DISSERTATION

THREE ESSAYS ON DEVELOPMENT: ACCESS TO SERVICES IN DEVELOPING COUNTRIES

Submitted by

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ABSTRACT

THREE ESSAYS ON DEVELOPMENT: ACCESS TO SERVICES IN DEVELOPING COUNTRIES

This dissertation aims to contribute to development economics related to sanitation and poverty in some selected developing countries using microdata. The focus is on Ethiopia, India, Peru, and Vietnam, chosen for various reasons. This culminates into three distinct essays. The first and second chapters use the Young Lives Study (YLS) data, a unique longitudinal dataset that follows a set of 12,000 children. The rationale for choosing Vietnam, India, Peru, and Ethiopia as interest countries for the YLS emerges from the desire to address child poverty effectively. This selection is guided by the substantial levels of child poverty in these regions, their cultural diversity, and the potential to generate policy-relevant recommendations. By considering these factors, the YLS ensures a comprehensive examination of child poverty within diverse contexts and in line with the tracking of progress towards the United Nations Millennium Development Goals (MDGs), paving the way for evidence-based policy recommendations to improve the lives of children in these countries. The final chapter uses the World Bank's Living standard measurement survey, the Ethiopian Socioeconomic Survey (ESS).

The first chapter of this dissertation uses the unique longitudinal data from four low- and middle-income countries to examine the relationship between early-life access to sanitation services and children's cognitive development. The primary focus of this chapter is directed towards the younger cohort rather than the older cohort of the YLS, as it is exclusively within the younger cohort that we can ascertain early exposure to sanitation practices occurring between the age range of 6 to 18 months. Conversely, the youngest child within the older cohort is approximately 5 years old, rendering it insufficient for observing the said early access to sanitation. Therefore, chapter one tracks 8,062 children over 15 years and uses a fixed effects model to analyze the impact of

early access to flush toilets and pit latrines on their vocabulary, math scores and health indicators, including height-for-age and BMI-for-age z-scores. The study also uses the hierarchical linear models (HLMs) to investigate the presence of community spillovers. The treatment variable in this chapter is early life access to sanitation both at the household and the community levels. The findings suggest a significant positive correlation between early access to sanitation services and children's cognitive development, although the results vary across countries. The study also supports a health mechanism: early access to flush toilets is significantly associated with improved height-for-age and BMI-for-age z-scores. Additionally, the study finds evidence of community spillovers for vocabulary but not math.

The second chapter examines the relationship between access to private sanitation facilities at home and psychosocial development among adolescents aged 12-22 in India and Ethiopia. In this study, the focus is on both the younger and older cohorts limited to rounds 4 and 5 of the YLS as they specifically encompass the adolescent phase and when extensive psychosocial outcomes were collected for both cohorts. Psychosocial outcomes were also collected using a smaller and modified set of statements in round 3, but in round 4, they were expanded and updated to better reflect validated scales and cater to older children. The treatment variable in this chapter is private sanitation in the household. Using a longitudinal two-way fixed effects model, the study finds that access to private sanitation (flush toilets or pit latrines in the household) is associated with significantly higher self-efficacy and self-esteem for adolescent girls but not boys. Associations are stronger for girls who live in communities with higher overall access to private sanitation, suggesting relative access may matter more for psychosocial development than absolute access. There is also evidence of a significant correlation with improved peer relations for girls in early (age 12 to 15) but not late (age 19 to 22) adolescence. The results do not portray evidence that the findings are operating through improved physical health, suggesting there may be a direct impact of private sanitation facilities at home and psychosocial development in adolescent girls. These findings suggest interventions should consider the health benefits of hygienic waste management,

the potential gains from improved sanitation experiences for women and girls, and the potential unintended spillover effects of inequitable roll-out.

Ethiopia is one country that has been unfortunate enough to experience severe drought in the last few decades. This has affected life in Ethiopia at so many levels. Specifically, the challenges of access to clean drinking water and cooking fuels have disproportionately impacted females as they spend more time collecting these resources. This has had the negative consequence of perpetuating time poverty among this group of people, and thereby their inability to participate in the labor market for paid work fully. Following an unbalanced panel of households from the World Bank's living standards measurement survey, this chapter uses the Ethiopian Socioeconomic Surveys (ESS) between 2012 and 2016 to investigate the determinants of households' choice of cooking fuel and drinking water sources in rural and small towns of Ethiopia. The final chapter investigates the factors influencing households' decisions regarding choices of cooking fuel and drinking water sources in rural and small towns of Ethiopia. The study employs probit models (ordered and regular) to examine the effects of improved fuel and water sources on labor outcomes by leveraging variations in access. The findings are that household size, asset ownership, and the education level of the household head as well as their ages, are key determinants influencing the choice of cooking fuel and drinking water. Furthermore, adopting improved water sources significantly and positively impacts family business labor, while using improved cooking fuels significantly enhances agricultural labor. These findings demonstrate the potential benefits of transitioning to improved fuel and water sources in rural Ethiopia, emphasizing the importance of considering social and economic factors in sustainable development initiatives.

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DEDICATION

To my beloved mom and all the single mothers out there. This dissertation expresses my deepest thanks and is a testament to a strong woman's boundless influence on my life.

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Chapter 1

Flush to Flourish: Exploring early sanitation access and childhood cognitive evolution

1.1 Introduction

In 2020, an estimated 4.2 billion people still relied on unsanitary sanitation services, with 673 million practicing open defecation due to the lack of improved sanitation facilities (hereafter ISF) worldwide (World Health Organization et al., 2020). This scarcity of ISF in developing countries forces households to resort to inadequate alternatives like widespread open defecation without basic hand-washing facilities. The adverse effects of poor sanitation include both direct and indirect implications, including externalities (Kresch et al., 2020), water pollution (Garg et al., 2018), and pathogen contamination (Cameron et al., 2021; Andres et al., 2018). Some of the direct health implications of poor sanitation are stunting (Cameron et al., 2021), anemia (Kothari et al., 2019), malnutrition (Rahman et al., 2020), diarrhea, and child mortality (Headey and Palloni, 2019). Children's early exposure to unimproved sanitation may negatively impact their future by delaying cognitive development through such health channels (Orgill-Meyer and Pattanayak, 2020; Sclar et al., 2017). Furthermore, ISF affects non-health outcomes, like changes in cleanliness behaviors or increased violence (Andres et al., 2018). Overall, poor sanitation and open defecation practices have a detrimental impact on public health and socioeconomic development. They contribute to the spread of waterborne diseases, impose economic burdens, degrade the environment, and perpetuate social inequalities. Addressing these issues is crucial for achieving sustainable development goals and improving overall well-being.

The global state of water, sanitation, and hygiene (hereafter WASH) infrastructure falls short of expectations. According to estimates, there has been a modest increase in the proportion of individuals relying on safely managed sanitation services worldwide, with coverage standing at

54% as of 2020 (up from 47% in 2015). However, rural and urban areas exhibit differing levels of coverage, at 44% (up from 36% in 2015) and 62% (up from 57% in 2015), respectively (WHO-UNICEF, 2021). Despite some of these global improvements, significant strides are still necessary to ensure widespread access and affordability. The World Health Organization (WHO)'s 2020-2022 progress report[1] predicts that if growth to WASH services is not accelerated, billions of children and families will lack access to essential WASH services by 2030. Further estimates suggest that by 2030, only 67% and 78% of the world population will have access to improved sanitation and basic hand-washing facilities, respectively, leaving 2.8 and 1.9 billion individuals without these fundamental services. Hence, urgent action is required to prioritize sanitation programs at both global and regional levels.

The state of access to improved sanitation in low- and middle-income countries is closely aligned with global trends. Notably, Ethiopia has achieved a substantial reduction in open defecation rates from 79% to 17% between 2000 and 2020 with some help from the implementation of a national sanitation strategy (Novotnỳ and Mamo, 2022a)[2]. Similarly, Peru has made progress in sanitation, as evidenced by a decline in the rate of open defecation, although certain sub-populations still remain underserved (Eagin and Graham, 2014). In Vietnam, the proportion of the population with access to improved sanitation increased from 36% in 1990 to 78% in 2015 (WHO/UNICEF Joint Water Supply and Sanitation Monitoring Programme, 2015). However, despite numerous initiatives implemented since the 1980s, the problem of open defecation in India remains stubbornly high at around 60% (Alexander et al., 2016). Consequently, the state of sanitation facilities in low- and middle-income countries, such as Ethiopia, India, Peru, and Vietnam, underscores the fact that many individuals in developing countries still lack access to improved sanitation services, despite years of efforts to address this issue.

The sluggish progress in improving access to proper sanitation has alarming consequences, such as the widespread practice of open defecation. This behavior can lead to the contamination of

[1]The report can be accessed here: https://www.who.int/publications/i/item/9789240050846

[2]The 2005 National Hygiene and Sanitation Strategy (report accessible here) and the One WASH National Program (phase I of the report accessible here).

various household items and the consumption of fecal pathogens, which may result in malnutrition, diarrhea, and intestinal worms among infants and children (Humphrey, 2009; Rahman et al., 2020). Consequently, open defecation can have severe implications for population health and behavioral changes. For instance, in India, it is estimated that 1,600 children die daily before their fifth birthday, many girls drop out of school, and 30% of women face violent assaults due to the need to travel long distances for relief (Dasra, 2012). Furthermore, the high disease burden in countries with open defecation significantly impacts healthcare systems and hinders socioeconomic development. Ultimately, poor sanitation can have long-term impacts on children's cognitive development and health.

This study investigates the relationship between early childhood exposure to improved sanitation and cognition over time. Massa et al. (2017) and Rheinländer et al. (2015) provide a compelling critiqueof the WHO/UNICEF Joint Water Supply and Sanitation Monitoring Programme (2015)'s definition of unimproved sanitation. To address this, the current study utilizes longitudinal data from four low- and middle-income countries and redefines sanitation using four categories: flush toilets, latrines (shared and private), open defecation, and "other." Early access to sanitation is defined as household access to a sanitation category when the children are between 6-18 months old. Conditional on the type of early access category, the study examines the evolution of children's cognitive development over time. Additionally, it investigates community spillovers between children's sanitation and cognition, considering the indirect effects of sanitation improvements on neighboring communities' health and well-being. Understanding the connection between children's sanitation and later life cognition is vital, as it reveals the long-term impact of sanitation on cognitive development (Currie and Almond, 2011; Nores and Barnett, 2010; Tanner et al., 2015). These insights emphasize the importance of early interventions and prioritizing sanitation initiatives for future success in developing economies. The study's findings can inform policymakers about the significance of sanitation in cognitive development and guide targeted policies and reforms. Furthermore, the unique nature of the longitudinal design enables observation of the same set of

children's cognition and health over 15 years, providing valuable insights into the long-term effects of inadequate access to improved sanitation.

Sanitation has been a widely studied topic across various fields for many years, with a particular focus on its impact on sanitation-related infectious diseases, nutritional status (Wolf et al., 2014), and overall well-being (Sclar et al., 2018a), including children's cognitive development and school attendance (Sclar et al., 2017). Early life exposure to improved WASH services has emerged as a growing area of interest in the literature due to the critical importance of early childhood development (ECD) in enabling children to reach their full growth potential (Black et al., 2017)[3]. Given that early childhood is a period of rapid brain development, it is expected that improved access to sanitation facilities during this time would be associated with better cognitive outcomes later in life, much like access to high-quality education improves cognitive abilities (Sclar et al., 2017).

To the best of my knowledge, the current study represents a significant contribution to the topic as it aims to examine the relationship between WASH and childhood development outcomes by addressing a gap in the existing literature. Cameron et al. (2021) and Dearden et al. (2017a,b) have laid some groundwork, albeit with limitations. Dearden et al. (2017a), and Dearden et al. (2017b) are notable in their similarity to the present study, as they use the same dataset (Young Lives Study data or YLS for short) and sample of countries. However, Dearden et al. (2017a) only focus on the association between WASH and the Peabody Picture Vocabulary test (hereafter PPVT) both contemporaneously and later in life but do not consider math test scores[4]. They find that access to improved water at 1 year is linked to higher vocabulary scores at 5 and 8 years with and without controls. Similarly, Dearden et al. (2017b) investigate the association between WASH and child growth in terms of health vis-à-vis height-for-age and BMI-for-age Z-score (hereafter HAZ and BMI-Z, respectively) in the sample countries. The study reveals that children with early access

[3]Also see Currie and Almond (2011); Nores and Barnett (2010); Tanner et al. (2015)

[4]Math test scores are present in the YLS from round 3 onward. Perhaps math test scores were ignored because Dearden et al. (2017a) considered only the association with the outcomes when the children were aged 5 and 8. Nonetheless, this would have been considered at the age of 8.

to improved toilets had a 50% lower risk of stunting during the same period compared to those without access. This difference persisted when the children reached ages 5 and 8, regardless of control variables.

On the other hand, Cameron et al. (2021) utilize village fixed effects and community controls to account for confounding factors. They find that children with access to improved sanitation facilities from conception to 24 months of age in Indonesia have a significantly lower risk of stunting, by 4-5 percentage points (hereafter pp), compared to their counterparts without access to such facilities. They also find evidence of community spillovers, where children residing in open defecation-free communities have a 12-15 percentage point lower likelihood of stunting later in life. Cameron et al. (2021) also report that having access to sanitation facilities, irrespective of quality, is associated with a 3.2 percentage point improvement in long-term cognitive performance.

This investigation builds on the literature by offering a unique contribution addressing some of the gaps in previous research. The main contribution of this paper is the utilization of a longer distinctive longitudinal dataset (unlike the shorter panels in Dearden et al. (2017a,b)) that tracks children's cognitive development after exposure to improved sanitation from approximately 1 to about 15 years old. This approach allows for the dynamic monitoring of children's performance in school, which is essential because it allows for early identification of issues, individualized support, progress tracking, intervention planning, and parental involvement. Secondly, the current study also expands on previous research by considering both vocabulary and math test scores as developmental outcomes and exploring underlying mechanisms via health. Understanding these mechanisms provides insights into the potential pathways through which WASH interventions may improve child development. Thirdly, the methodology in the study appreciates the nested nature of the data and employs a more robust model, the hierarchical linear model (HLM) (Matsuyama, 2020; Sullivan et al., 1999), to study potential community spillover effects. The implication of ignoring the nested structure of the observation with traditional regression (e.g., OLS) is biased standard errors and incorrect inference and additionally, the analysis requires estimation of 'group effects' of community-level variables. Finally, this study seeks to overcome the limitations of the

WHO/UNICEF definition of improved sanitation by employing a categorical variable with four distinct categories: flush toilets, latrines (shared and private), open defecation, and “other." The study’s overall objective is to address gaps in the existing literature and enhance our understanding of the relationship between WASH and child outcomes. Also, the findings will advance knowledge, inform policy, and guide future research on the topic.

This empirical study investigates the relationship between early childhood access to sanitation and cognition, focusing on understanding the underlying mechanisms through health in Peru, India, Vietnam and Ethiopia. The methodological approach includes the application of ordinary least squares (OLS) regression analysis with a country-community fixed-effects specified and the hierarchical linear model(HLM). The HLM framework allows for examining of potential community spillovers while accounting for unobservable community and country-invariant factors. The study utilizes individual-level sanitation treatment variables from 2002 (round 1), when the sample children were aged between 6-18 months old, and examines the outcomes (test scores, height, and BMI) in subsequent survey rounds conducted between 2006 and 2015 (rounds 2 to 5) when the same children were aged between 8 and 15 years old. I control for the child- and household-level characteristics. Additionally, to test for the possibility of the effects of community spillovers with HLM, the study incorporates community leaders’ survey responses about community-level sanitation.

The empirical results indicate that early access to flush toilets and pit latrines across all countries is significantly associated with higher vocabulary and math scores later in life after controlling for community unobservable factors. Specifically, early access to flush toilets is positively correlated with higher PPVT scores at ages 5, 8, 12, and 15 years old (confirming Dearden et al. (2017b)) and is associated with increased math scores at ages 8, 12, and 15 years old (also confirming Dearden et al. (2017a)). Similarly, early access to pit latrines is positively associated with higher vocabulary scores at ages 8 and 15 and significantly higher math scores at age 8, persisting into age 12, but the relationship dissipates by age 15. The findings also suggest that early access to flush toilets is significantly more important for contemporary vocabulary and math scores,

although the results vary across countries. Additionally, the results indicate that early access to flush toilets and pit latrines, compared to open defecation, is positively associated with children's health indicators. Additionally, the inquiry provides strong evidence of community spillovers, primarily in vocabulary rather than math skills.

The structure of this study is as follows: Section 1.2 presents the conceptual framework of the relationship between sanitation and cognitive outcomes. Section 1.3 provides an overview of the data used in this study, including descriptive statistics. Section 1.4 describes the empirical methodology and the estimation strategy employed. The findings of the analysis are presented and discussed in Section 1.5. Lastly, Section 1.6 summarizes the main results and concludes the investigation.

1.2 Conceptual framework

In theory, BMI and health in childhood can impact cognition through various mechanisms, including nutrition, physical activity, sleep, the environment and psychosocial support. BMI-for-age and height-for-age are growth indicators commonly used in assessing children's physical development. Adequate nutrition is essential for optimal brain development (Currie and Almond, 2011; Nores and Barnett, 2010; Tanner et al., 2015), and poor diet, low BMI or low Height-for-age can impair cognitive function (Deaton, 2007). Regular physical activity promotes cognitive abilities (Zeng et al., 2017; Best, 2010). However, a higher or lower BMI may be associated with decreased physical activity levels, with a moderate BMI generally being more favorable (Kahn et al., 2008). Additionally, psychosocial factors related to higher BMI may influence self-esteem and indirectly impact cognition (Lowry et al., 2007). Sleep disturbances, often associated with higher BMI, can impair cognitive performance (Paavonen et al., 2010). It is important to consider that individual-specific factors like genetics and environment also play a role (Wade et al., 2014). Nonetheless, promoting a healthy lifestyle with proper nutrition, physical activity, sleep, and psychosocial support can optimize childhood cognition.

The socioeconomic environment at the household or community level during the early years of children's lives is a critical determinant of early childhood development (ECD), and it is a vital component that helps shape the trajectory of children's cognition and physical health development at later stages of life. During the early years, children are developing and updating their internal 'brain software,' and those periods are critical in brain development (Currie and Almond, 2011; Nores and Barnett, 2010; Tanner et al., 2015). Therefore, access to different household or community level services early in the life of children plays a significant role in their overall development, which has profound consequences for later life outcomes. Studies have shown that early-life access to sanitation services can impact cognitive outcomes by influencing health-related factors as potential causal pathways (Wolf et al., 2014; Sclar et al., 2017).

Figure 1.1 shows a conceptual framework of these potential pathways. Not having toilets early in children's lives at the household, community, or school level implies that people have to find alternatives, such as open defecation practices. Open defecation at the household or community level leads to externalities and pollution. Such externalities and poor hygiene lead to a high fecal contamination risk in communities. If human waste is exposed to people, their food, or drinking water, the expectation is that sanitation-related infectious diseases will spread, especially to children. The high disease burden during the early parts of children's lives implies that their general health and nutritional uptake will be low. The low dietary uptake and poor general health affect children's weight and height (Deaton, 2007). Therefore, the expectation is a positive association between good sanitation and height-for-age z-score and BMI-for-age z-score (arrow (1)).

In addition, open defecation and the subsequent search for suitable open spaces may lead to detrimental consequences, including assaults (especially among women). This not only compromises their safety but also consumes valuable time that could be allocated to other activities, potentially resulting in children missing out on school. This absenteeism is particularly pronounced among girls, leading to potential disruptions in their education. (Dasra, 2012). Additionally, not having toilets at the school level further discourages children (especially teenage girls) from attending

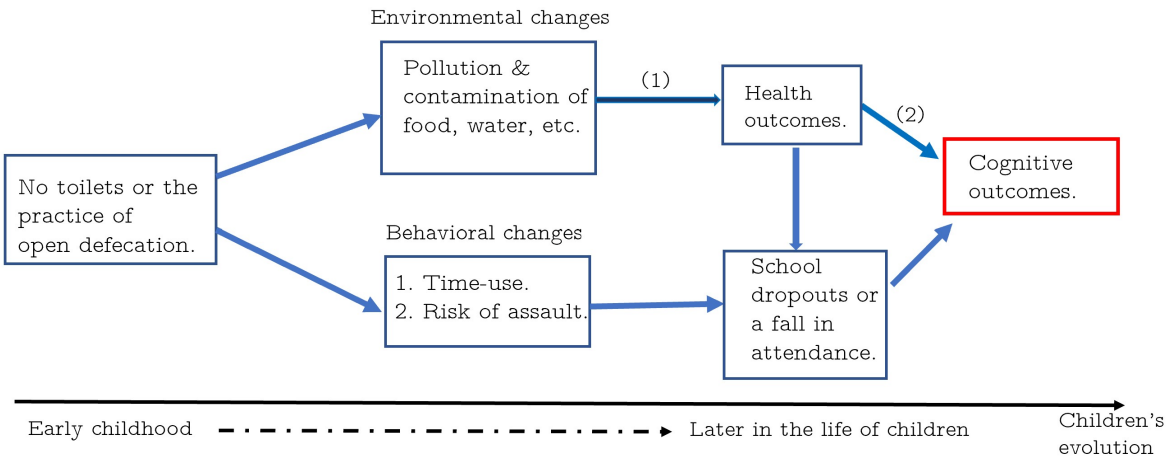

Figure 1.1. Lack of toilets early in life and later life outcomes

Source: Adaptation from Dasra (2012); Dearden et al. (2017b,a). This figure provides a graphical illustration of the conceptual understanding of the effect of poor sanitation. The figure indicates that if toilets are not available at home, school, or in the community early in the lives of children, the spillover of their absence tends to be related to health and cognition later in life. The association between early and later life outcomes happens through externalities, pollution, or sibling effects.

school, which may affect the younger one's cognitive development via sibling effects. The relationship between health and cognition is multifaceted, with potential direct and indirect pathways. On the one hand, health can directly impact cognition (represented by arrow (2)). On the other hand, health can indirectly influence cognition by affecting schooling (represented by arrows (3) and (4)). And poor sanitation, as an aspect of health, affects educational progress directly as well. This investigation is essential because early life conditions may impact later life outcomes such as labor market productivity or psycho-social development. Therefore, the conceptual framework for this study hinges upon the premise that early childhood access to adequate sanitation facilities should improve children's cognitive outcomes later in life. The health mechanism would subsequently be expected to be confirmed by a significant positive relationship between sanitation and health indicators such as height-for-age or BMI-for-age.

1.3 Data

This paper uses data from the Young Lives Study (YLS), a unique and extensive longitudinal study that offers valuable insights into the interplay of childhood development, education, and

poverty dynamics. The study follows 12,000 children in 20 communities in each of the four low- and middle-income countries: Ethiopia, India (Andhra Pradesh and Telangana), Peru, and Vietnam. The composition of these children is nearly 8,000 individuals born in 2001–2002 and 4,000 individuals born in 1994–1995 (Sánchez and Escobal, 2020). As of round 1 of the survey (2002), the younger cohort was aged between 6-18 months old, while the older cohort was between 7-8 years old and each country had 1000 older cohort children and 2000 younger cohort children (Barnett et al., 2013). This study focuses on the 2000 younger cohort of children for each country in the sample. These children are followed for over fifteen years of data collection for both cohorts (younger and older cohorts). The University of Oxford coordinates the collection of the YLS data at regular intervals with the support of the Department for International Development in collaboration with partners from leading national research institutes, government statistics departments, and Save the Children (Barnett et al., 2013).

The YLS was intended to collect rich information on children's development (including cognition), demographic, education, household and community-level characteristics to examine multiple and interlinked dimensions of child poverty (Wilson et al., 2006). However, due to national poverty-related priorities and budgetary and logistical issues, the sampling design employed by the YLS is a sentinel site sampling approach. The YLS teams selected 20 sites (communities) in their respective countries in this approach (Outes-Leon and Sanchez, 2008; Kumra, 2008a; Escobal and Flores, 2008; Nguyen, 2008). Rural areas were over-sampled across all countries. In each sentinel site, the YLS team identified and randomly selected 150 households with a child of the required age to create the younger and older cohort. Of the 150 randomly selected households in each site, 50 were related to households with older cohorts, while 100 were to the younger cohort. Therefore, since 2001, approximately two thousand (2000) Young Lives (hereafter YL) children are followed in each country, and the YL children are aged between 6 and 18 months at the baseline survey wave and were approximately 15 years old by the 2016 survey wave 5 (Barnett et al., 2013).

The YLS has certain limitations though the risks to external validity due to the limitations are low. Firstly, despite oversampling rural areas, the sample is representative of regions, policy

contexts, living conditions, and rural-urban divide in each of the four countries. This representativeness has been corroborated by different nationally and internationally recognized surveys, including the demographic and health surveys (DHS), the wealth monitoring surveys (WMS), and living standard measurement surveys (LSMS) (Barnett et al., 2013). Moreover, the YLS team ensured that the attrition rates were kept very low in the YLS, ranging between 2.2% and 5.7% due to country teams' retention strategies, with most attrition attributed to household mobility (Barnett et al., 2013). It is acknowledged that the cumulative attrition or loss of participants observable in most panel data setups has the potential to bias the inferences from such data because of possible correlations with observable characteristics and sample selection (Outes-Leon and Dercon, 2009). However, Sánchez and Escobal (2020), found that the cumulative year-to-year attrition rates of 0.5% and 0.8% for the younger and older cohorts, respectively, in the YLS are among the lowest attrition rates in longitudinal studies in low- and middle-income countries.

1.3.1 Treatment and outcome variables

The treatment variables in this study are individual-[5] and community-level improved sanitation. According to the WHO/UNICEF Joint Water Supply and Sanitation Monitoring Programme (2015), improved sanitation facilities are defined as "those that hygienically separate human waste from human contact." The WHO definition has the connotation that all shared or public-use sanitation facilities should not be considered improved. In addition, all flush or pour-flush that disposes of waste elsewhere other than the sewerage system, pit latrines without slabs or open pits, bucket latrines, hanging latrines, or open defecation are all not considered to be improved sanitation.

However, drawing upon experiences from different regions worldwide and employing rigorous statistical analyses such as bivariate and multivariate logistic regressions, Massa et al. (2017) and Rheinländer et al. (2015) provide a compelling argument against the definition provided by WHO/UNICEF Joint Water Supply and Sanitation Monitoring Programme (2015) regarding the classification of improved sanitation facilities. They argue that having a non-shared latrine is not

[5]Here, individual-level is the same as household-level since only one child in the household is the primary unit of analysis.

important because it does not guarantee the safety or categorization of being 'improved.' Instead, what matters more is the construction technology used for these facilities and the behaviors of its users. They also argue that the current definition by the WHO/UNICEF Joint Water Supply and Sanitation Monitoring Programme (2015) fails to recognize the importance of these aspects, thereby overlooking the diverse nature of sanitation practices. This is because shared would mean specific groupings, including shared facility by household (i.e., sharing between a limited number of households who know each other), public toilets (i.e., for a transient population, but often the main sanitation facility for poor neighborhoods) and institutional toilets (i.e., at workplaces or markets). These studies highlight the need for a revised definition that considers sanitation diversity, emphasizing the importance of construction techniques and user behaviors. A shift in focus toward these factors will lead to a more informed evaluation and deeper understanding of effective sanitation practices.

