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# The Impact of a New Piped Water System on the Well-being of Urban Residents: A Case Study in the City of Mandalay, Myanmar

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# The Impact of a New Piped Water System on the Well-being of Urban Residents:

# A Case Study in the City of Mandalay, Myanmar

（新規管路給水事業が都市住民の厚生に与える影響：

ミャンマー国マンダレー市の事例研究）

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## Summary of the doctoral dissertation

The Impact of a New Piped Water System on the Well-being of Urban Residents:
A Case Study in the City of Mandalay, Myanmar

Access to safe water is a basic needs for all people, which is considered as one of the important elements of well-being of human beings. In 2015, the international communities set the SDGs' goal 6 to ensure access to water and sanitation for all. However, six years after, the number of urban residents without safe drinking water has even nearly doubled because of the population concentration in the cities. The rapid growth of urban population has increased the demand for water and the risk of water scarcity in many low- and middle-income countries.

Under such circumstances, constructing a piped water supply system has been regarded as a solution to sustainably provide safe drinking water for urban residents. Yet, the installation of a piped water system requires a large financial investment. The authorities or water supply entities need to make the investment decision with careful planning and assessment on the returns to the investment. Despite the importance of academic research, empirical evidence on what would be brought by the installation of a new piped water system for urban residents have been scarce. Hence, the main objective of this research is to provide a new piece of evidence on the impact of a new piped water system on the well-being of urban residents.

This research focuses on a piped water project (hereafter the Project) in urban area of Mandalay city, Myanmar. In the city of Mandalay, local authority (Mandalay City Development Committee: hereafter MCDC) had planned to expand the coverage area of the piped water system in Pyi Gyi Tagon township, located in the southern part of the city, to satisfy the increasing demand for safe water. While the households' connection rate of the piped water system in the northern townships of the city was about 80

percent, the connection rate in Pyi Gyi Tagon township was only 10 percent as of 2018. Thus, this research in Pyi Gyi Tagon township focuses on some city blocks that were not yet reached by piped water supply before 2018 and where MCDC had planned to supply water service from a new piped water system by August 2018. It was expected that the new piped water supply would allow the users to obtain safe water disinfected by chlorine on the premises, which would improve the safety and convenience of water use among the households.

To evaluate the impact of the piped water system, this research employs a quasi-experimental approach with unique and detailed household panel survey data. The fundamental idea of the impact evaluation is to compare treatment blocks in the new water service area with control blocks in its neighboring area without a piped water service as of 2018. Prior to the baseline survey, an exhaustive block survey confirmed that both treatment blocks and control blocks had similar demographic and socio-economic characteristics. The baseline survey was conducted in May and June of 2018 (before the Project), and the end-line survey was conducted in June and July of 2019 (after the Project) in both the treatment blocks and control blocks.

This research begins with the analysis of water use situation before the installation of the piped water system with the baseline survey data. In the surveyed blocks of the research, majority of the households used water from the private wells in their premises for general purposes and purchased bottled water from vendors for cooking and drinking purposes. Households choose their water sources depending on the various aspects such as water quality, available water quantity, the cost to obtain water, and their socio-economic condition. Higher asset measure, which represents better household economic condition, is correlated with higher ownership of the private wells. Households with higher asset measure also report a higher ratio of purchasing bottled water and larger volume of bottled water consumption.

The baseline survey also inquired about the households' willingness-to-pay for the new piped water service. Before the Project, approximately 60 percent of households responded that they are willing to connect to the piped water system. The respondents who said that they were willing to connect were willing to pay 10.1 thousand kyat (7.48 USD) on the connection fee and 427 kyat (0.31 USD) per unit (1 $m^3$) of piped water on the average. Households with owned house have higher willingness to connect. They have the intention to have a piped water connection since it is their own property.

Overall, however, willingness-to-pay on the connection fee is much lower than the necessary connection cost charged by MCDC. If many households do not connect, it is difficult to explore how the installation of the piped water system would affect the well-being of the residential households. In actuality, the connection cost was subsidized for the households in order to accelerate the private connection. As the result, the connection rate was 91.2 percent, and 88.1 percent of the households in the treatment blocks used the newly constructed pipe water system as of the end-line survey.

The research setting with full-subsidy for private connection allows me to examine how the installation of the newly-installed piped water system has changed the water use pattern of urban residents under the condition that they had other alternatives of water sources such as a private well or bottled water and how it affected their well-being. If households use and drink piped water, it is expected that their well-being would improve because of better access to safe water supply or better health condition. Furthermore, the reduced time in obtaining water and improved health conditions, if any, may enable them to enhance their economic and social activities such as working and schooling.

To conduct rigorous analysis of the impact of the installation of the new piped water system, this research employs the Double Difference (hereafter DD) method, which combines before/after and with/without comparison. Firstly, this research examines the impact on water use pattern. After the installation of the piped water supply, the households in the treatment blocks used 19.2 $m^3$ of the piped water per month. The Project has reduced the use of private wells by 11.8 percentage points and its water use volume by 6.7 $m^3$ per month, as compared with the households in the control blocks. In addition, the Project has reduced the purchasing ratio of bottled water by seven percentage points and bottled water volume by 34 liters. It substituted the use of private wells with the use of piped water system, as the main water source. As the result, the Project has increased the total water use volume of the households by 11.2 $m^3$, as compared with the households in the control blocks.

Secondly, this research explores the health impact on the household members. Intention-to-treat (ITT) effect and average treatment effect on the treated (ATT) on those who used piped water and on those who drink piped water are estimated. The use of piped water reduced the cases of vomiting and diarrhea incidence within the last two weeks prior to the household interview by 0.008 and 0.011 cases, respectively (ATT on those who used piped water in the whole sample). The estimation results of ATT on those who used piped water reported more pronounced effect on the reduction of vomiting and diarrhea incidence in the working age sample, while there were mixed effects among household members who are of schooling age or under 5 years old. The estimation results of ATT on those who drink the piped water did not report any reduction on health incidence in the whole sample. Only 21.8 percent of the households used the piped water for drinking. There seems to exist some other pathways other than drinking through which the health benefits materialize. Since about 65 percent of households used the piped water for cooking purposes, there is a possibility that households who used contaminated private well water for cooking may have higher risk of vomiting and diarrhea. There are also other channels to have the contaminated water from other activities such as washing hands.

Thirdly, this research investigates the impact on the working and schooling status. The analyses are conducted using gender-divided samples in addition to age groups such as working-age sample, adolescent sample, and young children sample. However, the Project did not cause any change in the working and schooling status. This research also examines the impact on the pumping labor and time spent from using private well. The Project reduced the pumping labors of the household members, especially female adolescents. It reduced the household's pumping time of the private wells by 26 minutes per day. The gender disaggregated analysis reveals that the Project reduced the engagement of pumping labor by 19.4 percentage points among working-aged men and 15.1 percentage points among working-aged women. The large impact is among female adolescents with a reduction of 28.3 percentage points on their engagement of pumping labor. Despite the time reduction in pumping, the saved time may not be enough to encourage family members to seek new income-generating activities outside home or school.

Lastly, this research attempts to estimate the economic value of the piped water project by using a coping cost approach. To obtain safe water for living, households pay direct costs such as purchasing bottled water and volumetric fee for piped water and incur indirect costs such as waiting time for pumping water from private wells. Before the Project, households incurred a direct cost of 5,940 thousand kyat (4.4 USD) per month to obtain water from pre-existing water sources. This accounts for the bottled water expense and electricity cost of pumping. On the average, households spent 5,721 kyat (4.2 USD) to purchase bottled waters. The average monthly electricity cost for pumping from private wells is estimated at 219 kyat (0.2 USD). After the Project, households increased the direct costs of obtaining water by 2,821 kyat (1.4 USD) and paid 8,761 thousand kyat (5.8 UDS) in total. After the Project, households spent an average of 3,890 kyat (2.6 USD) per month for the maintenance cost and volumetric water charge for using the piped water, whereas the bottled water expense and the electricity cost for pumping were reduced by 1,069 thousand kyat (0.8 USD) per month.

For the indirect cost, using their pre-existing water sources, the time cost for pumping was 12.9 thousand kyat (9.6 USD) as of baseline survey. The time cost is estimated to be equal to 50 percent of the national minimum wage rate. Using the new piped water system, these labor costs decreased by 5,250 kyat (3.5 USD). Hence, even if the direct costs of obtaining water increased after the Project, the reduction of the indirect costs outweighed the increase in direct costs.

Moreover, households gained health benefits from the reduction of health incidence such as diarrhea. In case a household member has a health incidence such as diarrhea, the household member will not be able to work and will lose the opportunity to gain the wages. By using 50 percent of the national minimum wage rate and 2.8 days per incidence for suffering from each diarrhea incidence, the health benefit from having the better health condition is estimated to be 456 kyat (0.3 USD) per month.

In summary, the installation of the new piped water system increased the total water use volume (due to the use of piped water), as compared to the water use volume of the control blocks. Further, it reduced the usage, water volume, and expense for private well water and bottled water in the treatment blocks. While the direct costs for using water increased due to the newly-charged piped water fee, the economic value of the reduction of both direct and indirect costs of obtaining water from pre-existing water sources exceeds the additional direct costs for using the piped water, although this main conclusion rests on the assumption that the opportunity cost of the reduction in pumping labor is equivalent to 50 percent of the national minimum wage rate.

This research proved that by installing the new piped water system, the Project brought these benefits on the well-being of the urban residents, as the authority and the water supply entity expected. Yet, this research simultaneously reveals some challenges for improving the effectiveness and efficiency of materializing these benefits by the Project. First, the foreseen benefits on the well-being were realized because majority of the households connected to the piped water system with the full subsidy of the connection cost from the Project. Without the full subsidy, the benefits would not have been realized since there was a large gap between the connection fee and willingness to pay on the connection cost. Therefore, it is crucial to explore more efficient financial schemes rather than providing 100 percent subsidy to accelerate the private connection so that the expected benefits can materialize with lower public finance resources.

Second, it should be noted that the impact of the newly-constructed piped water system on the well-being of the urban residents was confirmed even under the situation that the drinking ratio of the piped water was low. If they used piped water more for drinking purpose, larger benefits in terms of the reduction of bottled water expense and improvement of health conditions would have been realized. However, the strange chemical odor and taste of the piped water might have discouraged the residents to drink it. Identifying the obstacles (in addition to chemical odor and strange taste of the piped water) for drinking and implementing some additional interventions to enhance the use of piped water for drinking purpose would improve the effectiveness of the Project.

Lastly, although the Project decreased the time burden for obtaining water, the reduction of pumping time from private wells may not be large enough to alter working or schooling status. Alternatively, there may exist only limited opportunities and constrains especially for female members to work outside home and attending school in the City. If this is the case, the water-related infrastructure investment alone cannot make any significant impact on both working and schooling status. Meanwhile, along with the Project, implementing policy measures aiming to improve employment opportunities outside home, particularly for females, and to enhance schooling outcomes would raise the economic value of the Project.

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## Chapter 1 Introduction

Access to safe water is a basic need for all people, which is considered as one of the important elements of well-being of human beings. With the continuous effort of each nation and the international community, 2.6 billion people have gained access to improved drinking water sources since 1990 (UNDP, 2018). However, in 2015, the target year of Millennium Development Goals (MDGs), 663 million people (9 percent of the global population) still lacked improved drinking water sources[1].

The United Nations and the global community have set the goal 6 to ensure access to water and sanitation for all in the Sustainable Development Goals (SDGs) toward 2030. The indicator of target 6.1 is the "proportion of population using safely managed drinking water services". "Safely managed drinking water" is defined as the use of improved drinking water sources[2], which are located on premises, available when needed, and free of fecal and priority chemical contamination (UNICEF and WHO, 2019). In 2020, 40 percent of rural population and 14 percent of urban population in the world did not use a safely managed drinking water. Between 2000 and 2020, the number of people who lacked even basic drinking water services was reduced by a third, from 1,123 million to 771 million. Eight out of ten of the population without basic drinking water services lived in rural areas (WHO & UNICEF, 2021). It is obvious

[1] WHO and UNICEF defined improved drinking water sources as those that have the potential to deliver safe water by nature of their design and construction. Improved sources include: piped water, boreholes or tube wells, protected dug wells, protected springs, rainwater, and packaged or delivered water. Unimproved water sources are an unprotected dug well, unprotected spring, river, dam, lake, pond, stream, canal or irrigation canal.

[2] WHO and UNICEF subdivided improved drinking water sources into three groups: safely managed drinking water service, basic drinking water service, and limited service. If any of the three conditions of safely managed drinking water is not met, but the improved source is within 30 minutes of the home, it is categorized as a "basic drinking water service". If water collection from an improved source exceeds 30 minutes, it will be categorized as a "limited service".

that the continuous efforts to expand the coverage of access to safe water, even basic drinking water, is necessary in rural area.

The challenge of water access in urban areas is more complex than that in rural area. From 2015 to 2020, while the number of people without safely managed services decreased by 193 million globally and by 225 million in rural areas, the number of people without safely managed services in urban areas increased by 32 million. During this period, the access ratio of safely managed drinking water among urban population had improved by only one percent . Since 2000, the number of residents without safely managed drinking water in urban area has nearly doubled because of the continued concentration of the people in the city (UN-Water, 2021). Even in areas where people have current access to water, there is possibility to face water scarcity due to the urbanization problem and population growth.

It is widely known that urbanization with population concentration is a serious problem in many low- and middle- income countries. About 55 percent of the world population live in towns and cities in 2018 and the ratio is expected to rise to 68 percent by 2050 (UN DESA, 2018). The rapid growth of urban population is expected to increase water demand and water scarcity risk. Padowski and Gorelick (2014) examined the vulnerability of large 70 cities in 39 countries regarding water scarcity and water-related environmental issues. The literature illustrates that 44 percent of cities will be vulnerable by 2040, and city subsidence because of overused ground water and lack of safe water access are projected even in the regions where surface water is relatively abundant. In addition, there are environmental problems caused by water use among the large urban population. There are many places with land subsidence due to the large amount of ground water used by residents, commercial facilities, and factories. Moreover, regarding water quality issues, the residents in urban areas will possibly face problems of water pollution from toxic materials of factories and drained water from insufficient or deteriorated drainage facilities. The sixth goal of the SDGs is to "ensure availability and sustainable management of water and sanitation for all". Sanitation is heavily linked to water supply. One of the most fundamental concepts in hydrology and in the water resource management is the hydrologic cycle[3] (also referred to as the water cycle) (Maidment, 1993). The hydrological cycle becomes more complex in urban areas because of many anthropogenic influences and interventions (McPherson, 1973; McPherson & Schneider, 1974). Major components of the urban water cycle are water supply, wastewater collection, and urban drainage. It is essential to manage the water resources as a cycle. Even though the sanitation, especially drainage system, is important part of the water cycle, the installation of the drainage system is very costly, and the authorities often install the water supply facilities first and then construct the drainage system afterwards on the process of the urban development. Even though sanitation issues are important for urban residents, in this research, one of the components of water cycle, which is water supply, is examined in the urban area context.

Many urban cities in low- and middle- income countries often expand its area without proper city planning. Urban area expansion has often been characterized by population growth and informal settlements (Jägerskog, et al. 2016). There are many areas without supply of public services (including water supply) in the process of urban development. Therefore, residents are forced to obtain safe water by their own effort and expense. Many people rely on informal water vending markets, so the quality and price of urban water services can vary widely. Households who purchase water from private companies often pay much higher cost compared to public water[4]. Some local communities dig their community wells with their collective expenses. In case the

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[3] Hydrologic cycle is defined as a conceptual model describing the storage and circulation of water between the biosphere, atmosphere, lithosphere, and the hydrosphere.

[4] From the surveys in 15 cities in the global South, many households relied on private water providers where municipally piped water was unavailable. From the case of Mumbai, India, water obtained from truck vendors costs as much as 52 times the cost of the city's piped water (Mitlin, et al. 2019).

residents use these water sources, the residents are forced to spare their time and labor to go and fetch water. Other households dig their private wells on their premises. Since the initial investment cost is large for the households, some households cannot afford to have their own private wells. As for drinking purpose, people in many countries have consumed more bottled water in the last decade.[5] However, the consumption of bottled water is directly linked with financial capacity of each household. Many people without quality water sources are forced to purchase bottled water in order to have safe water. It is a financial burden especially for poor households. This makes it necessary for governments to provide sufficient and quality water supply service to residents.

A piped water system is the fundamental infrastructure to supply large amount of safe water (with disinfection by chlorine) for urban residents. A piped water system allows the residents to use water in their premises through private connection with their own tap, making it more convenient for the households. Nowadays, a piped water system is a major water source, and four out of five urban residents use piped water supplies in the world (WHO &UNICEF, 2017). For more than a decade, it has been the main contributor for the improvement of safe water access[6]. However, in low- and middle- income countries, only less than half of the urban population have received piped water in their premises in 2015. It takes time and cost to provide enough piped water supply services given the limited budget.

If a government constructs a new piped water supply facility, it is expected for residents to have private connections of piped water in their premises and to use piped water. As a result, this would improve residents' well-being due to safe and easy-access water in the premises. However, it is uncertain if the residents will use piped water as

[5] Six of the top 10 bottled-water-consuming nations are lower-middle income countries (Brazil, China, India, Indonesia, Mexico and Thailand). Their consumption of bottled water has increased by 174 percent over the period (Cohen, 2017).

[6] Between 2000 and 2015, the population who used piped water increased from 3.5 billion to 4.7 billion, while the population who used non-piped water increased from 1.7 billion to 2.1 billion (WHO & UNICE, 2017).

planned especially in the area where they have access to their pre-existing water sources. It is also uncertain if the water use volume and household expenditure of water use will increase or decrease by using piped water. If the piped water charge is a financial burden for the users, they may not use the piped water as the government expected.

Before making decision of a costly investment on piped water supply facilities, it is important to clearly understand the potential changes and impacts of the investment especially for countries whose budget are limited. However, empirical evidence on the demand and use of safe water among urban population are still scarce. Therefore, it is worth investigating the demand for safe water in urban areas where the installation of a new piped water system is planned.

In this research, installation of a new piped water system in the newly-developed urban area of Mandalay city (hereinafter referred as “the City”), Myanmar, is chosen as a case for examining the impact of a new piped water system. The main purpose of this research is to examine the impact of a new piped water system on the well-being of urban residents. In the City, almost half of the population do not have access to piped water. It is considered that the City has the typical water-related issues which other urban areas of low- and middle- income countries face.

The following are the brief contents of each chapter. Chapter 2 presents background information such as water use situation and water administration of the City and the characteristics of the survey site. The City is the second largest city of 1.3 million populations. The survey site is the township where population is growing and where most dwellers are forced to find their own water source. Chapter 3 gives information on the installation project of the piped water system. There was no piped water system in the project site and approximately eight thousand households would benefit from the new piped water system. Normally, the residents are requested to pay the connection fee in the City. However, since this water supply project subsidizes the connection fee using the project's budget, the connection fee is not a constraining factor to make the decision of piped water use. This setting allows to exclude the factor of initial investment cost on the water use decision and to analyze how the people use piped water and other types of water with the consideration of the continuous piped water charge.

Chapter 4 examines the water use pattern among the urban residents by utilizing household survey data collected in the Project site before the installation of the piped water system. The household survey reveals that majority of the households used private wells in their own premises or neighbors' and consumed bottled water for drinking purpose. This chapter also examines the demographic and socio-economic characteristics of the households using private well water and bottled water to reveal what factors shape the demand for water of households without access to piped water. Moreover, this chapter explores the potential demand for water from the new piped water system of surveyed households by examining the factors associated with the willingness-to-pay for the connection and regular use of the piped water system.

Chapter 5 examines the impacts of the installation of the piped water system on water use such as water source choice (private well, piped water and bottled water), water volume, and its expenditures by utilizing the household survey data collected before and after the installation of the piped water system. It is expected that households will shift their water source from using private well to piped water and that they will drink the piped water instead of bottled water. Since the price of bottled water is relatively high, the shift in drinking water source would reduce the household expenditure on water use.

There are a limited number of research that examined the impact of installation of a new piped water system in urban areas where the water source shift from private well to piped water system is expected. If the government supplies sufficient and quality piped water and the residents decide to use piped water in their premises, it is expected that the residents would have higher utility from using the water. Utility level of the residents is examined as the results of using piped water. One of the possible benefits from the quality piped water is the improvement of health condition. Chapter 6 examines the individual health impact with the installation of the new piped water system by using the panel data. It is expected that the health condition caused by water-borne diseases would be improved with the use of the disinfected piped water. Chapter 7 examines the impact of the installation of the new piped water system on individual activities such as working and schooling. If household members are released from pumping labor, they may use their free time for other activities.

Chapter 8 examines the economic value of the new piped water system by employing the coping cost approach, which is one of the revealed preference methods to capture the value of goods. Using this approach, it is considered that people pay both direct and indirect costs. The direct costs include the water charge or electricity fee for pumping and the indirect costs are the time spent in pumping and fetching the water. The indirect cost may be the deciding factor with regard to water use. Valuation of water is important but is still limited because water is a non-market good. By assessing the impact and value of piped water supply among the users, this research would provide the empirical evidence for governments and water supply entities to make informed decision regarding the construction of piped water supply facilities.

# Chapter 2 Background information

## 2.1 General information of Myanmar

Myanmar is situated in Southeast Asia and is bordered by China, India, Thailand, Bangladesh, and Laos. It is the second largest country in Southeast Asia with abundant natural resources. The land size is 677,000 $km^2$, stretching out more than two thousand kilometers from north to south. The population is approximately 51.5 million in 2014, the year of national census. The average annual gross domestic product (GDP) growth is estimated at 8.5 percent from 2010 to 2014.

Alongside the economic growth, urbanization has progressed in large cities of Myanmar. Thirty percent of the population lives in urban areas. Much of the population concentration into the cities is attributed to internal migration. Yangon city and Mandalay city are the two largest cities, and the urban areas of these cities have expanded. However, public services for the residents are limited or malfunctioning. For example, solid waste management is limited to partial collection of urban waste. Both cities also have deteriorated water supply facilities and their water service areas are still limited.

In terms of the water supply situation at the national level, there is much room for improvement in Myanmar relative to its neighboring countries in 2017. Rate of access to at least basic drinking water source was only 82 percent in Myanmar, 77 percent in rural area and 93 percent in urban area. Eighty percent of urban population in Myanmar has water access in their premises but this is relatively lower compared to its neighbor countries. The rate of water access in their premises were more than 99 percent in Thai and Viet Nam, 94 percent in Lao PDR, and 77 percent in Cambodia. As for the rate of accessing to piped water system in urban area, Myanmar's rate was 57 percent, while Lao PDR's was 82 percent and Cambodia's was 77 percent. (UNICEF & WHO, 2019).

## 2.2 General information of Mandalay city

Mandalay City is the second largest city, which is the economic and cultural center of the upper Myanmar. It is located as the key junctions of trade and transportation between China and India, and the Ayeyarwady river runs just beside the City. The population is growing, and the geographical area are stretching to the outskirts. Mandalay City is composed of six townships: Aung Mye Tha Zan, Chan Aye Tha Zan, Maha Aungmye, Chanmyathazi, Pyi Gyi Tagon, and Amarapura, located from north to south (Map 1 in Appendix). The development of the City has progressed from the upper area, where the Mandalay Palace was located. The City was originally composed of northern four townships, and Pyi Gyi Tagon Township was integrated in 1993 when the industrial zone 1 was established. Amarapura was integrated into the City in 2011 and has the different social, cultural, and economic characteristics from other townships. The development of the residential area is stretching out beyond the eastern part of the City. The urban population of the City is about 1.3 million in 2014 based on the national census data. In 2000, it was approximately 0.8 million—its population has grown since and urbanization has progressed (MOIP, 2015).

The climate of the City is categorized at the border of tropical savanna climate and semi-arid climate, and the City has three seasons: rainy season, cool season, and dry season. April is the hottest month with an average maximum temperature of 38.4 degrees Celsius. The rainy season starts from May and ends in November. There are relatively light rainfalls from May to July, and heavier rain in September. The average annual rainfall is 1,161 mm (Grzybowski et al. 2019).

## 2.3 Water supply situation in Mandalay city

The 2014 population census data shows that 35.3 percent of households in the City use piped water and 59.6 percent use tube well or borehole, as the main water source for non-drinking purpose. Since the census surveyed even the temporal-staying households and informal settlers, which were not eligible to connect to piped water system, it may result to relatively lower ratio of piped water usage. Outside of the piped water supply area, the residents are forced to acquire water by digging own wells or getting water from others or public wells. Many private wells were dug without registration to Mandalay City Development Committee (hereinafter referred as “MCDC”).[7]

Since groundwater is a finite resource, arbitrary water use by each household may lead to lack of water resource in the area. In addition, there are possibilities that water from the wells is contaminated with harmful bacteria. The households use the septic tanks or pit latrines, which may bring fecal bacteria to the water sources. There are also no sewage water treatment facilities in the City. Water of their private water sources and public water sources may not be safe enough to use and drink, thus, many households in the City purchase bottled water.

Based on the survey conducted in all six townships in 2019, 80 percent of the surveyed users relied on more than one water source which may be piped water system, tube well, bottled water and other sources. The choice of the primary, secondary and tertiary water sources vary among townships depending on the various aspects such as availability of piped water and the quality of water. More than half of the respondents emphasized the quality of water as important factor for  water source selection. Meanwhile, the convenience of access, reliability of access or price of water were less important for them (Nagpal et al. 2020).

The first piped water supply facilities of the City was constructed in 1983 and most of their piped water supply facilities that were installed until 1992 were financed by Asian Development Bank (ADB), Organization of the Petroleum Exporting Countries (OPEC), and the Government of Myanmar (JICA, 2003). Afterwards, MCDC has constructed some water supply facilities and expanded the water supply area gradually.

[7] MCDC is the administrative body in charge of city planning, land administration, tax collection, urban development, and the provision of social services including water supply.

Based on the calculation using water bill data of MCDC, the piped water system served 0.73 million people out of a total population of 1.5 million in 2015, which means that the water coverage in Mandalay city is 49 percent of total urban population (Yi et al. 2017).

The number of the installed meter were 43,183 in 1994 and 65,413 in 2003 (Yi et al. 2017). In 2018, there are almost 100 thousand meters in the City. The connection rates in the six townships from north to south in 2014 were as follows: 88 percent for Aung Mye Tha Zan, 96 percent for Chan Aye Tha Zan, 80 percent for Maha Aungmye, 45 percent for Chanmyathazi, five percent for Pyi Gyi Tagon, and one percent for Amarapura (JICA, 2015). Since the urban development has progressed from north to south, the connection rate differs largely depending on the historical transition of the urban development. Map 1 (Appendix) shows the location of townships. The Mandalay Palace is a large square-shaped area in Aung Mye Tha Zan township, the northernmost one. Amarapura is a much larger township with suburb and rural area in the southern part of the City's territory.

There are nine water distribution facilities using ground water and two water treatment plant using surface water. Map 2 (Appendix) shows the location of water supply network. Many tube wells of the piped water supply facilities are located near the Ayeyarwady river, which runs at the western part of the City. The distribution pipes cover the wide area of upper four townships but cover a very limited area of Pyi Gyi Tagon Township.

The piped water supply facilities operate for approximately seven hours/day and seven days/week. Annually, the facilities supply about 30 million $m^3$ of water volumes through the existing infrastructure to water users (Yi et al. 2017). Because of the limited supply time, many households store water in their own water tanks. Households purchase metal or plastic large tanks and install them on top of their roof on their own expense. In the existing pipe water supply area, majority of households have shifted from private well to piped water system, while some households still use their private wells less frequently or keep their private wells as the back-up facility in case of emergency. From the qualitative interview, there were cases wherein the household chose to use the private well for drinking even though it is connected to the piped water system because of the bad quality of piped water.

About 90 percent of water of the piped water supply facilities in the City is sourced from ground water (Balac et al., 2019). It was estimated that groundwater abstraction is about 170,000 $m^3$/day, while the recharge rate is only 100,000 $m^3$/day (GMS, 2006). MCDC has a long-term plan to shift the main water resource from groundwater to surface water since Ayeyarwady river runs just beside the City. However, the incoming water from the river to the existing water treatment plan is very muddy. It takes a long time to treat the water with slow sand filtering system and produce much less water than the capacity of the plant. MCDC supplements the groundwater in the treatment process of the surface water treatment plant to meet the water demand. The construction cost and operational cost of water treatment plant are higher than those of the system using groundwater. Therefore, it will take a long time to fully utilize the abundant surface water. As another water source, MCDC allows residents close to the Palace to use the public well using the moat water of the Mandalay Palace. The moat water is sourced from the Sedawgy dam which is 50 kilometers away from the City. The public wells are installed on the streets and people use the moat water for bathing and cleaning at the wells.Because of the deterioration of the existing water distribution pipes, there are many breaks and leaks of pipes, which resulted to water contamination on the course of water distribution. Large portion of the piped water had been distributed without disinfection for a long time[8].

[8] The oldest water supply system, which covers wide water service area, had the disinfection facility, but it had a leakage accident of chlorine gas in 1994. MCDC could not afford to repair the facility and had supplied water without chlorination (GMS, 2006)

JICA's study detected that all the nine reservoirs of the piped water supply facilities using ground water tested positive for standard plate count bacteria. In addition, five out of those nine reservoirs were contaminated with fecal coliform (JICA, 2015). The disinfecting facilities were installed with the support of JICA, and the distributed water is now being disinfected. However, the water is re-contaminated when it goes through the deteriorated distribution pipes. Many residents think that they receive low-quality water especially for drinking purpose so they just opt to procure bottled water or continue the use of their private wells. Only 34 percent of the households connected to MCDC piped water supply drank the piped water. More than 70 percent of the households drink bottled water. (Nagpal et al. 2020).

In order to address the situation, ADB and the Agence Française de Développement (AFD) have implemented the Mandalay Urban Services Improvement Project (MUSIP) in 2016 to improve the water supply and wastewater management system in the northern four townships. ADB provided water supply components by loaning 60 million USD and granting 4 million USD. As for water supply systems, MUSIP has increased the water production capacity by rehabilitating existing treatment plant and two reservoirs, constructing a new treatment plant, constructing 19 km of main transmission lines and 116 km of distribution systems, and rehabilitating 18 km of existing network and expansion of new network (ADB, 2015).

Comparing the upper four townships, Pyi Gyi Tagon Township and Amarapura Township had much lower connection rate of piped water system. Thus, MCDC and JICA planned the project to install new piped water supply facilities for Pyi Gyi Tagon Township. In addition, another water supply project in the Township supported by the Dutch government was approved at the Assembly of the Union in 2019 (Myanmar times. 2019). With these two projects, most area of the Pyi Gyi Tagon township would be supplied with piped water. In Amarapura, the sixth township, the water supply situation is far beyond those of other townships. AFD pledged to construct the first pilot water supply system which was expected to provide connections to 2,000 households. However, a very limited number of households have connected with the system and there is no plan to construct new piped water system in the rest of Amarapura township.

In terms of wastewater management, there are no conventional central sewerage system in the City. Currently, the domestic wastewater directly flows into the drainages and canals from households, and it gathers in larger canals or river. It moves to the two large lakes of the western part of the City for natural depuration. Finally, the water is pumped out to the Ayeyarwady river, but is still smelly with yellow colors even before it is discharged into the river. MUSIP will provide the first sewerage system including a wastewater treatment plant with a capacity of 75,000m3/day, 27km sewerage networks, and a pumping station at Thingazar Creek. AFD supports the wastewater management portion with mixed finance of loan of 40 million Euro and grant of 8 million Euro (ADB, 2015). It is a great step toward better wastewater management, but the system covers only a limited area in the City. The lack of proper wastewater management may result in deterioration of groundwater quality and contamination of piped water through the deteriorated distribution pipes.

## 2.4 Water administration and water charge collection

Water and sanitation department, one of the fourteen departments in MCDC, oversees planning and administration of water supply service in the City. There are four sections in the department. The water distribution section provides the water supply service for the users after construction of piped water supply facilities. The household in the water service area makes a request to MCDC for private connection and the department does the construction works to connect the main pipe to their premises. For private connection, the households are generally requested to cover the connection cost, which approximately ranges from 100 thousand to 150 thousand kyat (Approximately 66 - 100 US dollars)[9] depending on the length of the branch pipe from the main pipe to the meter box in the premise.[10]

The revenue department is in charge of user fee collection of all the public services including the water charge collection. The department has meter-reading staffs and they visit the user's household bi-monthly for meter-reading and handing of invoice to the household. MCDC sets the unit price of piped water at 200 kyat per unit, which is $1m^3$ (1,000 liters). Based on the consumed units between the bi-monthly meter readings, water charge is calculated. Maintenance fee to use water meter is added in the water charge bill. Since the maintenance fee is only 50 kyat per meter per month, the unit cost of piped water is nearly equal to the unit price of piped water. The unit price was five kyat in 1989 and gradually increased to 10 kyat in 1996, 25 kyat in 2005, 55 kyat in 2007, and 85 in 2015. In 2017, it jumped up to 200 kyat. The unit price has been kept at low price and the production cost of piped water is more than the unit price. Based on the interview of the MCDC official, the production cost is estimated at more than 330 kyat per unit.

### 2.5 Water vending market

The 2014 population census data showed that 25.9 percent of households in the City drank a bottled water or purified water. The Myanmar Living Conditions Survey in 2017 reported the ratio of households which used bottled water as the main water source of drinking water from 2005 to 2017 in Myanmar. In the urban areas, it showed the following ratios: 5.4 percent in 2005, 13.4 percent in 2010, 31.3 percent in 2014, and 48.9 percent

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[9] Kyat is Myanmar currency, which is equivalent to 0.0007 US dollar (1 dollar = 1500 kyat) as of May 2019.

[10] As shown in Map 3 of Appendix, "construction of piped water supply facilities" is defined as a situation wherein MCDC constructs the water supply facilities including deep borehole, disinfection facilities, buster pump station, and main distribution pipes. "Private connection" refers to the connection from main distribution pipe to the meter box in the premise through branch pipes, based on the connecting decision of each household. "Installation of piped water system" refers to the overall situation in which the connected households can use piped water, distributed from piped water supply facilities, in their premises.

in 2017 (World Bank, 2018). Bottled water has been popular and its consumption has increased rapidly for the last several years.

In the City, there are the bottled water companies that sell, deliver and collect water bottles for households. The size of a large bottled water is 20 liters and its cost per bottle is approximately 350 kyat, which is about one-quarter of a US dollar. Since the companies regularly visit households for delivery and collection of bottles, households can easily purchase bottled waters. In addition, there are many small retail shops and markets that sell small water bottles such as 500 ml, one liter or two liters. According to a bottled water factory, more than 20 water vender companies operate bottled water business and belong to an association to maintain the production and sales of bottled water in the City. The association generally set the selling price of bottled water at 350 kyat per 20-liter bottle to make the market stable among water vender companies in the City. These companies receive authorization of water production from MCDC and are subject to yearly inspection by Food and Drug Administration of Ministry of Health to acquire the operational license of factories. However, there exists illegal water venders who produce and sell bottled water without those authorizations. Myanmar Drinking Water Entrepreneurs Association reported that only about 200 of the more than 6,000 bottled water manufacturers in whole Mandalay region (including the City) have permissions from the Food and Drug Administration (MMtimes, 2018). Those manufacturers without authorization sell the bottled water at a lower price.

Phyo. et al (2019) conducted bacteriological examination of 19 brands of bottled drinking water which were sold in markets in the City. Seven brands had total coliform counts ranging 6 MPN/ 100 ml to 16 MPN/100 ml. Among those seven contaminated brands, five are contaminated with *Escherichia coli (E. coli)*, which represents fecal contamination. For the examination, they used the water from 1-liter bottle of 14 brands and 20-liter bottle of five brands. Total coliform bacteria were detected in all the 20-liter bottles and *E. coli* were found in 20-liter bottles of four brands. Though it is not certain who produced those tested bottles (by the legitimate water venders or the illegal water venders), bottled water is not necessarily safe and there is a possibility that the residents drink unsafe bottled water without knowing that it is contaminated.

## 2.6 General information of Pyi Gyi Tagon Township

Pyi Gyi Tagon Township (hereinafter referred to as “the Township”), where the survey of this research was conducted, is located approximately 10 km away from the center of the City. It forms the southern edge of the urban residential area of the City and farmlands spread outside of the Township. The population of the Township in 2014 was 219 thousand, which is one sixth of the city’s population. The number of households was approximately 44 thousand.

In the Township, there are 16 wards, which are the lowest administrative bodies. Wards and townships are administrated by the Mandalay regional government, not by MCDC. MCDC is in charge of certain areas of public services and cooperate with the regional government for public administration in the City. In the wards, there are unofficial lots zoned by streets, which are named as “block” in this paper. The one-hundred household leader, who is the representative of each block, is selected from the residents of the block. The leaders take the role to coordinate between residents and the administrative bodies.

In the southern part of the Township, there are many factories, warehouses, and workshops that are located even outside of industrial zone area. The western part of the Township has area where the development of the residential area is still on-going, while large grass lands or wetland areas exist in some parts. Nine wards in the northern area of the Township are recognized as typical residential areas with dense population. The connection rate of water supply system of the Township was five percent in 2014. The piped water network stretches out into some blocks of two wards in the northwestern part of the Township. The remaining seven wards: Ngwe Taw Kyi Kone, Ga Nge, Ga

Gyi, Nga, Thin Pan Kone, Kha Gway, and Salone, are considered as typical residential areas without piped water system in the Township.

As for the drinking water, the 2014 Census reported that 71.3 percent of the households in the Township drink water from tube wells or boreholes and 23.1 percent drink bottled water or purified water. About 92.6 percent uses tube wells or boreholes and 2.3 percent uses tap water or piped water as their main non-drinking water source. Testing for water quality in the Township in 2014, total coliform was detected in all the samples of surveyed public taps and in nine samples out of the 14 tube wells, and E. coli were detected in some samples as well. From many samples, high level of turbidity, total dissolved solids (TDS), electrical conductivity (EC) were detected. The report concluded that the water quality of the Township was not suitable for drinking purposes (JICA 2015).

## Chapter 3 Outline of new piped water supply project

Based on the growing needs of piped water supply especially in the southern part of the City, MCDC made the request to have the assistance from the Government of Japan for construction of the new piped water supply facilities in Pyi Gyi Tagon Township. JICA implemented “the Project for Improvement of Water Supply System in Mandalay City” (hereinafter referred to as “the Project”), which constructed the piped water supply facilities for the Township and provided nine disinfection facilities to the existing piped water system in other townships from 2016 to 2018. The construction ended in July 2018 and the piped water supply service was commenced in August 2018. Approximately eight thousand households in the Township would benefit from the Project. It is a grant aid project amounting to 2.55 billion Japanese Yen (equivalent to approximately 22 million US dollars).

In the planning stage of the Project, the water service area were selected considering the financial limitation. It was considered that the piped water supply facilities would be efficiently constructed and effectively utilized by many residents. The lower part of the Township is a large industrial zone with little residential area. In the Township, there is another plan to construct piped water supply facilities using surface stream water from the river of the lower part of the Township with the Dutch assistance. The northwestern part of the Township is covered by different piped water supply facilities stretching from Chanmyathazi township. It is necessary to design the installation of the distributing pipe in an efficient manner by considering the future installation plan. As a result, the water service blocks in five wards: Ngwe Taw Kyi Kone, Thin Pan Kone, Ga Nge, Ga Gyi, and Nga, were chosen as water service areas by stretching out from the existing coverage area. MCDC selected the water service blocks considering various factors such as budget, number of beneficiaries, location, and constructional design of facilities.

Map 1 (Appendix) shows the location of the piped water supply facilities and its water service area (composed of water service blocks), which is shaped like a sewing machine. The ground water is utilized for the Project, even though the facilities are located near the lakes and Ayeyarwady river. The ground water is pumped up from three deep boreholes which reached to third aquifer with an average depth of 90 m. Then, pumped-up water is stored in the water reservoir. After disinfecting the water with chlorine, the buster pump station pumped out the water into the main distribution pipe. In the water service area, the secondary distribution pipes are buried to deliver the water to each water service block. Each household in the water service blocks requests MCDC to install the meter box and the branch pipes from the secondary pipes. It depends on each household's decision on whether to install further pipes and taps for them to use the water directly inside the house. Some households only put the hose out of the meter box and simply use the water outside of the house.

## Chapter 4 Examining demands for improved water

### 4.1 Background and research interest

Demand for water in urban areas has become increasingly difficult to meet due to various factors such as population growth and shortage of water resources (Mitlin, et al., 2019). Because of the population concentration in urban cities in many low- and middle- income countries, the number of urban residents who lacked safely managed drinking water have increased in recent years. Construction of piped water supply facilities is very costly for governments. Governments need to carefully consider if it is a prioritized investment given the limited budget of those countries and the numerous demands for various infrastructures such as road, school, hospital, and waste management plant. To cope up, governments have gradually constructed piped water supply facilities. However, in areas where governments have not yet constructed piped water supply facilities, households are forced to obtain safe water on their own efforts from various water sources such as public well, private well, and bottled water to meet their daily water needs.

To meet the increased demand for safe water, the supply of bottled water has expanded very rapidly. The consumption of bottled water highly rose in the last decade in many countries[11]. However, the purchase of bottled water is directly linked with financial capacity of households. Many households without access to safe water are forced to purchase bottled water to have drinking water which is a financial burden especially for poor households. Very poor households do not even have the capacity to purchase it. In addition, bottled water causes environmental problems since bottles turn into plastic wastes. In many countries, plastic waste is a growing concern. The pollution

[11] Over the last decade, six of the top 10 bottled-water-consuming nations have been Lower-Middle Income Countries (Brazil, China, India, Indonesia, Mexico and Thailand). Their consumption of bottled water have increased by 174 percent over the period (Cohen, 2018).

from micro-plastic is a challenge and the international community shed light on the need to reduce the use of plastic materials. Cohen (2017) warned the tendencies to heavily rely on bottled water as a means to access safe water in order to achieve one of the SDGs "universal and equitable access to safe and affordable drinking water for all." Since there are limited literatures that analyzed the use of bottled water especially in urban areas in low- and middle- income countries, it is worthwhile to examine if bottled water is an equitable and favorable solution as means of safe water access.

This chapter examines the water use pattern among the urban residents using the household survey data collected before the installation of the piped water system. More specifically, it examines the demographic and socio-economic characteristics of the households using private well water and bottled water to determine the factors affecting the demand for water of households without access to piped water.

In low- and middle- income countries, the determinants of water demand vary such as household income, income elasticity, household size, land size, water cost, asset, distance to the water source, trip time and waiting time, quality and reliability of source, pressure of water, daily water demand, and source of water (Bradley 2004; Jansen & Schulz 2006; Nauges & van den Berg 2006; Arouna & Dabbert 2009; Nauges & Whittington 2009; Choudhary et al. 2012; Poustie & Deletic 2014; Hussein et al. 2016; Makwiza & Jacobs 2016; Ahmad et al. 2017; Marinez-Santos 2017; Purshouse et al. 2017; Meyer et al. 2018). As for the household socioeconomic characteristics related to water use, income (or expenditure and educational level (or literacy)) have been found to be positively associated with households' choice of improved water source (Mandanat & Humplick, 1993; Nauges & van den Berg 2006; Nauges & Whittington 2009). Larson et al. (2006) showed a significant association between education and water use given that wealthier people have higher levels of education and better access to water. Tiwari & Nayak (2013) found that literacy rate and education are important determinants of water and sanitation access. It is considered that the people with higher educational level have more knowledge about water, hygiene and sanitation issues, and have deeper understating of the importance of quality water for their health. Therefore, educational level is an important factor for choosing the water sources for accessing quality water.

Firstly, this chapter explores demand-side factors associated with regular purchase of bottled water in order to examine if bottled water can be a solution for accessing safe water for all. Bottled water may be the most expensive water among various types of water. However, if bottled water is affordable for everyone, it may be a solution to achieve universal access to safe drinking water. Particularly, this chapter examines if perception on the cleanliness of their water source affects the purchase of bottled water.

Secondly, this chapter explores the potential demand for water from the new piped water system of the surveyed households by examining the factors associated with willingness-to-pay for the connection and regular use of the piped water system using contingent valuation method (CVM). CVM is often utilized for valuation of non-market goods including water using hypothetical questions such as willingness-to-pay on the goods. This method makes it possible to examine how people potentially use the new piped water system before its construction. This will give governments insights into how much a new piped water supply facilities are demanded among potential beneficiaries. Particularly, this chapter examines if positive perception on the cleanliness of their water source affects their willingness to use piped water. Further, since the construction cost of piped water supply facilities is very high, it is not practical to construct facilities that can only benefit a small number of residents. This research would provide the empirical evidence on the potential use and impact of a piped water system before making investment decision on the construction of piped water supply facilities.

## 4.2 Survey design and descriptive analysis of data

### 4.2.1 Survey design

For this part, the surveyed households were selected as follows. In the water service blocks where the Project would supply piped water, there are some blocks where many factories or large grasslands with few residents are located. Those blocks were excluded because this research focuses on the water use of the habitants of residential area. Ninety-seven blocks remained as project blocks. Among the 97 project blocks, 62 blocks were randomly selected as sampled blocks. From each sampled block, ten households were randomly selected[12]. In total, 620 households were surveyed in May and June of 2018.

### 4.2.2 Descriptive analysis

#### 4.2.2.1 Water use in the Pyi Gyi Tagon township

Table 4-1a shows the types of main water source used by households in the sampled blocks. The main water source is defined as the water source from which the households obtain their daily water most frequently. Majority of the households own private wells and normally use them as their main water source. In figures, that is 84.5 percent. The remaining 15.5 percent obtain their water from other sources such as neighbors' wells or public wells. There is also MCDC's overhead tank water system but only in very limited areas. Bottled water is not categorized as main water source since it is generally used for only drinking purpose. In the analysis, the main water sources were treated as the pre-existing condition and bottled water use is the alternative source of drinking water for the households. Among the 620 households, 12.1 percent of the households obtain water from two sources.

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[12] In order to select 10 households, the surveyors first counted and assigned the number to the eligible households in the block. The starting point of counting was selected randomly from the four corners of the block, which is normally square-shaped. After making the list of the eligible households for piped water system in the block, 10 households were randomly selected.

To compare water use among the households under different economic conditions, the households are divided into two groups: “high-consuming” households and “low-consuming” households. The households were categorized using their total monthly household expenses on various items such as food and beverage, non-food items, electricity, fuel, communication cost, education expenditure, health expenditure, transportation cost, donation, and others. As shown in Table 4-1b, half of the households are categorized as high-consuming households while the other half are categorized as low-consuming households. There are not large differences on the types of water source used by both groups. The distribution of the log of monthly household consumption of lower and higher consumption sample is shown in Appendix 4-1.

Approximately 32 percent of the 620 households drink water from their main water sources and 28.6 percent of the households drink water from their private wells. There are 50 households who do not drink water from their private wells, but drink water from public tap or public wells, their secondary source. About 25 percent of private well owners said that the water is not clear and relatively worse than the water from other sources. Yet, they still use private wells as their main source because private wells are located in their premises where they can access the water conveniently with less labor and time spent for fetching water. Households with own private wells use water in their premises, suggesting that ownership of private wells affect households’ water use.

**Table 4-1a Type of main water source, perception of cleanliness of the source, and percentage of drinking (all sample)**

| | All | | | |
|---|---|---|---|---|
| Type of water source as the main water source | Obs. | use ratio (%) | Ratio of perception of cleanliness on the water (%) | Drinking ratio of the water (%) |
| Total | 620 | (100.0) | 77.4 | 31.9 |
| Private well (Own) | 524 | (84.5) | 76.0 | 28.6 |
| Neighbor's well | 67 | (10.8) | 83.6 | 52.2 |
| Neighbor's tap (Piped water/ Stand pipe) | 16 | (2.6) | 81.3 | 43.8 |
| Connection with MCDC overhead tank(Own) | 3 | (0.5) | 100.0 | 66.7 |
| Public tap (Piped water/ Stand pipe) | 1 | (0.2) | 100.0 | 100.0 |
| Public well | 5 | (0.8) | 100.0 | 60.0 |
| Water bought from water seller | 4 | (0.6) | 100.0 | 0.0 |
| Bottled water* | 447 | 72.1 | | 100.0 |

Note: The table is compiled by the author.
*Bottled water is not categorized as main water source.

