other outcomes not expected to be impacted by EWB-MSU. Although the EWB and non-EWB groups are similar to one another regarding some characteristics, they differ in other notable characteristics. Each group is generally equivalent in primary household construction materials, sanitation facilities and orphan rates. However, households in the non-EWB group appear wealthier and to have better educated parents. Households in the EWB group appear to be located in more densely populated areas and have significantly greater access to piped water in household compounds. This final descriptive difference in piped water access suggests that EWB-MSU's relationship with shorter water trips is partially explained by a higher rate of piped water access within the EWB group.

The descriptive evidence does suggest that EWB-MSU is successfully prioritizing less well-off schools for project construction. It also suggests that the non-EWB group is *not* a good approximation of the EWB group's counterfactual. That is, had an EWB-MSU project not been constructed, EWB primary school students and their households might have already experienced *worse* outcomes in health, education and time-use relative to the non-EWB group. This conclusion illustrates the importance of utilizing empirical methods that control for selection bias. These are detailed in the following section.

EMPIRICAL METHODOLOGY

To test the welfare impact of Engineers Without Borders' water and sanitation projects, schools that have received projects are to be compared with schools that have not in order to examine the differences in welfare outcomes. However, EWB-MSU's projects are not randomized control trials, nor is the project treatment restricted to a single set of individuals, for the EWB and non-EWB groups may change over time. These facts give rise to two identification concerns.

First, as shown in the previous section, EWB communities are characteristically distinct from non-EWB communities. On the one hand, the non-EWB group appears to be wealthier and have better educated parents. These differences likely lead to worse welfare outcomes that conflict with the potential positive impact of EWB-MSU projects. Thus, these characteristics may understate the organization's relationship with welfare. On the other hand, EWB communities appear more densely populated and to have greater access to piped water.[25] These characteristic differences may overstate the organization's impact by positively affecting welfare outcomes simultaneously with EWB-MSU projects.

Second, an additional threat to identification is the possibility that households with certain characteristics may be more likely to send their children to an EWB school in order to have access to a project. Of these characteristics, only some may be observed, such as wealth and parental education. However, other characteristics may not be observed in these data. Positive welfare outcomes related to EWB-MSU may partially be explained by these households changing the characteristic composition of the EWB group over time. This may overstate the relationship between EWB-MSU projects and welfare outcomes, as projects are expected to simultaneously improve welfare outcomes. Anecdotal evidence from EWB-MSU's project coordinator, Jackson Nashitsakha,

[25] When using the aggregated school data, characteristic differences may be even greater, as the 21 schools with EWB-MSU projects are compared with more than 40 other primary schools around Khwisero. This is because many of these other schools are not being considered for future projects, as are schools in the survey categorized in the non-EWB group. Thus, these schools presumably experience even better welfare outcomes than both EWB schools *and* non-EWB schools.

suggests student's *do not* transfer to EWB schools in response to project implementation. However, the possibility of such individual-level endogeneity will motivate the use of empirical methods to safe-guard against it.

In order to identify EWB-MSU's impact on welfare outcomes, the two forms of selection bias presented here need to be controlled. The following is an elaboration of the empirical methodology designed to do so. In the subsequent results section, these strategies are used to estimate the impact of EWB-MSU projects on welfare outcomes.

Method (1): Ordinary Least Squares

Let all individual or household characteristics that determines EWB-MSU project placement, as well as one's attendance at an EWB school, be known and observed. If these characteristics are held constant, then any remaining variation in attendance at an EWB school, EWB_i, is random and the variable is said to be conditionally independent of the outcome of interest, y_i. Ordinary least squares analysis relies on the conditional independence assumption (CIA) in order to interpret the coefficient, δ, as the causal effect of EWB_i on y_i. This method is mathematically represented in Equation (1). The EWB_i dummy variable indicates either that primary student *i* is attending an EWB school or that household *i* was selected from an EWB school parent list. All relevant characteristics that allow the CIA are contained in the conditioning set $\mathbf{x_i}$. If the CIA holds, then selection bias at the community or household-level is controlled because any information that leads to this bias is held constant in the $\mathbf{x_i}$ set.

$$y_i = \alpha + \delta EWB_i + \mathbf{x_i} \cdot \boldsymbol{\beta} + \varepsilon_i \qquad (1)$$

In practice, the estimate of EWB-MSU's impact, $\hat{\delta}$, may be biased if relevant characteristics for the CIA are omitted from $\mathbf{x_i}$. Let the set $\mathbf{x_i}$ for each *i* be stacked into matrix $\mathbf{X}$, and let there exist another unobserved or unknown set of individual and household characteristics, **W**, such that the correlation between **X** and **W** is non-zero *and* the correlation between **W** and y_i is non-zero. In this case, omitted variable bias exists in the estimate $\hat{\delta}$ because it identifies variation in both EWB_i and **W** that affects y_i.

The conditioning matrix, **X**, varies by model. For household-level models, characteristics measured in **X** include a household asset score, house construction score, the head's education-level, the household's water and sanitation source quality and whether the household treats its water. For individual-level models, the control variable matrix includes those previously mentioned with the addition of age, gender, orphan status and parental education-level and excluding household head's education level. Each of these control variables is included because they are expected to explain variation in welfare outcomes, and many are additionally related to EWB-MSU project placement and EWB school attendance.

Method (2): Fixed Effect

In addition to the observed control variables, there may exist other *unobserved* characteristics that relate to EWB-MSU project placement, EWB school attendance and welfare outcomes. For example, Typhoid virus may be common in a community that EWB-MSU selects for project placement. The prevalence of the virus in that community will independently affect health outcomes. However, given that Typhoid is unobserved as well as related to EWB-MSU project placement, its omission from a model explaining health outcomes will bias the estimated impact of the organization.

The set of characteristics held by individual *i* has a *fixed effect* on the outcome of interest $y_{i,t}$ across time, t.[26] That is, *i*'s characteristics, be they observed or otherwise, have an average effect on $y_{i,t}$ that is constant in time. These individual fixed effects may also correlate with EWB-MSU project placement or EWB school attendance. Without controlling for *i*'s fixed effect, ρ_i, some unobserved portion of this variation may be

[26] For convenience, the discussion prototype for Method (2) will be an individual-level model. However, in practice, Method (2) will be applied to individual, household and school-level data.

inappropriately captured in δ, the effect of EWB-MSU on $y_{i,t}$. However, including individual fixed effects in the regression will remove selection bias in the estimate of δ that is caused by these time-invariant characteristics. This fixed effect estimation strategy is represented mathematically in Equation (2).

$$y_{i,t} = \alpha + \delta EWB_{i,t} + \tau_t + \rho_i + \varepsilon_{i,t} \tag{2}$$

Time-series data are required in order to observe i's fixed effect on the outcome of interest across time. However, there may additionally be an effect of each year t on $y_{i,t}$ that is constant across individuals. For instance, increasing wealth over time is expected to improve welfare outcomes for both EWB and non-EWB students in Khwisero. Including a time fixed effect, τ_t, removes variation in the outcome of interest explained by any such factors that are constant across individuals in year t.

In Equation 2, the variable $EWB_{i,t}$ is a treatment dummy indicating i has access to an EWB-MSU project. In the individual-level models, $EWB_{i,t}$ indicates individual i is attending a primary school that received an EWB-MSU project in year t or prior. In the household-level models, $EWB_{i,t}$ indicates that household i was selected from a school that has received an EWB-MSU project in year t or prior. In the school-level models, $EWB_{i,t}$ indicates that school i has received an EWB-MSU project in year t or prior.

The coefficient δ is the average effect of access to an EWB-MSU project on outcome $y_{i,t}$. If $y_{i,t}$ measures a desirable outcome, such as average grade points, then the estimate of EWB-MSU impact, $\hat{\delta}$, is expected to be positive. Accordingly, if the outcome of interest measures undesirable outcomes, then the estimated effect is expected to be negative. Time is expected to relate positively to welfare outcomes because of wealth growth.[27] The magnitude and sign of each individual fixed effect estimate, ρ_i will depend on the i^{th} individual's time-invariant characteristics.

[27] Kenya has experience between 4-9% annual GDP growth between 2010 to 2013 [37].

