WOMEN'S EDUCATION AND WORK IN CHINA – THE MENSTRUAL CYCLE AND THE POWER OF WATER

by

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SYNOPSIS

This study investigates the joint impact of menstrual cycle and poor access to water on women's education and labour market outcomes. The research context is chosen to be rural China. Two parallel hypotheses that are tested in this study are as follows: (1) Girls have less probability of school enrolment and shorter schooling duration due to the joint impact of poor access to water and menarche presumably because that poor access to water may raise time/health/psychic costs of school enrolment for girls post-menarche. (2) Women have less probability of participating in work for wages due to the joint impact of poor access to water and menstrual cycle presumably because that poor access to water may generate lower productivity and raise time/health/psychic costs of wage work participation for women pre-menopause. For testing, the researcher uses the data from rural villages in the China Health and Nutrition Survey. This study conducts two sets of empirical tests on each of the above hypotheses using regression models and propensity score matching estimators. It is found that the joint impact of poor access to water and menstrual cycle is indeed largely adverse on women's education and wage work participation. When the impacts of other confounding factors such as poverty and backward geographical location are controlled for, access to poor water is found to decrease the probability of school enrolment of post-menarche girls by 20 – 25 percentage points, and the probability of wage work participation of women pre-menopause by about 10 percentage points. This study concludes that a major benefit of policies to improve water supplies may not be the obvious household or industrial benefit, but rather an unseen benefit, the improvement in the position of women.

DEDICATION

To my mother
To the memory of my father

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LIST OF ABBREVIATIONS

2SLS – Two-Stage Least Squares

AFT – Accelerated Failure Time

AME – Average Marginal Effects

ATT – Average Treatment on Treated

CARE – Cooperative for Assistance and Relief Everywhere

CHNS – the China Health and Nutrition Survey

CNY – the currency of the People's Republic of China

CIA – Conditional Independence Assumption

FAWE – the Forum for African Women's Education

FE – Fixed Effects

GBP – the currency of the United Kingdom

IML – The Inverse Mills Ratio

IV – Instrumental Variable

NGO – Non-Governmental Organisation

PSM – Propensity Score Matching

RE – Random Effects

UN – United Nations

UNICEF – United Nation's International Children's Emergency Fund

CHAPTER ONE: INTRODUCTION

"If I had to pick the one thing we must do above all else to improve the world, I would say: 'educate girls' ", (Sashi Tharoor 2007: 165).[1]

"There is no tool for development more effective than the empowerment of women", (Cofi Annan, 2005)

This chapter introduces the origins and key problems of the research. The project rationale is presented in section 1.1. The aim and objectives of the research appear in section 1.2. The organisation of the thesis is outlined in the final section.

1.1 Project Rationale

Women's education is regarded not only as an important driving force of economic and social development (Schultz, 2002), but also a key prerequisite to improve their social and economic position. For example, Women with higher education have reduced fertility (Osili and Long, 2007; Heward, 1999; Ainsworth et al. 1996); are healthier (Currie and Moretti, 2003; Ross and Wu, 1995); are politically active (Timpone, 1998); and are more likely to enrol in wage work which can further improve their social and economic position (Zhang et al., 2002; Jacka, 1997). Women's education and wage work are therefore regarded as key indicators of women's empowerment (UN Data, 2009). However, substantial gender gaps still exist in school enrolment (Song et al, 2006; Hannum, 2005; Conelly and Zheng, 2003; Brown and Park, 2002) and wage work participation (Zhang et al., 2004; Hare, 1999)

[1] The researcher is grateful to Charles Diamond, Ex-MD of Econostat, for suggesting this quotation.

in rural China. This reality ignited the interest of the researcher to analyse the causes of those gaps and propose effective policy measures to help reduce them.

Much research has been conducted to account for these gaps. As for the education gender gap in China: (1) ‘higher opportunity cost of girls’ school enrolment’ is often suggested as a major cause (Li and Tsang, 2002; Knight and Li, 1996); (2) low household income is sometimes blamed for the gap because girls’ education is taken as a ‘luxury good’ by poor families, while sons’ education is regarded as ‘investment good’ (Song et al, 2005; Song, 2000). (3) backward geographical locations are sometimes considered for the gap because these locations are assumed to be associated with special ‘culture’ which favours sons’ education over daughters’ (Hannum, 2006; Li, 2005). (4) family size and sibling structure are also examined for their impacts on the gap due to the existence of one-child policy in China (Qian 2009; Yang, 2006; Yu and Su, 2006). As for the gap in wage work participation, the interpretations also follow the same logic as described above: (1) opportunity cost of involving in wage work is high for women (e.g. household work, farm work, child rearing, taking care of elderly) (Gao, 1994, Yang, 2000, Short et al., 2002); (2) special ‘culture’ which places women in subordinate position prevents women from attending work outside the home (Jacka, 1997; Mann, 2000). (3) family structure also plays different roles in supporting women to engage in wage work (Chen, 2004).

The researcher benefits from the above studies greatly. They provide useful information on the research context and present a theoretical background to understand the origin of the gaps in school enrolment and wage work participation in China. However, the researcher also encounters another set of literature which investigates the schooling and labour market outcomes of women through analysing women-specific physiological characteristics – namely – menstrual cycle. For example, Field and Arbus (2008), and Oster and Thornton (2009) analyse the impact of menarche on girls' school enrolment/attendance, while Ichino and Moretti (2009) analyse the impact of menstrual cycle on women's work attendance. Goldin and Katz (2002) also investigate how women's work participation increases due to menstrual intervention (e.g. delaying and regulating menstrual cycle using contraceptive pills so as to control pregnancy). These important works provide the researcher with the motivation to analyse the gender gaps in education and wage work participation in China using the same women-specific physiological characteristics – menarche and menopause.