**Table 4-1b Type of main water source, perception of cleanliness of the source, and percentage of drinking (higher and lower consumption sample)**

| | Upper half (Higher consumption) | | | | Lower half (Lower consumption) | | | |
|---|---|---|---|---|---|---|---|---|
| Type of water source as the main water source | Obs. | % of use | % of Cleanliness | % of drinking | Obs. | % of use | % of Cleanliness | % of drinking |
| Total | 310 | (100.0) | 74.8 | 28.4 | 310 | (100.0) | 80.0 | 35.5 |
| Private well (Own) | 280 | (90.3) | 74.3 | 24.6 | 244 | (78.7) | 77.9 | 33.2 |
| Neighbor's well | 20 | (6.5) | 75.0 | 65.0 | 47 | (15.2) | 87.2 | 46.8 |
| Neighbor's tap (Piped water/ Stand pipe) | 4 | (1.3) | 75.0 | 50.0 | 12 | (3.9) | 83.3 | 41.7 |
| Connection with MCDC overhead tank(Own) | 1 | (0.3) | 100.0 | 66.7 | 2 | (0.6) | 100.0 | 50.0 |
| Public tap (Piped water/ Stand pipe) | 1 | (0.3) | | | | | | |
| Public well | 3 | (1.0) | 100.0 | 100.0 | 2 | (0.6) | 100.0 | 50.0 |
| Water bought from water seller | 1 | (0.3) | 100.0 | 0.0 | 3 | (1.0) | 100.0 | 0.0 |
| Bottled water* | 236 | 76.1 | | 100.0 | 212 | 68.4 | | 100.0 |

Note: The table is compiled by the author.
*Bottled water is not categorized as main water source.

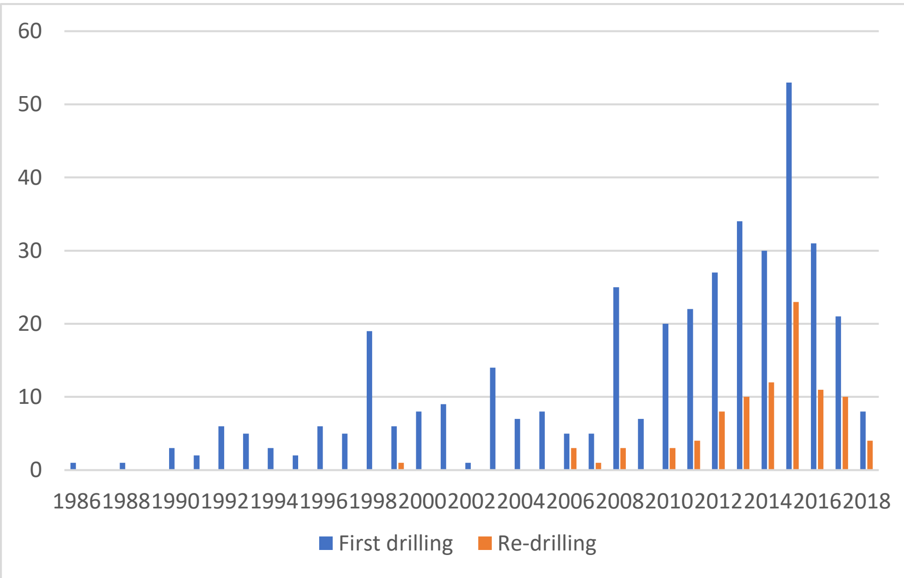
#### 4.2.2.2 Ownership of a private well

Owning a private well requires initial investments such as digging fee and equipment like pump and compressor. The average costs of initial drilling and redrilling amount to 104 thousand kyat and 137 thousand kyat, respectively; whereas the average cost of installing a compressor is 147 thousand kyat. The total initial investment of digging well and installation of the equipment is 251 thousand kyat, which is approximately 39 percent of the monthly household income of the treatment blocks.

The graphs 4-1 reports the year of drilling. The drilling cases increased after 2008 and the redrilling cases increased after 2010. Sixty-two percent (246 out of 394 households) of the private wells were dug in 2010 and in the succeeding years. Under the minimum wage law of 2013, the minimum daily wage for eight hours work was set at 3,600 kyat in 2015, and it increased to 4,800 kyat in 2018. From the qualitative interview, some households said that they were able to afford private wells because of higher wage rate. The cases of drilling jumped up rapidly in 2015. The initial investment of the private well seems to be a heavy financial burden for the households.

Twenty-four percent (93 out of 394 households) of the private well owners redrilled. Ninety-one percent of redrilling were conducted in 2010 and years after. The average gap from the first drilling to redrilling is 14.3 years. From the household survey, about 10 percent of the private well owners responded that the water quantity was not enough in dry season, but most of them have sufficient water during rainy and cool seasons. The other factor for the redrilling may be water quality issue. These redrilling cases imply that the households had difficulties to obtain quality or sufficient water. The depth of redrilled well is deeper than the original depth of the well by on average of 53 feet, and the cost of redrilling is higher than the first drilling by 77 thousand kyat. This is the additional financial burden for the households.

**Graph 4-1 Yearly cases of drilling**



4.2.2.3 Association of perception of water quality and use of bottled water

Some households drink water from their main water sources, but majority of the households purchase bottled water. Bottled water use is examined on the pre-existing condition that all the households use at least one type of water source. Water quality seems to be an important factor on the use of water obtained from the main water source. Therefore, the perception of water quality may be associated with use of bottled water. In terms of the perception of water quality of the main water sources, Table 4-1a shows that 77.4 percent of the 620 households consider their water as clear. The rest of them evaluated their water as a bit cloudy or cloudy.

Table 4-2a shows the descriptive statistics of bottled water use. Among the 620 households, 72.1 percent of them purchase bottled water, and their average expenditure on bottled water is 5.2 thousand kyat per month. Among high-consuming households in Table 4-2b, 76.1 percent of them purchase bottled water, and their average expense is 6.7 thousand kyat. About 68.4 percent of the low-consuming households purchase bottled water, and their average expense is 4.6 thousand kyat. It is not surprising that wealthier households have higher ratio and its expense for purchasing bottled water.

**Table 4-2a Descriptive analysis of bottled water purchase (all sample)**

| | All | | |
|---|---|---|---|
| Type of water source as the main water source | Obs. | Ratio of purchasing bottled water (%) | Monthly Expense of bottled water (1000 kyat) |
| Total | 620 | 72.1 | 5.2 |
| Private well (Own) | 524 | 75.8 | 6.0 |
| Neighbor's well | 67 | 50.7 | 3.4 |
| Neighbor's tap (Piped water/ Stand pipe) | 16 | 56.3 | 4.0 |
| Connection with MCDC overhead tank(Own) | 3 | 33.3 | 2.3 |
| Public tap (Piped water/ Stand pipe) | 1 | 0.0 | 0.0 |
| Public well | 5 | 40.0 | 1.4 |
| Water bought from water seller | 4 | 100.0 | 3.9 |

Note: Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.
The table is compiled by the author.

**Table 4-2b Descriptive analysis of bottled water purchase (higher and lower consumption sample)**

| | Upper half (Higher consumption) | | | Lower half (Lower consumption) | | |
|---|---|---|---|---|---|---|
| Type of water source as the main water source | Obs. | Ratio of purchasing bottled water (%) | Monthly Expense of bottled water (1000 kyat) | Obs. | Ratio of purchasing bottled water (%) | Monthly Expense of bottled water (1000 kyat) |
| Total | 310 | 76.1 | 6.7 | 310 | 68.4 | 4.6 |
| Private well (Own) | 280 | 80.4 | 7.1 | 244 | 70.5 | 4.8 |
| Neighbor's well | 20 | 35.0 | 2.7 | 47 | 57.5 | 3.6 |
| Neighbor's tap (Piped water/ Stand pipe) | 4 | 50.0 | 4.6 | 12 | 58.3 | 3.8 |
| Connection with MCDC overhead tank(Own) | 1 | 0.0 | 0.0 | 2 | 50.0 | 3.5 |
| Public tap (Piped water/ Stand pipe) | 1 | 0.0 | 0.0 | | | |
| Public well | 3 | 33.3 | 0.8 | 2 | 50.0 | 2.1 |
| Water bought from water seller | 1 | 100.0 | 7.0 | 3 | 100.0 | 2.8 |

Note: Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.
The table is compiled by the author.

4.2.2.4 Association of perception of water quality and willingness-to-connect to piped water system

Perception of water quality on the current water source is considered to be associated with the households' willingness-to-connect to piped water system. Table 4-1a reports the perception on water quality of the main water sources. Table 4-3a shows the descriptive statistics of willingness-to-connect to the piped water system and the households' willingness-to-pay for the connection fee. For the willingness-to-pay questions, households were asked about the maximum amount (in kyat) that they would like to pay for the connection fee. There were 595 answers among the 620 households.

On the households' willingness-to-connect to piped water system, 61.1 percent of them have the willingness-to-connect to the new piped water. The average willingness-to-pay for the connection is 6.1 thousand kyat among all the households including the households who are not willing to connect. Meanwhile, households who are willing to connect to the piped water system said that they are willing to pay an average of 10.1 thousand kyat for the connection fee.

In Table 4-3b, high-consuming households show higher percentage of willingness-to-connect to the piped water system and have higher willingness-to-pay for the connection fee. Poorer households have lower will to connect to the piped water system probably because they are less likely to afford better-quality water.

**Table 4-3a Descriptive analysis of willingness-to-connect to the piped water system (All)**

| | All | | |
|---|---|---|---|
| Type of water source as the main water source | Obs. | Willingness to connect (%) | WTP on connection (1000 kyat) |
| **1) WTP including the households which do not have willingness to connect** | 595 | 61.1 | 6.1 |
| **2) WTP of the households which have willingness to connect** | | | |
| Total | 595 | 61.1 | 10.1 |
| Private well (Own) | 506 | 61.5 | 10.0 |
| Neighbor's well | 65 | 58.5 | 9.4 |
| Neighbor's tap (Piped water/ Stand pipe) | 14 | 64.3 | 12.6 |
| Connection with MCDC overhead tank(Own) | 3 | 100.0 | 10.3 |
| Public tap (Piped water/ Stand pipe) | 1 | 100.0 | 5.0 |
| Public well | 4 | 25.0 | 5.0 |
| Water bought from water seller | 2 | 100.0 | 41.5 |

Note: Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.
There are 25 households which did not answer the questions related with willingness to pay on connection with piped water system.
The table is compiled by the authour.

**Table 4-3b Descriptive analysis of willingness-to-connect to the piped water system (higher and lower consumption sample)**

| | Upper half (Higher consumption) | | | Lower half (Lower consumption) | | |
|---|---|---|---|---|---|---|
| Type of water source as the main water source | Obs. | Willingness to connect (%) | WTP on connection (1000 kyat) | Obs. | Willingness to connect (%) | WTP on connection (1000 kyat) |
| **1) WTP including the households which do not have willingness to connect** | 302 | 64.2 | 7.2 | 293 | 58.0 | 4.9 |
| **2) WTP of the households which have willingness to connect** | | | | | | |
| Total | 302 | 64.2 | 11.3 | 293 | 58.0 | 8.7 |
| Private well (Own) | 274 | 63.1 | 10.7 | 232 | 59.1 | 9.0 |
| Neighbor's well | 19 | 68.4 | 12.5 | 46 | 54.4 | 7.7 |
| Neighbor's tap (Piped water/ Stand pipe) | 4 | 100.0 | 18.3 | 10 | 50.0 | 8.0 |
| Connection with MCDC overhead tank(Own) | 1 | 100.0 | 20.0 | 2 | 100.0 | 5.5 |
| Public tap (Piped water/ Stand pipe) | 1 | 100.0 | 5.0 | | | |
| Public well | 2 | 50.0 | 5.0 | 2 | 0.0 | 0.0 |
| Water bought from water seller | 1 | 100.0 | 75.0 | 1 | 100.0 | 8.0 |

Note: Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.
There are 25 households which did not answer the questions related with willingness to pay on connection with
The table is compiled by the authour.

4.2.3 Factors affecting the demand for improved water

The previous descriptive analyses briefly illustrate the situation of water use among the sampled households and suggest that household wealth and their perception on water quality can influence the demand for bottled water and water from piped water systems. Yet, other demand-side factors may affect the demand for improved water. Nauges and Whittington (2009) reviewed the existing water-related literatures. Regarding household size, larger households are found to have greater water volume in total, but their consumption decreases with the number of members because of the scale effects. Briand et al. (2009) showed that households with connections to piped water have larger families than those without connections, and household's wealth increases the probability to connect with tap water. Hu, et al. (2011) found that age and gender are associated with bottled water use. The respondent who was one year older was about two percent less likely to use bottled water as primary source of drinking water. Females also have higher probability to use bottled water. In terms of educational level, Mangyo (2008) showed that access to in-yard water sources improved child health only when mothers were well-educated. Water and sanitation behaviors may be related with education level. Francisco (2014) also found that the total number of schooling years of the household head and the presence of children ages 0 - 5 years have positive influence on using bottled water or purified water.

The convenience of water source may also be associated with water use. If the source of water is within the households' premises, they may have more will to obtain water. Devoto et al. (2012) found that households who shifted from sourcing water from public tap to own connection in yard increased their free time and welfare such as happiness and social inclusion, even though water quality itself were the same. Further, there is a possibility that households may invest more if the site is their own property. There are many literatures on association of land tenure and investment. Besley (1995) presented the conceptual framework of property rights and investment incentives and showed using the data of Ghana that better land rights facilitate investment. Fenske (2009) reviewed the literatures on the relationship between land property rights and agricultural investments in West Africa. He found statistically significant results on the linkage between tenure and investment in fallow and tree planting. Field (2005) showed that strengthening property rights in urban slums in Peru had a significant effect on residential investment such as the rate of housing renovation. The case suggests that property rights enhance the investment in urban area as well. In terms of perception on water quality, Francisco (2014) reported that households, who consider the water quality of their main water source as safe to drink without treatment, were less likely to purchase bottled or purified water regularly.

The variables listed in Table 4-4 are the factors that are potentially associated with water use and were selected as independent variables for further analysis. Asset level of households included to examine if households face liquidity constrains for choosing water sources and using water. Asset measure is created as a composite index by principal component analysis based on the household's ownership of various types of assets including automobiles, motorbikes, TV sets, computers, gas/electric cooker, refrigerators, air conditioners, electricity generator, pumping machine, overhead tank, etc. Even though a house is considered as one of the largest assets, ownership of house is separately used as an independent variable because it may be the important factor for the decision making of owning the private well or connection of the piped water[13]. There is a concern of the correlation between the ownership of house and asset measure, and the coefficients of these variables need to be interpreted with caution.

By employing multivariate regression models, the analyses in the following section try to disentangle seemingly very complicated associations among various factors that affect the demand for bottled water and willingness-to-pay for the new installation of the

[13] Correlation between independent variables is presented in Appendix 4-5. Correlation coefficient between asset measure and ownership of house is 0.31.

piped water system.

**Table 4-4 Summary statistics of covariates in the multivariate regression analysis**

| | Mean | S.D. | Min | Max |
|---|---|---|---|---|
| *Characteristics of household member* | | | | |
| Maximum schooling year of male household member (Year) | 8.3 | (4.6) | 0 | 16 |
| Maximum schooling year of female household member (Year) | 9.2 | (4.5) | 0 | 16 |
| *Characteristics of household* | | | | |
| Number of Household Members | 4.6 | (1.8) | 1 | 14 |
| Female household head (Female head = 1) | 0.23 | (0.4) | 0 | 1 |
| Household with Under 5 year children (=1) | 0.29 | (0.5) | 0 | 1 |
| Asset measure | 1.73 | (0.6) | 0 | 3.8 |
| Own house (=1) | 0.81 | (0.4) | 0 | 1 |
| Own the private well (=1) | 0.85 | (0.4) | 0 | 1 |
| Perception of quality of their water (Clear =1) | 0.77 | (0.4) | 0 | 1 |
| Observations | 620 | | | |

Note: The table is compiled by the author.

## 4.3 Ownership of private well

### 4.3.1 Empirical model

Using the cross-sectional data collected in the survey, the ownership of a private well is examined using the Probit model. The Probit model is a statistical probability model with binary dependent variable that takes on the values of zero or one. The Probit analysis shows whether the independent variables such as household characteristics increase or decrease the probability of owning a private well. Ownership of a private well is taken as 1, while non-ownership as 0. The independent variables listed in Table 4-4 (except ownership of the private well and perception on the quality of water) are used for the following analyses. The same series of estimations were conducted in the samples divided into high-consuming and low-consuming households.

4.3.2 Estimation results

Table 4-5 showed the estimation results of examining the factors associated with the ownership of private well. Asset measure and ownership of houses are highly correlated with ownership of private well in all the three estimations conducted (i.e., using whole, higher-consumption, and lower-consumption samples). Better economic condition is also highly correlated with the decision of owning a private well. Wealthier households afford to pay the investment cost of the private wells. Households with owned house have the intention to own private wells since the private well will be their own property.

**Table 4-5 Analysis on ownership of private well**

| Outcome | (1) | (2) | (3) |
|---|---|---|---|
| Ownership of Private well (=1) | ALL | Upper half (Higher-consumption) | Lower half (Lower-consumption) |
| Estimation model | OLS | OLS | OLS |
| Explanatory variables | | | |
| Maximum schooling year of male member (Year) | -0.001 | -0.023* | 0.010 |
| | (0.004) | (0.012) | (0.008) |
| Maximum schooling year of female member (Year) | 0.004 | 0.014 | 0.000 |
| | (0.004) | (0.013) | (0.008) |
| Number of Household members | 0.006 | -0.001 | 0.003 |
| | (0.010) | (0.031) | (0.022) |
| Household of female head (=1) | -0.008 | -0.061 | 0.042 |
| | (0.035) | (0.082) | (0.080) |
| Household with Under 5 year children(=1) | -0.035 | -0.124 | -0.096 |
| | (0.034) | (0.094) | (0.059) |
| Asset measure | 0.299*** | 0.276*** | 0.479*** |
| | (0.027) | (0.072) | (0.053) |
| Own house (=1) | 0.162*** | 0.281** | 0.206*** |
| | (0.037) | (0.136) | (0.054) |
| Observations | 620 | 310 | 310 |

Standard errors are shown in parentheses.
*t*-test or Fisher's exact test results are shown; * Significant at 10%, ** Significant at 5%, *** Significant at 1%.

### 4.4 Regular purchase of bottled water

#### 4.4.1 Empirical model

Using the cross-sectional data collected in the survey, the choice of purchasing bottled water is examined by employing the Probit analysis. On the other hand, the log of the monthly household expenditure on bottled water is analyzed using Heckman's sample selection model because some households did not consume bottled water and their expenditure data were censored at zero kyat. In addition, the expenditure on bottled water is analyzed using the Tobit model to confirm the robustness of the estimation results by the sample selection model.

By using these models, two types of estimations were conducted: 1) one with perception on water quality regardless of the type of water source as a regressor and 2) one with private well ownership indicator and its interaction term with water quality perception as regressors. The independent variables listed in Table 4-4 were used for the following analyses. The same series of estimations were conducted on the samples divided into high-consuming and low-consuming households.

#### 4.4.2 Estimation results

As shown in Table 4-2a, 72.1 percent of sampled households purchased bottled water. About 76.1 percent of high-consuming households purchased bottled water, while 68.4 percent purchased bottled water among the low-consuming households (Table 4-2b). Tables 4-6a, 4-6b, and 4-6c show the results of the analyses on the choice of purchasing bottled water using the Probit model and on the log of monthly expenditures of bottled water using Heckman's model. In total, there were twelve estimation results for the whole sample, higher-consumption sample, and lower-consumption sample.

The asset measure, which is a stock variable of household's economic condition, shows a positive association with the decision to purchase bottled water. A unit increase in asset measure increases the probability of purchase by 20.8 percentage points in model 1 and by 20.2 percentage points in model 3. In terms of the monthly bottled water consumption, a unit increase in asset measure increases the bottled water expense by 34.2 percentage points in model 2 and by 31.5 percentage points in model 4. In the high-consuming and low-consuming households, similar estimation results are found. Increase in the probability of purchasing bottled water is associated with a unit increase in asset measure—confirming that asset measure has statistically significant positive association on the households' purchase decision of bottled water. In addition, wealthier households can afford to purchase and consume more bottled water. This suggests that bottled water is not an equitable solution as means of safe water access for all.

Meanwhile, an increase in household size is associated with a decrease in the probability of purchase by 2.2 percentage points in model 1 and 2.3 percentage points in model 3. It is also associated with monthly bottled water expenditure increase by six percentage points in models 2 and 4.

Perception on water quality of main source is not found to be statistically significant in influencing the households' purchase decision of bottled water (Model 1). However, households who perceived the water quality of their main source as clear spent less on bottled water by 17.2 percentage points in model 2. Further, model 3 shows that households with own private wells and who perceived the water quality of their main source as clear are less likely to purchase bottled water by 8.5 percentage points. This is supported by model 4 which shows that households with own private wells and perceived the water quality of their main source as clear spent less on bottled water by 17.4 percentage points. And those with bad perception of water quality of their private well water spend 27.3 percent more on the bottled water.

As for the high-consuming households, model 7 reports that households with own private wells but perceived the water quality as bad have probability to purchase bottled water by 21.1 percentage points. Households with limited access to safe water seem to be obligated to purchase bottled water, i.e., obliged consumption.

The education of female household members (aged 18 years and above) in the whole sample has statistically significant positive association on the take-up of bottled water. One additional year on female schooling increases the probability of purchasing bottled water by 0.8 percentage points in models 1 and 3. Education of male household members in lower-consumption sample also has statistically significant positive association on the take-up of bottled water. One additional year on male schooling increases the probability of purchasing bottled water by 1.3 percentage points in model 9 and 1.4 percentage points in model 11. If household members have better education, households may have more knowledge related to hygiene or health issues and have more capacity to understand the importance of clean and safe water.

The estimation results of examining the monthly household expenditure on bottled water using the Tobit model are presented in Appendix 4-2a and 4-2b. An increase of one unit in wealth measure is associated with 2.75 thousand kyat increase on the expenses in model 1 and 2.45 thousand kyat in model 2. If water quality of their main source is perceived as clear, expenses are reduced by 1.08 thousand kyat in model 1. The positive perception on the water quality from private well also shows a decrease in expenditure by 1.2 thousand kyat, while the negative perception on water quality from private well increases the expenditure by 2.46 thousand kyat. Households who do not trust the cleanliness of water from their private wells are forced to consume more bottled water. Similar results are confirmed using higher-consumption and lower-consumption samples. The asset measure is clearly correlated with bottled water consumption in both samples. It was found that the estimation results of the Tobit model show similar results on the associated factors reported by the results of the Heckman sample selection model.

## Table 4-6a Estimation results of examining the factors associated with the purchase of bottled water and its consumption (All)

| | All | | | |
|---|---|---|---|---|
| | Dependent Variable | | Dependent Variable | |
| | Purchasing bottled water (0/1) | Log of monthly bottled water consumption (kyat) | Purchasing bottled water (0/1) | Log of monthly bottled water consumption (kyat) |
| | Probit | Heckman | Probit | Heckman |
| Independent Variables | Model 1 | Model 2 | Model 3 | Model 4 |
| Maximum schooling year of male member (Year) | 0.006 | -0.004 | 0.006 | -0.003 |
| | (0.004) | (0.009) | (0.004) | (0.009) |
| Maximum schooling year of female member (Year) | 0.008* | 0.007 | 0.008* | 0.007 |
| | (0.005) | (0.010) | (0.005) | (0.010) |
| Number of Household members | -0.022** | 0.060** | -0.023** | 0.058** |
| | (0.011) | (0.026) | (0.011) | (0.026) |
| Household of female head (=1) | -0.030 | -0.047 | -0.031 | -0.054 |
| | (0.046) | (0.084) | (0.046) | (0.085) |
| Household with Under 5 year children(=1) | 0.063 | 0.023 | 0.064 | 0.028 |
| | (0.041) | (0.089) | (0.041) | (0.090) |
| Asset measure | 0.208*** | 0.342** | 0.202*** | 0.315** |
| | (0.030) | (0.135) | (0.034) | (0.132) |
| Own house (=1) | -0.053 | -0.069 | -0.056 | -0.093 |
| | (0.048) | (0.098) | (0.049) | (0.104) |
| Perception of quality of their water (Clear =1) | -0.062 | -0.172** | | |
| | (0.044) | (0.084) | | |
| Own the private well (=1) | | | 0.092 | 0.273* |
| | | | (0.074) | (0.149) |
| The private well*Clear (1*1) | | | -0.085* | -0.174* |
| | | | (0.052) | (0.092) |
| Block fixed effect | included | included | included | included |
| Inverse Mills Ratio | | 0.712 | | 0.705 |
| | | (0.432) | | (0.438) |
| R-squared | | 0.231 | | 0.23 |
| Observations | 620 | 620 | 620 | 620 |

Note: Marginal effects evaluated at mean values are reported.
Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1500 kyat) as of May 2019.

## Table 4-6b Estimation results of examining the factors associated with the purchase of bottled water and its consumption (higher consumption sample)

| | Upper half (Higher-consumption) | | | |
|---|---|---|---|---|
| | Dependent Variable | | Dependent Variable | |
| | Purchasing bottled water (0/1) | Log of monthly bottled water consumption (kyat) | Purchasing bottled water (0/1) | Log of monthly bottled water consumption (kyat) |
| | Probit | Heckman | Probit | Heckman |
| Independent Variables | Model 5 | Model 6 | Model 7 | Model 8 |
| Maximum schooling year of male member (Year) | -0.000 | -0.007 | 0.001 | -0.006 |
| | (0.009) | (0.015) | (0.009) | (0.015) |
| Maximum schooling year of female member (Year) | 0.009 | -0.009 | 0.008 | -0.010 |
| | (0.010) | (0.017) | (0.010) | (0.017) |
| Number of Household members | -0.031 | 0.040 | -0.033 | 0.037 |
| | (0.021) | (0.048) | (0.020) | (0.052) |
| Household of female head (=1) | -0.104 | 0.193 | -0.104 | 0.184 |
| | (0.080) | (0.179) | (0.079) | (0.184) |
| Household with Under 5 year children(=1) | 0.122 | -0.011 | 0.137 | 0.016 |
| | (0.088) | (0.176) | (0.089) | (0.197) |
| Asset measure | 0.279*** | -0.071 | 0.253*** | -0.089 |
| | (0.072) | (0.252) | (0.070) | (0.246) |
| Own house (=1) | -0.020 | -0.197 | -0.050 | -0.239 |
| | (0.095) | (0.169) | (0.092) | (0.177) |
| Perception of quality of their water (Clear =1) | -0.039 | -0.127 | | |
| | (0.083) | (0.144) | | |
| Own the private well (=1) | | | 0.211* | 0.343 |
| | | | (0.126) | (0.425) |
| The private well*Clear (1*1) | | | -0.075 | -0.103 |
| | | | (0.088) | (0.158) |
| Block fixed effect | included | included | included | included |
| Inverse Mills Ratio | | -0.180 | | -0.174 |
| | | (0.600) | | (0.656) |
| R-squared | | 0.409 | | 0.419 |
| Observations | 310 | 310 | 310 | 310 |

Note: Marginal effects evaluated at mean values are reported.
Standard errors are given in parentheses with stars indicating the following: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1500 kyat) as of May 2019.

**Table 4-6c Estimation results of examining the factors associated with the purchase of bottled water and its consumption (lower consumption sample)**

| | Lower half (Lower-consumption) | | | |
|---|---|---|---|---|
| | Dependent Variable | | Dependent Variable | |
| | Purchasing bottled water (0/1) | Log of monthly bottled water consumption (kyat) | Purchasing bottled water (0/1) | Log of monthly bottled water consumption (kyat) |
| | Probit | Heckman | Probit | Heckman |
| Independent Variables | Model 9 | Model 10 | Model 11 | Model 12 |
| Maximum schooling year of male member (Year) | 0.013* | -0.002 | 0.014** | -0.005 |
| | (0.007) | (0.020) | (0.007) | (0.021) |
| Maximum schooling year of female member (Year) | 0.009 | -0.005 | 0.008 | -0.007 |
| | (0.008) | (0.017) | (0.008) | (0.016) |
| Number of Household members | -0.013 | 0.071 | -0.013 | 0.076* |
| | (0.018) | (0.044) | (0.019) | (0.044) |
| Household of female head (=1) | 0.056 | -0.040 | 0.057 | -0.056 |
| | (0.080) | (0.160) | (0.078) | (0.162) |
| Household with Under 5 year children(=1) | 0.029 | -0.050 | 0.027 | -0.059 |
| | (0.070) | (0.149) | (0.071) | (0.148) |
| Asset measure | 0.195*** | 0.198 | 0.232*** | 0.147 |
| | (0.057) | (0.244) | (0.061) | (0.273) |
| Own house (=1) | -0.181** | -0.039 | -0.169** | -0.010 |
| | (0.073) | (0.242) | (0.078) | (0.234) |
| Perception of quality of their water (Clear =1) | -0.129 | 0.030 | | |
| | (0.093) | (0.190) | | |
| Own the private well (=1) | | | 0.028 | -0.040 |
| | | | (0.126) | (0.206) |
| The private well*Clear (1*1) | | | -0.131 | 0.072 |
| | | | (0.108) | (0.197) |
| Block fixed effect | included | included | included | included |
| Inverse Mills Ratio | | 0.530 | | 0.061 |
| | | (0.726) | | (0.746) |
| R-squared | | 0.389 | | 0.389 |
| Observations | 310 | 310 | 310 | 310 |

Note: Marginal effects evaluated at mean values are reported.
Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1500 kyat) as of May 2019.

## 4.5 Willingness-to-connect to piped water system

### 4.5.1 Empirical model

Households are normally requested to pay the connection fee, which approximately costs 100 thousand to 150 thousand kyat depending on the length of the branch pipe from the main pipe to the yard. From the request of the households, MCDC connects the piped water to the household's water meter with necessary construction and material costs. The connection fee is expensive for households and can be the financial barrier for piped water use.

Table 4-3a presents the descriptive statistics of willingness-to-pay for connection. About 61.8 percent of households said that they are willing to connect to the piped water system and their willingness-to-pay for the connection fee is 6.1 thousand kyat. There are differences between high-consuming and low-consuming households in terms of their willingness-to-connect and willingness-to-pay for connection fee. Among high-consuming households, their willingness-to-connect is higher than that of low-consuming households. Around 64.2 percent of high-consuming households have willingness-to-connect while 58.0 percent of low-consuming households have willingness-to-connect. In terms of their willingness-to-pay for connection fee, high-consuming households are willing-to-pay 7.2 thousand kyat for the connection fee while low-consuming households are only willing-to-pay 4.9 thousand kyat on the average. Among households who are willing to connect, their average willingness-to-pay for the connection fee is far from the actual cost of connection. It can be inferred from here that much less households would connect with the piped water system without financial support. In the Project, the connection fee is subsidized by the assistance of the Japanese government. The households are only requested to pay the registration fee, which costs 100 kyat.

In order to analyze the factors associated with the households' willingness to connect to a piped water system and their willingness-to-pay for the connection fee, multivariate regressions were employed. The same empirical models in the previous section, the Probit model and Heckman's sample selection model, were used.

There are two types of estimations: 1) one with perception of water quality as a regressor and 2) one with private well ownership indicator and its interaction with water quality perception as regressors. Across the three samples used, four estimations were conducted: two analyses on the households' willingness-to-connect using the Probit model and another two on the households' willingness-to-pay for connection fee using Heckman's sample selection model. The independent variables listed in Table 4-4 were used in the analyses. In addition, willingness-to-pay for the connection fee was examined using the Tobit model in order to confirm the robustness of the estimation results of the Heckman's sample selection model.

4.5.2 Estimation results

The estimation results of the willingness to connect to a new piped water system and their willingness-to-pay for the connection fee are shown in Tables 4-7a (all sample), Table 4-7b (higher-consumption sample), and Table 4-7c (lower-consumption sample). From the results of all sample, ownership of house shows statistically significant positive association on the increase of households' willingness to connect by 16.9 percentage points in model 1 and by 19.8 percentage points in model 3. High-consuming households who own their houses are willing to spend higher connection fee by 17.3 percentage points in model 7. Similarly, low-consuming households who own their houses also show higher percentage of willingness-to-connect, 20.1 percentage points in model 9 and 25.8 percentage points in model 11. These results suggest that households are willing to invest more on their own property. The initial investment is required for the connection of piped water. However, households found it worthy to invest since they can continuously use the piped water because they own the house.

From the estimation results of the lower-consumption sample, households who perceived the water quality from their main source as good have lower willingness-to-connect by 17.8 percentage points in model 9. Model 11 further shows that households with own private wells and who perceived the water quality from their source as good have lower willingness-to-connect by 19.8 percentage points. If households consider their water quality as good enough, they have less intention to connect to the piped water system. Asset measure has statistically significant association with higher willingness-to-connect to the piped water system by 8.1 percentage points in model 3. However, in the rest of the estimations, asset measure is not found to be correlated with their willingness-to-connect (although asset measure is clearly correlated with bottled water use and expense as shown in Table 4-6a).

In Appendix 4-3a and 4-3b, the results of the willingness-to-pay for the connection fee using the Tobit model are presented. In model 2 for all sample, asset measure and ownership of the house are correlated with households' willingness-to-pay for the connection. An increase of one unit in asset measure is correlated to 4.68 thousand kyat increase on the households' willingness-to-pay for the connection fee. Ownership of the house also increases willingness-to-pay by 13.99 thousand kyat. Among high-consuming households, the ownership of house increases largely the willingness-to-pay for the connection fee, but the asset measure is not found to be correlated to their willingness-to-pay. Meanwhile, among low-consuming households, an increase of one unit in asset measure is correlated to 3.44 thousand kyat increase on their willingness-to-pay for the connection fee. Ownership of the house is also positively correlated to their willingness-to-pay by 4.8 thousand kyat. It can be said that among the lower-consumption sample, the economic situation of households is highly related to their willingness-to-pay for the connection fee.

**Table 4-7a Willingness-to-connect with piped water system and Willingness-to-pay the connection fee (All sample)**

| | All | | | |
|---|---|---|---|---|
| | Dependent Variable | | | |
| | Willingness to connect (0/1) | Log of WTP on connection (1000kyat) | Willingness to connect (0/1) | Log of WTP on connection (1000kyat) |
| | Probit | Heckman | Probit | Heckman |
| Independent Variables | Model 1 | Model 2 | Model 3 | Model 4 |
| Maximum schooling year of male member | -0.003 | 0.009 | -0.004 | 0.009 |
| (Year) | (0.004) | (0.011) | (0.004) | (0.011) |
| Maximum schooling year of female member | 0.006 | 0.007 | 0.006 | 0.007 |
| (Year) | (0.005) | (0.014) | (0.005) | (0.015) |
| Number of Household members | 0.002 | 0.017 | 0.002 | 0.019 |
| | (0.014) | (0.025) | (0.014) | (0.025) |
| Household of female head (=1) | -0.045 | -0.084 | -0.044 | -0.079 |
| | (0.054) | (0.125) | (0.054) | (0.122) |
| Household with Under 5 year children(=1) | 0.023 | 0.055 | 0.019 | 0.053 |
| | (0.044) | (0.102) | (0.044) | (0.098) |
| Asset measure | 0.054 | -0.018 | 0.081* | 0.022 |
| | (0.039) | (0.115) | (0.042) | (0.152) |
| Own house (=1) | 0.169*** | 0.294 | 0.198*** | 0.310 |
| | (0.052) | (0.322) | (0.054) | (0.358) |
| Perception of quality of their water (Clear =1) | -0.055 | 0.055 | | |
| | (0.051) | (0.141) | | |
| Own the private well (=1) | | | -0.072 | -0.258 |
| | | | (0.068) | (0.189) |
| The private well*Clear (1*1) | | | -0.067 | 0.080 |
| | | | (0.055) | (0.156) |
| Block fixed effect | included | included | included | included |
| Inverse Mills Ratio | | -0.094 | | -0.147 |
| | | (1.138) | | (1.088) |
| R-squared | | 0.293 | | 0.301 |
| Observations | 595 | 595 | 595 | 595 |

*Note:* Marginal effects evaluated at mean values are reported.
25 households did not answer willingness-to-pay questions.
Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1500 kyat) as of May 2019.

**Table 4-7b Willingness-to-connect with piped water system and willingness-to-pay the connection fee (higher consumption sample)**

| | Upper half (Higher-consumption) | | | |
|---|---|---|---|---|
| | Dependent Variable | | | |
| | Willingness to connect (0/1) | Log of WTP on connection (1000kyat) | Willingness to connect (0/1) | Log of WTP on connection (1000kyat) |
| | Probit | Heckman | Probit | Heckman |
| Independent Variables | Model 5 | Model 6 | Model 7 | Model 8 |
| Maximum schooling year of male member | 0.014* | -0.037 | 0.013 | -0.038 |
| (Year) | (0.008) | (0.073) | (0.009) | (0.066) |
| Maximum schooling year of female member | -0.000 | 0.001 | 0.001 | 0.005 |
| (Year) | (0.010) | (0.021) | (0.010) | (0.020) |
| Number of Household members | -0.007 | 0.004 | -0.006 | -0.009 |
| | (0.022) | (0.056) | (0.022) | (0.052) |
| Household of female head (=1) | -0.025 | 0.319 | -0.030 | 0.283 |
| | (0.106) | (0.229) | (0.106) | (0.243) |
| Household with Under 5 year children(=1) | 0.044 | 0.206 | 0.040 | 0.165 |
| | (0.081) | (0.256) | (0.080) | (0.232) |
| Asset measure | 0.048 | -0.228 | 0.061 | -0.178 |
| | (0.070) | (0.241) | (0.073) | (0.294) |
| Own house (=1) | 0.163 | 0.093 | 0.173* | 0.076 |
| | (0.101) | (0.920) | (0.100) | (0.923) |
| Perception of quality of their water (Clear =1) | -0.010 | 0.117 | | |
| | (0.075) | (0.162) | | |
| Own the private well (=1) | | | -0.076 | -0.334 |
| | | | (0.179) | (0.468) |
| The private well*Clear (1*1) | | | -0.024 | 0.083 |
| | | | (0.080) | (0.191) |
| Block fixed effect | included | included | included | included |
| Inverse Mills Ratio | | -2.040 | | -1.876 |
| | | (3.175) | | (3.048) |
| R-squared | | 0.478 | | 0.500 |
| Observations | 300 | 300 | 300 | 300 |

*Note:* Marginal effects evaluated at mean values are reported.
25 households did not answer willingness-to-pay questions.
Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1500 kyat) as of May 2019.

**Table 4-7c Willingness-to-connect with piped water system and Willingness-to-pay the connection fee (lower consumption sample)**

| | Lower half (Lower-consumption) | | | |
|---|---|---|---|---|
| | Dependent Variable | | | |
| | Willingness to connect (0/1) | Log of WTP on connection (1000kyat) | Willingness to connect (0/1) | Log of WTP on connection (1000kyat) |
| | Probit | Heckman | Probit | Heckman |
| Independent Variables | Model 9 | Model 10 | Model 11 | Model 12 |
| Maximum schooling year of male member | -0.016** | 0.014 | -0.016** | 0.021 |
| (Year) | (0.007) | (0.033) | (0.007) | (0.029) |
| Maximum schooling year of female member | 0.009 | -0.000 | 0.008 | -0.002 |
| (Year) | (0.008) | (0.023) | (0.008) | (0.021) |
| Number of Household members | 0.025 | -0.009 | 0.023 | -0.014 |
| | (0.023) | (0.053) | (0.023) | (0.050) |
| Household of female head (=1) | -0.040 | -0.364* | -0.037 | -0.334* |
| | (0.076) | (0.182) | (0.077) | (0.182) |
| Household with Under 5 year children(=1) | -0.012 | -0.208 | -0.024 | -0.196 |
| | (0.086) | (0.165) | (0.086) | (0.168) |
| Asset measure | 0.076 | -0.091 | 0.129 | -0.240 |
| | (0.068) | (0.209) | (0.080) | (0.250) |
| Own house (=1) | 0.201** | -0.292 | 0.258*** | -0.461 |
| | (0.085) | (0.425) | (0.094) | (0.452) |
| Perception of quality of their water (Clear =1) | -0.178** | 0.203 | | |
| | (0.082) | (0.360) | | |
| Own the private well (=1) | | | 0.000 | 0.078 |
| | | | (0.109) | (0.235) |
| The private well*Clear (1*1) | | | -0.198** | 0.331 |
| | | | (0.090) | (0.348) |
| Block fixed effect | included | included | included | included |
| Inverse Mills Ratio | | -0.669 | | -0.867 |
| | | (1.192) | | (1.017) |
| R-squared | | 0.530 | | 0.539 |
| Observations | 321 | 321 | 321 | 321 |

*Note:* Marginal effects evaluated at mean values are reported.
25 households did not answer willingness-to-pay questions.
Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1500 kyat) as of May 2019.

## 4.6 Willingness-to-pay for the regular use of piped water system

### 4.6.1 Empirical model

To use the piped water, it is necessary to pay the connection fee, maintenance fee and the water bill. After connecting the households to the piped water system, MCDC conducts meter reading every two months and hands the invoice of water bill to the customer in the next meter reading. MCDC charges piped water tariff of 200 kyat per 1,000 liters, as the unit cost of the piped water for non-commercial water users. Based on the bi-monthly meter readings, water bill is calculated and charged. Table 4-8a and 4-8b present the descriptive statistics of the households' willingness to use the piped water regularly and their willingness-to-pay the water bill per 1,000 liters. The average willingness-to-pay of households for piped water is 210 kyat per unit using all samples (Table 4-8a). This is approximately the unit price of the piped water charged by MCDC. The average willingness-to-pay per unit of piped water of households who are willing to use it regularly is 427 kyat, which is twice the average willingness-to-pay of all the sampled households. These households express higher demand for using piped water even if the water price is higher than current unit price charged by MCDC.

MCDC charges 100 kyat as the maintenance fee in every bill. The maintenance fee is a compulsory expense for piped water user to use MCDC's water meter. Though it is named as maintenance fee, it is not possible for MCDC to cover the necessary cost for repairing the deteriorated water supply facility in the City with such a low maintenance fee. Households' average willingness-to-pay for the maintenance fee is 502 kyat, which is much higher than the maintenance fee charged by the City (Appendix 4-4a).

In order to analyze the factors associated with the households' willingness-to-use piped water regularly and their willingness-to-pay the water bill per 1,000 liters, the same empirical models as in the previous section, the Probit model and Heckman's sample selection model, were employed in the analyses. Two types of estimations were conducted: 1) one with perception of water quality as a regressor and 2) one with private well ownership indicator and its interaction with water quality perception as regressors. There were four estimation results: two analyses on the willingness-to-use piped water regularly using the Probit model and another two on the willingness-to-pay the water bill per 1,000 liters using Heckman's sample selection model. These were the same models used in the previous section. The independent variables listed in Table 4-4 were used in the analyses.

In addition, willingness-to-pay the water bill per 1,000 liters and maintenance fee were analyzed using the Tobit model to confirm the robustness of the results of the sample selection model (Appendix 4-7a, Appendix 4-7b, and Appendix 4-7c).

**Table 4-8a Descriptive statistics of willingness-to-use piped water regularly and Willingness-to-pay water bill per 1,000 liters (all)**

| | All | | |
|---|---|---|---|
| Type of water source as the main water source | Obs. | Willingness to regular use (0/1) | WTP on regular use (kyat) |
| **1) WTP including the households which do not have willingness to use** | 595 | 61.2 | 210 |
| **2) WTP of the households which have willingness to use** | | | |
| Total | 595 | 61.2 | 427 |
| Private well (Own) | 506 | 61.3 | 377 |
| Neighbor's well | 65 | 58.5 | 346 |
| Neighbor's tap (Piped water/ Stand pipe) | 14 | 64.3 | 331 |
| Connection with MCDC overhead tank(Own) | 3 | 100.0 | 267 |
| Public tap (Piped water/ Stand pipe) | 1 | 100.0 | 0 |
| Public well | 4 | 25.0 | 200 |
| Water bought from water seller | 2 | 100.0 | 150 |

Note: Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.

There are 25 households which did not answer the questions related with willingness-to-pay on connection with piped water system.

The table is compiled by the authour.

**Table 4-8b Descriptive statistics of willingness-to-use piped water regularly and Willingness-to-pay water bill per 1,000 liters (higher and lower consumption sample)**

| | Upper half (Higher consumption) | | | Lower half (Lower consumption) | | |
|---|---|---|---|---|---|---|
| Type of water source as the main water source | Obs. | Willingness to regular use (0/1) | WTP on regular use (kyat) | Obs. | Willingness to regular use (0/1) | WTP on regular use (kyat) |
| **1) WTP including the households which do not have willingness to use** | 302 | 66.7 | 239 | 293 | 55.5 | 180 |
| **2) WTP of the households which have willingness to use** | | | | | | |
| Total | 302 | 66.7 | 399 | 293 | 55.5 | 338 |
| Private well (Own) | 274 | 62.8 | 414 | 232 | 59.5 | 331 |
| Neighbor's well | 19 | 68.4 | 244 | 46 | 54.4 | 401 |
| Neighbor's tap (Piped water/ Stand pipe) | 4 | 100.0 | 367 | 10 | 50.0 | 310 |
| Connection with MCDC overhead tank(Own) | 1 | 100.0 | 400 | 2 | 100.0 | 200 |
| Public tap (Piped water/ Stand pipe) | 1 | 100.0 | 0 | | | |
| Public well | 2 | 50.0 | 200 | 2 | 0.0 | 0 |
| Water bought from water seller | 1 | 100.0 | 100 | 1 | 100.0 | 200 |

Note: Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.
There are 25 households which did not answer the questions related with willingness to pay on connection with piped water system.
The table is compiled by the authour.

### 4.6.2 Estimation results

Tables 4-9a, 4-9b, and 4-9c present the estimation results of the households' willingness to use piped water regularly and willingness-to-pay the water bill per 1,000 liters, respectively in all sample, higher-consumption sample, and lower-consumption sample. The estimation results are very similar to their willingness-to-connect. From the results of full sample, ownership of house shows statistically significant association on the increase on their willingness-to-use piped water regularly by 17.0 percentage points in model 1 and by 19.8 percentage points in model 3. Further, both the high-consuming and low-consuming households with house ownership show higher percentage of willingness-to-use piped water regularly, 17.3 percentage points in model 7 for the former and 20.1 percentage points in model 9 and 25.8 percentage points in model 11 for the latter. These results suggest that households are willing to invest more on their own property. Households found it worthy to invest since they can continuously use the piped water since they have the ownership of the house.

From the estimation results of the lower-consumption sample, households who perceived the quality of water from their main source as good have lower willingness-to-use the piped water by 17.8 percentage points in model 9. Model 11 also shows that households with own private wells and who perceived the quality of water from their main source as good have lower willingness-to-use the piped water by 19.8 percentage points. If households consider the water quality from their main source as good enough, they have less intention to use the piped water.

Education of male household members aged 18 years and above show different directions of association with households' willingness-to-use piped water regularly, between higher-consumption and lower-consumption samples. Additional year in schooling is associated with 1.4 percentage points increase on the willingness-to-use piped water regularly among higher-consumption sample (model 5), while it is associated with 1.6 percentage points decrease on the willingness-to-use piped water regularly among lower-consumption sample (as shown in models 9 and 11). Asset measure increases the willingness-to-use the piped water system by 8.0 percentage points in model 3. Wealthier households are more willing to use it.

In Appendix 4-6a and 4-6b, the results of the willingness-to-pay for the regular use of piped water per unit using the Tobit model are presented. In models 1 and 2 for all sample, asset measure is found to be positively correlated with willingness-to-pay for the regular use of piped water. A unit increase in asset measure increases the households' willingness-to-pay by 161 kyat and 187 kyat in models 1 and 2, respectively.