Therefore, with this diversity of toilet facilities and following debates about the need to rethink the definition of what constitutes improved sanitation by the WHO definition, I create a categorical variable to represent sanitation or ways in which people relieve themselves with four categories: flush toilet, latrines (whether shared or not), open defecation or "other"[6]. I argue that this less restrictive definition is appropriate, especially for low- and middle-income countries. The treatment variables for the community-level analysis consist of early access to sanitation at both the household and the community levels. In addition to child and household questionnaires, the YLS also has a community questionnaire that complements the former. The community questionnaire is administered to key informants of the community, including community leaders, teachers, and health workers (Barnett et al., 2013). At the community level, the treatments are community flush toilets (CFT_{j1}) which takes on the value 1 if the community j has access to flush toilets[7] in round 1 and 0 otherwise; community pit latrines (CPL_{j1}) takes on the value 1 if the community j uses pit

[6]The survey questionnaires do not clearly indicate what constituted the "Other" category. Therefore, I kept that category separate without merging with flush toilets, latrines (whether shared or not), or open defecation categories.

[7]The survey question to community leaders was: *What are the main kinds of toilet facilities 'name of community' uses?*

latrines in round 1 and 0 otherwise; and community open defecation (COD_{j1}) takes on the value 1 if the community j uses open defecation practices in round 1 and 0 otherwise.

Table 1.1 shows the summary statistics of the different sanitation categories across countries at the baseline survey in 2002. In Ethiopia, flush toilet facilities were observed in only 1.2% of households and 8.3% of communities. Comparatively, India, Peru, and Vietnam exhibited higher household (community) access rates at 18.5% (36%), 44% (63%), and 22% (65%), respectively. Therefore, these findings indicate that in 2002, only a small share of households and communities had flush toilet facilities in Ethiopia, with the highest household-level percentage being in Peru. However, at the community level, Vietnam displayed the highest access. Household-level access rates were similar in India and Vietnam.

Table 1.1. Means of sanitation (individual and community), height- and BMI-for-age

	Ethiopia	India	Peru	Vietnam
Household Flush Toilets	0.012	0.185	0.442	0.220
Household Pit Latrines	0.368	0.113	0.344	0.272
Household Open Defecation	0.578	0.694	0.189	0.356
Household Other	0.043	0.005	0.026	0.152
Community Flush Toilets	0.083	0.363	0.625	0.647
Community Pit Latrines	0.605	0.422	0.850	0.329
Community Open Defecation	0.789	0.607	0.562	0.554
Height-for-age Z-score	-1.536	-1.301	-1.302	-1.116
	(1.851)	(1.481)	(1.297)	(1.256)
BMI-for-age Z-score	-0.629	-1.020	0.751	-0.401
	(1.450)	(1.135)	(1.186)	(0.963)
Observations	1999	2011	2052	2000

Notes: The statistics in the table are the authors' compilation from the YLS survey wave of 2002 when children were between 6 and 18 months old. The values in parentheses are standard deviations, and the rest are means. Individual-level access is as good as household-level access since the child represents the household. The summary statistics for vocabulary and math test scores are omitted from the table since, as standardized variables, they roughly all have a mean of 0 and a variance of 1. Height-for-age and BMI-for-age z-score are restricted, and an explanation is provided under the outcome variables subsection below.

In terms of pit latrine usage, the data reveals varying percentages for households (communities) in the four countries when the children in the sample were infants. Specifically, rates for households (communities) in Ethiopia, India, Peru, and Vietnam were 37% (61%), 11% (42%), 34% (85%),

and 27% (33%) when the children in the sample were 6-18 months old. At the household level, Ethiopia, Peru, and Vietnam exhibited relatively higher rates of access to pit latrines than India. However, at the community level, Peru and Ethiopia had substantially higher access rates to pit latrines at 85% and 61%, respectively, than India (42%) and Vietnam (33%). Shifting the focus to rates of open defecation, summary statistics in the table show that at the household (community) level, these were 58% (79%), 69% (61%), 19% (56%), and 36% (55%) in Ethiopia, India, Peru and Vietnam, respectively. At the household level, India had the highest rates of open defecation, while Peru had the lowest. At the community level, Ethiopia had the highest share of open defecation, with Vietnam having the lowest percentage.

To observe children's health and cognitive outcomes over time, the BMI-for-age z-score (BMI-Z), height-for-age z-score (HAZ), and cognition test scores are used. This paper uses the constructed BMI-Z and HAZ present in the YLS (Briones, 2018) data following the widely used growth standards for children below the age of five as per world health organization (WHO) recommendation (Jayachandran and Pande, 2017; WHO Multicentre Growth Reference Study Group and de Onis, 2006). Table 1.1 shows the baseline summary statistics for BMI-Z and HAZ[8]. Compared to the WHO reference population, all children included in the sample exhibit below-average height. Ethiopian children have the shortest average height, while Indian and Peruvian children have similar average heights. Vietnamese children are the tallest. Regarding BMI, Ethiopian, Indian and Vietnamese children have an average BMI that is lower than the WHO reference children population, whereas Peruvian children have a higher BMI. Additionally, the study uses vocabulary and math test scores. However, since the PPVT test scores are only available from rounds 2 to 5, I restrict the analysis for the vocabulary scores to the sample period between 2006 and 2016. On the other hand, the math scores are only available from round 3, hence the analysis restriction to rounds between 3 and 5.

[8]I do not show the summary statistics for PPVT and math test scores because they are standardized variables making their means and standard deviations equal to 0 and 1, respectively.

1.3.2 Control variables

For control variables, the present study employs household and child-level characteristics, including gender, wealth features, parents' education, child's age and whether a child is enrolled in school to examine their influence on the investigated vocabulary, math and health outcomes. Additionally, to address the potential influence of unobservable time-invariant community characteristics, the investigation incorporates community-fixed effects as a methodological strategy for control. Furthermore, the YLS data set has a constructed wealth index which is composed of the consumer durable index (CDI), housing quality index (HQI), and access to services index (ASI). The wealth index serves as a crucial tool for assessing household poverty status, as it assigns households in the YLS a position on a continuous scale. Higher values on this scale indicate greater household wealth. The wealth index is computed as an equally weighted average of three key indicators: CDI, HQI, and ASI (Briones, 2017). However, in order to account for the socioeconomic statuses of households, the wealth index is not employed in its entirety. This decision is made due to the fact that the access to services index (ASI), which is a component of the wealth index, encompasses various dimensions such as electricity quality, cooking fuel quality, drinking water quality, and sanitation quality. The exclusion of ASI avoids multicollinearity, imprecise estimators, and overstated standard errors (see Greene (2018, pp 93-97)). Therefore to avoid correlations with the treatment variable, the investigation does not control for the services index but instead only controls for housing quality and consumer durable index.

Table 1.2 shows summary statistics of select[9] control variables by survey waves across all countries. The housing quality index and durable consumer indexes, which are proxies for socioeconomic status, have increased over time across the five survey waves and countries. The gender of the children has relatively stayed the same, with boys (about 52%) being slightly more than girls (about 48%).

The average age of the YL children in round 1 was almost one year (11 months); by round five, the average age of the children was 15 years old (180 months). Most children were enrolled

[9]Other control variables are in the Appendix.

Table 1.2. Means of some of the controls by survey waves across for all country

	Round 1	Round 2	Round 3	Round 4	Round 5
Housing quality index	0.418	0.452	0.515	0.531	0.556
	(0.289)	(0.273)	(0.280)	(0.250)	(0.248)
Consumer durables index	0.226	0.308	0.389	0.442	0.468
	(0.209)	(0.308)	(0.232)	(0.217)	(0.224)
Gender of YL child	0.481	0.480	0.480	0.480	0.479
	(0.500)	(0.500)	(0.500)	(0.500)	(0.500)
YL child's Age in months	11.663	63.173	96.090	131.231	180.678
	(3.446)	(4.157)	(3.944)	(22.491)	(3.915)
Enrolled in School			0.935	0.972	0.907
			(0.247)	(0.166)	(0.291)
Observations	8062	7795	7720	7625	7536

Notes: The statistics in the table are the authors' compilation from across the YLS survey waves 1-5 for all countries. The values in parentheses are standard deviations. The school enrollment is not available in rounds 1 and 2: the children were aged 1 and 5 years old and most likely not enrolled in schools. Individual-level access is as good as household-level access.

in school in round 3 (93.5%), which further picked up in round 4 (97.2%) but then dropped in round 5 (90.7%). This may be because many 11–14-year-old adolescents are not progressing into the second cycle of primary education due to grade repetition or dropout (Sabates et al., 2010). Summary statistics of parent's education[10] shows more mothers have no education (28.9%) compared to fathers (15.8%). On the other end of the spectrum, more fathers (40.7%) have education above 8^{th} grade compared to mothers (30.3%).

1.4 Econometric models

The main objective of this study is to examine the association between early childhood exposure to improved sanitation and children's development, specifically in terms of vocabulary, math, HAZ (height-for-age z-score), and BMI-Z (body mass index z-score). To understand when these associations emerge and whether they persist over childhood, separate regressions are conducted for each survey round. Specifically, the analysis estimates the following community-country fixed

[10]The summary statistics of the parents' education are included in Appendix Table A.1.

effects model:

$$\mathrm{Y}_{ijt} = \beta_0 + \beta_1 \mathrm{ISF}_{ij1} + \beta_2 \mathrm{ISF}_{ijt} + \alpha \boldsymbol{X}_{ij1} + \gamma \boldsymbol{X}_{ijt} + \eta_j * \tau_c + \varepsilon_{ijt} \tag{1.1}$$

In Equation 1.1, Y_{ijt} represents standardized scores for vocabulary, math, HAZ, or BMI-Z of child i in the community j during survey round t.[11] The vocabulary and math scores data are available only from rounds 2 and 3. Therefore, the standardized PPVT scores regressions run for $t = 2, \ldots, 5$ while for the math scores regressions, they run for $t = 3, \ldots, 5$. The exposure variable is represented by ISF_{ij1} and ISF_{ijt} which are categorical sanitation facilities variables in round 1 and in the respective contemporaneous rounds for respective countries. The model also includes control variables represented by $\boldsymbol{X}_{ij1}$ and $\boldsymbol{X}_{ijt}$ which are vectors capturing child-level and household-level characteristics in round 1 and in the contemporaneous rounds, respectively. The investigation includes the community-country fixed effects (η_j), with the subscript j unique across each community, to account for unobserved heterogeneity across communities within each country and across different countries, i.e., to capture how the impact of sanitation or other factors vary within and between communities and countries. The coefficients α and γ are vectors of coefficients for the control variables.

Additionally, the study investigates the role of community spillovers on children's outcomes. That is, seeing if community access has spillover effects on children (even if the child themselves does not have access), which may happen due to better hygiene practices or reduced disease transmission. Following Cameron et al. (2021), the paper investigates whether community spillovers play a role in enabling children's later life outcomes. Naively, the investigation would directly use community flush toilets (CFT), community pit latrines (CPL), and community open defecation (COD), which are all dummy variables as additional treatments. Therefore, the estimated model for community spillovers would be given by Equation 1.2:

$$\mathrm{Y}_{ijt} = \rho_0 + \rho_1 \mathrm{ISF}_{ij1} + \rho_2 \mathrm{ISF}_{ijt} + \rho_3 \mathrm{CFT}_{j1} + \rho_4 \mathrm{CPL}_{j1} + \rho_5 \mathrm{COD}_{j1} + \lambda \boldsymbol{X}_{ij1} + \xi \boldsymbol{X}_{ijt} + \varepsilon_{ijt} \tag{1.2}$$

[11] That is, wave t=1=2002, wave t=2=2006, wave t=3=2009, wave t=4=2013 and wave t=5=2016.

Here all variables except CFT_{j1}, CPL_{j1} and COD_{j1} are defined as before. The variables CFT_{j1}, CPL_{j1} and COD_{j1} are each dummy variables. λ and ξ are vectors of coefficients for the control variables. However, such a community-level analysis would not sufficiently control for unobservable community-level characteristics.

In other words, this modeling technique to estimate the effect of community-level covariates (CFT, CPL and COD) on child-level outcomes (vocabulary scores, math scores, and HAZ/BMI) ignores the idea that individuals are nested at the community level, which are, in turn, also nested at the country level. In Equation 1.1, this 'clustering effect' was accounted for by including a vector of fixed intercepts for the community (η_j). Doing this for Equation 1.2 would be insufficient since we are interested in assessing community spillovers. To control for unobserved community heterogeneity based on the assumption that the community-level covariates would account for community differences, a different model is applied: hierarchical linear models (hereafter HLM),[12] can handle these hierarchical data structures (Sullivan et al., 1999; Matsuyama, 2020). HLMs are useful as they introduce a random intercept for community-level heterogeneity in the model when estimating the fixed effects of community-level covariates. Therefore, the fixed effects HLM model used in this study is shown in Equation 1.3:

$$\text{Y}_{ijt} = \theta_0 + \theta_1 \text{ISF}_{ij1} + \theta_2 \text{ISF}_{jt} + \theta_3 \text{CFT}_{j1} + \theta_4 \text{CPL}_{j1} + \theta_5 \text{COD}_{j1} + \lambda \boldsymbol{X}_{ij1} + \xi \boldsymbol{X}_{ijt} + \delta_j + \tau_c + \varepsilon_{ijt} \quad (1.3)$$

Here Y_{ijt} is the outcome variable for child i in the community j at time t. All the other variables except δ_j and τ_c are defined as before. δ_j represents the random effect of community j, capturing the deviation of community j from the overall mean intercept. τ_c represents the fixed effect of country c, capturing the deviation of country c from the overall mean intercept. This allows for the estimation of the correlations with the outcome variable while accounting for the nesting structure of the data. The HLM approach assumes that the random error term (ε_{ijt}) is normally distributed with a mean of zero and constant variance (Sullivan et al., 1999; Matsuyama, 2020).

[12] These models are also known as multi-level linear models, nested models, mixed linear models or covariance components models (Sullivan et al., 1999; Matsuyama, 2020).

For the model in Equation 1.1, the expectations concerning the relevant[13] coefficient, β_1, is that it will be positive and for the community-country-level analysis in Equation 1.3, the expectations of θ_3 and θ_4 are that they are also positive. However, the expectation of the sign for θ_5 is that it should be negative. I hypothesize this because, with improved sanitation, I expect the benefits of working through the health channel to provide dividends for the cognitive test scores, HAZ and BMI-Z. To account for the hierarchical structure of the data, the standard errors for the pooled regressions across countries are clustered at the community level, ensuring robustness to intra-group correlations. Additionally, for individual countries, the standard errors are robust to heteroskedasticity.

1.5 Results

The results of this study are presented in two parts: the first considers the core results of the relationship between early childhood access to sanitation and later life outcomes using community-fixed effects to control for time-invariant community-level heterogeneity. The order of discussion is by first presenting the results for all countries in the sample and then moving on to the results disaggregated by individual countries. This is done first for cognitive and math outcomes and then for the relationship between early access to sanitation, height, and BMI for the children in the sample. The second part considers community-level analysis, where I add community-level dummy variables as additional treatment variables derived from the community surveys.

1.5.1 Controlling for community heterogeneity

Table 1.3 shows the relationship between early childhood access to sanitation and test scores between 2001 and 2016 pooled over all countries while controlling for the community fixed effects and child- and household-level characteristics. Compared to open defecation, access to flush toilets early in the child's life (between 6 and 18 months old) has a significant positive relationship with

[13]The coefficient β_2 is also relevant although I focus on β_1 when the children are in their infancy stages of life in line with the literature on early childhood exposure.

later life cognitive scores when children are 5, 8, 12, and 15 years old. The study findings provide compelling evidence of a significant association between early-life access to flush toilets and higher vocabulary scores. On average, this is reflected in a significant association with higher vocabulary scores by 0.15 standard deviations (sd) (column 1), 0.11 sd (column 2), 0.10 sd (column 3), and 0.12 sd (column 4) as children progress from the ages of 5, 8, 12, and 15, respectively. Furthermore, a similar significant association is observed for math scores, where flush toilets, compared to open defecation, are linked to higher math scores by between 0.08 sd and 0.11 between 2009 (at age 8) and 2016 (at age 15), respectively. These findings underscore the persistent positive relationship between early childhood access to flush toilets and cognitive outcomes, specifically vocabulary and math test scores, spanning from the age of 5 to 15. The persisting impact highlights the pivotal role of early access to flush toilets in enhancing test scores throughout the formative years and adolescence.

Table 1.3. Regressions of cognitive outcomes on wave 1 treatments: All Countries

	PPVT Scores				Math Scores		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	R2	R3	R4	R5	R3	R4	R5
Flush Toilet R1	0.15***	0.11**	0.10*	0.12*	0.11*	0.10**	0.08**
	(0.05)	(0.04)	(0.05)	(0.06)	(0.05)	(0.05)	(0.03)
Latrines R1	0.06	0.07**	0.07	0.10**	0.05*	0.07*	0.02
	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)
Other R1	-0.00	-0.04	0.05	0.07	0.08*	0.09	0.01
	(0.05)	(0.06)	(0.07)	(0.04)	(0.04)	(0.06)	(0.04)
Community FE	YES	YES	YES	YES	YES	YES	YES
Observations	6907	6942	6832	6642	7011	6726	6728
Adjusted R^2	0.405	0.371	0.360	0.293	0.382	0.293	0.279

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

Notes: Table 1.3 shows the main regression results. R1, R2, R3, R4, and R5 stand for rounds 1, 2, 3, 4, and 5, respectively. The treatment variable is a categorical variable of sanitation equal to 1 if a household has flush toilets, 2 if it has pit latrines (in the household and shared), 3 if they use open defecation and 4 for "other" forms. The outcomes are the Peabody Picture Vocabulary Test and math test scores. The controls in these regressions are the YL child's gender, parent's education, a dummy variable for the child's school enrolment status, the YL child's age, and both early and concurrent individual sanitation, housing quality index, and durable consumer index.

The presence of pit latrines, compared to open defecation, also demonstrates a significant positive correlation with vocabulary and math test scores later in life. Specifically, when a child is 1 year old, having access to pit latrines shows a significant and positive relationship with vocabulary and math scores at the age of 8, 12 and 15, on average. Math test and vocabulary scores are both expected to be respectively higher by 0.07 and 0.05 sd (columns 2 & 6). These results seem to endure to age 15 for vocabulary and age 12 for math. However, the results for vocabulary (at age 12) and math (at age 15) are not significant but have expected signs. Additionally, the impact of the “other" sanitation category, compared to open defecation, is largely non-significant, except for its association with math scores at 8 years old. Early childhood access to the “other" sanitation category is associated with significantly higher math test scores by 0.08 sd (column 5) at 8 years old. Comparing the results of Table 1.3, it becomes evident that the strength of the relationship between early access to sanitation and later-life vocabulary and math test scores is more pronounced for flush toilets in comparison to latrines or the “other" category.

Table 1.4 provides a breakdown of the results presented in Table 1.3 focusing on individual countries. The analysis below sequentially explains the relationship between the type of toilet (with open defecation as the comparison) and the corresponding outcomes for the four countries under investigation. Firstly, let’s consider vocabulary scores across all panels. The availability of flush toilets during early childhood, as opposed to practicing open defecation, shows a significant positive relationship with later life vocabulary outcomes in Vietnam, Peru and India (Panels A, B and D, respectively). On average, early access to flush toilets is linked to significantly higher vocabulary scores when children are 5 years old by 0.18 sd and 0.23 sd (column 1) in Peru and India, respectively. Furthermore, the findings demonstrate that the positive relationship between flush toilets and vocabulary scores persists only in India. That is, in India, early access to flush toilets is also associated with significantly higher vocabulary scores when children are 15 years old by 0.25 sd (column 4). However, in Ethiopia, flush toilets appear to have a significant negative relationship with vocabulary scores at age 5 years and persist to age 8. This could be due to other factors not captured in this model.

Next, let's explore the implications for math scores across the different panels. In Vietnam and India (Panels A and D, respectively), there is a significant positive association between early access to flush toilets and later math outcomes. On average, children in Vietnam with early access to flush toilets are associated with significantly higher math scores at the age of 12 by 0.22 sd (column 6). Similarly, in India, the availability of flush toilets during early childhood is linked to significantly higher math scores at the age of 5 by 0.21 sd (column 5). The findings highlight the positive association between early access to flush toilets and vocabulary and math scores in Vietnam, Peru, and India. However, it is important to note the contrasting negative relationship observed in Ethiopia, suggesting the potential presence of other unaccounted factors influencing the results. Another possible explanation for this observation is that very few households (1.2%) in Ethiopia had access to flush toilets when the children were aged 6-18 months old (see summary statistics in Table 1.1)

Contrarily, the association of pit latrines during early childhood with later life vocabulary and math outcomes in Vietnam and Peru (Panels A and B) appears to be less significant. Specifically, the availability of pit latrines during early childhood shows a positive correlation with math scores at the age of 8 in Vietnam and at the age of 12 in Peru. This implies that early access to pit latrines is associated with significantly higher math scores by 0.11 sd in Vietnam (column 5) and 0.15 sd in Peru (column 6). Notably, pit latrines are only associated with higher vocabulary scores in Peru when children reach the age of 15. That is, in Panel B, vocabulary scores are significantly higher by 0.14 sd (column 4). However, in Ethiopia and India, pit latrines do not demonstrate a significant relationship with either vocabulary or math scores. These findings shed light on the varying influence of pit latrines on cognitive outcomes in different countries.

Early access to the "other" category, when compared to open defecation, demonstrates a negative relationship with children's scores at different ages across several countries. In Peru, this negative association is observed at the age of 5 years, resulting in significantly lower scores by 0.26 sd (column 1). Similarly, in both Ethiopia and India, the negative relationship becomes apparent at the age of 8 years, leading to lower scores by 0.21 sd and 0.55 sd, respectively (column 2).

Table 1.4. Regressions of cognitive outcomes on wave 1 treatments: By Country

	PPVT Scores				Math Scores		
	(1) R2	(2) R3	(3) R4	(4) R5	(5) R3	(6) R4	(7) R5
Panel (A): Vietnam							
Flush Toilet R1	0.02	0.03	0.23***	0.03	0.04	0.22***	0.09
	(0.10)	(0.08)	(0.08)	(0.09)	(0.08)	(0.08)	(0.09)
Latrines R1	0.09	0.09	0.10	0.06	0.11*	0.08	0.02
	(0.06)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
Other R1	0.06	-0.01	0.14**	0.10	0.09	0.10	-0.01
	(0.07)	(0.06)	(0.06)	(0.07)	(0.06)	(0.07)	(0.07)
Observations	1692	1754	1838	1819	1827	1797	1810
Panel (B): Peru							
Flush Toilet R1	0.18**	0.13	0.06	0.10	0.11	0.05	-0.03
	(0.07)	(0.09)	(0.08)	(0.09)	(0.08)	(0.09)	(0.09)
Latrines R1	0.06	0.10	0.05	0.14**	0.09	0.15**	-0.00
	(0.05)	(0.07)	(0.06)	(0.07)	(0.07)	(0.07)	(0.06)
Other R1	-0.26**	0.04	-0.07	0.09	0.18	0.11	-0.09
	(0.13)	(0.13)	(0.13)	(0.13)	(0.15)	(0.14)	(0.13)
Observations	1630	1554	1571	1522	1593	1568	1545
Panel (C): Ethiopia							
Flush Toilet R1	-0.45**	-0.32*	-0.13	-0.17	-0.06	-0.09	0.16
	(0.20)	(0.19)	(0.11)	(0.11)	(0.19)	(0.19)	(0.21)
Latrines R1	0.05	0.07	-0.05	0.04	-0.01	-0.02	0.04
	(0.06)	(0.06)	(0.05)	(0.05)	(0.06)	(0.06)	(0.06)
Other R1	-0.00	-0.21*	-0.11	-0.04	-0.07	0.07	0.13
	(0.10)	(0.11)	(0.14)	(0.13)	(0.10)	(0.14)	(0.14)
Observations	1746	1745	1536	1483	1699	1518	1580
Panel (D): India							
Flush Toilet R1	0.23**	0.14	0.03	0.25***	0.21**	0.14	0.16
	(0.10)	(0.10)	(0.10)	(0.10)	(0.09)	(0.09)	(0.10)
Latrines R1	0.05	-0.07	0.08	0.11	-0.00	-0.02	-0.04
	(0.08)	(0.10)	(0.07)	(0.09)	(0.08)	(0.08)	(0.08)
Other R1	-0.37	-0.55***	-0.36	-0.54	-0.22	-0.07	-0.10
	(0.35)	(0.21)	(0.47)	(0.46)	(0.15)	(0.24)	(0.17)
Observations	1839	1889	1887	1818	1892	1843	1793
Community FE	YES	YES	YES	YES	YES	YES	YES

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

Notes: The table shows the main regression results. R1, R2, R3, R4, and R5 stand for rounds 1, 2, 3, 4, and 5, respectively. The treatment variable is a categorical variable of sanitation equal to 1 if the household has flush toilets, 2 if it has pit latrines (in the household and shared), 3 if they use open defecation and 4 for "other" forms of relief. The outcomes are the vocabulary and math test scores. The controls in these regressions are the YL child's gender, parent's education, a dummy variable for the child's school enrolment status, the YL child's age, and both early and concurrent individual sanitation, housing quality index, and durable consumer index. All estimations for each of the countries have community-fixed effects.

Furthermore, in Vietnam, a significant negative relationship between early access to the "other" category and scores is observed at the later age of 12 years. Although these associations tend to become statistically insignificant as children grow older, they still retain negative and considerable magnitudes, particularly in the case of India.

1.5.2 Health mechanism

This investigation hypothesizes that having access to better sanitation improves children's health, and healthy children tend to perform cognitively better. This study aims to explore this hypothesis. The measurement of stunting or low height for age (HAZ) represents a child's accumulated health and nutritional experience (Deaton, 2007). As such, height and BMI serves as a determinant of a child's development trajectory, encompassing health, cognitive development, and future labor outcomes. The community fixed effects results pooled for all countries are presented in Table 1.5, and the disaggregated result by country are in Table 1.6.

1.5.2.1 Health outcomes over childhood

Table 1.5 presents the findings regarding the relationship between sanitation access, HAZ and BMI-Z for all countries combined. In comparison to open defecation, early childhood access to flush toilets and pit latrines demonstrates a significant positive association with children's HAZ, both at the time of measurement and in subsequent years. Specifically, early childhood access to flush toilets is linked to a significantly higher contemporaneous height-for-age by 0.18 sd (column 1) and 0.18 sd (column 1), respectively, during the 6-18 month period. This significant association persists for both flush toilets and pit latrines throughout the ages of 5, 8, 12, and 15 years, indicating that early access to these sanitation facilities is associated with consistently taller children. Notably, the magnitudes of the point estimates for the associations for flush toilets tend to be larger than those for pit latrines, suggesting a potentially greater link of flush toilets on children's height.

On the contrary, the analysis reveals noteworthy findings regarding the associations between early access to flush toilets and BMI-Z. The results demonstrate that significant relationships begin to emerge when children reach the age of 8 years and persist until the age of 12 years. Specifically, flush toilets exhibit a robust relationship with BMI-Z at these ages, indicating that children with early access to flush toilets tend to have significantly higher BMI by 0.13 sd (column 8) and 0.15 sd (column 9), respectively. In contrast, early childhood access to pit latrines and other forms of relief do not exhibit a significant relationship with BMI-Z, either contemporaneously or later in life, when compared to the reference category of open defecation.