In addition, it is vital to test whether the impact of menarche/menopause on schooling (labour market) outcomes differ for girls (women) with good and poor access to water (a generally accepted proxy for hygiene, Jalan and Ravallion, 2003) since it is found that poor hygiene makes menstruation related problems worse (Ahmad and Yesmin, 2008; Dagwood 1995; Severino and Moline, 1995). A number of NGOs, being well aware of this problem, have already started some projects to help adolescent girls and adult women with their menstruation related problems at schools and workplaces. For example, some bigger NGOs pledge huge amount of funds (the largest being 5 million USD) to support projects which aim to increase school enrolment of girls by providing hygiene facilities and products (Deutsch 2007; and Cooke, 2006). Some other NGOs (UNICEF, FAWE and CARE) also involve in similar projects (Cooke, 2006; Bharadwaj and Patkar, 2004).

However, no empirical work has been conducted to examine the significance and the intensity of the joint impact of menstrual cycle and poor access to water on women's education and work. The researcher therefore aims to investigate the joint impact on schooling and wage work participation using a variety of statistical methods. Since the data to be used for the tests come from rural China, the results should be particularly useful to formulate education and wage work policy in China. Nevertheless, the findings of the research are relevant to any settings as long as poor access to water is prevalent, which includes most of the poor areas of less developed countries in the world. In fact, poor access to water is not much of a problem in modern China. The good Chinese data available enables the researcher to explain the importance of access to water.

1.2 The Research Hypotheses and Objectives

This study has two parallel hypotheses:

Hypothesis-1: Girls have less probability of school enrolment and shorter schooling duration due to the joint impact of poor access to water and menarche presumably because that poor access to water may raise time/health/psychic costs of school enrolment for girls post-menarche.

Hypothesis-2: Women have less probability of participating in work for wages due to the joint impact of poor access to water and menstrual cycle presumably because that poor access to water may generate lower productivity and raise time/health/psychic costs of wage work participation for women pre-menopause.

The specific research objectives under the above two hypothesis are outlined separately as follows:

1. Investigating the joint impact of menarche and poor access to water on girls' school enrolment and schooling duration

If the joint impact of menarche and access to water is indeed significant and quantitatively relevant, it may help explain why there is considerable gender education gap in secondary schools in less developed settings (e.g. rural areas of China). Therefore, a focused literature survey will be conducted to identify the relevant research findings about the impacts of poor access to water and menarche on girls' schooling. The researcher is aware of the general situation of the current research on gender education gap in China, but more survey related to the topic is necessary. The objective to conduct these two sets of literature survey (focused and general) is to obtain up-to-date research findings directly relevant to the research hypothesis and also identify other confounding factors which must be controlled for when conducting the empirical tests.

Following the literature survey, a theoretical framework will be developed to model the joint impact of poor access to water and menarche on girls' schooling. The model should relate demand and supply factors that are associated with children's schooling. Menarche and access-to-water should also appear in the model explicitly to explain the mechanism with which the joint impact takes effect. Besides, all control variables obtained from the literature survey should make them seen as much as possible in the theoretical model, so that an empirical model which is designed based on the theoretical model will be more relevant and complete.

After setting up the theoretical model, the relevant data will be collected from the China Health and Nutrition Survey (CHNS) jointly collected by the University of North Carolina and the Chinese Academy of Preventive Medicine, Beijing. Preliminary tests on the data will then be conducted to provide descriptive statistics. However, the joint impact of menarche and poor access to water on girls' schooling must be confirmed after including essential control variables in a multivariate analysis. Two types of empirical strategies will be adopted to test the hypothesis. The first strategy will use regression analysis to test whether poor access to water has any significant impact on girls' schooling after menarche using probit (for school enrolment) and hazard models (for school duration) in a multivariate context where essential control variables are in place. The second set of empirical tests will use Propensity Score Matching (PSM) methods to conduct alternative testing of the same hypothesis.

Regression analysis provides a complete mechanism to analyse the treatment effects. In particular, any possible selection bias can be tackled by including all 'necessary' variables in ideal circumstances in the regression as controls (the so called 'long model') and appropriate instrumentation (see Angirst and Pischke, 2009). However, the Propensity Score Matching (PSM) technique provides alternative approach to test the robustness of the regression results and is believed to reduce the bias of regression estimates by making the observational studies more like natural experiments where allocation of treatment is believed to be purely random (Becker and Ichino, 2002). Besides, PSM uses semi-parametric methods to estimate the treatment effects so there is no need to assume any functional form for the estimation (Guo and Fraser, 2009).

2. Investigating the joint impact of menstrual cycle and poor access to water on women's wage work participation

In the second part of this study, the researcher will investigate whether women's wage work participation is also subject to the adverse joint impact of menstrual cycle and poor access to water (the hypothesis-2 of this study). It is found that the menstrual cycle indeed affects women's work attendance – again presumably due to the menstruation related health/time/psychic problems when access to water is poor. For example, Ichino and Moretti (2009) find that about 30% of the gender differences in days of absenteeism is caused by menstrual symptoms. However, if the impact of menstrual cycle on women's work attendance is mainly through menstruation related illnesses, this impact should be worse for women with poor access to water, since the menstrual problems are reported to be more pronounced for women with poor hygiene facilities (Ahmad and Yesmin, 2008; Dagwood 1995).

Therefore, a focused literature survey will be conducted to identify the relevant research findings about the impacts of poor access to water and menstrual cycle on women's wage work participation. A more general survey of literature will also be conducted to identify the recent research findings of women's wage work participation in rural China. As noted earlier, the objective to conduct these two sets of literature survey (focused and general) is again to obtain up-to-date research findings directly relevant to the research hypothesis and also identify other confounding factors which must be controlled for when conducting the empirical tests.