Appendix 4-7a, 4-7b, and 4-7c show the estimation results of the households' willingness-to-maintain the piped water system and their willingness-to-pay on the maintenance fee, in all sample, higher-consumption sample, and lower-consumption sample. The estimation results are similar with the results on the households' willingness-to-use the piped water regularly. From the results of all sample, ownership of house shows statistically significant positive association on the willingness-to-maintain piped water system by 16.9 percentage points in model 1 and by 19.8 percentage points in model 3. Both the high-consuming and low-consuming households with house ownership show higher percentage of willingness-to-maintain piped water system, 17.3 percentage points in model 7 for the former while 20.1 percentage points in model 9 and 25.8 percentage points in model 11 for the latter. These results suggest that households are willing to invest more on their own property. Households found it worthy to invest since they can continuously use the piped water because they own the house.

From the estimation results of the lower-consumption sample, households who perceived the quality of water from their main source as good have lower willingness-to-use the piped water by 17.8 percentage points in model 9. Model 11 further shows that households with own private wells and who perceived the quality of water from their main source as good have lower willingness-to-use the piped water by 19.8 percentage points. If households perceived that water quality from their main source is good enough, they have less intention to use the piped water. Asset measure has statistically significant association with higher willingness-to-use the piped water system by 8.1 percentage points in model 3 (Appendix 4-7a). Wealthier households have more intention to use it.

In Appendix 4-8a and 4-8b, the results on the willingness-to-pay for maintenance fee of piped water using the Tobit model are presented. In models 1 and 2 for all sample, ownership of house shows positive correlation to households' willingness-to-pay for regular use. A unit increase in asset measure increases willingness-to-pay by 344 kyat. Among high-consuming households, those with house ownership have higher willingness-to-pay for maintenance fee by 505 kyat (model 4). Meanwhile, among the low-consuming households, a unit increase in asset measure increases their willingness-to-pay for the maintenance fee by 537 kyat. Among the lower-consumption sample, the economic situation of the households is related to their willingness-to-pay for the maintenance fee.

**Table 4-9a Willingness-to-use piped water regularly and Willingness to pay the water bill per 1,000 liters (All sample)**

| | All | | | |
|---|---|---|---|---|
| | Dependent Variable | | Dependent Variable | |
| | Willingness to regular use (0/1) | Log of WTP on regular use (kyat) | Willingness to regular use (0/1) | Log of WTP on regular use (kyat) |
| | Probit | Heckman | Probit | Heckman |
| Independent Variables | Model 1 | Model 2 | Model 3 | Model 4 |
| Maximum schooling year of male member (Year) | -0.003 | -0.000 | -0.003 | -0.003 |
| | (0.004) | (0.015) | (0.004) | (0.016) |
| Maximum schooling year of female member (Year) | 0.007 | -0.034 | 0.007 | -0.028 |
| | (0.005) | (0.022) | (0.005) | (0.022) |
| Number of Household members | 0.000 | 0.061 | 0.000 | 0.060 |
| | (0.014) | (0.038) | (0.014) | (0.037) |
| Household of female head (=1) | -0.047 | 0.040 | -0.045 | -0.000 |
| | (0.054) | (0.184) | (0.053) | (0.177) |
| Household with Under 5 year children(=1) | 0.023 | 0.112 | 0.019 | 0.127 |
| | (0.044) | (0.145) | (0.043) | (0.140) |
| Asset measure | 0.052 | -0.017 | 0.080* | 0.013 |
| | (0.039) | (0.168) | (0.042) | (0.218) |
| Own house (=1) | 0.170*** | -0.286 | 0.198*** | -0.144 |
| | (0.053) | (0.492) | (0.054) | (0.530) |
| Perception of quality of their water (Clear =1) | -0.053 | 0.090 | | |
| | (0.051) | (0.203) | | |
| Own the private well (=1) | | | -0.073 | 0.073 |
| | | | (0.068) | (0.277) |
| The private well*Clear (1*1) | | | -0.066 | 0.034 |
| | | | (0.055) | (0.225) |
| Block fixed effect | included | included | included | included |
| Inverse Mills Ratio | | -0.367 | | 0.246 |
| | | (1.705) | | (1.593) |
| R-squared | | 0.293 | | 0.294 |
| Observations | 595 | 595 | 595 | 595 |

*Note:* Marginal effects evaluated at mean values are reported.
25 households did not answer willingness-to-pay questions.
Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1500 kyat) as of May 2019.

**Table 4-9b Willingness-to-use piped water regularly and Willingness-to-pay the water bill per 1,000 liters (Higher consumption sample)**

| | Upper half (Higher-consumption) | | | |
|---|---|---|---|---|
| | Dependent Variable | | Dependent Variable | |
| | Willingness to regular use (0/1) | Log of WTP on regular use (kyat) | Willingness to regular use (0/1) | Log of WTP on regular use (kyat) |
| | Probit | Heckman | Probit | Heckman |
| Independent Variables | Model 5 | Model 6 | Model 7 | Model 8 |
| Maximum schooling year of male member (Year) | 0.014* | -0.037 | 0.013 | -0.038 |
| | (0.008) | (0.073) | (0.009) | (0.066) |
| Maximum schooling year of female member (Year) | -0.000 | 0.001 | 0.001 | 0.005 |
| | (0.010) | (0.021) | (0.010) | (0.020) |
| Number of Household members | -0.007 | 0.004 | -0.006 | -0.009 |
| | (0.022) | (0.056) | (0.022) | (0.052) |
| Household of female head (=1) | -0.025 | 0.319 | -0.030 | 0.283 |
| | (0.106) | (0.229) | (0.106) | (0.243) |
| Household with Under 5 year children(=1) | 0.044 | 0.206 | 0.040 | 0.165 |
| | (0.081) | (0.256) | (0.080) | (0.232) |
| Asset measure | 0.048 | -0.228 | 0.061 | -0.178 |
| | (0.070) | (0.241) | (0.073) | (0.294) |
| Own house (=1) | 0.163 | 0.093 | 0.173* | 0.076 |
| | (0.101) | (0.920) | (0.100) | (0.923) |
| Perception of quality of their water (Clear =1) | -0.010 | 0.117 | | |
| | (0.075) | (0.162) | | |
| Own the private well (=1) | | | -0.076 | -0.334 |
| | | | (0.179) | (0.468) |
| The private well*Clear (1*1) | | | -0.024 | 0.083 |
| | | | (0.080) | (0.191) |
| Block fixed effect | included | included | included | included |
| Inverse Mills Ratio | | -2.040 | | -1.876 |
| | | (3.175) | | (3.048) |
| R-squared | | 0.478 | | 0.482 |
| Observations | 300 | 300 | 300 | 300 |

*Note:* Marginal effects evaluated at mean values are reported.
25 households did not answer willingness-to-pay questions.
Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1500 kyat) as of May 2019.

## Table 4-9c Willingness-to-use piped water regularly and Willingness-to-pay the water bill per 1,000 liters (Lower consumption sample)

| | Lower half (Lower-consumption) | | | |
|---|---|---|---|---|
| | Dependent Variable | | Dependent Variable | |
| | Willingness to regular use (0/1) | Log of WTP on regular use (kyat) | Willingness to regular use (0/1) | Log of WTP on regular use (kyat) |
| | Probit | Heckman | Probit | Heckman |
| Independent Variables | Model 9 | Model 10 | Model 11 | Model 12 |
| Maximum schooling year of male member (Year) | -0.016** | 0.014 | -0.016** | 0.021 |
| | (0.007) | (0.033) | (0.007) | (0.029) |
| Maximum schooling year of female member (Year) | 0.009 | -0.000 | 0.008 | -0.002 |
| | (0.008) | (0.023) | (0.008) | (0.021) |
| Number of Household members | 0.025 | -0.009 | 0.023 | -0.014 |
| | (0.023) | (0.053) | (0.023) | (0.050) |
| Household of female head (=1) | -0.040 | -0.364* | -0.037 | -0.334* |
| | (0.076) | (0.182) | (0.077) | (0.182) |
| Household with Under 5 year children(=1) | -0.012 | -0.208 | -0.024 | -0.196 |
| | (0.086) | (0.165) | (0.086) | (0.168) |
| Asset measure | 0.076 | -0.091 | 0.129 | -0.240 |
| | (0.068) | (0.209) | (0.080) | (0.250) |
| Own house (=1) | 0.201** | -0.292 | 0.258*** | -0.461 |
| | (0.085) | (0.425) | (0.094) | (0.452) |
| Perception of quality of their water (Clear =1) | -0.178** | 0.203 | | |
| | (0.082) | (0.360) | | |
| Own the private well (=1) | | | 0.000 | 0.078 |
| | | | (0.109) | (0.235) |
| The private well*Clear (1*1) | | | -0.198** | 0.331 |
| | | | (0.090) | (0.348) |
| Block fixed effect | included | included | included | included |
| Inverse Mills Ratio | | 0.200 | | -0.867 |
| | | (1.852) | | (1.017) |
| R-squared | | 0.503 | | 0.539 |
| Observations | 295 | 295 | 295 | 295 |

*Note:* Marginal effects evaluated at mean values are reported.
25 households did not answer willingness-to-pay questions.
Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1500 kyat) as of May 2019.

## 4.7 Conclusion

This chapter examines the water use pattern and demand for piped water among the urban residents. More specifically, it examines the demographic and socio-economic characteristics of the households who use private well water and bottled water to determine the factors affecting the demand for water of households who have no access to piped water. Moreover, this chapter explores the potential demand for water from the new piped water system of the surveyed households by examining the factors associated with willingness-to-pay for the connection and regular use of the piped water system.

From the estimation results regarding bottled water, wealthier households with richer asset decide to purchase bottled water and consume more bottled water. Dividing the samples by household consumption, I found that both high-consuming and low-consuming households decide to purchase bottled water if they have richer asset. The purchase of bottled water is highly correlated with the household's economic condition. The results imply that poorer households have financial constraints in consuming bottled water. SDGs are targeting "achieve universal and equitable access to safe and affordable drinking water for all", but bottled water is not an equitable means to acquire safe water and may contribute to inequality among people.

As for the association between the perception on water quality and bottled water use, regular purchase of bottled water decreases if households consider the water of their main source as clear. This suggests that households with seemingly safe water access tend not to consume bottled water, but households without safe water access are obligated to consume bottled water. In terms of education, maximum years of schooling of female household members in all sample and that of male household members in the lower-consumption sample show positive association on bottled water use. This implies that education and knowledge level are correlated with better understanding of the importance of safe water.

The estimation results examining the ownership of private wells show clear correlation between asset measure and ownership of private wells, that is, better economic condition could lead households to make an investment decision. This was evident in the increase on the number of drilling and redrilling cases after the setting of national minimum wages, which provided higher income for the household members. However, households decide to have private wells if there is no public water supply service. Households owning private wells are forced to spend the initial investment cost, which is particularly expensive, for the pumping equipment, its maintenance cost, and electricity fee for running the pump. In addition, some households spend redrill cost if the ground water level go down or the quality of ground water gets worse. Further, the compressors make loud noise while running, which may annoy the neighborhood. Also, even though the running cost is only the electricity fee for operating the compressor, it should be noted that the users spent time by the well during pumping. On the other hand, households without their private wells are forced to fetch water from public and neighbors' wells, and they consume less amount of water since their capacity of carrying water is limited. It was found that households choose their water sources by considering various aspects such as the cost, convenience to use, and the quality and taste of water.

Demand for piped water was examined  using willingness-to-pay questions related to the new piped water system. Only 61 percent of the households are willing to connect to the piped water system. There is demand for the piped water, but it is not remarkably high. The demand for the connection among the lower-consumption sample is lower relative to the higher-consumption sample. For the last several years, the number of drilling and redrilling of the private wells have increased. Because of the large upfront investment cost of owning private wells, the decision to own private well is a high stake especially for poorer households. Those households who already made the investment decision on the private well may have stronger will to use the private wells continuously or simply financial constraints to connect to the new water source since it involves additional expense. From the estimation results in all sample, asset measure shows statistically significant positive association with the households' willingness-to-connect to the piped water system. Since the connection cost and the water charge for the piped water entail additional cost for the households, wealthier households are the ones who show intention to connect to the piped water and use it. In addition, ownership of house is highly correlated with higher willingness-to-connect to the piped water system. It is conjectured that households want to have the piped water system within their premises as their property.

The piped water system may improve the household's well-being by providing easier access to safe water and convenience to use water in their premises. However, it will happen only if the household can connect to the piped water system. If the connection fee is too high, it will be a financial constraint. There are large differences between the required cost for the connection and the survey result of willingness-to-pay on the connection fee. The ratio of willingness-to-connect to the pipe water system is also not high enough. Therefore, many households may not connect to the piped water system given their water use situation and their financial constraints.

To promote the shift of main water source from private well to piped water system, each household should understand the value of piped water in terms of quality and cost. Fortunately, at present, the Project subsidizes the connection fee from main pipe to the water meter in the households' premises, but MCDC does not support the connection fee normally. The connection fee is a large investment for households, and it would constrain them from using piped water. Therefore, it is important to subsidize the connection fee or set the payment scheme of initial connection fee in installments in order to promote piped water use.

In addition to safe water access, the piped water system may mitigate the problems caused by urbanization. The improper groundwater use may cause future water scarcity or ground subsidence of the cities in the long term, as the existing literatures illustrated. As discussed in this chapter, many households in the survey area re-drill their private wells due to the increasing difficulty to obtain water. In addition, the use of plastic bottles causes environmental problems such as micro-plastics pollution and increase in plastic wastes. Even though bottles are reused by the bottled water industry, it should be noted that these bottles are still plastic wastes in the end.

The residents of the surveyed area seem to manage their lives with the existing water sources, which are mainly private wells and bottled water. However, inequality and environmental issues for accessing the safe water persist. Even though water supply infrastructure requires large investment, it is necessary to install the infrastructures to resolve the problems raised from coming urbanization. In order to understand the impact of water supply infrastructures, further research is necessary to analyze how the people can benefit from the facilities and how they can change their water use behaviors.

# Chapter 5 Exploring the effect of a new piped water system on water use

## 5.1 Background and research interest

Many households in low- and middle- income countries use more than one of several types of water sources, such as in-house tap connections, public or private well, water vendors, and rainwater collection (Nauges & Whittington, 2009). Households decide their choice of water sources taking into account the purpose of use, water quality, available quantity of each water source, and the costs of obtaining water.

The number of studies rigorously examining the water demand and use in low- and middle- income countries are still small. More specifically, studies examining the impact of the installation of a new piped water system are very limited. The comprehensive review on water demand in those countries pointed the analytical difficulties in comparing the results with those of developed countries (Nauges & Whittington, 2009).

Another issue in examining the impact of installing piped water system is the difficulty in collecting water use data, especially from unmetered sources. The review also pointed out that much research used cross-sectional data, which makes it generally difficult to ascribe a causal relationship of the independent variables to the dependent variables of water demand (Nauges & Whittington, 2009). The impact of tap connection on water consumption in the urban area of Senegal was examined using cross-sectional data and by employing the sample selection model (Briand, et al., 2009). The study compared the connected and non-connected households. There may be confounding factors that affect households' decisions to connect which may contain selection bias leading to inappropriate comparison.

The surveys for this research collected the panel data of water use of households, including water volume and expenditures of multiple water sources. The data is unique in a sense that it captures the water use situation before and after the installation of new piped water system in the project area and non-project area. In addition, while other research often uses the data of the area where the piped water system already exists, this research analyzes the change of water use pattern before and after the installation of new piped water system.

The practice of using multiple sources of water has been reported in many countries across Asia, Africa, the Americas, and the Pacific, but is broadly neglected. Meanwhile, relevant studies have focused almost exclusively on the household's "main source of drinking water." (Elliot, et. al. 2019).

In the City, 80 percent of the households surveyed in all six townships in 2019 relied on more than one water source including piped water system, tube well, bottled water, and other sources. The choice of the primary, secondary, and tertiary water sources vary among townships depending on various aspects such as availability of piped water and the quality of water. More than half of the respondents emphasized the quality of water as important factor for the water source selection, and the convenience of access, reliability of access or price of water were less important for them (Nagpal et al. 2020).

In the Project, the baseline survey revealed that private well water is used for general purpose of any water-related activities in the households. Some households drink the private well water with/without water treatment. Bottled water is used for drinking and cooking. Even though a unit cost of bottled water is higher than any other water, more than 70 percent of the households purchase bottled water. The end-line survey confirmed that more than 90 percent of the households connected to the new piped water system by the Project. Meanwhile, only 21.6 percent of the households in the treatment blocks drank the piped water. More that 75 percent of the households in treatment blocks continuously used their private well.

This chapter examines the impacts of the installation of the piped water system on water use such as water source choice (private well, piped water, and bottled water), water volume, and water expenditures. The new piped water is supposed to be used for both drinking purpose and general purpose. With installation of the new piped water system, it is expected that households may shift their water source from private well to piped water and drink the piped water instead of bottled water. Since bottled water is priced higher than the unit cost of the water from other sources, the shift of drinking water source would reduce the household expenditure on water use. Yet, the water use survey of all six townships in 2019 reported that only 34 percent of households who connected to MCDC piped water system drank the piped water. More than 70 percent of the households drink bottled water. (Nagpal et al. 2020). It is an empirical question whether the newly connected households would drink the piped water or continue to drink bottled water.

Even if households are eligible to connect to the piped water system, households can choose whether they will connect to the piped water system or not. Fee for private connection is hurdle since it can be a financial burden especially for people in low- and middle- income countries[14]. In this research, because the cost of the private connection was fully subsidized (except registration fee of 100 kyat), it is expected that most residents would connect to the piped water supply system. However, fee for the monthly maintenance cost and volumetric water charge may discourage them to continue using

[14] Basani et, al. (2008) argued that the initial cost of the connection fee is the hindrance and providing a connection subsidy scheme is an important step to provide water to a greater number of households. The case in the urban area in Morocco suggested a facilitation campaign and door-to-door awareness to inform households of the accessible credit which can be availed for the upfront payment for the connection (Devoto, et al., 2012).

the piped water. Therefore, even if the private connection is successfully completed, it is uncertain if they will continue to use the piped water as expected.[15]

Piped water is recommended because it has more available water and is easy to use in the premises. However, its unit cost may be higher when compared to water from private wells and residents may not continue to use piped water. For drinking purposes, households may switch from bottled water to piped water to reduce costs because the unit cost of piped water is much lower than that of bottled water,. However, chemical odor and taste due to chlorine residuals in piped water are not favorable, and some people prefer not to drink piped water (Prasetiawan, et al., 2017, Francisco, 2014). Therefore, on how the installation of a piped water system affects water use of urban residents is an empirical question. Financial resources for urban infrastructure investment are very limited particularly in low- and middle-income countries. Exploring the rigorous impact of the piped water system on water use pattern and providing a new piece of empirical evidence will help governments in making investment decisions on the basic infrastructure.

In this research, these changes of water use would be rigorously examined. More specifically, this research aims to examine the following three research questions: 1) for general use, to what extent did the installation of pipe water system substitute the use of water from private wells? 2) for drinking purpose, to what extent did the installation of the pipe water system substitute the purchase of bottled water? and 3) how did the installation of the piped water system affect total water demand? By answering the third question, this study also aims to estimate the change in total expenditures for water with the installation of the piped water system.

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[15] A systematic review reported that many households in low- and middle- income countries use multiple water sources, and those with access to improved water sources including piped water still use unimproved water sources (Daly et al., 2021).

5.2 Survey design

To examine the impact of the installation of the piped water system, the double difference estimation method (hereinafter referred to "DD") is employed. The DD method is a combination of before/after comparison and with/without comparison. The central assumption for the methodology to be valid is the "parallel trend" assumption, which assumes that the change over the two periods should be common (without the installation) between the treatment and control blocks. For this assumption to hold, a paired-site sampling is employed.

For this chapter, the analyzed households were selected as follows. In the water service blocks where the Project would supply piped water, there are some blocks with many factories or large grasslands but few residents. Those blocks were excluded because this research focuses on the water use of the habitants of residential area. Ninety-seven (97) blocks remained as project blocks in the five wards (Ngwe Taw Kyi Kone, Thin Pan Kone, Ga Nge, Ga Gyi, and Nga). Among the 97 project blocks, 62 blocks were randomly selected as treatment blocks. Map 3 (Appendix) shows the location of the piped water supply facilities and the areas of treatment and control blocks.

In the control area which is outside of the water service blocks, the exhaustive block survey was conducted in April 2018. One hundred twenty-four (124) non-project blocks across the three wards (Thin Pan Kone, Kha Gway and Salone) were surveyed. Based on the block survey data, 33 control blocks which have similar characteristics with the treatment blocks were purposefully selected from non-project blocks. In total, there were 95 selected blocks that were composed of 62 treatment blocks and 33 control blocks. From each selected block, ten households were randomly chosen[16]. Nine

[16] In order to select 10 households, the surveyors first counted and assigned the number to the eligible households in the block. The starting point of counting was selected randomly from the four corners of

hundred and fifty (950) households were interviewed in the baseline survey in May and June of 2018.

As illustrated in Chart 1 (See Appendix), the baseline survey was conducted before the commencement of water supply service in August 2018. The endline survey was conducted in June and July of 2019, which is approximately one year after the conduct of the baseline survey, to assess the water use change after the commencement of the piped water service. In the endline survey, the number of the interviewed households was reduced to 791. Some households moved out while other households refused the interview or were unreached during the survey period. The attrition rate from baseline survey to endline survey is 16.7 percent. Table 5-1 summarizes the number of sampled households in both the treatment and control blocks.

The balance tests of characteristics of the surveyed households and blocks were carried out (Appendix 5-1). As for the characteristics of the sampled households, there are no statistically significant differences in all listed variables except for the number of household members. Regarding the characteristics of the blocks, the household and population densities are similar between the treatment and control blocks, which are typical residential areas in the Township. It is considered that these households and blocks have similar and comparable characteristics, assuming that the parallel trend assumption holds.

**Table 5-1 Sampled households in the analysis**

| | Baseline | | | End-line | | | Attrition | | |
|---|---|---|---|---|---|---|---|---|---|
| | Treatment blocks | Control blocks | All | Treatment blocks | Control blocks | All | Treatment blocks | Control blocks | Attrition rate (%) |
| Number of blocks | 62 | 33 | 95 | 62 | 33 | 95 | | | |
| Number of households | 620 | 330 | 950 | 522 | 269 | 791 | 98 | 61 | 16.7 |

Note: The table is compiled by the author.

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the block, which is normally square-shaped. After making the list of the eligible households for piped water system in the block, 10 households were randomly selected.

## 5.3 Descriptive analysis of water use

### 5.3.1 Water use of various water sources

Table 5-2 presents the types of water sources used, perception ratio on cleanliness of the water, and ratio of drinking by the households in treatment and control blocks at the time of the baseline survey. Households obtained water from various types of sources such as private well, neighbor's well or tap, MCDC's overhead tank system, public well or tap, water seller, and bottled water. Private well is the major water source and 86.6 percent of households in both blocks use the private well. About 24.3 percent of households in the treatment blocks and 22.3 percent households in the control blocks drink private well water. For drinking purpose, bottled water is the major source and 72.6 percent of households in the treatment blocks and 74.3 percent households in the control blocks purchase and drink bottled water.

Tables 5-3a (treatment block) and 5-3b (control block) present the water use volume, total water expenditures, and calculated unit price of the water at the time of the baseline survey. The average of the total water use volume of the treatment blocks and control blocks were 36.4 $m^3$ and 36.7 $m^3$, respectively, and their monthly household expenditures for water were 6.1 thousand kyat and 6.2 thousand kyat, respectively. Households who use private wells and MCDC overhead tank consume large amount of water, while households who use other types of water sources obtain much less amount of water since they need to spend much time and labor to fetch the water. Households who use private wells consume approximately 40 $m^3$ and 300 liters per capita per day (LPCD)[17]. Expenditure for pumping the private well water is low. This cost is calculated based on the unit price of the electricity fee and calculated electricity volume from pumping time. As for bottled water users, treatment blocks' bottled water users purchased 443 liters of

[17] Chenoweth (2008) estimated that 135 LPCD (Liter per capita per day) is the minimum water requirement for human health and for economic and social development.

bottled water (22 bottles of 20-liter bottle) and spent 7.9 thousand kyat per month while households in the control blocks purchased 443 liter of bottled water and spent 7.7 thousand kyat per month.

Table 5-4 reports the water use pattern at the endline survey. In the treatment blocks, 84.5 percent households used the piped water system. The connection rate is high with subsidy for private connection by the Project and the eligible households need to pay only the registration fee (amounting to 100 kyat), which is almost free of charge. Among the 522 households in the treatment blocks, 476 households connected to the piped water. As of the endline survey, 441 households are using piped water. One hundred fourteen (114) households (21.8 percent of 522 households) drink the piped water. The ratio of using private well water in treatment blocks decreased to 75.7 percent, while the ratio in control blocks is 86.6 percent, which is the same percentage as in the baseline survey. The ratio of those who purchased bottled water in treatment blocks slightly decreased to 70.3 percent, while the ratio in control blocks increased to 78.8 percent.

Tables 5-5a (treatment block) and 5-5b (control block) show the water use volume and expenditure in each water source at the endline survey. The water use volume of private well decreased largely in both treatment and control blocks. Even though there is a possibility that this was due to the timing of the survey or weather condition, there is also a possibility that the water use volume at the baseline survey was overestimated. It must be noted that it is difficult to accurately measure the water use volume especially the pumping volume of wells. These data issues are commonly observed in both blocks, and most of the water use situation is similar on both blocks at the time of baseline survey. Further, the balance test of characteristics of the surveyed blocks found similar and comparable characteristics. It is assumed that the parallel trend assumption holds.

## Table 5-2 Usage rate of water sources and drinking rate of the water at the baseline survey

| Block | Treatment block | | | | Control block | | | |
|---|---|---|---|---|---|---|---|---|
| Purpose of use | General use | | Drinking | | General use | | Drinking | |
| | Obs. | % | Obs. | % | Obs. | % | Obs. | % |
| Private well (Own) | 452 | 86.6 | 127 | 24.3 | 233 | 86.6 | 60 | 22.3 |
| Neighbor's well | 57 | 10.9 | 34 | 6.5 | 21 | 7.8 | 9 | 3.3 |
| Neighbor's tap (Piped water/ Stand pipe) | 10 | 1.9 | 3 | 0.6 | 1 | 0.4 | 1 | 0.4 |
| Connection with MCDC overhead tank(Own) | 4 | 0.8 | 2 | 0.4 | 13 | 4.8 | 4 | 1.5 |
| Public tap (Piped water/ Stand pipe) | 35 | 6.7 | 34 | 6.5 | | | | |
| Public well | 18 | 3.4 | 17 | 3.3 | 4 | 1.5 | 1 | 0.4 |
| Water bought from water seller | 3 | 0.6 | 0 | 0.0 | 3 | 1.1 | 1 | 0.4 |
| Purchase of bottled water | 379 | 72.6 | 379 | 72.6 | 200 | 74.3 | 200 | 74.3 |
| Number of sampled households | 522 | | 522 | | 269 | | 269 | |

Note: The table is compiled by the author.

## Table 5-3a Water use volume and expenditure of the households by type of water source in treatment blocks at the baseline survey

| Block | Treatment block | | | |
|---|---|---|---|---|
| | **Household water use volume** | **Individual water use volume** | **Expenditure for water use** | **Unit cost of water** |
| unit | **m³/month** | **LPCD (litter per capita per** | **1000 kyat/ month** | **kyat/m³** |
| | **Mean** | **Mean** | **Mean** | **Mean** |
| Private well (Own) | 39.5 | 309.8 | 0.3 | 6 |
| Neighbor's well | 2.1 | 17.2 | 0.6 | 265 |
| Neighbor's tap (Piped water/ Stand pipe) | 1.8 | 17.9 | 1.4 | 778 |
| Connection with MCDC overhead tank(Own) | 13.4 | 88.8 | 2.8 | 212 |
| Public tap (Piped water/ Stand pipe) | 0.6 | 5.1 | 0.0 | |
| Public well | 1.2 | 8.5 | 0.1 | 90 |
| Water bought from water seller | 1.7 | 10.8 | 0.0 | 0 |
| Purchase of bottled water | ※ 443(L) | 3.4 | 7.9 | 18 (kyat/L) |
| Total water use of all sources | 36.4 | 284.7 | 6.1 | 166 |
| Number of sampled households | 522 | | 522 | |

Note: ※ Unit of bottled water use is litter, not m³.

Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018

The table is compiled by the author.

**Table 5-3b Water use volume and expenditure of the households by type of water source in control blocks at the baseline survey**

| Block | Control block | | | |
|---|---|---|---|---|
| | **Household water use volume** | **Individual water use volume** | **Expenditure for water use** | **Unit cost of water** |
| unit | **$m^3$/month** | **LPCD (litter per capita per** | **1000 kyat/ month** | **kyat/$m^3$** |
| | **Mean** | **Mean** | **Mean** | **Mean** |
| Private well (Own) | 39.9 | 292.7 | 0.2 | 0 |
| Neighbor's well | 2.4 | 20.6 | 0.2 | 0 |
| Neighbor's tap (Piped water/ Stand pipe) | 0.3 | 2.5 | 0.0 | 0 |
| Connection with MCDC overhead tank(Own) | 17.7 | 113.8 | 4.0 | 0 |
| Public tap (Piped water/ Stand pipe) | | | | |
| Public well | 0.5 | 3.8 | 0.0 | 0 |
| Water bought from water seller | 0.4 | 3.1 | 0.7 | 1514 |
| Purchase of bottled water | ※ 443(L) | 3.3 | 7.7 | 17 (kyat/L) |
| Total water use of all sources | 36.7 | 270 | 6.2 | 0 |
| Number of sampled households | 269 | | 269 | |

Note: ※ Unit of bottled water use is litter, not $m^3$.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018
The table is compiled by the author.

**Table 5-4 Usage rate of water sources and drinking rate of the water at the endline survey**

| Block | Treatment block | | | | Control block | | | |
|---|---|---|---|---|---|---|---|---|
| Purpose of use | General Use | | For drinking | | General Use | | For drinking | |
| | Obs. | % | Obs. | % | Obs. | % | Obs. | % |
| *Water sources* | | | | | | | | |
| MCDC piped water | 441 | 84.5 | 114 | 21.8 | | | | |
| Private well (Own) | 395 | 75.7 | 101 | 19.3 | 233 | 86.6 | 65 | 24.2 |
| Neighbor's well | 15 | 2.9 | 5 | 1.0 | 17 | 6.3 | 5 | 1.9 |
| Neighbor's tap (Piped water/ Stand pipe) | 9 | 1.7 | 4 | 0.8 | 4 | 1.5 | 2 | 0.7 |
| Connection with MCDC overhead tank(Own) | 5 | 1.0 | 2 | 0.4 | 13 | 4.8 | 5 | 1.9 |
| Public tap (Piped water/ Stand pipe) | 6 | 1.1 | 5 | 1.0 | 1 | 0.4 | 0 | 0.0 |
| Public well | 4 | 0.8 | 3 | 0.6 | 4 | 1.5 | 0 | 0.0 |
| Water bought from water seller | 0 | 0.0 | 0 | 0.0 | 2 | 0.7 | 1 | 0.4 |
| Purchase of bottled water | 367 | 70.3 | 367 | 70.3 | 212 | 78.8 | 212 | 78.8 |
| Number of sampled households | 522 | | 522 | | 269 | | 269 | |

Note: The table is compiled by the author.

## Table 5-5a Water use volume and expenditure of the households by type of water source in treatment blocks at the endline survey

| Block | Treatment block | | | |
|---|---|---|---|---|
| | Household water use volume | Individual water use volume | Expenditure for water use | Unit cost of water |
| unit | m³/month | LPCD (litter per capita per day) | 1000 kyat/ month | kyat/m³ |
| | Mean | Mean | Mean | Mean |
| MCDC piped water | 21.7 | 173 | 4.4 | 202 |
| Private well (Own) | 14.8 | 112 | 0.1 | 7 |
| Neighbor's well | 2.0 | 14 | 0.0 | 0 |
| Neighbor's tap (Piped water/ Stand pipe) | 3.0 | 25 | 0.0 | 0 |
| Connection with MCDC overhead tank(Own) | 18.0 | 113 | 4.0 | 223 |
| Public tap (Piped water/ Stand pipe) | 0.3 | 2 | 0.0 | 0 |
| Public well | 0.4 | 4 | 0.0 | 0 |
| Water bought from water seller | | | | |
| Purchase of bottled water | ※ 362(L) | 3 | 7.0 | 19 (kyat/L) |
| Total water use of all sources | 31.6 | 247 | 8.9 | 283 |
| Number of sampled households | 522 | | 522 | |

Note: ※ Unit of bottled water use is litter, not m³.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1500 kyat) as of May 2019
The table is compiled by the author.

## Table 5-5b Water use volume and expenditure of the households by type of water source in control blocks at the endline survey

| Block | Control block | | | |
|---|---|---|---|---|
| | Household water use volume | Individual water use volume | Expenditure for water use | Unit cost of water |
| unit | m³/month | LPCD (litter per capita per day) | 1000 kyat/ month | kyat/m³ |
| | Mean | Mean | Mean | Mean |
| MCDC piped water | | | | |
| Private well (Own) | 21.4 | 155 | 0.2 | 0 |
| Neighbor's well | 1.7 | 13 | 0.0 | 0 |
| Neighbor's tap (Piped water/ Stand pipe) | 1.6 | 15 | 1.3 | 1255 |
| Connection with MCDC overhead tank(Own) | 26.4 | 179 | 3.4 | 0 |
| Public tap (Piped water/ Stand pipe) | 0.5 | 3 | 0.0 | 0 |
| Public well | 1.0 | 8 | 0.0 | 0 |
| Water bought from water seller | 0.3 | 2 | 0.0 | 0 |
| Purchase of bottled water | ※ 375(L) | 3 | 7.5 | 20 (kyat/L) |
| Total water use of all sources | 20.8 | 150 | 6.3 | 302 |
| Number of sampled households | 269 | | 269 | |

Note: ※ Unit of bottled water use is litter, not m³.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1500 kyat) as of May 2019
The table is compiled by the author.

5.3.2 Summary of water use situation at the baseline and endline surveys

Table 5-6 compares the water use in the treatment and control blocks at time of the baseline and endline surveys in more detail. The average volumes of the monthly household water use in the treatment blocks and the control blocks are 36.4 $m^3$ and 36.7$m^3$, respectively, and the average individual water use volumes are 285 and 270 LPCD, respectively. The monthly bottled water volume consumed per household in treatment and control blocks are 322 liters and 329 liters, respectively, and the monthly household expenditures for bottled water are 5.7 thousand kyat in both blocks. Households using private wells pay the electricity fee to run the compressor for pumping. Households in treatment and control blocks spent 220 kyat and 204 kyat, respectively, for the electricity fee for pumping. The electricity fee for pumping was calculated using the unit cost of electricity fee of the City, which is 35 kyat per kwh. The conversion rate of electricity usage of pumping was based on the survey result of electricity use in Myanmar (Myanmar Engineering Society, 2015)[18].

In all the data of the baseline survey, there is no statistically significant difference on the water use situation of treatment and control blocks. It is considered that water use situation of both blocks is similar and comparable for the analyses.

At time of the endline survey, the large differences of water use between treatment and control blocks were found after the installation of the new piped water system. Households in the treatment blocks use 10.8 $m^3$ more water and spent 2.7 thousand kyat more for water use than those in the control blocks. Households in the treatment blocks use 19.2 $m^3$ piped water, but they use 7.3 $m^3$ less private well water than the households in the control blocks. Individual daily water use of piped water is 154 LPCD, and monthly expenditure of piped water is 3.9 thousand kyat. The ratio of those who

[18] The conversion value of electricity seems to be very low. There is a possibility that the calculated value of electricity cost for pumping may be lower than the actual cost.

purchased bottled water in the treatment blocks is lower by 8.5 percent than the ratio in the control blocks. Households in the treatment blocks spent one thousand kyat less for bottled water based on the endline survey.

In the last row of the table, the difference-in-differences of the water use between before/after data of the treatment and control blocks are presented. The difference-in-differences of the ratio of using private well is negative 11.3 percent and the difference-in-differences of the use of private well water is negative 6.9 $m^3$. Due to the reduction of private well water use, pumping time decreases by 26 minutes. In addition, the expense of bottled water decreases by one thousand kyat. Using 19.2 $m^3$ of piped water, the treatment households were able to consume more water and spend more for water use. The difference-in-differences of total water use volume is 11.2 $m^3$ and that of the total water expenditures is 2.8 thousand kyat.

**Table 5-6 Summary statistics of water use at the baseline and endline surveys**

| Survey timing | | Baseline survey | | | | End-line survey | | | | Difference | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Treatment blocks | Control blocks | Diff | Stat. Sig | Treatment blocks | Control blocks | Diff | Stat. Sig | Diff in diff | Stat. Sig |
| | Unit | mean | mean | | | mean | mean | | | | |
| **1) Water use** | | | | | | | | | | | |
| Ratio of Using private well | % | 86.6 | 86.6 | 0.0 | | 75.7 | 87 | -11.3 | *** | -11.3 | *** |
| Ratio of purchasing bottled water | % | 77.4 | 81.4 | -4.0 | | 70.3 | 78.8 | -8.5 | ** | -4.5 | |
| Ratio of connecting with piped water system | % | 0 | . | | | 91.2 | . | | | . | |
| Ratio of using piped water system among connected house | % | 0 | . | | | 96.7 | . | | | . | |
| Perception of quality of their water (Clear =1) | % | 77.4 | 81.4 | -4.0 | | 78.5 | 76.6 | 1.9 | | 5.9 | |
| Household bottled water volume per month | Liter | 322 | 329 | -7.1 | | 255 | 296 | -41.0 | ** | -33.9 | |
| Water use volume of private well | $m^3$ | 34.2 | 34.6 | -0.4 | | 11.3 | 18.6 | -7.3 | *** | -6.9 | *** |
| Monthly water use volume of piped water | $m^3$ | 0 | . | | | 19.2 | . | | | . | |
| Total water use volume | $m^3$ | 36.4 | 36.7 | -0.3 | | 31.6 | 20.8 | 10.8 | *** | 11.2 | *** |
| Total private well water use volume (litter per day per capita) | LPCD | 268 | 254 | 15 | | 86 | 134 | -48.6 | *** | -63.3 | *** |
| Piped water use volume (litter per day per capita) | LPCD | 0 | . | | | 154 | . | | | . | |
| Total water use volume (litter per day per capita) | LPCD | 285 | 270 | 15 | | 247 | 150 | 97.2 | *** | 82.7 | *** |
| **2) Cost** | | | | | | | | | | | |
| Pumping time of the private well | minutes | 83 | 81 | 2 | | 32 | 60 | 28 | *** | 26 | *** |
| Monthly electricity expense for pumping | kyat | 220 | 204 | 16 | | 81 | 154 | -72.7 | *** | -88.7 | *** |
| Household bottled water cost per month | 1000kyat | 5.7 | 5.7 | 0.0 | | 4.9 | 5.9 | -1.0 | *** | -1.0 | * |
| Monthly expenditure of piped water | 1000kyat | 0 | . | | | 3.9 | . | | | . | |
| Total expense to use water | 1000kyat | 6.1 | 6.2 | -0.1 | | 8.9 | 6.3 | 2.7 | *** | 2.8 | *** |
| Obs. | | 522 | 269 | | | 522 | 269 | | | | |

Note: Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018 and 0.0007 US dollar (1 dollar = 1500 kyat) as of May 2019.
Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
The table is compiled by the author.

## 5.4 Analysis of the effect of the new piped water system on water use

### 5.4.1 Estimation strategy

In order to rigorously examine the impact of the installation of the new piped water system on water use, multivariate regression models were utilized. The basic specification for the DD methodology is as follows:

$$Y_{ijt} = \beta_0 + \beta_1 \cdot t + \beta_2 \cdot S_j + \beta_3 \cdot (S_j \cdot t) + \epsilon_{ijt} \quad (1)$$

where: i refers to a household, j points to block and t is time (*t* = 0 for baseline and *t* = 1 for endline). This model estimates the intention-to-treat (ITT)[19] impact of the Project to measure the impact of the installation of new piped water system. *Yijt* is the dependent variable and may either be a binary variable or a continuous variable, depending on the type of analysis. ITT is employed for this chapter because of the high connection rate, which is more than 90 percent. Analysis for ITT may capture the underestimated impacts in comparing the analysis for average treatment effect. Yet, if ITT estimation confirms the positive impact of the Project, it can be interpreted that the Project caused the impact on water use though it reports the underestimated impact.

The dependent variables including private well water use, bottled water purchase, and total water use were examined by DD estimator. Turning to the right-hand side variables, Sj is a binary variable that takes the value 1 if the household is in the project block and 0 otherwise. $\beta_0$ to $\beta_3$ are the parameters to be estimated. $\beta_3$ is the parameter of our interest and measures the impact of the Project on the outcomes. $\epsilon_{ijt}$ is a well-behaved error term. The ordinary least squared (OLS) estimation was employed to estimate the coefficients.

The parallel trend assumption in the DD estimator may be violated if changes caused by covariates are not common between the treatment and control blocks. Thus,

[19] Intention-to-treat (ITT) refers to the analysis that is based on the initial treatment assignment and not on the treatment eventually received. In the case of this paper, the treatment effect of the households in the project blocks were analyzed regardless of whether the households connected or not.

we also employ an empirical model with some covariates since we examine if this is the case. The covariates take two forms (summary statistics of the covariates are shown in Appendix 5-2); $X_{ijt}$ is a vector to include a set of household characteristics and $X_{jt}$ is a vector containing a set of block j's characteristics other than Treatment (Sj). $X_{jt}$ contains dummy variables that capture block-level fixed effects and $X_{ijt}$ contains three dummy variables that capture seasonal differences in the survey months: May, June, or July, with reference to June. By adding those covariates, the following model is formed.

$$Y_{ijt} = \beta_0 + \beta_1 \cdot t + \beta_2 \cdot S_j + \beta_3 \cdot (S_j \cdot t) + X_{ijt} \cdot \gamma_1 + X_{jt} \cdot \gamma_2 + \epsilon_{ijt} \quad (2)$$

where $\gamma_1$ and $\gamma_2$.are the parameters to be estimated along with $\beta_0$ to $\beta_3$.

### 5.4.2 Estimation results

#### 5.4.2.1 Effect on the use of private wells

Table 5-7 reports the results of the DD estimations to analyze the ITT effect of the Project on the use of private well water. The installation of the piped water system reduced the usage rate of private wells by 11.8 percentage points in model 2 controlling for the block fixed effects. On the average, the Project reduced the use of private well water by 6.7 $m^3$ in model 4. As for individual water use, model 6 shows a decrease of 63.7 LPCD. These estimation results suggest a shift of their main water source from private well to the piped water system.

**Table 5-7　Double difference estimation on the use of water from private well**

| Model | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Dependent Variable | Use of private well (Yes=1) | | Monthly household water volume from private well (m3) | | Water use volume from the private well per day per capita (LPCD) | |
| Estiamation type | OLS | OLS | OLS | OLS | OLS | OLS |
| ***Treatment and year dummy variables*** | | | | | | |
| Treatment block * Year 2019 (=1) | -0.113*** | -0.118*** | -6.9*** | -6.7*** | -63.3*** | -63.7*** |
| (treatment_effect) | (0.039) | (0.036) | (2.6) | (2.5) | (21.0) | (20.1) |
| Year dummy | 0.004 | -0.011 | -16.0*** | -17.2*** | -119.3*** | -122.9*** |
| (2018/Baseline=0, 2019/End-line= 1) | (0.032) | (0.033) | (2.1) | (2.3) | (17.1) | (18.2) |
| Treatment block (=1) | -0.000 | | -0.4 | | 14.7 | |
| | (0.028) | | (1.8) | | (14.8) | |
| Household characteristics | | Included | | Included | | Included |
| Block fixed effect | | Included | | Included | | Included |
| R-squared | 0.019 | 0.236 | 0.156 | 0.280 | 0.147 | 0.280 |
| No. of observations | 1,582 | 1,582 | 1,582 | 1,582 | 1,582 | 1,582 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1500 kyat) as of May 2019.

5.4.2.2 Effect on the purchase of bottled water

Table 5-8 reports the results of the DD estimations to analyze the ITT effect of the Project on the purchase of bottled water. Seventy-seven percent (77%) of the households in treatment blocks and 81 percent in control blocks drink bottled water and spent an average of 5.7 thousand kyat in both blocks at time of the baseline survey, as shown in Table 5-6. With the installation of the new piped water system, households may switch from the use of bottled water to the piped water. Table 5-8 reports that the decision to purchase bottled water decreased by seven percentage points in model 2 and monthly bottled water expenditure decreased by 0.98 thousand kyat, which is approximately equivalent to the cost of three 20-liters bottles (model 6). This is a 17-percentage point decrease in the bottled water expenditure of households in the control block from the baseline survey. The shifting of drinking water source from bottled water to piped water can be attributed to the installation of the piped water system.

As of the endline survey, only 21.8 percent of the households in the treatment block drink piped water. The unit cost of piped water is much cheaper than that of bottled water. One liter of bottled water costs approximately 17 kyat, while the piped water costs 0.2 kyat per liter. Even though there is such a large difference in the unit cost, many households do not promptly change their drinking behavior. It may require more time for the households to change their behaviors of using piped water.

**Table 5-8 Double difference estimation on the purchase, volume, and expenditure of bottled water**

| Model | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Dependent Variable | Purchase of bottled water (Yes =1) | | Monthly volume of bottled water (Litter) | | Monthly expenditure of bottled water (1000kyat) | |
| Estiamation type | OLS | OLS | OLS | OLS | OLS | OLS |
| ***Treatment and year dummy variables*** | | | | | | |
| Treatment block * Year 2019 (=1) | -0.068 | -0.070* | -33.9 | -34.7 | -0.96* | -0.98** |
| (treatment_effect) | (0.047) | (0.042) | (28.7) | (26.0) | (0.54) | (0.49) |
| Year dummy | 0.045 | 0.005 | -33.6 | -50.8** | 0.17 | -0.11 |
| (2018/Baseline=0, 2019/End-line= 1) | (0.038) | (0.038) | (23.3) | (23.6) | (0.44) | (0.45) |
| Treatment block (=1) | -0.017 | | -7.1 | | -0.03 | |
| | (0.033) | | (20.3) | | (0.38) | |
| Household characteristics | | Included | | Included | | Included |
| Block fixed effect | | Included | | Included | | Included |
| R-squared | 0.004 | 0.262 | 0.013 | 0.250 | 0.006 | 0.234 |
| No. of observations | 1,582 | 1,582 | 1,582 | 1,582 | 1,582 | 1,582 |

Note: Standard errors are given in parentheses with stars indicating the following: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1500 kyat) as of May 2019.

### 5.4.2.3 Effect on the total volume of water use

Table 5-9 reports the results of the DD estimations to analyze the ITT effect of the Project on the total water use. Total water volume and expenditure in all water sources were combined. As for the ITT effect of the installation of piped water system, total monthly water use volume increased by 11.2 $m^3$ for a family of 4.7 members, and individual daily water use volume increased by 82 LPCD, which is 53 percent more compared to the households of the control blocks at time of the endline survey. As a result, the total monthly household expenditure on water increased by 2.8 thousand kyat. This is about 44 percent more of the average monthly total water expenditure of the households in the control blocks as of the endline survey.

**Table 5-9 Double difference estimation on the total volume and expenditure of water**

| Model | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Dependent Variable | Monthly household total water volume (m3) | | Total water volume of household member per day per capita (Litter per capita per day/ LPCD) | | Monthly household expenditure for water use (1000 kyat) | |
| Estiamation type | OLS | OLS | OLS | OLS | OLS | OLS |
| ***Treatment and year dummy variables*** | | | | | | |
| Treatment block * Year 2019 (=1) | 11.2*** | 11.2*** | 83*** | 82*** | 2.8*** | 2.8*** |
| (treatment_effect) | (2.8) | (2.7) | (23) | (22) | (0.6) | (0.6) |
| Year dummy | -16.0*** | -16.8*** | -120*** | -123*** | 0.1 | -0.2 |
| (2018/Baseline=0, 2019/End-line= 1) | (2.3) | (2.4) | (19) | (20) | (0.5) | (0.5) |
| Treatment block (=1) | -0.3 | | 15 | | -0.1 | |
| | (2.0) | | (16) | | (0.4) | |
| Household characteristics | | Included | | Included | | Included |
| Block fixed effect | | Included | | Included | | Included |
| R-squared | 0.044 | 0.179 | 0.043 | 0.205 | 0.052 | 0.259 |
| No. of observations | 1,582 | 1,582 | 1,582 | 1,582 | 1,582 | 1,582 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1500 kyat) as of May 2019.