EWB and non-EWB group specific time trends in the outcomes of interest are a further identification concern for estimating EWB-MSU's impact with individual fixed effects. Neither the estimated individual fixed effects or year fixed effects control for variation in $y_{i,t}$ explained by disparate time trends, because the former is constant across t and the later is constant across i. If these trends are identical, $\hat{\delta}$ is an estimate of the variation in $y_{i,t}$ explained *exclusively* by EWB-MSU projects. However, if the trends are not identical across time, the difference will be picked up in the estimated effect of EWB-MSU because of the trends dependence on the $EWB_{i,t}$ dummy. Hence, $\hat{\delta}$ will be biased.

The dataset used in this analysis provides limited time-series data for use with the fixed effect methodology. The analysis will utilize retrospective measures of welfare outcomes and school-level time-series data. Unfortunately, other covariates related to the outcomes of interest, $y_{i,t}$, do not exist in this dataset prior to the Summer of 2014. Thus, any other covariates otherwise used as control variables may not be used in Method (2). Some of these covariates may measure time-*variant* characteristics that are related to $y_{i,t}$. Such variation over time may be the cause of unequal time trends between the EWB and non-EWB group, leading to a biased estimate of δ. However, if it is assumed that all characteristics relevant to explaining welfare outcomes have a time-*invariant* effect on welfare outcomes, then the set's covariation with $y_{i,t}$ is completely captured by the coefficient, ρ_i.

Method (3): Instrumental Variables

As previously indicated, there may remain other characteristics of EWB schools and households with children who attend those schools that are not observed in the dataset. These unobserved characteristics may be correlated with welfare outcomes as well as the likelihood of receiving an EWB-MSU project or the likelihood of sending children to primary schools with EWB-MSU projects. Another approach utilizes distance from the nearest EWB school, $Dist_{i,j}$, as an instrument to control for individual i's decision to attend an EWB school in community j, $EWB_{i,j}$. This two stage model is represented mathematically in Equations (3.1) & (3.2).

First-Stage Regression:

$$\begin{aligned} EWB_i &= \pi_0 + \pi_1 Dist_{i,j} + \mathbf{x_{i,j}} \cdot \boldsymbol{\gamma} + \eta_j + u_{i,j} \\ \widehat{EWB}_i &= \hat{\pi}_0 + \hat{\pi}_1 Dist_{i,j} + \mathbf{x_{i,j}} \cdot \hat{\boldsymbol{\gamma}} + \hat{\eta}_j \end{aligned} \tag{3.1}$$

Second-Stage Regression:

$$y_{i,j} = \alpha + \delta \widehat{EWB}_{i,j} + \mathbf{x_{i,j}} \cdot \boldsymbol{\beta} + \zeta_j + \varepsilon_{i,j} \tag{3.2}$$

Distance from the nearest EWB school is a relevant instrument if it is correlated with attendance at an EWB school. The instrument, $Dist_{i,j}$ is validly excludable from the model explaining the outcome of interest if it is unrelated to $y_{i,j}$, conditional on EWB school attendance. Given that both relevance and valid excludability hold true, selection bias of the individual's attendance decision is eliminated. However, $Dist_{i,j}$ is not expected to be relevant in EWB-MSU project placement. That is, EWB-MSU likely does not place projects based on population density of households around the school. Thus, a community dummy, ζ_j, is included to capture variation in $y_{i,j}$ explained by other community characteristics that are not already explained by the observed characteristics in the conditioning set, $\mathbf{x_{i,j}}$. If community effects and instrumenting with $Dist_{i,j}$ control for community and individual endogeneity present in $EWB_{i,j}$, $\hat{\delta}$ may be interpreted as an estimate of the causal impact of EWB-MSU on the welfare outcome of interest.

The valid excludability assumption is false if a relationship exists between the instrument, $Dist_{i,j}$ and welfare outcomes, conditional on $EWB_{i,j}$. Two threats to this assumption are presented here. First, households may change locations in order to be closer to an EWB-MSU project. A household that does so plausibly demonstrates characteristics that consequently connect distance to the EWB school with welfare outcomes, conditional on access to an EWB-MSU project. Second, EWB schools may be located in population centers where wealth and other resources are concentrated. In this case, households that are farther from EWB schools and populations centers may also tend to have characteristics that affect the welfare outcome of interest. If this is the case, distance to an EWB school is related to welfare outcomes independent of EWB school attendance.

Other Threats to Identification of EWB-MSU's Impact

The methodology section has detailed how community and individual selection bias in the estimated effect of EWB project access may be controlled. However, other threats to identification of EWB-MSU's impact may not. These include measurement error that reduces the precision of the estimated impact, lack of statistical power due to small sample size and disparate time trends between groups that is unobserved in the data.

Measurement Error

Measurement error likely exists in the welfare outcomes of interest including disease symptoms, average grade points and distance to primary drinking water sources. This is because these measures were reported by household respondents who may not precisely relate such information to the survey enumerators. Let $y_{i,t}^{*}$ be the actual welfare outcome and $y_{i,t}$ be the observed outcome with measurement error.

$$y_i^* = \alpha + \delta EWB_i + \varepsilon_i$$

$$y_i = \alpha + \delta EWB_i + \varepsilon_i + u_i$$

Where

$$u_i = y_i - y_i^*$$

If respondents are randomly reporting error, then the precision of the OLS estimator decreases as u_i increases the estimated standard error of the error term, $\hat{\sigma}_\varepsilon = \sigma_\varepsilon + \sigma_u$. This may occur if respondents do not remember the disease symptoms of family members accurately, if a student's report cards are unavailable or if they have forgotten exactly how much time household members spent traveling to their primary water source for years past. If all household respondents, independent of EWB group, bias the welfare measures upward or downward, then the estimated intercept term, $\hat{\alpha} = \alpha + u_i$, will be bigger or smaller than the population intercept parameter, α, respectively. This may occur if respondents underestimate disease symptoms because of a lack of communication between household members, or if respondents inflate grades when report cards are unavailable because they want to impress the enumerator.[28] In either of these cases, the estimate of δ will remain unbiased because u_i is independent of EWB_i.

If the measurement error is "non-classical" because it is related to EWB-MSU project implementation then the estimated impact, $\hat{\delta}$, becomes biased relative to the true population parameter, δ.[29] It is plausible that respondents in EWB communities may report better welfare outcomes than they actually experience in order to give an

[28]Enumerators were asked to collect grades from report cards, when possible; or from respondent memory, when report cards were unavailable. It is not known how often report cards were used to record grades versus the latter method.

[29]That is, $\text{Cov}(u_{i,t}, EWB_{i,t}) \neq 0$.

impression that EWB-MSU projects are working. In this case, the estimate $\hat{\delta}$ will be biased upwards. Alternatively, respondents may report worse outcomes than truly experienced in hopes of receiving another project. In this case, $\hat{\delta}$ will instead be biased downward.[30] Ultimately, whether these data contain biased measurement error is unknowable. The potential implications of measurement error in the outcome measures is considered throughout the subsequent empirical results.

Measurement error is unlikely to be an issue in the explanatory variable of interest, EWB_i. Instead, it seems likely that household respondents will know which members are attending which schools and if those schools have an EWB-MSU project. Further, there is no reason to suspect respondents might claim a household member is not a student at an EWB school when they truly are, and vice versa. However, measurement error may exist in i's reported distance to the nearest EWB school, $Dist_i$. This variable is used as an instrument for attendance at an EWB school. Respondents from the EWB group may report distance to EWB schools with greater accuracy than non-EWB group households leading to variance of the error term that is related to the explanatory variable of interest. This heteroskedasticity of the error term will lead generally to over-estimated standard errors for EWB-group households and increase the likelihood of a false negative test. Whites heteroskedasticity-consistent standard errors are used in these models as a safe-guard to this potential issue.