Following the literature survey, a theoretical framework will be developed to model the joint impact of poor access to water and menstrual cycle on women's wage work participation. A conventional demand and supply analysis will be used for the modelling. In addition, a labour-leisure model will also be used to explain the mechanism. After setting up the theoretical model, the relevant data will be collected. Preliminary tests on the hypothesis will then be conducted to provide descriptive statistics.

However, the joint impact of menstrual cycle and poor access to water on women's wage work participation must also be tested using multivariate analyses where essential control variables are all present. The researcher will again use two types of empirical strategies to test the hypothesis. The first strategy will use regression analysis to test whether poor access to water has any significant impact on women's wage work participation pre-menopause using probit models. The second set of empirical tests will use Propensity Score Matching (PSM) methods to conduct alternative testing of the same hypothesis.

1.3 The Organisation of the Thesis

The two parallel hypotheses will be tested separately using the same methodologies. When conducting the test on the first hypothesis of this study (hypothesis-1 in page 3), the researcher will present relevant research contents and research methodologies in detail. For example, such contents as the structure of the dataset to be used, the mechanism of survival (duration) models, the validity of the instrumental variable used in probit models, the mechanism of propensity score matching techniques, will be described in relevant sections.

However, since the second part of the study tests a parallel hypothesis using the same survey data and methodology, no detailed description of the data and methodology will be provided.

For the reasons given above, the first part of the study takes up a space of three chapters (Chapter 2 – Chapter 4), while the second part is only confined in one chapter (Chapter 5). The specific contents to be included in each of the following chapters are as follows:

In Chapter 2, a focused literature survey will be conducted to identify how poor access to water creates specific problems on girls' schooling particularly after menarche. Besides, a more general literature survey will also be conducted to follow the development of current research on the gender education gap in China. Moreover, a theoretical model will be developed to outline the mechanism of the joint impact of poor access to water and menarche on girls' schooling. Furthermore, the data to be used in this study will be introduced and the major variables that are to be used to test the hypothesis will be analysed. Finally, simple descriptive tests on the hypothesis will be conducted.

In Chapter 3, the overall strategy of regression analysis designed to test the first hypothesis of this study will be outlined. Two types of regression models (probit models for school enrolment and hazard models for school duration) will be introduced. Relevant control variables that are to be included in the estimation will be briefly reviewed. In the latter sections, the results from the regression models will be analysed. In addition, the impacts of menarche will be analysed separately for older sisters, younger sisters and single daughters to test the robustness of the results of Field and Arbus (2008) regarding the menarche – early marriage – low female education link. Some more sensitivity tests will also be conducted by restricting the sample on specific type of villages. Survival distributions will be presented using the regression results. Finally, the village level analysis will be conducted to focus on policy aspects of access to water, since water supply generally occurs at a village level.

In Chapter 4, second type of empirical strategy will be used to test the robustness of the regression results obtained from the last chapter. Specific contents to be included in this chapter are as follows: First, the mechanism of the propensity score matching technique will be investigated. Secondly, the propensity scores will be estimated. Third, the Average Treatment on Treated will be estimated and the results will be compared to the regressions results. In this chapter, the researcher also analyses the advantages and disadvantages of observational studies over randomised experiments. A typical study (Oster and Thornton, 2009) which uses randomised experiments to analyse the impact of menarche on girls' school attendance will be reviewed and the practical difficulties of obtaining 'true' treatment effect from randomised experiments will be highlighted.

In Chapter 5, the second part of the study which investigates the joint impact of poor access to water and menstrual cycle on women's wage work participation will be presented. First, the overall situation of wage work participation in rural China will be introduced. Secondly, the mechanism with which the joint impact takes effect on women's wage work participation will be discussed. Third, the empirical strategies and research methodologies will be described briefly only, since the same strategies and methods are already explained in detail in previous chapters. Finally, the results of regression analyses and propensity score matching will be discussed. The results will also be compared to each other to justify the robustness of the joint impact.

In Chapter 6, overall conclusions of the study will be provided. This study finds that poor access to water decreases the probability of school enrolment of post-menarche girls by 20 – 25 percentage points holding other things equal, while it also decreases the probability of wage work participation of pre-menopause women by 10 percentage points holding other things equal. Also summarised in this chapter will be the arguments on the ‘culture effects’. A widely held belief is that a special ‘culture’ which prefers sons over daughters in school enrolment; and prefers men over women in wage work participation exists in rural China (Song et al, 2006 and Jacka, 1997). The poor access to water, being mainly a problem of rural areas in China, may reflect the impact of such a ‘culture’ on women’s education and work in empirical tests. However, the results obtained from this study cast doubt on the intensity of such ‘culture effects’ and support the independence of the impact of poor access to water on women’s education and work. The final section in this chapter will present the relevance of the results of this study to the empowerment of women in less developed countries.

CHAPTER TWO: ACCESS TO WATER, MENARCHE AND GIRLS' EDUCATION

> *"Lack of adequate water and sanitation both at home and school prevents girls from attending school when menstruating. Girls have a sense of being unclean when there is little clean water to wash themselves, and this can lead them to stay away from school. Also there are rarely private facilities at school where girls can go to the toilet or wash the rags they use during their periods. They can also pick up infections if the water they use to wash rags is dirty, leading to more time off school"* (Burrows et al, 2004, 14)

2.1 Introduction

In this chapter, the mechanism through which the interaction of poor access to water and menarche impacts on girls' schooling is analysed. In fact, the mechanism is well presented in the quote given above. If the arguments presented above are all true then the interaction of poor access to water and the onset of menarche should signal a significant drop in girls' school enrolment, since early drop-outs from school are associated with frequent absence (Rumberger and Larson, 1998).