Table 1.5. Regressions of height & BMI on household sanitation: All Countries

	Height-for-age					BMI-for age				
	(1) R1	(2) R2	(3) R3	(4) R4	(5) R5	(6) R1	(7) R2	(8) R3	(9) R4	(10) R5
Flush Toilet R1	0.18**	0.19***	0.14**	0.19***	0.09**	0.05	-0.00	0.13**	0.15*	0.07
	(0.06)	(0.05)	(0.06)	(0.06)	(0.04)	(0.07)	(0.06)	(0.06)	(0.08)	(0.07)
Latrines R1	0.18***	0.11**	0.10**	0.11**	0.11**	0.02	-0.02	0.03	0.03	-0.01
	(0.05)	(0.04)	(0.05)	(0.05)	(0.04)	(0.04)	(0.03)	(0.03)	(0.04)	(0.03)
Other R1	-0.09	0.01	-0.01	0.02	0.03	-0.11	-0.08	-0.08	-0.04	0.03
	(0.08)	(0.05)	(0.05)	(0.05)	(0.06)	(0.07)	(0.06)	(0.05)	(0.08)	(0.09)
Community FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	7213	7281	7135	7077	6844	7148	7279	7104	7067	6836
Adjusted R^2	0.166	0.226	0.209	0.229	0.144	0.324	0.374	0.401	0.429	0.358

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

Notes: R1, R2, R3, R4, R5 and FE stand for rounds 1, 2, 3, 4, 5, and fixed effects, respectively. The treatment variable is a categorical variable of sanitation equal to 1 if the household has flush toilets, 2 if they have pit latrines (in the household and shared), 3 if they use open defecation and 4 for "other" forms of relief. The outcomes are the height-for-age and BMI-for-age z-scores. The controls in these regressions are the YL child's gender, mother's education, father's education, a dummy variable for the child's school enrolment status, YL child's age, and both early and concurrent individual sanitation, housing quality index, and durable consumer index.

To further explore the findings presented in Table 1.5, the analysis in Table 1.6 provides a breakdown of the results by country, specifically focusing on the health indicators. For instance, the analysis reveals significant positive relationships between early access to flush toilets during childhood and later life height and BMI in Vietnam and Peru (Panels A and B, respectively).

In Vietnam, early access to flush toilets is consistently associated with significantly taller children by a range of 0.16 sd to 0.21 sd, emerging at age 5 and persisting until age 12 years. Similarly, in Peru, early access to flush toilets is strongly linked to significantly taller children ranging from 0.15 sd to 0.17 sd, emerging at the age of 5 and persisting until age 15. Furthermore, early access to flush toilets is associated with significantly higher BMI in both Vietnam and Peru. It is higher in Vietnam by between 0.20 sd and 0.33 sd, indicating a substantial positive association across various ages. In Peru, while the relationship is significant for ages 1 and 12, the associations for other ages are not statistically significant, although still positive in direction. In contrast, the relationship between access to flush toilets and health indicators in Ethiopia and India appears weaker. No significant associations are observed for height- and BMI-for-age, except for a significant relationship between early access and BMI among 12-year-olds in Ethiopia.

Table 1.6. Household sanitation, Height and BMI: By Country

	Height-for-age					BMI-for-age				
	(1) R1	(2) R2	(3) R3	(4) R4	(5) R5	(6) R1	(7) R2	(8) R3	(9) R4	(10) R5
Panel (A): Vietnam										
Flush Toilet R1	0.13	0.16*	0.17*	0.21**	0.09	0.11	0.20*	0.29**	0.33**	0.24*
	(0.10)	(0.09)	(0.10)	(0.10)	(0.09)	(0.09)	(0.10)	(0.13)	(0.13)	(0.12)
Latrines R1	0.14	0.09	0.05	0.08	0.05	0.06	0.01	-0.06	0.04	-0.06
	(0.10)	(0.07)	(0.07)	(0.08)	(0.07)	(0.08)	(0.08)	(0.09)	(0.10)	(0.09)
Other R1	-0.09	0.05	-0.01	0.04	0.01	-0.16*	-0.04	-0.10	-0.05	-0.01
	(0.09)	(0.07)	(0.08)	(0.08)	(0.07)	(0.08)	(0.08)	(0.11)	(0.11)	(0.10)
Observations	1907	1894	1841	1847	1821	1915	1896	1830	1847	1821
Panel (B): Peru										
Flush Toilet R1	0.13	0.17*	0.17*	0.11	0.15*	0.20*	0.06	0.16	0.20**	0.15
	(0.11)	(0.10)	(0.09)	(0.10)	(0.08)	(0.11)	(0.08)	(0.10)	(0.10)	(0.09)
Latrines R1	0.01	0.07	0.09	0.07	0.12*	0.11	0.06	0.15**	0.17**	0.16**
	(0.09)	(0.07)	(0.07)	(0.07)	(0.07)	(0.09)	(0.06)	(0.07)	(0.07)	(0.07)
Other R1	-0.22	-0.13	-0.11	-0.18	-0.16	0.20	0.03	0.02	0.26	0.21
	(0.17)	(0.16)	(0.15)	(0.15)	(0.13)	(0.15)	(0.17)	(0.16)	(0.16)	(0.15)
Observations	1669	1671	1626	1577	1541	1662	1666	1624	1576	1540
Panel (C): Ethiopia										
Flush Toilet R1	-0.07	0.24	-0.25	-0.31	-0.09	0.28	-0.05	0.06	0.41*	-0.18
	(0.36)	(0.22)	(0.20)	(0.22)	(0.18)	(0.30)	(0.23)	(0.18)	(0.21)	(0.24)
Latrines R1	0.43***	0.15*	0.16**	0.20***	0.10	-0.06	-0.10	-0.03	-0.08	-0.15*
	(0.14)	(0.08)	(0.07)	(0.07)	(0.07)	(0.10)	(0.08)	(0.07)	(0.07)	(0.08)
Other R1	0.02	0.13	0.19	0.08	0.16	-0.14	-0.16	-0.07	0.02	0.06
	(0.28)	(0.21)	(0.19)	(0.16)	(0.17)	(0.21)	(0.15)	(0.14)	(0.14)	(0.19)
Observations	1736	1792	1765	1759	1661	1657	1792	1757	1753	1656
Panel (B): India										
Flush Toilet R1	0.12	0.09	0.02	0.15	0.02	-0.11	-0.18*	0.01	0.00	-0.03
	(0.14)	(0.09)	(0.09)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)	(0.14)	(0.14)
Latrines R1	0.01	0.04	0.01	0.02	0.05	0.02	-0.03	0.05	0.01	0.01
	(0.14)	(0.09)	(0.08)	(0.09)	(0.09)	(0.12)	(0.09)	(0.10)	(0.13)	(0.13)
Other R1	-0.55	-0.82***	-0.51	-0.42**	0.28	-0.03	-0.09	-0.15	-0.55**	0.41
	(0.41)	(0.28)	(0.34)	(0.21)	(0.32)	(0.43)	(0.35)	(0.34)	(0.28)	(0.64)
Observations	1901	1924	1903	1894	1821	1914	1925	1893	1891	1819
Community FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

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

Notes: Table shows the main regression results. R1, R2, R3, R4, and R5 stand for rounds 1, 2, 3, 4, and 5, respectively. The treatment variable is a categorical variable of sanitation equal to 1 if the HH has flush toilets, 2 if HH has pit latrines (in the household and shared), 3 if they use open defecation, and 4 for "other" forms of relief. The outcomes are the Peabody Picture Vocabulary Test and math test scores. The controls in these regressions are the YL child's gender, parent's education, a dummy variable for the child's school enrolment status, the YL child's age, and both early and concurrent individual sanitation, housing quality index, and durable consumer index. All estimations for each of the countries have community-fixed effects.

The "other" category, although generally not statistically significant for the majority of the health indicators, presents somewhat noteworthy results in the cases of Vietnam and India. Early access to the "other" type of toilet is found to be significantly associated with shorter children at the age of 5 (by 0.82 sd), and this association persists until the age of 12 (children shorter by 0.42 sd). Furthermore, early access to the "other" type of toilet demonstrates a strong association with lower

BMI among children by 0.16 and 0.55, respectively, at approximately 1 year old in Vietnam and 12 in India. However, it is important to note that the surveys do not provide specific information regarding the types of toilets included in the “other" category.

However, among the countries analyzed, only Peru and Ethiopia exhibit a noteworthy and somewhat persistent relationship between early access to pit latrines and health indicators. In Peru, early access to pit latrines is strongly associated with higher HAZ, indicating taller children by 0.12 sd at the age of 12. In Ethiopia, access to pit latrines is significantly associated with taller children at ages 1, 5, 8, and 12 by standard deviations ranging from 0.15 sd to 0.43 sd. Moreover, early access to pit latrines in Peru is also associated with significantly higher BMI-Z by a range from 0.15 sd to 0.17 sd at the ages of 8, 12, and 15 years. However, in Ethiopia, early access to pit latrines is found to be strongly associated with shorter children of 0.15 sd only at the age of 15 years. Prominently, early access to pit latrines does not demonstrate significant associations with the investigated health indicators in Vietnam and India.

1.5.3 Community-level analysis

1.5.3.1 Community spillovers on cognition

Table 1.7 shows community-level analyses that use an extra early access sanitation treatment at the community level when the children are 6-18 months and utilize the hierarchical linear model (HLM). The community-level sanitation dummy variables, namely community flush toilets, community latrines, and community open defecation, are derived directly from the community survey questionnaires, which were responded to by knowledgeable community leaders. By introducing community-level sanitation variables as additional treatments, the findings confirm the statistically significant association between individual access to flush toilets during infancy and cognitive performance in later stages of life. Specifically, early childhood access to flush toilets and pit latrines are associated with significantly higher vocabulary test scores, as thoroughly discussed in the preceding sections.

Table 1.7. HLM Results: Cognition and Treatments: All Countries

	PPVT Scores				Math Scores		
	(1) R2	(2) R3	(3) R4	(4) R5	(5) R3	(6) R4	(7) R5
Flush Toilet R1	0.14***	0.10**	0.09**	0.08**	0.10*	0.09**	0.08**
	(0.05)	(0.04)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)
Latrines R1	0.07*	0.08***	0.08*	0.12***	0.06**	0.09***	0.05*
	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)
Other	0.00	-0.03	0.11	0.08*	0.08	0.10*	-0.01
	(0.04)	(0.07)	(0.07)	(0.04)	(0.05)	(0.06)	(0.04)
CFT	0.10***	0.09	0.08	0.16***	-0.06	0.02	-0.03
	(0.02)	(0.06)	(0.08)	(0.06)	(0.08)	(0.07)	(0.05)
CPL	0.08***	0.09	0.05	0.13*	0.09	0.04	0.07
	(0.03)	(0.08)	(0.07)	(0.08)	(0.06)	(0.06)	(0.06)
COD	0.03	-0.02	-0.05	-0.01	-0.01	-0.06	-0.06
	(0.05)	(0.06)	(0.06)	(0.07)	(0.08)	(0.06)	(0.07)
Country-community FE	YES	YES	YES	YES	YES	YES	YES
Observations	6789	6825	6718	6527	6896	6615	6615

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

Notes: The table shows community-level analysis using a mixed-effects model. R1, R2, R3, R4, R5 and FE stand for rounds 1, 2, 3, 4, 5, and fixed effects, respectively. The standard errors are clustered at the community level. Treatment variables are household and community-level sanitation when the child is approximately 1 year old. The community variables are community-level sanitation dummy variables, i.e., community flush toilets=1 if the community uses flush toilets and 0 otherwise; community latrines=1 if the community uses latrines and 0 otherwise; and community open defecation=0 if the community members relieve themselves using open defecation. The outcomes are the Peabody Picture Vocabulary Test and math test scores. The controls in these regressions are the YL child's gender, the parent's education, a dummy variable for the child's school enrolment status, the YL child's age, whether the child lives in a rural or urban area, and both early and concurrent individual sanitation, housing quality index, and durable consumer index.

The main community-country fixed effects HLM results in Table 1.7 relate to the relationship between community-level access to sanitation and cognition. The findings demonstrate that early childhood access to flush toilets and pit latrines at the community level when the children are 6-18 months old is strongly linked to higher vocabulary scores when the children are aged 5 years by 0.1 sd and 0.08 sd, respectively. Notably, this significant correlation between early access to flush toilets and pit latrines at the community level with vocabulary scores persists up to the age of 15 years. Specifically, early childhood access to community flush toilets and pit latrines is significantly associated with higher vocabulary performance by 0.16 sd and 0.13 sd, respectively (column 4). Although not statistically significant, positive associations between early community access and vocabulary are also observed at other ages, such as 8 and 12 years. This robust evidence supports the notion of community spillovers, whereby individuals benefit from the presence of flush toilets and pit latrines in their communities, leading to improved vocabulary achievements.

However, there is no observed strong association between early community access to flush toilets, pit latrines, or open defecation categories with math scores. This finding implies that community spillovers are present for community flush toilets and pit latrines with regard to vocabulary but not math.

1.5.3.2 Community spillovers on health

Table 1.8 also shows community-level analyses that utilize an HLM model. By employing an HLM approach, this study incorporates the valuable framework necessary to examine the relationship between early childhood sanitation access and children's BMI-Z and HAZ. Notably, the results continue to demonstrate a persistent and significant positive association between individual level access to flush toilets and pit latrines during early childhood and children's BMI-Z and HAZ, both contemporaneously and later in life, as seen in Table 1.5 before. This finding underscores the importance of early childhood access to improved sanitation facilities in promoting healthy growth and development.

Table 1.8. HLM regressions of sanitation on HAZ and BMI-Z for all Countries combined

	Height					BMI				
	(1) R1	(2) R2	(3) R3	(4) R4	(5) R5	(6) R1	(7) R2	(8) R3	(9) R4	(10) R5
Flush Toilet R1	0.14**	0.18***	0.18***	0.23***	2.24*	0.08	0.01	0.14**	0.18**	0.10*
	(0.06)	(0.05)	(0.05)	(0.04)	(1.31)	(0.06)	(0.05)	(0.06)	(0.08)	(0.06)
Latrines R1	0.18***	0.10**	0.11**	0.09**	-1.73	0.04	-0.03	0.01	0.05	0.04
	(0.06)	(0.04)	(0.04)	(0.05)	(2.04)	(0.05)	(0.04)	(0.03)	(0.04)	(0.03)
Other	-0.07	-0.02	0.02	0.06	1.35	-0.07	-0.03	-0.02	0.02	0.12*
	(0.09)	(0.07)	(0.04)	(0.04)	(1.05)	(0.07)	(0.05)	(0.04)	(0.06)	(0.06)
CFT	0.18**	0.12*	0.03	0.02	-5.31	-0.00	-0.01	0.04	0.11***	0.09*
	(0.07)	(0.07)	(0.05)	(0.04)	(4.63)	(0.07)	(0.04)	(0.04)	(0.03)	(0.05)
CPL	0.15	0.01	-0.02	0.00	0.13	0.07	0.04	-0.04	-0.12**	-0.04
	(0.10)	(0.07)	(0.04)	(0.05)	(0.75)	(0.13)	(0.05)	(0.05)	(0.05)	(0.06)
COD	-0.05	-0.01	-0.04	-0.09*	-1.96	-0.10	0.01	0.04	0.01	-0.03
	(0.09)	(0.06)	(0.05)	(0.05)	(1.40)	(0.09)	(0.07)	(0.06)	(0.04)	(0.04)
CC FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	7152	7177	7028	6966	6736	7067	7177	7018	6965	6725

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

Notes: Table shows the relationship between sanitation and health. R1, R2, R3, R4, R5, and CC-FE stand for rounds 1, 2, 3, 4, 5, and community-country fixed effects, respectively. The Treatment variable is individual household improved sanitation and the community level sanitation when the child is aged approximately 1 year. The outcomes are the Peabody Picture Vocabulary Test and math test scores. The controls in these regressions are: contemporaneous individual sanitation, housing quality index, consumer durable index, gender, mother's education, father's education, a dummy for whether the child is enrolled in school or not, YL child's age and whether the child lives in a rural or urban area. I also control for some community-level characteristics, such as the community-level housing quality index and consumer durable index.

The primary focus of this section revolves around the community-level associations observed in the HLM results. Examining early access to community flush toilets (CFT), significant associations with both HAZ and BMI-Z are evident. Specifically, early life access to sanitation at the community level is linked to significantly taller children by 0.18 sd and 0.12 sd at approximately 1 year old and persisting until the age of 5. However, the strength of these associations diminishes in subsequent ages, although children are expected to be taller. Moreover, the association between community-level access to flush toilets and BMI-Z emerges at the age of 12 and persists until 15 years old, indicating that children have higher BMI-Z by 0.11 sd and 0.09 sd, respectively.

On the other hand, community latrines display a significant negative association with BMI-Z at the age of 12, indicating a lower BMI by 0.12 sd. In contrast, community open defecation (COD) does not yield significant results for the most part, although children exposed to COD early in life are significantly shorter at the age of 12. While the general trend suggests a shorter stature for children exposed to COD at other ages as well, the point estimates are statistically insignificant. Overall, these findings shed light on the community-level associations between sanitation access and health outcomes, demonstrating the potential link between community spillovers on children's growth and BMI.

1.6 Conclusion

This study is motivated by the continued lack of access to basic sanitation services across the globe. The aim was to investigate the association between early childhood exposure to improved sanitation and children's development, considering vocabulary, math, HAZ, and BMI-Z. The analysis includes separate regressions for each survey round and incorporates fixed effects at the community and country levels. By employing an HLM, the study accounts for the nested nature of the data, enabling a more rigorous investigation into potential community spillovers.

The study's findings suggest that early access to flush toilets is linked to higher vocabulary and math test scores from ages 5 to 15. Pit latrines also show positive associations with test scores, primarily at ages 8 and 12. The concurrent relationship between flush toilets and test scores at

different ages is notable. These results emphasize the significance of early access to flush toilets in enhancing cognitive outcomes during childhood and adolescence. Furthermore, the country-specific analysis reveals interesting patterns. Flush toilets demonstrate positive associations with vocabulary and math scores in Vietnam, Peru, and India. Pit latrines display mixed effects, with positive associations observed in Vietnam and Peru, but no significant impact in Ethiopia and India. Additionally, flush toilets appear to have a positive influence on height and BMI in Vietnam and Peru, while the effects are less pronounced in Ethiopia and India.

Early childhood access to flush toilets and pit latrines at the community level has a strong and persistent positive association with higher vocabulary scores. This correlation remains significant up to the age of 15, indicating the presence of community spillovers, where individuals benefit from the presence of improved sanitation facilities in their communities. However, there is no significant association between community-level access to flush toilets, pit latrines, or open defecation and math scores, suggesting that community spillovers primarily affect vocabulary achievements. The use of an innovative HLM confirms the statistically significant relationship between individual access to flush toilets during infancy and cognitive performance later in life.

These insights have important implications for policy and interventions aimed at promoting cognitive development and improving children's health outcomes through targeted sanitation interventions at both individual and community levels. Further research is warranted to better understand the underlying mechanisms and contextual factors driving some of the associations, enabling more effective strategies for enhancing child well-being. The findings suggest that policy efforts should prioritize improving access to flush toilets and pit latrines in communities to enhance cognitive development, particularly vocabulary scores. Community-level interventions and consideration of the broader community context are crucial for maximizing the benefits of sanitation improvements. Comprehensive approaches that address multiple aspects of cognitive development, including math skills, should be considered. Integrated policies focusing on sanitation infrastructure can contribute to better educational outcomes.

Chapter 2

Private sanitation facilities at home and psychosocial development in adolescent girls

2.1 Introduction

The impact of sanitation infrastructure on human health has been studied extensively over the past few decades. It is now well established that access to improved sanitation reduces exposure to pathogens that pose health risks, such as diarrhea, malnutrition, and transmissible intestinal nematode infections (worms) (Freeman et al., 2017). Research also shows that access to private household facilities is associated with improved physical health outcomes compared to using shared facilities (Heijnen et al., 2014). This line of inquiry has fueled a global call to action as exemplified by the United Nations' Sustainable Development Goal (SDG) target 6.2, which calls for access to adequate and equitable sanitation for all by the year 2030. The target also calls for special attention to be paid to the needs of women and girls with regard to sanitation. However, in comparison to physical health, there is comparatively little research on potential psychological and social benefits to women and girls from access to private sanitation at home.

Women and girls face increased vulnerability to sexual harassment, violence, and stigma when defecating outside or in communal facilities (Sclar et al., 2018b). When proper sanitation is lacking, many women walk long distances from their homes to use public toilet facilities or open defecation, sometimes waiting until dawn or dusk to avoid being seen by others (Saleem et al., 2019). Such practices are inconvenient and unsanitary, and a growing body of research suggests that how women experience sanitation is linked to levels of psychosocial stress (Bisung and Elliott, 2017). Given the surrounding cultural taboos, the problem only intensifies when women are menstruating. As a result, the lack of adequate sanitation facilities can make it difficult for women

and girls to fully engage in daily life, which can have negative effects on their dignity and self-respect.

Despite a global push to improve sanitation services, nearly one in four people in the world (1.7 billion) lacked access to basic improved sanitation at home in 2020 (WHO and UNICEF, 2021). This includes 465 million who continued to practice open defecation. While India has made significant progress over the past decade, 29% of the population still lack at least basic sanitation (400 million) and 15% practice open defecation (207 million) (WHO and UNICEF, 2021). Ethiopia has achieved the largest recent reduction in open defecation rates worldwide—dropping from 79% in 2000 to 17% in 2020 (Novotnỳ and Mamo, 2022b). Much of this decline has stemmed from increased access to private toilet facilities in the household. However, a significant portion of these household latrines fail to meet WHO standards for improved sanitation and 91% of Ethiopians still lacked access to basic improved sanitation in 2020 (105 million) (Novotnỳ and Mamo, 2022b). Moreover, it is estimated that 20% of women and girls in Ethiopia lacked access to a private place to wash and change while at home (WHO and UNICEF, 2021).

In this study, we focus on the relationship between home sanitation facilities (HSF) and adolescent self-efficacy and self-esteem changes. We use data collected from two cohorts of adolescents in Ethiopia and India. The data is unique in its longitudinal nature and repeated collection of a number of validated psychosocial measures. We examine raw correlations in the data as well as estimate two-way fixed effects models that exploit the repeated collection of outcomes. We further use the estimator proposed by de Chaisemartin and D'Haultfoeuille (2020) to allow for treatment effect heterogeneity. In our preferred model specification, we find that access to HSF is associated with an increase in self-efficacy and self-esteem in girls of 0.265 and 0.237 standard deviations, respectively. In contrast, we find no association between increased access to HSF and psychosocial outcomes in boys. Associations are also stronger for girls that live in communities with higher overall access to HSF, suggesting relative access may matter more for psychosocial development than absolute access. In other words, if an adolescent's peers have access to sanitation at home, then having personal access to HSF appears to matter more for the child's psychosocial

outcomes. In contrast, if no one in their community has access to HSF, then personal access does comparatively little to improve outcomes. The implications of this finding for policy are significant, as it emphasizes how disparities during the implementation of sanitation initiatives could lead to unintended spillover effects.

The pattern of main results are similar in both Ethiopia and India when estimated separately, though associations between HSF and psychosocial outcomes are weaker for Indian girls. We also find a significant correlation with improved peer relations for girls in early (age 12 to 15) but not late (age 19 to 22) adolescence. Again, there is no association for boys. We do not find evidence that results are operating through improved physical health, suggesting there may be a direct impact of private sanitation facilities at home and psychosocial development in adolescent girls. Consistent with a direct channel, we also show private sanitation at home mitigates the likelihood of missing school due to menstruation for Indian girls in early adolescence (similar data was not collected for older girls or in Ethiopia).

There is a growing body of qualitative and cross-sectional research suggesting that women's experience of sanitation affects them by increasing their level of psychosocial stress and reducing their empowerment (Sclar et al., 2018b; Bisung and Elliott, 2017; Saleem et al., 2019; Pearson and McPhedran, 2008; MacArthur et al., 2020; Dery et al., 2020; Caruso et al., 2022; Bernasek et al., 2022). In a recent cross-sectional study in rural India, Caruso et al. (2018) found that access to a functional latrine in the household was associated with higher mental well-being scores for women. Hulland et al. (2015) show in the same population that more restricted sanitation activities like menstruation were associated with the highest degree of stress. Studies in India and Kenya have shown that women who use open defecation are more likely to experience non-partner violence (Jadhav et al., 2016; Winter and Barchi, 2016). In response to poor sanitation, women have also reported increased feelings of fear, shame, and marginalization as well as negative identity, increased harassment, and withholding of food and water to limit urination or defecation (Caruso et al., 2017; Kulkarni et al., 2017; O'Reilly, 2016; Bisung and Elliott, 2016; Hirve et al., 2015; Sahoo et al., 2015).

In terms of younger girls, most related studies have focused on school sanitation facilities finding similar associations between poor sanitation and increased feelings of anxiety, fear, and lack of privacy, particularly around managing menstruation (Sclar et al., 2018b). For example, in their study on the national program for school toilet expansion in India since 2005, Adukia (2017) finds that sex-specific toilets improve school enrollment for pubescent-age girls through improved privacy and safety. Based on a meta-analysis of related studies, Van Eijk et al. (2016) found that a quarter of adolescent girls in India did not attend school during menstruation due to a lack of adequate facilities at school. Singolyo and Ngussa (2019) find that adequate facilities at school are associated with improved self-esteem and a higher likelihood of girls attending class regularly in Tanzania. Qualitative data from Ethiopia suggests girls who experienced teasing and humiliation by classmates around menstruation commonly dropped out of school (Tegegne and Sisay, 2014).

We contribute to this line of research by using longitudinal data to document if changes in access to HSF are associated with changes in adolescent psychosocial outcomes over time. Importantly, the use of panel data allows us to control for permanent or time-invariant unobserved heterogeneity across individuals and estimate a more robust association between HSF and psychosocial outcomes. Permanent unobserved heterogeneity refers to individual-level factors that are stable over time and not directly observable or measurable, such as early childhood experiences, personality traits, or family background. These factors can affect both the likelihood of having access to HSF and levels of self-efficacy and self-esteem, making it difficult to establish a clear causal relationship between HSF and psychosocial outcomes. By controlling for such unobserved heterogeneity, we can account for the effects of these individual-level factors and reduce their impact on the estimated associations. This can increase the internal validity of the study and provide more accurate estimates of the true causal effects of access to sanitation facilities at home on self-efficacy and self-esteem. By doing so, we can provide more reliable evidence about the impact of sanitation interventions on individuals' well-being, which can inform policy decisions and improve public health outcomes.

2.2 Data and methods

2.2.1 Data

The data for our analysis comes from the panel surveys of the Young Lives Study (YLS). The YLS is an international study of childhood poverty following children in multiple countries over 15 years. We use data collected from Ethiopia and India (in the states of Andhra Pradesh and Telangana) where expansion in access to HSF was substantial over the survey period. The study follows two cohorts of children in each country born seven years apart: a younger cohort of 2,000 children born in 2001/02 and an older cohort of 1,000 children born in 1994/95. Each survey round was conducted every three to four years, which means that children from both cohorts were interviewed at similar ages from 20 community clusters in each country. We use data collected in the fourth (2013) and fifth (2016) wave of the YLS when children were adolescents and extensive psychosocial outcomes were collected for both cohorts. The younger cohort was aged 12 in round four and aged 15 in round five. The older cohort was aged 19 in round four and aged 22 in round five. Though the samples are not statistically representative of the national populations—as poorer regions were over-sampled—comparisons with nationally representative data sets show that YLS reflects heterogeneity of ethnicity, religion and living standards in each of the countries (Outes-Leon and Sanchez, 2008; Kumra, 2008b).