Statistical Power & Group-Specific Time Trends

Lacking statistical power and group specific time trends are further threats to identification of EWB-MSU's impact. Even if EWB-MSU has an impact on welfare outcomes, the likelihood of detecting such impact may be low due to the sample size. Further, the effect of group specific time trends is not addressed with the methodology. Such disparate trends may correlate with group designation while simultaneously affecting

[30]The the bias will make estimate $\hat{\delta}$ inconsistent. Mathematically, for all $\gamma > 0$ and n observations sampled from this population, as $n \to \infty$ the functional estimate $\delta(n)$ does not consistently estimate the population parameter δ. That is, $\lim_{n\to\infty} \mathrm{P}\left[|\delta(n) - \delta^{*}| > \gamma\right] \neq 0$

the rate of change in welfare outcomes. Thus, without controlling for the potential differences in time trends, the estimated impact of EWB-MSU projects may be biased.

RESULTS

The structure of the data that measure the three outcomes of interest determines which Methods, (1), (2) or (3), from the previous section are used to test EWB-MSU's impact. First, EWB-MSU's relationship with several health outcomes is estimated with ordinary least squares (OLS) and instrumental variables, Methods (1) & (3). These methods are selected because health measures were collected for a single point in time and, thus, only non-panel data OLS and instrumental variables are appropriate. Health estimates are provided in Table 9. Second, the impact of EWB school attendance on student average grade points is estimated with OLS and individual fixed effects, Methods (1) & (2). Fixed effect methods are selected, in addition to OLS, because education outcomes were collected for multiple points in time. These estimates are provided in Table 14. Further, EWB-MSU's impact on education is tested using *school* fixed effects and school-level measures of KCPE exam performance and enrollment numbers. These estimates are presented in Table 15. Third, the effect of EWB-MSU's water projects on household time spent collecting water is estimated with OLS and household fixed effects, Methods (1) & (2). Fixed effect methods are also appropriate for this analysis because time-use measures were collected for multiple points in time. These estimates may be found in Table 12.

EWB-MSU's Impact on Health

EWB-MSU's impact on primary student health outcomes is tested using OLS and instrumental variables, Methods (1) & (3). Contrary to expectations, estimates do not provide evidence that EWB-MSU is positively impacting health outcomes. In fact, evidence to support a relationship between reported health outcomes and *any* covariates in the data are difficult to find in these models. Further, R^2 values are exceptionally low in these models. This may partially be explained by measurement error in health outcomes. This error may lead to insignificant relationships with many covariates due to higher standard errors. Alternatively, this may be explained by omitted control variables that explain variation in health outcomes.[31]

Ordinary Least Squares Estimates

Estimates for the impact of EWB-MSU on probability of experiencing illness symptoms using Method (1) are presented in Table 9.[32] Health outcomes are generally unrelated to whether or not a student attends an EWB school. The exception to this is observed in the OLS estimates for malaria morbidity. However, contrary to expectation attending an EWB school has a *positive* relationship with the probability of contracting malaria in the previous year by about 9%.

In this model, the control variable matrix includes age, gender, household asset score and house construction score, parental education level, distance to the nearest clinic, and dummies for "good" household water source, water treatment in house, and "good" household sanitation source. Further, community fixed effects are included that capture other unobserved characteristics that may related to EWB-MSU project placement. Contrary to expectations, none of these controls are consistently found to relate significantly with health outcomes with the exception of age. Age relates negatively with diarrhea, vomiting and malaria, as expected.

Unexpectedly, good water source and the asset score are significantly and *positively* related to one of the disease symptoms. Both are signals of wealth, which should related to decreases in illness. Further, having a good water source should help household members avoid enteric disease. Nevertheless, conditional on control variables, students are almost 2% more likely to experience vomiting in the previous three months per relative point in their household's asset score. Further, students from households with

[31] The notably small R^2 values in the instrumental variables models is further explained by unique calculation of the value for this estimation strategy. In instrumental variables, the total sum of squares (TSS) is allowed to be larger than the sum of squared residuals (RSS), in contrast to estimates in ordinary least squares.

[32] Table 18 in Appendix B also contains OLS and instrumental variables estimates for the relationship between EWB-MSU projects and health. However, the dependent variable in Table 18 is instead the *number* of illness episodes experienced by the individual student in the past three months. The results are effectively equivalent in regards to EWB-MSU's impact on health.

Table 9: EWB-MSU's Impact on Health

	Dependent Variable:									
	Diarrhea		Fever		Vomitting		Malaria†		Sick Day††	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Instrument: Dist. to EWB School	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
EWB (indiv.)	0.019	0.769	0.035	1.011	0.094**	2.237**	0.098	-1.865	0.117**	-0.710
	(0.039)	(0.693)	(0.068)	(1.056)	(0.043)	(1.060)	(0.075)	(1.265)	(0.051)	(1.046)
Age	-0.007***	-0.008**	-0.006	-0.007	-0.015****	-0.018****	-0.017****	-0.013**	-0.002	-0.002
	(0.003)	(0.003)	(0.004)	(0.005)	(0.003)	(0.005)	(0.004)	(0.006)	(0.003)	(0.004)
Girl	-0.010	-0.016	-0.013	-0.033	-0.003	-0.016	-0.009	-0.016	-0.025	-0.033
	(0.017)	(0.019)	(0.027)	(0.029)	(0.021)	(0.032)	(0.027)	(0.035)	(0.024)	(0.026)
Orphan	-0.037	-0.032	-0.229***	-0.281***	-0.102	-0.123	-0.015	0.016	-0.099	-0.122
	(0.050)	(0.064)	(0.084)	(0.094)	(0.071)	(0.129)	(0.111)	(0.162)	(0.093)	(0.102)
Asset Score	-0.000	-0.002	0.004	0.008	0.016***	0.015**	0.013*	0.015*	0.006	0.008
	(0.003)	(0.004)	(0.006)	(0.007)	(0.006)	(0.007)	(0.007)	(0.008)	(0.006)	(0.007)
House Construction Score	0.002	0.003	-0.012	-0.013	-0.025****	-0.021*	-0.012	-0.021*	-0.000	-0.004
	(0.006)	(0.007)	(0.010)	(0.010)	(0.008)	(0.011)	(0.010)	(0.012)	(0.009)	(0.010)
Father Edu. Level	-0.000	0.009	0.001	0.006	-0.011	-0.001	0.008	0.003	-0.005	-0.009
	(0.007)	(0.008)	(0.011)	(0.014)	(0.009)	(0.016)	(0.012)	(0.016)	(0.010)	(0.012)
Mother Edu. Level	0.001	-0.001	0.007	0.006	0.001	0.000	0.017	0.018	-0.012	-0.009
	(0.009)	(0.010)	(0.014)	(0.016)	(0.010)	(0.017)	(0.014)	(0.018)	(0.012)	(0.013)
Dist. to Clinic (min.)	0.000	0.001	-0.001	-0.000	-0.001**	-0.001	0.001	0.000	-0.001	-0.001*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
"Good" Water Source (dry)†††	0.012	0.046*	-0.011	0.055	0.059**	0.120***	-0.021	-0.064	0.096****	0.081*
	(0.020)	(0.027)	(0.034)	(0.047)	(0.026)	(0.045)	(0.034)	(0.053)	(0.027)	(0.042)
Water Treatment	0.009	0.015	0.036	0.014	-0.001	0.007	-0.049	-0.078*	-0.037	-0.066**
	(0.019)	(0.023)	(0.031)	(0.035)	(0.025)	(0.038)	(0.032)	(0.040)	(0.028)	(0.031)
Sanitation Fac.	-0.022	-0.033	-0.098**	-0.106*	-0.064	-0.079	-0.091	-0.104	0.030	0.036
	(0.028)	(0.031)	(0.049)	(0.054)	(0.039)	(0.062)	(0.058)	(0.066)	(0.050)	(0.054)
Constant	0.175***	–	0.560****	–	0.458****	–	0.751****	–	0.350****	–
	(0.065)		(0.092)		(0.071)		(0.091)		(0.082)	
Observations	1295	1211	1295	1211	1295	1211	1295	1211	1295	1211
Adjusted R^2	-0.003	-0.249	0.015	-0.160	0.047	-1.122	0.030	-0.577	0.030	-0.136
Community Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

With the exception of "Sick Day" and "Malaria", the dependent variables are dummies indicating whether the primary student has experienced the illness symptom at least once in the past three months. School fixed effects are not shown. Standard errors are in parentheses.

†"Malaria" indicates the primary student has experienced at least one case of malaria in the past year.

††"Sick Day" indicates the primary student has experienced at least one day off from school due to illness in the past month.