If the joint impact of menarche and access to water is indeed significant and quantitatively relevant, it may help explain why there is considerable gender education gap in secondary schools in less developed settings (e.g. rural areas of China). Therefore, the first set of literature survey is conducted to identify the relevant research findings about the impacts of poor access to water and menarche on girls' schooling. Extensive search of literature reveals that those impacts were widespread and identified in many different countries (see, for example, Bista (2004) for Nepal, Nahar (2006) for Pakistan, Kirk and Sommer (2006) for some African countries). However, no such study is found for China.

The arguments in the literature suggest that greater time, health and psychic costs of post-menarche girls with poor access to water make them drop out school more compared to other girls with good access to water and boys (see, for example, Burke and Beegle, 2004; Hill and King, 1995, for time costs; Dagwood 1995; Severino and Moline, 1995, for health costs; Kirk and Sommer, 2006; Burrow et al., 2006, for psychic costs). However, while economists consider the role of the menstrual cycle more in economic outcomes (e.g., Ichino and Moretti, 2009, link the cycle to women's absenteeism), only Field and Arbus (2008) and Oster and Thornton (2009) have so far considered the link with education, but without considering the all-important interaction with access to water.

According to the above findings, the research hypothesis of this study is moulded as follows: Girls education suffers (early drop out and shorter duration) from the joint impact of poor access to water and menarche, presumably due to the time, health and psychic costs generated by the joint impact. By definition, this joint impact does not exist for pre-menarche girls, girls with good access to water or boys. Therefore, as noted above, the impact, if tested to be true and large, should be useful to explain gender education gaps in less developed settings, where, often, access to water is poor.

A general survey of literature on gender education gap with a particular focus on China is also necessary. The survey should provide essential information about the research context and current developments of the research topic in general. Household income, parental education and occupational status, children's market work and household work, sibling structure, geographical locations, and 'culture' are found to be considered as possible causes to explain the gender education gap in China (relevant discussions about the 'culture' and its effects will be briefly outlined in Section 2.3). The impacts of these variables will be controlled for when conducting multivariate analysis in this study.

Following the literature survey, a theoretical framework is developed to model the joint impact of poor access to water and menarche on girls' schooling. The model is based on the concept that children's education is a household investment which aims to maximise the total utility of household members. The interaction of poor access to water and menarche enters the model explicitly as a cost element that only exists for post-menarche girls when they enrol at school. Higher average costs of girls' education require higher average returns from the educational investment to balance. Higher average costs inevitably leads post-menarche girls with poor access to water to drop out of school early (accumulate less years of schooling) when the return from schooling is assumed to be the same between boys and girls.

After setting up the theoretical model, it is essential to test the hypothesis using appropriate data. The data used to test the hypothesis comes from the China Health and Nutrition Survey (CHNS, 2009), jointly conducted by the University of North Carolina and the Chinese Academy of Preventive Medicine, Beijing. The data from 6 waves of CHNS

(1989-2004) are used in the empirical models. The CHNS provides detailed information on children's schooling (enrolment status and years of schooling); household access to water and menarche, which are all crucial to test the hypothesis of this study. Besides, almost all other necessary individual, household and community control variables can also be found in the data, including household income, sibling structure, children's household and market work, parental education and occupational status. Some of these variables can be directly downloaded from the original questionnaire and some of them are constructed using the relevant information in the data.

The descriptive statistics (mean comparison, Kaplan-Meier survival curves) support the hypothesis. Post-menarche girls have higher school drop out rates and shorter schooling duration when access to water is poor. The impact of poor access to water on pre-menarche girls and boys are not found to be as pronounced as it is on post-menarche girls. Obviously, a multivariate analysis is needed to derive the true impact of access to water on schooling of boys and girls when the impacts of other confounding factors are controlled for. The relevant multivariate tests will be conducted in the next chapter.

This chapter is organised as follows: In section 2.2, a literature survey is conducted to identify how poor access to water creates specific problems on girls' schooling particularly after the onset of menarche. The hypothesis of the study is moulded, and relevant research questions are designed. In section 2.3, another set of literature survey is conducted to follow the development of current research on gender education gap in China. In section 2.4, a theoretical model is developed to outline the mechanism of the joint impact of poor access to water and menarche on girls' schooling. In section 2.5, the data used in this study will be introduced and the major variables that are to be used to test the hypothesis will be analysed. Simple descriptive tests on the hypothesis will also be conducted. In the final section, conclusions of the chapter are presented.

2.2 Access to Water, Menarche and Girls' Education – Literature Survey

A literature survey on girls' school enrolment reveals how post-menarche girls tend to drop out more when hygiene facilities are not in place (Bista, 2004, Nahar, 2006; Kirk and Sommer, 2006; and Singh et al, 1999). A quote from Burrows et al (2004, 14) which is given at the beginning of this chapter explains well the mechanism through which the interaction of poor access to water and menarche impacts on girls' schooling. According to that quote, post-menarche girls with poor access to water are simply subject to more psychic and health problems which will affect their school attendance. In fact, Rostami (2007) find that about 15% (85 out of 660) high school girls in their sample report that they suffer from severe menstrual pain which affects their daily activity. Moreover, a joint research of the Iranian government with Thehran University finds that about 15% of the school girls do not attend school from 1 to 7 days during their menstrual period (Tjon A Ten, 2007), and the figure is 17% in Sharma et al (2008). Repeated absence from schools leads early drop outs and shorter school duration (Rumberger and Larson, 1998).

If the arguments presented above are all true then the interaction of poor access to water and the onset of menarche should signal a significant drop in girls' school enrolment. The arguments related to the effect of access to water and menarche on girls' schooling will be summarised.