## 5.5 Conclusion

This chapter examines the short-term impacts of the installation of the new piped water system on the water use of the urban population in Mandalay city, Myanmar. In the survey area, the residents mainly used private wells for general use and purchase bottled water for drinking purpose before the installation. After the installation, approximately 90 percent of the households connected with new piped water system with full subsidy on the connection fee in the treatment blocks. The installation of the piped water system reduced the usage of and consumption of water from private wells, suggesting a substitution from private well to piped water. Around 19.2 $m^3$ of piped water is used, while there is a decrease in the usage of private well water by 6.7 $m^3$. Even though the unit cost of pumping private well is marginal and that of piped water is much higher, households prefer to use piped water.

It is assumed that households prefer to use the piped water since it is convenient to use (convenience of use is one of the factors identified that can increase the demand for water). With the piped water, they can simply turn on the tap, whereas they need to pump and store water in the tank when they use private well. The piped water system reduced the burden and time to obtain water, thus they decided to use piped water even though the unit cost of the water is much higher than that of private well.

As for drinking behavior, it was expected that households would drink the piped water instead of bottled water. The unit cost of piped water for drinking purpose is much lower than that of bottled water, and the shift from bottled water to piped water would reduce expenditure for water use. Indeed, the piped water system reduced the ratio of households who purchase bottled water by seven percentage points, and monthly bottled water expenditure decreased by 0.98 thousand kyat, which is approximately equivalent to three large bottles. This is a 17-percent decrease relative to the bottled water expenditure of the households in the control blocks at the endline survey. Even though the reduction is not very large, the shifting of drinking water source from bottled water to piped water occurred with installation of piped water system.

In total, the installation of piped water increased the monthly household water use volume by 11.2 $m^3$ and individual daily water use volume by 82 LPCD, as compared to the water use volume of control blocks at the endline survey. Households in the treatment blocks spent more expenditure on water by 2.8 thousand kyat, which is equivalent to 44 percent more than the expenditure of the control blocks. These results suggest that the piped water system increased the demand for water in total and the water expenditure.

Lastly, although the new piped water system reduced the purchase of bottled water, this chapter revealed that only 22 percent of households drink the water at the time of the endline survey. This might be because the connected households do not like the chemical odor and taste of the piped water. To supply a safe and drinkable water is one of the important objectives in making a large investment on the construction of new piped water system. If households do not know the benefit of disinfected piped water and do not drink the water, the objective of the investment will not be fully achieved.

Therefore, the water service providers should discuss how to promote the drinking of piped water among households.

## Chapter 6 Examining the effect of the piped water on individual health

### 6.1 Background and research interest

Water-borne diseases have been one of the major causes of death in low- and middle- income countries. Contaminated water can transmit diseases such as diarrhea, cholera, dysentery, typhoid, and polio. With the great efforts to increase safe water access for decades, the situation has improved. The 2010 global burden of disease (GBD) study reported large declines in diarrheal diseases and the mortality from diarrheal diseases is reported to have fallen by 41.9 percent from 2.5 million in 1990 to 1.4 million in 2010 (Lozano et al. 2012). Nowadays, diarrheal death caused by contaminated drinking water is estimated at 485,000 each year (UN, 2019).

Previous literatures have found that some water treatment interventions such as filtering or chlorination had significant impact on reducing water-related illnesses (Clasen et al. 2006; Hunter 2009; Waddington et al. 2009; Cairncross et al. 2010). The systematic review on the impact of drinking safe water on diarrheal disease in low- and middle- income countries revealed that there are large risk reductions in diarrheal disease. The most effective household-level intervention is found to be the point-of-use filter in combination with safe water storage. At the community level, introduction of high-quality piped water is the most effective intervention (Wolf, et al., 2014). In the systematic review, it was confirmed that several water sanitation and hygiene interventions were associated with lower risk of diarrheal morbidity. Point-of-use filter interventions with safe storage reduced the risk of diarrhea by 61 percent. Higher quality of piped water within the premises and its continuous availability reduced diarrhea by 75 percent and 36 percent, respectively, compared to unimproved drinking water.

To reduce illness from contaminated water is one of the reasons for installing piped water system. The analysis using Demographic Health Survey (DHS) data from 1986 to

2010 in Peru revealed that access to piped water for drinking and flushing toilets or latrines reduced the prevalence of diarrhea. It was found that having access to piped water reduced the reported prevalence of diarrhea by 10 percent (Diaz & Andrade, 2015). The analysis using repeated cross-section data of rural South Africa illustrates that there is a positive and causal relationship between child health and piped water access (Wapenaar & Kollamparambil, 2019). On the other hand, there are some pieces of contrasting evidence on the impact of piped water on health. Lechtenfeld (2012) found that the provision of piped water in urban Yemen led to an increased prevalence of diarrhea in children under the poor management of water supply facilities. Hence, even though the number of studies examining the impact of piped water on health have increased, the results are mixed, depending on the circumstances surrounding the piped water facilities. This makes it worthy to analyze the impact of newly installed piped water system especially in urban area such as the city of Mandalay in Myanmar.

This study examines the impact of the installation of the piped water system on health using the incidence of abdominal pain, vomiting, and diarrhea as indicators. These health symptoms are caused by various reasons[20]. However, the major cause of these symptoms is the intake of contaminated foods and/or water, infected by various types of bacteria, viruses, and parasites. According to UNICEF (2022), diarrheal diseases are the leading cause of mortality in the world among children aged five years and below, and the major cause of these diarrheal diseases are pathogens spread by feces-contaminated water (WHO, 2017).

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[20] Abdominal pain can be caused by a broad spectrum of diseases from primarily trivial and self-limited (e.g. gastroenteritis) to acute and life-threatening conditions (e.g. abdominal aortic aneurysm) (Viniol, et al. 2014). Vomiting may be caused by problems in the gastrointestinal tract or central nervous system or may be a symptom of a number of systemic conditions (MSD). Diarrhea is a symptom of infections caused by a host of bacterial, viral and parasitic organisms. Infection is more common when there is inadequate sanitation, hygiene, and safe water for drinking, cooking and cleaning. Rotavirus and *Escherichia coli*, are the two most common etiological agents of moderate-to-severe diarrhea in low-income countries. Other diarrhea-causing pathogens also include *cryptosporidium* and *shigella* species (WHO, 2017).

Therefore, it is widely believed that supplying disinfected piped water would lead to the improvement of health outcomes. However, if the symptoms are caused by other pathways, disinfected piped water may not effectively reduce such health risks. In addition, it should be noted that some pathogens such as Cryptosporidium and Giardiasis have tolerance to chlorine. Hence, the health effect of piped water is highly dependent on the environmental conditions surrounding the households and whether the supply of chlorinated piped water reduces these symptoms is an empirical question.

## 6.2 Survey design

To examine the impact of installing the piped water system on health, the DD estimation method was employed. In this section, the surveyed households were selected as follows. In the water service blocks where the Project would supply piped water, there are some blocks with many factories or large grasslands but few residents. Those blocks were excluded because this research focuses on the water use of the habitants of residential area. Ninety-seven (97) blocks were remained as project blocks in five wards (Ngwe Taw Kyi Kone, Thin Pan Kone, Ga Nge, Ga Gyi and Nga). Of the 97 project blocks, 62 blocks were randomly selected as treatment blocks.

In the control blocks, which are outside of the water service blocks, the exhaustive block survey was conducted in April 2018. One hundred and twenty-four (124) non-project blocks in three wards (Thin Pan Kone, Kha Gway and Salone) were surveyed. Based on the block survey data, 33 control blocks which have similar characteristics as the treatment blocks were purposefully selected from non-project blocks. In total, there were 95 selected blocks composed of 62 treatment blocks and 33 control blocks. From each selected block, ten households were randomly chosen. Nine hundred and fifty (950) households were interviewed in the baseline survey in May and June of 2018.

Table 6-1 summarizes the number of sampled households in both the treatment and control blocks and the piped water use in the treatment blocks. At the endline survey, the number of the interviewed households was reduced to 791. Some households moved out, while other households refused to be interviewed or were unreached during the survey period. The attrition rate of households from baseline to endline survey are 15.8 percent in treatment blocks and 18.5 percent in control blocks.

The balance tests of water use and household characteristics of the surveyed blocks were carried out (Appendix 6-1). The water use situation is similar between treatment and control blocks. There is no statistically significant difference in listed variables aside from the individual schooling year. Regarding the characteristics of the blocks, the household and population densities were similar for treatment and control, which are typical residential areas in the Township. These households and blocks have similar and comparable characteristics, assuming that the parallel trend assumption holds.

**Table 6-1 Sampled Households and their piped water use**

| | Baseline survey | | End-line survey | | Attrition | |
|---|---|---|---|---|---|---|
| **Treatment blocks** | | | | | | |
| No of Block | 62 | | 62 | | | |
| No of HHs | 620 | (100.0) | 522 | (100.0) | 98 | (15.8) |
| No of HH members | 2,872 | (100.0) | 2,488 | (100.0) | 384 | (13.4) |
| Connect to piped water | | | 476 | (91.2) | | |
| Use piped water | | | 460 | (88.1) | | |
| Drink piped water | | | 114 | (21.8) | | |
| **Control blocks** | | | | | | |
| No of Block | 33 | | 33 | | | |
| No of HHs | 330 | (100.0) | 269 | (100.0) | 61 | (18.5) |
| No of HH members | 1,601 | (100.0) | 1,363 | (100.0) | 238 | (14.9) |

The table is compiled by the author.

## 6.3 Descriptive analysis of the impact of piped water on health

In order to examine the impact of installing the piped water system, three health symptoms: abdominal pain, vomiting, and diarrhea, were analyzed. Table 6-2 presents the descriptive analysis of these health symptoms for all household members, members that are of working age (17-60 years old), members that are of schooling age (6-16 years old), and those under 5 years old, in both treatment and control blocks.

In the analysis of the whole sample, there is no statistically significant difference between the treatment and control blocks at baseline survey. In the schooling age group, there is statistically significant difference in the diarrhea incidence at baseline survey. In other subgroups, there is no difference in any health symptom at the time of the baseline survey. The difference-in-differences of any symptoms in all the groups are not statistically significant.

**Table 6-2 Summary statistics of individual health incidence**

| Health related incidence (Individual level) | Treatment blocks | Control blocks | Diff. | Treatment blocks | Control blocks | Diff. | Diff. in Diff |
|---|---|---|---|---|---|---|---|
| | (A) | (B) | (C) | (D) | (E) | (F) | |
| ***(1) Whole sample*** | | | | | | | |
| ***No. of observations*** | 2,872 | 1,601 | | 2,488 | 1,363 | | |
| Abdominal pain incidence (=1) | 0.039 | 0.038 | 0.001 | 0.009 | 0.012 | -0.003 | -0.004 |
| Vomiting incidence (=1) | 0.012 | 0.014 | -0.001 | 0.003 | 0.007 | -0.003 | -0.002 |
| Diarrhea incidence (=1) | 0.014 | 0.009 | 0.005 | 0.003 | 0.003 | 0.000 | -0.005 |
| ***(2) Working age (17-60)*** | | | | | | | |
| ***No. of observations*** | 1650 | 842 | | 1620 | 834 | | |
| Abdominal pain incidence (=1) | 0.041 | 0.043 | -0.002 | 0.009 | 0.014 | 0.005** | -0.003 |
| Vomiting incidence (=1) | 0.010 | 0.015 | -0.005 | 0.001 | 0.006 | -0.005 | -0.000 |
| Diarrhea incidence (=1) | 0.012 | 0.008 | 0.004 | 0.003 | 0.004 | -0.001 | -0.004 |
| ***(3) Schooling age (6-16)*** | | | | | | | |
| ***No. of observations*** | 430 | 245 | | 448 | 252 | | |
| Abdominal pain incidence (=1) | 0.028 | 0.029 | -0.001 | 0.011 | 0.008 | 0.003 | -0.004 |
| Vomiting incidence (=1) | 0.005 | 0.008 | -0.003 | 0.007 | 0.008 | -0.001 | 0.002 |
| Diarrhea incidence (=1) | 0.014 | 0.000 | 0.014* | 0.002 | 0.000 | 0.002 | -0.012 |
| ***(4) Under five years old*** | | | | | | | |
| ***No. of observations*** | 146 | 94 | | 101 | 61 | | |
| Abdominal pain incidence (=1) | 0.021 | 0.021 | 0.000 | 0.010 | 0.000 | 0.010 | 0.011 |
| Vomiting incidence (=1) | 0.041 | 0.021 | 0.020 | 0.010 | 0.000 | 0.010 | -0.001 |
| Diarrhea incidence (=1) | 0.021 | 0.053 | -0.032 | 0.010 | 0.000 | 0.010 | 0.042 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
Health related incidence over the last two weeks reported by the respondents of the sampled households.

## 6.4 Estimation strategy

In order to rigorously examine the impact of the installation of the new piped water system on health symptoms, multivariate regression models were utilized. For this chapter, two types of impact estimates: (i) the mean project impact on all households in the treatment areas, which is the intention-to-treat (ITT) impact and (ii) the average treatment effect on the treated (ATT) impact on the households who use or drink the piped water, were examined.

For ITT estimation, double difference (DD) estimation was used. The basic specification for the DD methodology is as follows:

$$Y_{ijt} = \beta_0 + \beta_1 \cdot t + \beta_2 \cdot S_j + \beta_3 \cdot (S_j \cdot t) + \epsilon_{ijt} \quad (1)$$

where: i refers to an individual, j points to block and t is time ($t$ = 0 for baseline and $t$ = 1 for endline). This model estimates the ITT impact of the Project to measure the impact of the installation of new piped water system. $Yijt$ is the dependent variable and takes a continuous variable. Analysis for ITT may capture the underestimated impacts when compared with the average treatment effect. Yet, if ITT estimation confirms the positive impact of the Project, it can be interpreted that the Project caused the impact on individual health though it reports the underestimated impact.

The dependent variables are the incidences of abdominal pain, vomiting, and diarrhea experienced by the household members within two weeks prior to the conduct of the interview. Turning to the right-hand side variables, $S_j$ is a binary variable that takes the value 1 if the household is in the project block and 0 otherwise. $\beta_0$ to $\beta_3$ are the parameters to be estimated. $\beta_3$ is the parameter of our interest and measures the impact of the Project on the outcomes. $\epsilon_{ijt}$ is a well-behaved error term. The ordinary least squared (OLS) estimation was employed to estimate the coefficients.

The parallel trend assumption in the DD estimator may be violated if the changes caused by covariates are not common between the treatment and control blocks. Thus, we also employ an empirical model with some covariates because we examined if this is the case. The covariates take two forms (summary statistics of the covariates are shown in Appendix 6-2). $X_{ijt}$ is a vector that includes a set of household characteristics. $X_{ijt}$ contains three dummy variables that capture seasonal differences in the survey months: May, June, or July, with reference to June. $X_{ijkt}$ is a vector that includes a set of individual characteristics. The α contains variables that capture either block-level fixed effects, $\alpha_i$, or household fixed effects, $\alpha_k$. By adding these covariates, the following model is formed.

$$Y_{ijt} = \beta_0 + \beta_1 \cdot t + \beta_2 \cdot S_j + \beta_3 \cdot (S_j \cdot t) + X_{ijt} \cdot \gamma_1 + X_{ijkt} \cdot \gamma_2 + \alpha + \epsilon_{ijt} \quad (2)$$

where $\gamma_1$ and $\gamma_2$.are the parameters to be estimated along with $\beta_0$ to $\beta_3$.

In examining the ATT impact on the individual health outcomes, two types of estimation, which are Propensity score matching (PSM) and Propensity score (PS) weighted regression, were employed. A combination of DD estimation and PSM allow to circumvent the self-selection problem by controlling observable and unobservable variables that may affect the choice to use the piped water.

For the estimation with the combination of DD estimation and PSM, D = 1 if the household uses/drinks the piped water and D = 0 if they do not use/drink. The health outcome of being treated with piped water system and the counterfactual outcome are denoted by

$$DD = E(Y^T_{2019} - Y^T_{2018} \mid D = 1) - E(Y^T_{2019} - Y^c_{2018} \mid D = 0)$$
$$= E(Y^T_{2019} - Y^c_{2019} \mid D = 1) + (E(Y^T_{2019} \mid D = 1) - E(Y^c_{2019} \mid D = 0))$$
$$- (E(Y^T_{2018} \mid D = 1) - E(Y^c_{2018} \mid D = 0)) - E(Y^T_{2019} - Y^c_{2019} \mid D = 0)$$
$$- E(Y^T_{2018} - Y^c_{2018} \mid D = 1)$$
$$= E(Y^T_{2019} - Y^c_{2019} \mid D = 1) + \beta_{2019} - \beta_{2018} - M_{2019} - M_{2018}$$

where $\beta_t$ is the selection bias in period t and $M_{2019}$ is the difference of control and treatment blocks assuming without piped water use/drink in 2019 and $M_{2018}$ is the difference of control and treatment blocks assuming with piped water use/drink in 2018. If $M_{2019}$ and $M_{2018}$ are positive and selection bias is constant over time, the DD estimator will yield a lower bound of project impact conditioning on $\beta_{2019} = \beta_{2018}$.

If the initial household characteristics which may affect the health outcome are distributed differently between the treatment and the control blocks, the condition $\beta_{2019} = \beta_{2018}$ will not hold. To satisfy the condition, PS matching is employed to balance these variables. The assumption underlying PS matching is that, conditional on observables, changes in outcome variables, if untreated, are independent of actual treatment with the assumption $(Y_{2019}^{c} - Y_{2018}^{c}) \perp D|P(x)$, where the PS is defined as Prob(D=1|x) (Rosenbaum and Rubin 1983).

In addition to DD estimation with PSM, PS-weighted regression method (Hirano, Imbens, and Ridder 2003) was used. This provides an estimate of the ATT as parameter in the weighted least-square regression:

$$Y_{it} - Y_{i,t-1} = \alpha + \beta_2 \cdot D_i + \epsilon_i$$

Where i is the household ID. The weights are equal to one for treated observations and $\hat{P}(x)/(1 - \hat{P}(x))$ for non-treated observations.

To obtain consistent and efficient estimates, the common support region of PS is calculated based on the trimming method (Crump, Hotz, Imbens & Mitnik 2007). The estimations of PS weighted regression and DD estimation with PSM were conducted on the trimmed sample.

## 6.5 Estimation results of the impact of piped water on individual health

Table 6-3 presents the ITT impact of the installation of piped water system on each health symptom of household members. ITT was estimated controlling for household characteristics, block fixed effects or household fixed effects.

While all the results report a decrease of each health incidence, the differences are not statistically significant. The number of these incidence are not large even before the installation of the piped watery system. Since the ITT estimations include the households who do not use or drink piped water, the effects captured are underestimated. The ITT estimation results of the subgroups: working age members (17-60 years old), schooling age members (6-16 years old), and those members under 5 years old, are shown in Appendix 6-3, 6-4, and 6-5. The estimation results report no ITT impact in these samples.

The ATT impact on health outcomes on individuals who consider using and drinking of piped were examined. The estimation results of propensity score of piped water connection, use, and drinking in treatment blocks are presented in Appendix 6-6. By applying the same estimates, the predicted value of the propensity score in the control blocks were calculated. The comparison of the distribution of the propensity score in the treatment and control blocks are illustrated in Appendix 6-7 and 6-8. Appendix 6-7 presents the distribution of the values of propensity score of piped water use and Appendix 6-8 presents those of piped water drinking. The distributions of the values of propensity score are confirmed to be well-balanced.

Using these estimated propensity scores, the common support regions for the estimations were calculated. For ATT estimation of piped water use, the samples of which PS is over 0.94 were trimmed. For ATT estimation of piped water drinking, the samples of which PS is over 0.62 were trimmed.

Table 6-4 reports the estimation results of ATT of piped water use on the health symptoms. For vomiting incidence, PS weighted regression result reports a decrease of the incidence by 0.008. For diarrhea incidence, PS weighted regression and DID-PSM results report a decrease of the incidence by 0.011 and 0.010, respectively. From the estimation results of ATT of the use of piped water for the working age sample, more pronounced effect on the reduction of vomiting and diarrhea incidence are confirmed.

On the other hand, there is no statistically significant difference on the health incidences in the schooling age group. In the under 5 years old group, the vomiting incidence even increased. Such a result may be found since there are very limited cases of these health symptoms in the small sample size.

Table 6-5 presents the estimation results of ATT of drinking the piped water on the health symptoms. The impacts on health symptoms are not confirmed from any estimations. Since the drinking ratio of piped water among the households in the treatment block is only 21.8 percent, piped water drinking did not cause a decrease in the health incidence. The estimations among schooling age group even report an increase in vomiting and diarrhea incidences, and those of under 5 years old group also reports an increase in diarrhea incidence. The small number of incidence cases and the small sample size among subgroups might have caused such results.

**Table 6-3 DD estimation of individual health symptoms (Whole sample)**

| VARIABLES | abdominal pain | | vomiting incidence | | diarrhea incidence | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | ITT, Block FE | ITT, Household FE | ITT, Block FE | ITT, Household FE | ITT, Block FE | ITT, Household FE |
| Treatment and year dummy variables | | | | | | |
| Treatment block * year 2019(=1) | -0.005 | -0.005 | -0.001 | -0.002 | -0.005 | -0.006 |
| (treatment effect) | (0.007) | (0.007) | (0.004) | (0.004) | (0.004) | (0.004) |
| Year dummy | -0.021*** | -0.025*** | -0.007* | -0.006 | -0.006 | -0.005 |
| (2018=0, 2019= 1) | (0.007) | (0.006) | (0.004) | (0.004) | (0.004) | (0.004) |
| | | | | | | |
| Other control var | Included | Included | Included | Included | Included | Included |
| Block fixed effect | Included | | Included | | Included | |
| Household fixed effect | | Included | | Included | | Included |
| | | | | | | |
| Observations | 7,675 | 7,695 | 7,675 | 7,675 | 7,675 | 7,675 |
| R-squared | 0.029 | 0.010 | 0.020 | 0.004 | 0.024 | 0.006 |
| Number of HHID | | 796 | | 796 | | 796 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

**Table 6-4 Average treatment effect on treated of the piped water use on the individual health symptoms**

| Dependent variables | Abdominal pain incidence | | Vomiting incidence | | Diarrhea incidence | |
|---|---|---|---|---|---|---|
| Estimation model | (1) PSM | (2) PS weighted | (3) PSM | (4) PS weighted | (5) PSM | (6) PS weighted |
| **[1. Whole sample]** | | | | | | |
| drinking of piped water (=1) | -0.004 | -0.004 | -0.004 | -0.008* | -0.010** | -0.011*** |
| | (0.008) | (0.009) | (0.004) | (0.004) | (0.005) | (0.004) |
| Individual characteristics covariates | | Included | | Included | | Included |
| Observations | 2,962 | 2,962 | 2,962 | 2,962 | 2,962 | 2,962 |
| **[2) Working age between 17 - 60]** | | | | | | |
| drinking of piped water (=1) | -0.007 | -0.005 | -0.007 | -0.011** | -0.010* | -0.012** |
| | (0.011) | (0.012) | (0.005) | (0.005) | (0.006) | (0.005) |
| Individual characteristics covariates | | Included | | Included | | Included |
| Observations | 1,858 | 1,858 | 1,858 | 1,858 | 1,858 | 1,858 |
| **[Schooling age between age 6 and 16]** | | | | | | |
| drinking of piped water (=1) | 0.007 | 0.006 | 0.007 | 0.008 | -0.010 | -0.010 |
| | (0.017) | (0.020) | (0.009) | (0.012) | (0.009) | (0.008) |
| Individual characteristics covariates | | Included | | Included | | Included |
| Observations | 526 | 526 | 526 | 526 | 526 | 526 |
| **[Under 5 years old]** | | | | | | |
| drinking of piped water (=1) | -0.016 | -0.018 | 0.052* | 0.033* | 0.054 | 0.054 |
| | (0.030) | (0.028) | (0.029) | (0.020) | (0.038) | (0.038) |
| Individual characteristics covariates | | Included | | Included | | Included |
| Observations | 117 | 117 | 117 | 117 | 117 | 117 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

**Table 6-5 Average treatment effect on treated of the piped water drinking on the individual health symptoms**

| Dependent variables | Abdominal pain incidence | | Vomiting incidence | | Diarrhea incidence | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Estimation model | PSM | PS weighted | PSM | PS weighted | PSM | PS weighted |
| **[1. Whole sample]** | | | | | | |
| drinking of piped water (=1) | 0.007 | 0.012 | -0.006 | -0.004 | -0.001 | 0.000 |
| | (0.011) | (0.010) | (0.006) | (0.008) | (0.006) | (0.007) |
| Individual characteristics covariates | | Included | | Included | | Included |
| Observations | 3,467 | 3,467 | 3,467 | 3,467 | 3,467 | 3,467 |
| **[2) Working age between 17 - 60]** | | | | | | |
| drinking of piped water (=1) | -0.007 | -0.001 | -0.006 | -0.004 | -0.003 | 0.000 |
| | (0.014) | (0.013) | (0.007) | (0.008) | (0.007) | (0.008) |
| Individual characteristics covariates | | Included | | Included | | Included |
| Observations | 2198 | 2198 | 2198 | 2198 | 2198 | 2198 |
| **[Schooling age between age 6 and 16]** | | | | | | |
| drinking of piped water (=1) | 0.033 | 0.031 | 0.025** | 0.024 | 0.021* | 0.020* |
| | (0.021) | (0.022) | (0.012) | (0.016) | (0.011) | (0.011) |
| Individual characteristics covariates | | Included | | Included | | Included |
| Observations | 608 | 608 | 608 | 608 | 608 | 608 |
| **[Under 5 years old]** | | | | | | |
| drinking of piped water (=1) | 0.009 | -0.003 | 0.080** | 0.070 | -0.045 | -0.032 |
| | (0.041) | (0.084) | (0.040) | (0.054) | (0.052) | (0.058) |
| Individual characteristics covariates | | Included | | Included | | Included |
| Observations | 130 | 130 | 130 | 130 | 130 | 130 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

## 6.6 Conclusion

This chapter examines the impact of the installation of the piped water system on individual health symptoms such as abdominal pain, vomiting, and diarrhea. If the people use and drink the disinfected piped water, it is expected that the incidence of these health symptoms may decrease.

From the ITT estimation results, the decreases of health symptoms are not confirmed. ITT estimation captures the underestimated impact since it includes the households without the piped water. The ATT estimation results of the piped water users report a decrease in vomiting and diarrhea incidences, while the impact of piped water drinking in improving the individual health of the piped water drinkers is not found. From these results, it can be said that the use of piped water would provide a positive impact in decreasing the vomiting and diarrhea incidences by allowing the people to use the disinfected water. The ratio of bottled water use in the treatment blocks at the endline survey is high at 70.3 percent. Meanwhile, the drinking ratio of the piped water is merely 21.8 percent. Therefore, the health impact is caused by using the piped water, not by drinking the water. From the results of the previous chapter, the usage ratio of bottled water has decreased by seven percentage points. The shift from bottled water to piped water with the installation of the piped water system somewhat occurred, but the shift is still on-going.

From the ATT estimation results for piped water use, it was found that the use of piped water leads to reduction of vomiting and diarrhea incidences. On a day-to-day basis, people use large amount of water for various purposes such as cooking, bathing, or for toilet use. The water use volume for these daily uses is much larger than the drinking volume. For cooking purpose, 52 percent of the households in the treatment blocks at the baseline survey used the private well water for cooking, and the ratio of use for cooking decreases to 35 percent at the endline survey. Meanwhile, 65 percent of the households in the treatment blocks use the piped water for cooking at the endline survey. If households use the water without sterilizing for their meals, there is a possibility that they may have consumed contaminated water. The shift of using private well water to piped water for cooking purpose may have caused the decrease in vomiting and diarrhea incidences. Aside from cooking, there is also possibility that the household may have consumed the contaminated water through the various activities. For example, they may ingest the water while bathing. Also, if they wash their hands with contaminated water, they may have more health risks. Yet, if they use the disinfected piped water, those risks would decrease.

Even though the existence of *E. coli* in the water of the households' main water sources is detected by the water quality test kits, there is a possibility that the water is contaminated with other pathogens which may cause the vomiting and diarrhea incidence.

Increasing the volume of safe water can also improve the health conditions especially of those households who do not own private wells at the baseline survey. Their total water use volume is much lower than other households' water use volume. They needed to go and fetch water from the other people’s water sources and store them in a jar or water tank. There is a higher risk of contamination by pathogens when the household members carry the water from outside and store it at home. If they shift to the piped water, they may have lesser risk in consuming contaminated water.

The installation of a new piped water system has the potential to improve the health conditions even if the household members do not drink it. The use of piped water for cooking is considered as one of the possible ways to improve their health conditions. In the survey areas, many households own their private wells and purchase bottled water before the installation of the piped water system. Even if the piped water is not used for drinking purpose, the disinfected piped water would have the potential to improve the people’s health condition in the urban area

# Chapter 7 Examining the effect of the piped water on individual activities

## 7.1 Background and research interest

A large number of literatures report that women in low- and middle- income countries spend long time on domestic works and too little time on other productive tasks, including wage employment (Ferrant, Pesando, & Nowacka 2014; Fletcher, Pande, & Moore 2017). Many girls spare their time for fetching water and have lost schooling opportunities. Graham et al. (2016) estimated that 3.4 million children and 13.5 million adult females in 24 sub-Saharan countries were responsible for water collection (with the collection time of more than 30 minutes. In a cross-country analysis focusing nine low- and middle- income countries, it was found that a reduction in the time spent for accessing water is positively correlated with women's off-farm work in countries such as Yemen, Uganda, and Nepal. It also improves children's enrolment in schools in countries such as Yemen, Morocco, Nepal, and Pakistan (Koolwal and Van de Walle, 2013).

If there is a better access of water supply, household members will not be burdened in obtaining water and can afford to spare the saved time for other activities such as salaried work, schooling, or leisure. Accordingly, the intra-household allocation of time and tasks among household members may change. Piped water within the households' premises is one of the potential measures to address the burden of obtaining water (Ilahi and Grimard, 2000; Dinkelman, 2011). In Western Kenya, the piped water supply has reduced the work of women and girls in seven rural communities (Crow, et al., 2012).

In addition to reduced time for obtaining water, the better quality of water supply which may improve the household's health condition may also change the time allocation of the household for various activities. In the previous chapter, this research confirms that the Project caused a positive impact on health of the household members, reducing the vomiting and diarrhea incidences. If the working age members are suffering from those symptoms and are refrain from working, their earnings would decrease. In case other household members such as a young child have a sickness, the adult needs to take care of the child. If the members have better health condition from using safe water, the household members could afford to spare their time for other activities including labor force participation or schooling.

There are very limited number of literatures that examined the impact of piped water supply intervention on individual activities, especially in urban area of low- and middle-income countries.[21] Sedai (2021) examined the impact of the access to indoor piped drinking water in India using the nationwide panel data of 2005 and 2012. He assessed the heterogeneous effects in both rural and urban areas and found that the time spent for water collection in urban areas did not change, while it decreased in rural areas by six minutes. Regarding employment of both male and female in rural areas, the likelihood of any employment increased by one percent, while the effect on employment is not confirmed in urban areas. On the other hand, Devoto, et al. (2012) examined the piped water connection in the premises of the urban area in Morocco and found that private connections to piped water could increase the households' leisure time and social activities.

Previous literatures have examined the impacts of access to a new water supply on individual or aggregate (household) level. The intra-household allocation of resources especially of the use of time needs more attention since there may be heterogenous impact by gender or by age. As described, more women and girls are engaged in domestic works including fetching water. The time spent by male and female in accomplishing these tasks is not necessarily equal. Gross, et al. (2017) found that while

[21] Cuong & Thieu (2013) measured the effects of piped water on both rural and urban Vietnamese household welfare including income, working effort and sickness using the nationwide household survey data. By employing DD estimation with propensity score matching, they found that the effects of piped water on household income and labor supply are positive, but not statistically significant.

the installation of improved water supply in rural Benin reduces the average time for one roundtrip to collect water, the women are continuously engaged in fetching much more than men. The men are the first to be relieved from the burden of water fetching activities. Hence, the benefit of these water supply interventions varies between gender.

In the Project, the new piped water system was installed in the area without existing piped water system. Many households have their private wells in their premises and spend much time for pumping water. If they use the piped water and are released from pumping work, the household member engaged in pumping activities would have opportunities to work outside or to go to school. This chapter analyzes the impact of the installation of piped water system on the working or schooling status of the adult members, adolescent members, and young children in urban area, considering the heterogeneous effect by gender.

## 7.2 Survey design

In this chapter, the impact of the installation of the piped water system on individual activities, working, and schooling of the household members are examined by employing the DD estimation methodology. The same sample analyzed in Chapter 6 is used. There were 95 selected blocks composed of 62 treatment blocks and 33 control blocks. From each selected block, ten households were randomly chosen. After selecting whole survey samples, subgroup of adult members between 19-60 years old, subgroup of adolescent members between 15-18 years old, and the subgroup of young schooling-age children between 6-14 years old at the time of the endline survey were selected for the following analyses.

Table 7-1 summarizes the number of sampled households in both treatment and control blocks and the piped water use in the treatment blocks. At the endline survey, the number of the interviewed households was reduced to 791. Some households moved out, while other households refused to be interviewed or were unreached during the survey period. The attrition rate of households from the baseline to endline surveys are 15.8 percent and 18.5 percent, respectively in treatment and control blocks.

The balance tests of water use and household characteristics of the surveyed blocks were carried out (Appendix 6-1). The water use situation is similar between treatment and control blocks. There are no statistically significant differences in listed variables aside from the individual schooling year. For characteristics of the blocks, the household and population densities were similar between treatment and control blocks, which are typical residential areas in the Township. These households and blocks have similar and comparable characteristics, assuming that the parallel trend assumption holds.

**Table 7-1 Sampled Households and their piped water use**

| | Baseline | End-line | | Attrition | |
|---|---|---|---|---|---|
| **Treatment blocks** | | | (%) | | (%) |
| No of Block | 62 | 62 | | | |
| No of HHs | 620 | 522 | | 98 | (15.8) |
| No of HH members | 2,872 | 2,488 | | 384 | (13.4) |
| No of working-age members (19-60) | 1,820 | 1,598 | | 222 | (12.2) |
| No of adolescent members (15-18) | 193 | 167 | | 26 | (13.5) |
| No of schiooling-age children (6-14) | 398 | 360 | | 38 | (9.5) |
| Connect to piped water | | 476 | (91.2) | | |
| Use piped water | | 460 | (88.1) | | |
| Drink piped water | | 114 | (21.8) | | |
| **Control blocks** | | | | | (%) |
| No of Block | 33 | 33 | | | |
| No of HHs | 330 | 269 | | 61 | (18.5) |
| No of HH members | 1,601 | 1,363 | | 238 | (14.9) |
| No of working-age members (19-60) | 969 | 834 | | 135 | (13.9) |
| No of adolescent members (15-18) | 113 | 99 | | 14 | (12.4) |
| No of schiooling-age children (6-14) | 230 | 205 | | 25 | (10.9) |

The table is compiled by the author.

7.3 Descriptive analysis of the pumping labor of the private well

At the baseline survey, the households spent an average of 86 minutes for pumping water from private well. Tables 7-2, 7-3 and 7-4 present the summary statistics of the ratio of the household members who are engaged in pumping of each sub-sample.

In the working age sample, about 60 percent of the total household members are engaged in pumping of the private wells at the baseline survey, and the difference between treatment blocks and control blocks are statistically significant. More household members in treatment blocks are engaged in pumping. In the adolescent sample, 42 percent of household members in treatment blocks and 33 percent in the control blocks are engaged in pumping, but the difference is not statistically significant. In the young children sample, about 14 percent of children between 6 to 14 years old are engaged in pumping. The difference of the ratio is not statistically significant. The adult members are the main actors of the pumping work, and the adolescent members are also engaged in the work.

**Table 7-2 Summary statistics of pumping private well water in the working age sample (19-60 years old)**

| | Baseline survey | | | End-line survey | | | |
|---|---|---|---|---|---|---|---|
| Pumping private well water (=1) | Treatment blocks | Control blocks | Diff. | Treatment blocks | Control blocks | Diff. | Diff. in Diff |
| | (A) | (B) | (C) | (D) | (E) | (F) | |
| ***(All: 19-60)*** | | | | | | | |
| ***No. of observations*** | 1,567 | 806 | | 1536 | 798 | | |
| working (=1) | 0.684 | 0.594 | 0.090*** | 0.540 | 0.650 | -0.110*** | -0.200*** |
| | (0.012) | (0.684) | (0.021) | (0.013) | (0.017) | (0.021) | (0.030) |
| ***(Male: 19-60)*** | | | | | | | |
| ***No. of observations*** | 687 | 361 | | 671 | 358 | | |
| working (=1) | 0.587 | 0.504 | 0.082*** | 0.492 | 0.623 | -0.131*** | -0.214*** |
| | (0.019) | (0.026) | (0.032) | (0.019) | (0.026) | (0.032) | (0.046) |
| ***(Female: 19-60)*** | | | | | | | |
| ***No. of observations*** | 880 | 445 | | 865 | 440 | | |
| working (=1) | 0.650 | 0.587 | 0.063*** | 0.577 | 0.673 | -0.096*** | -0.159*** |
| | (0.016) | (0.023) | (0.028) | (0.017) | (0.022) | (0.028) | (0.040) |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
The table is compiled by the author.

**Table 7-3 Summary statistics of pumping private well water in the adolescent sample (15-18 years old)**

| | Baseline survey | | | End-line survey | | | |
|---|---|---|---|---|---|---|---|
| Pumping private well water (=1) | Treatment blocks | Control blocks | Diff. | Treatment blocks | Control blocks | Diff. | Diff. in Diff |
| | (A) | (B) | (C) | (D) | (E) | (F) | |
| ***(All: 15-18)*** | | | | | | | |
| ***No. of observations*** | 161 | 93 | | 167 | 99 | | |
| working (=1) | 0.416 | 0.333 | 0.083 | 0.365 | 0.475 | -0.110* | -0.192** |
| | (0.039) | (0.049) | (0.063) | (0.037) | (0.050) | (0.062) | (0.089) |
| ***(Male: 15-18)*** | | | | | | | |
| ***No. of observations*** | 86 | 35 | | 80 | 45 | | |
| working (=1) | 0.384 | 0.343 | 0.041 | 0.375 | 0.355 | 0.020 | -0.021 |
| | (0.053) | (0.081) | (0.098) | (0.054) | (0.072) | (0.091) | (0.133) |
| ***(Female: 15-18)*** | | | | | | | |
| ***No. of observations*** | 75 | 58 | | 87 | 54 | | |
| working (=1) | 0.453 | 0.328 | 0.126 | 0.356 | 0.574 | -0.218*** | -0.343*** |
| | (0.058) | (0.062) | (0.086) | (0.052) | (0.068) | (0.085) | (0.120) |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
The table is compiled by the author.

**Table 7-4 Summary statistics of pumping private well water in the young children sample (6-14 years old)**

| | Baseline survey | | | End-line survey | | | |
|---|---|---|---|---|---|---|---|
| Pumping private well water (=1) | Treatment blocks | Control blocks | Diff. | Treatment blocks | Control blocks | Diff. | Diff. in Diff |
| | (A) | (B) | (C) | (D) | (E) | (F) | |
| ***(All: 6-14)*** | | | | | | | |
| ***No. of observations*** | 328 | 188 | | 360 | 205 | | |
| Student (=1) | 0.143 | 0.133 | 0.010 | 0.130 | 0.141 | -0.011 | -0.022 |
| | (0.019) | (0.025) | (0.032) | (0.018) | (0.024) | (0.030) | (0.044) |
| ***(Male: 6-14)*** | | | | | | | |
| ***No. of observations*** | 179 | 95 | | 178 | 89 | | |
| Student (=1) | 0.140 | 0.147 | -0.008 | 0.133 | 0.178 | -0.046 | -0.038 |
| | (0.026) | (0.037) | (0.045) | (0.024) | (0.038) | (0.043) | (0.062) |
| ***(Female: 6-14)*** | | | | | | | |
| ***No. of observations*** | 149 | 93 | | 148 | 89 | | |
| Student (=1) | 0.148 | 0.118 | 0.029 | 0.128 | 0.106 | 0.022 | -0.007 |
| | (0.029) | (0.018) | (0.046) | (0.026) | (0.030) | (0.041) | (0.061) |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
The table is compiled by the author.

## 7.4 Descriptive analysis of the impact of piped water on working status

In the survey data, primary activities of each household member are categorized into: salaried work (full time/part time), self-employment, casual labor, family chore, retirees, student, dependent and unemployed.

Table 7-5 presents the working status among the working age household members (19 - 60 years old): 29.4 percent are engaged in salaried work, 2.6 percent in casual labor, and 28.3 percent are self-employed. This means that about 60 percent are engaged in any of these three jobs. The male working ratio is 79 percent, while female working ratio is 45 percent.

In the endline survey, the detailed industrial category of each working type is surveyed as shown in Appendix 7-1a, 7-1b, and 7-1c. For salaried work, the major categories in the total sample are: 1) wholesale and retail trade (10%), 2) manufacturing (13%), 3) construction work (12%), and 4) food and beverage production (11%). Among male members, construction work (19%) and transport (17%) are the two major categories. Meanwhile, among female members, wholesale and retail trade (13%), manufacturing (15%), food and beverage production (17%), and teaching (15%) are the major categories. In the self-employment sample, 30 percent of members are engaged in wholesale and retail trade. Forty-six (46) percent of female members work in this sector. Male members work in wholesale and retail trade (17%), repairing of vehicles and goods (15%), construction work (15%), and transport (21%), and food and beverage production (11%). In the casual labor sample, 40 percent of members work in construction sector and more than 50 percent of male members work in this sector. Female members work primarily in food and beverage production sector (19%).

Between gender, there are large differences in the working ratio and the sectors they engaged in. The working ratio of male member is much higher than that of female members. Male members work in labor-intensive sectors such as construction and transport while many female members work in the wholesale and retail trade of the self-employment such as selling at a small kiosk by the street.

**Table 7-5 Summary of working status of household members aged 19 – 60 years old (baseline survey)**

| Type of workig situation | Wage work | | Self-employment (%) |
|---|---|---|---|
| | Salaried work (%) | Casual labor (%) | |
| All | 29.4 | 2.6 | 28.3 |
| Male | 39.4 | 4.3 | 35.4 |
| Femalie | 21.4 | 1.2 | 22.7 |

Note: The table is compiled by the author.

In order to examine the impact of installing piped water system on the working status, the sample of working age members (19-60 years old) and the sample of adolescent members (15-18 years old) were analyzed. If the members are engaged in any works (full time employment, part time employment, casual work, and self-employment), the working status is one, and zero otherwise. For the sample of working age members (19-60 years old), another dummy variable for the working status of either family chore or unemployment is also constructed. It is considered that these household members engage in the domestic works and have the potential capacity to have the paid work.

Table 7-6 presents the summary statistics of the working status of the working age sample in the treatment and control blocks at baseline and endline surveys. There is no statistically significant difference in the working status of all sample, male sample, and female sample at the baseline survey. The impact on the working status, which is the difference-in-differences in the last row of the table, is not confirmed in all samples.

Table 7-7 presents the summary statistics of working status of the adolescent age members in the treatment and control blocks at baseline and endline surveys. There is no statistically significant difference in the working status of all sample and female sample, while the working ratio of male members in the control blocks is significantly higher than the working ratio in the treatment block at the baseline survey. At the endline survey, the working ratio of male members increased while that of female members decreased largely. However, the difference-in-differences of the working status in male sample is not confirmed. The difference-in-differences of working ratio in all the three samples are not statistically significant.

**Table 7-6 Summary statistics of working status of working age sample (19-60 years old)**

| Working status (working =1) | Baseline survey | | | End-line survey | | | |
|---|---|---|---|---|---|---|---|
| | Treatment blocks | Control blocks | Diff. | Treatment blocks | Control blocks | Diff. | Diff. in Diff |
| | (A) | (B) | (C) | (D) | (E) | (F) | |
| ***(All: 19-60)*** | | | | | | | |
| ***No. of observations*** | 1,567 | 806 | | 1536 | 798 | | |
| working (=1) | 0.595 | 0.617 | -0.022 | 0.665 | 0.669 | -0.004 | 0.018 |
| | (0.012) | (0.017) | (0.021) | (0.012) | (0.017) | (0.021) | (0.030) |
| ***(Male: 19-60)*** | | | | | | | |
| ***No. of observations*** | 687 | 361 | | 671 | 358 | | |
| working (=1) | 0.778 | 0.814 | -0.036 | 0.852 | 0.872 | -0.019 | 0.017 |
| | (0.016) | (0.020) | (0.026) | (0.014) | (0.018) | (0.023) | (0.035) |
| ***(Female: 19-60)*** | | | | | | | |
| ***No. of observations*** | 880 | 445 | | 865 | 440 | | |
| working (=1) | 0.452 | 0.456 | -0.004 | 0.519 | 0.505 | 0.015 | 0.019 |
| | (0.016) | (0.023) | (0.029) | (0.017) | (0.024) | (0.029) | (0.035) |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
The table is compiled by the author.

**Table 7-7 Summary statistics of working status of adolescent age sample (15-18 years old)**

| Working status (working =1) | Baseline survey | | | End-line survey | | | |
|---|---|---|---|---|---|---|---|
| | Treatment blocks | Control blocks | Diff. | Treatment blocks | Control blocks | Diff. | Diff. in Diff |
| | (A) | (B) | (C) | (D) | (E) | (F) | |
| ***(All: 15-18)*** | | | | | | | |
| ***No. of observations*** | 161 | 93 | | 167 | 99 | | |
| working (=1) | 0.137 | 0.156 | -0.019 | 0.180 | 0.212 | -0.033 | -0.029 |
| | (0.019) | (0.026) | (0.032) | (0.030) | (0.041) | (0.050) | (0.063) |
| ***(Male: 15-18)*** | | | | | | | |
| ***No. of observations*** | 86 | 35 | | 80 | 45 | | |
| working (=1) | 0.0465 | 0.1428 | -0.096 * | 0.200 | 0.333 | -0.133* | -0.037 |
| | (0.023) | (0.060) | (0.052) | (0.045) | (0.071) | (0.080) | (0.098) |
| ***(Female: 15-18)*** | | | | | | | |
| ***No. of observations*** | 75 | 58 | | 87 | 54 | | |
| working (=1) | 0.147 | 0.069 | 0.078 | 0.161 | 0.111 | 0.050 | -0.028 |
| | (0.016) | (0.034) | (0.016) | (0.040) | (0.043) | (0.061) | (0.082) |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
The table is compiled by the author.

## 7.5 Descriptive analysis of the impact of piped water on schooling

In order to examine the impact of installing the piped water system on schooling, schooling of adolescent members (15-18 years old) and young children (6-14 years old) were analyzed. Six-year-old children in Myanmar enter primary schools and complete the lower secondary (middle school) education at 14 years old. Those who are aged 15 and 16 years old are in higher secondary (high school) and those between 16 to 20 years old are in universities. Only a small proportion (7.3 percent) of the population aged 25 and over graduate from a university or pursue higher level of education (MOIP, 2017).

Tables 7-8 and 7-9 present the descriptive analysis of the schooling of adolescent members (15-18 years old) and young children (6 - 14 years old). If the category of primary activities is student, the dummy variable of schooling is one and zero otherwise. There is no statistically significant difference in schooling between treatment and control blocks at baseline in both tables. The difference-in-differences on schooling is not confirmed as well.