2.2.1.1 Psychosocial outcomes

We use composite measures of self-efficacy and self-esteem as our primary psychosocial outcomes. Self-esteem reflects an individual's judgment of their own self-value or self-worth and has been shown to be strongly correlated with many health and economic outcomes (e.g., wages, life satisfaction, education). There is also strong evidence that self-esteem leads to greater happiness (Baumeister et al., 2003; Trzesniewski et al., 2006). Self-efficacy reflects an individual's sense of empowerment or agency over their own life and is closely related to the psychological concept of locus of control. The YLS self-efficacy measure is based on the generalized self-efficacy scale developed by Schwarzer and Jerusalem (1995) and aims to reflect an individual's belief in their

own capabilities to achieve goals and to cope with adversity. Self-efficacy (or an internal locus of control) has been shown to positively affect behavioral outcomes such as educational attainment or subjective belief of the probability of finding a job (Coleman and DeLeire, 2003; Caliendo et al., 2015). Generally positive effects have also been found on wages and other labor market outcomes, but the strength of the evidence is more mixed (Andrisani, 1981; Heineck and Anger, 2010; Piatek and Pinger, 2010).

Outcome measures are constructed on the basis of a child's agreement to a series of statements related to self-efficacy and self-esteem. Agreement with each statement is measured on a four-point Likert scale [1=strongly disagree to 4=strongly agree]. For example, *'I can solve most problems if I invest the necessary effort'* is one item related to self-efficacy. The full list of statements are listed in appendix table B.1. Using the statements to construct single composite measures of self-efficacy and self-esteem was extensively pilot tested and subjected to psychometric validation by the YLS (Ogando and Yorke, 2018). As recommended, statements were standardized to z-scores (with a mean of zero and standard deviation of one) within each cohort, survey round, and country and composite scales were constructed by averaging all relevant z-scores across the non-missing dimensions (Ogando and Yorke, 2018; Revollo and Portela, 2019). To enhance interpretation, we then standardized the composite scales to have mean zero and standard deviation one. This allows us to interpret results as standard deviation changes.

The YLS also collected agreement to statements centered around a child's relationship with parents and peers. For example, *'I like my parents'* and *'I make friends easily'* were included items (complete list of statements provided in appendix table B.1). These statements were used to create two additional psychosocial outcomes. Of the four psychosocial competencies, parent and peer relationship scales have been considered narrower constructs than self-efficacy and self-esteem (Ogando and Yorke, 2018). The parent relationship questions were also not asked of the older cohort. Nonetheless, the scales have been generally validated (Ogando and Yorke, 2018) and serve as a useful secondary set of outcome measures for our study.

2.2.1.2 Sanitation and control variables

Our treatment variable is a binary indicator for reported access to a sanitation facility in the household (HSF). Specifically, the survey asked *'What kind of toilet facility does your household use?'*. HSF takes a value of one if the respondent answered flush toilet, septic tank, or pit latrine in the household.[14]

We include a number of other household infrastructure measures as controls in our analysis. First, a housing quality index (HQ index) that takes values from zero to one. The HQ index is constructed by the YLS survey team and is based on crowding (rooms per person) and quality of materials used for the walls, roof, and floor. Second, a set of three indicators for access to electricity, piped water, and adequate fuels for cooking. We also use the consumer durable index (CD index) provided by the YLS team which takes values from zero to one. The CD index is based on the number of non-productive assets owned by the household. Lastly, we include household size as a final control.

In addition to our primary analysis, we conduct several secondary analyses to examine evidence for potential mechanisms linking HSF to psychosocial development among YLS children. Given the body of existing literature connecting sanitation to health risk, it is plausible that HSF could alter self-efficacy and self-esteem by improving physical health. In order to explore this mechanism we detail how our main results change when additional health controls are included. Specifically, we consider the survey child's body mass index (BMI) and subjective health. Subjective health was collected on a scale from 1 (very poor) to 5 (very good). We created an indicator taking a value of one if subjective health was reported as good or very good.

Existing research also suggests that psychosocial stress around sanitation for girls may be elevated during menstruation. In round five of the survey, the younger cohort of Indian girls were asked *'Do/did you avoid school during days when you are menstruating?'*. We use the response to this question as an additional outcome variable to explore this mechanism further. We also

[14] A few respondents reported in round five that either: (1) the YLS child no longer resided in the household for which the survey data was collected; or (2) that women were not permitted to use HSF in the household. These cases were dropped from all analyses given the uncertainty around true access to HSF.

examine how strongly HSF relates to this outcome compared to the perceived state of sanitation facilities at school. In particular, the same girls were asked if toilets at their school (1) were neat and clean; (2) have water available; (3) have soap available; and (4) have disposal for sanitary napkins available. We look at each of these separately and then sum them to create a school toilet quality scale running from zero to four.

2.2.2 Empirical model

We use pooled ordinary least squares (OLS) and two-way fixed effects (FE) regressions to estimate the relationship between private sanitation facilities at home and our outcome variables of interest. We run all models separately for girls and boys given the previous evidence of a potential differentiated impact. While our main specification is the FE model, pooled OLS provides a baseline estimation to which we compare the FE regressions to highlight the potential bias in coefficients when not controlling for individual time-invariant unobserved characteristics. The pooled OLS model is given by:

$$Y_{ict} = \alpha + \beta \text{HSF}_{ict} + \gamma \mathbf{X}_{ict}^{'} + \nu_c + \delta_t + \varepsilon_{ict}. \tag{2.1}$$

Here Y_{ict} represents the outcome of interest (self-efficacy, self-esteem) for child i in community c, in survey year t. $\mathbf{X}_{ict}^{'}$ is a vector of time-varying observed household characteristics which could potentially affect the outcome variable of interest. These include household size, CD index, HQ index, and indicators for access to electricity, piped water, and adequate cooking fuels. As we pool observations across cohorts in our benchmark model, we also include a dummy in this control vector that takes a value of one if the child is in the younger YLS cohort (we also estimate results separately by cohort). We further include community fixed effects ν_c and time (survey wave) fixed effects δ_t. These account for aggregate time period effects and permanent unobserved heterogeneity at the community level. Finally ϵ_{it} is an error term assumed to be IID or come from a low-order moving-average process. In our FE estimation we add child level fixed effects η_i as

follows:

$$Y_{ict} = \alpha + \beta \text{HSF}_{ict} + \gamma \mathbf{X}'_{ict} + \eta_i + \delta_t + \varepsilon_{ict}. \tag{2.2}$$

Note that we drop the community fixed effects due to colinearity. Given recent econometric concerns about bias driven by treatment effect heterogeneity in two-way fixed models, we also present results using the estimation strategy of de Chaisemartin and D'Haultfoeuille (2020). Henceforth, we refer to this as the D&D estimator.[15]

Our coefficient of interest is β in both model specifications. This coefficient provides the association between HSF and psychosocial outcomes, controlling for other modelled covariates. However, these associations can only be interpreted as causal if HSF access is uncorrelated with any unobserved determinants of our psychosocial outcomes. In other words, estimates could suffer from reverse causality or omitted variable bias. We would argue it unlikely that psychosocial competency in adolescents significantly impacts changes in household access to improved sanitation infrastructure. However, we cannot rule out the possibility of such reverse causation. In terms of omitted variables, important time-invariant characteristics such as caste, religion, and geography are controlled for by the child fixed effect η_i, which also captures any time-invariant unobserved household characteristics.

We also include time-varying controls related to housing infrastructure—HQ index and access to electricity, water, and cooking fuel. This helps account for broader infrastructure changes at the household level that my correlate with HSF and psychosocial outcomes. In contrast to sanitation, there is also little existing theoretical or qualitative evidence to suggest that these other household infrastructures should impact psychosocial outcomes differently for girls and boys. This serves as a useful test of our results against existing theory. In other words, if associations between outcomes and household infrastructure measures are significant across the board, this raises more concerns about omitted variable bias from the presence of some other factor correlated with general

[15]The D&D estimator is computed using the Stata command of de Chaisemartin et al. (2019).

household infrastructure and outcomes. This is particularly true if this pattern exists for say girls, but not boys. However, it is important to note that we cannot fully rule out bias due to possible correlation between time-varying unobserved heterogeneity and changes in access to HSF.

It is also of interest to understand if any associations arising in our previous models are stemming from absolute or relative access to HSF. In other words, does access to HSF matter more for psychosocial development if one is surrounded by peers with access? In order to explore this question, we create a variable in each survey wave that contains the mean of our individual HSF indicator at the community level (CHSF). We then standardize this measure within country and survey wave so a unit increase in CHSF can be interpreted as a standard deviation change in mean community-level access to HSF. We then estimate the following model:

$$Y_{ict} = \alpha + \beta \text{HSF}_{ict} + \nu \text{CHSF}_{ct} + \rho(\text{HSF}_{ict} \times \text{CHSF}_{ct}) + \gamma \mathbf{X}'_{ict} + \eta_i + \delta_t + \varepsilon_{ict}. \tag{2.3}$$

Here the key variable of interest is ρ on the interaction between individual and community-level access to HSF. If ρ is positive, this suggests the association between personal access to HSF and psychosocial outcomes is stronger in communities with higher overall levels of access. This would be consistent with the argument that relative access matters.

2.3 Results

This section presents the empirical results of this study in segments. First, we present the descriptive statistics by sex and country and examine raw correlations of the primary outcomes and treatment variable. Second, we present the association between private sanitation and psychosocial development by sex, country, and cohort. Additionally, we examine if results differ for those gaining versus losing access between rounds. Lastly, we explore the potential mechanism at play by examining the impact of HSF directly on health and on mitigating girls missing school during menstruation.

2.3.1 Descriptive statistics

Table 2.1 presents descriptive statistics by sex and country for 2013 and 2016. In Ethiopia, 61% of girls and 64% of boys reported access to HSF in 2013. Note that this is significantly higher than the WHO's estimate of 7% of the population with access to basic improved sanitation in 2015 (WHO and UNICEF, 2021). This reflects that many household pit latrines in Ethiopia do not meet the common definition of improved sanitation (e.g., pit latrines with a slab or platform). By 2016, the share of YLS Ethiopian households that reported HSF *declined* to 59% for girls and boys. This moderate decline in HSF rates is consistent with other studies that have found recent increases in open defecation rates in Ethiopia. In a recent meta-analysis, Abebe and Tucho (2020) find the main factors for the increase in open defecation in Ethiopia include lack of technical support and marketing, financial constraints, low-quality building materials, and poor sanitation program implementation.

Table 2.1. Mean descriptive statistics

	Ethiopia				India			
	2013		2016		2013		2016	
	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys
HSF	0.61	0.64	0.59	0.59	0.42	0.42	0.51	0.50
HQ index	0.35	0.37*	0.37	0.39	0.69	0.68	0.71	0.70
Electricity	0.61	0.62	0.67	0.66	0.98	0.97	0.98	0.98
Cooking fuel	0.09	0.09	0.19	0.17	0.43	0.46	0.68	0.72**
Water	0.49	0.45*	0.57	0.58	0.99	0.98	0.99	0.99*
CD index	0.27	0.28	0.32	0.33	0.38	0.39*	0.41	0.42**
HH size	5.76	5.87	5.46	5.59	4.87	4.86	4.77	4.79
Younger cohort	0.73	0.72	0.73	0.72	0.71	0.72	0.71	0.72
Self-efficacy	-0.08	0.06***	-0.05	0.05**	-0.02	0.06**	-0.03	0.06**
Self-esteem	-0.05	0.04**	-0.03	0.04*	0.07	-0.04**	0.07	-0.02**
Parent relations	0.01	-0.01	0.06	-0.04**	-0.02	0.03	0.04	-0.08**
Peer relations	-0.09	0.09***	-0.10	0.10***	0.07	-0.04**	0.08	-0.03***
Observations	1128	1307	1128	1307	1112	1313	1112	1313

Notes: Stars indicate a significant mean difference between boys and girls in a given country and year based on a t test. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

In India, 42% of girls and boys in the YLS survey reported access to HSF in 2013. These rates increased quite substantially to 51% for girls and 50% for boys by 2016. The significant increase could be associated with the Swachh Bharat Abhiyan (Clean India Campaign) started in 2014, which emphasized increasing access to private sanitation (toilets) at the household level and

reducing open defecation. These rates are slightly under the 2015 WHO national estimates of 57% with access to at least basic sanitation in India (WHO and UNICEF, 2021). This likely reflects that poorer regions were over-sampled by the YLS.

Compared to Ethiopia, YLS households in India scored significantly higher across other household infrastructure measures—housing quality, electricity access, improved cooking fuel use, and improved water access. India also scored higher on the consumer durable index. Both countries showed some improvement on each household infrastructure measure and the consumer durable index between survey rounds. The size of Ethiopian households averaged about one additional person compared to India, with modest declines across waves in both countries. Moreover, there was little difference between the households of girls and boys within countries on any of these control measures. The younger cohort also made up just over two-thirds of the total sample in both countries.

Table 2.1 also provides mean psychosocial outcome scores—recall these were standardized within country, year, and cohort. Girls in Ethiopia scored lower on self-efficacy and self-esteem than boys, though these gaps closed some between survey rounds. Specifically, the gap in self-efficacy fell from 0.14 in 2013 to 0.10 in 2016. The analogous gap in self-esteem fell from 0.09 to 0.07. In India, girls also reported lower self-efficacy than boys, with a gap of 0.08 in 2013. In contrast, girls scored 0.11 *higher* on self-esteem than boys in India. Moreover, these gaps remained quite stable in India between the survey years.

In 2013, girls in Ethiopia scored just 0.02 higher on the parent relationships measure than boys. This gap widened to 0.10 by 2016. However, girls scored much lower than boys on peer relationships, with a gap of 0.18 that increased slightly between waves. Indian girls also did not report a significant difference with boys on the parent relationship scale in 2013. However, by 2016 girls scored 0.12 higher than boys. In contrast to Ethiopia, girls in India also scored 0.11 higher than boys on the peer relationships scale in both waves of the survey.

We next turn to correlations in the raw data between our primary psychosocial outcomes and changes in access to HSF between survey rounds. We present simple descriptive means here for

visual inspection, with more formal test statistics provided in appendix Table B.3. Figure 2.1 plots the change in mean outcome scores between rounds for three groups: (1) those with no change in access to HSF between rounds; (2) those that gained access to HSF between rounds; and (3) those that lost access to HSF between rounds.

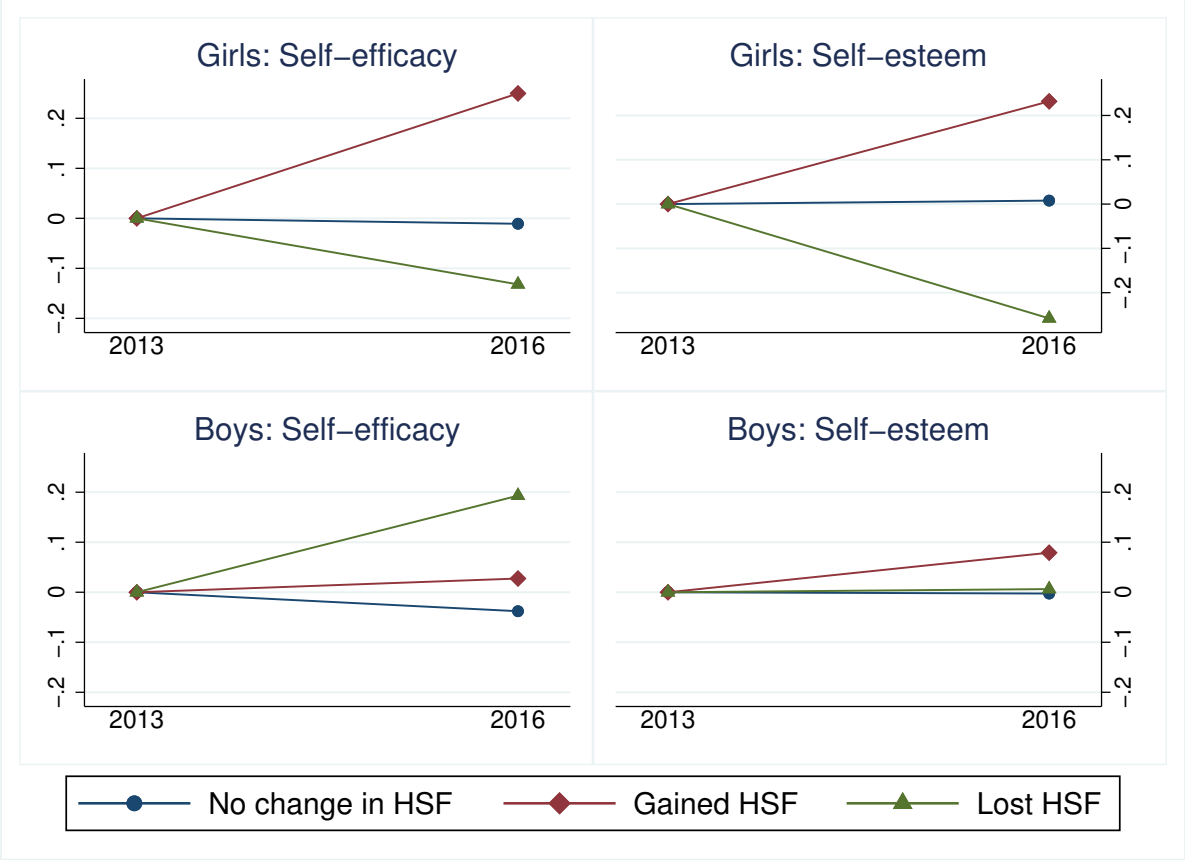

Figure 2.1. Change in Mean Psychosocial Outcomes by Change in HSF Status Between 2013 and 2016

Here we have normalized the 2013 scores for all groups to zero to focus on the change in scores by 2016. There was a slight statistically insignificant decline between rounds in mean scores for both girls and boys that had no change in HSF access. However, there was a large significant increase of more than 0.2 SD in both self-efficacy and self-esteem for girls that gained access to HSF. Boys that gained access also showed some uptick in outcome measures, but these increases were insignificant and much smaller than girls. Girls that lost access to HSF reported a reduction in psychosocial measures, particularly self-esteem. In contrast, boys that lost access experienced

little change in self-esteem and an *increase* in self-efficacy. The latter result is unexpected and we will return to it in our analyses below. Overall, these raw descriptive patterns support a potential positive impact of HSF access for girls, with much weaker and somewhat mixed results for boys.

One potential threat to interpreting the outcome changes in Figure 2.1 as causal is the possibility of treatment-specific pre-trends. For example, if outcomes for girls that gained HSF were already trending upward prior to 2013, the increase observed in 2016 could be more plausibly attributed to some unobserved factor rather than a direct causal relationship. As previously detailed, psychosocial outcomes were also collected in round three of the YLS (2009-10). However, these scales are not directly comparable to those constructed for 2013 and 2016. Nonetheless, to the extent that round three measures can proxy for earlier self-efficacy and self-esteem, they can be used to test for pre-trends.

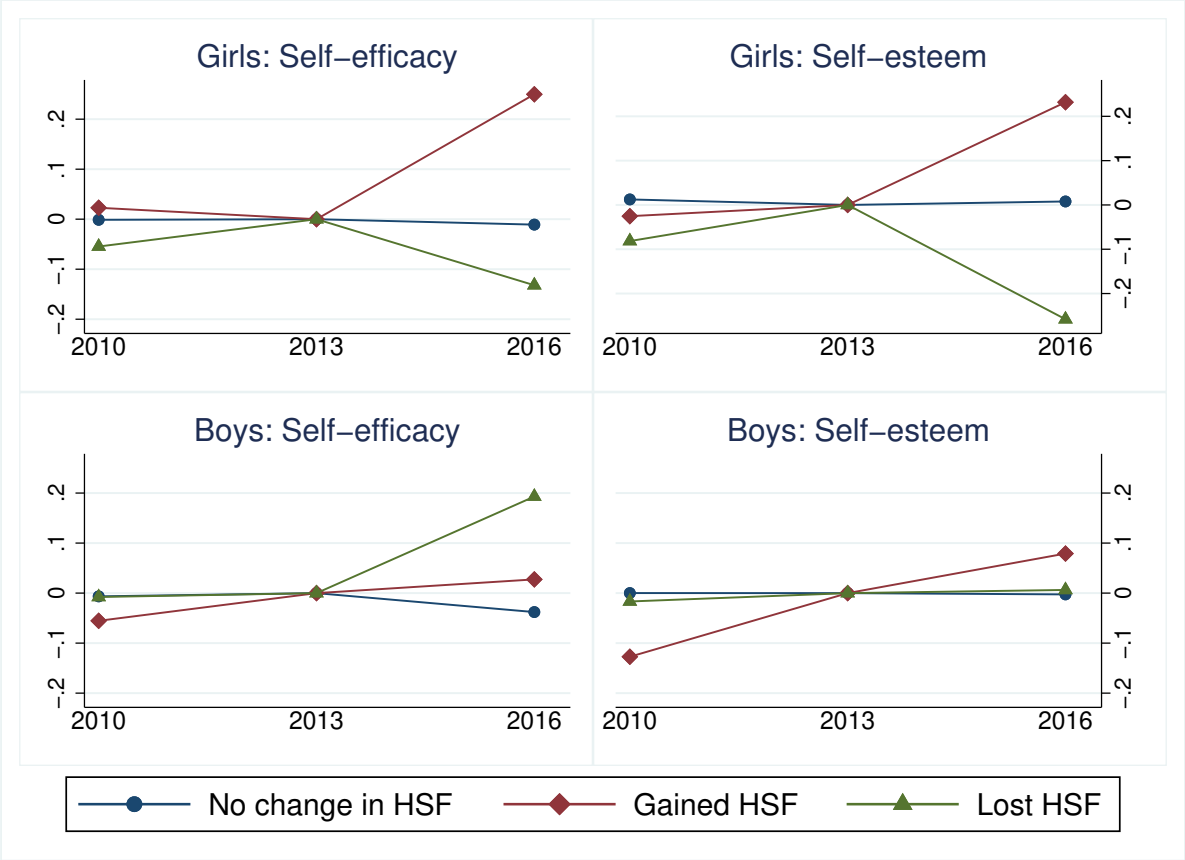

Figure 2.2. Change in Mean Psychosocial Outcomes from 2010-2016 by Change in HSF Status Between 2013 and 2016

Figure 2.2 adds round three data for visual inspection with formal statistical test results provided in appendix Table B.3. Visually, there is little evidence of concerning pre-trends for girls. More formally, the change between 2010 and 2013 is statistically insignificant for all outcomes except self-esteem in boys. These patterns offer suggestive evidence that the observed improvement in psychosocial outcomes for girls with access to HSF was not driven by pre-trends, although the evidence is somewhat less convincing for boys.

In order to further understand these patterns for girls, Figure 2.3 plots the change in mean outcome scores between rounds four and five without normalizing the 2013 scores. We also split girls without a change in access to HSF between rounds into two groups: (1) those that had access to HSF in both rounds (Always HSF); and (2) those that did not have access in either round (Never HSF). In 2013, girls with access to HSF (Always HSF and Lost HSF) scored higher on both outcomes than girls without access (Gained HSF and Never HSF). The most striking feature of the data is that girls that gained access completely closed the gap with those that always had access. Moreover, girls that lost access fell further behind girls that maintained access. Girls that never had access saw similar declines as those that lost access for self-efficacy but reported a slight improvement in self-esteem. Overall, these patterns suggest gaining access to HSF may significantly reduce disparities in psychosocial outcomes among adolescent girls.

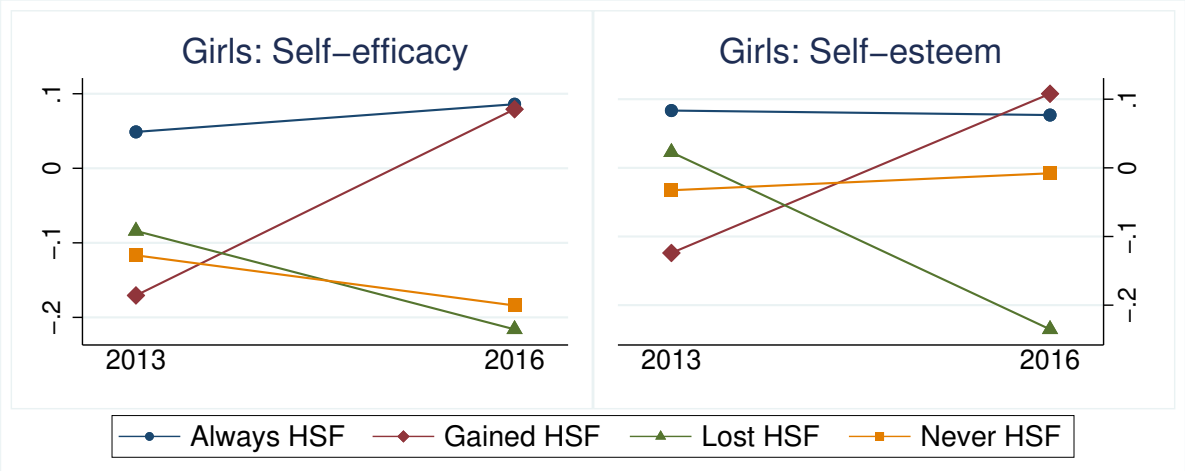

Figure 2.3. Mean Psychosocial Outcomes of Girls by Change in HSF Status in 2013 and 2016

2.3.2 Pooled results

Our main pooled results are presented in Table 2.2. Panel A presents results for girls and Panel B for boys. Columns labeled model (1) provide raw OLS correlations with no controls. The subsequent columns add controls and child fixed effects to the model specification. As shown in model (1), HSF has a significant positive raw association with self-efficacy and self-esteem for both girls and boys. For example, access to HSF is associated with an increase in self-efficacy of 0.215 sd for girls and 0.109 sd for boys. When adding controls in model (2), the magnitude of the association is diminished for girls but remains statistically significant. In contrast, the association for boys approaches zero. Model (3) shows that adding child fixed effects has little impact on point estimates for boys—the association between access to HSF remains statistically insignificant and qualitatively close to zero. Girls, in contrast, show somewhat stronger associations between HSF and outcomes when adding child fixed effects. In our preferred D&D specification (4), these associations remain large and significant for girls. Specifically, we find that access to HSF is associated with an increase in self-efficacy and self-esteem in girls of 0.265 and 0.237 sd, respectively.

Table 2.2 also presents results for other household infrastructure measures and the consumer durable index for comparison to access to HSF. In the pooled OLS model (2), the CD index shows significant positive associations with psychosocial outcomes for both girls and boys (along with access to cooking fuel for boys). However, with the inclusion of child fixed effects in model (3), the associations with CD index become insignificant and close to zero for girls.[16] For boys, the associations with CD index and cooking fuel are more persistent but only remain marginally significant. Overall, one pattern that is clear is that none of these measures show as much consistency in association with outcomes over model specifications as HSF for girls. This is consistent with previous theoretical and qualitative evidence and does not suggest evidence of substantial omitted variable bias.

[16]Coefficients for control variables are not reported for the D&D model as their interpretation is not straightforward under this approach.