†††"Good" Water Source indicates the household is using a protected spring, protected well, bore hole, rain water or piped water in the dry season. The dry season is specified because households often switch to rain water during the wet season; a "good" source. Using a good source during the dry season might be a better measure of the year round quality of the household's water source.

good drinking water sources are about 7% more likely to take a sick day from school in the previous month conditional on controls.

Instrumental Variable Estimates

Instrumental variables estimates for EWB-MSU's health impact using Method (3) are also provided in Table 9.[32] This method controls for potential endogeneity in the choice to attend an EWB school, and community fixed effects capture other community characteristics that may cause selection bias in project implementation. There remains almost no detectable impact on health outcomes contrary to expectations. The goodness-of-fit statistics are very low, indicating low explanation of variation in health outcomes.

EWB school attendance is instrumented with distance to the nearest EWB school. The first stage regression is reported in Table 10. There are two apparent problems with this instrument. First, the instrument forms a weak relationship with the variable of interest, EWB_i. The F-test for joint significance reports a F-statistic just below the threshold for a *non*-weak instrument.[33] Further, the R^2 value is low in the first-stage, indicating the right-hand-side variables poorly explain variation in EWB school attendance. Each of these statistics indicate that $EWB_{i,j}$ is weakly identified. Second, the distance instrument may not be validly excluded from a model explaining health outcomes. Table 11 provides some evidence that distance to the nearest EWB school is positively related to the mother's education level.[34] Further, distance to the student's primary school (i.e. not necessarily an EWB school) is positively related to wealth measures. In turn, wealth and parental education levels are related to the child's health outcomes. This constitutes evidence that distance is *not* exogenous to models explaining health and, therefore, an invalid instrument for EWB school attendance.

These two problems with distance as an instrument for EWB_i may lead to bias in the estimates for EWB-MSU's impact on health. If the instrument exogeneity condition does not hold then the estimate bias worsens with a weaker relationship between the instrument and the explanatory variables.[35] Bias in the instrumental variable estimator

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[33] An F-statistic for joint significance is generally regarded to identify a weak instrument when below 10. The statistic reported in Table 10 is approximately 9.5.

[34] Evidence is also found that distance to school is negatively related to the father's education level. It is unclear why the relationship between distance and paternal education would be inverse to the corresponding relationship with maternal education.

[35] To see this mathematically, first construct the instrumental variables estimator with matrix notation, $\boldsymbol{\beta}^{IV} = (\mathbf{Z}'\mathbf{X})^{-1}\mathbf{Z}'\mathbf{y}$, where $\mathbf{Z}$ is the explanatory variable matrix from the first stage regression. Assuming $\mathrm{E}[\mathbf{Z}'\varepsilon] \neq 0$, the expected value of the estimator, $\mathrm{E}\left[\boldsymbol{\beta}^{IV}\right] = \boldsymbol{\beta} + \mathrm{E}\left[(\mathbf{Z}'\mathbf{X})^{-1}\mathbf{Z}'\varepsilon\right]$, becomes increasingly biased as $\mathrm{Cov}(\mathbf{Z}'\mathbf{X}) \to 0$.

Table 10: First Stage Regression for Instrumented Health Impact Models

	Dependent Variable: (1) EWB (indiv.)
Dist. to Nearest EWB School (min.)	-0.001***
	(0.000)
Age	0.002
	(0.002)
Girl	0.002
	(0.011)
Orphan	0.013
	(0.048)
Asset Score	0.000
	(0.002)
House Construction Score	-0.002
	(0.004)
Father's Education Level	-0.005
	(0.006)
Mother's Education Level	0.001
	(0.006)
Distance to Clinic (min.)	0.000
	(0.000)
Water Source (dry)	-0.033***
	(0.010)
Water Treatment	-0.005
	(0.012)
Sanitation Facility	0.003
	(0.022)
Observations	1211
Adjusted R^2	-0.012
F-Stat	9.44
Community Fixed Effects	Yes

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

may partially explain the lack of significance in instrumented estimates for the impact of EWB-MSU health outcomes.

Table 11: Distance to School's Relationship with Welfare

	Dependent Variable:	
	(1)	(2)
	Dist. to Nearest EWB-School (min.)	Dist. to School (min.)
EWB (indiv.)	-16.28****	-3.318***
	(1.039)	(1.166)
Mother's Education Level	1.770****	2.282****
	(0.485)	(0.542)
Father's Education Level	-0.521	-1.089**
	(0.424)	(0.475)
Assets Score	-0.234	0.514**
	(0.214)	(0.242)
House Construction Score	-1.142****	0.585*
	(0.288)	(0.319)
Constant	32.71****	21.03****
	(1.249)	(1.377)
Observations	1140	1212
Adjusted R^2	0.195	0.035

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

EWB-MSU Impact on Time-Use

EWB-MSU's impact on time-use is tested with ordinary least squares and fixed effects Methods (1) & (2). Each empirical strategy is applied to two models, one for the wet season and one for the dry. The division is made in order to remove variation explained by changing water sources during the wet season, relative to the dry.[36] For these time-use models, the right-hand-side variable of interest, EWB_i, indicates a *water* project has been implemented at a school, at which household i has a student in attendance. This removes from the "treatment" group households that send students to EWB schools with latrines, which are not expected to receive any time-use benefits in water collection.

[36]For a discussion of this variation, see the Outcomes subsection in the Data Description section.

Ordinary Least Squares Estimates

Households selected from parent lists at EWB schools with bore hole well projects spend less time collecting water during the dry season, conditional on wealth and water source type (Table 12). These households spend a little over two and a quarter fewer minutes on travel to primary drinking water sources than the non-EWB group during the dry season. The significance disappears in the wet season which is possibly explained by popular usage of rain water for drinking during that season (see Table 3). Evidence for this is provided in the highly significant and negative relationship between using rain water and time spent collecting water. If households switch to a plentiful and nearby supply of rain water as their primary drinking water source, they may not choose to use an EWB-MSU well.

As expected, wealth is estimated to improve welfare outcomes in this context. The asset score is negatively related to time spent collecting water. However, the evidence is limited to the asset measure. The building material score has a *positive*, significant impact on time spent collecting water. It is not clear why this is the case. As expected, tap water usage relates negatively with time spent collecting water. This is expected for two reasons. First, using a tap water source is a signal of wealth, which is also expected to related negatively with time spent collecting water. Second, taps may tend to be closer to the household compound than other sources.

Fixed Effect Estimates

EWB-MSU's impact on time-use is further tested using fixed effects, Method (2). The estimates are reported in Table 12. After removing variation explained by individual household characteristics, as well as variation explained by time, living in an EWB-MSU water project community is estimated to have a negative and significant impact on the amount of time required for households to reach their primary drinking water source. The significance and magnitude of the impact decreases in the wet season. This is plausibly

Table 12: EWB-MSU's Impact on Time-use – The Intended Treatment Group

	Dependent Variable:					
	(1)	(2)	(3)	(4)	(5)	(6)
	Minutes	Minutes	Minutes	Minutes	Minutes	Minutes
Season	Wet	Wet	Wet	Dry	Dry	Dry
EWB Project†	-2.192*	-0.836*	-0.764*	-3.310***	-1.221***	-0.739*
	(1.233)	(0.426)	(0.419)	(1.197)	(0.414)	(0.395)
Asset Score	-0.516**			-0.585**		
	(0.234)			(0.227)		
House Construction Score	1.124****			0.680**		
	(0.311)			(0.300)		
HH Head's Education Level	-0.190			-0.094		
	(0.364)			(0.353)		
Piped Water in Compound	-15.114****		-22.259****	-11.455****		-19.786****
	(2.690)		(4.263)	(2.441)		(2.962)
Water Src: Public Tap	-2.546		-16.471*	1.471		-11.432**
	(1.819)		(9.620)	(1.439)		(5.629)
Water Src: Rain Water	-14.409****		-16.876****	5.784		
	(1.314)		(3.060)	(7.809)		
2011		-0.001	-0.037		-0.121*	-0.072
		(0.111)	(0.060)		(0.069)	(0.047)
2012		-0.006	0.065		0.003	0.051
		(0.093)	(0.058)		(0.081)	(0.059)
2013		-0.140	-0.110*		-0.193**	-0.080
		(0.121)	(0.066)		(0.096)	(0.052)
2014		-0.227**	-0.073		-0.262***	-0.071
		(0.103)	(0.045)		(0.097)	(0.053)
Constant	20.337****	15.516****	21.609****	17.464****	16.536****	18.791****
	(1.069)	(0.083)	(1.225)	(1.024)	(0.069)	(0.849)
Observations	678	3853	3853	678	3861	3861
Adjusted R^2	0.190	0.013	0.399	0.058	0.032	0.354
Household Fixed Effects	No	Yes	Yes	No	Yes	Yes

The dependent variable, "Minutes", refers to the amount of minutes required to reach a household's primary water source. Least squares estimates only use hauling time data from 2014. Household fixed effects are omitted. Standard errors in parentheses.
†"EWB Project" indicates the household is in a community that has received an EWB-MSU well in the current year or previously.

related to increased rain water usage, as mentioned above. Piped water access has a lot of explanatory power in the time-use impact estimation. After controlling for piped water access, households in EWB-MSU well communities spend approximately 1.5 fewer minutes, round-trip, collecting water in either season.