**Table 7-8 Summary statistics of schooling status of adolescent age sample (15-18 years old)**

| | Baseline survey | | | End-line survey | | | |
|---|---|---|---|---|---|---|---|
| Working status (working =1) | Treatment blocks | Control blocks | Diff. | Treatment blocks | Control blocks | Diff. | Diff. in Diff |
| | (A) | (B) | (C) | (D) | (E) | (F) | |
| ***(All: 15-18)*** | | | | | | | |
| ***No. of observations*** | 161 | 93 | | 167 | 99 | | |
| Student (=1) | 0.801 | 0.839 | -0.038 | 0.671 | 0.717 | -0.047 | -0.009 |
| | (0.032) | (0.038) | (0.051) | (0.036) | (0.045) | (0.059) | (0.078) |
| ***(Male: 15-18)*** | | | | | | | |
| ***No. of observations*** | 86 | 35 | | 80 | 45 | | |
| Student (=1) | 0.791 | 0.829 | -0.038 | 0.663 | 0.600 | 0.063 | 0.100 |
| | (0.044) | (0.065) | (0.081) | (0.050) | (0.074) | (0.090) | (0.122) |
| ***(Female: 15-18)*** | | | | | | | |
| ***No. of observations*** | 75 | 58 | | 87 | 54 | | |
| Student (=1) | 0.813 | 0.845 | -0.031 | 0.678 | 0.815 | -0.137* | -0.105 |
| | (0.045) | (0.048) | (0.067) | (0.050) | (0.053) | (0.079) | (0.102) |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
The table is compiled by the author.

**Table 7-9 Summary statistics of schooling status of children between ages 6 – 14**

| | Baseline survey | | | End-line survey | | | |
|---|---|---|---|---|---|---|---|
| Working status (working =1) | Treatment blocks | Control blocks | Diff. | Treatment blocks | Control blocks | Diff. | Diff. in Diff |
| | (A) | (B) | (C) | (D) | (E) | (F) | |
| ***(All: 6-14)*** | | | | | | | |
| ***No. of observations*** | 328 | 188 | | 360 | 205 | | |
| Student (=1) | 0.979 | 0.973 | 0.005 | 0.963 | 0.966 | -0.003 | -0.008 |
| | (0.008) | (0.012) | (0.014) | (0.010) | (0.013) | (0.021) | (0.021) |
| ***(Male: 6-14)*** | | | | | | | |
| ***No. of observations*** | 179 | 95 | | 178 | 89 | | |
| Student (=1) | 0.978 | 0.979 | -0.001 | 0.954 | 0.980 | -0.026 | -0.025 |
| | (0.011) | (0.015) | (0.019) | (0.015) | (0.014) | (0.023) | (0.030) |
| ***(Female: 6-14)*** | | | | | | | |
| ***No. of observations*** | 149 | 93 | | 148 | 89 | | |
| Student (=1) | 0.980 | 0.968 | 0.012 | 0.976 | 0.952 | 0.024 | 0.012 |
| | (0.012) | (0.018) | (0.021) | (0.012) | (0.021) | (0.023) | (0.031) |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
The table is compiled by the author.

## 7.6 Estimation strategy

In order to rigorously examine the impact of the installation of the new piped water system on working status and schooling, multivariate regression models were utilized. For this chapter, two types of impact estimates: (i) the mean project impact on all households in the treatment areas, which is the intention-to-treat (ITT) impact, and (ii) the average treatment effect on the treated (ATT) impact on households who use the piped water, were examined. In examining ATT impact on the individual activity outcomes, two types of estimation were employed: Propensity score matching (PSM) and Propensity score (PS) weighted regression. For these estimations, the same estimation model as shown in chapter 6 to examine the impact on individual health outcomes was used. The methodological explanation of the estimation model is also discussed in chapter 6.

The dependent variables are the working status and schooling status, which are dummy variables. The same covariates are used for the estimation and the summary statistics of the covariates are shown in Appendix 6-2.

## 7.7 Estimation results of the impact of piped water use on pumping labor

Table 7-10 presents the ITT estimation results of the impact of the piped water use on pumping activities of working age sample by using DD estimation methodology. At the baseline survey, there is statistically significant difference on the ratio of pumping engagement between treatment and control blocks. The household members in treatment blocks pump the private well more than the those in control blocks by nine percent. Even though the difference at the baseline survey is relatively large, the DD estimation results in Table 7-10 presents large reduction of the ratio of household members engaged in pumping (by 17 percentage points in all sample).

From gender disaggregated sample, the ratio of pumping labor engagement decreased by 19.4 percentage points in male sample (model 4) and 15.1 percentage points in female sample (model 6). Table 7-11 shows the ATT estimation results of the households who used the piped water. The ratio of pumping labor engagement decreased by 19.2 percentage points in all sample, 21.6 percentage points in male sample, and 17.6 percentage points in female sample. There are statistically significant differences in the ratio of pumping labor engagement of the working age sample from the baseline survey. The ratio of pumping labor engagement in the treatment blocks is higher than that in control blocks by nine percent in all sample. Yet, the households in treatment blocks and control blocks are considered to be comparable since the parallel trend shift is assumed to be kept under the similar characteristics of the blocks, households, and the members between those blocks.

For adolescent age sample, Table 7-12 presents the ITT estimation results and Table 7-13 presents the ATT estimation results of the impact of the piped water use on pumping activities. From the ITT results, no impact is found in all sample and male sample, but there is a large reduction of pumping work in female sample by 28.3 percentage points (model 6). The ATT estimation results with PSM and PS weighted regression presents 21.8 percentage points decrease in the pumping engagement in all sample and 28.6 percentage points decrease in the female sample, while there is no impact found in the male sample.

The estimation results of young children sample do not present any impact of the piped water use on the pumping activities (Table 7-14).

**Table 7-10 DD estimation of the impact on pumping activities in the working age sample (19-60 years old)**

| VARIABLES | All sample | | Male sample | | Female sample | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Dependent variable: Pumping of private well (=1) | ITT, Block FE | ITT, Household FE | ITT, Block FE | ITT, Household FE | ITT, Block FE | ITT, Household FE |
| Treatment and year dummy variables | | | | | | |
| Treatment block * year 2019(=1) | -0.171*** | -0.172*** | -0.199*** | -0.194*** | -0.151*** | -0.151*** |
| (treatment_effect) | (0.029) | (0.024) | (0.044) | (0.037) | (0.038) | (0.030) |
| Year dummy | 0.027 | 0.038* | 0.044 | 0.041 | 0.017 | 0.032 |
| (2018=0, 2019= 1) | (0.026) | (0.022) | (0.040) | (0.033) | (0.034) | (0.028) |
| | | | | | | |
| Other control var | Included | Included | Included | Included | Included | Included |
| Block fixed effect | Included | | Included | | Included | |
| Household fixed effect | | Included | | Included | | Included |
| | | | | | | |
| Observations | 4,690 | 4,690 | 2,064 | 2,064 | 2,626 | 2,626 |
| R-squared | 0.139 | 0.072 | 0.145 | 0.060 | 0.168 | 0.081 |
| Number of HHID | | 780 | | 710 | | 759 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

**Table 7-11 Average treatment effect on treated of the piped water use on pumping activities in the working age sample (19-60 years old)**

| Pumping of private well (=1) | (1) Propensity score matching | (2) Propensity score weighted regression |
|---|---|---|
| **(All: 19-60)** | | |
| Pumping of private well (=1) | -0.199*** | -0.192*** |
| | (0.024) | (0.024) |
| Observations | 2,096 | 2,096 |
| **(Male: 19-60)** | | |
| Pumping of private well (=1) | -0.219*** | -0.216*** |
| | (0.039) | (0.040) |
| Observations | 912 | 912 |
| **(Female: 19-60)** | | |
| Pumping of private well (=1) | -0.183*** | -0.176*** |
| | (0.030) | (0.030) |
| Observations | 1,184 | 1,184 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

**Table 7-12 DD estimation of the impact on pumping activities in adolescent sample (15-18 years old)**

| VARIABLES | All sample | | Male sample | | Female sample | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Dependent variable: Pumping of private well (=1) | ITT, Block FE | ITT, Household FE | ITT, Block FE | ITT, Household FE | ITT, Block FE | ITT, Household FE |
| Treatment and year dummy variables | | | | | | |
| Treatment block * year 2019(=1) | -0.138 | -0.128 | 0.002 | 0.099 | -0.253** | -0.283** |
| (treatment_effect) | (0.086) | (0.087) | (0.136) | (0.147) | (0.111) | (0.112) |
| Year dummy | 0.010 | 0.014 | -0.113 | -0.167 | 0.141 | 0.147 |
| (2018=0, 2019= 1) | (0.078) | (0.081) | (0.132) | (0.147) | (0.098) | (0.101) |
| | | | | | | |
| Other control var | Included | Included | Included | Included | Included | Included |
| Block fixed effect | Included | | Included | | Included | |
| Household fixed effect | | Included | | Included | | Included |
| | | | | | | |
| Observations | 520 | 520 | 246 | 246 | 274 | 274 |
| R-squared | 0.323 | 0.056 | 0.446 | 0.156 | 0.498 | 0.156 |
| Number of HHID | | 273 | | 144 | | 161 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

**Table 7-13 Average treatment effect on treated of the piped water use on pumping activities in adolescent sample (15-18 years old)**

| Pumping of private well (=1) | (1) Propensity score weighted regression | (2) Propensity score matching |
|---|---|---|
| **(All: 15-18)** | | |
| Pumping of private well (=1) | -0.218** | -0.215** |
| | (0.091) | (0.098) |
| Observations | 198 | 198 |
| **(Male: 15-18)** | | |
| Pumping of private well (=1) | -0.127 | -0.072 |
| | (0.147) | (0.154) |
| Observations | 93 | 93 |
| **(Female: 15-18)** | | |
| Pumping of private well (=1) | -0.286** | -0.296** |
| | (0.117) | (0.117) |
| Observations | 105 | 105 |

Note: Standard errors are given in parentheses with stars indicating the following:
*** p<0.01, ** p<0.05, * p<0.1.

**Table 7-14 DD estimation of the impact on pumping activities in young children sample (6-14 years old)**

| VARIABLES | All sample | | Male sample | | Female sample | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Dependent variable: Pumping of private well (=1) | ITT, Block FE | ITT, Household FE | ITT, Block FE | ITT, Household FE | ITT, Block FE | ITT, Household FE |
| Treatment and year dummy variables | | | | | | |
| Treatment block * year 2019(=1) | -0.031 | -0.048 | -0.066 | -0.076 | -0.004 | -0.036 |
| (treatment_effect) | (0.042) | (0.036) | (0.060) | (0.055) | (0.056) | (0.051) |
| Year dummy | -0.007 | 0.023 | 0.041 | 0.047 | -0.041 | 0.007 |
| (2018=0, 2019= 1) | (0.037) | (0.033) | (0.053) | (0.049) | (0.052) | (0.047) |
| | | | | | | |
| Other control var | Included | Included | Included | Included | Included | Included |
| Block fixed effect | Included | | Included | | Included | |
| Household fixed effect | | Included | | Included | | Included |
| | | | | | | |
| Observations | 1,081 | 1,081 | 571 | 571 | 510 | 510 |
| R-squared | 0.212 | 0.047 | 0.272 | 0.037 | 0.346 | 0.035 |
| Number of HHID | | 407 | | 252 | | 235 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

## 7.8 Estimation results of the impact of piped water use on working status

Table 7-15 presents the ITT estimation results of the installation of piped water system on the working status of the working age members, controlling for household characteristics, block fixed effect, or household fixed effect. The same estimations were employed on separate male and female samples. Even though the treatment effects of all the estimation results show an increase in the ratio of working status, the differences are not statistically significant.

The ATT impact on the individual working status of those who consider the use of piped water was examined. The estimation results of propensity score of piped water connection and use in treatment blocks are presented in Appendix 6-6. By applying the same estimates, the predicted value of the propensity score in the control blocks are calculated. The comparison of the distribution of the propensity score in the treatment and control blocks are illustrated in Appendix 6-7. Appendix 6-7 presents the distribution of the values of propensity score of piped water use. The distributions of the values of propensity score are confirmed to be well-balanced. Using these estimated propensity scores, the common support region for the estimations is calculated. For ATT estimation of piped water use, the samples of which PS is over 0.94 were trimmed. Table 7-16 reports the estimation results of ATT of piped water use on working status of the working age members across all sample, male sample, and female sample. The ATT impact on working is not confirmed in all the estimation results.

The same ITT and ATT estimation models were employed in examining the impact of the installation of piped water system on the working status of adolescent sample. Table 7-17 presents the ITT estimation results. No impact is found on working status in all sample, male sample, and female sample. Table 7-18 presents ATT estimation results of piped water use. In all sample and male sample, impacts on working status are confirmed. In female sample, the working ratio decreases by 9.6 percentage points in the results of both PS weighted regression and PSM.

**Table 7-15 DD estimation of individual working status in the working age sample (19-60 years old)**

| VARIABLES | All sample | | Male sample | | Female sample | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Dependent variable: Working (=1) | ITT, Block FE | ITT, Household FE | ITT, Block FE | ITT, Household FE | ITT, Block FE | ITT, Household FE |
| Treatment and year dummy variables | | | | | | |
| Treatment block * year 2019(=1) | 0.017 | 0.019 | 0.008 | 0.005 | 0.030 | 0.035 |
| (treatment_effect) | (0.028) | (0.027) | (0.034) | (0.032) | (0.040) | (0.036) |
| Year dummy | 0.069*** | 0.061** | 0.062** | 0.050* | 0.072** | 0.068** |
| (2018=0, 2019= 1) | (0.025) | (0.024) | (0.031) | (0.029) | (0.036) | (0.033) |
| | | | | | | |
| Other control var | Included | Included | Included | Included | Included | Included |
| Block fixed effect | Included | | Included | | Included | |
| Household fixed effect | | Included | | Included | | Included |
| | | | | | | |
| Observations | 4,690 | 4,690 | 2,064 | 2,064 | 2,626 | 2,626 |
| R-squared | 0.176 | 0.200 | 0.122 | 0.036 | 0.132 | 0.076 |
| Number of HHID | | 780 | | 710 | | 759 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

### Table 7-16 Average treatment effect on treated of the piped water use on the individual working status in the working age sample (19-60 years old)

| Dependent variables: Working (=1) | (1)<br>Propensity score matching | (2)<br>Propensity score weighted regression |
|---|---|---|
| **(All: 19-60)** | | |
| Working (=1) | 0.014 | 0.017 |
| | (0.017) | (0.017) |
| Observations | 2,096 | 2,096 |
| **(Male: 19-60)** | | |
| Working (=1) | 0.023 | 0.023 |
| | (0.023) | (0.022) |
| Observations | 912 | 912 |
| **(Female: 19-60)** | | |
| Working (=1) | 0.007 | 0.013 |
| | (0.024) | (0.024) |
| Observations | 1,184 | 1,184 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

### Table 7-17 DD estimation of individual working status in the adolescent sample (15-18 years old)

| VARIABLES | All sample | | Male sample | | Female sample | |
|---|---|---|---|---|---|---|
| Dependent variable: Working (=1) | (1)<br>ITT, Block FE | (2)<br>ITT, Household FE | (3)<br>ITT, Block FE | (4)<br>ITT, Household FE | (5)<br>ITT, Block FE | (6)<br>ITT, Household FE |
| Treatment and year dummy variables | | | | | | |
| Treatment block * year 2019(=1) | -0.018 | 0.034 | 0.043 | 0.072 | -0.065 | -0.027 |
| (treatment_effect) | (0.059) | (0.052) | (0.095) | (0.073) | (0.072) | (0.056) |
| Year dummy | 0.066 | 0.085* | 0.062 | 0.099 | 0.052 | 0.086* |
| (2018=0, 2019= 1) | (0.054) | (0.048) | (0.092) | (0.073) | (0.064) | (0.051) |
| Other control var | Included | Included | Included | Included | Included | Included |
| Block fixed effect | Included | | Included | | Included | |
| Household fixed effect | | Included | | Included | | Included |
| Observations | 520 | 520 | 246 | 246 | 274 | 274 |
| R-squared | 0.371 | 0.145 | 0.538 | 0.450 | 0.531 | 0.304 |
| Number of HHID | | 273 | | 144 | | 161 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

**Table 7-18 Average treatment effect on treated of the piped water use on the individual working status in the adolescent sample (15-18 years old)**

| Dependent variables: Working (=1) | (1)<br>Propensity score matching | (2)<br>Propensity score weighted regression |
|---|---|---|
| **(All: 15-18)** | | |
| Working (=1) | -0.017 | -0.035 |
| | (0.045) | (0.046) |
| Observations | 198 | 198 |
| **(Male: 15-18)** | | |
| Working (=1) | 0.045 | 0.062 |
| | (0.078) | (0.074) |
| Observations | 93 | 93 |
| **(Female: 15-18)** | | |
| Working (=1) | -0.096* | -0.109** |
| | (0.049) | (0.054) |
| Observations | 105 | 105 |

Note: Standard errors are given in parentheses with stars indicating the following:
*** p<0.01, ** p<0.05, * p<0.1.

7.9 Estimation results of the impact of piped water on schooling

Table 7-19 presents the ITT estimation results of installing the piped water system on schooling status of the adolescent members (15-18 years old). Table 7-20 presents the ATT impact on the schooling status on those who consider the use of piped water. The same estimation models of ITT and ATT employed in section 7.6 were employed. From these ITT and ATT estimations, the impacts of the installation of the piped water system on schooling of adolescent members are not confirmed.

For young children sample (6 -14 years old), the same ITT and ATT estimations were employed to confirm the impact of the installation of the piped water on their schooling. Table 7-21 reports the ITT estimation results and Table 7-22 reports the ATT estimation results. From these ITT and ATT estimations, the impacts of the installation of the piped water system on schooling of young children are not confirmed as well. For the young children, the schooling ratio does not increase. The schooling ratio is approximately 97 percent at the baseline survey. The engagement of pumping labor among young children decreases, but the estimation result is not statistically significant. The change of pumping labor is not large enough to affect the schooling status of young children.

**Table 7-19 DD estimation of individual schooling in the adolescent sample (15-18 years old)**

| VARIABLES | All sample | | Male sample | | Female sample | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Dependent variable: Student (=1) | ITT, Block FE | ITT, Household FE | ITT, Block FE | ITT, Household FE | ITT, Block FE | ITT, Household FE |
| Treatment and year dummy variables | | | | | | |
| Treatment block * year 2019(=1) | -0.017 | -0.038 | -0.011 | -0.044 | 0.016 | 0.020 |
| (treatment_effect) | (0.058) | (0.054) | (0.096) | (0.076) | (0.075) | (0.070) |
| Year dummy | -0.027 | -0.062 | -0.039 | -0.117 | -0.042 | -0.071 |
| (2018=0, 2019= 1) | (0.053) | (0.050) | (0.092) | (0.076) | (0.066) | (0.064) |
| Other control var | Included | Included | Included | Included | Included | Included |
| Block fixed effect | Included | | Included | | Included | |
| Household fixed effect | | Included | | Included | | Included |
| Observations | 520 | 520 | 246 | 246 | 274 | 274 |
| R-squared | 0.600 | 0.272 | 0.685 | 0.258 | 0.680 | 0.324 |
| Number of HHID | | 273 | | 144 | | 161 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

**Table 7-20 Average treatment effect on treated of the piped water use on the individual schooling status in the adolescent sample (15-18 years old)**

| Dependent variables: Schooling (=1) | (1) Propensity score matching | (2) Propensity score weighted regression |
|---|---|---|
| **(All: 15-18)** | | |
| Student (=1) | 0.009 | 0.020 |
| | (0.048) | (0.050) |
| Observations | 198 | 198 |
| **(Male: 15-18)** | | |
| Student (=1) | -0.059 | -0.054 |
| | (0.073) | (0.073) |
| Observations | 93 | 93 |
| **(Female: 15-18)** | | |
| Student (=1) | 0.078 | 0.097 |
| | (0.064) | (0.069) |
| Observations | 105 | 105 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

**Table 7-21 DD estimation of individual schooling of those aged 6 to 14**

| VARIABLES | All sample | | Male sample | | Female sample | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Dependent variable: Student (=1) | ITT, Block FE | ITT, Household FE | ITT, Block FE | ITT, Household FE | ITT, Block FE | ITT, Household FE |
| Treatment and year dummy variables | | | | | | |
| Treatment block * year 2019(=1) | -0.013 | -0.007 | -0.036 | -0.024 | 0.004 | 0.020 |
| (treatment_effect) | (0.019) | (0.016) | (0.028) | (0.023) | (0.027) | (0.021) |
| Year dummy | -0.000 | -0.005 | 0.011 | -0.001 | -0.005 | -0.004 |
| (2018=0, 2019= 1) | (0.017) | (0.015) | (0.024) | (0.020) | (0.025) | (0.019) |
| | | | | | | |
| Other control var | Included | Included | Included | Included | Included | Included |
| Block fixed effect | Included | | Included | | Included | |
| Household fixed effect | | Included | | Included | | Included |
| | | | | | | |
| Observations | 1,081 | 1,081 | 571 | 571 | 510 | 510 |
| R-squared | 0.329 | 0.087 | 0.342 | 0.078 | 0.429 | 0.120 |
| Number of HHID | | 407 | | 252 | | 235 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

**Table 7-22 Average treatment effect on treated of the piped water use on the individual schooling of those aged 6 to 14**

| Dependent variables: Schooling (=1) | (1) Propensity score matching | (2) Propensity score weighted regression |
|---|---|---|
| **(All: 6-14)** | | |
| Student(=1) | -0.018 | -0.013 |
| | -0.018 | (0.018) |
| Observations | 472 | 472 |
| **(Male: 6-14)** | | |
| Student(=1) | -0.001 | 0.004 |
| | (0.027) | (0.027) |
| Observations | 249 | 249 |
| **(Female: 6-14)** | | |
| Student(=1) | -0.034 | -0.033 |
| | (0.023) | (0.024) |
| Observations | 223 | 223 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

## 7.10 Conclusion

This chapter examines the impact of the installation of piped water system on pumping activity, working status, and schooling status among different subgroups:

working age sample, adolescent sample, and young children sample. Many literatures have reported that women and girls in low- and middle- income countries spend long time on domestic works including fetching water. The intra-household allocation of time is not equal between gender or among different age groups. If people have better access to water supply, their labor works for fetching or pumping would be relieved. Those impact may also differ by gender or age-groups. There are very limited studies that examined the impact of new water supply on individual activities such as working status and schooling status of household members in the urban areas of in low- and middle- income countries.

From the estimation results of the impact of the piped water use on pumping engagement, the ratio of the working age members who pump the private well is likely to decrease. For adolescent members, ATT estimation of piped water use shows a reduction in the ratio of pumping engagement in all sample and female sample, while such impact is not found in male sample. For young children, the impact is not confirmed which might be because there are not many children who pump private wells. From these results, it can be said that pumping work is reduced among the household members, especially among adolescent female members.

The working status and schooling status were also examined using DD estimation method. For working age members, there is no impact found on their working status. Meanwhile, the ratio of working status of either family chore or unemployment decreased by 6.8 percentage points in ITT estimation using female sample. The ATT estimations of the piped water present a decrease in the ratio of family chore or unemployment by 3.6 percentage points in all sample and five percentage points in female sample.

For adolescent sample, ITT estimation results on the working status do not present any impact, but ATT estimation results using female sample present statistically significant decrease in the working ratio by 9.6 percentage points from the estimations of PS weighted regression and PSM. As for schooling of female sample, the ATT estimation results of female sample report an increase in the schooling ratio by 7.8 percentage points, though it is not statistically significant. The schooling rate of adolescent member is approximately 80 percent, which is high at the baseline survey. The working ratio of the adolescent members is about 15 percent. A trade-off or substitution between working and schooling status may have occurred. Some female adolescents may have stopped working and decide to go to school. For young children, all the estimation results did not report any impact of the piped water use on schooling ratio.

The pumping time of private wells in the household decreased by 26 minutes per day as presented in Table 5-6 of chapter 5. With the installation of the piped water system, household members engaged in the pumping activities are relieved from the labor and can spare more time for other activities. However, the pumping time reduction did not lead to a large change in working and schooling status. The time reduction may not be enough for starting a new job or income-generating activities. Alternatively, there are limited opportunities especially for women to work outside home.

For the young children, the schooling ratio did not increase. The schooling ratio is approximately 97 percent at the baseline survey, which is already a high ratio. The pumping work may not be the main factor affecting their decision to go to school. If the children pump water after school, the work is not directly linked with schooling.

The household members may use the saved time for other activities including leisure. Since this research does not collect data on their detailed use of time, it is difficult to conduct the time-use analysis. There may be various changes and benefits not only on the status of individual activities from the installation of new piped water system. It is worth investigating the benefit of new water supply including the reduction of pumping time, from the aspect of economic value for the households.

## Chapter 8 Estimating the economic value of piped water using coping cost approach

### 8.1 Background and research interest

Many households in low- and middle- income countries have no access to public water supply service and are forced to find their water source for their daily use by their own efforts. To cope up, some dig their own private wells. Others go and fetch water from their neighbor's water source, while some just purchase from water sellers. However, in some cases, even if households have access to water sources, they still need to take some actions in case the water from their source is insufficient or not suitable for drinking. For instance, some people boil water or use chlorine tablets in order to make their water drinkable. Others purchase bottled water for drinking. Unsafe water may bring waterborne diseases to the households, entailing additional cost for medicine and time for treatment.

Using piped water could change water use patterns of the beneficiaries. Past literatures have examined the economic value of water, which is a nonmarket good. One of the approaches is using the stated preference method. Willingness-to-pay questions have been widely used especially in the field of environmental economics. Another approach is using revealed preference (RP) method which is used to measure the demand for nonmarket goods. One of the RP methods to examine the value of water is the coping cost approach (averting expenditure). The typical procedure of the approach is to decompose the coping cost to obtain a monetary valuation of benefits such as the reduction of pumping time of private well, the electricity fee for pumping, the expenditure for bottled water, water charge cost of piped water, and the health benefits accrued by avoiding any adverse effects on health and employment caused by waterborne diseases.

The studies of coping cost under poor water supply situation in low- and middle-income countries are limited. Nastiti et al. (2017) described the various coping strategies and the framework of the risk assessment and averting behaviors in the insufficient water supply situation in Bandung, Indonesia. Pattanayak et al. (2005) examined the coping behavior and expenditures incurred due to unreliable water quality in Kathmandu, Nepal. The results showed that households spent almost one percent of the income as coping costs. Zerah (2000) analyzed the coping strategy of the households under the poor municipal piped water supply in Delhi. Many households invest to increase their capacity to store water rather than to reduce time spent for fetching water. High-income households own tube wells, while low-income households sacrificed their time in fetching water because their time opportunity cost is low. Income and lack of reliability of water system play a major role in the households' choices of averting activities.

Cook et al. (2016) examined in detail the coping cost under the poor water supply in rural area of Kenya. The details of the theoretical background of coping cost analysis are discussed in the study and their paper referred to three coping cost items: 1) the coping costs in terms of financial expenditure and lost wage income, 2) the costs of illness, and 3) any monetary values associated with pain and suffering from poor health. The first one includes the costs such as water collection time, payment to use public or other peoples' water source, the expenditure to own and use private tube wells, and expenditure on water treatment.

These literatures that examined the coping cost of water use in low- and middle-income countries mainly focused on capturing the detailed situation of the coping cost using cross-sectional survey data. Even though it is important to know how the people cope with the situation under the various constraints in accessing water, they only present the water use situation and their coping behavior at a single point in time.

The main interest in this chapter is to examine the economic value of using the piped water using the coping cost approach. With a quasi-experimental setting using panel data, this research allows to clarify the rigorous impact of the installation of the new piped water system on the coping cost of water use with the revealed preference methods. There are limited literatures that examined the impact of the water supply sources with the coping cost approach. Shimamura et al. (2022) examined the rigorous impact of the installation of new water supply facilities, which are deep boreholes, in rural Zambia (Shimamura, et al., 2022). For the urban water supply cases, the comparison of the coping cost of household water use between two periods in Kathmandu, Nepal was conducted (Gurung, et al., 2017). Even though the magnitude of the effect of gaining a private water connection was analyzed, it was not assured that the difference of the coping cost was caused by the new connection since the study did not employ an experimental or a quasi-experimental method. In another literature, the large-scale community water supply and sanitation program of the state government of Maharashtra, India was examined using coping cost approach. Quasi-experimental method using DD estimation with Propensity score matching was employed in analyzing the program impact on the coping costs such as time cost for fetching water, medical expense, and patients' lost income. The study examined the impact of the community demand-driven water supply and sanitation program. However, since the components of the program were determined by the communities and therefore, vary per community, it was not possible to solely determine the impact of the water supply intervention. The literature focused on the change in the coping costs brought about by the program interventions but did not pay attention on the additional expenses incurred for using the newly introduced facilities such as the tap and toilet.

This chapter examines the value of piped water among the urban households in a large city of low- and middle- income country using coping cost approach. The survey area of this research was the area where the installation of the piped water system was planned but not yet implemented at the time of the baseline survey. The endline survey was conducted after the piped water system started its water supply service. Therefore, the conditions allow to analyze the change of water use and its coping cost with the introduction of piped water system. This chapter would provide new evidence for the economic value of the new piped water using the coping cost approach in a causal way.

## 8.2 Theoretical framework

For gauging the benefit of piped water, the following unitary household utility maximization model was used to examine the revealed preference for the value of safe water made available by the installation of the piped water system.

$maxU(G\ K, M, N, X, L_l, S(G, K, M, N, C))$

s.t. $p_0^G + p_1 G + p_2 K + p_3 M + p_4 N + p_5 C + X \leq$ Y (budget constraint)

$p_3$M=$p_e$*$e$(M) (electricity fee for pumping)

$L_e + L_l + L_m + L_n \leq$ T(S) (time endowment)

$L_m$=$f_3$(M), $L_n$=$f_4$(N) (water collection time)

w$L_e$ = Y (income)

where the notations are as follows: *G* for the volume of piped water; *K* for the volume of bottled water; M for the volume of water from private wells; N for the volume of water from other sources; C for water treatment;
$p_0$ is the fixed cost of using piped water; $p_1$ is the unit cost of piped water; $p_2$ is the unit cost of bottled water; $p_3$ is the unit cost of private well water, $p_4$ is the unit cost to use other water source; $p_5$ is the unit cost of water treatment ; $p_e$ is the unit price of electricity ; $e$(M) is a function calculating the electricity volume for private well use; *X* refers to composite goods; *S* for sickness; $L_e$ for the time spent for work; $L_l$ for the time spent for leisure; $L_m$ for the time spent for pumping private well; $L_n$ for the time spent in collecting water from other water sources; $f_3$(M) for the calculation of pumping time ; $f_4$(N) for the calculation of water collection time ; *T*(*S*) for the time endowment adversely affected by sickness ( $\frac{\partial T}{\partial S} < 0$); and *w* for the minimum wage rate.

The Lagrange function is given by:

$L= U - \lambda(w(T(S) - L_l - L_m - L_n) - p_0^G - p_1G - p_2K - p_3M - p_4N - p_5C - X)$

By applying the duality, the equation for the cost minimization problem can be expressed as follows:

$\psi = w\ (L_e + L_l + L_m + L_n - T(S)) + p_0^G + p_1G + p_2K + p_3M + p_4N + p_5\mathrm{C} + X - \mu(U^*-U)$

By taking the derivative with respect to *G*, we can use the following equation to consider the willingness-to-pay for using piped water:

$\frac{\partial\psi}{\partial G} = w(\frac{\partial L_e}{\partial G} + \frac{\partial L_l}{\partial G} + \frac{\partial L_m}{\partial G} - \frac{\partial T}{\partial G}) + p_1 + p_2\frac{\partial K}{\partial G} + p_3\frac{\partial M}{\partial G} + p_4\frac{\partial N}{\partial G} + p_5\frac{\partial C}{\partial G} + \frac{\partial X}{\partial G} - \mu\frac{\partial U}{\partial G}$

At the time of the baseline survey, water supply from the piped water system was zero: *G* = 0, thus, the constraint was binding. After the piped water system were installed by the endline survey, households began using the piped water *G* by paying $p_0$ and $p_1$. The cost of obtaining water *G* from the piped water system is the fixed cost of piped water use $p_0$(100 kyat per two months) and the cost based on the volumetric method with unit price of piped water $p_1$. The variable cost can be measured using the time spent on pumping of private well and water collection from other water sources, evaluated against the opportunity cost (i.e., market wage rate *w*). By utilizing more piped water, households are expected to reduce the volume of water from other pre-existing water sources (a decrease in the expense of K, M, and N) and the time spent for pumping private well and collecting water from other water sources ( $w\frac{\partial L_m}{\partial G}$ (<0) and $w\frac{\partial L_n}{\partial G}$ (<0)). Before using piped water, households utilize some water treatment methods by paying $p_5$C. The availability of safe piped water may influence C and thus, the cost of utilizing water treatment methods is measured by $p_5\frac{\partial C}{\partial G}$ $(< 0)$. Under the liquidity constraint, the consumption of composite goods is also affected, $\frac{\partial X}{\partial G}$. In addition to the time spent for pumping of private wells and collecting water from other water sources, the value of leisure time is measured by the opportunity cost $w\frac{\partial L_l}{\partial G}$. Other gains are realized through a change in utility caused by the change in resource allocation. Furthermore, improvement of health status affects utility level $\mu\frac{\partial U}{\partial S}\frac{\partial S}{\partial G}$.

Utilizing the theoretical framework, the costs and benefits of the newly installed piped water system were estimated. Table 8-1 sets out the costs and benefits of the piped water system by component. The benefits of the project are defined as the coping costs avoided compared with the costs paid for using the pre-existing water sources such as private wells. I calculated the benefits arising from (1) reduction of electricity fee for pumping, (2) reduction in pumping time of private wells, (3) reduction in purchases of water including bottled water, and (4) health impact of using piped water. By employing DD estimation, these benefits from the installation of the piped water system were examined.

**Table 8-1 Items for analyzing costs and benefits of piped water (by component)**

| Time | Cost | | | Benefit | |
|---|---|---|---|---|---|
| | Item | Analyze, calculation | | Item | Analyze |
| 1(=after) | ***1) Monthly payment for piped water*** **【Direct cost】**<br>Fixed cost:<br>(1) Maintenace fee of piped water use<br>Volumetric charge:<br>(2) Monthly water charge | 50kyat for using meter per month<br>200kyat/Unit(1㎥) | | ***1) Coping cost***<br>**【Direct cost】**<br>[Private well]<br>(1) Reduction of electricity fee for pumping<br>[Botteld water]<br>(2) Reduction in purchases of bottled water<br>[Other's water source]<br>(3) Reduction in payment to use other's water source<br>**【Indirect cost】**<br>[Private well]<br>(4) Reduction of time spent on pumping of pirvate well (on premises)<br>[Other's water source]<br>(5) Reduction in time spent on water collection from other's water source<br>***2) Health outcomes***<br>(6) Reduction of diarrhea incidence | Yes<br>Yes<br>Negligible<br>Yes<br>Negligible<br>Yes |

The table is compiled by the author.

## 8.3 Survey design

To examine the impact of the installation of the piped water system, the DD estimation methodology was employed. In this section, the surveyed households were selected as follows. In the water service blocks where the Project would supply piped water, there were some blocks with many factories or large grasslands but few residents. Those blocks were excluded because this research focuses on the water use of the habitants of residential area. Ninety-seven (97) blocks were remained as project blocks in five wards (Ngwe Taw Kyi Kone, Thin Pan Kone, Ga Nge, Ga Gyi, and Nga). Among the 97 project blocks, 62 blocks were randomly selected as treatment blocks.

In the control blocks which were outside of the water service blocks, the exhaustive block survey was conducted in April 2018. One hundred twenty-four (124) non-project blocks in three wards (Thin Pan Kone, Kha Gway, and Salone) were surveyed. Based on the block survey data, 33 control blocks which have similar characteristics with the treatment blocks were purposefully selected from non-project blocks. In total, there 95 selected blocks composed of 62 treatment blocks and 33 control blocks. From each selected block, ten households were randomly chosen. Nine hundred and fifty (950) households were interviewed in the baseline survey in May and June of 2018.

Table 8-2 summarizes the number of sampled households in both the treatment and control blocks and the piped water use in the treatment blocks. At the endline survey, the number of the interviewed households was reduced to 791. Some households moved out, while other households refused to be interviewed or were unreached during the survey period. The attrition rate of households from baseline to endline survey is 16.7 percent.

The balance tests of water use and household characteristics of the surveyed blocks were carried out (Appendix 5-1). The water use situation is similar between treatment and control blocks. There is no statistically significant difference in the listed variables aside from the water use volume per day per capita. For the characteristics of the sampled households, there is no statistically significant difference in the listed variables aside from the ratio of perception of water quality from their main source. For characteristics of the blocks, the household and population densities were similar between treatment and control blocks, which are typical residential areas in the Township. These households and blocks have similar and comparable characteristics, assuming that the parallel trend assumption holds.

**Table 8-2 Sampled households for the analysis**

| | Baseline | | | End-line | | | Attrition | | |
|---|---|---|---|---|---|---|---|---|---|
| | Treatment blocks | Control blocks | All | Treatment blocks | Control blocks | All | Treatment blocks | Control blocks | Attrition rate (%) |
| Number of blocks | 62 | 33 | 95 | 62 | 33 | 95 | | | |
| Number of households | 620 | 330 | 950 | 522 | 269 | 791 | 98 | 61 | 16.7 |

8.4 Water use situation related to the items of the coping cost

Table 8-3 summarizes the water uses in the treatment and control blocks at the time of the baseline and endline surveys. Items related to the coping costs are listed in the table. There are direct costs of using private well, which are the time spent for pumping and electricity fee for pumping. The pumping time is related to the electricity fee for pumping. Another direct cost is the purchase of bottled water. From the baseline survey, there is no statistically significant difference on the water use situation of treatment and control blocks. It is considered that the water use situation of both blocks is similar and comparable for the analyses.

At time of the endline survey, the large differences of these water use between treatment and control blocks are found after the installation of the new piped water system. In the last row of the table, the difference-in-differences of the water use between before/after data of the treatment and control blocks are presented. The difference-in-differences of the ratio of using private well is negative 11.3 percentage points and the water use of private well water is negative 6.9 $m^3$, which are the impact of installing the piped water system in the treatment blocks. Due to the reduction of private well water use, the pumping time decreased by 26 minutes.

The difference-in-differences in the ratio of purchase of bottled water is negative 4.5 percentage points, though it is not statistically significant. The cost of purchasing bottled water significantly decreased by one thousand kyat. For the 19.2 $m^3$ piped water, 3.9 thousand kyat of the piped water fee is charged and the difference-in-differences in the total water expense is 2.8 thousand kyat. Though the total water expense has increased, the total water use volume also increased by 11.2 $m^3$.

**Table 8-3 Summary statistics of water use and costs related to valuation of the coping cost at the baseline and endline surveys**

| **Survey timing** | | Baseline survey | | | | End-line survey | | | | Difference | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Treatment blocks | Control blocks | Diff | Stat. Sig | Treatment blocks | Control blocks | Diff | Stat. Sig | Diff in diff | Stat. Sig |
| | Unit | mean | mean | | | mean | mean | | | | |
| **1) Water use** | | | | | | | | | | | |
| Ratio of Using private well | % | 86.6 | 86.6 | 0.0 | | 75.7 | 87 | -11.3 | *** | -11.3 | *** |
| Ratio of purchasing bottled water | % | 77.4 | 81.4 | -4.0 | | 70.3 | 78.8 | -8.5 | ** | -4.5 | |
| Ratio of connecting with piped water system | % | 0 | . | | | 91.2 | . | | | . | |
| Ratio of using piped water system among connected house | % | 0 | . | | | 96.7 | . | | | . | |
| Household bottled water volume per month | Liter | 322 | 329 | -7.1 | | 255 | 296 | -41.0 | ** | -33.9 | |
| Water use volume of private well | $m^3$ | 34.2 | 34.6 | -0.4 | | 11.3 | 18.6 | -7.3 | *** | -6.9 | *** |
| Monthly water use volume of piped water | $m^3$ | 0 | . | | | 19.2 | . | | | . | |
| Total water use volume | $m^3$ | 36.4 | 36.7 | -0.3 | | 31.6 | 20.8 | 10.8 | *** | 11.2 | *** |
| **2) Cost** | | | | | | | | | | | |
| **2-1) Cost for using private well** | | | | | | | | | | | |
| Pumping time of the private well | minutes | 83 | 81 | 2 | | 32 | 60 | 28 | *** | 26 | *** |
| Monthly electricity expense for pumping | kyat | 220 | 204 | 16 | | 81 | 154 | -72.7 | *** | -88.7 | *** |
| **2-2) Cost for purchasing bottled water** | | | | | | | | | | | |
| Household bottled water cost per month | 1000kyat | 5.7 | 5.7 | 0.0 | | 4.9 | 5.9 | -1.0 | *** | -1.0 | * |
| **2-3) Cost for using water** | | | | | | | | | | | |
| Monthly expenditure of piped water | 1000kyat | 0 | . | | | 3.9 | . | | | . | |
| Total expenditure to use water | 1000kyat | 6.1 | 6.2 | -0.1 | | 8.9 | 6.3 | 2.7 | *** | 2.8 | *** |
| Obs. | | 522 | 269 | | | 522 | 269 | | | | |

Note: Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018 and 0.0007 US dollar (1 dollar = 1500 kyat) as of May 2019.
Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
The table is compiled by the author.

## 8.5 Estimation strategy

In order to rigorously examine the impact of the installation of the new piped water system on the various coping cost, multivariate regression models were utilized. The basic specification for the DD methodology is as follows:

$$Y_{ijt} = \beta_0 + \beta_1 \cdot t + \beta_2 \cdot S_j + \beta_3 \cdot (S_j \cdot t) + \epsilon_{ijt} \quad (1)$$

where: i refers to the household, j points to the block and t is time ($t = 0$ for baseline and $t = 1$ for endline).

This model estimates the intention-to-treat (ITT) impact of the Project to measure the impact of the installation of new piped water system. *Yijt* is the dependent variable and takes continuous variable. ITT is employed for this chapter because of the high usage rate of the piped water system. Analysis for ITT may capture the underestimated impacts compared to the average treatment effect. Yet, if ITT estimation confirms the positive impact of the Project, it can be said that the Project caused the impact on the coping cost though it reports the underestimated impact.

The dependent variables are the variables related with coping cost. Turning to the right-hand side variables, $S_j$ is a binary variable that takes the value 1 if the household is in the project block and 0 otherwise. $\beta_0$ to $\beta_3$ are the parameters to be estimated. $\beta_3$ is the parameter of our interest and measures the impact of the Project on the outcomes. $\epsilon_{ijt}$ is a well-behaved error term. The ordinary least squared (OLS) estimation was employed to estimate the coefficients.

The DD methodology is a combination of before/after and with/without comparison. The central assumption for the methodology to be valid is the "parallel trend" assumption, which assumes that a change over two periods should be common (without the interventions) on both the treatment and control blocks. The parallel trend assumption in the DD estimator may be violated if changes caused by covariates are not common between the treatment and control blocks. Thus, I also employed an empirical model with some covariates because I examined if this is the case.

The balance tests of the water use situation and the household characteristics for the analyses were carried out. The differences on the water use and household characteristics of treatment and control households are not statistically significant in all the listed variables except for the number of household members (Appendix 5-1).

The covariates take two forms (summary statistics of the covariates are shown in Appendix 5-2): $X_{ijt}$ is a vector to include a set of household characteristics and $X_{jt}$ is a vector containing a set of block j's characteristics other than Treatment ($S_j$). $X_{jt}$ contains dummy variables that capture block-level fixed effects and $X_{ijt}$ contains three dummy variables that capture seasonal differences in the survey months: May, June, or July, with reference to June. By adding these covariates, the following model is formed.

$$Y_{ijt} = \beta_0 + \beta_1 \cdot t + \beta_2 \cdot S_j + \beta_3 \cdot (S_j \cdot t) + X_{ijt} \cdot \gamma_1 + X_{ijkt} \cdot \gamma_2 + \alpha_i + \epsilon_{ijt} \quad (2)$$

where $\gamma_1$ are the parameters to be estimated along with $\beta_0$ to $\beta_3$.

In the previous chapter which focused on the individual health symptoms, ATT impact on the individual health outcomes was examined by employing two types of estimation, which are propensity score matching (PSM) and propensity score (PS) weighted regression. In this chapter, the impact of piped water use on household level health outcomes were examined by ITT and ATT estimations using the same methodologies as in the previous chapter.

## 8.6 Analysis of the coping cost for using piped water

### 8.6.1 Cost of piped water use

There are costs and benefits from using the new piped water. Majority of the residents have used private wells. Upon installation of private well, households need only to pay the electricity fee for pumping as the direct cost. In addition, to the maintenance cost of the equipment. Meanwhile, the additional cost for using piped water is the water charge of piped water. After connecting to the piped water system, households need to pay the fixed cost to maintain the use of water meter, 50 kyat per month, and the volumetric water charge calculated based on their water consumption. The unit cost of water tariff set by MCDC is 200 kyat per unit (1 unit is equal to 1 $m^3$). The average monthly household water use volume of piped water is 19.2 $m^3$, which is equivalent to 3,840 kyat. Even though this additional payment is charged, households prefer to use piped water. The aggregated value of these direct costs for using the piped water is 3,890 kyat. This is considered as the actual value of the willingness-to-use the piped water regularly.

The average value of the willingness-to-use the piped water regularly reported in Chapter 5 is 210 kyat per unit among the households in the treatment blocks as of the baseline survey. This value is almost the same as the actual unit price set by MCDC, 200 kyat per unit of piped water. The respondents who said that they were willing to connect answered that they were willing to pay 427 kyat (0.31 USD) per unit (1 $m^3$) of piped water.

The unit price set by MCDC, 200 kyat, is lower than the actual cost for supplying the piped water. The MCDC official said that MCDC spent over 300 kyat per unit to produce and supply the piped water. Hence, there is a concern for the sustainability of the management and operation of the water supply service under MCDC even though the households' willingness-to-pay per unit in using the piped water regularly and the MCDC's unit price of piped water is of approximate value. Households who are willing to connect to the piped water system are willing to pay more than the cost of water production and supply.

### 8.6.2 Benefit of the piped water use

There are various potential benefits from using piped water as shown in Table 8-1. If the households shift their main water source from the private well to the piped water system, the time for pumping may decrease. In case the households use other people's water source, households may save some time for fetching or some costs/fee to obtain water. If households drink the piped water, they can reduce the expense for bottled water. Drinking of piped water disinfected by chlorine may prevent the households from acquiring water-borne diseases and they may be able to increase their working time due to better health conditions. In the following sections, the change in the coping cost items and the potential benefits of the piped water use were examined.

### 8.6.3 Coping costs for pumping private well water

#### 8.6.3.1 Electricity fee for pumping

The average pumping-up time per day is 86 minutes in the treatment blocks at the baseline survey. Households spent electricity fee for pumping the private well water. Electricity fee for running pump is calculated based on the total pumping time per day, the average wattage of pump and unit price of electricity fee. For the calculation, the average power consumption of water pump machine was used, which is about 145.83 watts (from the survey results of household energy consumption under MECON project[22]). The electricity fee of one unit is 35 kyat per one kWh in the City. By using the wattage and pumping hours, kWh was calculated, and the monthly electric fee for pumping was estimated by multiplying the total kWh with the unit price of electricity. Based on the above information, the monthly electricity fee for pumping is estimated at 219 kyat. This is about 2.2 percent of the monthly electricity fee, 9,875 kyat. Since other information source reports that a typical water pump's wattage can vary between 250 to 1,100 watts, there is a possibility that the reported energy consumption in the survey may underestimate the electric consumption of water pump.

Table 8-3 shows the ITT estimation results of the impact of the installation of piped water use on private well use. The water use volume of the private well decreased by 6.7 $m^3$ and the time for pumping per day decreased by 35 minutes. Based on the above

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[22] The survey covers 334 households in the various areas in Myanmar, including Mandalay region (Myanmar Engineering Society, 2015).

conversion rate, the reduction in the monthly electricity fee for pumping is estimated at 89 kyat.

**Table 8-4 Double difference estimation on water use of private well**

| Dependent Variable | (1) Monthly household water volume of private well (m3) | (2) Time for pumping the private well water (minutes) |
|---|---|---|
| Estiamation type | ITT + block fixed effect | ITT + block fixed effect |
| Treatment and year dummy variables | | |
| Treatment block * year 2019(=1) | -6.7*** | -35.0*** |
| (treatment_effect) | (2.5) | (7.5) |
| Year dummy | -17.2*** | -20.7*** |
| (2018=0, 2019= 1) | (2.3) | (6.8) |
| Block fixed effect | Included | Included |
| Household characteristics | Included | Included |
| Observations | 1,582 | 1,582 |
| R-squared | 0.281 | 0.218 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

8.6.3.2 Labor cost for pumping

While pumping, household members need to check whether the compressor and the pump function well and stop the operation when the water tank or container is already filled. This pumping work is considered as the labor cost for using the private well.