Table 2.2. HSF and psychosocial development by gender

	Self-Efficacy				Self-Esteem			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Panel A: Girls								
HSF	0.215***	0.122**	0.201**	0.265***	0.135**	0.105**	0.245***	0.237***
	(0.056)	(0.049)	(0.077)	(0.092)	(0.060)	(0.048)	(0.074)	(0.088)
HQ Index		-0.016	0.010			-0.052	0.050	
		(0.081)	(0.161)			(0.083)	(0.143)	
Electricity		-0.013	-0.137			-0.019	-0.043	
		(0.071)	(0.129)			(0.067)	(0.123)	
Cooking Fuel		0.071	-0.046			0.041	-0.031	
		(0.051)	(0.083)			(0.048)	(0.075)	
Water		0.101	0.021			0.088	0.052	
		(0.073)	(0.109)			(0.074)	(0.135)	
CD Index		0.435***	0.122			0.232*	0.024	
		(0.133)	(0.203)			(0.127)	(0.196)	
Panel B: Boys								
HSF	0.109**	-0.002	-0.081	-0.107	0.117**	0.026	0.027	0.012
	(0.054)	(0.039)	(0.061)	(0.082)	(0.056)	(0.046)	(0.065)	(0.076)
HQ Index		0.049	-0.029			0.135	0.198	
		(0.095)	(0.128)			(0.090)	(0.147)	
Electricity		-0.001	-0.047			0.006	0.002	
		(0.050)	(0.153)			(0.046)	(0.115)	
Cooking Fuel		0.127**	0.126			0.089*	0.109*	
		(0.050)	(0.076)			(0.050)	(0.064)	
Water		0.058	-0.018			0.067	0.026	
		(0.062)	(0.110)			(0.062)	(0.105)	
CD Index		0.492***	0.454*			0.172	0.048	
		(0.129)	(0.228)			(0.132)	(0.248)	
Controls	NO	YES	YES	YES	NO	YES	YES	YES
Child FE	NO	NO	YES	YES	NO	NO	YES	YES
D&D estimator	NO	NO	NO	YES	NO	NO	NO	YES

Notes: Cluster robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Additional controls: household size and time, cohort, and community (site) dummies.

2.3.3 Absolute versus relative access

Table 2.3 presents results when mean community-level access to sanitation at home (CHSF) is added to the model. As CHSF is standardized, the estimated coefficients on HSF can roughly be interpreted as the association between HSF and outcomes for a child residing in a community with the mean overall access to HSF in the country. Columns labeled (1) show raw correlations between HSF and outcomes in these communities are significant for both girls and boys. However, for girls, the interaction estimate is also positive and statistically significant. This implies the association between personal access to HSF and psychosocial outcomes is stronger in communities with higher overall levels of access. For example, in communities with mean access one sd above average, the raw association between HSF and self-efficacy for girls is 0.216 sd higher than in

the average community. The interaction is also positive for boys, but statistically insignificant and quantitatively much smaller than for girls.

Table 2.3. Absolute versus relative access to HSF and psychosocial development by gender

	Self-Efficacy			Self-Esteem		
	(1)	(2)	(3)	(1)	(2)	(3)
Panel A: Girls						
HSF	0.216***	0.134***	0.209***	0.145***	0.120**	0.246***
	(0.049)	(0.048)	(0.072)	(0.051)	(0.045)	(0.071)
CHSF	-0.104**	-0.050	-0.171	-0.127***	-0.028	-0.138
	(0.042)	(0.179)	(0.178)	(0.047)	(0.154)	(0.159)
HSF × CHSF	0.216***	0.108**	0.280***	0.245***	0.153***	0.283***
	(0.059)	(0.045)	(0.103)	(0.064)	(0.051)	(0.088)
Panel B: Boys						
HSF	0.101*	0.011	-0.074	0.107**	0.034	0.016
	(0.051)	(0.038)	(0.056)	(0.047)	(0.046)	(0.060)
CHSF	-0.033	-0.023	-0.049	-0.029	0.052	0.013
	(0.044)	(0.105)	(0.117)	(0.037)	(0.082)	(0.090)
HSF × CHSF	0.089	0.068	0.147*	0.086	0.086*	0.163**
	(0.064)	(0.051)	(0.084)	(0.056)	(0.050)	(0.068)
Controls	NO	YES	YES	NO	YES	YES
Child FE	NO	NO	YES	NO	NO	YES

Notes: Cluster robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Controls: household size, HQ index, CD index, and electricity, cooking fuel, water, time, cohort, and community (site) dummies.

Columns labeled (2) in Table 2.3 present results when additional controls are included in the pooled OLS model. Again, the magnitude of the association and interaction term are diminished for girls but remain statistically significant. Moreover, when adding child fixed effects in model (3), the point estimate on the interaction term increases quite substantially. More specifically, increasing CHSF by one sd increases the association between HSF and each outcome by about 0.28 sd for girls. Note also that these results suggest personal access to HSF may have limited psychosocial benefits in communities with low access overall. Figure 2.4 illustrates this point more clearly by plotting the average marginal effect of HSF by average community-level access based on model (3). For both outcomes, effects are statistically insignificant for girls in communities falling more than a half standard deviation below the mean level of access. A final result of note is that the interaction term in the FE model for boys is statistically significant for both outcomes. This suggests that not having access to HSF in communities with very high rates overall could be detrimental to the psychosocial development of even boys. However, Figure 2.4 shows that

average marginal effects for boys remain insignificant even in communities with access levels up to 1.5 standard deviations above the overall mean.

Figure 2.4. Average marginal effect of HSF by average community-level access (CHSF)

2.3.4 Sub-group analyses

Table 2.4 presents main HSF results separately by country and cohort. It also provides estimates for those that gained or lost access to HSF between survey waves.

2.3.4.1 Results by country

Panels A and B of Table 2.4 present main HSF results separately for Ethiopia and India. Columns labeled model (1) are raw correlations and those labeled model (2) are our preferred FE D&D specification. The raw correlation between access to HSF and each outcome is positive

for girls in both countries (though self-esteem is not statistically significant in India). Moving to our preferred model (2), HSF remains associated with a significant increase in self-efficacy and self-esteem in Ethiopian girls of 0.363 and 0.288 sd, respectively. A significant association in self-efficacy of 0.165 sd is found for girls in India. However, the association between HSF and self-esteem is smaller and insignificant at 0.091 sd for Indian girls.

Table 2.4. HSF and psychosocial development by gender and sub-group

	Girls				Boys			
	Self-Efficacy		Self-Esteem		Self-Efficacy		Self-Esteem	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Panel A: Ethiopia								
HSF	0.148*	0.363***	0.156**	0.288**	0.066	-0.090	0.158*	0.141
	(0.076)	(0.131)	(0.075)	(0.116)	(0.066)	(0.122)	(0.082)	(0.088)
N	2,256	2,256	2,256	2,256	2,614	2,614	2,614	2,614
Panel B: India								
HSF	0.301***	0.165*	0.148	0.091	0.157*	-0.105	0.062	-0.180
	(0.080)	(0.092)	(0.088)	(0.146)	(0.085)	(0.114)	(0.080)	(0.125)
N	2,224	2,224	2,224	2,224	2,626	2,626	2,626	2,626
Panel C: Younger cohort								
HSF	0.201***	0.234**	0.133**	0.265**	0.120*	-0.078	0.116*	0.024
	(0.055)	(0.096)	(0.064)	(0.105)	(0.061)	(0.082)	(0.058)	(0.083)
N	3,218	3,218	3,218	3,218	3,750	3,750	3,750	3,750
Panel D: Older cohort								
HSF	0.263***	0.313**	0.141*	0.124	0.074	-0.174	0.115	-0.007
	(0.086)	(0.122)	(0.074)	(0.122)	(0.065)	(0.126)	(0.070)	(0.115)
N	1,262	1,262	1,262	1,262	1,490	1,490	1,490	1,490
Panel E: Gained HSF								
HSF	0.233**	0.335**	0.144	0.214	0.095	0.050	0.167	0.066
	(0.095)	(0.132)	(0.118)	(0.146)	(0.091)	(0.104)	(0.104)	(0.104)
N	2,180	2,180	2,180	2,180	2,472	2,472	2,472	2,472
Panel F: Lost HSF								
HSF	0.268***	0.168	0.310***	0.270***	-0.000	-0.296***	0.052	-0.051
	(0.089)	(0.115)	(0.083)	(0.104)	(0.091)	(0.114)	(0.096)	(0.085)
N	2,300	2,300	2,300	2,300	2,768	2,768	2,768	2,768
Controls	NO	YES	NO	YES	NO	YES	NO	YES
Child FE	NO	YES	NO	YES	NO	YES	NO	YES
D&D estimator	NO	YES	NO	YES	NO	YES	NO	YES

Notes: Cluster robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Controls: household size, HQ index, CD index, and electricity, cooking fuel, water, time, cohort, and community (site) dummies.

Raw correlations for boys are weaker than girls but show a similar overall pattern when examined by country. In Ethiopia, the raw correlations are large and significant only for self-esteem in boys. The opposite is true in Indian boys, with a stronger correlation between HSF and self-

efficacy. However, when fixed effects are added, all of these associations attenuate towards zero and become insignificant for boys in both countries. So overall, the finding of robust associations between access to HSF and psychosocial outcomes in girls but not boys also holds across study countries, though results are stronger in Ethiopia.

2.3.4.2 Results by cohort

Panels C and D of Table 2.4 presents our main results separately for the younger and older cohorts in the YLS. Recall that the younger cohort is moving from roughly age twelve to fifteen between survey waves. The older cohort is moving from age nineteen to twenty-two. Also recall that the younger cohort makes up about two-thirds of the total sample, helping explain the generally smaller standard errors found in the table for the younger cohort.

As shown in model (1), access to HSF has a significant positive raw association with self-efficacy and self-esteem for both younger and older girls. The raw associations are also positive for boys, although they are marginally significant in only the younger cohort. For girls in both cohorts, all associations remain positive and qualitatively meaningful in magnitude when moving to our preferred model (2) with child fixed effects. However, given the small sample, the association between HSF and self-esteem in the older cohort is no longer statistically significant. For boys, all associations in both cohorts attenuate towards zero when child fixed effects are added.

2.3.4.3 Results by gained/lost HSF

As discussed in the descriptive statistics, there were a fair amount of children that *lost* access to HSF between survey waves, particularly in Ethiopia. Therefore, it may of interest to know if results are driven by children that gained or lost access. In this context, panels E and F of Table 2.4 present results when we isolate associations only for those that gained or lost access to HSF. Specifically, the panel labeled *Gained HSF* presents results when all children with access to HSF in 2013 are excluded from the sample. In this way, results are comparing children that gained access between waves to those that did not have access in either wave. Likewise, results under the panel labeled *Lost HSF* exclude all children *without* access in 2013. Here, we are comparing children

that lost access to those that had access in both waves. The results for children that lost HSF can be somewhat confusing to interpret as we still expect coefficients to be positive. As a clarifying example, the first column in Panel F of Table 2.4 implies that girls that maintained access to HSF scored 0.268 sd higher on the self-efficacy measure than girls that lost access between survey rounds. Other results can be interpreted analogously.

As shown in the columns labeled (1) in Table 2.4, the positive raw association between HSF and outcomes holds for girls whether they gained or lost HSF. When moving to our preferred model (2) with child fixed effects, associations for girls that gained HSF remain positive and meaningful in magnitude, though statistically significant only for self-efficacy. For girls that lost HSF, we again see positive associations remain with child fixed effects, but in this case it is self-esteem that retains statistical significance. Overall, there is not strong evidence that our main pooled results for girls are being driven disproportionately by those that gained or lost HSF between waves. More broadly, this suggests that both gaining access or taking away access to HSF can each significantly impact psychosocial development in adolescent girls.

Adding child fixed effects again attenuates associations towards zero for boys that gained access to HSF. However, here we again see the somewhat surprising result that boys that lost HSF between waves actually reported significantly higher self-efficacy. Digging deeper into this result revealed that the negative association obtains in both Ethiopia and India. However, the result is stronger for the older cohort compared to the younger cohort. Moreover, the association is somewhat stronger for boys that reportedly moved localities between survey waves than those that did not. So it is possible that some of the negative association is driven by older boys gaining self-efficacy with mobility, for example when moving away from their parents. Of course, given the inconsistency with previous evidence or theory, the result could also simply reflect statistical noise in the data. In any case, this negative association only obtains in the D&D model for self-efficacy in boys that lost HSF. Results for boys are consistently null across all other outcomes and sub-samples.

2.3.5 Parent and peer relations

Table 2.5 presents results using alternate psychosocial measurement scales based on a child's relationship with parents and peers. Results are reported separately for younger and older cohorts as the older cohort was not asked any items on the parent relationship scale. As shown in model (1), access to HSF has a significant positive raw association with the parent and peer relationship scale for girls and boys in the younger cohort. There was also a positive correlation in the peer relationship scale for older girls but not boys. However, with the inclusion of child fixed effects these associations mostly attenuate toward zero. The only exception is for peer relationships in the younger cohort of girls. So there is some evidence that access to HSF during early adolescents (age 12-15) could improve relationships with peers for girls. Associations for other household infrastructure measures are also reported in Table 2.5 for comparison to results from our primary self-efficacy and self-esteem outcomes. Similar to the primary outcomes, the infrastructure measures are not strongly or robustly associated with parent or peer relationship scales.

Table 2.5. HSF and parent and peer relationship scales by gender and cohort

	Parent (age 12-15)			Peer (age 12-15)			Peer (age 19-22)		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Panel A: Girls									
HSF	0.187***	0.071	0.031	0.142**	0.222***	0.233**	0.158*	-0.069	-0.126
	(0.058)	(0.081)	(0.124)	(0.060)	(0.065)	(0.096)	(0.079)	(0.096)	(0.125)
Panel B: Boys									
HSF	0.126**	-0.043	-0.041	0.141**	0.018	0.047	0.063	0.017	-0.101
	(0.048)	(0.083)	(0.098)	(0.054)	(0.085)	(0.114)	(0.065)	(0.097)	(0.129)
Controls	NO	YES	YES	NO	YES	YES	NO	YES	YES
Child FE	NO	YES	YES	NO	YES	YES	NO	YES	YES
D&D estimator	NO	NO	YES	NO	NO	YES	NO	NO	YES

Notes: Cluster robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Additional controls: household size and time, cohort, and community (site) dummies.

2.3.6 Evidence on mechanisms

Table 2.6 presents results with the inclusion of additional physical health controls—BMI and reported good health. Columns labeled model (1) show raw correlations with no health controls.

Note the raw associations are not exactly the same as our benchmark estimates as here we have excluded children with missing health controls to ensure a constant sample to facilitate comparison across columns. As shown in columns labeled model (2), there are positive associations between physical health measures and each psychosocial outcome for both girls and boys. Although, the association with BMI is generally small and only statistically significant for self-efficacy in boys. Moreover, the associations between HSF and psychosocial outcomes attenuate only slightly when the additional heath measures are added to the model. Formally, Sobel tests reveal a statistically significant mediation effect of good health on each outcome for girls and boys (see Sobel results in appendix Table B.2). In contrast, BMI has a statistically significant mediation effect only for self-esteem in girls and self-efficacy in boys. Quantitatively, however, these mediation effects are small, with 1-6% of the total association of HSF with any outcome explained by either health measure.

Table 2.6. HSF and psychosocial development by gender: health mechanism

	Self-Efficacy				Self-Esteem			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Panel A: Girls								
HSF	0.213***	0.204***	0.190**	0.190**	0.132**	0.121**	0.234***	0.233***
	(0.056)	(0.053)	(0.075)	(0.073)	(0.060)	(0.058)	(0.076)	(0.076)
Good Health		0.090**		-0.008		0.088*		0.050
		(0.041)		(0.051)		(0.046)		(0.044)
BMI		0.008		0.025		0.011		0.034**
		(0.009)		(0.017)		(0.008)		(0.016)
Panel B: Boys								
HSF	0.111**	0.096*	-0.083	-0.082	0.118**	0.110*	0.028	0.028
	(0.054)	(0.052)	(0.062)	(0.063)	(0.056)	(0.056)	(0.066)	(0.066)
Good Health		0.135***		0.027		0.115***		0.023
		(0.045)		(0.060)		(0.041)		(0.053)
BMI		0.017**		0.006		0.004		-0.001
		(0.007)		(0.019)		(0.005)		(0.015)
Controls	NO	NO	YES	YES	NO	NO	YES	YES
Child FE	NO	NO	YES	YES	NO	NO	YES	YES

Notes: Cluster robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Controls: household size, HQ index, CD index, and electricity, cooking fuel, water, time, cohort, and community (site) dummies. All regressions exclude individuals with missing health variables.

Columns labeled (3) and (4) in Table 2.6 show results from our FE model specification with and without physical health controls. With child fixed effects, the association between the health

measures and outcomes are all close to zero and statistically insignificant (with the exception of BMI and self-esteem for girls). This suggests much of the raw correlation between health measures and outcomes is driven by confounding factors. Again we see very little attenuation of HSF results towards zero when health control are added. Formally, Sobel tests do not find a statistically significant mediation effect of health measures on any outcome in the FE model (appendix Table B.2). Hence, these results provide little evidence that access to sanitation at home is improving psychosocial outcomes through improved physical health. Of course, we only examine a limited number of physical health measures based on data availability, so these results should be viewed as suggestive.

Existing literature also provides evidence of increased psychosocial stress around menstruation for adolescent girls (Tegegne and Sisay, 2014; Van Eijk et al., 2016; Adukia, 2017; Sclar et al., 2018b; Singolyo and Ngussa, 2019). In order to explore if HSF might mitigate this stress, Table 2.7 provides logistic regression results using an indicator for self-reporting missing school during days when menstruating. Recall this data was only collected from the younger cohort of girls in India, so the sample size is quite small. It was also only collected in round five so we can only run a pooled OLS specification. Nonetheless, results can provide some clues if HSF may have improved psychosocial outcomes in girls by mitigating general stress during menstruation.

The first column in Table 2.7 shows that access to HSF is associated with significantly lower odds of missing school during menstruation. The column also shows that all other household infrastructure measures are not significantly related to missing school, though the standard errors on some of these are quite large given the small sample. The second column adds four indicators for the quality of sanitation facilities at school. Each indicator is associated with lower odds of missing school, but the relationship is only statistically significant for the availability of facilities for disposal of sanitary napkins. In the third column the four indicators are replaced with their sum as a more general measure of school toilet quality. This measure is strongly associated with lower odds of missing school suggesting that school sanitation matters in mitigating stress surrounding menstruation. However, note that the inclusion of school sanitation quality indicators does not

Table 2.7. HSF and missing school when menstruating

	Miss School			Self-Efficacy		Self-Esteem	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
HSF	0.493**	0.536*	0.527*		0.228**		0.129
	(0.174)	(0.193)	(0.189)		(0.106)		(0.120)
HQ Index	1.470	1.568	1.515	0.140	0.086	0.016	-0.015
	(0.803)	(0.860)	(0.832)	(0.223)	(0.220)	(0.200)	(0.203)
Electricity	0.702	0.686	0.740	0.058	0.086	0.407	0.422
	(0.489)	(0.469)	(0.509)	(0.292)	(0.292)	(0.253)	(0.259)
Cooking Fuel	1.485	1.519	1.510	0.122	0.063	0.015	-0.018
	(0.498)	(0.507)	(0.506)	(0.104)	(0.107)	(0.099)	(0.105)
Water	0.344	0.319	0.338	-0.260	-0.240	-0.176	-0.164
	(0.307)	(0.282)	(0.297)	(0.307)	(0.294)	(0.336)	(0.329)
CD Index	0.782	0.812	0.825	0.412	0.255	-0.288	-0.377
	(0.719)	(0.740)	(0.750)	(0.362)	(0.378)	(0.334)	(0.341)
School toilet: clean		0.478					
		(0.221)					
School toilet: water		0.851					
		(0.398)					
School toilet: soap		0.881					
		(0.237)					
School toilet: disposal		0.542**					
		(0.138)					
School toilet: sum			0.661***				
			(0.084)				
Miss school				-0.188*	-0.172	-0.122	-0.113
				(0.113)	(0.112)	(0.114)	(0.114)
Observations	632	632	632	632	632	632	632

Notes: Odds ratio from logit regressions reported in first three columns. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Additional controls: household size and community (site) dummies. Regressions only include younger cohort of girls in India in round five of the survey.

have a large impact on the estimated association between HSF and missing school. This is at least tentatively consistent with HSF potentially improving psychosocial outcomes in girls through mitigating general stress around menstruation.

The final four columns in Table 2.7 more directly examine the relationship between missing school and our psychosocial outcomes. As shown in column (4), girls that reported missing school when menstruating also reported significantly lower self-efficacy. Moreover, when HSF is added to the regression, the association diminishes and becomes statistically insignificant. However, the change is small (Sobel test does not show a statistically significant mediation effect), suggesting increased school attendance is likely not the primary direct channel through which HSF may improve self-efficacy. The final two columns show the same pattern of results also hold for self-esteem, though associations with missing school are smaller and statistically insignificant given the small sample size. Nonetheless, we view the general pattern of associations presented in Table 2.7

as broadly consistent with a potential mechanism linking HSF to changed feelings and/or behavior around menstruation for adolescent girls.

2.4 Discussion

This paper presents an analysis of the impact of access to private sanitation facilities at home on psychosocial health. Our study shows that private sanitation facilities are positively associated with self-efficacy and self-esteem for both girls and boys. However, after controlling for various factors such as child-fixed effects and time-varying controls, we find that access to private sanitation is only linked to higher self-efficacy and self-esteem for girls but not boys. Furthermore, we investigate whether access to private sanitation is more important for psychosocial growth when children are surrounded by peers with access. We find that private access to sanitation may have limited psychosocial benefits in communities with low access overall.

There remain many important avenues for future research examining the link between access to sanitation facilities and psychosocial development. First, while our results show a positive association between HSF and outcomes for girls between 2013 and 2016, it is important to investigate whether these results persist over time. Future research could follow children over a longer period to examine the long-term effects of HSF on psychosocial development. Second, it is possible that additional individual or contextual factors may moderate the impact of access to HSF on self-efficacy and self-esteem. For example, factors such as socioeconomic status or cultural background may influence how individuals perceive and respond to access to alternate forms of sanitation. Future research could investigate these moderating factors to identify subgroups of the population that may benefit more or less from intervention. Third, there are various types of interventions that may be used to improve access to sanitation facilities, such as building household latrines, promoting hand hygiene, or providing community-level sanitation facilities. Future research could compare the effectiveness of these different types of interventions in improving psychosocial outcomes, and identify the most effective strategies for improving well-being. Finally, while we provide some tentative evidence of mechanisms linking HSF to improved outcom-

es, a more complete understanding of channels would provide valuable insight. All of these areas of research could help to deepen our understanding of the relationship between access to sanitation facilities and well-being, and inform the design and implementation of effective interventions.

2.5 Conclusion

The health benefits of access to improved sanitation through reduced exposure to pathogens is now well-established in the literature. This study provides novel evidence that a better sanitation experience for adolescent girls may also have psychological and social related benefits. We show that when girls in Ethiopia and India obtained access to home sanitation facilities they reported higher levels of self-efficacy and self-esteem. There was no such relationship for boys. However, we also find evidence suggesting relative access for girls may matter more than absolute access. This has important policy implications, particularly highlighting that inequities present in the roll-out of sanitation interventions may have unintended spillover consequences. It is important that we continue to investigate the social and behavioral mechanisms through which sanitation may contribute to psychosocial development over the life course, particularly for women and girls. A deeper understanding of these causal pathways is essential for developing effective policies and interventions that seek to help children thrive and reach their full potential.

Chapter 3

Fuel, water, and labor: Household's choices and impact on labor in Ethiopia

Access to clean water, sanitation, and hygiene (hereafter WASH), as well as clean cooking fuels, is a crucial global issue. Efforts to improve access to sources of drinking water (hereafter SDW) have been underway for decades, with the Millennium Development Goals (MDGs) and now the Sustainable Development Goals (SDGs) focusing on this issue (Clasen, 2012). Target 7C of the MDGs aimed to halve the number of people without access to sustainable SDW and basic sanitation. Global access to improved SDW was only 76% in 1990 but had increased to 91% by 2015, representing significant progress towards the international drinking water target (Everard, 2019), despite some skepticism about the progress being artificial (Clasen, 2012). The recognition of access to WASH as a human right by the UN General Assembly in 2010 was a major milestone (United Nations General Assesmbly, 2010), yet large numbers of people still lack access to basic drinking water supplies, as highlighted in the sixth SDG[17].

On the other hand, according to the 2019 International Energy Agency progress report, about 3 billion people worldwide still lack access to clean cooking fuels and improved cooking technologies. The reason for the observed deficit can be attributed to the fact that the growth in access to these fuels and technologies is being outpaced by population growth, especially for places such as Sub-Saharan Africa (World Health Organization et al., 2019). Specifically, as of 2020, only a mere 17% of Sub-Saharan Africa's population relies on clean cooking fuels, emphasizing the severity of the situation (International Energy Agency, 2020).

A household's choice of cooking fuel not only has a localized impact on the health of individuals in a household but also bears a broader global environmental impact (Rahut et al., 2020). Similarly,

[17]Before the Covid-19 pandemic in 2017, about 2.2 billion people lacked safely managed drinking water, and 4.2 billion people lacked safely managed sanitation. With Covid-19 in the picture, approximately nearly 3 billion people lack basic hand washing facilities at home (https://www.un.org/sustainabledevelopment/water-and-sanitation/).

the quality and access to clean drinking water are crucial with regard to well-being and environmental sustainability (Heltberg, 2004; Usman et al., 2019b). The choices of cooking fuels and drinking water sources have far-reaching impacts on the time available for both adult and children members of a household. For instance, the parental investment of time in childcare has implications on children's cognitive and noncognitive developments (Leibowitz, 1974), which in turn, are significant for future life outcomes (Becker, 1981). Whether household heads have more time or not to invest in childcare partly depends on the nature of the cost and ease of access to clean cooking fuel or drinking water. For households in low- and middle-income countries, tasks such as fetching water or collecting firewood entail burdensome responsibilities (Choudhuri and Desai, 2021). Choudhuri and Desai (2021) underscore that doing different unpaid household work has implications on the intergenerational disadvantage for children, arguing it happens through the time-poverty and opportunity cost mechanisms. More unpaid household chores of this nature mean the parents are time-poor, with less time for vital childcare and supervision. Additionally, such household chores imply that parents have to forego regular jobs that would pay an income. The foregone income effect suggests that the household is bereft of resources that would complement the purchase of school supplies or paying helpers/maids. The combined impact of time poverty and opportunity cost adversely affects children's care supervision, implying intergenerational disadvantage and simultaneously affecting how much adults must commit to the labor market. Time poverty and opportunity costs are a challenge for developing countries, with recent estimates indicating that over 890 million people in Sub-Saharan Africa alone still rely on traditional fuels such as firewood, crop residues, charcoal, and dung-cakes (Heltberg, 2004; McLean et al., 2019; Wassie and Adaramola, 2021). Similarly, despite SDW being recognized as a fundamental human right, billions still lack access to the basics.