Time costs: A time cost generated by fetching water is the usual reason for including access to water as a schooling determinant in the demand for schooling models, since girls are considered the main water-fetchers in many African and South Asian Countries (Burke and Beegle, 2004; Hill and King, 1995). According to the statistics of UNICEF (2008), 'on average, women and girls in developing countries walk 6 kilometres a day, carrying 20 litres of water, greatly reducing the time they have for other productive work or for girls to attend school.' Multivariate analyses also show a strong negative link between distance to water sources and girls' schooling. For example, Akabayashi and Psachapopoulos (1999) find a significant negative impact of distance to water sources on girls' school hours but not on boys'. Furthermore, apart from carrying water to their homes and farms for daily chores, girls have to travel to the water sources more during their period for hygienic purposes (Ahmad and Yesmin, 2008). This will generate more time costs for girls who can otherwise use the time to travel to their school. Children in rural China may also fetch water for farm and household work, the relevant time cost and its impact on their schooling are controlled for by introducing work variables.

Health Costs: A significant amount of disease could be prevented especially in developing countries through better access to safe water supply, adequate sanitation facilities and better hygiene practices. In rural China, access to clean water has also been regarded as a major social issue. Wu et al (1999) find half of the population (700 million) in China is consuming contaminated water which is a major source of infectious and parasite disease. They also find that the situation is much worse in rural China. Moreover, from August 2006 to May 2007 China's Ministry of Health conducted a survey of drinking water and hygiene in the rural areas in 31 provinces, regions and cities. At least 300 million rural residents in China were estimated to have no access to safe and clean drinking water, and only 31 percent of rural toilets reach hygienic standards (China View[2], 13 Aug 2006).

Water-related diseases include those due to micro-organisms and chemicals in water people drink; diseases like schistosomiasis which have part of their lifecycle in water; diseases like malaria with water-related vectors; and others such as legionellosis carried by aerosols containing certain micro-organisms. It also contributes to the spread of dangerous food related illnesses like salmonella and E. coli (For other demographic and economic studies about the link between access to safe water and general health outcomes, see Barrera, 1990; Jalan and Ravallion, 2003). Hence both girls' and boys' schooling may be affected by the general health related consequences of poor water, since it is found that children's health is an important determinant of their schooling (Colclough et al, 2000).

However, poor access to water may interact with menarche to further reduce girls' schooling. Hygienic practices are always improper if the access to clean and safe water becomes difficult. Furthermore, girls meet extra health problems if there are no hygienic practises or facilities for them to do the essential cleaning during their period. Filmer (2000) finds that girls in Tanzania enjoy a slight advantage in school attendance when they are 6-11 year old, but when they are 12-14 year old, the advantage shifts to the boys. Age 12-14 for girls are the typical years for the onset of menarche. During menstruation, dysmenorrhoea is the most important symptom. Poor access to water makes such symptoms occur more frequently and recovery is difficult. For example, Kirk and Sommer (2006) and Singh et al.

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[2] For more information, see http://news.xinhuanet.com/english/2006-08/13/content_4955367.htm

(1999) argue that poor protection and inadequate washing facilities may increase susceptibility to menstruation related infection. Research also found that girls' health is at risk if proper personal hygiene is not in place after menarche (see Ahmad and Yesmin, 2008; Dagwood 1995; Severino and Moline, 1995), a problem which arises particularly when poor access to water means girls are unable to clean themselves (see Bista, 2004, Nahar, 2006; Kirk and Sommer, 2006; and Singh et al., 1999). Reduced health and cleanliness worries will clearly impact more on girls' education.

As frequent and prolonged spending on children's health related expenses increases, parents will have to cut the family budget for children's schooling. Since girls have much bigger probability of having special gender-related symptoms, poverty stricken parents may not be able to afford the related health costs for their daughters, and may consider it essential to withdraw their daughters from school and arrange them for a 'necessary' marriage that can transfer the further health costs to the maternal family (Kirk and Sommer, 2006). Moreover, even though parents are financially better off, they will seek to maximize the return from investing in their children's schooling and hence are more likely to invest in healthier children's schooling (Ayalev, 2005). In this respect, girls with recurring illness due to the joint impact of menarche and poor access to water may have to quit school first. Furthermore, menstruation related symptoms resulted from lack of water and timely cleaning also lead to severe discomfort and pain to girls, and in turn, disturbs their schooling. For example, Huerta (1994) finds that even though girls suffering from pain go to school, they will lose concentration, coordination and be subject to further depression.

Psychic costs: Poor access to water may also generate typical psychic costs on post-menarche girls' schooling. There is quite a large literature on poor sanitation in rural schools, and its adverse consequences for girls' education (e.g., El-Gilany et al, 2005; Behrman at al. 1999a). After having conducted interviews with many school girls, Snel & Shordt (2005) conclude that school drop-out rates and low literacy levels, especially among adolescent girls, can be attributed in part to inadequate sanitation and health conditions in schools. Cairncross et al. (1996) also find that a school sanitation programme in Bangladesh increased girls' enrolment by 11 per cent. Lidonde (2005) asserts that girls from poor African counties are marginalized in accessing education because of inadequate sanitation facilities that allow them no privacy, especially during their menstrual period. Behrman et al (1997), using detailed data from rural Pakistan, find that poor access to water and toilet facilities significantly reduces school performance. Lidonde (2005) also finds about 1 in 10 school age African girls do not attend school during menstruation or they drop out altogether at puberty because of a lack of clean and private facilities. The lack of private sanitary facilities for girls at schools will also contribute to there being fewer women teachers to encourage girls to attend schools (Bista, 2004).

If the schools in rural areas do not provide adequate sanitation facilities for girls' special hygienic needs during their period, homes will become primary cleaning places for girls. For example, Oster and Thornton (2009) find girls in general come back home from school to wash their rags and involve self cleaning activities during their period. If girls do not have clean and safe water sources either at home or school, they may find it difficult to remove the odour and spot resulted from menstruation and may thus be subject to physical and sexual abuse from boys and even male teachers (Bista, 2004).