In order to express the labor cost of pumping into the monetary terms, the national minimum wage (4,800 kyat for 8-hour work) is used. The hourly minimum wage is about 600 kyat. Whittington and Cook (2018) reviewed existing literatures related to the value of time for the various activities. They found that many literatures estimate the value of time between 25 to 75 percent of the after-tax wage rate for time changes in activities in the informal sector such as collecting water. Since 50 percent is widely used in estimating the value of time, 50 percent of after-tax wages is used in this paper. The monthly labor cost for pumping is 12.9 thousand kyat, which is three percent of the monthly household income.

A reduction of 35 minutes in pumping leads to 40 percent decrease in pumping labor. By using the same conversion rate, the mean of the monthly coping cost for pumping the private well is 5,250 kyat.

### 8.6.4 Coping cost of bottled water use

Many households purchase bottled water for drinking purposes. The average monthly expense for purchasing bottled water among households in the treatment blocks is 6,050 kyat, which is 1.4 percent of the household income. However, when the piped water is disinfected with chlorine, it can be considered as drinkable and the household may shift from drinking bottled water to piped water.

ITT estimation result of the impact of the installation of piped water system reports a decrease in the monthly household bottled water expense by 980 kyat (Table 8-4). This is about 17 percent decrease in the monthly bottled water expense from the baseline survey. Further, model 2 shows that the bottled water expense of the households who use piped water decreased by 1,100 kyat, while there is no significant impact found on the bottled water expense of households who do not use piped water.

**Table 8-5 Double difference estimation on the purchase, volume, and expenditure of bottled water**

| Model | (1) | (2) |
|---|---|---|
| Dependent Variable | Monthly expenditure of bottled water (1000kyat) | |
| Estiamation type | ITT, block fixed effect | ITT, block fixed effect |
| Treatment and year dummy variables | | |
| Treatment block * year 2019(=1) | -0.98** | |
| (treatment_effect) | (0.49) | |
| Pipedwater_User * year 2019(=1) | | -1.10** |
| (treatment_effect) | | (0.50) |
| Pipedwater_Non-User * year 2019(=1) | | -0.14 |
| | | (0.77) |
| Year dummy | -0.11 | -0.09 |
| (2018=0, 2019= 1) | (0.45) | (0.45) |
| Block fixed effect | Included | Included |
| Household characteristics | Included | Included |
| Observations | 1,582 | 1,582 |
| R-squared | 0.234 | 0.235 |

Standard errors in parentheses
t-test or Fisher's exact test results are shown; * Significant at 10%, ** Significant at 5%, *** Significant at 1%.

8.6.5 Estimates of the health benefits of the project

8.6.5.1 Descriptive analysis of the impact of piped water on health

If the working age members will acquire water-borne diseases, they will lose working opportunities. In order to examine the impact of the installation of piped water system on health, its impact on the three health symptoms such as abdominal pain, vomiting, and diarrhea were analyzed. If the Project improved the health conditions of the working age members of the household, the benefit in terms of monetary value is calculated with the market wage of the working age members. Diarrhea is known as the major water-borne disease in many low- and middle-income countries so its incidence among the household members is chosen to estimate the health effect of the use of piped water in this study.

At the baseline survey, there are 0.034 cases of working age household members who had diarrhea incidence within two weeks before the interview. If adults over 16 years old have diarrhea, they will suffer for 2.8 days (Lamberti, et al. 2012). By using the conversion rate of time use, which is 50 percent of national minimum wage, the monthly household cost for having diarrhea is estimated at 456 kyat, which is equivalent to 0.1 percent of the monthly household income.

Table 8-5 presents the descriptive analysis of these health symptoms among household members of working age (between 19 to 60 years old). The dependent variables are the sum of the cases of each member's health incidence. No statistically significant difference is found between the treatment and control blocks at the baseline survey. As for difference-in-differences in the health symptoms at the endline survey, there is also no statistically significant difference found between the two blocks.

**Table 8-6 Descriptive analysis of health symptoms among the working age household members (19 – 60 years old)**

| Working age sample | Baseline survey | | | End-line survey | | | Diff. in Diff |
|---|---|---|---|---|---|---|---|
| | Treatment | Control | diff. | Treatment | Control | diff. | |
| Abdominal pain incidence of | 0.128<br>(0.018) | 0.123<br>(0.024) | 0.006<br>(0.030) | 0.027<br>(0.007) | 0.045<br>(0.016) | -0.018<br>(0.015) | -0.023<br>(0.033) |
| Vomiting incidence of household | 0.033<br>(0.009) | 0.045<br>(0.013) | -0.012<br>(0.015) | 0.004<br>(0.003) | 0.019<br>(0.012) | -0.015<br>(0.010) | -0.003<br>(0.018) |
| Diarrhea incidence of household | 0.034<br>(0.008) | 0.022<br>(0.009) | 0.012<br>(0.013) | 0.010<br>(0.005) | 0.011<br>(0.011) | -0.002<br>(0.011) | -0.014<br>(0.017) |

Note: Standard errors are given in parentheses with stars indicating below.
*** p<0.01, ** p<0.05, * p<0.1.
The table is compiled by the author.

8.6.5.2 Estimation results of the impact of piped water on health

Table 8-6 presents the ITT estimation results of installing the piped water system on each health symptom among household members of working age, controlling for household characteristics and block fixed effects. While all the results report a decrease in each health incidence, the differences are not statistically significant. The number of these incidence are not large even before the installation of the piped water system. Since the ITT estimations include households who do not use or drink piped water, the captured effects are underestimated.

**Table 8-7 DD estimation of the impact of installing piped water system on health outcomes among working age sample (19-60 years old)**

| Model | (1) | (2) | (3) |
|---|---|---|---|
| Dependent variable | Adominal pain incidence of household | Vomiting incidence of household | Diarrhea incidence of household |
| Estimation model | ITT (Block FE) | ITT (Block FE) | ITT (Block FE) |
| ***Treatment and year dummy variables*** | | | |
| Treatment block * Year 2019 (=1) | -0.021 | -0.010 | -0.026 |
| (treatment effect) | (0.044) | (0.024) | (0.023) |
| Year dummy | -0.109*** | -0.035 | -0.032 |
| (2018/Baseline=0, 2019/End-line= 1) | (0.040) | (0.022) | (0.020) |
| Other control var | Included | Included | Included |
| Block fixed effect | Included | Included | Included |
| Observations | 1,582 | 1,582 | 1,582 |
| R-squared | 0.080 | 0.076 | 0.077 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

The ATT impact on the health outcomes of households who use and drink the piped water were examined. The estimation results of propensity score of piped water connection, use, and drinking in treatment blocks are presented in Appendix 6-6. By using the same estimates, the predicted value of the propensity score in the control blocks were calculated. The comparison of the distribution of the propensity score in the treatment and control blocks is illustrated in Appendix 6-7 and Appendix 6-8. Appendix 6-7 presents the distribution of the values of propensity score of piped water use and Appendix 6-8 presents those of piped water drinking. The distributions of the values of propensity score are confirmed to be well-balanced.

Using these estimated propensity scores, the common support regions for the estimations were calculated. For ATT estimation of piped water use, the samples of which PS is over 0.94 were trimmed. For ATT estimation of piped water drinking, the samples of which PS is over 0.62 were trimmed.

Table 8-8 reports the estimation results of ATT impact of piped water use on the health outcomes of working age household members. For diarrhea incidence, PS weighted regression result reports a decrease in the incidence by 0.03. Table 8-9 reports the estimation results of ATT impact of piped water drinking on the health outcomes of working age household members. However, no statistically significant difference is found .

Based on the ATT results of piped water use on diarrhea symptom, the use of piped water decreases the number of diarrhea incidence by 0.03 cases among the household members who are in the working age sample (between 19 to 60 years old).

**Table 8-8 ATT estimation for piped water use on the impact of installing the piped water system on health outcomes among working age sample (19-60 years old)**

| Dependent variable | Abdominal pain incidence of household | | Vomiting incidence of household | | Diarrhea incidence of household | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Estimation model | ATT (PS-weighted/ use) | ATT (DID-PSM/ use) | ATT (PS-weighted/ use) | ATT (DID-PSM/ use) | ATT (PS-weighted/ use) | ATT (DID-PSM/ use) |
| Treatment effect | -0.031 | -0.025 | -0.009 | -0.017 | -0.031* | -0.034** |
| | (0.034) | (0.038) | (0.017) | (0.017) | (0.018) | (0.016) |
| Observations | 713 | 713 | 713 | 713 | 713 | 713 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

**Table 8-9 ATT estimation for piped water drinking on the impact of installing piped water system on health outcomes among working age sample (Baseline - End-line survey)**

| Dependent variable | Abdominal pain incidence of household | | Vomiting incidence of household | | Diarrhea incidence of household | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Estimation model | ATT (PS-weighted/ use) | ATT (DID-PSM/ use) | ATT (PS-weighted/ use) | ATT (DID-PSM/ use) | ATT (PS-weighted/ use) | ATT (DID-PSM/ use) |
| Treatment effect | -0.024 | -0.013 | -0.008 | -0.015 | -0.017 | -0.032 |
| | (0.045) | (0.051) | (0.024) | (0.021) | (0.023) | (0.023) |
| Observations | 791 | 791 | 791 | 791 | 791 | 791 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

### 8.6.6 Cost to use piped water and comparison with the willingness-to-pay on piped water use

As calculated in section 8.6.1, the households in the treatment blocks directly spent an average of 3,890 kyat for the use of piped water per month. Since the total direct cost of using water from any water source at the baseline survey in the treatment blocks is 6,051 kyat, the monthly cost of using piped water is equal to 64 percent of the direct cost based on the baseline survey.

On the average, the willingness-to-pay per unit for the regular use of piped water is 210 kyat (shown in Table 4-8a) and the willingness-to-pay for the monthly maintenance fee is 502 kyat (shown in Appendix 4-5a). By using these values and the monthly piped water volume of 19.2 $m^3$, the total value of willingness-to-pay for the use of piped water per month is estimated at 4,534 kyat, which is 16.6 percent higher than the actual cost of using the piped water. This shows that households' valuation of the piped water is slightly higher than the actual water charge.

However, it should be noted that there are large differences between actual cost for the connection and willingness-to-pay on the connection fee. MCDC staff said that the connection cost is about 100 to 150 thousand kyat (66 – 100 USD). By using the lower bound value (100 thousand kyat), the connection cost is approximately 23 percent of the household monthly income. On the other hand, willingness-to-pay on the connection fee is 6.1 thousand kyat on the average, which is only six percent of the actual connection cost. In addition, the ratio of the household who are willing to connect is only 61 percent. The connection rate would have been much lower than the realized connected rate if there was no subsidy from the Project.

8.6.7 Benefit from using the piped water

Table 8-10 reports the coping cost for using any water among the households in the treatment blocks at the baseline survey. The total coping cost is 19 thousand kyat (14 USD), which is 4.4 percent of the total monthly household income. The calculated labor cost for pumping the private well is the largest cost, which is 12.9 thousand kyat (9.6 USD). The second largest cost is the bottled water expense, which is 5.7 thousand kyat (4.2 USD).

As for the benefits of using the piped water, each calculated value is compiled in Table 8-12. For the direct cost, the monthly bottled water expense decreased by 980 kyat. This is equivalent to 2.8 bottles of 20-liter size bottled water, and a 17 percent reduction in the bottled water expense at the baseline survey in the treatment blocks. The reduction in electricity cost for pumping the private well water is estimated at 89 kyat. The total reduction in the direct cost of coping is 1,169 kyat. For the indirect cost, the time cost for pumping is 12.9 thousand kyat (9.6 USD) from the baseline survey. Using the new piped water system, the labor cost of pumping the private wells decreased by 5,250 kyat (3.5 USD). In total, the benefit of using the piped water due to the total estimated reduction in the coping cost is 6,319 kyat (4.2 USD).

In addition, regarding the benefit on the health outcome, having better health condition due to reduction of diarrhea incidence is estimated at 456 kyat (0.3 USD). As the coping cost related to health, the medical treatment expense is not considered in the calculation of the coping cost. From the nation-wide household survey in 2017, households spend on average almost 300,000 kyat per year in health expenditures, which includes costs incurred from healthcare utilization (i.e., inpatient and outpatient care and associated transportation and accommodation costs) as well as other expenditures on medication and drugs. The survey reported the health expenditures constituted 7.6 percent of total household consumption in 2017 (CSO, UNDP & WB, 2020). There is the possibility to underestimate the benefit of the Project because the medical treatment expense to cure these symptoms is not surveyed and included for the estimation.

In this research, the economic valuation of the Project was estimated with the inferable change and available data. It should be noted that these estimations would vary due to the choice of the conversion rate of their labor work and the availability of the data used for analysis. The total benefits including both the direct and indirect costs is larger than the additional direct cost of using the new piped water. In addition, households benefitted from using larger volume of water than households in the control areas due to the use of piped water.

However, the benefits from reduced bottled water use and better health condition are not maximized since the drinking ratio of the piped water is low. In this research, the information interventions such as sharing ways to mitigate the odor and taste of residual chlorine in the piped water to enhance the use of piped water are presented in Appendix A. The estimation results present no impact of the intervention on the piped water use. The interventions may not be effective or its impact may not be realized in a short period of time since the change in behavior with regard to piped water use may take longer time. If more people will use and drink the piped water, it is expected that they will have larger benefits from reduced bottled water expense and better health conditions. Hence, it is necessary to consider some actions/interventions that could enhance the use and drinking of piped water.

**Table 8-10 Monthly coping costs of using pre-existing water source by component (baseline survey)**

| Coping cost | | | |
|---|---|---|---|
| Item | Amount (kyat, USD) | Ratio of the cost in household income | Data source/calculation |
| Total coping cost | 19 thousand kyat (14.0 USD) | 4.40% | Aggregated the below items |
| **【Direct cost】** | | | |
| [Private well]<br>(1) Electricity fee for pumping private well | 219 kyat<br>(0.2 USD) | 0.10% | Survey data and estimates of unit price of electricity (35kyat) * electricity volume for pumping |
| [Bottled water]<br>(2) Purchases of bottled water | 5.7 thousand kyat<br>(4.2 USD) | 1.30% | Survey data and estimates of unit price of 20L bottle(350kyat) * number of bottle |
| [Other's water source]<br>(3) Payment to use other's water source | Negligible | Negligible | |
| **【Indirect cost】** | | | |
| [Private well]<br>(4) Labor cost for pumping private well | 12.9 thousand kyat (9.6 USD) | 3.00% | Survey data and estimates from pumping/water collection time * 50% of national minimum wage (4800kyat/day), 86 minutes/day |
| [Other's water source]<br>(5) Labor cost for water collection from other's water source | Negligible | Negligible | |

Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.
The table is compiled by the author.

**Table 8-11 Monthly benefit on health outcome**

| Health outcomes | | | |
|---|---|---|---|
| Item | Amount (kyat, USD) | Ratio of the benefit in household income | Data source/calculation |
| Economic valuation of income lost due to diarrhea among member | 456 kyat<br>(0.3 USD) | 0.20% | Survey data and estimates from diarrhea cases within two weeks * 50% of national minimum wage (4800kyat/day), 2.8 days of diarrhea symptoms/per time |

Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.
The table is compiled by the author.

## Table 8-12 Costs and benefits of piped water by component (Kyat/month)

| Time | Cost | | | Benefit | | |
|---|---|---|---|---|---|---|
| | Item | Amount | Data source/calculation | Item | Amount | Data source/calculation |
| | | | | ***Coping cost*** | | |
| | **【Direct cost】** | | | **【Direct cost】** | | |
| 1(=after) | Fixed cost: Maintenace fee of piped water use | 50 kyat (0.03 USD) | MCDC data (100 kyat/ 2 months) | [Private well] (1) Reduction of electricity fee for pumping | 89 kyat (0.06 USD) | Survey data and etimates of unit price of electricity (35kyat) * electricity volume for pumping |
| | Volumetric charge: Monthly piped water charge | 3,840 kyat (2.55 USD) | MCDC data and estimates of unit price of piped water (200kyat) * used volume (Unit), 19.2m³: average piped water use volume. | [Botteld water] (2) Reduction in purchases of bottled water | 980 kyat (0.65 USD) | Survey data and etimates of unit price of 20L bottle(350kyat) * number of bottle |
| | | | | [Other's water source] (3) Reduction in payment to use other's water source | Negligible | Survey data and esimates from pumping/water collection time * 50% of national minimum wage (4800kyat/day), 35 minutes/day reduction |
| | | | | **【Indirect cost】** | | |
| | | | | [Private well] (4) Reduction of time spent on pumping of pirvate well (on premises) | 5,250 kyat (3.5 USD) | Survey data and esimates from pumping/water collection time * 50% of national minimum wage (4800kyat/day), 35 minutes/day reduction |
| | | | | [Other's water source] (5) Reduction in time spent on water collection from other's water source | Negligible | |
| | | | | ***Health outcomes*** | | |
| | | | | (6) Economic valuation of income lost due to diarrhea among member | 456 kyat (0.3 USD) | Survey data and esimates from diarrhea cases within two weeks * 50% of national minimum wage (4800kyat/day), 2.8 days of diarrhea symptoms/per time |
| | Total | 3,890 kyat (2.59 USD) | | Total | 6,775 kyat (5 USD) | |

Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1500 kyat) as of May 2019.

The table is compiled by the author.

## 8.7 Conclusion

Households without access to safe water need to obtain water using their own efforts. The total coping cost to use any water in treatment blocks at the baseline survey is 19 thousand kyat (14 USD), which is 4.4 percent of total monthly household income (460 thousand kyat or 350 USD).

The coping costs relative to household income vary under the different water supply and water use situations: one percent of the income as the coping cost in Nepal (Pattanayak, et al., 2005), more than ten percent of income for over half of surveyed households in rural Kenya (Cook, et al., 2016), and four percent of monthly expenditure in urban Jordan (Orgill-Meyer, et al., 2018). The coping costs also vary among economic status, for example, 15 percent of income for lower income households while only one percent for rich households (Pattanayak, et al., 2010). Even though it is difficult to say what is the average ratio of the coping cost relative to income, there is so-called "5 percent rule" that households cannot afford to spend more than five percent of their monthly household income on water and sanitation service (Cook, et al., 2016). About 4.4 percent of household income is the coping cost to use any water in the treatment blocks though it does not include sanitation cost. The households in the survey site have coped with the situation without access to the piped water by sparing the coping cost equivalent to almost five percent of income.

As for the benefits of using the piped water, the total estimated reduction in the coping cost is 6,319 kyat (4.2 USD). This is 33 percent of the total coping cost at the baseline survey. The largest portion of the benefit is the reduction in pumping labor cost. In using the piped water, the additional direct costs such as the volumetric water charge and the fixed maintenance fee need to be paid. The total cost to use the piped water is 3,890 kyat (2.59 USD) per month. This is larger than the reduced direct cost in the coping cost (such as the electricity fee for pumping and the bottled water expense). If only the direct expenses on using piped water will be considered, the piped water use would lead to more financial burden for the households. However, when indirect cost is accounted, the total estimated reduction in the coping cost, the sum of the direct and the indirect costs, would be larger than the direct cost of piped water use. The reduction in the labor cost for pumping is interpreted as the most valuable benefit for the piped water users. The calculated value is even bigger than the monthly water charge of the piped water.

It should be noted that households in the treatment blocks use larger amount of water with the use of piped water. The difference of the total volume between treatment and control blocks is very large, and it is assumed that the utility level of households who use the piped water would be higher since they have more convenient source and access to safe water. However, since the total water use volume decreases both in treatment and control blocks relative to the water use volume at the baseline survey and the direct cost of using water increases, the unit cost of using water increased with the use of piped water. Even so, there is the demand for safe and convenient water, and households benefited from using the piped water.

## Chapter 9 Conclusion and Discussion

### 9.1 Conclusion of the research

A piped water supply is the major source of safely managed drinking water service for urban residents in the world. The demand for piped water supply has increased due to the urban population growth especially in low- and middle- income countries. Yet, the installation of piped water system requires a large financial investment for those countries. The authorities or water supply entities need to make the investment decisions with careful planning and assessment on the returns to investment. However, empirical evidence on what would be brought by the installation of a new piped water system for urban residents has been scarce. Hence, the main objective of this research is to provide a new piece of evidence on the impact of a new piped water system on the well-being of urban residents.

This research begins with the analysis of water use situation before the installation of the piped water system using the baseline survey data. In the surveyed blocks of the research, majority of the households used water from the private wells in their premises for general purposes and purchased bottled water from vendors for cooking and drinking purposes. Households choose their water sources depending on the water quality, available water quantity, the cost to obtain water, and the household socio-economic condition, among others. Higher asset measure, which represents better household economic condition, is correlated with higher ownership of the private wells. It is also confirmed that households with higher asset measure reports a higher ratio of purchasing the bottled water and larger volume of bottled water consumption.

The baseline survey also asked about the households' willingness-to-pay for the new piped water service. Before the project, approximately 60 percent of the households said that they are willing to connect to the piped water system. The respondents who said that they are willing to connect said that they are willing to pay 10.1 thousand kyat

(7.48 USD) on the connection fee and 427 kyat (0.31 USD) per unit (1 $m^3$) of piped water, on the average. Households who own their house have higher willingness-to-connect. They have the intention to have a piped water connection since it is their own property. Households with higher asset measure also show higher willingness-to-connect to the piped water system.

Overall, however, willingness-to-pay on the connection fee is much lower than the necessary connection cost charged by MCDC. If many households do not connect, it is difficult to explore how the installation of the piped water system affects the well-being of the residential households. In actuality, the connection cost was subsidized to accelerate the private connection among households. As a result, the connection rate was 91.2 percent, and 88.1 percent of the households in the treatment blocks used the newly constructed piped water system as of the endline survey.

This research setting with full subsidy for private connection allows me to examine how the installation of the newly installed piped water system changed water use pattern and affected the well-being of urban residents under the condition that they had other alternatives of water sources such as private well or bottled water. If the households use and drink the piped water, it is expected that their well-being would be improved by having better access to water or having better health conditions. Furthermore, reduced time in obtaining water and improved health conditions, if any, may be able to enhance their economic and social activities such as working and schooling.

To conduct rigorous analysis of the impact of the installation of the new piped water system, this research employs the DD estimation methodology. First, this research examines the impact on water use pattern. After the installation of the piped water supply, the households in the treatment blocks used 19.2 $m^3$ of the piped water per month. I also found that the Project reduced the use of private wells by 11.8 percentage points and its water use volume by 6.7 $m^3$ per month, relative to the households in the control blocks. In addition, the Project also reduced the purchasing ratio of bottled water by seven percentage points and water volume by 34 liters. The Project encouraged the substitution from the use of private wells to the use of the piped water system as the main water source. As a result, the Project increased the total water use volume of the households by 11.2 $m^3$, relative to the households in the control blocks.

Secondly, this research explores the impact on the health of the household members. Intention-to-treat (ITT) effect and average treatment effect on the treated (ATT) of the use of the piped water and ATT of drinking of the piped water were estimated. The use of piped water reduced the cases of vomiting and diarrhea incidence within the last two weeks prior to the household interview by 0.008 and 0.011 cases, respectively (ATT of use of the piped water in whole sample). The estimation results of ATT of the use of the piped water reported more pronounced effect on the reduction of vomiting and diarrhea incidence in working age sample, while there are mixed effects among the members of schooling age group or those under five years old. The estimation results of ATT of drinking of the piped water do not report any reduction in the health incidence in whole sample. Only 21.8 percent of the households used the piped water for drinking. There seems to exist some other pathways except drinking through which the health benefits materialize. For instance, about 65 percent of households used the piped water for cooking purpose. Hence, the risk of experiencing vomiting and diarrhea incidence due to the use of contaminated water from private well in cooking (or washing hands) is reduced.

Thirdly, this research investigates the impact on the working status and schooling status of the household members. The analyses are conducted using gender-divided samples in addition to age-groups such as working-age sample, adolescent sample, and young children sample. Yet, the Project did not cause changes in the working status and schooling status. Further, this research examines the impact on pumping labor and time spent from using the private well. The Project reduced the pumping labors of the household members, especially female adolescents. It also reduced the household's pumping time of the private wells by 26 minutes per day. The gender disaggregated analysis reveals that the project reduced the engagement in pumping by 19.4 percentage points among working-aged men and 15.1 percentage points among working-aged women. The impact is the largest among female adolescents, and the reduction was 28.3 percentage points. Despite the time reduction in pumping time, the saved time may not be enough for encouraging such family members to seek new income-generating activities outside home or to go to school.

Lastly, this research estimated the economic value of the piped water project by using a coping cost approach. To obtain safe water for living, households pay direct costs such as bottled water expense and volumetric fee for piped water and incur indirect costs such as waiting time for pumping water from private wells. Before the Project, in order to obtain water, households paid 5,940 thousand kyat (4.4 USD) per month as the direct cost (such as bottled water expense and electricity cost for pumping) to use their pre-existing water sources. On the average, households spent 5,721 kyat (4.2 USD) for the purchase of bottled water. The average monthly electricity cost for pumping from private wells is estimated at 219 kyat (0.2 USD). After the Project, the households increased the direct costs of obtaining water by 2,821 kyat (1.4 USD) and paid 8,761 thousand kyat (5.8 UDS) in total. They also began spending an average of 3,890 kyat (2.6 USD) per month for the maintenance cost and volumetric water charge for using the piped water, whereas their bottled water expense and electricity cost for pumping were reduced by 1,069 thousand kyat (0.8 USD) per month.

For the indirect cost to use their pre-existing water sources, the time cost for pumping was 12.9 thousand kyat (9.6 USD) based on the baseline survey. The time cost is calculated using 50 percent of the national minimum wage rate. Using the new piped water system, the labor costs of using their pre-existing water sources decreased by 5,250 kyat (3.5 USD). Even though the direct costs of obtaining water increased, the reduction in the indirect costs outweighed the extent of increase of the direct costs.

Moreover, households gained health benefits due to reduced health incidence such as diarrhea incidence. In case a household member has the health incidence such as diarrhea, he/she may not be able to work and lose the opportunity to earn the wages. By using 50 percent of the national minimum wage rate and the 2.8 days per incidence for suffering from each diarrhea incidence, the health benefit from having better health condition is estimated to be 456 kyat (0.3 USD) per month.

In summary, the installation of the new piped water system increased the total water use volume due to the use of piped water, relative to the water use volume of the control blocks. It reduced the use of the private water and bottled water in terms of the usage rate, water volume, and expense in the treatment blocks. While the direct costs for using water increased due to the newly charged piped water fee, the economic value of the reduction of both direct and indirect costs of obtaining water from pre-existing water sources surpasses the additional direct costs for using the piped water.

## 9.2 Discussion

As presented above, this research proved that the Project brought benefits on the well-being of the urban residents by installing the new piped water system, as the authority and the water supply entity expected. The reduction of coping cost is equal to 34 percent of the total coping cost at the baseline survey. The large portion of the reduced cost is from the reduction of the pumping labor, and 50 percent of the national minimum wage rate is used as the conversion rate. The conversion rate for the economic valuation of time use varies across literatures. Even though 50 percent is used in many literatures, some research used 25 percent or 75 percent. There is no standard on the conversion rate. If 25 percent is used in this research, the reduction of the coping cost is estimated at 3,694 kyat, which is slightly lower than the additional direct cost to use the piped water. Since the working status of the working age sample did not change, the reduction of pumping labor did not lead to income generation. The benefit from using the piped water varies widely due to the time use conversion rate. Yet, the households obtain more free time from reduced pumping labor and can spare the saved time for other activities including leisure. They also were able to use much more water in total, relative to the households without access to the piped water.

This research also reveals some challenges in improving the effectiveness and efficiency of materializing the benefits of the Project. First, the foreseen benefits on the well-being were realized because majority of the households connected to the piped water system with full subsidy in the connection cost from the Project. Without the full subsidy, the benefits would not have been realized since there was a large gap between the connection fee and willingness-to-pay on the connection cost. The household's willingness-to-pay on the connection fee is only 4.5 percent of the necessary connection cost. Since many households made large financial input to own their private wells, it would be a high hurdle to make additional payment on the connection cost of the piped water system. The households will notice the value of the piped water if they use it in their daily life. In case they do not know the value of the piped water and face the necessity of redrilling in times of water scarcity, households may choose the redrilling and spend more on the redrilling cost. However, the ground water level is not controllable by the households, and the private well is not considered as a sustainable water source under the pressure of urbanization and rapid population growth.

To mitigate the financial burden of the households and promote the private connection, the government needs to have a financial scheme for the potential piped water users. The full subsidy is favorable for households but may not be financially sustainable for the government and the water supply entities. Therefore, it is critical to explore more efficient financial schemes rather than the 100 percent subsidy for accelerating the private connection so that the expected benefits will be materialized with lower cost to public finance resources.

The various concerns related to urban water access is compiled in the analytical report of urban water supply in the low- and middle- income countries (Mitlin, et al., 2019). To promote the use of piped water, their first suggestion is to reduce the connection charges or create opportunities that will spread the initial cost over multiple payments. The second suggestion is to reduce the price of piped water for low-income households. The third one is to allow the household without the connection to access piped water supplies through kiosks with more favorable differential pricing.

There are multiple cases that improve the piped water access by subsidizing the connection cost in several countries. In South Africa, capital subsidy for housing including meter water connection has been provided for more than two million households. The local authorities in the urban area of Kenya, Uganda, and Senegal cover large portion of the connection cost. For example, in Dakar, Senegal, the households pay only 20 percent of the actual connection costs. With these public supports, the number of connections has increased in these countries. There are also several case studies that present those governments' efforts, but there are very limited literatures that rigorously examine how the financial support works on the connecting decision. The private connection of piped water in their premises in the urban area of Morocco is one case that examined the impact of the credit access intervention for the use of piped water. The study confirmed that the randomized encouragement design of information and marketing campaign of the credit scheme for the private connection increased the probability of obtaining the private connection (Devoto, et al., 2012).

In order to know what kind of financial interventions may lead to more private connection of piped water, it is necessary to examine the potential intervention rigorously. At present, the Project subsidized the private connection costs, but it may be difficult to employ the same measure in the other areas managed by MCDC or in other municipalities. From the results of the study, I found that households who are willing to connect have higher willingness-to-pay for the unit price of water, 427 kyat per unit.

This is more than double of the current unit price set by MCDC. Hence, there is a possibility of covering the connection costs for low-income households by differentiating the piped water price depending on the economic level of the households. Willingness-to-pay on the maintenance fee is 502 kyat per month on the average among all the households, which is much higher than the current maintenance cost set by MCDC. Since many households are willing to pay the fixed costs to use the piped water, the upfront connecting costs may be reduced by paying later including the monthly maintenance fee. Those financial arrangements have the potential to increase the private connection for households who cannot afford to pay the initial connecting cost. How to facilitate and encourage the private connection are the remaining issues that need to be examined to promote the use of piped water system in low- and middle- income countries.

Second, it should be noted that the impact of the newly constructed piped water system on the well-being of the urban residents was confirmed even under the situation that the drinking ratio of the piped water was low. If they used piped water more for drinking purpose, larger benefits in terms of reduced bottled water expense and improved health conditions would have been realized. The strange chemical odor and taste of the piped water might have discouraged the residents to drink it. Identifying the hindrances besides chemical odor and taste of the piped water for drinking and implementing some additional interventions to promote the use of piped water for drinking would improve the effectiveness of the Project. Because of the large investment cost of the piped water supply facilities, it is highly expected that the households utilize the piped water system especially for drinking purpose. This research attempted some information interventions to enhance the use of piped water by reducing the chlorine residuals for drinking purpose, but the interventions did not work to enhance the piped water use and drinking. The piped water with strange chemical odor and taste is the new goods for the residents of the area where the piped water was not available prior to the installation. The attempts to facilitate the piped water use especially for drinking purpose remains as a continuous challenge for the authorities or water supply entities, and further research are needed to confirm what factors discourage the drinking use of the piped water in more detail and what kind of interventions to promote the drinking use of the piped water are effective.

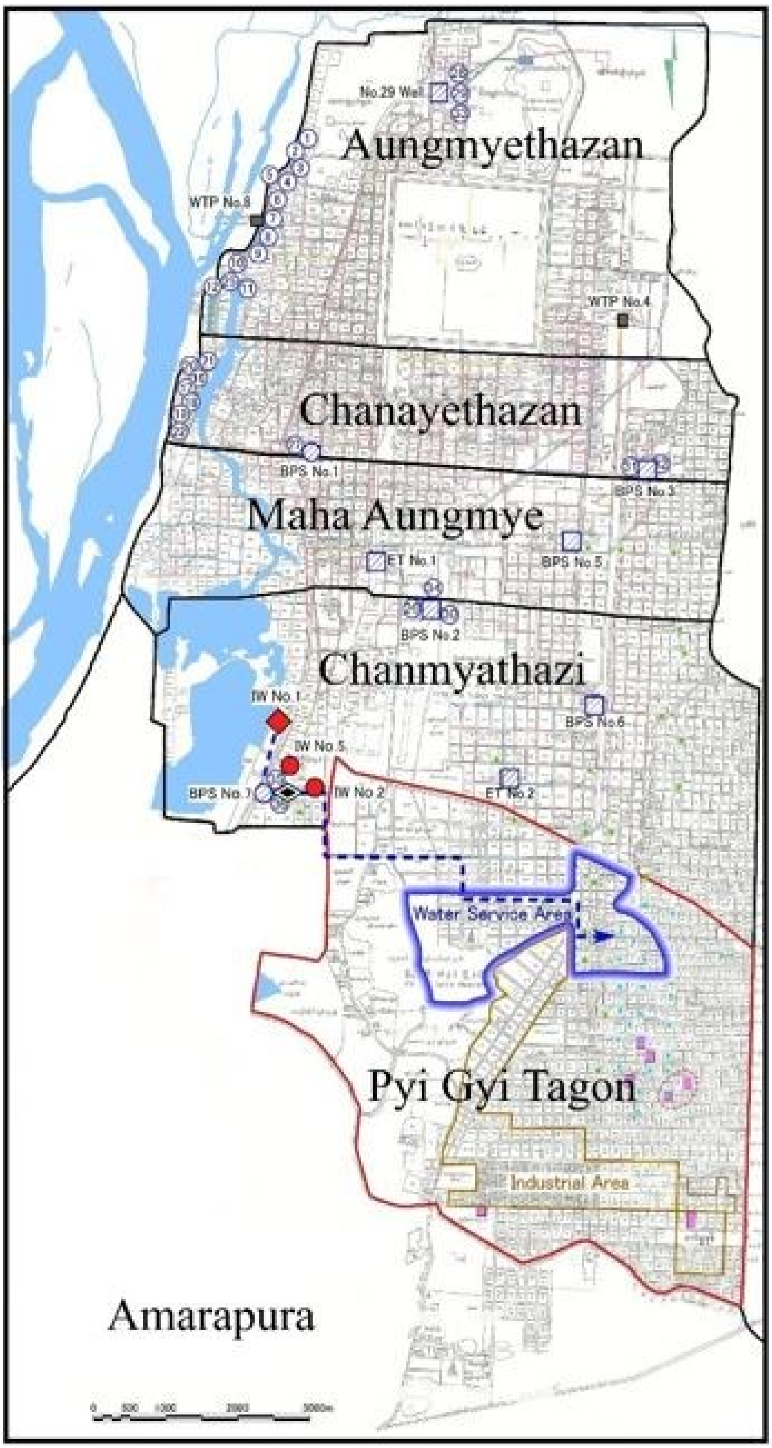
Lastly, although the Project decreased the time burden for obtaining water, the reduction of pumping time from private wells may not be large enough to alter working or schooling status. Alternatively, there may exist only limited opportunities and constraints especially for female members to work outside home and attend school in the City. If this is the case, the water-related infrastructure investment alone cannot make any significant impact on both working and schooling status. While the ratio of male labor participation is more than 80 percent, the female ratio is about 50 percent in Myanmar. Female members need to take care of the young children and have less work experience for finding a job. The national enrollment rate of higher education among the over 15 years old members is less than 20 percent. Hence, implementing relevant policy measures, particularly for females, to improve employment opportunities outside home and provide better educational environment would also raise the economic value of the Project.

The construction of the piped water supply facilities alone is not enough to fully utilize the capacity of the facilities and to elicit a larger effect on the well-being of the beneficiaries of the piped water supply. The complemental measures to enhance the use of piped water and to establish the social and economic environment are needed to maximize the impact of the installation of the piped water system. If the relevant policy measures, particularly for females, to improve employment opportunities outside home and to provide better educational environment is implemented, the labor market would be more developed and the employment opportunities would increase, resulting in the raise of wage in the end. Accordingly, the opportunity cost for the pumping labor would be higher and the people who are released from pumping work may seek for a job outside. Installation of the piped water system alone may not be sufficient to change the people's working status and schooling. The external environment such as labor market is a promoting factor to enhance the impact of the piped water supply. If these surrounding environments are set, the economic value of impact of the Project would have improved.

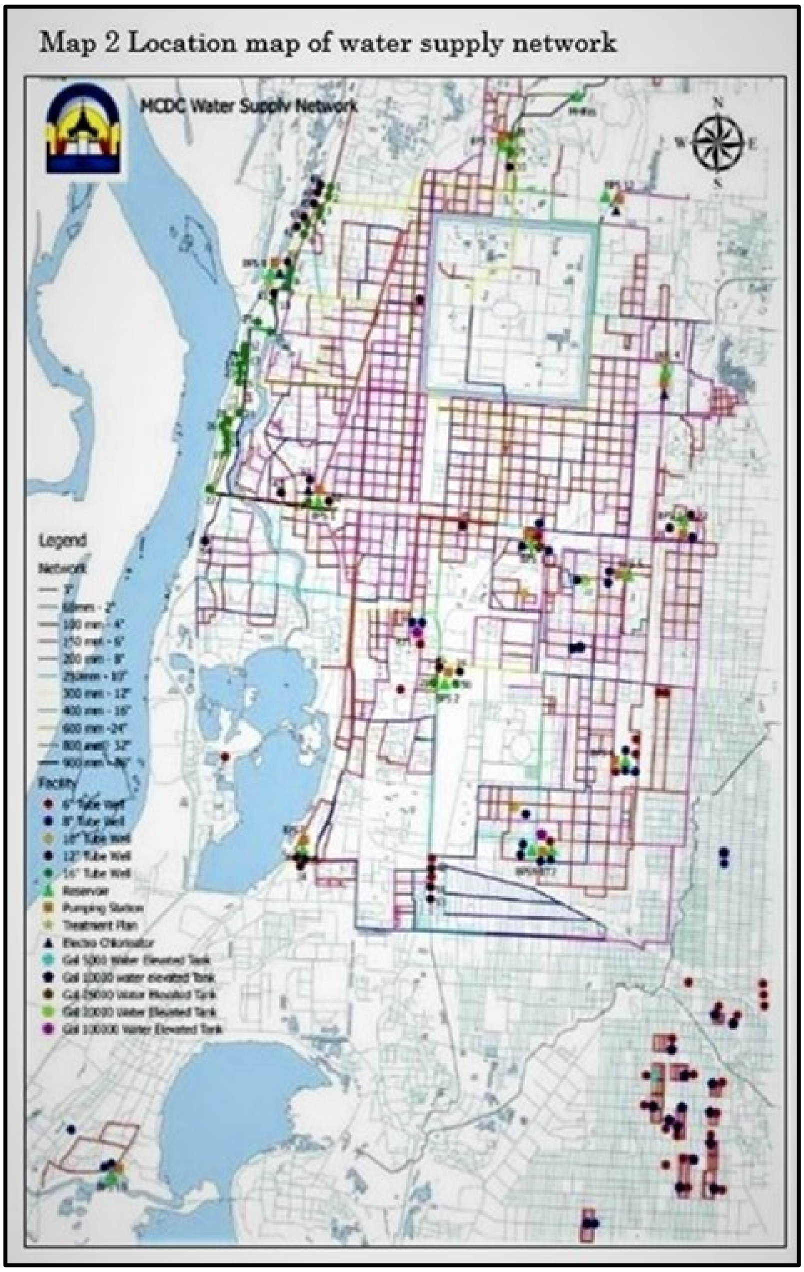
**Appendix**

Map

Map 1 Map of Mandalay city

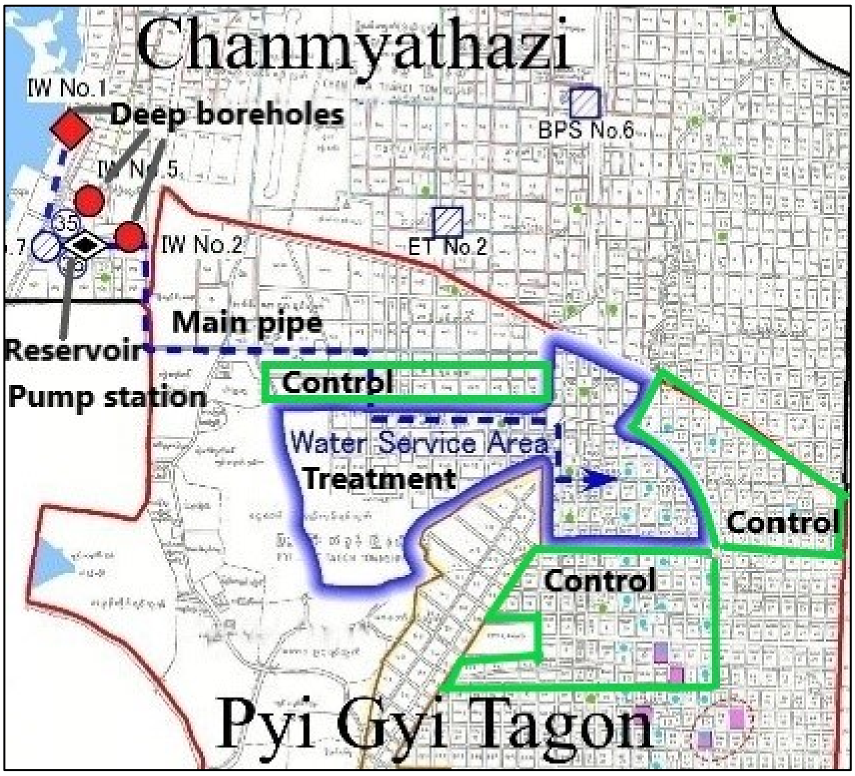


**Map2 Location map of water supply network**



**Map 3**

**Location map of the Project**
**(Piped water supply facilities, treatment blocks, and control blocks)**




* In this research, “construction of piped water supply facilities” is defined as the situation wherein MCDC constructs the water supply facilities including deep boreholes, reservoir, disinfection facilities, buster pump station, and main distribution pipes.

“Private connection” refers to the connection from main pipe to the meter box on the premise through branch pipes, based on the connecting decision of each household in treatment blocks.

“Installation of piped water system” means the overall situation in which the connected households are able to use piped water, which is distributed from piped water supply facilities to their premises.

## Chart

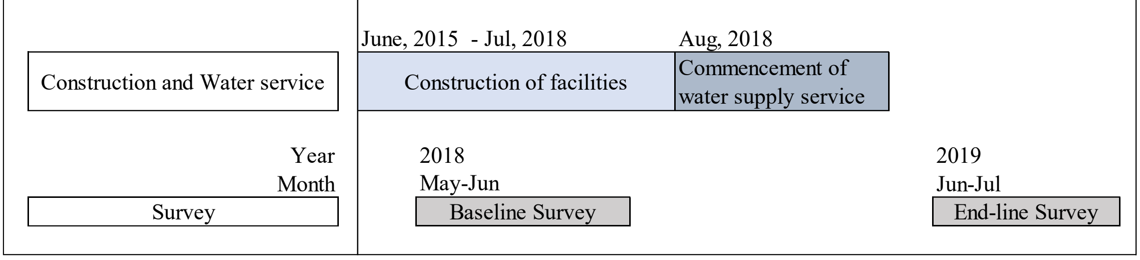
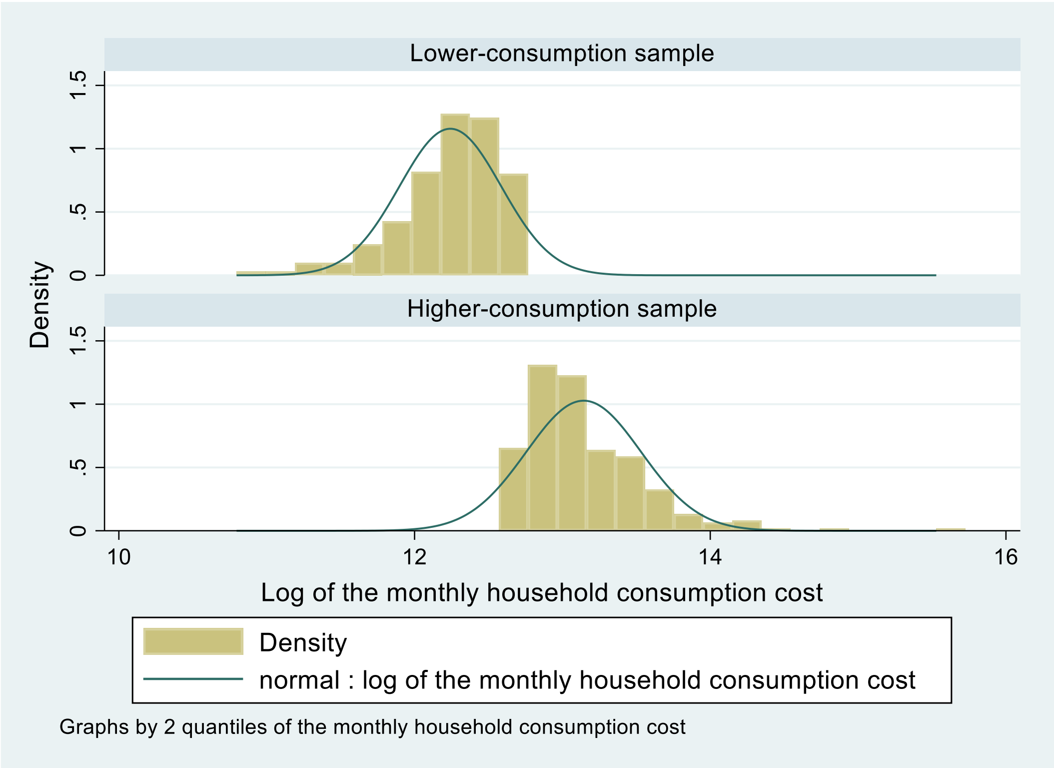



**Chart 1 Flow of Surveys**

Appendix of chapter 4

**Appendix 4-1 Distribution of log of monthly household consumption of lower and higher consumption sample**



**Appendix 4-2a Estimation result of examining the factors associated with the purchase of bottled water and its consumption (all)**

| Dependent Variable | Monthly bottled water consumption (1000kyat) | |
|---|---|---|
| Estimation model | Tobit | |
| | All | |
| | Model 1 | Model 2 |
| ***Independent Variables*** | | |
| Maximum schooling year of male member (Year) | 0.01 | 0.01 |
| | (0.06) | (0.06) |
| Maximum schooling year of female member (Year) | 0.14* | 0.14* |
| | (0.07) | (0.07) |
| Number of Household members | 0.06 | 0.05 |
| | (0.15) | (0.16) |
| Household of female head (=1) | -0.40 | -0.44 |
| | (0.71) | (0.71) |
| Household with Under 5 year children(=1) | 0.30 | 0.37 |
| | (0.61) | (0.59) |
| Asset measure | 2.75*** | 2.45*** |
| | (0.54) | (0.60) |
| Own house (=1) | -0.57 | -0.84 |
| | (0.84) | (0.86) |
| Perception of quality of their water (Clear =1) | -1.08* | |
| | (0.64) | |
| Own the private well (=1) | | 2.46** |
| | | (1.20) |
| The private well*Clear (1*1) | | -1.20* |
| | | (0.65) |
| Block fixed effect | included | included |
| Observations | 620 | 620 |

Note: Marginal effects evaluated at mean values are reported.
Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.