This paper examines the factors influencing households' selection of cooking fuel and drinking water in rural areas and small towns of Ethiopia. Additionally, it investigates the effects of improved SDW services and access to improved cooking fuel on labor outcomes. Ethiopia is the second-most populous country in Africa, with a population of about 112 million as of 2019,

over a landlocked land area[18] of approximately 1.1 million square kilometers. The country exhibits distinct regional characteristics, with the East and South mainly being arid and ideal for herding animals. The western lowlands remain mostly uncultivated with small populations. In contrast, the highlands are ideal for farming, hence the limited availability of land compounded by the dense population in the area (Haile and Kasa, 2015; Reimann et al., 2003). Most of the population (80%) lives in rural areas and utilizes solid fuels, while the other 20% live in urban areas, of whom 75% use solid fuels (Beyene et al., 2018). Notably, the common source of cooking fuel in Ethiopia was firewood accounting for 76% as of 2016 (Beyene et al., 2018). Ethiopia presents an intriguing case for study because of the population growth[19] and its susceptibility to weather-related exogenous shocks which play a significant role in the demand for WASH services. These historic exogenous shocks[20], such as the infamous El Niños, can potentially negatively affect the WASH situation in a country. Generally, these droughts historically occur once every decade, although they have been quite frequent in the recent past. Kassaye et al. (2021) documents that 1984, 1986, 2002, and 2014/15 were the worst extreme drought years across all locations in Ethiopia. The current study utilizes the third Ethiopian socioeconomic survey conducted from 2014 to 2016, which coincided with the most recent drought and exogenous shock, emphasizing the relevance of this paper.

Previous studies have examined the impact of access to energy markets and piped water on children's educational outcomes and gender differences using cross-sectional surveys. For instance, Choudhuri and Desai (2021) and Mosa (2016) used cross-sectional surveys to address whether access to energy markets and piped water affects children's educational outcomes and gender differences. They study the relationship between access to infrastructure and children's educational outcomes through the mother's time availability channel. Similarly, investigations into determinants of cooking fuel and drinking water sources have also relied on cross-sectional data (Behera and

[18]It is bordered by Eritrea, Djibouti, Somalia, Kenya, and Sudan.

[19]McLean et al. (2019) use the Demographic and Health Surveys for 69 countries to show that considerable variation across countries in their use of solid fuels exists because of the population growth.

[20]According to Kassaye et al. (2021), the Ethiopian history of droughts dates back to 250 BC.

Sethi, 2020; Fotue and Sikod, 2012; Usman et al., 2016; Irianti et al., 2016; Rauf et al., 2015; Liao et al., 2019; Rahut et al., 2020; Behera and Sethi, 2020; Paudel et al., 2018a).

However, in this paper, the approach is based on panel data using three-panel surveys focusing on Ethiopia's rural areas and small towns. I use the World Bank's living standards measurement survey (LSMS), the Ethiopian Social Economic Survey (hereafter ESS), for 2011/12, 2013/14, and 2015/16. One of the research questions this paper addresses is to explore the main determinants of a household's choice of cooking fuel and source of drinking water when the household is observed repeatedly. I use the ordered probit for cooking fuels and probit models for drinking water to understand the households' choices. Additionally, I investigate the impact of access to improved services, vis-à-vis improved cooking fuels and drinking water, on labor time activities. The upside of using the panel data is that it allows me to observe variations in access to clean fuel and sources of drinking water across different survey waves. To the best of my knowledge, the closest paper I have seen so far employing a panel data set-up is by Alem et al. (2016), who study determinants of cooking fuel for Urban Ethiopia. However, the current study explicitly examines rural and small towns.

Numerous research has shown that WASH and clean cooking fuels impact the health of a population (Fan and Mahal, 2011; Usman et al., 2019b; Silwal and McKay, 2015; Lin and Wei, 2022; Das et al., 2017; Imran and Ozcatalbas, 2020; Tian et al., 2021). For instance, using the 1994 Human Development Index survey for India, Fan and Mahal (2011) apply different matching methods to show that WASH impacts individual child-level health regarding dysentery and diarrhea. A similar sample of children under the age of 5 was also observed in an Ethiopian primary household survey, in which instrumental variables regression and bivariate probit model are used to address local average treatment effects. The findings demonstrated that access to uncontaminated water reduced diarrhea (Usman et al., 2019b).

Some types of cooking fuels also have negative health implications for households, including respiratory, neurological, or eye health problems. Evidence from a unique Indonesian household survey shows that individuals living in households that use firewood had reduced lung capacity

Silwal and McKay (2015). At the same time, Das et al. (2017) found similar res on ults in a small sample of households in Malawi where household members experienced shortness of breath, difficulty breathing, or chest pains. Regarding household medical expenses, Lin and Wei (2022) show that these health expenses for households that rely on dirty cooking energy tend to be higher by 1.4-1.9% ceteris paribus. Unfortunately, the brunt of this falls disproportionately on rural women since they handle most of the household chores (Imran and Ozcatalbas, 2020) and also because of the rural-urban divide in cooking energy (Irianti et al., 2016; Tian et al., 2021).

There is also vast literature that studies households' determinants of sources of drinking water (Behera and Sethi, 2020; Fotue and Sikod, 2012; Irianti et al., 2016; Rauf et al., 2015) and households' choices of cooking fuels (Liao et al., 2019; Rahut et al., 2020; Behera and Sethi, 2020; Paudel et al., 2018a) all with varying jurisdictions, methodologies, and results. For instance, using three waves of the living standards measurement cross-sectional urban data for Nepal, Behera and Sethi (2020) applied multinomial logit modeling to show that education levels, distance to the market, wealth characteristics, and location matter for households' choices of sources of drinking water. In addition to distance and household size and using a similar methodology, Fotue and Sikod (2012) showed that a welfare proxy such as expenditure is also important. However, a common thread among most of these studies is that they all use cross-sectional data, which has certain limitations. Cross-sectional studies provide a snapshot of data at a specific point in time and do not capture changes or trends over time. They can also be subject to selection bias and do not establish causality. Additionally, cross-sectional studies may not account for confounding variables or allow for examination of long-term effects (Greene, 2018).

In addition, the absence of improved services results in a significant deprivation of time for households. Notably, households that rely on contaminated cooking fuel have to endure picking firewood, the dirtier energy. The arduous task is challenging for household members, and this is compounded by poor road networks and most areas being beleaguered by deforestation. Similarly, not having access to clean water implies that households rely on nearby rivers or lakes or poor alternatives to meet their daily needs. Unfortunately, most empirical studies consistently highlight

that women disproportionately bear the brunt of this drudgery (Nauges and Strand, 2017; Gross et al., 2018). As a consequence of these impacts on health and time poverty, the educational outcomes of children in these households tend to be affected as well (Choudhuri and Desai, 2021).

This paper makes a significant contribution to this rapidly growing literature on WASH variables and cooking energy fuel in two ways. Firstly, it offers a different conceptual understanding that elucidates the complicated connection between household decisions to use certain drinking water sources and certain cooking fuels. By examining the interplay between these two critical aspects, the paper sheds light on the dimensions of the main determinants of the sources of drinking water and cooking energy fuel. Secondly, this study employs a robust research design by incorporating repeated observations, allowing for a deeper analysis that considers the inherent heterogeneity among individual households and their members. Taking this approach enhances internal and external validity and, therefore, the reliability of the findings because of acknowledging the diverse circumstances and characteristics within households over time. While previous research has made remarkable progress regarding the understanding of the impact of WASH variables and cooking energies on different populations' time-use, health, educational, and gendered labor outcomes, most of these studies have relied on cross-sectional data. Similarly, a large body of work has devoted efforts to understanding what determines households' decisions regarding types of cooking fuels or sources of drinking water. However, by employing a longitudinal approach in this paper, I attempt to address an essential gap in the existing literature, contributing to a deeper comprehension of the long-term effects and dynamics of SDW and cooking energy fuel choices. This paper's rigorous approach, innovative conceptual framework, and use of repeated observations contribute significantly to the scholarly discourse on SDW and cooking energy fuel. The research design and methodology enhance credibility and offer the potential for further research and policy interventions in this field.

The paper is structured as follows: the next section (3.1) provides an overview of the economy, cooking fuels and WASH in Ethiopia, followed by a conceptual review in Section 3.2. The subsequent section detail the data sources, variables and descriptive statistics (Section 3.3). The

Table 3.1. Population, LFPR and GDP between 1960-2020

	Population in millions							
	1960	1970	1980	1990	2000	2010	2020	
Rural Population	20.726	25.975	31.483	41.844	56.463	72.462	90.022	
Urban Population	1.425	2.440	3.658	6.044	9.762	15.178	24.941	
Total Population	22.151	28.415	35.142	47.888	66.225	87.640	114.964	
Population Growth	-	28.3%	23.7%	36.3%	38.3%	32.3%	31.2%	
Annual Female LFPR	-	-	-	67.8%	72.92%	76.28%	-	
Annual Male LFPR	-	-	-	90.32%	90.55%	89.98%	-	
	GDP in billions of US$, GDP Per Capita and Annual GDP Growth							
	1985	1990	1995	2000	2005	2010	2015	2020
GDP	10.296	13.225	13.897	17.353	23.704	39.727	64.589	95.069
GDP Per Capita	253.72	276.16	243.60	262.03	310.48	453.30	640.54	826.95
Annual GDP Growth	-11.14%	2.73%	6.13%	6.07%	11.82%	12.55%	10.39%	6.06%

Notes: The data presented here has been compiled by using WDI data. GDP refers to Gross Domestic Product at constant 2015 prices. Population growth is calculated as the percentage change over a 10-year period. LFPR represents the labor force participation rate, specifically for the female population (i.e., the percentage of females aged 15-64) based on estimates provided by the International Labor Organization (ILO).

econometric models used in the study are in Section 3.4, while the empirical results and discussion appear in Section 3.5. The conclusion with key insights and implications is in Section 3.6.

3.1 The economy, energy, and water

According to the World Bank's World Development Indicators (WDI), the population of Ethiopia as of 2020 was 114 million and had been growing by almost a third every decade since the 1960s. Available World Bank data on the labor force participation rate (LFPR) shows that the annual LFPR has been considerably higher for men than women, although this gap has been reducing with time. In terms of the economic profile, the country's output was about $95 billion, with a relatively decent annual growth rate and a relatively low per capita income of less than a thousand US dollars in 2020. These statistics are shown in Table 3.1.

The economy of Ethiopia is dominated by agriculture, industry and services as key sectors[21]. In terms of cooking fuel energy, Ethiopia has been working towards utilizing renewable energy

[21] https://data.worldbank.org/country/ethiopia

sources (Berhanu et al., 2017; Guta, 2020). This includes efforts to reduce reliance on traditional biomass fuels such as firewood and charcoal by promoting the use of cleaner cooking technologies like improved cookstoves and biogas. These initiatives aim to improve energy efficiency, reduce indoor air pollution, and mitigate environmental degradation. Access to clean drinking water is also a priority in Ethiopia Usman et al. (2019a). While the country has abundant water resources, challenges persist, especially in rural areas. Efforts are being made to enhance water management, expand water supply infrastructure, and improve water quality through purification systems. These initiatives (including the ONEWASH National Programme (OWNP)[22]) aim to ensure safe and reliable access to clean drinking water for all Ethiopians. The Ethiopian economy is diverse, with ongoing efforts to promote sustainable development. Initiatives in cooking fuel energy focus on transitioning to cleaner alternatives, while measures to enhance access to clean drinking water aim to improve public health and well-being.

3.2 Choice of cooking fuel and water sources

Improved services,[23] gender and power dynamics within the household, including intrahousehold bargaining, interact to shape resource access and well-being. As discussed in the previous sections, access to clean cooking energy and water promotes health (Fan and Mahal, 2011; Usman et al., 2019b; Silwal and McKay, 2015; Lin and Wei, 2022; Das et al., 2017; Imran and Ozcatalbas, 2020; Tian et al., 2021). Access to these services plays a crucial role in ensuring the well-being of individuals and households. However, gender and power dynamics within the household may affect water and energy resource allocation (Pachauri and Rao, 2013; Clancy et al., 2003; Fatona et al., 2013; Haddad et al., 1997). Traditional gender roles and power imbalances may lead to inequalities, limiting certain individuals' access to these vital resources. Furthermore, the distribution of bargaining power within a household influences the process of decision-making (Schneebaum and Mader, 2013; Bernard et al., 2019). Household members' relative power and

[22]The OWNP Phase 1 report is accessible here.

[23]In this study, improved services are cooking fuel and drinking water services.

influence can impact resource allocation and access. Improving access and well-being for everyone requires addressing all these factors in an all-inclusive manner that considers improved services, gender dynamics, power dynamics within the household, and intrahousehold bargaining power.

The mechanism for the choice of cooking energy fuels is intricately intertwined with the accessibility of energy markets and the affordability of infrastructure services for households. I theorize that having such infrastructure as piped water facilities is linked to having access to improved cooking energy. In order to enhance the understanding of household cooking energy research, I propose an extension to the widely recognized energy ladder hypothesis (hereafter ELH) (Heltberg, 2004; Leach, 1992; Rahut et al., 2020). This extension incorporates the influence of infrastructure services on the decision-making process of households, thereby augmenting the existing ELH framework. By integrating the impact of infrastructure services, my study aims to provide a robust and comprehensive analysis of the factors shaping households' choices in the context of cooking energy.

The ELH posits that fuel switching in communities happens progressively in a phased manner. According to the hypothesis, cooking fuels are ranked based on their quality and price on a spectrum from the least desirable to the most desirable, both from the point of view of household welfare and global considerations. At the lower end of the spectrum, we find the least desirable cooking fuels, called polluting cooking fuels. These fuels include biomass sources such as firewood, animal waste, agricultural residues, or dung. Moving up the ladder, we encounter transitional cooking fuels such as charcoal, coal, or kerosene, which represent an intermediate stage. Finally, the switch is made to the more desirable clean cooking fuels, including liquefied petroleum gas (LPG), natural gas, biogas, or electricity (Heltberg, 2004; Rahut et al., 2020; Van der Kroon et al., 2013). The hypothesis suggests that households ascend the fuel ladder based on various factors including income levels, fuel prices, degree of urbanization, and availability of biomass resources (Heltberg, 2004; Rahut et al., 2020).

It is also important to recognize that households can use multiple sources of cooking fuels simultaneously, as indicated by Heltberg (2004), therefore, uptake of new preferred fuels does

not imply abandoning polluting fuels. Rahut et al. (2020) explain this energy stacking[24] using what has become known as the ladder-within-a-ladder energy hypothesis. The ladder-within-a-ladder energy hypothesis can be expanded to include the idea that households' access to various infrastructure services can contribute to income growth. By providing more time and financial resources, improved infrastructure enables households to have a greater range of fuel options at their disposal. I argue that the availability and accessibility of infrastructure services, such as piped water facilities, have a profound impact on a household's cooking fuel selection. In a study of eight developing countries[25], Heltberg (2004) underscores the critical role of piped water regarding fuel switching or transition. For instance, the study demonstrates that having access to infrastructure services such as piped water into a dwelling in Brazil impacts the switch to LPG, a relatively cleaner fuel. Conversely, outside water source does not show the same impact. Therefore, accessibility to piped water emerges as a crucial variable in the switching from solid to non-solid fuels. Building upon this conceptual foundation, I posit that when a household has access to piped water running directly into the dwelling, more often than not, resources are freed up since accessing water away from the residence entails costs (both in terms of time and income). The saved time from improved water would further translate into increased labor market participation among household members, leading to higher income and incentivizing a switch in the type of cooking fuel. The freed-up resources allow the household to switch and move up the energy hypothesis ladder. However, I recognize and acknowledge that if a household has piped water, the implication is that there is [may be] also a need to pay costly water bills, which may be substantial. In this conceptualization, however, I assume that the cost of maintaining piped water is comparatively lower than the daily task of fetching water, considering the additional opportunity costs.

Figure 3.1 shows that a household's decision-making is shaped by an interplay of economic and non-economic factors. Among the economic factors, we have two scenarios: whether a

[24]Energy stacking is defined as the simultaneous use of multiple cooking fuel choices. (Rahut et al., 2020)

[25]Brazil, Ghana, Guatemala, India, Nepal, Nicaragua and South Africa, and Vietnam. Note that Ethiopia was not part of these countries.

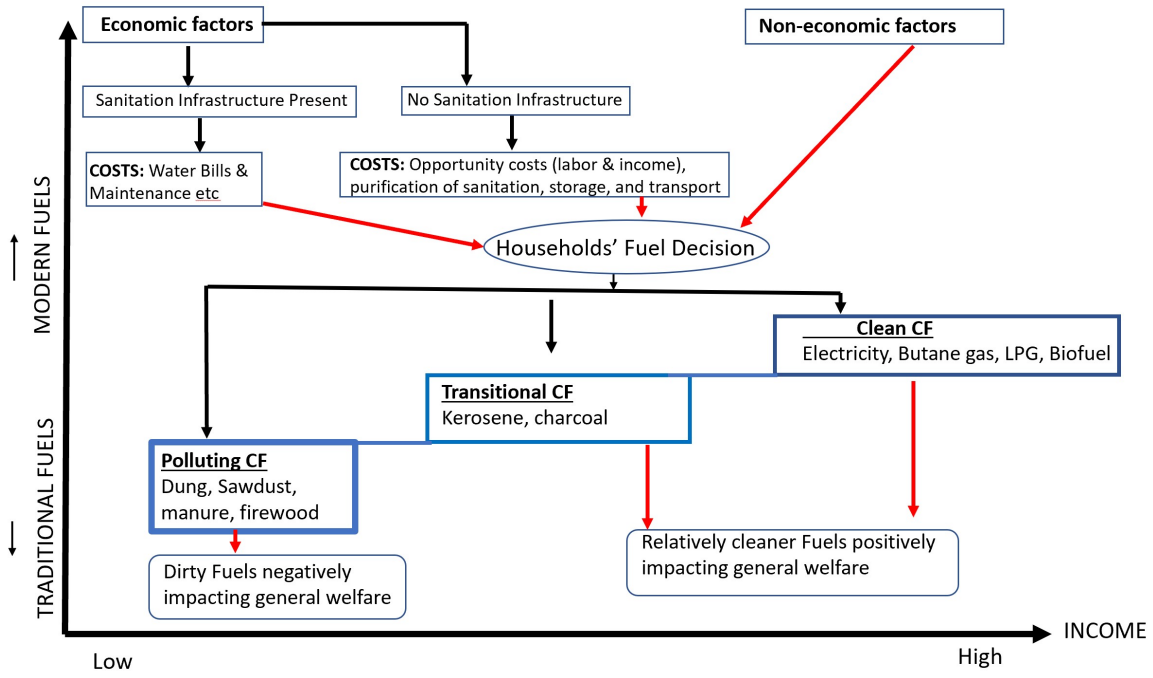

Figure 3.1. Households' decision making.

This figure is an adaptation and modification of Amoah (2019), Van der Kroon et al. (2013) and Danlami et al. (2015). CF stands for cooking fuel.

household has piped water infrastructure or not. Each respective scenario implies different costs to the household which have further implications for the speed of a household's transition on the energy ladder. I propose a hypothesis that when a household has piped water infrastructure, the transition to cleaner fuels is quicker than when it does not because the presence of infrastructure affords the household access to freed-up resources, indirectly increasing household income. In other words, a household will have a higher probability of deciding to use relatively cleaner fuel when that household has water infrastructure due to some relief from time poverty.

3.3 Data

This paper uses three waves of the Ethiopian Socioeconomic Surveys (ESS) between 2012 and 2016 to analyze the determinants of the household's choice of cooking fuel and SDW. The survey employs a two-stage stratified probability sample sampling design, with the first sampling stage using simple random sampling to select enumeration areas (EA) categorized as rural and small

towns. As such, the ESS dataset provides representative information for rural and small towns in Ethiopia. In the second sampling, the survey employs systematic random sampling to select households surveyed within the selected enumeration area. The survey encompassed a total of 3,969 households in 2012, 3,776 households in 2014, and 3,699 households in 2016 from rural and small-town areas in Ethiopia[26]. Furthermore, the survey data from these years and households comprised information on 18,866 individuals in 2012, 20,910 individuals in 2014, and 22,807 individuals in 2016 residing in rural and small-town settings.

3.3.1 Outcome and Treatment Variables

This study utilizes ordered probit, regular probit, and fixed effects regression models to examine various aspects of the research questions. The outcome variables in the probit models correspond to the categorical variables representing the choice of cooking fuel: polluting, transitional and clean cooking fuels. The outcome variables in the probit model for studying the determinants of sources of drinking water (SDW) are the categorical variables representing improved or unimproved water. It is important to note that these categorical variables for cooking fuel follow a natural ordering, whereas I argue that the variable representing SDW does not exhibit such an inherent order.

The WHO defines clean, transitional and polluting cooking fuels with regard to specific thresholds[27] and the literature in the field follows these definitions (Van der Kroon et al., 2013; Rahut et al., 2020; Heltberg, 2004). Clean fuels refer to fuels that are considered safe for health when used and produce minimal particulate matter and carbon monoxide emissions and include solar, electric, biogas, natural gas, liquefied petroleum gas (LPG), and alcohol fuels, including ethanol. Transitional cooking fuels, on the other hand, offer some health benefits but may not meet the technical thresholds established by the WHO. These fuels include kerosene, charcoal or coal. Finally, polluting fuels are those that do not provide any health benefits and have detrimental

[26]There were large urban towns that appeared in the sample in rounds 2 and 3 (1,486 and 1,255, respectively) but these were not part of the current investigation as the focus is on rural and small towns only.

[27]Technical definitions can be found here: Defining clean fuels and technologies.

effects on human health and include biomass i.e., firewood, agricultural residue, and dung. This paper adheres to these established conventions for defining categories of cooking fuels.

Additionally, the WHO refers to improved drinking-water sources as those characterized by their potential to be safeguarded against external contamination, with particular emphasis on fecal matter[28][29]. For the purposes of this study, improved water is defined as including piped water into dwellings, piped water into yards/plots, piped water at public tap/standpipes, tubewells/boreholes, protected dug wells, protected springs, and rainwater collection. Anything else other than this is not improved, including sources such as unprotected wells/springs, surface water, river or lakes.

In the final analysis, I look at the impact of improved access to SDW and CF on labor hours. Here the fixed effects regressions in the panel data models focus on estimating the allocation of labor hours across different categories, including agricultural labor, family business labor, labor outside the household, and total labor (the sum of the former three categories). It is important to note that the labor hours considered in this analysis pertain to the past seven days, providing a recent and comprehensive perspective on labor allocation patterns. In the context of the ESS survey, agricultural labor encompasses activities related to agriculture, livestock, and fishing, regardless of whether the output is intended for sale or household consumption. Family business labor refers to activities undertaken by household members to support non-agricultural or non-fishing household businesses, regardless of their scale. Importantly, the output of these activities benefits the household member or the household itself. Labor outside the household encompasses casual, part-time, or temporary employment, involving wage, salary, commission, or any form of payment and unpaid apprenticeships[30]. Total labor hours were derived by aggregating the three aforementioned categories.

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[28]The WHO lists of improved sources of water: household connections, public standpipes, boreholes, protected dug wells, protected springs, and rainwater collection systems.Link to WHO website.

[29]The WHO lists of unimproved sources of water: Unprotected wells, unprotected springs, surface water sources such as rivers, dams, or lakes, water provided by vendors, bottled water (unless water for other purposes is sourced from an improved source), and water supplied by tanker trucks. Link to WHO website.

[30]All the surveys can be accessed on the World Bank website: https://microdata.worldbank.org.

3.3.2 Control Variables

The study uses a set of controls consisting of demographic characteristics, human capital (educational characteristics of the household head), wealth characteristics, accessibility factors, and spatial characteristics[31].

The study incorporates a comprehensive set of controls to examine the determinants of drinking water and cooking fuel sources. Among the demographic characteristics, the age of the household head is considered, allowing for an exploration of how age influences water source preferences. Additionally, I include the squared age variable in the probit models to account for potential nonlinear effects. A sex dummy variable is added to investigate potential gender-related differences in water source choices. Household size, measured by the number of family members, provides insights into the impact of household composition on cooking fuel and drinking water source selection. Furthermore, robustness checks consider subgroup characteristics, such as the number of elderly, children, or adults within a household.

For human capital and education characteristics, I include the education level of the household head, captured through a series of dummy variables. Starting with a “no education" dummy variable as the comparison group, the study examines education levels below primary, primary completion, middle school completion, secondary school completion, senior secondary school completion, and completion of university-level education. Moreover, a dummy variable accounts for whether one has obtained a certificate, diploma, or some college education, while another captures postgraduate studies. These controls enable an examination of the role of educational attainment in shaping drinking water and cooking fuel source preferences.

To account for wealth-related factors, the study includes a wealth proxy created by a principal component analysis (PCA)[32]. These wealth characteristics shed light on the relationship between socioeconomic status, cooking fuels, and drinking water source selection. Furthermore, spatial controls were incorporated to account for regional variations in the analysis, ensuring robustness

[31] An expanded list of these control variables is provided in Appendix section C.4.

[32] The details of the list of assets included in the PCA for creating the asset index can be found in Appendix section C.3

and addressing potential confounding factors related to geographic location in Ethiopia. Overall, incorporating these comprehensive controls, encompassing demographic, human capital and education, wealth and spatial characteristics, allows for a robust analysis of the determinants of cooking fuel and drinking water sources. By considering these factors, the study aims to provide valuable insights into the complex dynamics influencing cooking fuel and drinking water source preferences and contribute to a deeper understanding of the subject.

3.3.3 Descriptive Statistics

Table 3.2 shows selected descriptive statistics.[33] The table offers a comprehensive overview of the summary statistics across three years: 2012, 2014, and 2016. The variables are organized into three broad categories. Firstly, there are statistics that are conditioned on positive values, capturing the intensive margins. Secondly, the variables are separated into dummy variables (0/1), where the corresponding variables are assigned a value of 1 if they are positive and 0 otherwise, representing the extensive margins. Lastly, there are variables whose statistics are reported without the aforementioned restrictions.

The statistics regarding improved sources of safe drinking water reveal notable variations in the proportion of households accessing such sources over the years. In 2012, approximately 44% of households had improved sources of safe drinking water, which increased to 53% in 2014 and reached nearly 80% in 2016. The potential explanation for this improvement is that Ethiopia established a unique WASH sector-wide approach (SWAp) under the umbrella of the ONEWASH National Programme (OWNP), which has led to millions gaining access to improved water[34]. Similarly, albeit to a very lesser extent, there were observed differences in the main sources of cooking energy fuels. The proportion of households utilizing improved sources of cooking energy exhibited little variation, with values staying relatively flat at 11.5% in 2012, 11.2% in 2014, and

[33]The other sets of descriptive statistics of can be found in Appendix section C.1

[34]The report is accessible here.

11.4% in 2016. The average age in the sample is in the early 20s, while the average household size is about 6.

Analyzing the intensive margin (for values greater than zero), the mean number of agricultural labor hours experienced a decline from 23.9 hours in 2012 to 22.1 hours in 2016. However, the mean number of labor hours in family businesses increased from 24.3 hours in 2012 to 29.7 hours in 2014 and then decreased to 25.8 hours in 2016. A similar trend was observed for labor hours outside the household, which increased from 21.6 hours in 2012 to 28.9 hours in 2016, with a slight decrease in 2014. Overall, all labor hours (sum of the agricultural, family business, and outside-of-household labor hours) consistently declined the mean number of hours, decreasing from 31.3 hours in 2012 to 25.2 hours in 2016. The standard deviation for these labor hours ranged from 23.3 hours in 2012 to 19.6 hours in 2016.