Table 13 uses the same estimation strategy as before, except the EWB-MSU project variable is replaced with whether or not a household is actually using an EWB-MSU well as their primary water source. There are only seven households in the sample that report doing so, equivalent to 15% of the sample from Mundaha Primary School. Estimates for the impact of EWB-MSU's water projects on those households actually using them agree in sign value with estimates of EWB-MSU's impact on the intended treatment group (Table 12). However, the estimated effect of the treatment on the treated (i.e. households actually using the EWB-MSU wells) is much larger in absolute terms. These households spend between 40 to 60 fewer minutes collecting water in the dry and wet season respectively.

EWB-MSU's Impact on Education

EWB-MSU's impact on education is tested with OLS and fixed effect Methods (1) & (2) using retrospective average grade point measures from 2011 - 2013. Another test of EWB-MSU's impact on education uses Method (2) on enrollment and KCPE exam scores from all Khwisero primary schools. No evidence is found for an impact on education outcomes.

There are at least two explanations for the lack of observed impact on education. First, this analysis hasn't found evidence of an EWB-MSU impact on *health* outcomes. Additionally, time-use impacts are limited to a small number of households. Thus, If EWB-MSU is not meaningfully affecting health and time-use outcomes, and these are the only two vectors through which education improvements are expected, then an EWB-MSU impact on education outcomes clearly cannot be expected. Second, Khwisero

Table 13: EWB-MSU's Impact on Time-use – The Treated Group

	Dependent Variable:					
	(1)	(2)	(3)	(4)	(5)	(6)
	Time	Time	Time	Time	Time	Time
Season	Wet	Wet	Wet	Dry	Dry	Dry
Water Src: EWB Well	-10.292*	-33.388****	-34.849****	-8.778*	-22.801****	-23.662****
	(5.315)	(6.003)	(5.484)	(5.164)	(5.799)	(5.714)
Asset Score	-0.483**			-0.563**		
	(0.235)			(0.229)		
House Construction Score	1.158****			0.738**		
	(0.310)			(0.300)		
HH Head's Education Level	-0.255			-0.167		
	(0.364)			(0.355)		
Piped Water in Compound	-16.030****		-22.972****	-12.616****		-20.347****
	(2.656)		(4.173)	(2.420)		(2.896)
Water Src: Public Tap	-2.730		-20.170***	1.418		-12.970**
	(1.820)		(7.727)	(1.446)		(5.067)
Water Src: Rain Water	-14.682****		-16.798****	4.262		
	(1.315)		(3.060)	(7.822)		
2011		-0.001	-0.040		-0.121*	-0.072
		(0.111)	(0.063)		(0.069)	(0.048)
2012		-0.105	-0.026		-0.141**	-0.032
		(0.084)	(0.043)		(0.070)	(0.049)
2013		-0.137	-0.068		-0.299***	-0.043
		(0.117)	(0.061)		(0.097)	(0.037)
2014		-0.224**	-0.035		-0.368****	-0.033
		(0.102)	(0.038)		(0.104)	(0.041)
Constant	20.138****	15.568****	22.026****	16.928****	16.536****	19.032****
	(1.045)	(0.074)	(1.091)	(0.999)	(0.060)	(0.775)
Observations	678	3853	3853	678	3861	3861
Adjusted R^2	0.190	0.363	0.779	0.051	0.311	0.667
Household Fixed Effects	No	Yes	Yes	No	Yes	Yes

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$
Least squares estimates only use hauling time data from 2014. Household fixed effects are omitted
†"EWB Project" indicates the household is in a community that has received an EWB-MSU well in the current year or previously.

primary schools likely use relative grading schemes. If grading is entirely relative then a welfare shock that uniformly affects all students is not expected to change the relative grades for any specific student. Thus, even if EWB-MSU projects improve the educational performance of all students at a school equally, relative grades will obscure the effect.

However, this explanation does not apply to the lack of observed impact on KCPE exam scores and enrollment, each measured relative to other schools.

Ordinary Least Squares Estimates

Whether or not an individual attends an EWB school does not have a significant relationship with 2013 student grade point averages according to Method (1) estimates (Table 14). Other covariates are estimated to form an expected relationship with education outcomes. Whether or not a household always treats water at home is significantly and positively related to grade point by a large absolute margin. Students from these households score an average of about 17 points higher on a 500 point scale, than do those students from households that do not treat. A possible explanation of this may be the characteristics of households that treat water at home also positively influence the household pupils' academic performance. Alternatively, the pupil's health benefits from treated water translate into academic benefits at school. The relationship between water treatment and grade points provides some evidence that improved health is indeed a vector for improved education outcomes.

Of the wealth measures, only household construction quality appears to relate significantly to grade point outcomes. The father's education level is also significantly and positively related. For every increment in level of education of the father, the student's grade point gains almost 5 points.[37] It appears that fathers who are well educated are also likely to have high achieving sons and daughters. Curiously, the same relationship does not exist between mothers and offspring in these data.

Contrary to expectation, age is *negatively* related to grade point outcomes. The student's gender is not significantly related to grade point. Further, covariates, including clinic distance, "good" household drinking water source and sanitation facility, are not estimated to have a significant relationship with education outcomes as expected.

[37]The education level of the parent of minor (< 18 years) i is measured by partial or full completion of standard institutional academic levels. That is, (0) "none", (1) "some primary school", (2) "completed primary school", (3) "some secondary", and so on.

Table 14: EWB-MSU's Impact on Education

	Dependent Variable: (1) Grade (2013)	(2) Grade†
EWB	-8.375	-1.254
	(5.223)	(3.290)
Age	-6.523****	
	(0.823)	
Girl	6.316	
	(5.132)	
Orphan (1 parent)	114.5**	
	(49.15)	
Asset Score	-1.197	
	(0.976)	
House Construction Score	3.985**	
	(1.981)	
Father's Education Level	4.287*	
	(2.196)	
Mother's Education Level	-0.617	
	(2.600)	
Clinic Distance	-0.150	
	(0.112)	
"Good" Water Source†	-7.311	
	(5.875)	
Treat Water	18.95****	
	(5.300)	
"Good" Sanitation	-2.897	
	(10.70)	
2nd year		2.772
		(1.857)
3rd year		9.742****
		(2.539)
Constant	367.8****	295.0****
	(12.55)	(1.222)
Observations	1130	5331
Adjusted R^2	0.074	0.007
Individual Fixed Effects	No	Yes

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$
In the OLS model, "EWB" variable indicates the student is attending an EWB school in 2014 that has previously received a project. In the fixed effect model, "EWB" is a dummy variable that is turned on for individuals attending an school that has received an EWB-MSU project in the current year or previously.
†"Good" Water Source indicates the household is using a protected springs and wells, bore holes, rain water or piped water. The dry season is used because households often switch to rain water during the wet season; a "good" source. Using a good source during the dry season might be a better measure of the year round quality of the household's water source.
††"Good" Sanitation indicates the household is using an improved latrine, an EWB-MSU latrine or a toilet.