**Appendix 4-2b Estimation result of examining the factors associated with the purchase of bottled water and its consumption (higher and lower consumption samples)**

| Dependent Variable | Monthly bottled water consumption (1000kyat) | | | |
|---|---|---|---|---|
| Estimation model | Tobit | | | |
| | Upper half (Higher-consumption) | | Lower half (Lower-consumption) | |
| | Model 3 | Model 4 | Model 5 | Model 6 |
| ***Independent Variables*** | | | | |
| Maximum schooling year of male member (Year) | -0.03 | 0.01 | 0.01 | 0.01 |
| | (0.11) | (0.12) | (0.09) | (0.09) |
| Maximum schooling year of female member (Year) | 0.16 | 0.14 | 0.09 | 0.09 |
| | (0.13) | (0.13) | (0.10) | (0.09) |
| Number of Household members | -0.12 | -0.14 | 0.10 | 0.09 |
| | (0.26) | (0.26) | (0.26) | (0.26) |
| Household of female head (=1) | -0.74 | -0.68 | 0.31 | 0.25 |
| | (1.34) | (1.31) | (0.88) | (0.86) |
| Household with Under 5 year children(=1) | 1.00 | 1.16 | -0.60 | -0.57 |
| | (1.18) | (1.17) | (0.77) | (0.79) |
| Asset measure | 2.33** | 1.93** | 2.49*** | 2.46*** |
| | (0.93) | (0.94) | (0.71) | (0.76) |
| Own house (=1) | 0.08 | -0.46 | -1.66* | -1.73* |
| | (1.54) | (1.50) | (0.92) | (0.98) |
| Perception of quality of their water (Clear =1) | -0.66 | | -1.45* | |
| | (0.98) | | (0.88) | |
| Own the private well (=1) | | 5.02** | | 5.02** |
| | | (2.45) | | (2.45) |
| The private well*Clear (1*1) | | -1.00 | | -1.00 |
| | | (0.97) | | (0.97) |
| Block fixed effect | included | included | included | included |
| Observations | 310 | 310 | 310 | 310 |

Note: Marginal effects evaluated at mean values are reported.
Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.

## Appendix 4-3a Estimation result of examining the factors associated with the willingness-to-pay for the connection fee (all)

| Dependent Variable | WTP on connection (1000kyat) | |
|---|---|---|
| Estimation model | Tobit | |
| | All | |
| | Model 1 | Model 2 |
| ***Independent Variables*** | | |
| Maximum schooling year of male member (Year) | -0.04 | -0.06 |
| | (0.23) | (0.24) |
| Maximum schooling year of female member (Year) | 0.14 | 0.15 |
| | (0.26) | (0.26) |
| Number of Household members | 0.12 | 0.18 |
| | (0.59) | (0.60) |
| Household of female head (=1) | -2.82 | -2.80 |
| | (3.53) | (3.52) |
| Household with Under 5 year children(=1) | 2.89 | 2.73 |
| | (2.38) | (2.35) |
| Asset measure | 3.26 | 4.68** |
| | (2.15) | (2.38) |
| Own house (=1) | 12.64** | 13.99** |
| | (5.41) | (5.65) |
| Perception of quality of their water (Clear =1) | -3.56 | |
| | (2.46) | |
| Own the private well (=1) | | -3.41 |
| | | (3.53) |
| The private well*Clear (1*1) | | -3.94 |
| | | (2.72) |
| Block fixed effect | included | included |
| Observations | 620 | 620 |

Note: Marginal effects evaluated at mean values are reported.
Standard errors are given in parentheses with stars indicating the following: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.

## Appendix 4-3b Estimation result of examining the factors associated with the willingness-to-pay for the connection fee (higher and lower consumption samples)

| Dependent Variable | WTP on connection (1000kyat) | | | |
|---|---|---|---|---|
| Estimation model | Tobit | | | |
| | Upper half (Higher-consumption) | | Lower half (Lower-consumption) | |
| | Model 3 | Model 4 | Model 5 | Model 6 |
| ***Independent Variables*** | | | | |
| Maximum schooling year of male member (Year) | 0.64 | 0.58 | -0.20 | -0.20 |
| | (0.45) | (0.44) | (0.14) | (0.15) |
| Maximum schooling year of female member (Year) | -0.56 | -0.52 | 0.19 | 0.18 |
| | (0.65) | (0.65) | (0.18) | (0.17) |
| Number of Household members | -1.38 | -1.34 | 0.85* | 0.90** |
| | (1.20) | (1.20) | (0.44) | (0.45) |
| Household of female head (=1) | 0.40 | 0.09 | 1.04 | 0.96 |
| | (5.01) | (5.01) | (1.74) | (1.72) |
| Household with Under 5 year children(=1) | 9.44 | 9.16 | -1.27 | -1.50 |
| | (5.85) | (5.77) | (1.63) | (1.73) |
| Asset measure | 2.31 | 3.23 | 2.15* | 3.44** |
| | (3.39) | (3.40) | (1.30) | (1.57) |
| Own house (=1) | 13.19** | 14.02** | 4.08** | 4.80** |
| | (6.68) | (6.72) | (1.80) | (1.96) |
| Perception of quality of their water (Clear =1) | -0.35 | | -3.49* | |
| | (3.68) | | (1.82) | |
| Own the private well (=1) | | 5.02** | | -0.74 |
| | | (2.45) | | (2.36) |
| The private well*Clear (1*1) | | -1.00 | | -3.33 |
| | | (0.97) | | (2.06) |
| Block fixed effect | included | included | included | included |
| Observations | 310 | 310 | 310 | 310 |

Note: Marginal effects evaluated at mean values are reported.
Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.

## Appendix 4-4a Descriptive statistics of Willingness-to-maintain piped water system and willingness-to-pay the maintenance fee (all)

| | All | | |
|---|---|---|---|
| Type of water source as the main water source | Obs. | Willingness to maintain the system (0/1) | WTP on maintenance fee (kyat) |
| **1) WTP including the households which do not have willingness to maintain the piped water system** | 595 | 59.0 | 502 |
| **2) WTP of the households which have willingness to maintain the piped water system** | | | |
| Total | 595 | 59.0 | 823 |
| Private well (Own) | 506 | 61.3 | 805 |
| Neighbor's well | 65 | 58.5 | 873 |
| Neighbor's tap (Piped water/ Stand pipe) | 14 | 64.3 | 1222 |
| Connection with MCDC overhead tank(Own) | 3 | 100.0 | 833 |
| Public tap (Piped water/ Stand pipe) | 1 | 100.0 | 500 |
| Public well | 4 | 25.0 | 1000 |
| Water bought from water seller | 2 | 100.0 | 1000 |

Note: Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.

There are 25 households which did not answer the questions related with willingness to pay on connection with piped water system.

The table is compiled by the authour.

## Appendix 4-4b Descriptive statistics of willingness-to-maintain piped water system and willingness-to-pay the maintenance fee (higher and lower consumption samples)

| | Upper half (Higher consumption) | | | Lower half (Lower consumption) | | |
|---|---|---|---|---|---|---|
| Type of water source as the main water source | Obs. | Willingness to maintain the system (0/1) | WTP on maintenance fee (kyat) | Obs. | Willingness to maintain the system (0/1) | WTP on maintenance fee (kyat) |
| **1) WTP including the households which do not have willingness to maintain the piped water system** | 302 | 64.2 | 546 | 293 | 58.0 | 457 |
| **2) WTP of the households which have willingness to maintain the piped water system** | | | | | | |
| Total | 302 | 64.2 | 854 | 293 | 58.0 | 788 |
| Private well (Own) | 274 | 63.1 | 851 | 232 | 59.1 | 747 |
| Neighbor's well | 19 | 68.4 | 738 | 46 | 54.4 | 944 |
| Neighbor's tap (Piped water/ Stand pipe) | 4 | 100.0 | 1500 | 10 | 50.0 | 1000 |
| Connection with MCDC overhead tank(Own) | 1 | 100.0 | 500 | 2 | 100.0 | 1000 |
| Public tap (Piped water/ Stand pipe) | 1 | 100.0 | 500 | | | |
| Public well | 2 | 50.0 | 1000 | 2 | 0.0 | 0 |
| Water bought from water seller | 1 | 100.0 | 1000 | 1 | 100.0 | 1000 |

Note: Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.
There are 25 households which did not answer the questions related with willingness to pay on connection with piped water system.
The table is compiled by the authour.

## Appendix 4-5 Correlation between independent variables

| | Maximum schooling year of male member (Year) | Maximum schooling year of female member (Year) | Number of Household members | Household of female head (=1) | Household with Under 5 year children(=1) | Asset measure | Own house (=1) | Own private well (=1) |
|---|---|---|---|---|---|---|---|---|
| Maximum schooling year of male member (Year) | 1.00 | | | | | | | |
| Maximum schooling year of female member (Year) | 0.28 | 1.00 | | | | | | |
| Number of Household members | 0.16 | 0.22 | 1.00 | | | | | |
| Household of female head (=1) | -0.18 | 0.07 | -0.06 | 1.00 | | | | |
| Household with Under 5 year children(=1) | 0.04 | 0.03 | 0.28 | -0.02 | 1.00 | | | |
| Asset measure | 0.30 | 0.34 | 0.12 | -0.03 | -0.09 | 1.00 | | |
| Own house (=1) | 0.05 | 0.07 | 0.11 | 0.07 | -0.14 | 0.25 | 1.00 | |
| Own private well (=1) | 0.12 | 0.19 | 0.07 | 0.01 | -0.11 | 0.45 | 0.31 | 1.00 |

**Appendix 4-6a Estimation result of examining the factors associated with the willingness-to-pay for the regular use of piped water per unit (all)**

| Dependent Variable | WTP on regular use per a unit (1000kyat) | |
|---|---|---|
| Estimation model | Tobit | |
| | All | |
| | Model 1 | Model 2 |
| ***Independent Variables*** | | |
| Maximum schooling year of male member (Year) | 0.019* | 0.018 |
| | (0.011) | (0.011) |
| Maximum schooling year of female member (Year) | 0.008 | 0.008 |
| | (0.010) | (0.010) |
| Number of Household members | 0.006 | 0.007 |
| | (0.023) | (0.023) |
| Household of female head (=1) | -0.027 | -0.025 |
| | (0.112) | (0.111) |
| Household with Under 5 year children(=1) | 0.105 | 0.102 |
| | (0.111) | (0.113) |
| Asset measure | 0.161** | 0.187** |
| | (0.069) | (0.073) |
| Own house (=1) | 0.064 | 0.093 |
| | (0.143) | (0.151) |
| Perception of quality of their water (Clear =1) | -0.112 | |
| | (0.118) | |
| Own the private well (=1) | | -0.005 |
| | | (0.162) |
| The private well*Clear (1*1) | | -0.152 |
| | | (0.122) |
| Block fixed effect | included | included |
| Observations | 620 | 620 |

Note: Marginal effects evaluated at mean values are reported.
Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.

## Appendix 4-6b Estimation result of examining the factors associated with the willingness-to-pay for the regular use of piped water per unit (higher and lower consumption samples)

| Dependent Variable | WTP on connection (1000kyat) | | | |
|---|---|---|---|---|
| Estimation model | Tobit | | | |
| | Upper half (Higher-consumption) | | Lower half (Lower-consumption) | |
| | Model 3 | Model 4 | Model 5 | Model 6 |
| ***Independent Variables*** | | | | |
| Maximum schooling year of male member (Year) | 0.039* | 0.039* | 0.008 | 0.008 |
| | (0.021) | (0.021) | (0.015) | (0.015) |
| Maximum schooling year of female member (Year) | 0.004 | 0.004 | 0.007 | 0.006 |
| | (0.016) | (0.016) | (0.013) | (0.012) |
| Number of Household members | -0.019 | -0.019 | 0.017 | 0.017 |
| | (0.037) | (0.037) | (0.038) | (0.037) |
| Household of female head (=1) | -0.056 | -0.058 | 0.080 | 0.078 |
| | (0.186) | (0.187) | (0.156) | (0.154) |
| Household with Under 5 year children(=1) | 0.161 | 0.157 | 0.042 | 0.035 |
| | (0.128) | (0.127) | (0.160) | (0.163) |
| Asset measure | 0.122 | 0.130 | 0.087 | 0.141 |
| | (0.093) | (0.097) | (0.118) | (0.123) |
| Own house (=1) | 0.174 | 0.173 | -0.078 | -0.034 |
| | (0.188) | (0.185) | (0.232) | (0.235) |
| Perception of quality of their water (Clear =1) | 0.091 | | -0.392 | |
| | (0.135) | | (0.248) | |
| Own the private well (=1) | | -0.053 | | 0.206 |
| | | (0.175) | | (0.271) |
| The private well*Clear (1*1) | | 0.033 | | -0.428 |
| | | (0.124) | | (0.272) |
| Block fixed effect | included | included | included | included |
| Observations | 310 | 310 | 310 | 310 |

Note: Marginal effects evaluated at mean values are reported.
Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.

## Appendix 4-7a Willingness-to-maintain piped water system and willingness-to-pay the maintenance fee (all)

| | All | | | |
|---|---|---|---|---|
| | Dependent Variable | | Dependent Variable | |
| | Willingness to maintain the system (0/1) | Log of WTP on maintenance fee (kyat) | Willingness to maintain the system (0/1) | Log of WTP on maintenance fee (kyat) |
| | Probit | Heckman | Probit | Heckman |
| Independent Variables | Model 1 | Model 2 | Model 3 | Model 4 |
| Maximum schooling year of male member | -0.003 | -0.005 | -0.004 | -0.005 |
| (Year) | (0.004) | (0.010) | (0.004) | (0.011) |
| Maximum schooling year of female member | 0.006 | -0.000 | 0.006 | -0.002 |
| (Year) | (0.005) | (0.014) | (0.005) | (0.014) |
| Number of Household members | 0.002 | -0.002 | 0.002 | -0.003 |
| | (0.014) | (0.025) | (0.014) | (0.025) |
| Household of female head (=1) | -0.045 | -0.045 | -0.044 | -0.035 |
| | (0.054) | (0.120) | (0.054) | (0.118) |
| Household with Under 5 year children(=1) | 0.023 | 0.110 | 0.019 | 0.103 |
| | (0.044) | (0.101) | (0.044) | (0.097) |
| Asset measure | 0.054 | -0.040 | 0.081* | -0.040 |
| | (0.039) | (0.111) | (0.042) | (0.147) |
| Own house (=1) | 0.169*** | 0.036 | 0.198*** | 0.007 |
| | (0.052) | (0.313) | (0.054) | (0.348) |
| Perception of quality of their water (Clear =1) | -0.055 | 0.041 | | |
| | (0.051) | (0.136) | | |
| Own the private well (=1) | | | -0.072 | -0.056 |
| | | | (0.068) | (0.182) |
| The private well*Clear (1*1) | | | -0.067 | 0.022 |
| | | | (0.055) | (0.151) |
| Block fixed effect | included | included | included | included |
| Inverse Mills Ratio | | -0.055 | | -0.192 |
| | | (1.096) | | (1.056) |
| R-squared | | 0.22 | | 0.221 |
| Observations | 595 | 595 | 595 | 595 |

Note: Marginal effects evaluated at mean values are reported.
25households did not answer willingness-to-pay questions.
Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.

## Appendix 4-7b Willingness-to-maintain piped water system and willingness-to-pay the maintenance fee (higher consumption sample)

| | Upper half (Higher-consumption) | | | |
|---|---|---|---|---|
| | Dependent Variable | | Dependent Variable | |
| | Willingness to maintain the system (0/1) | Log of WTP on maintenance fee (kyat) | Willingness to maintain the system (0/1) | Log of WTP on maintenance fee (kyat) |
| | Probit | Heckman | Probit | Heckman |
| Independent Variables | Model 5 | Model 6 | Model 7 | Model 8 |
| Maximum schooling year of male member | 0.014* | 0.011 | 0.013 | 0.023 |
| (Year) | (0.008) | (0.080) | (0.009) | (0.074) |
| Maximum schooling year of female member | -0.000 | -0.006 | 0.001 | -0.004 |
| (Year) | (0.010) | (0.022) | (0.010) | (0.022) |
| Number of Household members | -0.007 | -0.040 | -0.006 | -0.045 |
| | (0.022) | (0.062) | (0.022) | (0.059) |
| Household of female head (=1) | -0.025 | -0.427* | -0.030 | -0.471* |
| | (0.106) | (0.250) | (0.106) | (0.271) |
| Household with Under 5 year children(=1) | 0.044 | 0.270 | 0.040 | 0.276 |
| | (0.081) | (0.290) | (0.080) | (0.268) |
| Asset measure | 0.048 | 0.047 | 0.061 | 0.150 |
| | (0.070) | (0.265) | (0.073) | (0.328) |
| Own house (=1) | 0.163 | 0.558 | 0.173* | 0.768 |
| | (0.101) | (1.019) | (0.100) | (1.037) |
| Perception of quality of their water (Clear =1) | -0.010 | 0.140 | | |
| | (0.075) | (0.176) | | |
| Own the private well (=1) | | | -0.076 | -0.391 |
| | | | (0.179) | (0.520) |
| The private well*Clear (1*1) | | | -0.024 | 0.071 |
| | | | (0.080) | (0.212) |
| Block fixed effect | included | included | included | included |
| Inverse Mills Ratio | | 1.470 | | 2.198 |
| | | (3.497) | | (3.406) |
| R-squared | | 0.388 | | 0.338 |
| Observations | 300 | 300 | 300 | 300 |

Note: Marginal effects evaluated at mean values are reported.
25households did not answer willingness-to-pay questions.
Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.

## Appendix 4-7c Willingness-to-maintain piped water system and willingness-to-pay the maintenance fee (lower consumption sample)

| | Lower half (Lower-consumption) | | | |
|---|---|---|---|---|
| | Dependent Variable | | Dependent Variable | |
| | Willingness to maintain the system (0/1) | Log of WTP on maintenance fee (kyat) | Willingness to maintain the system (0/1) | Log of WTP on maintenance fee (kyat) |
| | Probit | Heckman | Probit | Heckman |
| Independent Variables | Model 9 | Model 10 | Model 11 | Model 12 |
| Maximum schooling year of male member | -0.016** | 0.042 | -0.016** | 0.048* |
| (Year) | (0.007) | (0.030) | (0.007) | (0.026) |
| Maximum schooling year of female member | 0.009 | -0.028 | 0.008 | -0.035* |
| (Year) | (0.008) | (0.020) | (0.008) | (0.018) |
| Number of Household members | 0.025 | -0.099** | 0.023 | -0.103** |
| | (0.023) | (0.049) | (0.023) | (0.046) |
| Household of female head (=1) | -0.040 | -0.051 | -0.037 | -0.017 |
| | (0.076) | (0.164) | (0.077) | (0.159) |
| Household with Under 5 year children(=1) | -0.012 | 0.360** | -0.024 | 0.422*** |
| | (0.086) | (0.154) | (0.086) | (0.154) |
| Asset measure | 0.076 | -0.301 | 0.129 | -0.371 |
| | (0.068) | (0.196) | (0.080) | (0.238) |
| Own house (=1) | 0.201** | -0.590 | 0.258*** | -0.825* |
| | (0.085) | (0.398) | (0.094) | (0.418) |
| Perception of quality of their water (Clear =1) | -0.178** | 0.826** | | |
| | (0.082) | (0.336) | | |
| Own the private well (=1) | | | 0.000 | -0.437** |
| | | | (0.109) | (0.210) |
| The private well*Clear (1*1) | | | -0.198** | 0.965*** |
| | | | (0.090) | (0.317) |
| Block fixed effect | included | included | included | included |
| Inverse Mills Ratio | | -0.096 | | -2.463*** |
| | | (0.483) | | (0.915) |
| R-squared | | 0.503 | | 0.611 |
| Observations | 295 | 295 | 295 | 295 |

Note: Marginal effects evaluated at mean values are reported.
25households did not answer willingness-to-pay questions.
Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.

## Appendix 4-7a Estimation result of examining the factors associated with willingness-to-pay the maintenance fee (all)

| Dependent Variable | WTP on maintenance fee (1000kyat) | |
|---|---|---|
| Estimation model | Tobit | |
| | All | |
| | Model 1 | Model 2 |
| ***Independent Variables*** | | |
| Maximum schooling year of male member (Year) | -0.003 | -0.003 |
| | (0.013) | (0.013) |
| Maximum schooling year of female member (Year) | 0.001 | 0.001 |
| | (0.013) | (0.013) |
| Number of Household members | 0.041 | 0.041 |
| | (0.035) | (0.035) |
| Household of female head (=1) | -0.036 | -0.036 |
| | (0.136) | (0.136) |
| Household with Under 5 year children(=1) | -0.006 | -0.006 |
| | (0.121) | (0.121) |
| Asset measure | 0.160 | 0.160 |
| | (0.100) | (0.100) |
| Own house (=1) | 0.344** | 0.344** |
| | (0.159) | (0.159) |
| Perception of quality of their water (Clear =1) | -0.171 | |
| | (0.127) | |
| Own the private well (=1) | | -0.176 |
| | | (0.196) |
| The private well*Clear (1*1) | | -0.225 |
| | | (0.141) |
| Block fixed effect | included | included |
| Observations | 620 | 620 |

Note: Marginal effects evaluated at mean values are reported.
Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.

## Appendix 4-7b Estimation result of examining the factors associated with willingness-to-pay the maintenance fee (higher and lower consumption samples)

| Dependent Variable | WTP on maintenance fee (1000kyat) | | | |
|---|---|---|---|---|
| Estimation model | Tobit | | | |
| | Upper half (Higher-consumption) | | Lower half (Lower-consumption) | |
| | Model 3 | Model 4 | Model 5 | Model 6 |
| ***Independent Variables*** | | | | |
| Maximum schooling year of male member (Year) | 0.007 | 0.005 | -0.010 | -0.011 |
| | (0.023) | (0.024) | (0.017) | (0.019) |
| Maximum schooling year of female member (Year) | 0.009 | 0.010 | -0.014 | -0.017 |
| | (0.019) | (0.019) | (0.020) | (0.020) |
| Number of Household members | -0.021 | -0.020 | 0.095* | 0.104** |
| | (0.051) | (0.052) | (0.052) | (0.049) |
| Household of female head (=1) | -0.072 | -0.083 | 0.030 | 0.043 |
| | (0.201) | (0.198) | (0.172) | (0.168) |
| Household with Under 5 year children(=1) | 0.075 | 0.066 | -0.099 | -0.145 |
| | (0.190) | (0.183) | (0.193) | (0.198) |
| Asset measure | -0.021 | 0.008 | 0.302 | 0.537** |
| | (0.173) | (0.185) | (0.189) | (0.214) |
| Own house (=1) | 0.481* | 0.505* | 0.180 | 0.318 |
| | (0.265) | (0.265) | (0.233) | (0.237) |
| Perception of quality of their water (Clear =1) | -0.015 | | -0.351* | |
| | (0.162) | | (0.206) | |
| Own the private well (=1) | | -0.180 | | -0.246 |
| | | (0.359) | | (0.259) |
| The private well*Clear (1*1) | | -0.066 | | -0.484** |
| | | (0.174) | | (0.238) |
| Block fixed effect | included | included | included | included |
| Observations | 310 | 310 | 310 | 310 |

Note: Marginal effects evaluated at mean values are reported.
Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.

Appendix of chapter 5

## Appendix 5-1 Balance test of sample characteristics as of baseline survey

| | Treatment blocks | Control blocks | Difference | Statitical significance |
|---|---|---|---|---|
| Variable | Mean | Mean | | |
| *Household water use* | **n=620** | **n=330** | | |
| Total water use volume ($m^3$) | 36.0 | 36.2 | -0.2 | |
| Water use volume per day per capita (liter) | 284 | 274 | 9 | |
| Use of private well (%) | 84.8 | 84.5 | 0.3 | |
| Water use volume of private well ($m^3$) | 33.6 | 33.3 | 0.3 | |
| Purchase of bottled water (%) | 72.1 | 76.7 | -4.6 | |
| Household bottled water use per month (liter) | 316 | 331 | -15 | |
| Household bottled water cost per month (1000kyat) | 5.6 | 5.8 | -0.2 | |
| Perception of quality of their water (Clear =1) (%) | 77.4 | 81.2 | -3.8 | |
| *Characteristics of Households* | **n=620** | **n=330** | | |
| Maximum schooling year of household member (Year) | 10.8 | 10.6 | 0.2 | |
| Number of Household Members | 4.6 | 4.9 | -0.2 | * |
| Household with Under 5 year old children (%) | 28.7 | 33.3 | -4.6 | |
| Household monthly household income (1000 kyat) | 435 | 472 | -37 | |
| Asset Measure | 1.7 | 1.7 | 0.0 | |
| Own the private well (%) | 84.8 | 84.5 | 0.3 | |
| Own house (%) | 81.5 | 77.9 | 3.6 | |
| Monthly electricity fee (1000 kyat) | 9.7 | 9.8 | -0.1 | |
| *Characteristics of Block* | **n=62** | **n=33** | | |
| Population density (number per 10,000 sq feet) | 16.8 | 16.2 | 0.5 | |
| Density of buildings (number per 10,000 sq feet) | 3.3 | 3.1 | 0.2 | |

The value displayed for t-tests are the differences in the means across the groups.
***, **, and * indicate significance at the 1, 5, and 10 percent significance level.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.

## Appendix 5-2 Summary statistics of independent variables

| **Baseline Survey** | Mean | S.D. | Min | Max |
|---|---|---|---|---|
| *Characteristics of household member* | | | | |
| Maximum schooling year of household member (Year) | 10.81 | (3.83) | 0 | 16 |
| *Characteristics of household* | | | | |
| Number of Household Members | 4.79 | (1.91) | 1 | 14 |
| Household with Under 5 year old children (=1) | 0.3 | (0.46) | 0 | 1 |
| Asset Measure | 1.75 | (0.61) | 0 | 3.8 |
| Perception of quality of their water (Clear =1) | 0.79 | (0.41) | 0 | 1 |
| *Survey timing* | | | | |
| Survey in May, 2018 | 0.34 | (0.47) | 0 | 1 |
| Survey in June, 2018 | 0.66 | (0.47) | 0 | 1 |
| Observations | 791 | | | |

| **End-line Survey** | Mean | S.D. | Min | Max |
|---|---|---|---|---|
| *Characteristics of household member* | | | | |
| Maximum schooling year of household member (Year) | 10.83 | (3.82) | 0 | 16 |
| *Characteristics of household* | | | | |
| Number of Household Members | 4.87 | (2.08) | 1 | 16 |
| Household with Under 5 year old children (=1) | 0.31 | (0.46) | 0 | 1 |
| Asset Measure | 1.87 | (0.61) | 0 | 3.7 |
| Perception of quality of their water (Clear =1) | 0.79 | (0.42) | 0 | 1 |
| *Survey timing* | | | | |
| Survey in June, 2019 | 0.97 | (0.18) | 0 | 1 |
| Survey in July, 2019 | 0.03 | (0.18) | 0 | 1 |
| Observations | 791 | | | |

## Appendix of chapter 6

### Appendix 6-1 Balance test of sample characteristics as of baseline survey (whole sample)

| | Treatment blocks | Control blocks | Difference | Statitical significance |
|---|---|---|---|---|
| Variable | Mean | Mean | | |
| ***Individual characteristics*** | **n=2872** | **n=1601** | | |
| Female (%) | 46.0 | 47.1 | -1.1 | |
| Age | 32.3 | 31.8 | 0.5 | |
| Schooling year | 7.0 | 6.7 | 0.3 | ** |
| *Characteristics of Households (Average of each block)* | **n=620** | **n=330** | | |
| Maximum schooling year of household member (Year) | 10.8 | 10.6 | 0.2 | |
| Number of Household Members | 4.6 | 4.9 | -0.2 | |
| Household with Under 5 year old children (%) | 0.29 | 0.33 | -0.05 | |
| Household monthly household income (1000 kyat) | 435 | 472 | -37.00 | |
| Asset Measure | 1.73 | 1.72 | 0.02 | |
| Own the private well (=1) | 0.85 | 0.85 | 0.00 | |
| Own house (=1) | 0.82 | 0.78 | 0.04 | |
| Perception of quality of their water (Clear =1) | 0.77 | 0.81 | -0.04 | |
| Monthly electricity fee (1000 kyat) | 9.7 | 9.8 | -0.1 | |
| Characteristics of Block | **n=62** | **n=33** | | |
| Population density (number per 10,000 sq feet) | 16.8 | 16.2 | 0.5 | |
| Density of buildings (number per 10,000 sq feet) | 3.3 | 3.1 | 0.2 | |

The value displayed for t-tests are the differences in the means across the groups.
*t* -test or Fisher's exact test results are shown; * Significant at 10%, ** Significant at 5%, *** Significant at 1%.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.
Table is compiled by the author.

**Appendix 6-2 Summary statistics of independent variables for analysis of health incidences (Individual)**

| **Baseline Survey** | Mean | S.D. | Min | Max |
|---|---|---|---|---|
| ***Individual characteristics (n=4473)*** | | | | |
| Female (=1) | 0.46 | (0.50) | 0 | 1 |
| Age | 32.14 | (19.75) | 0 | 95 |
| Schooling years | 6.91 | (4.50) | 0 | 16 |
| ***Characteristics of household member (n=791)*** | | | | |
| Maximum schooling year of household member (Year) | 10.96 | (3.59) | 0 | 16 |
| ***Characteristics of household (n=791)*** | | | | |
| Number of Household Members | 5.44 | (2.04) | 1 | 14 |
| Household with Under 5 year old children (=1) | 0.36 | (0.48) | 0 | 1 |
| Asset Measure | 1.75 | (0.61) | 0 | 3.8 |
| Perception of quality of their water (Clear =1) | 0.78 | (0.41) | 0 | 1 |
| *Survey timing* | | | | |
| Survey in May, 2018 | 0.33 | (0.47) | 0 | 1 |
| Survey in June, 2018 | 0.67 | (0.47) | 0 | 1 |

| **End-line Survey** | Mean | S.D. | Min | Max |
|---|---|---|---|---|
| ***Individual characteristics (n=3851)*** | | | | |
| Female (=1) | 0.46 | (0.50) | 0 | 1 |
| Age | 32.5 | (20.20) | 0 | 96 |
| Schooling years | 6.9 | (4.60) | 0 | 16 |
| ***Characteristics of household member (n=791)*** | | | | |
| Maximum schooling year of household member (Year) | 11.14 | (3.59) | 0 | 16 |
| ***Characteristics of household (n=791)*** | | | | |
| Number of Household Members | 5.76 | (2.32) | 1 | 15 |
| Household with Under 5 year old children (=1) | 0.39 | (0.49) | 0 | 1 |
| Asset Measure | 1.89 | (0.59) | 0.1 | 3.8 |
| Perception of quality of their water (Clear =1) | 0.78 | (0.41) | 0 | 1 |
| *Survey timing* | | | | |
| Survey in June, 2019 | 0.97 | (0.16) | 0 | 1 |
| Survey in July, 2019 | 0.03 | (0.16) | 0 | 1 |

* Table is compiled by the author.

## Appendix 6-3 DD estimation of individual health symptoms (Working age sample: between 17 and 60 years old )

| VARIABLES | abdominal pain | | vomiting incidence | | diarrhea incidence | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | ITT, Block FE | ITT, Household FE | ITT, Block FE | ITT, Household FE | ITT, Block FE | ITT, Household FE |
| Treatment and year dummy variables | | | | | | |
| Treatment block * year 2019(=1) | -0.004 | -0.005 | 0.001 | 0.001 | -0.004 | -0.005 |
| (treatment effect) | (0.010) | (0.009) | (0.005) | (0.005) | (0.005) | (0.005) |
| Year dummy | -0.024*** | -0.027*** | -0.007 | -0.006 | -0.004 | -0.004 |
| (2018=0, 2019= 1) | (0.009) | (0.008) | (0.005) | (0.005) | (0.005) | (0.004) |
| | | | | | | |
| Other control var | Included | Included | Included | Included | Included | Included |
| Block fixed effect | Included | | Included | | Included | |
| Household fixed effect | | Included | | Included | | Included |
| | | | | | | |
| Observations | 4,929 | 4,929 | 4,929 | 4,929 | 4,929 | 4,929 |
| R-squared | 0.039 | 0.009 | 0.039 | 0.009 | 0.030 | 0.006 |
| Number of HHID | | 786 | | 786 | | 786 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

## Appendix 6-4 DD estimation of individual health symptoms (Schooling age sample: between 6 and 16 years old)

| VARIABLES | abdominal pain | | vomiting incidence | | diarrhea incidence | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | ITT, Block FE | ITT, Household FE | ITT, Block FE | ITT, Household FE | ITT, Block FE | ITT, Household FE |
| Treatment and year dummy variables | | | | | | |
| Treatment block * year 2019(=1) | 0.008 | 0.004 | 0.005 | 0.002 | -0.010 | -0.013 |
| (treatment effect) | (0.015) | (0.014) | (0.009) | (0.010) | (0.008) | (0.008) |
| Year dummy | -0.026* | -0.021* | -0.007 | -0.007 | -0.004 | -0.003 |
| (2018=0, 2019= 1) | (0.014) | (0.011) | (0.008) | (0.009) | (0.007) | (0.007) |
| | | | | | | |
| Other control var | Included | Included | Included | Included | Included | Included |
| Block fixed effect | Included | | Included | | Included | |
| Household fixed effect | | Included | | Included | | Included |
| | | | | | | |
| Observations | 1,375 | 1,375 | 1,375 | 1,375 | 1,375 | 1,375 |
| R-squared | 0.111 | 0.008 | 0.083 | 0.019 | 0.091 | 0.018 |
| Number of HHID | | 454 | | 454 | | 454 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

## Appendix 6-5 DD estimation of individual health symptoms (Under 5 years old)

| VARIABLES | abdominal pain | | vomiting incidence | | diarrhea incidence | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | ITT, Block FE | ITT, Household FE | ITT, Block FE | ITT, Household FE | ITT, Block FE | ITT, Household FE |
| Treatment and year dummy variables | | | | | | |
| Treatment block * year 2019(=1) | -0.005 | -0.012 | -0.004 | 0.024 | 0.026 | 0.054 |
| (treatment effect) | (0.025) | (0.023) | (0.034) | (0.025) | (0.032) | (0.034) |
| Year dummy | 0.005 | 0.000 | -0.028 | -0.019 | -0.047 | -0.039 |
| (2018=0, 2019= 1) | (0.024) | (0.018) | (0.032) | (0.024) | (0.030) | (0.033) |
| | | | | | | |
| Other control var | Included | Included | Included | Included | Included | Included |
| Block fixed effect | Included | | Included | | Included | |
| Household fixed effect | | Included | | Included | | Included |
| | | | | | | |
| Observations | 402 | 402 | 402 | 402 | 402 | 402 |
| R-squared | 0.374 | 0.004 | 0.203 | 0.044 | 0.300 | 0.042 |
| Number of HHID | | 231 | | 231 | | 231 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.

## Appendix 6-6 Analysis on piped water use (as of March 2019)

| Outcome variables | Connect to piped water (Yes=1) | Use piped water (Yes=1) | Drink piped water (Yes=1) |
|---|---|---|---|
| Model | (1) | (2) | (3) |
| Estimation model | Probit | Probit | Probit |
| Explanatory variables | | | |
| Maximum schooling year of household member (Year) | 0.057** | 0.042** | -0.034* |
| | (0.022) | (0.020) | (0.018) |
| Number of Household members | 0.082 | 0.081* | 0.046 |
| | (0.050) | (0.045) | (0.037) |
| Household with Under 5 year children(=1) | -0.385** | -0.220 | -0.185 |
| | (0.181) | (0.168) | (0.150) |
| Asset measure | 0.273* | 0.214 | -0.368*** |
| | (0.149) | (0.133) | (0.116) |
| Perception of quality of their water (Clear =1) | 0.171 | 0.044 | -0.160 |
| | (0.190) | (0.176) | (0.148) |
| | | | |
| Observations | 522 | 522 | 522 |

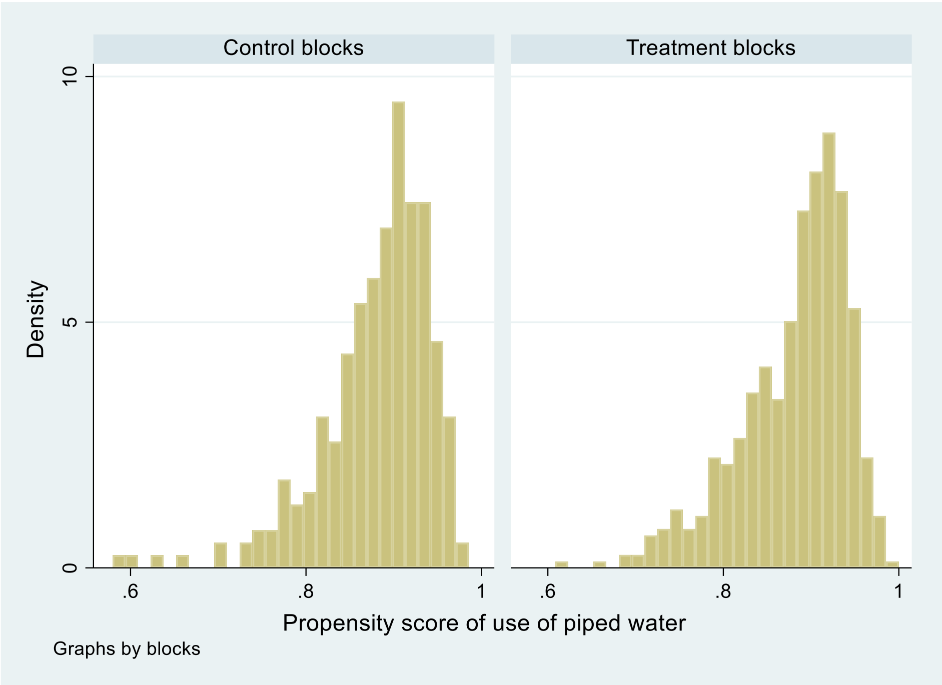
t-test or Fisher's exact test results are shown; * Significant at 10%, ** Significant at 5%, *** Significant at 1%.

Explanatory variables in baseline survey is used.

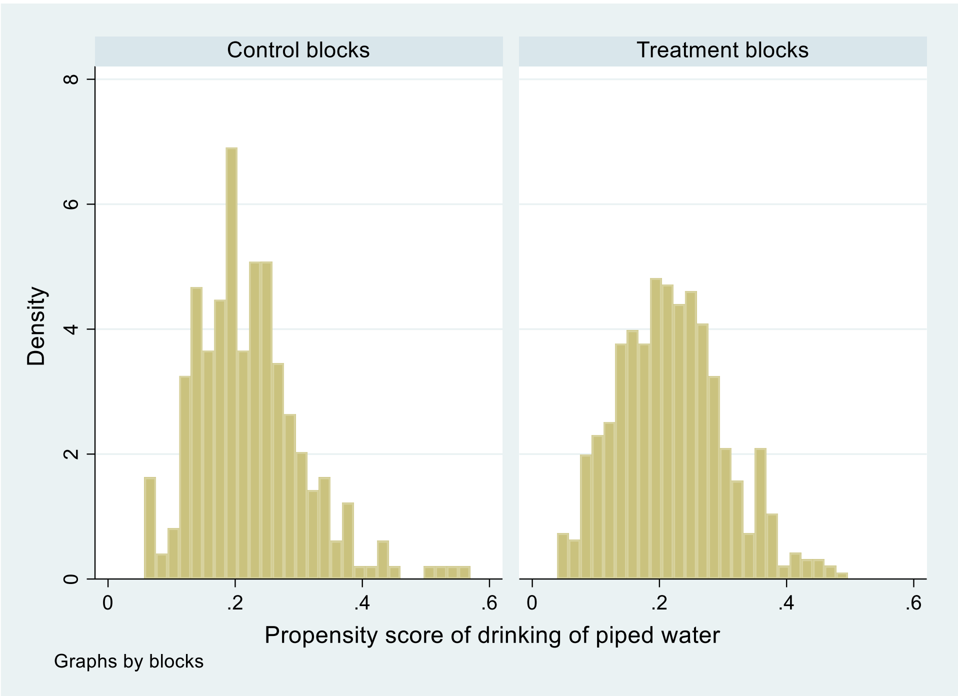
Marginal effect is presented.

The piped water use before information interventions is examined.

**Appendix 6-7 Distribution of propensity score of use of piped water (Whole sample)**




**Appendix 6-8 Distribution of propensity score of drinking of piped water (Whole sample)**



Appendix of chapter 7

## Appendix 7-1a Type of industry of the salaried workers (at the endline survey)

| Salaried work (furll time/part time job) | | | | | | |
|---|---|---|---|---|---|---|
| **Type of industry** | ALL | | Male | | Female | |
| Wholesale and retail trade | 65 | (10.1) | 28 | (8.0) | 37 | (12.7) |
| Repair of vehicles and goods | 23 | (3.6) | 20 | (5.7) | 3 | (1.0) |
| Manufacturing | 85 | (13.2) | 42 | (12.0) | 43 | (14.7) |
| Textile/Clothing | 12 | (1.9) | 3 | (0.9) | 9 | (3.1) |
| Construction work | 78 | (12.1) | 66 | (18.9) | 12 | (4.1) |
| Transport | 62 | (9.7) | 59 | (16.9) | 3 | (1.0) |
| Warehousing business | 2 | (0.3) | 1 | (0.3) | 1 | (0.3) |
| Food and beverage production | 72 | (11.2) | 23 | (6.6) | 49 | (16.8) |
| Restaurant and tea shop | 4 | (0.6) | | | 4 | (1.4) |
| Hotel/Guesthouse | 4 | (0.6) | 2 | (0.6) | 2 | (0.7) |
| Agriculture, forestry or Fishing | 4 | (0.6) | 3 | (0.9) | 1 | (0.3) |
| Financial intermediation | 23 | (3.6) | 7 | (2.0) | 16 | (5.5) |
| Real estate | 3 | (0.5) | 3 | (0.9) | | |
| Education/Teacher | 51 | (7.9) | 8 | (2.3) | 43 | (14.7) |
| Health and social work | 15 | (2.3) | 1 | (0.3) | 14 | (4.8) |
| Community, social and personal service | 22 | (3.4) | 13 | (3.7) | 9 | (3.1) |
| Government Service | 36 | (5.6) | 19 | (5.4) | 17 | (5.8) |
| Tourism | 3 | (0.5) | 2 | (0.6) | 1 | (0.3) |
| Other | 78 | (12.1) | 50 | (14.3) | 28 | (9.6) |
| Total | 642 | (100) | 350 | (100) | 292 | (100) |

Note: The table is compiled by the author.

**Appendix 7-1b Type of industry of the self-employment workers (at the endline survey)**

| Self-employment | | | | | | |
|---|---|---|---|---|---|---|
| **Type of industry** | ALL | | Male | | Female | |
| Wholesale and retail trade | 229 | (30.3) | 70 | (16.9) | 159 | (46.4) |
| Repair of vehicles and goods | 61 | (8.1) | 60 | (14.5) | 1 | (0.3) |
| Manufacturing | 38 | (5.0) | 15 | (3.6) | 23 | (6.7) |
| Textile/Clothing | 43 | (5.7) | 3 | (0.7) | 40 | (11.7) |
| Construction work | 62 | (8.2) | 61 | (14.8) | 1 | (0.3) |
| Transport | 90 | (11.9) | 87 | (21.1) | 3 | (0.9) |
| Warehousing business | | | | | | |
| Food and beverage production | 49 | (6.5) | 19 | (4.6) | 30 | (8.7) |
| Restaurant and tea shop | 35 | (4.6) | 8 | (1.9) | 27 | (7.9) |
| Hotel/Guesthouse | 1 | (0.1) | | | 1 | (0.3) |
| Agriculture, forestry or Fishing | 9 | (1.2) | 9 | (2.2) | | |
| Financial intermediation | 2 | (0.3) | | | 2 | (0.6) |
| Real estate | 17 | (2.2) | 14 | (3.4) | 3 | (0.9) |
| Education/Teacher | 7 | (0.9) | 1 | (0.2) | 6 | (1.7) |
| Health and social work | 2 | (0.3) | 1 | (0.2) | 1 | (0.3) |
| Community, social and personal service | 19 | (2.5) | 15 | (3.6) | 4 | (1.2) |
| Government Service | | | | | | |
| Tourism | | | | | | |
| Other | 92 | (12.2) | 50 | (12.1) | 42 | (12.2) |
| Total | 756 | (100) | 413 | (100) | 343 | (100) |

Note: The table is compiled by the author.

## Appendix 7-1c Type of industry of the casual labors (at the endline survey)

| Casual labor | | | | | | |
|---|---|---|---|---|---|---|
| **Type of industry** | ALL | | Male | | Female | |
| Wholesale and retail trade | 4 | (1.7) | 2 | (1.2) | 2 | (3.2) |
| Repair of vehicles and goods | 7 | (3.0) | 7 | (4.2) | | |
| Manufacturing | 11 | (4.8) | 4 | (2.4) | 7 | (11.3) |
| Textile/Clothing | | | | | | |
| Construction work | 94 | (40.9) | 85 | (50.6) | 9 | (14.5) |
| Transport | 18 | (7.8) | 18 | (10.7) | | |
| Warehousing business | 1 | (0.4) | | | 1 | (1.6) |
| Food and beverage production | 14 | (6.1) | 2 | (1.2) | 12 | (19.4) |
| Restaurant and tea shop | 1 | (0.4) | | | 1 | (1.6) |
| Hotel/Guesthouse | | | | | | |
| Agriculture, forestry or Fishing | 1 | (0.4) | | | 1 | (1.6) |
| Financial intermediation | | | | | | |
| Real estate | 2 | (0.9) | 1 | (0.6) | 1 | (1.6) |
| Education/Teacher | 1 | (0.4) | | | 1 | (1.6) |
| Health and social work | | | | | | |
| Community, social and personal service | 17 | (7.4) | 13 | (7.7) | 4 | (6.5) |
| Government Service | | | | | | |
| Tourism | 2 | (0.9) | 1 | (0.6) | 1 | (1.6) |
| Other | 57 | (24.8) | 35 | (20.8) | 22 | (35.5) |
| Total | 230 | (100) | 168 | (100) | 62 | (100) |

Note: The table is compiled by the author.

Appendix A Examining the effect of information interventions for enhancing piped water use

## 1 Background and research interest

One of the main objectives for installing piped water systems is to supply safe and drinkable water, disinfected by chlorine before distribution to users. Yet, it is uncertain if the residents use piped water as planned especially in the area where they have access to pre-existing water sources. Odor and taste of residual chlorine often remain in piped water, and the chlorinous flavor is the main reason why piped water users do not drink the piped water (Piriou, et al. 2015). Some people just purchase bottled water for drinking or drink water from other sources. A unit cost of bottled water is much higher than that of piped water. People who drink water from their pre-existing water sources may consume contaminated water. Supply of disinfected piped water would mitigate the financial burden of purchasing bottled water or reduce their health risks from the contaminated water.

The ratio of drinking piped water in low- and middle- income countries are low because many people do not trust water quality of piped water from the deteriorated water supply facilities and distribution pipes. Those households are forced to purchase bottled water because of low-quality piped water. Because the supply of poor-quality piped water from deteriorated facilities are common in many low- and middle- income countries, limited literatures have assessed how people from these countries use and drink the piped water in case they have access to high-quality water with disinfection.

The Project installed the new piped water system and allows examining the impact of the high-quality piped water on water use. Table A-1 reports the piped water use in treatment blocks in March 2019, which is between the baseline and endline surveys of this Project. The connection rate is more than 90 percent and usage rate is 86 percent. Although the drinking rate is merely 16.5 percent. Many households without access to piped water system in the City drink bottled water or drink water from other sources. The people may not know the benefit of disinfected piped water and dislike the odor and taste of chlorine residuals in the piped water. Even though the chlorine residuals are not perfectly removed from piped water, mitigating measures of chlorine residuals may encourage drinking behavior of piped water.

This section examines whether providing additional information on the importance of chlorination and on how to mitigate odor and taste of chlorine residuals from water would promote the drinking behavior of piped water. This section also examines whether providing additional information about the danger of contaminated water and recommending the filtering and boiling of their water would encourage them to practice water treatment activities to improve water quality. In many areas of low- and middle-income countries, people do not have access to safe and drinkable piped water. Those people need to obtain their drinking water by their own efforts. Some people drink their water directly from the source without any water treatment although it is recommended to conduct water treatments such as filtering, boiling, and disinfection by chlorine. There are two possible sources of water contamination. First, sourced water may be already contaminated by harmful bacteria at the water source. Second, safe water may be contaminated while carrying back from source to residence or to water storage/container at the house. Many literatures reported that water from improved water source was often contaminated during collection, transport, and household storage (Wright, et al., 2004; Rufener, et al., 2010; Shaheed, et al., 2014). Therefore, it is essential to keep water safe and drinkable at point of use before its consumption.