Consequently, in areas where there is poor access to water parents do not feel safe sending their girls to male-dominated environments, e.g. schools, during their period (Kirk 2005). This reality indicates the existence of a typical psychic cost on parents' side as well as on the girls' side to prevent the girls from attending school during their period for safety concerns. Furthermore, in rural India, menstruating girls are often subject to certain taboos. Girls are asked to remove themselves from public spaces such as classrooms and thus suffer their schooling during all the menstruation period (Nahar, 2006). However, this phenomenon is believed to be a less common practice in China.

The arguments above boil down to the possibility that that post-menarche girls' education suffers due to the greater time, health and psychic costs associated with poor access to clean water. All these 'special' costs induced by the interaction of the poor water access and menarche are likely to make girls drop school early. However, while economists are beginning to consider the role of the menstrual cycle in economic outcomes (e.g., Ichino and Moretti, 2009, link the cycle to women's absenteeism), only Field and Arbus (2008) and Oster and Thornton (2009) have so far considered the link with education, but without considering the all-important interaction with access to water. In this study, poor access to water is defined as having no access to tap water, since water from other sources (e.g lakes, wells) are found to be contaminated and is a source of infectious and parasite disease in rural China (Wu, 1999). The researcher also uses other definitions like 'other water sources outside the courtyard' (water4 in Table 2.1) as 'access to poor water' in empirical specifications to check for the robustness of the results. A theoretical model for the argument is provided below.

.3 A Survey on Gender Education Gap Research in China

A general survey of literature on gender education gap with a particular focus on China is also necessary. The survey should provide essential information about the research context and current developments of the research topic in general. Household income, parental education and occupational status, children's market work and household work, sibling structure, geographical locations, and 'culture' are generally considered as possible causes to explain the gender education gap in China. The impacts of these variables will be controlled for when conducting multivariate analysis in next chapter.

In China, primary and secondary education takes 12 years to complete, divided into primary, junior secondary and senior secondary stages. In general, primary education lasts 6 years (age 6 to 12). At junior secondary stage, most have 3 years schooling (age 12 to 16). The 9-year schooling period in primary and junior secondary schools pertains to 'compulsory' education. General senior secondary education lasts a further 3 years (often age 17 to 19) (Yang, 2006). Gender gaps arise particularly in this secondary stage, and the literature can be categorised as follows:

<u>Opportunity cost</u>: According to Li and Tsang (2002), in the past two decades the transition to a market oriented economy has allowed many privately owned enterprises to hire young female workers with limited education in the manufacturing and service sectors, especially in the booming coastal cities. Furthermore, rural villages and towns have developed various small-scale factories and enterprises that hire young women with limited education (see also Connelly and Zheng 2003 and Song et al. 2006). In addition, Knight and

Li (1996) argue that girls' education has a higher opportunity cost, since "traditionally" girls are family helpers.

The data to be used in this study have detailed information on children's time spent on household work and market work. The researcher will test whether working time has different impacts in the education models for girls and boys, and whether the impacts vary among girls who have good and bad access to water.

<u>Household income</u>: Household income is an important source of support for children's education (Behrman and Knowles, 1999). In China, girls' education should arguably be more sensitive to household income in the Chinese context of patrilocal marriage traditions (Song et al., 2006). In other words, the woman moves into the husband's family, which therefore benefits from investments in the wife's education, while a son's education directly benefits his own family (see also Li and Tsang, 2002) These arguments imply lower education chances for girls from poor families, which are presumably more sensitive to possible losses due to daughters moving away.

Parental education and occupation are also important indicators of children's schooling, partly because of their link with household income and perhaps also because of a link with "values" (e.g., Lauer, 2003) placed on education. It is also possible that more educated parents are more able to provide goods and services that are complements to children's learning (Strauss and Thomas, 1995; Brown, 2006). Parental educational attainment is always found to have strong positive impacts on children's educational outcomes (Farre et al, 2009; Cattaneo et al, 2007; Burke and Beegle, 2004; Beutel and

Axinn, 2002). However, some did not find such strong impacts (Black et al, 2005), while others find that the impacts of fathers' and mothers' education are different on children's educational outcome (Chevalier, 2004). Holmlund et al. (2008) concludes that such different results arise mainly due to the differences of statistical methods employed.

In fact, the literature has not come to a solid conclusion either in China with regards to the impact of household income and parental education/occupation on gender gaps in education. Brown and Park (2002) suggest the importance of household income in determining educational outcomes, but there is little indication in their empirical findings that poverty affects girls more severely than boys (see also Connelly and Zheng2003, Song et al 2006, and Yueh 2006). Brown (2006) finds no systematic gender bias in China in terms of pecuniary and time investment to children's schooling from the parents. In this analysis therefore there are twofold interests in the household income variable. First, the household income (also parental education and occupation) is to be controlled well to ensure that the access to water variable is not simply picking up the poverty of families which have poor access to water. Second, the researcher will investigate whether girls' education is more sensitive to household income than boys'.

Siblings and early marriage: Different numbers of siblings and sibling structure may also have different impacts on parents' education decisions (Conelly and Zheng 2003, Yang 2006, Tsui and Rich 2002) and the overall allocation of limited household resources (Makepeace and Pal, 2008).While the findings remain mixed, the researcher agrees that detailed controls for sibling structure are necessary.

Field and Arbus's work (2008) on Bangladesh finds that eldest sisters experience a greater negative impact of menarche on their schooling than younger. They believe this effect is a result of the Bangladesh custom of early marriage, with eldest sisters being required to marry off first after menarche, and their schooling therefore suffering. However, Bangladesh's early marriage rate is much higher than China's. While an estimated 75% of rural girls in Bangladesh (Field and Arbus, 2008, 886) are married before the age of 16, the data in this study give the corresponding figure for China as under 5% (CHNS, 2009, The dataset used in this study is to be introduced in section 2.5).