Fixed Effect Estimates

The fixed effect Method (2) is used to test EWB-MSU's impact on primary student grade point outcomes. These estimates are also reported in Table 14.[38] After removing variation explained by individual fixed effects and time fixed effects, the impact of attending a school with an EWB-MSU project on grade points remains unknown. As mentioned above, it is perhaps unsurprising that an EWB-MSU project, which presumably benefits all students at the school equally, doesn't affect grade points within a relativistic grading regime.

A positive and significant effect of 2013 (the 3rd year) is detected on grades across primary schools. It is unclear what occurred that year that would lead to an overall increase in grade points. The relationship of time and grade points provides some evidence that grades are at least partially absolute rather than purely relativistic. That is, teachers may compare students to fixed achievement goals rather than exclusively to each other. Otherwise, overall average grade points would not change over time.

Method (2) is also used to test EWB-MSU's impact on education outcomes at the school-level. These estimates relate to enrollment and average test score on the KCPE exam as the outcome of interest. After controlling for school fixed-effects and year fixed effects, there is no evidence that EWB-MSU is impacting education outcomes at the school-level either. This confirms the findings from the individual-level models and is similarly unsurprising due to the lack of evidence for an EWB-MSU *health* impact. Estimates of the effect of years 2012 and 2013 provide some evidence that Khwisero primary students in Class 8 are performing better than the area average on KCPE exams in recent years. It is also clear from year estimates that enrollment in Khwisero primary schools is growing over time.

[38] The individual fixed effects are not reported.

Table 15: EWB-MSU's Impact on Education at the School-level

	Dependent Variable:	
	(1)	(2)
	KCPE Exam Score†	Enrollment
EWB	-1.851	-5.57
	(5.583)	(16.31)
2005	5.051	2.80
	(3.107)	(5.814)
2006	1.698	5.80
	(3.889)	(8.128)
2007	2.098	27.45*
	(4.897)	(10.93)
2008	1.458	42.57****
	(4.575)	(11.56)
2009	9.388*	42.99***
	(4.030)	(14.34)
2010	4.957	24.66
	(4.265)	(17.94)
2011	2.395	35.76*
	(4.712)	(19.19)
2012	8.596*	38.91*
	(5.028)	(19.67)
2013	9.433*	38.21*
	(5.058)	(22.83)
2014		45.62**
		(21.42)
constant	250.3****	463.7****
	(3.235)	(12.07)
Observations	566	623
Adjusted R^2	0.013	0.041
School Fixed Effects	Yes	Yes

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$
School fixed effects are omitted. Standard errors are in parentheses.
†Kenya Certificate of Primary Education (KCPE) exam score average.

CONCLUSION

Estimation of the effect EWB-MSU has on welfare outcomes in Khwisero, Kenya was the primary goal of this research. The analysis does not provide evidence that EWB-MSU water and sanitation projects affect health or education outcomes. However, it does find evidence that EWB-MSU *water* projects reduce the amount of time households spend collecting water. On average, households in communities with EWB-MSU water projects are spending approximately 1.5 fewer minutes per trip collecting drinking water. Only 7 households in the sample, or approximately 4% of sampled households surrounding EWB-MSU water projects, are using the projects as their primary water source.

The lack of evidence for an EWB-MSU impact on health and education may be explained by three short-comings of the dataset. First, measurement error in the outcomes of interest undoubtedly exists due to survey respondent error. It is possible the extra noise in the outcome measures leads to less precise estimates of the EWB-MSU effect. Second, EWB and non-EWB groups may experience disparate rates of change over time that counteract an EWB-MSU impact on the outcomes of interest. For instance, non-EWB communities may experience a greater rate of investment in teachers over time relative to the corresponding rate in the EWB communities. Such time-variant information is not observed in the dataset. If disparate time trends between groups indeed exist, the estimated effect of EWB-MSU may be biased towards zero due to counteracting variation over time. Finally, the analysis may be under-powered due to the sample size of the dataset. That is, if an EWB-MSU impact on the outcomes of interest exists, the likelihood of observing those outcomes may be low due to insufficient sample size. Thus, an EWB-MSU effect on these outcomes should not be ruled out.

Alternatively, the lack of evidence supporting an EWB-MSU impact on health and education may indicate that the organization truly does not impact these outcomes. If EWB-MSU's efforts are failing in this dimension, it is important to ask why. There are three potential explanations for a null effect. First, in order to observe a positive health impact, a threshold of investment in water and sanitation infrastructure may be required. For instance, a student might begin drinking clean water at an EWB school but continue drinking contaminated water at home. Similarly, the student may sometimes use a composting latrine at school, but an unimproved pit latrine other times. Consequently, this student may not experience measurable improvements in health. As indicated in the results, very few children have access to EWB-MSU's water source while at home. Furthermore, EWB-MSU composting latrines generally replace only one of several pit latrines at a primary school, are often limited to one gender and often cannot even serve all members of that gender all the time. Additionally, although composting latrines seal-in some human waste, the other remaining pit latrines continue to contaminate the ground water. For these reasons, EWB-MSU's projects may fail to exceed the threshold required for observable health improvements.

Second, the vectors through which EWB-MSU is expected to improve education outcomes are either through a direct improvement of health outcomes or a reduction in household labor required to collect water. Given that no effect on health outcomes are observed, and that the effect on household time-use is limited to a handful of households, it is not surprising that positive education outcomes are also not observed.

Third, anecdotal evidence from conducting the household survey suggests Khwisero primary student grades are curved. Thus, if EWB-MSU projects impact all students at one school equally, then no effect is expected on curved grade points. That is, if students are evaluated relative to one another, then a positive welfare shock to all students should not affect the grade distribution. However, the existence of grade curving does not explain the absence of observed impact on national exam scores, nor on enrollment at EWB schools. KCPE exam scores are relative to all Class 8 students in Kenya who take the exam. Enrollment measures are relative to other primary schools. Thus, A positive welfare shock at an EWB school is expected to improve performance on the KCPE exam and increase enrollment regardless of how student performance is evaluated within the school.

This thesis *does* find evidence for an EWB-MSU impact on household time-use. The average effect on households in water project communities (i.e. the intended treatment group) is about two minutes saved per trip back and forth to an EWB-MSU water project in the dry season. After controlling for growing piped water access in Khwisero, EWB-MSU's estimated effect on the intended treatment group decreases in significance in the dry season and becomes insignificant in the wet season. This indicates that household piped water access is increasing disproportionately over time in communities with EWB-MSU water projects relative to non-EWB communities. This trend is occurring simultaneously with EWB-MSU water project implementation.

The average effect on time-use for households actually using an EWB-MSU well (i.e. the effect of the treatment on the treated) is more than 40 minutes saved per trip in the dry season and more than an hour saved per trip in the wet season. Only 7 households in the sample data report using an EWB-MSU well, all of which surround Mundaha Primary School. These households constitute about 15% of the households sampled from Mundaha (See Table 16 in Appendix A). Utilizing this sample proportion of households and extrapolating with the total number of households in the Mundaha Primary School student population, it is estimated that at least 25 households are using the EWB-MSU well at Mundaha Primary.[39] Assuming that households make two trips to collect water per day, the EWB-MSU bore hole well at Mundaha saves 30 hours of labor every day for benefiting households. These 25 benefiting households constitute approximately 3% of almost 950 households surrounding surveyed schools with EWB-MSU water projects.

The impact of EWB-MSU's water projects on time use is simultaneously hopeful and disappointing for EWB-MSU. On the one hand, some households are saving an economically significant amount of time. With an extra 1.5 to 2 hours per day, household

[39]This estimate probably misses even more households using this well because these households do not have children attending Mundaha Primary and, thus, they are missing from the dataset.

members may now attend more school, increase labor force participation, increase the productivity of non-market household activities, or spend more time enjoying each other's company. On the other hand, the amount of households benefiting from these water projects is small relative to the number of households surrounding them. There are two potential explanations for the lack of household usage. First, other households may have closer primary water sources that they prefer. These households also may not be aware that the EWB-MSU wells might provide safer water for consumption. Second, schools with projects and surrounding households may be unable to work out a resource sharing arrangement due to transaction costs. Anecdotal evidence suggests households are often unwilling to contribute monetary resources towards project repairs. In return, schools are unwilling to share the water, as they alone bear the costs.