At the extensive margin (0/1), the proportion of individuals participating in agricultural labor slightly declined from 52.3% in 2012 to 46.2% in 2016. The proportion of individuals engaging in family business labor and labor outside the household declined from 22.1% and 14.4% in 2012 to 6.3% and 5.5% in 2016, respectively. Overall, the share of individuals participating in any labor decreased from 66.5% in 2012 to 53.0% in 2016. Appendix section C.1 compiles additional summary statistics related to regions and education. The Tigray, Amhara, Oromia, and SNNP regions emerge as the prominent geographical entities in terms of size, collectively representing approximately 77% of households surveyed. A significant proportion of household heads, constituting roughly 64%, displayed a lack of formal education and only about 25% of the heads of households were women.

3.4 Model specifications

The present study employs three modeling approaches to examine the determinants of cooking fuels and drinking water choices and the impact of improved services on labor hours. Specifically, the two modeling techniques for determining cooking fuels (hereafter CF) and SDW are the

Table 3.2. Summary Statistics for various labor and household characteristics (2012-2016)

	2012	**2014**	**2016**
	mean/sd	mean/sd	mean/sd
Agriculture Labor Hours (if > 0)	2.888	2.939	2.791
	0.848	0.858	0.878
Agricultural Labor Hours (0/1)	0.523	0.468	0.462
	0.499	0.499	0.499
Family Business Labor Hours (if > 0)	2.898	3.043	2.896
	0.830	0.924	0.911
Family Business Labor Hours (0/1)	0.221	0.074	0.063
	0.415	0.262	0.244
Labor Outside HH Hours (if > 0)	2.693	3.210	2.989
	0.956	0.858	0.995
Labor Outside HH Hours (0/1)	0.144	0.044	0.053
	0.351	0.206	0.225
All Labor Hours (if > 0)	3.142	3.057	2.906
	0.869	0.875	0.900
All Labor Hours (0/1)	0.665	0.539	0.530
	0.472	0.499	0.499
Improved Water	0.446	0.532	0.777
	0.497	0.499	0.416
Improved CF	0.110	0.113	0.147
	0.313	0.316	0.354
Household Size	5.969	5.996	5.969
	2.345	2.365	2.385
Age	24.871	21.964	22.737
	17.816	18.401	18.988
Asset Index Proxy	-0.110	-0.095	0.179
	2.258	1.624	1.892
Observations	18866	20910	22593

Notes: This table presents the means of several key variables: labor, water, cooking energy fuel, household characteristics, and asset index proxy. The values in parentheses are standard deviations. The variables with (if > 0) indicate that they are being conditioned on positive values only (intensive margins), while the variables with $(0/1)$ represent extensive margins. In other words, these variables take a value of 0 when the corresponding variable is 0, and a value of 1 when the corresponding variable is greater than 0.

random-effects[35] ordered probit and probit models. In addition, the paper capitalizes on the observed variation in sources of cooking fuel and drinking water by using the panel fixed effects specification. This approach facilitates the understanding of the impact of improved water and cooking fuel on hours spent in agriculture, family businesses, and labor outside the household. The ensuing section provides a comprehensive discussion of these three models sequentially.

Households in the Ethiopian Socioeconomic Survey have several choices for sources of cooking fuel. However, I reclassified these into three groups for the purposes of this study and to match the ELH, i.e., polluting fuels, transitional fuels, and clean fuels. These fuel choices have a natural ordering from unclean to cleaner and are defined in the previous subsection (Heltberg, 2004; Leach, 1992; Rahut et al., 2020; Van der Kroon et al., 2013). Given the naturally ordered CF and a panel of unbalanced households over three waves of surveys[36], I model the determinants of cooking fuel using the random-effects ordered probit model to analyze the determinants of cooking fuel selection. This modeling approach extends the conventional cross-sectional studies (Rahut et al., 2020; Behera and Ali, 2016; Amoah, 2019). The justification for the ordered probit model emanates from the data structure with more than two outcomes for the dependent variable (i.e., polluting, transitional and clean fuels) and three survey waves. The cooking fuel choice dependent variable is ranked on an ordinal scale in which households can choose either the first-ranked choice of polluting cooking fuels, the second-ranked option of transitional fuel, or the third-ranked choice of clean cooking fuel. The households using relatively cleaner cooking fuel are ranked higher, while those choosing dirtier fuels are ranked lower. As suggested by Greene (2018) and Rahut et al. (2020), the model is consistently estimated using the maximum likelihood method due to the nature of the dependent variable.

[35]Stata only allows for random effects for both the panel probit models and ordered probit models. See the Stata documentation, respectively, here:
https://www.stata.com/manuals/xtxtprobit.pdf and here:
https://www.stata.com/manuals/xtxtoprobit.pdf.

[36]ESS1-2011/12, ESS2-2013/14 and ESS3-2015/16

The concept of an ordered probit model, as discussed by Greene (2018), revolves around a latent regression. Building upon Greene (2018), Rahut et al. (2020), and Winkelmann (2005), I represent the exact but unobserved explanatory variable y_{it}^* as follows:

$$y_{ct}^* = f(\boldsymbol{X}_{ct}'\beta) + u_c + \varepsilon_{ct} \tag{3.1}$$

Here c denotes an index for the individual household; t is an index for time or survey round; $\boldsymbol{X}$ is a vector of controls comprising a set of demographic, human capital, wealth, and spatial characteristics; u_c is the time-invariant household-specific characteristics; and ϵ_{ct} are independently and identically distributed random error terms with mean 0 and variance 1. Since y_{ct}^* is unobserved, what is instead observed are household response categories below, which are a form of censoring, i.e.,

$$\begin{cases} y = 0 \text{ if } y_{ct}^* \leq 0, \\ y = 1 \text{ if } 0 < y_{ct}^* \leq \mu_1, \\ y = 2 \text{ if } \mu_1 < y_{ct}^* \leq \mu_2, \\ \dots \\ y = J \text{ if } \mu_{J-1} \leq y_{ct}^* \end{cases}$$

This paper employs the random effects ordered probit model for panel data to analyze the relationship between cooking fuel choices and household characteristics. The cooking fuel dependent variable takes on the values of 0, 1, and 2 based on the ranking where:
$y = 0$ if cooking fuel is polluting fuel, $y = 1$ if cooking fuel is transitional and $y = 2$ if cooking fuel is clean cooking fuel. The random effects ordered probit model uses observations on this kind of censored data on y_{ct}^*, i.e., y to estimate both the unknown parameters μ's and βs (Greene, 2018; Rahut et al., 2020). This modeling approach enables the examination of the determinants of cooking fuel choices while accounting for panel data structure and the ordinal nature of the dependent variable.

On the other hand, unlike cooking energy, the sources of drinking water do not follow a natural order (Fotue and Sikod, 2012; Rauf et al., 2015; Behera and Sethi, 2020; Emenike et al., 2017), which would necessitate the use of a different model including a multinomial logit (Rauf et al., 2015). However, in this study, the multinomial logit model is inappropriate since the sources of drinking water are dichotomized into improved water and unimproved to facilitate the estimation of a panel probit model instead. Therefore, this paper employs a panel probit model to examine the relationship between SDW and a set of explanatory variables. This model is apt as it allows the estimation of the probability of observing improved water. The random-effects panel data model is shown in Equation 3.2 below:

$$\text{SDW}_{ct} = \gamma \boldsymbol{X}_{ct} + \alpha_c + \varepsilon_{ct} \tag{3.2}$$

Here, the dichotomized dependent variable (SDW_{it}), takes on a binary form, indicating improved water if equal to 1 or unimproved otherwise for household c at time t. Independent variables such as demographic, wealth, education and spatial characteristics are denoted by $\boldsymbol{X}_{ct}$ while γ represents the corresponding coefficients. α_c represents the household-specific random effects, capturing the unobserved time-invariant characteristics that vary across households. The last term, ε_{ct}, is the idiosyncratic error term, representing the unobserved factors that affect the SDW for household c at time t. The model assumes a latent variable framework, where the unobserved underlying variable follows a standard normal distribution.

To investigate the impacts of improved cooking fuel and drinking water on labor hours in agriculture, family businesses, labor outside the household, and total rural and small towns labor hours over the last seven days in Ethiopia, it is crucial to control for time-invariant omitted variables. To address this, individual fixed effects models are employed, which allow for the identification of within-individual variations in labor hours. The models are specified as follows:

$$L_{it} = \phi_M \cdot M_{it} + \phi \boldsymbol{X}_{it} + \alpha_i + \delta_t + \varepsilon_{it} \tag{3.3}$$

In the specified models, the index i represents individual units, encompassing a range from 1 to n individuals. The time or survey wave is denoted by t, specifically covering the years 2012, 2014, and 2016. The variable L_{it} denotes the natural logarithms of labor time in hours for individual i during survey year t when the analysis is focused on the intensive margins (labor> 0). However, for the extensive margin regressions, the variable L_{it} is a binary indicator denoting 0 for no labor and 1 for positive labor hours. The focus of interest is on various types of labor hours: (1) agricultural labor, (2) family business labor, (3) labor outside the household, and (4) total labor hours. The independent variable M_{it} represents one of the two main treatment variables for individual i in year t: improved cooking fuel and improved water. Additionally, control variables denoted by $\boldsymbol{X}_{it}$ are incorporated to account for other factors that potentially influence labor hours. This vector of controls includes variables such as wealth, age, household size, and the gender of the household head.

To account for individual-specific characteristics that persist over time, I introduce the fixed effects term α_i in the models. The upside of fixed effects is that it allows me to capture both time-constant observed and unobserved heterogeneity (Angrist and Pischke, 2009; Rüttenauer and Ludwig, 2023; Baltagi and Baltagi, 2008) among individuals that may affect their labor hours. Additionally, the time-specific effects, denoted by δ_t, are included to account for any time-varying factors that may influence labor hours across survey waves. In order to address potential omitted variable bias and unobserved heterogeneity, I incorporate the error term ε_{it} into the models. This term captures unobserved factors that are unique to each individual and year, as well as random variation in labor hours that cannot be explained by the included variables.

3.5 Results

The empirical findings presented in Tables 3.3 provide insights into the marginal effects of the ordered probit and the regular probit models regarding households' decision-making on cooking fuel and drinking water options. Additionally, to examine the impact of cooking fuel and improved water services on different labor categories, fixed effects regression analyses were conducted. The

results of these analyses are presented in Tables 3.4 and 3.5, showcasing the influence of these improved services on various labor categories.

3.5.1 Determinants of cooking fuels and drinking water sources

The findings obtained from the ordered probit and the ordinary probit model analyses, as presented in Table 3.3, offer valuable insights into the factors influencing households' choices regarding cooking fuel and drinking water in rural and small towns of Ethiopia. Specifically, the study identifies a number of variables that demonstrate significance as main determinants such as the household size, wealth, and education of the head of household for choices for water and fuel. Interestingly, the age of the household head emerges as a significant factor affecting the selection of drinking water sources, while its influence on cooking fuel choices is not statistically significant. Notably, the study reveals that a one-year increase in the age of the household head corresponds to a 3.52% higher probability of utilizing improved sources of drinking water.

Household size emerged as a significant determinant in selecting the cooking energy fuel and water sources. The analysis reveals that an increase of one unit in the household size is associated with a significant decrease in the likelihood of choosing clean cooking fuel by 0.36%. Conversely, each unit increase in household size led to a notable increase in the likelihood of selecting polluting fuels by 0.67%. This finding aligns with intuition and can be attributed, firstly, to the notion that a larger number of household members have a greater capacity for specialization, facilitating the task of fetching polluting fuels such as firewood or biomass. Secondly, the financial aspect cannot be ignored, as larger households may face higher electricity bills, potentially making improved fuels less economically feasible in poor settings such as rural and small towns in Ethiopia. The analysis did not find a strong relationship between household size and the choice of water sources.

Previous studies confirm a significant relationship between household wealth and fuel choices (Qing et al., 2023; Ali et al., 2019; Paudel et al., 2018b; Rahut et al., 2020). In this paper's results, if the wealth of a household increases by a unit, the likelihood of a household using polluting fuels for cooking significantly decreases by 0.48% while at the same time increasing by 0.22%

and 0.26% for relatively cleaner cooking fuels, i.e., transitional and clean fuels, at the 1% level of significance. For drinking water, the wealth index has the expected impact. As such, if the wealth of a household increases by a unit, the chance of a household using improved water sources significantly increases by 5.44% at the 1% level of significance.

The household head's education as a determinant of sources of cooking energy fuel and water (SDW) varied in significance and magnitude across different education levels. Notably, a characteristic of household heads having an education at the stage the primary level does not have a significant influence on the choice of cooking energy fuel compared to those without any education. However, having some primary level of education as opposed to none is significant in influencing the chance of choosing an improved SDW with a higher probability of between 15.9% and 34.6%. On the other hand, when the head of the household had an education beyond middle school, it significantly affected the selection of both the source of cooking fuel and drinking water. Specifically, households with middle, senior secondary, some college and university education were 2.6%, 4.7%, 8.5%, 11.7% and 17.6%, respectively, less likely to use polluting fuels at statistically significant levels ranging from 1% to 5%. Consequently, they were significantly more inclined to use relatively cleaner fuels. Similarly, households with middle and senior secondary schooling exhibited a significant increase in the likelihood of using improved water sources by 52.3% and 70.1%. Moreover, attaining senior secondary schooling, certificate, and university education leads to a more than proportional change in the probability of using improved SDW (116%, 113% and 153%, respectively) demonstrating the positive impact of education on accessing improved SDW. This paper's findings support Rahut et al. (2020), showing that as education levels increase, so do the point estimates for cooking fuel and SDW, indicating a higher propensity for adopting these improved alternatives. These findings highlight the critical role of the household head's education in influencing energy fuel and water source preferences, with higher education levels correlating with a reduced reliance on polluting fuels (consequently increased adoption of relatively cleaner cooking fuels) and improved drinking water sources.

Table 3.3. Determinants of choices of cooking fuel and drinking water (Average Marginal Effects)

	Cooking fuels			Drinking water
	(1) Polluting	(2) Transitional	(3) Clean	(4) Improved
Demographics				
Age of HoH	0.000912	-0.000419	-0.000493	0.0352***
	(0.000832)	(0.000383)	(0.000450)	(0.00734)
Female HoH	0.00426	-0.00196	-0.00230	0.0521
	(0.00468)	(0.00215)	(0.00254)	(0.0480)
Household Size	0.00667***	-0.00307***	-0.00361***	0.00656
	(0.00116)	(0.000561)	(0.000643)	(0.00888)
Wealth characteristics				
Asset Index Proxy	-0.00477***	0.00219***	0.00258***	0.0544***
	(0.000666)	(0.000325)	(0.000381)	(0.0116)
Human capital & education:				
Below Primary	-0.00308	0.00157	0.00151	0.159***
	(0.00580)	(0.00295)	(0.00285)	(0.0517)
Primary	-0.00874	0.00440	0.00434	0.346***
	(0.00655)	(0.00327)	(0.00329)	(0.0629)
Middle school	-0.0263**	0.0127**	0.0135**	0.523***
	(0.0107)	(0.00504)	(0.00577)	(0.0943)
Secondary school	-0.0471***	0.0220***	0.0251***	0.701***
	(0.0155)	(0.00689)	(0.00886)	(0.131)
Senior secondary school	-0.0846***	0.0372***	0.0474**	1.163***
	(0.0311)	(0.0123)	(0.0191)	(0.285)
Some college	-0.117***	0.0491***	0.0680***	1.134***
	(0.0189)	(0.00773)	(0.0121)	(0.120)
University	-0.176***	0.0679***	0.108***	1.526***
	(0.0321)	(0.0108)	(0.0225)	(0.204)
Access to improved infrastructure services:				
Improved Water	-0.00560	0.00258	0.00301	
	(0.00359)	(0.00168)	(0.00192)	
Location:				
Afar	-0.00514	0.00229	0.00285	-0.825***
	(0.0146)	(0.00652)	(0.00812)	(0.132)
Amhara	0.00168	-0.000758	-0.000926	-0.189**
	(0.00868)	(0.00390)	(0.00478)	(0.0751)
Oromia	0.0220***	-0.0102***	-0.0117***	-0.465***
	(0.00802)	(0.00363)	(0.00447)	(0.0741)
Somalie	-0.0589***	0.0243***	0.0347***	-0.876***
	(0.0158)	(0.00682)	(0.00923)	(0.0894)
Benshagul Gumuz	0.0292***	-0.0138***	-0.0154***	-0.0240
	(0.00992)	(0.00471)	(0.00534)	(0.114)
SNNP	0.0222***	-0.0103***	-0.0118***	-0.409***

Continued on next page

Table 3.3 – Continued from previous page

	Cooking fuels			Drinking water
	(1) Polluting	(2) Transitional	(3) Clean	(4) Improved
	(0.00785)	(0.00359)	(0.00434)	(0.0719)
Gambelia	0.0402***	-0.0195***	-0.0207***	1.427***
	(0.00787)	(0.00367)	(0.00447)	(0.188)
Harari	0.0186	-0.00862	-0.00997	-0.332***
	(0.0126)	(0.00588)	(0.00674)	(0.105)
Diredwa	-0.00244	0.00109	0.00135	-0.0162
	(0.0142)	(0.00633)	(0.00785)	(0.138)
Observations	10966	10966	10966	10991

Standard errors in parentheses.

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

The polluting cooking fuel category encompasses the collection and purchase of firewood; crop residues/leaves, dung/manure, and sawdust. The transitional cooking fuel includes charcoal, coal and kerosene. Clean cooking fuel comprises electricity, butane/gas, biogas, and solar energy. The reference groups for the dummy variables are: males for gender and individuals without education for the different levels of education. The reference region for the regional dummy variable is Tigray region. Addis Ababa was excluded from the analysis due limited number of observations. University under the education panel encompasses completed university and postgraduate studies. Below primary is kindergarten to the 4th grade, primary is grades 5-7th, middle school is 8-9th, secondary school is 10-11th and senior secondary school is 10-11th while senior secondary is 12th. Some college includes having obtained a certificate, diploma or some college

The ordered probit model for cooking fuel incorporates improved water as an independent variable[37] to investigate the hypothesis that water infrastructure accelerates the household's transition to improved fuel. As argued in the conceptual framework, a household's access to improved water may be crucial in understanding their cooking fuel preferences. However, empirical results in this study show that the conceptual model correctly predicted the direction, but the estimates are not very strong. When a household has access to improved water sources, the likelihood of using the relatively dirtier fuel falls, although the results are insignificant (Table 3.3). On the other hand, when household size is disaggregated by age groups, i.e., children ($<$ 15 years old), adults by gender (15 to 64 years old), and the elderly ($\geq$65years old), the results are shown in Table

[37]The probit model for sources of water(Column 4) does not include this variable as that would lead to perfect multicollinearity.

C.5 in the Appendix demonstrates that having water infrastructure does significantly decrease the likelihood of using polluting fuels by 0.63% (column 1) while the likelihood of using relatively cleaner fuels increases by 0.29% and 0.34% (columns 2 & 3, respectively), influence choices of fuels. More research is warranted on the impact of improved water infrastructure and its impact on cooking fuel transitions.

Regarding spatial heterogeneity, the results present a mix of findings. Amhara, Oromiya, SNNP, and Tigray are the most populous regions in rural and small towns. Consequently, Tigray is chosen as the comparison group for analysis due to its demographic similarities with the previously mentioned regions. Smaller regions include Afar, Benshangul Gumuz, Dire Dawa, Gambella, Harari, and Somalie[38]. Empirical findings indicate that only the relatively small region of Somalie exhibits a significantly higher likelihood of utilizing clean cooking fuel, surpassing Tigray with a margin of 3.5%. Conversely, the regions of Oromia, Benshangul Gumuz, SNNP, and Gambella demonstrate a significantly higher probability of using polluting fuel compared to Tigray by 2.2%, 2.9%, 2.2%, and 4%, respectively. In contrast, most regions, except for Gambella and Dire Dawa, display a significantly lower probability of using improved sources of drinking water compared to unimproved sources. Nonetheless, the region of Gambella exhibits an impressive probability of more than certainty in utilizing improved SDW. These findings underscore the substantial variation in the utilization of clean cooking fuel and SDW across regions, highlighting the influence of geographical factors and local circumstances. The observed disparities emphasize the necessity for region-specific interventions and targeted policies to address the challenges related to access to improved services.

As a form of robustness check, I included an alternative specification where the household size is disaggregated by age groups as in Rahut et al. (2020). The household size is disaggregated by different age groups of family members such as children ($<$ 15 years old), adults by gender (15 to 64 years old), and the elderly ($\geq$65years old), and the results are shown in Appendix section C.6.

[38]It is important to note that the sample does not provide representative data for the smaller regions such as Afar, Benshangul Gumuz, Dire Dawa, Gambella, Harari, and Somalie. A description of the sampling design can be found on the survey website: https://microdata.worldbank.org/index.php/catalog/2247.

These results reveal that a higher number of children and female adult members in a household is significantly associated with an increased likelihood (0.63% and 1.3%, respectively) of using polluting fuels for cooking purposes and, as a consequence, significantly reducing the likelihood of using clean fuels. A higher number of children, male adults and elderly members in a household is significantly associated with an increased likelihood (4.8%, 5.5% and 3.46%, respectively) of using improved drinking water. These findings shed light on the intricate decision-making dynamics within households, underscoring the pivotal roles of women and children in matters pertaining to cooking practices. Male adults in the household have an insignificant role in cooking fuel choices, while collective factors influence choices related to drinking water. The other results in the Appendix table in section C.6 more or less hold as before. These robustness checks reinforce the validity and enhance our understanding of the factors influencing the choice of sources of cooking fuel and drinking water.

3.5.2 Cooking fuel, water and labor

Table 3.4 and Table 3.5 provide the empirical findings of our regression analyses, focusing on the effects of cooking fuel improved water and services on various labor categories. The tables present results for both extensive and intensive labor margins. In Table 3.4, I examine the extensive margins, which represent the presence or absence of labor in agricultural activities, family business activities outside the household, and overall labor across all groups. These outcomes are binary variables, taking a value of one when labor is observed and zero otherwise. Table 3.5, on the other hand, focuses on the intensive margins, which consider only positive labor hours. In this case, I analyze labor outcomes that are conditional on the presence of labor. The regression models utilized in both tables control for additional factors, including time-fixed effects, individual-fixed effects, individual age, household size, a proxy for household wealth (asset index), and the gender of the household head. These control variables help account for potential confounding factors and provide a more accurate estimation of the effects of improved water and cooking energy fuel services on labor outcomes in rural and small towns of Ethiopia.

Regarding the extensive margin results presented in Table 3.4, an interesting pattern emerges when considering the impact of improved water on different labor categories. In Column 1, where individual fixed effects are not controlled for, it appears that improved water has a significant negative effect on agricultural labor. Upon controlling for individual fixed effects (column 2), the expected sign emerges, and the significance of the effect disappears. This indicates that improved water in Ethiopia is associated with a decrease in agricultural labor, although when individual fixed effects are included in the model, the significance of this effect disappears. This suggests that individual-specific factors explain the relationship between improved water and agricultural labor. Therefore, I find that improved water does not significantly impact agricultural labor at the extensive margins. In contrast, the effect of improved water on family business hours is positive and statistically significant, with an increase of 2.6 percentage points (hereafter pp). This suggests that improved water services do contribute to higher levels of labor in family business activities.

Table 3.4. Extensive Margins: Impact of improved services on labor

	Agriculture		Family Business		Outside Household		All	
	1	2	3	4	5	6	7	8
Improved Water	-0.022***	0.004	0.023***	0.026***	0.004	-0.001	-0.008	0.007
	(0.007)	(0.009)	(0.005)	(0.007)	(0.004)	(0.006)	(0.007)	(0.009)
Improved CF	0.024**	0.036***	0.002	0.014	-0.004	0.010	0.028***	0.031**
	(0.010)	(0.013)	(0.007)	(0.011)	(0.005)	(0.008)	(0.010)	(0.014)
Individuals	18813	18813	18812	18812	18815	18815	18785	18785
Observations	42252	42252	42211	42211	42181	42181	42019	42019
Individual FE	No	Yes	No	Yes	No	Yes	No	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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

Additional Notes: This table shows the regressions of extensive margins of labor hours (0/1) on treatments. The dependent variable in the analysis are the extensive margins of agricultural labor, family business labor outside of household labor and all labor hours, while the treatment variables are cooking fuels and improved water. The regression models also incorporate additional control variables such as time-fixed effects, individual-fixed effects, individual age, household size, wealth and the gender of the head of the household.

For improved cooking energy fuel, I observe a significant positive impact on agricultural labor, with an increase of 3.6 pp. This finding indicates that using improved cooking energy fuels leads to higher labor participation in agricultural activities. However, neither improved water nor improved cooking energy fuel demonstrates a significant effect on labor hours provided outside the

household. This implies that these improved services do not have a discernible impact on labor in activities conducted outside the household at the extensive margin.

Considering the overall labor hours (agriculture, family business, and labor outside the household), the results indicate that improved water does not have a significant impact. However, improved cooking energy fuel leads to a significant increase of overall by 3.1 pp in all labor hours, at the 5% level of significance.

Table 3.5 provides the findings for the intensive margins analysis (labor hours > 0). It is worth noting that, similar to the extensive margin results, controlling for individual fixed effects is essential for accurately understanding the relationship between improved water and agricultural labor. As in the results at the extensive margins, in column 1, where individual fixed effects are not accounted for, improved water exhibits a significant negative effect on agricultural labor. However, this significant effect disappears when individual fixed effects are included (column 2). This suggests that individual-specific factors are crucial in explaining the relationship between improved water and agricultural labor. Controlling these factors provides a more accurate estimation of the impact. Interestingly, improved water does have a significant impact on labor hours outside the household. In particular, it significantly reduces 0.19 hours for the last seven days in rural and small towns of Ethiopia. This implies that the availability of improved water services is associated with a decrease in the number of labor hours dedicated to activities outside the household. The negative link between improved water services and labor hours outside the household can be attributed to socioeconomic factors. For instance, improved water services may be accompanied by better economic opportunities in the local vicinity, and individuals may prioritize income-generating activities and allocate fewer labor hours to tasks outside the household.

In the context of cooking energy fuel, the coefficients associated with models including both individual and time-fixed effects (columns 2, 6, and 8) demonstrate positive associations, except for the family business labor column (column 4). These coefficients range from 0.11 to 0.13, indicating a significant increase in labor hours in relation to improved cooking fuel. Specifically, improved cooking fuel leads to a noteworthy increase of 0.13 hours in agricultural labor hours

Table 3.5. Intensive Margins: Impact of improved services on labor

	Agriculture		Family Business		Outside Household		All	
	1	2	3	4	5	6	7	8
Improved Water	-0.064***	-0.016	-0.043	0.013	0.029	-0.217**	-0.019	0.005
	(0.020)	(0.031)	(0.032)	(0.071)	(0.043)	(0.102)	(0.018)	(0.028)
Improved CF	0.134***	0.131***	0.111***	-0.058	0.088	0.103	0.124***	0.103**
	(0.026)	(0.045)	(0.042)	(0.108)	(0.058)	(0.127)	(0.023)	(0.040)
Individuals	12110	12110	4084	4084	2893	2893	13962	13962
Observations	20106	20106	5096	5096	3369	3369	24021	24021
Individual FE	No	Yes	No	Yes	No	Yes	No	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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

Additional Notes: This table shows the regressions of labor hours on treatments conditional on strictly positive labor hours. The dependent variable in the analysis is the intensive margins of agricultural labor, family business labor outside of household labor and all labor hours, while the treatment variables of interest are cooking fuels and improved water. The regression models also incorporate additional control variables such as time-fixed effects, individual-fixed effects, individual age, household size, wealth and the gender of the head of the household.

during the last seven days. Moreover, when considering overall labor hours, improved cooking fuel is associated with a statistically significant increase of 0.10 hours within the same time frame.