Geographical location: Children living in remote areas lack nearby schools, adequate transportation and information. All these may have negative impacts on their school enrolment. The negative impact is plausibly larger for girls (Li and Tsang, 2002). However, Connelly and Zheng (2003) find little evidence that living in a hilly county has a significant negative impact on school attendance of girls. Nevertheless, it is vital to control for location effects – since poor access is likely to overlap with remote geography. The controls for household income, and also for location (151 villages) will hopefully sweep out this effect.

'Culture and pro-son bias': Many researchers address Chinese tradition and cultural factors that may have potential impacts on the school enrolment of boys and girls. Li and Tsang (2002) describe how "families without sons are recorded as having died out". This rigid lineage system, along with patrilocal marriage patterns might cause a pro-son bias in schooling decisions (Though Lee, 2008, finds little evidence of this). Thus, Song et al. (2006) argue that a son's education is more of an 'investment good' in rural China, whereas a daughter's is often taken as a 'luxury good'.

The difficulty with arguments relying on culture is that one needs to know where the "culture" itself comes from (Yueh, 2006). If girls in poor water areas have always had to drop out of school early, a culture will evolve of educating boys, and using the girls as family helpers – or marrying them off (as in Bangladesh). Therefore girls within a cultural setting (village) would experience same school drop out no matter they have poor or good access to water. If it is found that within a village, girls with good access to water tend to have more education than those without, controlling for other individual and household characteristics, the 'culture' argument will become less convincing.

2.4 The Mechanism of the Joint Impact on Girls' Education

Following the method of Brown and Park (2002), the researcher models the household educational investment decision. Some modifications are made to the model since access to water and menarche variables should also appear in the model explicitly. Assume a family consisting of parents and a child. The decision of educational investments with regards to the number of years of schooling of the child is made by parents. Over the years, family well-being is measured as a weighted sum of generational utility functions:

$$U = U_{parents} + \gamma U_{child} \qquad (\gamma > 0).$$

Let Y denote the level of household income (for simplicity it is assumed that there is no additional income from borrowing). For each year of an E_c years of schooling of the child, the household needs to pay P (price for a unit year of schooling) which includes the school related fees and any opportunity costs of child's time which are assumed to accrue to parents. The interaction of poor access to water and menarche increases average costs of girls' education and serves to decrease the overall utility of the household. This is because parents will have to find ways to have good water access at home to tackle the problem associated with the special needs of their post-menarche daughters. However, this is difficult because the tap water access can hardly be possible without government investment/construction.

In China, water pipeline constructions are often jointly carried out in many villages and invested by the central, provincial or county level governments. For example, an online report by Ma An Shan city government notes that the government plans to invest 200 million CNY (approx. 19 million GBP) for a pipeline construction in surrounding rural villages which will provide tap water for 600 thousand people (Ma An Shan water pipeline construction project, 2008). Nevertheless, the households may raise collective funds and support government investment in water pipeline construction. Alternatively, parents may buy clean water (if they are rich enough) to meet the special needs of their daughters which however puts extra costs on girls' schooling. This extra cost can be hazardous to already poverty stricken parents. Let $\theta\delta\sigma$ be the component which denotes the extra (special) cost. θ is 1 if the child is a girl, 0 otherwise. δ is 1 if the access to water is poor, 0 otherwise, and σ is 1 when menarche has begun, 0 otherwise. In this specification, the special cost component only takes effect when both poor access to water and menarche occur. This component ($\theta\delta\sigma$) will then be interacted with E_c by which it can be ensured that this special cost only exists when girls go to school.

R is the return to the child's schooling. Let α be the share of the return that will be retained by the parents and hence $1-\alpha$ will be the child's share. A is an indicator of parental altruism, and equals to 1 if parents are fully altruistic (They care about their children as much as they care about themselves). Family consumption is omitted from the model for simplicity (Following Brown and Park, 2002). Nevertheless, the inclusion of the consumption in the model does not alter the final conclusion of the model. The utility maximisation problem can thus be reduced to:

$$\text{Max } U_{\text{edu}} = Y - (P + \theta\delta\sigma)E_c + \alpha R(E_c) + A(1-\alpha)R(E_c) \qquad (1)$$

where α~[0,1] and A~[0,1]. The cost of education is subject to the income constraint $(P + \theta\delta\sigma)E_c \leq Y$. Educational expenditure (direct costs plus menstruation related special costs) enters the equation with a negative sign because it reduces joint utility. Family income Y is assumed to be exogenous not affected by children's role as family labourers (household work and market work variables are included in the empirical models).

Following Brown and Park (2002), the researcher makes further assumptions. The share of return to the parents may differ by the child's sex, because boys tend to stay at the parental home after the marriage and girls leave (see the discussion about the patrilocal marriage system discussed in Chapter 2). So the share α can be a function of the child's sex, i.e. $\alpha=\alpha(S)$. Moreover, altruism is set to be a linear combination of mothers' and fathers' preferences (A_m *and* A_f) and the relative weight depends on the mother's bargaining power β inside the household.

$$A = \beta A_m + (1-\beta)A_f \quad \beta\text{~}[0,1] \quad (2)$$

The parental preferences could be a function of child's sex (S) and parental education (E_m *and* E_f):

$$A_m = aS + bE_m$$

$$A_f = cS + dE_f$$

hence $A = A(\beta, S, E_m, E_f)$. Now assume a Cobb-Douglas function with decreasing returns, so that the return function has the following form:

$$R(E_c) = rE_c^{\eta} \qquad (3)$$

where $0<\eta<1$. Let $\boldsymbol{X}$ be a vector that includes individual $\boldsymbol{X_c}$, household $\boldsymbol{X_h}$ and community $\boldsymbol{X_v}$ variables that affect the returns to the schooling, so that $r = \boldsymbol{w'X}$, where $\boldsymbol{w}$ is a coefficient vector.