Finally, out of this research comes two policy recommendations for Engineers Without Borders-Montana State University. First, continued empirical study of EWB-MSU's impacts is crucial for the organization's long run improvement. Supplementing the baseline dataset used in this analysis with follow-up data may clarify whether a lack of evidence for an impact on health and education is a result of flawed data or an absence of impact in truth. If evidence for such an impact is detected with the combined dataset, then EWB-MSU may use the results both as a reference point for improvement and a marketing tool for funding. Alternatively, if evidence of an impact on health and education is not provided by follow-up data, such information may fuel critical thought, and ultimately improvement of project implementation. Further, follow-up data collection may allow time-series analysis of EWB-MSU's impact on other observable outcomes measured with the household survey. Due to a lack of time-series data, this analysis did not investigate the organization's impact on the amount of time students spend collecting water during school, nor on the aspirations held by people in Khwisero regarding their future. EWB-MSU may affect each of these outcomes, and follow-up data collection will allow their observation over time.

Second, EWB-MSU should investigate solutions to potential project ineffectiveness in case further research confirms the the organization does not impact health, education or time-use outcomes. For instance, EWB-MSU should study Mundaha Primary School and its surrounding community, because this group exhibits the sole observed case where households are using an EWB-MSU water project. Understanding how this arrangement functions between Mundaha Primary and surrounding households may provide insight into how water sharing can be encouraged at the other water projects. EWB-MSU may subsequently create a policy for encouraging such behavior based on what the organization learns. Additionally, EWB-MSU should experiment with complete replacement of school sanitation facilities with composting latrines. In conjunction with follow-up data collection, such a policy change will help determine if greater concentration of these projects may provide the expected welfare benefits for students. Both of these recommendations are likely to increase water and sanitation access for primary students in Khwisero. Thus, implementing such policies will address a potential hindrance of EWB-MSU's projects: that they do not exceed a threshold of investment in water or sanitation infrastructure required to observe an improvement in welfare outcomes.

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APPENDICES

APPENDIX A:

MISCELLANEOUS

Table 16: Household Surveys

School	EWB-School[†]	Population Size	Households Sampled[†]	Households Surveyed	Percent Pop. Surveyed	Percent Missing[††]
Buhili	no	209	49	49	23.4%	0.0%
Ebukanga	no	233	50	44	18.9%	12.0%
Ebukutenga	no	266	48	47	17.7%	2.1%
Ebukwala	yes	138	50	45	32.6%	10.0%
Ekatsombero	yes	260	48	48	18.5%	0.0%
Emulole	no	285	60	59	20.7%	1.7%
Eshibinga	no	290	48	48	16.6%	0.0%
Eshikhungula	no	167	53	48	28.7%	9.4%
Eshinutsa	yes	203	48	48	23.6%	0.0%
Khwisero	yes	295	60	60	20.3%	0.0%
Luanda AC	yes	216	50	43	19.9%	14.0%
Mundaha	yes	174	48	47	27.0%	2.1%
Mundoli	yes	174	48	48	27.6%	0.0%
Munjeche	no	239	47	47	19.7%	0.0%
Munjiti	no	157	48	47	29.9%	2.1%
Shiongo	yes	114	48	48	42.1%	0.0%
TOTAL/AVG	-	3420	803	776	24.2%	3.3%

[†]EWB schools are those with projects implemented *prior* to the summer of 2014.
[††]Houses that were randomly selected but repeats within the sample, or had moved/transferred are not counted towards the number sampled. These incidences are households that are not unique members of our target population: households with children attending the school.
[†††]Missing households included those that were sampled but not located. This may be due to being unable to locate a child of or a friend of a parent's name found on a primary schools register.

Table 17: Table of Variables

Variable Name	Description
τ_t	The year fixed effect that is not variant between units of observation.
α_i	The time-invariant fixed effect for unit of observation *i*.
Asset score$_i$	The first principal component element *i* (for household *i*) of a matrix of household assets.
Bore Hole Well$_{i,t}$ (dummy)	Household *i* used a bore hole well as their primary drinking water source in year *t*. Generally defined as a drilled well that is sealed at the top with concrete and has pump access.
clinic dist.$_i$	The number of minutes it takes to walk from household *i* to the nearest clinic
Covered Latrine$_i$ (dummy)	Household *i* uses a covered latrine as their primary sanitation facility.
Diarrhea$_i$ (dummy)	Individual *i* experienced diarrhea at least once in the previous three months
Dist$_i$	The number of minutes it takes to walk from household *i* to the nearest EWB school.
Distance to Primary Water Source$_{i,t}$	The number of minutes necessary to walk from household *i* to their primary water source in year *t*

Continued on next page

Table 17 – *Continued from previous page*

Variable Name	Description
Electricity access$_i$ (dummy)	Household i is connected to an electrical grid.
Enrollment$_{i,t}$	Number of students enrolled at primary school i in year t
EWB Bore Hole$_{i,t}$ (dummy)	Household i used an EWB-MSU bore hole well as their primary drinking water source in year t. Generally defined as a drilled well that is sealed at the top with concrete and has pump access.
EWB Latrine$_i$ (dummy)	Household i uses an EWB-MSU composting latrine as their primary sanitation facility.
EWB$_{i,t}$ (dummy)	In individual-level models, Indicates primary student i is attending a school with an EWB-MSU project in year t. In household-level models, indicates household i has at least one primary student at a school with an EWB-MSU project in year t. In school-level models, indicates primary school i received a project in year t.
Father's Education$_i$	The education level of the father of minor ($<$ 18 years) i. Measured by partial or full completion of standard institutional academic levels. That is, (0) "none", (1) "some primary school", (2) "completed primary school", (3) "some secondary", and so on.
fever$_i$ (dummy)	Individual i experienced fever at least once in the previous three months
Flush Toilet$_i$ (dummy)	Household i uses a flush toilet as their primary sanitation facility.
Good Facility$_i$ (dummy)	Household i uses a "good" sanitation facility as their primary source. A good facility is defined as an improved latrine, an EWB-MSU latrine or a toilet.
Good floor$_i$ (dummy)	Household i's floor (primary building) is constructed of "good" material: concrete.
Good roof$_i$ (dummy)	Household i's floor (primary building) is constructed of "good" material: metal or tile.
Good wall$_i$ (dummy)	Household i's walls (primary building) is constructed of "good" material: brick or stone.
Good Water Source$_{i,t}$ (dummy)	Household i used a "good" source as their primary drinking water source in year t, defined here as protected springs and wells, bore holes, rain water or piped water.
Grades$_{i,t}$	The average grade received by student i in year t
Household Pipe$_{i,t}$ (dummy)	Household i used an in-compound pipe as their primary drinking water source in year t.
Improved Latrine$_i$ (dummy)	Household i uses an improved latrine as their primary sanitation facility. This is generally defined as a covered latrine with a vent, sometimes with a screen to catch flies
KCPE exam average score$_{i,t}$	Average score on the Kenya Certificate of Primary Education (KCPE) exam by Class 8 students at primary school i in year t
Lake/Pond$_{i,t}$	Household i used a lake or pond as their primary drinking water source in year t.
Malaria$_i$ (dummy)	Individual i experienced malaria at least once in the previous three months