Water and hygiene education have been widely conducted for decades in the world. The systematic reviews covering water quality issues for preventing diarrhea suggested that household water treatments (HWTS) are more effective in preventing diarrhea than water quality interventions at the point of water distribution facilities (Fewtrell, et al., 2005; Clasen, et al., 2006; Waddington, et al., 2009). There are evidence that household water treatments may be exaggerated due to reporting bias. There is the issue of sustained adoption of HWTS. Only 27 percent of studies related to water and sanitation interventions have found a continuous use of HWTS during follow-up (Fiebelkorn, et al., 2012). The research examining the water boiling practices at home in urban area of Cambodia illustrated that only 31 percent of household boiled water at follow-up visit, while more than 90 percent of those households had reported they boiled water in the prior visit. There are hurdles for people to conduct water treatments. These include cost, time, or chore.

In the project blocks, many people use private wells and purchase bottled water. Some households complained that their water contain small particles such as sand. There are possibilities of water contamination with fecal bacteria because private well water is often pumped up from first aquifer, sub-surface water layer of approximately 10 m depth. Basic water treatments such as filtering and boiling are at least recommended. Some households in the project blocks drink their private well water without any water treatments and said that they liked the taste of their private well water. Those people are accustomed to drink their private well water and may not drink piped water. With providing information on water treatment, people may choose to drink private well water rather than piped water.

With the above-mentioned concerns, this section examines the impact of two types of information intervention on their water use behavior: (1) importance of chlorination and on how to mitigate odor and taste of chlorine residuals of piped water and (2) importance of water treatments on water from their pre-existing sources.

**Table A-1 Piped water use in treatment blocks, March, 2019**

| | Number of HHs | Ratio(%) |
|---|---|---|
| Connect to piped water | 517 | 91.8 |
| Use piped water | 485 | 86.1 |
| Drink piped water | 93 | 16.5 |

The number of sampled households in the treatment blocks is 563.
The average monthly piped water use volume of the using household is 15.1 $m^3$.
The table is compiled by the author.

## 2 Survey design

For the analysis of this section, the surveyed households were selected as follows. In the water service blocks where the Project supplies piped water, there were some blocks with many factories or large grasslands but with few residents. Those blocks were excluded because this research focused on the water use of the habitants of residential area. Ninety-seven (97) blocks were remained as project blocks in five wards (Ngwe Taw Kyi Kone, Thin Pan Kone, Ga Nge, Ga Gyi, and Nga). Among the 97 project blocks, 65 blocks were randomly selected as treatment blocks. Map 3 shows the location of piped water supply facilities and the areas of treatment and control blocks.

In the control area which is outside of the water service blocks, the exhaustive block survey was conducted in April 2018. One hundred twenty-four (124) non-project blocks in three wards (Thin Pan Kone, Kha Gway, and Salone) were surveyed. Based on the block survey data, 65 control blocks which have similar characteristics with the treatment blocks were purposefully selected from non-project blocks. In total, there were 130 selected blocks composed of 65 treatment and 65 control blocks. From each selected block, ten households were randomly chosen[23]. One thousand and three hundred (1,300) households were interviewed in the baseline survey in May and June of

[23] In order to select 10 households, the surveyors first counted and assigned the number to the eligible households in the block. The starting point of counting was selected randomly from the four corners of the block, which is normally square-shaped. After making the list of the eligible households for piped water system in the block, 10 households were randomly selected.

2018. As illustrated in Chart 2, the water supply service of the Project commenced in August 2018. In March 2019, the additional information which could affect water use behavior were given to the selected households. The endline survey was conducted in June and July of 2019, which is approximately one year after the baseline survey, to assess the water use change after the commencement of the piped water service.

The two types of information intervention were conducted in March 2019, between the baseline and endline surveys. First intervention is to provide the importance of disinfection using chlorine and on how to mitigate chlorine odor and taste from piped water using brochure with pictures. Many users of piped water are unwilling to drink piped water. Even though some households dislike the unfamiliar odor and taste, the chlorination is essential to provide safe piped water. Information on the importance of chlorination may encourage the proper water use and enhance drinking of the piped water at the newly installed piped water supply area.

The information on chlorination and ways to mitigate the odor and taste of piped water were compiled as one package of intervention to enhance the use of piped water. Half of the randomly selected households in the project blocks received the information. The enumerator explained why disinfection of water by chlorination is essential in supplying safe water which reduces the risk of water-borne diseases. Then, the enumerator informed the households of the mitigating methods. The first mitigating method is to store the piped water in 20-liter bottle or water storage pot and put it under sunshine for a day. Another method is to pour the piped water in a jar and to store it in their refrigerator for drinking. The enumerator demonstrated drinking of piped water and the mitigated piped water in front of the respondents and asked the respondents to drink the two kinds of water. Many respondents accepted to drink the water.

The second intervention is to inform the importance of water treatment for obtaining safe water. Households without access to piped water are forced to obtain safe water by their own efforts. Many households purchase bottled water for drinking purpose. Some drink water from their private well or other peoples' water sources. Some of them conduct filtering of water by using a small filtering net and boiling of water for drinking purpose. The ratio of filtering or boiling is not high. Chlorination at home is not popular because it is difficult to procure the chlorine tablets or powder in the market.

The information and methods of water treatments were compiled as one package of the intervention for promoting water treatment. Half of the households were randomly selected in treatment and control blocks. Households in the treatment blocks received the information on the importance of water treatments and the recommendation to conduct filtering and boiling with the use of pamphlet with pictures of water treatment. Then, the water treatment behaviors were confirmed in the endline survey.

In addition to two interventions, water quality test of their main existing source was conducted in March 2019. If they use more than two water sources, their main water source was selected. Piped water is not tested because it is disinfected at water supply facility site. The test kit of water quality test has the capacity to detect the existence of E. coli in the water. If the water test result is positive, it means that the water is contaminated and the users were informed that the water is contaminated. Results showed that 16.6 percent of households' main water source were contaminated (Appendix A-1).

Table A-2 summarizes the number of sampled households with and without information interventions in treatment and control blocks. In treatment blocks, half of the households received information intervention for enhancing use of piped water. Half of the households received the information intervention for enhancing water treatment. In total, there were four groups: those who received both interventions, those who received only information intervention for enhancing use of piped water, those who received only information intervention for enhancing water treatment, and those who did not receive any information intervention. Among 1300 households interviewed in the baseline survey, there are 11 households of which the data such as volume of private well water use are considered as outliers. Those households were omitted and 1289 household data is analyzed.

Among 1289 households, 1020 households were interviewed in the baseline and endline surveys and were surveyed at the time of information interventions. Of the 1020 households, there are 500 households in the treatment blocks and 520 households in the control blocks. The attrition rate from baseline survey to endline survey is 22 percent and 19.8 percent in treatment blocks and control blocks, respectively. The analyses in this section used the data of the 1020 households.

**Table A-2 Information intervention in both treatment and control blocks**

| | Before Intervention | | After intrervention | | Attrition | |
|---|---|---|---|---|---|---|
| **Treatment area** | | | | | | |
| No of Block | 65 | | 65 | | | |
| No of HHs | 641 | (100.0) | 500 | (100.0) | 141 | (22.0) |
| ***1) Information Intervention for enhancing use of piped water*** | | | | | | |
| Treatment | 323 | (50.4) | 252 | (45.9) | 71 | (22.0) |
| Control | 318 | (49.6) | 248 | (45.2) | 70 | (22.0) |
| ***2)Information Intervention for enhancing water treatment*** | | | | | | |
| Treatment | 314 | (49.0) | 253 | (46.1) | 61 | (19.4) |
| Control | 327 | (51.0) | 248 | (45.2) | 79 | (24.2) |
| ***3) Combination of Information intervenstion 1) & 2)*** | | | | | | |
| Treatment 1 (Both information 1 & 2) | 159 | (24.8) | 123 | (24.8) | 36 | (22.6) |
| Treatment 2 (use of piped water) | 164 | (25.6) | 129 | (26.2) | 35 | (21.3) |
| Treatment 3 (water treatment) | 155 | (24.2) | 129 | (25.3) | 26 | (16.8) |
| Control (No information) | 163 | (25.4) | 119 | (23.7) | 44 | (27.0) |
| **Control area** | | | | | | |
| No of Block | 65 | | 65 | | | |
| No of HHs | 648 | (100.0) | 520 | (100.0) | 128 | (19.8) |
| ***Information Intervention for enhancing water treatment*** | | | | | | |
| Treatment | 323 | (49.8) | 254 | (82.5) | 69 | (21.4) |
| Control | 325 | (50.2) | 266 | (86.4) | 59 | (18.2) |

The table is compiled by the author.

## 3 Descriptive analysis of the impact of information interventions on piped water use in treatment blocks

It is up to each household on whether they will use and drink the piped water. Table A-3 presents ratio of use and drinking of piped water system and monthly piped water volume among households with and without the information intervention for enhancing use of piped water in treatment blocks. Before the intervention, there were some differences of usage rate and drinking rate between treatment and control households, but the differences were not statistically significant. At the endline survey, usage ratio of piped water increased in both blocks. Drinking ratio increased in both treatment and control households, but the difference-in-differences between these households in two periods are not statistically significant.

Table A-4 presents ratio of use and drinking of piped water and piped water use volume among households with and without the information intervention for enhancing water treatment in treatment blocks. Before the intervention, there are statistically significant differences in piped water volume between treatment and control households.

Table A-5 presents the ratio of water treatments of the piped water, reducing odor and taste of chlorine residuals in the piped water and storing the piped water in refrigerator for drinking purpose, among households with and without the information intervention for enhancing piped water use in treatment blocks. Table A-6 presents the ratio of the water treatments of the piped water among households with and without the information intervention for enhancing water treatment in treatment blocks.

The ratios of reducing chlorine residuals and of storing the piped water in refrigerators are very low before the information interventions. The differences of these ratios are not statistically significant between samples in both tables. However, after the interventions, these ratios increased slightly. The households received the interventions and some of them start doing the treatments for drinking purpose, but the difference-in-differences is not statistically significant. Since the drinking ratio of the piped water is low, the ratio of these water treatments for the households who drink the piped water is also very low.

**Table A-3 Piped water use with/without information intervention for enhancing use of piped water in treatment blocks**

| Information Intervention for enhancing use of piped water | Before information intervention | | | After information intervention | | | Diff. in Diff |
|---|---|---|---|---|---|---|---|
| | Treatment | Control | diff. | Treatment | Control | diff. | |
| 1)Usage rate (%) | 87.7 | 85.5 | 2.2 | 88.4 | 88.0 | 0.5 | -1.7 |
| 2)Drink rate (%) | 18.3 | 14.9 | 3.4 | 23.8 | 20.9 | 2.9 | -0.5 |
| 3)Monthly piped water volume( $m^3$) | 15.0 | 13.2 | 1.8 | 20.6 | 16.8 | 3.76** | 2.0 |

Note: ***, **, and * indicate statistically significance at the 1, 5, and 10 percent level.
The number of sampled household in the treatment blocks is 500.
The table is compiled by the author.

**Table A-4 Piped water use with/without information intervention for enhancing water treatment in treatment blocks**

| Information Intervention for enhancing water treatment | Before information intervention | | | After information intervention | | | Diff. in Diff |
|---|---|---|---|---|---|---|---|
| | Treatment | Control | diff. | Treatment | Control | diff. | |
| 1)Usage rate (%) | 84.5 | 88.7 | -4.2 | 86.5 | 89.9 | -3.4 | 0.8 |
| 2)Drink rate (%) | 15.8 | 17.3 | -1.5 | 20.2 | 24.5 | -4.3 | -2.8 |
| 3)Monthly piped water volume( $m^3$) | 12.9 | 15.1 | -2.2* | 16.9 | 20.4 | -3.5** | -1.3 |

Note: ***, **, and * indicate statistically significance at the 1, 5, and 10 percent level.
The number of sampled household in the treatment blocks is 500.
The table is compiled by the author.

**Table A-5 Water treatment of the piped water with/without information intervention for enhancing use of piped water in treatment blocks**

| Information Intervention for enhancing use of piped water | Before information intervention | | | After information intervention | | | Diff. in Diff |
|---|---|---|---|---|---|---|---|
| | Treatment | Control | diff. | Treatment | Control | diff. | |
| 1)Water treatment for reducing chlorine odor and taste of piped water | 0.8 | 0.8 | 0.0 | 3.5 | 2.0 | 1.5 | 1.5 |
| 2)Storing of the piped water in refrigerator (%) | 2.4 | 3.2 | -0.8 | 5.6 | 4.0 | 1.6 | 2.4 |

Note: ***, **, and * indicate statistically significance at the 1, 5, and 10 percent level.
The number of sampled household in the treatment blocks is 500.
The table is compiled by the author.

**Table A-6 Water treatment of the piped water with/without information intervention for enhancing water treatment in treatment blocks**

| Information Intervention for enhancing water treatment | Before information intervention | | | After information intervention | | | Diff. in Diff |
|---|---|---|---|---|---|---|---|
| | Treatment | Control | diff. | Treatment | Control | diff. | |
| 1)Water treatment for reducing chlorine odor and taste of piped water | 0.8 | 0.8 | 0.0 | 2.8 | 2.8 | 0.0 | 0.0 |
| 2)Storing of the piped water in refrigerator (%) | 1.6 | 4.0 | -2.4* | 4.8 | 4.8 | 0.0 | 2.4 |

Note: ***, **, and * indicate statistically significance at the 1, 5, and 10 percent level.
The number of sampled household in the treatment blocks is 500.
The table is compiled by the author.

## 4 Descriptive analysis of the impact of information interventions for enhancing water treatment on water treatment behaviors in control blocks

In control blocks, households cannot access the new piped water system and are requested to use their pre-existing water sources continuously. The information intervention for enhancing water treatment is randomly assigned to half of the sampled households in control blocks.

Table A-7 presents water use and sample characteristics of treatment and control households of information intervention for enhancing water treatment on piped water use in control blocks. There is no statistically significant difference on the water treatment behaviors between treatment and control groups, which means that those treatment and control households have similar and comparable characteristics.

More than one third of households conducted water treatment before the information intervention for enhancing water treatment. There are much less households who conduct boiling compared to the number of households who conduct filtering. After intervention, there is large decrease of water treatment implementation, although the reason for the decrease is not clear. The difference-in-differences in the descriptive analysis is not statistically significant. The treatment effect of the intervention does not seem to be found from the descriptive analysis.

**Table A-7 Piped water use with/without information intervention for enhancing water treatment in treatment blocks**

| Information Intervention for enhancing water | Before information intervention | | | After information intervention | | | Diff. in Diff |
|---|---|---|---|---|---|---|---|
| | Treatment | Control | diff. | Treatment | Control | diff. | |
| Filtering (%) | 34.2 | 28.2 | 6.0 | 19.7 | 16.5 | 3.2 | -2.8 |
| Boiling (%) | 9.8 | 10.9 | -1.1 | 2.8 | 3 | -0.2 | 0.9 |
| Any water treatment (%) | 36.6 | 32.4 | 4.2 | 20.1 | 17.3 | 2.8 | -1.4 |

Note: ***, **, and * indicate statistically significance at the 1, 5, and 10 percent level.
The number of sampled household in the treatment blocks is 520.
The table is compiled by the author.

## 5 Estimation strategy and results

### 5.1 Estimation strategy

As described in section 2, each information intervention was randomly assigned in treatment and control blocks. It is expected that observable and unobservable characteristics in treatment and control households are similar and comparable, if the random assignment goes well. Though it is possible to examine the impact of each intervention only with endline survey data, it is recommended to utilize the panel data to control covariates which may potentially have the correlation with the interventions.

The double difference estimation methodology (hereinafter referred to "DD") is employed. The DD methodology is a combination of before/after comparison and with/without comparison. The central assumption for the methodology to be valid is the "parallel trend" assumption, which assumes that a change over two periods should be common (without the interventions) between the comparison blocks. The parallel trend assumption in the DD estimator may be violated if the changes caused by covariates are not common between the treatment and control households. Thus, I employed an empirical model with some covariates because I examined if this is the case.

The balance tests of the water use situation and the household characteristics for the analyses were carried out. Appendix A-2 reports the water use and characteristics of treatment and control households of information intervention for enhancing use of piped water in the treatment blocks. Appendix A-3 reports that of information intervention for enhancing water treatment on piped water use in the treatment blocks. The water use and household characteristics of treatment and control households for examining the impact of the information interventions are not significantly different in all the listed variables. It is considered that those treatment and control households have similar and comparable characteristics.

For information intervention to enhance water treatment in control blocks, the water use and household characteristics of treatment and control households are not significantly different in the listed variables (Appendix A-4). Water use situation was similar between treatment and control households. It is considered that the random assignment of each intervention was successfully done. These households have the similar and comparable characteristics of households, conjecturing that the parallel trend assumption holds. In order to rigorously examine the impact on water use with information interventions, multivariate regression models were utilized.

The basic specification for the DD methodology is as follows:

$$Y_{ijt} = \beta_0 + \beta_1 \cdot t + \beta_2 \cdot S_j + \beta_3 \cdot (S_j \cdot t) + \beta_4 \cdot R_j + \beta_5 \cdot (R_j \cdot t) + \epsilon_{ijt} \quad (1)$$

where: i refers to a household, j points to block and t is time (*t* = 0 for before intervention and *t* = 1 for after intervention).

To confirm the effect of the information intervention for enhancing the use of piped water and the effect of the information intervention for enhancing water treatment on piped water, both interventions were included in the model. The information intervention for enhancing use of piped water is assumed to promote drinking of piped water, whereas the information intervention for enhancing water treatment may lead to the decrease of drinking use of piped water because the households may prefer to drink private well water rather than piped water with unfavorable odor and taste. There are two treatment variables for this estimation. $S_j$ is for the information intervention to enhance use of piped water and $R_j$ is for the information intervention to enhance water treatment. For the analysis of information intervention for enhancing use of piped water in treatment blocks, both $S_j$ and $R_j$ are included. For the analysis of information intervention to enhance water treatment in control blocks, only $R_j$ is included.

This model estimates the intention-to-treat (ITT) impact of the Project to measure the effect of the installation of new piped water system on piped water use. *Yijt* is the dependent variable and takes two forms: binary variable or continuous variable, depending on each analysis. ITT is employed for this section because of the high piped water use rate, which is more than 86 percent. Analysis for ITT may capture the underestimated impacts compared to the analysis for average treatment effect. Yet, if ITT estimation confirms the positive impact of the Project, it can be interpreted that the Project caused the impact on water use though it reports the underestimated impact.

The dependent variables examined by DD estimator are piped water use (ratio of use and drinking and piped water use volume) and water treatment (ratio of filtering, boiling, and any water treatments). Turning to the right-hand side variables, Sj and $R_j$ are binary variables that take the value 1 if the information intervention is provided to the household and 0 otherwise. $\beta_0$ to $\beta_5$ are the parameters to be estimated. $\beta_3$ and $\beta_5$ are the parameter of our interest and measures the impact of the Project on the outcomes for the analysis of information intervention for enhancing use of piped water in treatment blocks. For the analysis of information intervention to enhance water treatment in control blocks, $\beta_0$, $\beta_1$, $\beta_4$ and $\beta_5$ are estimated. $\beta_5$ is the parameter of my interest. $\epsilon_{ijt}$ is a well-behaved error term. The ordinary least squared (OLS) estimation was employed to estimate the coefficients.

$$Y_{ijt} = \beta_0 + \beta_1 \cdot t + \beta_2 \cdot S_j + \beta_3 \cdot (S_j \cdot t) + \beta_4 \cdot R_j + \beta_5 \cdot (R_j \cdot t) + X_{ijt} \cdot \gamma_1 + X_{jt} \cdot \gamma_2 + \epsilon_{ijt} \quad (2)$$

The covariates take two forms (summary statistics of the covariates are shown in Appendix A-5 and Appendix A-6); $X_{ijt}$ is a vector to include a set of household characteristics and $X_{jt}$ is a vector containing a set of block j's characteristics other than treatment ($S_j$). $X_{jt}$ contains dummy variables that capture block-level fixed effects. $X_{ijt}$ contains three dummy variables that capture seasonal differences in the survey months: May, June, or July, with reference to June. $\gamma_1$ and $\gamma_2$.are the parameters to be estimated along with $\beta_0$ to $\beta_5$ .

5.2 Estimation result of the impact of information interventions on piped water use in treatment blocks

Table A-8 presents the estimation results of the impact of information interventions on piped water use between the timing of information interventions and endline survey. There were no treatment effects of information intervention for enhancing the piped water use on use and drinking of the piped water system and piped water use volume. The information intervention did not cause the change of drinking behavior of piped water. Time variable shows statistically significant increase of drinking use ratio by 8.9 percent in model 4. The results suggest that the number of the households who drink the piped water increase because the people may get used to use and drink the piped water gradually by seeing neighbors' water use.

The information intervention for enhancing conventional water treatments, boiling or filtering, on the water of their pre-existing water sources did not cause any impact on piped water use as well. If the households dislike the odor and taste of the piped water and come to know the water treatment methods on their pre-existing water such as water from their private well, they may shift from using piped water to the private well water. However, the shift did not happen. It is conjectured that many households have already understood the importance of those treatment methods even before they receive the intervention. Alternatively, the recommended contents in the intervention might not be acceptable because of the additional burden of mitigating measures[24].

Table A-9 presents the estimation results of the impact of information interventions on water treatments behaviors of the piped water, which are reducing the odor and taste of chlorine residuals in the piped water and storing the piped water in refrigerator for drinking purpose. There were no treatment effects of information interventions on both water treatment behaviors. The treatment effect variable of information intervention 1

[24] The associated factors on the decision of water treatment in treatment blocks are presented in Appendix A-8.

shows an increase in the ratio by a minimal percentage, though it is not statistically significant.

Households who did not drink the piped water were questioned on whether they understood the importance of chlorination and heard how to remove the chlorine odor and taste from the piped water. The descriptive analyses of their answers are presented in Appendix A-7a and A-7b. In the survey, the respondents tasted the mitigated water and confirmed it was drinkable. Sixty-five percent (65%) of the households who do not drink the piped water answered that they knew the importance of chlorination. Forty-four percent (44%) of those answered that they had the knowledge on how to remove the smell of chlorine at the endline survey.

Even among households who drink the piped water at the endline survey, only 13 percent of the households conducted the water treatment to mitigate odor and taste of chlorine residuals in the piped water. The ratio is low because the odor and taste of the piped water may not be a serious constraining factor for households who already drink the piped water. Even if they are not in favor of the odor and taste, the additional water treatments may be burdensome for them and they can bear to drink the piped water directly.

In the area, many households purchase bottled water. Even though bottled water expense is somewhat financial burden for households, the expense may be affordable for many households. If the households are not in favor of the chemical odor and taste, they are likely to purchase and use bottled water continuously rather than drinking the piped water with removed/reduced chlorine residual.

**Table A-8 DD estimation on the impact of information interventions on piped water use in treatment blocks (Before/After interventions)**

| VARIABLES | Use of piped water (Yes = 1) | | Drinking of piped water (Yes = 1) | | Piped water use volume ($m^3$) | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Estimation model | ITT (DD) | ITT (DD, Block FE) | ITT (DD) | ITT (DD, Block FE) | ITT (DD) | ITT (DD, Block FE) |
| ***Treatment and time dummy variables*** | | | | | | |
| Intrervention 1 * After intervention (=1) | -0.016 | -0.013 | -0.006 | -0.005 | 1.812 | 1.881 |
| (treatment_effect） | (0.042) | (0.038) | (0.050) | (0.048) | (2.137) | (2.016) |
| Intrervention 1: | 0.021 | 0.026 | 0.033 | 0.019 | 2.026 | 2.895* |
| (Enhancing piped water use(=1)) | (0.030) | (0.028) | (0.035) | (0.035) | (1.511) | (1.477) |
| Intrervention 2 * After intervention (=1) | 0.007 | 0.005 | -0.029 | -0.029 | -1.216 | -1.409 |
| (treatment_effect） | (0.042) | (0.038) | (0.050) | (0.048) | (2.137) | (2.017) |
| Intrervention 2: | -0.041 | -0.033 | -0.014 | -0.001 | -2.145 | -2.587* |
| (Enhancing water treatment(=1)) | (0.030) | (0.028) | (0.035) | (0.035) | (1.511) | (1.471) |
| Time dummy | 0.020 | 0.013 | 0.076* | 0.089** | 4.355** | 4.144** |
| （After intervention (=1)) | (0.037) | (0.034) | (0.044) | (0.043) | (1.880) | (1.783) |
| Household characteristics | | Included | | Included | | Included |
| Block fixed effect | | Included | | Included | | Included |
| Observations | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |
| R-squared | 0.004 | 0.240 | 0.008 | 0.145 | 0.034 | 0.202 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
Intervention 1 is "Information intervention for enhancing use of piped water".
Intervention 2 is "Information intervention for enhancing water treatment".

**Table A-9 DD estimation on the impact of information interventions on piped water treatment in treatment blocks (Before/After intervention)**

| VARIABLES | Reduce chlorine | | Store in refrigerator | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Estimation model | ITT (DD) | ITT (DD, Block FE) | ITT (DD) | ITT (DD, Block FE) |
| ***Treatment and time dummy variables*** | | | | |
| Intrervention 1 * After intervention (=1) | 0.016 | 0.016 | 0.024 | 0.025 |
| (treatment_effect) | (0.017) | (0.017) | (0.024) | (0.024) |
| Intrervention 1: | -0.000 | -0.003 | -0.009 | -0.003 |
| (Enhancing piped water use(=1)) | (0.012) | (0.012) | (0.017) | (0.018) |
| Intrervention 2 * After intervention (=1) | 0.000 | 0.000 | 0.024 | 0.025 |
| (treatment_effect) | (0.017) | (0.017) | (0.024) | (0.024) |
| Intrervention 2: | -0.000 | 0.002 | -0.025 | -0.018 |
| (Enhancing water treatment(=1)) | (0.012) | (0.012) | (0.017) | (0.017) |
| Time dummy | 0.012 | 0.015 | -0.005 | -0.005 |
| (After intervention (=1)) | (0.015) | (0.015) | (0.021) | (0.021) |
| Household characteristics | | Included | | Included |
| Block fixed effect | | Included | | Included |
| Observations | 1,000 | 1,000 | 1,000 | 1,000 |
| R-squared | 0.007 | 0.093 | 0.006 | 0.098 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
Intervention 1 is "Information intervention for enhancing use of piped water".
Intervention 2 is "Information intervention for enhancing water treatment".

5.3 Estimation results of information intervention of water treatment on drinking behavior in control blocks

Table A-10 shows the results of the difference-in-differences estimations in examining the impact of information intervention for enhancing water treatment in control blocks. From the estimation using the baseline and midline survey data, the effect of the intervention is not confirmed[25]. Filtering behavior decreased by 11.7

[25] The associated factors on the decision of water treatment in control blocks are presented in Appendix A-9.

percentage points (model 2) and boiling behavior decreased by 6.5 percent points (model 4). It is not clear, however, why those households stopped filtering and boiling.

The information intervention did not make changes of water treatment behaviors. It is conjectured that many households have understood the importance of conventional water treatment methods even before they receive the intervention or the informed intervention is not acceptable because of the burden from additional action, thus the intervention did not make the any difference.

**Table A-10 DD estimation on the impact of information intervention for enhancing water treatment in control blocks (Baseline survey – End-line survey)**

| VARIABLES | filtering | | boiling | | any water treatment | |
|---|---|---|---|---|---|---|
| Estimation model | (1) ITT (DD) | (2) ITT (DD, Block FE) | (3) ITT (DD) | (4) ITT (DD, Block FE) | (5) ITT (DD) | (6) ITT (DD, Block FE) |
| ***Treatment and time dummy variables*** | | | | | | |
| Intrervention 2 * Year 2019 (=1) | -0.029 | -0.026 | 0.008 | 0.005 | -0.015 | -0.013 |
| (treatment_effect) | (0.053) | (0.050) | (0.031) | (0.030) | (0.054) | (0.051) |
| Intrervention 2 (=1) | 0.061 | 0.038 | -0.011 | -0.006 | 0.043 | 0.022 |
| | (0.037) | (0.037) | (0.022) | (0.022) | (0.038) | (0.037) |
| Time dummy | -0.117*** | -0.117*** | -0.079*** | -0.065*** | -0.150*** | -0.155*** |
| (2018/Baseline=0, 2019/End-line= 1) | (0.037) | (0.041) | (0.021) | (0.024) | (0.038) | (0.041) |
| Other control variables | | Included | | Included | | Included |
| block fixed effect | | Included | | Included | | Included |
| Observations | 1,040 | 1,040 | 1,040 | 1,040 | 1,040 | 1,040 |
| R-squared | 0.026 | 0.184 | 0.023 | 0.126 | 0.034 | 0.191 |

Note: Standard errors are given in parentheses with stars indicating the following: *** p<0.01, ** p<0.05, * p<0.1.
Intervention 2 is "Information intervention for enhancing water treatment".

## 6. Conclusion

This section examines the effect of information interventions for enhancing the use of piped water in the area where the new piped water system was installed in Mandalay city, Myanmar. Nearly 90 percent of households used the new piped water system in the water service area, while only 17 percent of the households drink piped water. The odor and taste of the chlorinated water are considered as the main reasons for which many people dislike the drinking of piped water. In order to enhance the drinking use of piped water, half of the households randomly selected in treatment blocks received the information about the importance of chlorination and on how to mitigate the odor and taste from the chlorine residuals of the piped water.

As another information intervention, half of the households in treatment and control blocks received the information about the importance of water treatment such as filtering and boiling. Some people might prefer to drink their private well water even if they have the access to piped water. If they are encouraged to conduct water treatment of boiling or filtering and find it necessary to have safe water, some of the piped water users may refrain from using piped water. The households in the control blocks may conduct the recommended water treatment on their water from their pre-existing water sources such as the private wells.

The estimation results of analyzing the above information interventions on piped water use reported that either intervention did not cause impact on piped water use. Though the drinking ratio of piped water increased by nine percent after intervention, it is not the treatment effect caused by the intervention. The estimation results of analyzing the information interventions to enhance water treatment of their water reported that the intervention did not cause impact on water treatment behavior as well.

The estimation results of examining the impact of information intervention on water treatments behaviors of the piped water, which are reducing odor and taste of chlorine residuals in the piped water and storing the piped water in refrigerator for drinking purpose, reported no treatment effect. Even though the households received the information to change the water quality for better odor and taste, they did not take the water treatment actions.

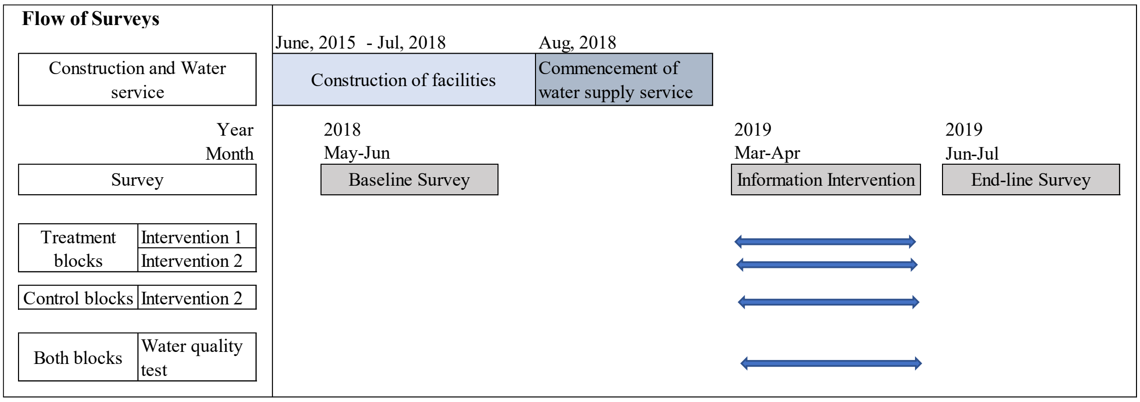
There are many literatures related to water chlorination that reviewed the negative emotional response to the odor and taste of chlorine. A third of participants in the intervention to increase water treatment in Guatemala mentioned that chlorine had a disagreeable smell and taste, even though more than 90 percent said that chlorination was an effective way to purify water (Sobel et al., 1998). In the Dominican Republic, the bad odor and taste of chlorine was the second more common reason stated for not using chlorine in the water (McLennan, 2000). The bad or unusual taste and odor of the chlorinated water were interpreted even as a health risk from the water (Jardine et al., 1999).

Taste and smell of the water are concerns not only in low- and middle- income countries but also in other cultures. For example, in a metropolitan area of Quebec, Canada, 30 percent of survey respondents expressed dissatisfaction with the taste of their tap water, and 14 percent were dissatisfied with the smell. The main predictor of the use of alternatives to tap water such as bottled water was dissatisfaction with the taste of tap water. Those who disliked its taste were six times more likely to use an alternative source than those who did not mind its taste (Levallois, et al.,1999).

Governments of low- and middle- income countries have made large investments on the installation of water supply facilities. The main objective of the installations is common, that is, to provide safe and drinkable water for people. However, there is a high stake for the users to drink the chlorinated water.

In the Project, the drinking ratio of piped water is low and the information interventions to enhance the use of piped water did not work. The literatures focusing on social and behavioral factors for HWTS pointed that people do not easily change behavior as intended by the water treatment interventions if the benefits are not clear for them (Figueroa & Kincaid, 2010). In this research, the respondents tasted the water mitigated by the recommended water treatment method in the interventions. Though some households started to conduct the water treatment for reducing the chlorine residuals, the intervention did not cause the drastic change of using and drinking of the piped water. On the other hand, the drinking ratio increased between the time periods of the intervention and the endline survey. The households using the piped water may observe the neighbor's drinking behaviors and start drinking it. Yet, it would take time for the residents to change their water use behaviors. It is important to encourage the drinking use in order to boost the impact of the piped water use on their well-being. Further research are needed to examine how to encourage the behavior change of water use and what kind of interventions or information would work for the change to happen.

## Chart




Intervention 1: Information Intervention for enhancing use of piped water
Intervention 2: Information Intervention for enhancing water treatment

## Appendix A-1 Descriptive analysis of water test result

| | Treatment blocks | | Control blocks | | Total | |
|---|---|---|---|---|---|---|
| | No of HHs | % | No of HHs | % | No of HHs | % |
| Contaminated (= 1) | 86 | 16.8 | 77 | 16.3 | 163 | 16.6 |
| Observation | 512 | | 472 | | 984 | |

*36 households were not tested. Some households only use piped water.

## Appendix A-2 Balance test of sample characteristics for analysis of information intervention of enhancing use of piped water in treatment blocks (as of baseline survey)

| Intervention 1: Information Intervention for enhancing use of piped water | Treatment (=1) | Control (=0) | Difference | Statitical significance |
|---|---|---|---|---|
| Variable | Mean | Mean | | |
| *Household water use* | **n=323** | **n=318** | | |
| Total water use volume ($m^3$) | 35.0 | 35.8 | -0.8 | |
| Water use volume per day per capita (liter) | 280 | 291 | -10 | |
| Use of private well (%) | 83.6 | 87.4 | -3.8 | |
| Water use volume of private well ($m^3$) | 32.2 | 33.7 | -1.5 | |
| Purchase of bottled water (%) | 71.2 | 72.3 | -1.1 | |
| Household bottled water use per month (liter) | 308 | 317 | -9 | |
| Household bottled water cost per month (1000 kyat) | 5.4 | 5.7 | -0.3 | |
| *Characteristics of Households (Average of each block)* | **n=323** | **n=318** | | |
| Maximum schooling year of household member (Year) | 10.4 | 10.8 | -0.3 | |
| Number of Household Members | 4.7 | 4.6 | 0.1 | |
| Household with Under 5 year old children (%) | 31 | 27 | 4 | |
| Household monthly household income (1000 kyat) | 441 | 428 | 13 | |
| Asset Measure | 1.73 | 1.77 | 0.0 | |
| Own the private well (=1) | 83.6 | 87.4 | -3.8 | |
| Own house (=1) | 80.8 | 80.8 | 0.0 | |
| Perception of quality of their water (Clear =1) | 79.9 | 74.5 | 5.4 | |
| Monthly electricity fee (1000 kyat) | 9.7 | 9.9 | 0 | |

The value displayed for t-tests are the differences in the means across the groups.
***, **, and * indicate statistically significance at the 1, 5, and 10 percent level.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.

## Appendix A-3 Balance test of sample characteristics for analysis of information intervention of enhancing water treatment in treatment blocks (as of baseline survey)

| Intervention 2: Information Intervention for enhancing water treatment | Treatment (=1) | Control (=0) | Difference | Statitical significance |
|---|---|---|---|---|
| Variable | Mean | Mean | | |
| *Household water use* | **n=314** | **n=327** | | |
| Total water use volume ($m^3$) | 36.4 | 34.4 | 2.0 | |
| Water use volume per day per capita (liter) | 288 | 283 | 4 | |
| Use of private well (%) | 86.1 | 89.6 | -3.5 | |
| Water use volume of private well ($m^3$) | 32.7 | 34.1 | -1.4 | |
| Purchase of bottled water (%) | 74.5 | 69.1 | 5.4 | |
| Household bottled water use per month (liter) | 311 | 332 | -21 | |
| Household bottled water cost per month (kyat) | 5.9 | 5.3 | 0.6 | |
| Watter treatment (filtering) | 25.2 | 21.4 | 3.8 | |
| Watter treatment (boiling) | 5.4 | 3.7 | 1.7 | |
| Watter treatment (any) | 27.4 | 23.2 | 4.2 | |
| *Characteristics of Households (Average of each block)* | **n=314** | **n=327** | | |
| Maximum schooling year of household member (Year) | 10.7 | 10.5 | 0.2 | |
| Number of Household Members | 4.6 | 4.6 | 0.0 | |
| Household with Under 5 year old children (%) | 31 | 27.2 | 3.70 | |
| Household monthly household income (1000 kyat) | 426 | 443 | -17 | |
| Asset Measure | 1.76 | 1.73 | 0.03 | |
| Own the private well (=1) | 86 | 84.7 | 1.60 | |
| Own house (=1) | 80 | 81.7 | -1.80 | |
| Perception of quality of their water (Clear =1) | 76 | 78.3 | -2.20 | |
| Monthly electricity fee (1000 kyat) | 10.0 | 9.7 | 0.3 | |

The value displayed for t-tests are the differences in the means across the groups.
***, **, and * indicate statistically significance at the 1, 5, and 10 percent level.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.

## Appendix A-4 Balance test of sample characteristics for analysis of information intervention for enhancing water treatment (as of baseline survey)

| Intervention 2 (Water treatment) | Treatment (=1) | Control (=0) | Difference | Statitical significance |
|---|---|---|---|---|
| Variable | Mean | Mean | | |
| *Household water use* | **n=323** | **n=325** | | |
| Total water use volume ($m^3$) | 32.0 | 31.2 | 0.8 | |
| Water use volume per day per capita (liter) | 249 | 236 | 13 | |
| Use of private well (%) | 84.2 | 84.3 | -0.1 | |
| Water use volume of private well ($m^3$) | 28.9 | 28.9 | 0.0 | |
| Purchase of bottled water (%) | 74.3 | 79.1 | -4.8 | |
| Household bottled water use per month (liter) | 317 | 348 | -30 | |
| Household bottled water cost per month (1000kya | 5.4 | 6.1 | -0.6 | |
| Watter treatment (filtering) | 30.3 | 28.9 | 1.4 | |
| Watter treatment (boiling) | 10.5 | 11.1 | -0.6 | |
| Watter treatment (any) | 33.7 | 33.2 | 0.5 | |
| *Characteristics of Households (Average of each block)* | **n=323** | **n=325** | | |
| Maximum schooling year of household member (Year) | 10.3 | 10.3 | 0.0 | |
| Number of Household Members | 4.9 | 4.7 | 0.1 | |
| Household with Under 5 year old children (%) | 33.7 | 36.0 | -2.3 | |
| Household monthly household income (1000 kyat) | 433 | 448 | -15 | |
| Asset Measure | 1.7 | 1.7 | 0.0 | |
| Own the private well (=1) | 84.2 | 84.3 | -0.1 | |
| Own house (=1) | 77.4 | 77.2 | 0.2 | |
| Perception of quality of their water (Clear =1) | 83.9 | 84.9 | -1.0 | |
| Monthly electricity fee (1000 kyat) | 9.2 | 8.6 | 0.7 | |

The value displayed for t-tests are the differences in the means across the groups.
***, **, and * indicate statistically significance at the 1, 5, and 10 percent level.
Myanmar kyat is equivalent to 0.0007 US dollar (1 dollar = 1350 kyat) as of May 2018.

**Appendix A-5 Summary statistics of independent variables for the analysis of the impact of information intervention in treatment blocks**

| **Baseline Survey** | Mean | S.D. | Min | Max |
|---|---|---|---|---|
| *Characteristics of household member* | | | | |
| Maximum schooling year of household member (Year) | 10.85 | (3.90) | 0 | 16 |
| *Characteristics of household* | | | | |
| Number of Household Members | 4.74 | (1.86) | 1 | 14 |
| Household with Under 5 year old children (=1) | 0.3 | (0.46) | 0 | 1 |
| Asset Measure | 1.77 | (0.61) | 0 | 3.8 |
| Perception of quality of their water (Clear =1) | 0.77 | (0.42) | 0 | 1 |
| *Survey timing* | | | | |
| Survey in May, 2018 | 0.30 | (0.46) | 0 | 1 |
| Survey in June, 2018 | 0.70 | (0.46) | 0 | 1 |
| Observations | 500 | | | |

| **End-line Survey** | Mean | S.D. | Min | Max |
|---|---|---|---|---|
| *Characteristics of household member* | | | | |
| Maximum schooling year of household member (Year) | 10.9 | (3.82) | 0 | 16 |
| *Characteristics of household* | | | | |
| Number of Household Members | 4.84 | (2.08) | 1 | 15 |
| Household with Under 5 year old children (=1) | 0.31 | (0.46) | 0 | 1 |
| Asset Measure | 1.89 | (0.63) | 0 | 3.7 |
| Perception of quality of their water (Clear =1) | 0.8 | (0.40) | 0 | 1 |
| *Survey timing* | | | | |
| Survey in June, 2019 | 0.97 | (0.17) | 0 | 1 |
| Survey in July, 2019 | 0.03 | (0.17) | 0 | 1 |
| Observations | 500 | | | |

**Appendix A-6 Summary statistics of independent variables for the analysis of the impact of information intervention for enhancing water treatment in control blocks**

| **Baseline Survey** | Mean | S.D. | Min | Max |
|---|---|---|---|---|
| *Characteristics of household member* | | | | |
| Maximum schooling year of household member (Year) | 10.3 | (3.93) | 0 | 16 |
| *Characteristics of household* | | | | |
| Number of Household Members | 4.89 | (2.05) | 1 | 14 |
| Household with Under 5 year old children (=1) | 0.34 | (0.47) | 0 | 1 |
| Asset Measure | 1.68 | (0.57) | 0 | 3.8 |
| Perception of quality of their water (Clear =1) | 0.85 | (0.36) | 0 | 1 |
| *Survey timing* | | | | |
| Survey in May, 2018 | 0.36 | (0.48) | 0 | 1 |
| Survey in June, 2018 | 0.64 | (0.48) | 0 | 1 |
| Observations | 520 | | | |

| **End-line Survey** | Mean | S.D. | Min | Max |
|---|---|---|---|---|
| *Characteristics of household member* | | | | |
| Maximum schooling year of household member (Year) | 10.4 | (3.86) | 0 | 16 |
| *Characteristics of household* | | | | |
| Number of Household Members | 5.01 | (2.22) | 1 | 16 |
| Household with Under 5 year old children (=1) | 0.35 | (0.48) | 0 | 1 |
| Asset Measure | 1.76 | (0.59) | 0 | 3.8 |
| Perception of quality of their water (Clear =1) | 0.78 | (0.41) | 0 | 1 |
| *Survey timing* | | | | |
| Survey in June, 2019 | 0.97 | (0.16) | 0 | 1 |
| Survey in July, 2019 | 0.03 | (0.16) | 0 | 1 |
| Observations | 520 | | | |

## Appendix A-7a Reason for non-drinking of piped water

| Reason | Bad odor | | Bad taste | | Not Clean (ex:Cloudy) | | Other reason | |
|---|---|---|---|---|---|---|---|---|
| | Freq. | Percent | Freq. | Percent | Freq. | Percent | Freq. | Percent |
| Yes=1 | 173 | 52.6 | 55 | 16.7 | 39 | 11.9 | 110 | 33.4 |

Observation: 329 households which do not drink piped water
The table is compiled by the author.

## Appendix A-7b Detailed answer of [Other reason] for non-drinking of piped water

| | Freq. | Percent |
|---|---|---|
| Because I drink other purified water (bottled water) | 76 | (68.3) |
| Because I drink tube-well water | 11 | (9.2) |
| Because I do not know it is drinkable. | 8 | (7.5) |
| Because I get purified water from the monestry | 6 | (5.8) |
| Because it is hot water. | 3 | (4.2) |
| Because it is frothy. | 2 | (1.7) |
| Because of my health | 2 | (1.7) |
| Because they used to much disinfection. | 1 | (0.8) |
| I do not drink because it is mixed with tube-well | 1 | (0.8) |
| Total | 110 | (100.0) |

The table is compiled by the author.

**Appendix A-8 Analysis on implementing water treatment in treatment blocks (as of baseline survey)**

| Model | (1) | (2) | (3) |
|---|---|---|---|
| Outcome variables | Filtering (Yes=1, No=0) | Boiling (Yes=1, No=0) | Any water treatment (Yes=1, No=0) |
| Estimation model | Probit | Probit | Probit |
| Explanatory variables | | | |
| Maximum schooling year of household member (Year) | -0.036** | 0.043 | -0.032* |
| | (0.018) | (0.032) | (0.017) |
| Number of Household members | 0.043 | -0.015 | 0.043 |
| | (0.037) | (0.062) | (0.037) |
| Household with Under 5 year old children(=1) | -0.216 | 0.013 | -0.187 |
| | (0.152) | (0.243) | (0.149) |
| Asset measure | -0.500*** | -0.299 | -0.480*** |
| | (0.124) | (0.202) | (0.122) |
| Perception of quality of their water (Clear =1) | -0.167 | -0.430* | -0.162 |
| | (0.150) | (0.225) | (0.147) |
| Constant | 0.472 | -1.375*** | 0.446 |
| | (0.293) | (0.496) | (0.288) |
| Observations | 500 | 500 | 500 |

Note: ***, **, and * indicate statistically significance at the 1, 5, and 10 percent level. Marginal effect if presented.

**Appendix A-9 Analysis on implementing water treatment in control blocks (as of baseline survey)**

| Model | (1) | (2) | (3) |
|---|---|---|---|
| Outcome variables | Filtering (Yes=1, No=0) | Boiling (Yes=1, No=0) | Any water treatment (Yes=1, No=0) |
| Estimation model | Probit | Probit | Probit |
| Explanatory variables | | | |
| Maximum schooling year of household member (Year) | -0.038** | 0.010 | -0.040** |
| | (0.016) | (0.021) | (0.016) |
| Number of Household members | 0.091*** | 0.048 | 0.078** |
| | (0.031) | (0.039) | (0.031) |
| Household with Under 5 year old children(=1) | -0.250* | -0.396** | -0.264** |
| | (0.135) | (0.187) | (0.133) |
| Asset measure | -0.189* | -0.213 | -0.182 |
| | (0.113) | (0.147) | (0.112) |
| Perception of quality of their water (Clear =1) | 0.367** | 0.241 | 0.421** |
| | (0.178) | (0.240) | (0.175) |
| Constant | -0.475* | -1.349*** | -0.354 |
| | (0.284) | (0.373) | (0.280) |
| Observations | 520 | 520 | 520 |

Note: ***, **, and * indicate statistically significance at the 1, 5, and 10 percent level. Marginal effect if presented.

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