Appendix section C.5 presents a comprehensive analysis of the impact of cooking fuel and improved water on child labor and adult labor, disaggregated by age, gender, and region. For child labor (below 15 years old),[39] the findings indicate that improved water significantly reduces child labor in agriculture, while improved cooking fuel decreases child labor in family businesses and labor outside the household. At an extensive margin, gender-specific effects show that improved cooking fuel significantly increases agricultural labor for women and improved cooking fuel reduces their labor hours outside the household (intensive margin results are insignificant) while men experience increased agricultural labor and decreased labor outside the household due to improved drinking water. In small towns of Ethiopia, improved fuel and water significantly reduce labor hours outside the household at the extensive margins. In rural areas, on the other hand, improved water significantly increases family business labor hours (at the extensive margin) while reducing labor outside the household at the intensive margin. Improved cooking fuel in rural areas improves

[39]Under Article 89 of the Labour Proclamation, the statutory minimum age for young workers is 14 years. And the Ethiopian Constitution gives children general protection from exploitative labor practices. The link to the country labor profile is here: https://www.ilo.org/ifpdial/information-resources/national-labour-law-profiles/WCMS_158894/lang--en/index.htm

agricultural labor and labor outside the household. These results underscore the need for targeted interventions considering gender, age, and regional contexts to address child labor and optimize labor allocation.

The findings provide insights into the relationship between improved services and labor outcomes, considering various control variables. I find that at the extensive margins, improved water services do not significantly influence agricultural labor and labor outside the household but they do have a significant positive impact on family business hours. Improved cooking energy fuel, on the other hand, has a significant positive effect on agricultural labor and overall labor hours.

3.6 Conclusion

In this study, the aim was to assess the main determinants of the choices of sources of cooking fuel and drinking water when the household is observed repeatedly. To investigate this, I use the ordered probit and probit models while controlling for demographic, human capital, economic, and spatial characteristics. Additionally, I investigate the impact of access to improved services, vis-à-vis improved cooking fuels and drinking water, on labor hours in agriculture, family businesses, labor outside the household and total labor. The focus of these investigations is on rural and small towns in Ethiopia.

The findings provide valuable insights into the complex relationship between essential services and labor dynamics, particularly in developing countries. The household size, gender of the head of household, wealth, and education emerged as significant determinants of cooking fuel and drinking water choices, corroborating previous empirical studies (Rahut et al., 2020), although age did not demonstrate a significant influence in this study. However, the results concerning the impact of improved services on labor, as hypothesized in the conceptual framework, were not robust, despite the expected direction of the point estimates.

Regarding the impact of improved services on labor, investigations were done at extensive and intensive margins levels. Regarding the impact of cooking fuels, the results indicate that improved cooking fuel significantly increases agricultural labor hours and total labor hours. This implies

that the availability of cleaner and more efficient cooking fuels positively influences productivity and labor allocation in the studied communities. These findings highlight the potential benefits of promoting access to improved cooking fuels as a means to enhance labor outcomes and livelihoods.

On the other hand, the analysis of improved water services revealed mixed results. While improved water did not significantly impact agricultural labor at the extensive margin, controlling for individual fixed effects yielded important insights. It was observed that improved water had a significant negative effect on agricultural labour when individual fixed effects were not accounted for. However, this negative effect disappeared when controlling for individual-specific factors, indicating the importance of considering individual heterogeneity in understanding the relationship between improved water and agricultural labor. Additionally, improved water services were found to significantly reduce labor hours outside the household, suggesting that improved water access saves time and contributes to a shift in labor allocation within the household. This highlights the potential role of improved water services in promoting productivity and socio-economic development at the household level.

The findings of this study confirm the significance of wealth, household size, have of the head of household and education as key determinants of cooking fuel and drinking water sources in rural and small towns of Ethiopia. These variables play a crucial role in shaping the household's choices in accessing these essential resources. Moreover, the study underscores the importance of improved cooking fuels and drinking water services in influencing labor outcomes within rural and small-town areas of Ethiopia. The research provides valuable insights that can guide policymakers and development practitioners in formulating targeted interventions aimed at improving access to these services. By enhancing accessibility to improved cooking fuels and drinking water sources, sustainable livelihoods can be fostered, thereby contributing to the overall economic growth of the communities under examination. To further advance our understanding, it is recommended that future research delve deeper into the underlying mechanisms through which these services impact labor dynamics. Exploring potential synergies between cooking fuels, water access, and broader development goals would also be beneficial. By examining these aspects in greater detail, we

can uncover additional strategies and interventions that effectively leverage the potential of these services for promoting inclusive and sustainable development.

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Appendix A: Chapter 1

A.1 Additional summary statistics

Table A.1. Summary of Parents' Education

	Mother's Education	Father's Education
No Education ,	0.289	0.158
	0.453	0.365
Grades 1-3	0.083	0.079
	0.277	0.269
Grades 4-8	0.272	0.280
	0.445	0.449
Above 8th Grade	0.303	0.407
	0.460	0.491
Missing	0.00025	0.00174
	0.016	0.042
Observations	7795	7795

Notes: Authors' own compilation from the YLS survey for the year 2002 when the children were aged between 6 and 18 months.

Appendix B: Chapter 2

B.1 Measures of psycho-social welfare

Table B.1. Measures of Psycho-social Welfare, YLS, India and Ethiopia, 2013-2016

Measures of Psycho-social Welfare			
Self-efficacy	*Self-esteem*	*Parent relations*	*Peer relations*
I can always manage to solve difficult problems if I try hard enough.	I do lots of important things.	I like my parents.	I make friends easily.
If someone opposes me, I can find the means and ways to get what I want.	In general, I like being the way I am.	My parents like me.	I am popular with kids of my own age.
It is easy for me to stick to my aims and accomplish my goals.	Overall, I have a lot to be proud of.	My parents and I spent a lot of time together.	Most other kids like me.
I am confident that I could deal efficiently with unexpected events.	I can do thing as well as most people.	My parents understand me.	Other kids want me to be their friend.
Thanks to my resourcefulness, I know how to handle unforeseen situations.	Other people think I am a good person.	My parents are easy to talk to.	I have more friends than most other kids.
I can solve most problems if I invest the necessary effort.	A lot of things about me are good.	My parents and I have a lot of fun together.	I have lots of friends.
I can remain calm when facing difficulties because I can rely on my coping abilities.	I am as good as most other people.	I get along well with my parents.	I am easy to like.
When I am confronted with a problem, I can usually find solutions.	When I do something, I do it well.	If I have children of my own, I want to bring them up like my parents raised me.	I get along with other kids easily.
If I am in trouble, I can usually think of a solution.			
I can usually handle whatever comes my way.			

Source: Authors elaboration from the YLS survey and reports, 2013-2016.

B.2 Mediation analysis

Table B.2. HSF and psychosocial development by gender: health mechanism Sobel mediation tests

	Self-Efficacy				Self-Esteem			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Panel A: Girls								
HSF	0.209***	0.208***	0.190**	0.189**	0.128**	0.125**	0.233***	0.234***
	(0.055)	(0.054)	(0.074)	(0.074)	(0.060)	(0.058)	(0.076)	(0.075)
Good Health	0.089**		-0.005		0.087*		0.054	
	(0.041)		(0.051)		(0.046)		(0.044)	
BMI		0.007		0.025		0.011		0.034**
		(0.009)		(0.017)		(0.008)		(0.016)
Sobel p-value	0.044	0.113	0.320	0.754	0.046	0.028	0.140	0.750
Explained	0.018	0.023	0.016	0.003	0.029	0.053	0.031	0.004
Panel B: Boys								
HSF	0.104*	0.101*	-0.082	-0.083	0.112*	0.115**	0.028	0.028
	(0.053)	(0.053)	(0.063)	(0.062)	(0.056)	(0.056)	(0.066)	(0.066)
Good Health	0.147***		0.028		0.118***		0.023	
	(0.044)		(0.060)		(0.041)		(0.054)	
BMI		0.018***		0.006		0.005		-0.001
		(0.007)		(0.019)		(0.005)		(0.015)
Sobel p-value	0.003	0.001	0.941	0.415	0.011	0.229	0.941	0.876
Explained	0.058	0.089	-0.003	0.035	0.044	0.025	-0.000	0.002
Controls	NO	NO	YES	YES	NO	NO	YES	YES
Child FE	NO	NO	YES	YES	NO	NO	YES	YES

Notes: Cluster robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Controls: household size, HQ index, CD index, and electricity, cooking fuel, water, time, cohort, and community (site) dummies. All regressions exclude individuals with missing health variables. P-value from Sobel test of statistical mediation and proportion of total effect of HSF explained by meditating health variable reported.

Table B.3. Change in Mean Outcomes between 2010 and 2016 by Change in HSF Status Between 2013 and 2016

	Girls				Boys			
	Self-Efficacy		Self-Esteem		Self-Efficacy		Self-Esteem	
	2010-13	2013-16	2010-13	2013-16	2010-13	2013-16	2010-13	2013-16
No change	0.001	-0.011	-0.013	0.008	0.007	-0.038	-0.000	-0.003
	(0.033)	(0.032)	(0.033)	(0.032)	(0.031)	(0.028)	(0.031)	(0.029)
Gained HSF	-0.023	0.250***	0.025	0.232***	0.055	0.027	0.127*	0.079
	(0.080)	(0.078)	(0.080)	(0.079)	(0.078)	(0.070)	(0.077)	(0.073)
Lost HSF	0.055	-0.132	0.082	-0.258***	0.008	0.193**	0.017	0.006
	(0.095)	(0.092)	(0.095)	(0.093)	(0.085)	(0.077)	(0.085)	(0.080)
N	4,476	4,480	4,476	4,480	5,224	5,240	5,225	5,240

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. "No change" are children with no change in access to HSF between 2013 and 2016; "Gained HSF" are children that gained access to HSF between 2013 and 2016; "Lost HSF" are children that lost access to HSF between 2013 and 2016. Columns labeled "2013-16" show the change in outcomes between 2013 and 2016 for each group (i.e., the treatment effect). Columns labeled "2010-13" show the change in outcomes between 2010 and 2013 for each group (i.e., pre-trends).

Appendix C: Chapter 3

C.1 Additional summary statistics

Table C.1. Means for the spatial and educational characteristics (2012-2016)

	2012	2014	2016
Panel A: Gender of HoH			
Females	0.251	0.245	0.246
Panel B: Regions			
Somalie Region	0.069	0.065	0.062
Tigray Region	0.103	0.103	0.105
Afar Region	0.036	0.033	0.035
Amhara Region	0.215	0.214	0.217
Oromia Region	0.197	0.200	0.201
Benishagul G. Region	0.033	0.033	0.034
SNNP Region	0.253	0.258	0.254
Gambelia Region	0.033	0.030	0.028
Harari Region	0.030	0.032	0.032
Dire Dawa Region	0.030	0.031	0.032
Panel C: Education			
Below Primary	0.154	0.151	0.144
Primary	0.095	0.096	0.106
Middle School	0.036	0.035	0.036
Senior Secondary	0.019	0.020	0.021
Secondary School	0.008	0.009	0.007
Diploma/College	0.035	0.030	0.029
University	0.008	0.011	0.013
No Education	0.643	0.645	0.641
Households	3969	3776	3696

Notes: This table presents the descriptive statistics (means) of variables for gender, regions and education levels for 2012, 2014, and 2016. The number of observations (households) varies for each panel and year, with the total number of households pertaining to rural and small towns only, i.e., large and medium towns that appeared in 2014 and 2016 surveys are not part of the analysis for this current investigation.

C.2 Survey questions

The survey questions pertaining to drinking water were:

- What is the main source of drinking water in the rainy season? and
- What is the main source of cooking fuel?

Table A1: Main Sources of Drinking Water, Cooking Fuel, and Time-Use

Drinking Water	Cooking Fuel	Time-Use
1. Tap inside the house	1. Collecting firewood	1. How many hours did you spend yesterday collecting water?
2. Private tap in the compound	2. Purchase firewood	2. How many hours did you spend yesterday collecting firewood (or other fuel materials)?
3. Shared tap in the compound	3. Charcoal	3. How many hours in the last seven days did you spend on household agricultural activities (including livestock and fishing-related), whether for sale or household use?
4. Communal tap outside the compound	4. Crop residue/leaves	4. How many hours in the last seven days did you run or help with any kind of non-agricultural or non-fishing household business, big or small, for yourself or the household?
5. Water from kiosks/retailers	5. Dung/manure	5. How many hours in the last seven days did you engage in casual, part-time, or temporary labor?
6. Protected well/spring (private)	6. Sawdust	6. How many hours in the last seven days did you do any work for a wage, salary, commission, or any payment in kind, excluding temporary?
7. Protected well/spring (shared)	7. Kerosene	7. How many hours in the last seven days did you engage in an unpaid apprenticeship?
8. Unprotected well or spring	8. Butane-gas	
9. River/lake/pond	9. Electricity	
10. Rainwater	10. Solar energy	
11. Other (specify)	11. Bio gas	
	12. None	
	13. Other (specify)	

Notes: The questions are directly from the household questionnaires of the ESS.

C.3 PCA for asset index

I use a principal component analysis (PCA) to create an asset index using the households' asset ownership. The asset index was created on whether a household owned some assets or not. The assets in question are blanket, mattress and/or bed, wristwatch/clock, fixed-line telephone, mobile telephone, radio/radio/tape, television, CD/VCD/DVD/Video deck, satellite dish, sofa set, bicycle, motorcycle, cart (hand pushed), cart (animal drawn), sewing machine, weaving equipment, refrigerator, private car, jewels (Gold and silver), wardrobe, shelf for storing goods, sickle, ax, pick axe, plow (traditional) or plow (modern)[40]. In addition to these assets, I also considered the characteristics of the dwellings by adding to the above list the dummy variables for whether the household had improved walls, roofs and whether it has an inside kitchen or not.

C.4 Control variables

Below is the expanded list of these characteristics:

1. Demographic Characteristics:

    - Age of household head in years.
    - Square of the age of household head in years to take nonlinearity into account.
    - A sex dummy equals 1 if the household head is a female and 0 otherwise.

[40] An asset variable called "mofer and Kember," i.e., Ethiopian traditional plowing equipment was omitted because it only appeared in wave 1 but was missing in subsequent survey waves.

- Household size measured by the number of family members. In our robustness checks or alternative specification, we exploited the different characteristics of numbers in the groups of members of the household, i.e., the number of elderly, children, or adults in a household.

2. Human Capital and Education Characteristics consisted of several dummies:

   - No education dummy takes on the value of 1 if the household head has not attended school or 0 otherwise (this is the comparison group).
   - Below primary, equal to 1 if the household head is educated up to less than the primary level (i.e., $<$ 5th grade) or 0 otherwise.
   - Primary completed equals 1 if the household head has completed the primary level but not middle school (i.e., $\geq 5^{\text{th}}$ grade $< 8^{\text{th}}$ grade) or 0 otherwise.
   - The middle school completed dummy: a dummy that takes on the value of 1 if the household head has completed middle school but not secondary school (i.e., $\geq 8^{\text{th}}$ grade and $< 10^{\text{th}}$ grade) or 0 otherwise.
   - The secondary school completed dummy: a dummy that takes on the value of 1 if the household head has completed secondary school but not senior secondary school (i.e., $\geq 10^{\text{th}}$ grade and $< 12^{\text{th}}$ grade) or 0 otherwise.
   - The senior secondary school completed dummy: a dummy that takes on the value of 1 if the household head has completed senior secondary school but not the university (i.e., $\geq 12^{\text{th}}$ grade but not completed university) or 0 otherwise.
   - Certificate, diploma, or some college: a dummy that takes on the value of 1 if the household head has not only completed senior secondary school but has also completed some extra courses (i.e., $\geq$ grade 12 completed university). This means that the household head has also acquired some certificate or diploma in a trade or has attended some form of college, and the dummy variable takes on the value of 0 if none of these applies.
   - University completed: a dummy that takes on the value of 1 if the household head has completed university-level education or 0 otherwise.
   - Postgraduate Studies: a dummy that takes on the value of 1 if the household head has completed university-level education and has either acquired or is in the process of acquiring some form of postgraduate studies or 0 otherwise.

3. Spatial Characteristics

   - For each region: Somalie, Tigray, Afar, Amhara, Oromia, Benishangul Gumuz, Gambela, Harar and Addis Ababa[41]; a dummy that takes a value of 1 if the household is located in that region or 0 otherwise (this is the comparison group).

[41] Addis Ababa was not part of the analysis as the focus is on rural and small town.

C.5 Heterogeneity results

Table C.2. Impact of improved services on labor by age

	Extensive Margins				Intensive Margins			
	Ag.L	FBL	LOHH	AL	Ag.L	FBL	LOHH	AL
Panel A: All individuals < 15 years old								
Improved Water	-0.013	0.006	-0.001	-0.014	-0.145***	0.001	0.434***	-0.135**
	(0.016)	(0.008)	(0.005)	(0.016)	(0.054)	(0.217)	(0.105)	(0.054)
Improved CF	0.034	0.010	-0.001	0.029	0.092	-1.258***	-1.945***	0.096
	(0.025)	(0.013)	(0.007)	(0.026)	(0.070)	(0.253)	(0.037)	(0.072)
Individuals	7603	7608	7608	7586	4234	684	293	4597
Observations	13746	13747	13742	13682	5926	718	301	6399
Panel B: All individuals ≥ 15 years old								
Improved Water	0.007	0.032***	-0.001	0.014	0.029	0.006	-0.197*	0.044
	(0.010)	(0.008)	(0.007)	(0.010)	(0.033)	(0.072)	(0.105)	(0.029)
Improved CF	0.027*	0.013	0.011	0.022	0.148***	-0.010	0.109	0.117***
	(0.015)	(0.012)	(0.011)	(0.015)	(0.052)	(0.106)	(0.129)	(0.044)
Individuals	12932	12921	12921	12904	8486	3438	2607	10064
Observations	28506	28464	28439	28337	14217	4387	3072	17665
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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

Additional Notes: The sub-column labels “Ag.L," “FBL," “LOHH," and “AL" correspond to agricultural labor hours, family business labor hours, labor hours outside of the household, and total labor hours, respectively. The dependent variable in the analysis is labor (extensive and intensive margins), while the treatment variables of interest are improved water and cooking fuels. Panel A pertains to individuals below the age of 15, while Panel B presents regression results for individuals aged 15 and above. The regression models also incorporate additional control variables such as time-fixed effects, individual-fixed effects, individual age, household size, wealth and the gender of the head of the household.

Table C.3. Impact of improved services on labor by gender

	Extensive Margins				Intensive Margins			
	Ag.L	FBL	LOHH	AL	Ag.L	FBL	LOHH	AL
Panel A: All Males								
Improved Water	0.003	0.029***	0.009	0.010	-0.011	-0.023	-0.308***	0.007
	(0.011)	(0.008)	(0.008)	(0.011)	(0.034)	(0.093)	(0.116)	(0.032)
Improved CF	0.009	0.008	0.016	0.006	0.141***	-0.080	0.078	0.122***
	(0.016)	(0.012)	(0.012)	(0.016)	(0.049)	(0.134)	(0.149)	(0.045)
Individuals	9586	9579	9579	9567	6649	1720	1798	7423
Observations	20901	20839	20827	20756	11698	2169	2145	13424
Panel B: All Females								
Improved Water	0.002	0.020**	-0.011*	0.003	-0.019	0.011	0.011	0.005
	(0.012)	(0.009)	(0.006)	(0.012)	(0.042)	(0.092)	(0.203)	(0.037)
Improved CF	0.062***	0.021	0.006	0.058***	0.105	0.018	0.156	0.076
	(0.018)	(0.014)	(0.008)	(0.020)	(0.072)	(0.126)	(0.206)	(0.061)
Individuals	9797	9802	9806	9786	5612	2382	1103	6718
Observations	21351	21372	21354	21263	8445	2936	1228	10640
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses.

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

Additional Notes: The sub-column labels “Ag.L," “FBL," “LOHH," and “AL" correspond to agricultural labor hours, family business labor hours, labor hours outside of the household, and total labor hours, respectively. The dependent variable in the analysis is labor (extensive and intensive margins), while the treatment variables of interest are improved water and cooking fuels. Panel A pertains to male individuals, while Panel B presents regression results for females. The regression models also incorporate additional control variables such as time-fixed effects, individual-fixed effects, individual age, household size, wealth and the gender of the head of the household.

Table C.4. Impact of improved services on labor by region

	Extensive Margins				Intensive Margins			
	Ag.L	FBL	LOHH	AL	Ag.L	FBL	LOHH	AL
Panel A: Small towns								
Improved Water	-0.012	0.028	-0.040*	-0.013	-0.297	0.079	-0.089	-0.070
	(0.022)	(0.025)	(0.022)	(0.028)	(0.225)	(0.118)	(0.203)	(0.089)
Improved CF	-0.011	-0.012	-0.043*	-0.039	0.168	0.085	-0.023	-0.079
	(0.030)	(0.032)	(0.026)	(0.034)	(0.553)	(0.140)	(0.164)	(0.103)
Individuals	2129	2127	2127	2123	523	940	499	1390
Observations	4700	4700	4698	4681	675	1362	655	2241
Panel B: Rural								
Improved Water	0.005	0.026***	0.002	0.011	-0.008	-0.024	-0.211*	0.012
	(0.010)	(0.007)	(0.006)	(0.010)	(0.031)	(0.088)	(0.117)	(0.029)
Improved CF	0.044***	0.018	0.019**	0.042***	0.132***	-0.150	0.165	0.134***
	(0.015)	(0.012)	(0.009)	(0.015)	(0.045)	(0.160)	(0.190)	(0.043)
Individuals	16684	16685	16688	16662	11595	3150	2396	12579
Observations	37552	37511	37483	37338	19468	3743	2718	21823
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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

Additional Notes: The sub-column labels “Ag.L," “FBL," “LOHH," and “AL" correspond to agricultural labor hours, family business labor hours, labor hours outside of the household, and total labor hours, respectively. The dependent variable in the analysis is labor (extensive and intensive margins), while the treatment variables of interest are improved water and cooking fuels. Panel A pertains to individuals in rural areas, while Panel B presents regression results for individuals in small towns in Ethiopia. The regression models also incorporate additional control variables such as time-fixed effects, individual-fixed effects, individual age, household size, wealth and the gender of the head of the household.

C.6 Robustness checks

Table C.5. Determinants of choices of cooking fuel and drinking water (Average Marginal Effects)

	Cooking fuels			Drinking water
	(1) Polluting	(2) Transitional	(3) Clean	(4) Improved
Demographics				
Age of HoH	0.000773	-0.000356	-0.000417	0.0227***
	(0.000864)	(0.000399)	(0.000466)	(0.00765)
Female HoH	-0.00392	0.00180	0.00212	0.141***
	(0.00532)	(0.00245)	(0.00288)	(0.0504)
Number of children (≤ 15)	0.00625***	-0.00288***	-0.00338***	0.0484***
	(0.00134)	(0.000646)	(0.000725)	(0.0116)
Number of adult males ($15 < x < 65$)	-0.00248	0.00114	0.00134	0.0547**
	(0.00245)	(0.00113)	(0.00132)	(0.0222)
Number of adult females ($15 < x < 65$)	0.0129***	-0.00596***	-0.00699***	0.0281
	(0.00362)	(0.00169)	(0.00199)	(0.0235)
Number of Elderly (≥ 65)	0.00321	-0.00148	-0.00173	0.0346**
	(0.00203)	(0.000949)	(0.00109)	(0.0152)
Wealth characteristics				
Asset Index Proxy	-0.00480***	0.00221***	0.00259***	0.0518***
	(0.000660)	(0.000323)	(0.000378)	(0.0114)
Human capital & education:				
Below Primary	-0.00266	0.00136	0.00130	0.149***
	(0.00569)	(0.00290)	(0.00279)	(0.0521)
Primary	-0.00886	0.00446	0.00439	0.339***
	(0.00655)	(0.00328)	(0.00329)	(0.0634)
Middle school	-0.0268**	0.0130***	0.0138**	0.535***
	(0.0108)	(0.00505)	(0.00580)	(0.0949)
Secondary school	-0.0472***	0.0221***	0.0251***	0.703***
	(0.0156)	(0.00691)	(0.00887)	(0.132)
Senior secondary school	-0.0794***	0.0353***	0.0442**	1.198***
	(0.0305)	(0.0122)	(0.0186)	(0.289)
Certificate, Diploma & Some college	-0.119***	0.0498***	0.0690***	1.197***
	(0.0190)	(0.00772)	(0.0123)	(0.122)
University	-0.182***	0.0701***	0.112***	1.604***
	(0.0325)	(0.0108)	(0.0231)	(0.208)
Access to improved infrastructure services:				
Improved Water	-0.00627*	0.00290*	0.00337*	
	(0.00359)	(0.00169)	(0.00192)	
Location:				
Tigray	0	0	0	0
	(.)	(.)	(.)	(.)
Afar	-0.00574	0.00257	0.00317	-0.844***
	(0.0145)	(0.00649)	(0.00801)	(0.135)
Amhara	-0.000517	0.000233	0.000284	-0.179**
	(0.00852)	(0.00385)	(0.00468)	(0.0758)
Oromia	0.0204***	-0.00954***	-0.0108**	-0.491***
	(0.00787)	(0.00358)	(0.00436)	(0.0750)
Somalie	-0.0610***	0.0252***	0.0358***	-0.906***
	(0.0158)	(0.00686)	(0.00923)	(0.0907)
Benshagul Gumuz	0.0279***	-0.0133***	-0.0147***	-0.0258
	(0.00978)	(0.00466)	(0.00523)	(0.115)
SNNP	0.0212***	-0.00995***	-0.0113***	-0.425***
	(0.00765)	(0.00351)	(0.00421)	(0.0726)
Gambelia	0.0387***	-0.0189***	-0.0199***	1.415***
	(0.00773)	(0.00362)	(0.00436)	(0.191)
Harari	0.0181	-0.00841	-0.00964	-0.342***
	(0.0122)	(0.00574)	(0.00651)	(0.107)

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Table C.5 – Continued from previous page

	Cooking fuels			Drinking water
	(1) Polluting	(2) Transitional	(3) Clean	(4) Improved
Diredwa	-0.00376	0.00169	0.00207	-0.0259
	(0.0139)	(0.00624)	(0.00769)	(0.139)
Observations	10970	10970	10970	10995

Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
The polluting cooking fuel category encompasses the collection and purchase of firewood; crop residues/leaves, dung/manure, and sawdust. The transitional cooking fuel includes charcoal, coal and kerosene. Clean cooking fuel comprises electricity, butane/gas, biogas, and solar energy. The reference groups for the dummy variables are: males for gender and individuals without education for the different levels of education. The reference region for the regional dummy variable is Tigray region. Addis Ababa was excluded from the analysis due limited number of observations. University under the education panel encompasses completed university and postgraduate studies. Below primary is kindergarten to the 4th grade, primary is grades 5-7th, middle school is 8-9th, secondary school is 10-11th and senior secondary school is 10-11th while senior secondary is 12th. Some college includes having obtained a certificate, diploma or some college