Continued on next page

Table 17 – *Continued from previous page*

Variable Name	Description
Mother's Education$_i$	The education level of the mother of minor (< 18 years) i. Measured by partial or full completion of standard institutional academic levels. That is, (0) "none", (1) "some primary school", (2) "completed primary school", (3) "some secondary", and so on.
No Facility$_i$ (dummy)	Household i does not have a primary sanitation facility.
Orphan (1 parent)$_i$ (dummy)	Individual i has at least one deceased biological parent.
Orphan (2 parent)$_i$ (dummy)	Individual i has no living biological parents.
Present Income (KES)$_i$	Reported annual income from household i in Kenyan Shillings.
Present Income (USD)$_i$	Reported annual income from household i in PPP adjusted US dollars. This was calculated from the KES measure using conversions based on PPP-adjusted exchange rate of 34 KES/1 USD. This figure was obtained using the imprecise exchange rate of 85 KES/1 USD from the summer of 2014 and the World Bank's price level ratio of PPP conversion factor (GDP) to market exchange rate of 0.4 for Kenya between 2010 and 2014.
Public tap$_{i,t}$ (dummy)	Household i used a public tap as their primary drinking water source in year t.
Rain$_{i,t}$ (dummy)	Household i used rain water as their primary drinking water source in year t.
Rivers/Streams$_{i,t}$ (dummy)	Household i used a river or stream their primary drinking water source in year t.
Sick Day$_i$ (dummy)	Individual i missed at least one day of school due to illness in the previous month
Spring (protected)$_{i,t}$ (dummy)	Household i used a protected spring as their primary drinking water source in year t, generally defined as a spring that is sealed at the top with concrete and an open pipe.
Spring (unprotected)$_{i,t}$ (dummy)	Household i used an unprotected spring as their primary drinking water source in year t, generally defined as a spring that wells up onto exposed earth.
Treat Water in Household$_i$ (dummy)	Indicates the household *always* treats drinking water in house
Treat Water$_i$ (dummy)	Indicates the household *always* treats drinking water in house *or* the drinking water is treated at the source.
Uncovered Latrine$_i$ (dummy)	Household i uses an uncovered latrine as their primary sanitation facility.
Vomit$_i$ (dummy)	Individual i experienced vomiting at least once in the previous three months
Well (protected)$_{i,t}$ (dummy)	Household i used a protected well as their primary drinking water source in year t. Generally defined as a hand dug well that is sealed at the top with concrete and door or pipe access.
Well (unprotected)$_{i,t}$ (dummy)	Household i used an unprotected well as their primary drinking water source in year t. Generally defined as a hand dug well that is open at the top.

APPENDIX B

AUXILLARY REGRESSION RESULTS

Table 18: EWB-MSU's Impact on Health Using Incidence of Disease

	Dependent Variable:									
	Diarrhea		Fever		Vomiting		Malaria†		Sick Day††	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Instrument: Dist. to EWB School	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
EWB (indiv.)	0.041	1.081	0.070	2.763	0.194**	6.861**	0.349*	-8.823*	0.755****	-6.162
	(0.084)	(1.651)	(0.191)	(3.104)	(0.099)	(3.304)	(0.185)	(4.873)	(0.181)	(6.375)
Age	-0.013*	-0.015*	-0.027*	-0.033**	-0.043****	-0.056***	-0.046****	-0.034	-0.026	-0.018
	(0.007)	(0.008)	(0.015)	(0.016)	(0.011)	(0.018)	(0.014)	(0.023)	(0.022)	(0.026)
Girl	-0.041	-0.051	-0.189**	-0.229**	-0.091	-0.123	-0.123	-0.139	-0.289**	-0.368**
	(0.041)	(0.044)	(0.083)	(0.092)	(0.062)	(0.099)	(0.091)	(0.139)	(0.141)	(0.163)
Orphan	-0.096	-0.101	-0.600****	-0.685***	-0.269	-0.359	-0.132	0.015	-0.057	-0.943**
	(0.064)	(0.087)	(0.170)	(0.220)	(0.174)	(0.376)	(0.335)	(0.573)	(0.958)	(0.478)
Asset Score	-0.013*	-0.014*	0.002	0.010	0.052***	0.052**	-0.002	0.005	0.146***	0.165****
	(0.007)	(0.008)	(0.017)	(0.019)	(0.020)	(0.025)	(0.020)	(0.028)	(0.045)	(0.047)
House Construction Score	-0.000	0.001	-0.040	-0.040	-0.060**	-0.047	-0.008	-0.039	-0.053	-0.086
	(0.012)	(0.013)	(0.027)	(0.029)	(0.025)	(0.034)	(0.034)	(0.048)	(0.049)	(0.054)
Father Edu. Level	-0.009	0.005	0.010	0.037	-0.029	0.003	0.048	0.029	-0.155***	-0.180**
	(0.014)	(0.018)	(0.029)	(0.038)	(0.026)	(0.048)	(0.043)	(0.065)	(0.056)	(0.071)
Mother Edu. Level	0.011	0.006	-0.000	-0.012	0.011	0.007	0.008	0.010	-0.037	-0.035
	(0.020)	(0.022)	(0.033)	(0.038)	(0.025)	(0.050)	(0.046)	(0.075)	(0.060)	(0.075)
Dist. to Clinic (min.)	-0.000	0.000	-0.000	0.000	-0.004*	-0.003	0.002	0.000	-0.002	-0.010**
	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)	(0.006)	(0.004)
"Good" Water Source (dry)	0.036	0.084	0.127	0.262**	0.258****	0.477****	-0.053	-0.319	0.317**	0.189
	(0.052)	(0.062)	(0.099)	(0.131)	(0.072)	(0.142)	(0.121)	(0.215)	(0.154)	(0.274)
Water Treatment	-0.019	-0.012	0.152*	0.125	-0.016	0.002	0.000	-0.067	-0.164	-0.317*
	(0.049)	(0.055)	(0.092)	(0.103)	(0.073)	(0.118)	(0.104)	(0.154)	(0.145)	(0.183)
Sanitation Fac.	-0.000	-0.014	-0.246*	-0.269*	-0.190	-0.227	-0.344**	-0.339	0.327	0.400
	(0.066)	(0.069)	(0.132)	(0.149)	(0.120)	(0.194)	(0.173)	(0.239)	(0.384)	(0.417)
Constant	0.355***	–	1.219****	–	0.984****	–	1.585****	–	1.970****	–
	(0.128)		(0.255)		(0.199)		(0.290)		(0.486)	
Observations	1295	1211	1295	1211	1295	1211	1295	1211	1295	1211
Adjusted R^2	0.004	-0.086	0.017	-0.111	0.065	-1.203	0.027	-1.102	0.049	-0.242
Community Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

With the exception of "Sick Days" and "Malaria", the dependent variables indicate how many times the primary student has experienced the illness symptom in the past three months. School fixed effects are not shown. Standard errors are in parentheses.

†"Malaria" indicates how many times the primary student has experienced malaria in the past year.

††"Sick Day" indicates how many times the primary student has experienced days off from school due to illness in the past month.

†††"Good" Water Sources are defined here as protected springs and wells, bore holes, rain water or piped water. The dry season is used because households often switch to rain water during the wet season; a "good" source. Using a good source during the dry season might be a better measure of the year round quality of the household's water source.

APPENDIX C

THE EXPERIMENTAL IDEAL

The Ideal Data

EWB-MSU seeks to improve the welfare of children attending primary school. Accordingly, the ideal data would provide information at the individual-level on children at Khwisero primary schools over a period of time. It is expected that EWB-MSU projects improve the safety of the school childrens' water source. Thus, one would collect health data on Khwisero students' water borne illness morbidity such as typhoid and diarrhea. It is expected that healthier students are able to increase school attendance and performance. Thus, one would collect education records on individual students such as grades, exam scores, and attendance records. It is expected that EWB-MSU's water projects reduce water collection times for students while at school. Thus, one would collect data on the students' water collection labor. It is expected that EWB-MSU projects raise the students' aspirations for their future via interactions with collegiate foreigners and demonstration of welfare improvements through collective action. Thus, one would collect data on what these students' aspire to achieve academically, professionally and socio-politically in the future. In addition, one would collect individual-level information on other known covariates that related to the enumerated welfare outcomes. These might include the student's household wealth and parental education levels. Doing so will allow the removal variation explained by these other factors and increase the precision of estimates in the econometric analysis of these data.

The Experimental Ideal

The ideal experiment to test the welfare impacts of EWB-MSU would randomly assign students to schools with or without EWB-MSU projects. A "treatment" group of students would attend a school that receives a project, while a "control" group would not. The ideal data described would be collected from all "treatment" and "control" individuals and their families.

$$y_i = \alpha + \delta EWB_i + \mathbf{x_i}\boldsymbol{\beta} + \varepsilon_i$$

Random assignment would remove the possibility of selection bias in community characteristics and bias from choice in attendance of EWB schools. Therefore, the effect of EWB-MSU on the outcome of interest, y_i, may be interpreted as causal. From the ideal data, a conditioning set, $\mathbf{x_i}$, may be used to increase estimate precision but is not necessary for estimating a causal effect.