The first order condition for (1) is:

$$\frac{\partial R}{\partial E_c} = \frac{P + \theta\delta\sigma}{\alpha + (1-\alpha)A} \qquad (4)$$

So for the Cobb-Douglas return function, the solution to the unconstrained optimum will be:

$$E_c^u = \left[\frac{[\alpha + (1\text{-}\alpha)A]\eta \boldsymbol{w'X}}{P + \theta\delta\sigma}\right]^{\frac{1}{1\text{-}\eta}} \qquad (5)$$

When α=1 (when all the return to education is retained by parents) or A=1 (when parents are fully altruistic) then the return function can be reduced to:

$$\frac{\partial R}{\partial E_c} = P + \theta\delta\sigma \qquad (6)$$

thus the marginal return will be equal to the marginal cost. This equation suggests that if the incremental cost component $\theta\delta\sigma$ does exist, then it will require higher return of investment at optimum.

Figure 2.1 provides a visual model of the hypothesis of this study. The researcher draws the cost curve as taking a step upwards with menarche in families with poor access to water (due to the extra cost component $\theta\delta\sigma$). For given education demand (*D*), girls in these families will choose only *A* years of schooling. Girls in otherwise similar families, but with good access to water – as well as boys – will choose *B* years of schooling. Of course, household income will shift both demand and supply curves, and the researcher controls for income in the empirical specification. Ability is more of a problem, but should not be correlated with menarche or access to water. Nutrition may also be relevant to menarche and poor access to water, and thus generate omitted variables bias in empirical estimation. An IV probit model is therefore estimated by instrumenting access to water.

In sum, the educational investment decisions can be a function of the following arguments (note that Cobb-Douglas function in previous equations are used for exposition, and is not relevant for the following equation):

$$E_c = E_c[\boldsymbol{X}, P, \theta\delta\sigma, A(S, E_f, E_m, \beta), \alpha(S)]$$

X includes individual, household and community characteristics that could affect the educational outcome. One important factor is the per capita household income. It is difficult to measure the variable in rural settings because the value of household commodity and goods (livestock, garden and farm goods) is not realised by the market, but instead 'imputed'. Nevertheless, the CHNS provides the most detailed computation of household income from all possible sources and its method is in line with the international practice (see for example, Jalan and Ravallion (2003) for a similar rural income data for India).

P and $\theta\delta\sigma$ are cost factors. P is the direct costs of schooling (tuition, books and transportation). In the CHNS, no information is available for tuition and book fees. However, the impact of such type of direct costs on children's schooling may not be too big since the proportion of those costs in total household income is only about 5% in rural China (Song et al, 2006). Anyway, there is detailed information about the access to water and girls' menarche from which the $\theta\delta\sigma$ component can be constructed. As for the altruism (A) and share of return (α), the researcher includes their deterministic factors (child gender, parental education and bargaining power) directly into the regression.

Brown and Park (2002) derived the measure for the bargaining power (β) of the parents from the question 'which parent decides whether children attend school'. The bargaining power variable is set to 1 if the wife decides, 0.5 if both parents decide and 0 if father decides. They have an advantage of using a direct measure for the 'bargaining power' in children's schooling decision, but the variable may suffer from measurement error (e.g. parents may not report the truth). The proportion of the household asset (land, house) that husband or wife acquires is sometimes used to measure the bargaining power of the parents. But this measure is vague given the possibility that household assets may become common goods a few years after marriage. Furthermore, Friedberg and Webb (2006) find that the effect of the current and lifetime earnings on the bargaining power is also slim.

The cultural norms are sometimes taken as an explanatory factor. In this study, however, the researcher uses the relative educational attainment of the parents as a proxy for the bargaining power since mothers' education relative to fathers' is believed to increase the bargaining power of mothers (Thomas, 1994). Moreover, the researcher also runs separate regressions for boys and girls and allow the impact of bargaining power (relative educational attainment of parents) to vary between girls and boys. The survival analysis technique will be used to estimate the school attainment as the dependent variable (years of schooling) is right censored. A probit model of school drop-out is also estimated using the same right hand side variables as an additional specification to test the same hypothesis. The access to water variable is treated as exogenous in theoretical model, but this assumption will be relaxed when conducting the empirical tests.

The researcher has detailed information on children's time spent on household work and market work. It can be tested whether working time has different impacts on girls' and boys' schooling, and whether the impact varies between girls who have good and poor access to water. As for the future dependence argument (parents prefer sons' education over daughters' since they rely upon the income of their sons' when they get old), if there is a widespread and systematic different treatment towards girls by the parents in rural China who are very much concerned about their future dependence, this type of attitude should exist no matter whether the household has tap water or not. In other words, girls with poor access to water as well as girls with good access will have to drop out of school earlier than boys. If girls with good access to water do equally well in terms of school enrolment as boys, the future dependence argument will become less reliable.

Furthermore, the researcher will discuss whether the access to water variable is picking up location effect – since poor access is likely to overlap with remote geography. Nevertheless, the controls for household income, and also for location (village fixed effects) will hopefully sweep out this effect. However, if the access to water simply picks up the location effect, the effect should be the same for girls pre- and post-menarche. If, however, the impact of poor water is significantly worse for girls post-menarche controlling for other factors (e.g. age), there will be reasons to believe that poor access to water means more than a remote location.

2.5 The Data and the Descriptive Support

2.5.1 The China Health and Nutrition Survey

The data used in this study come from the Chinese Health and Nutrition Survey (CHNS), jointly conducted by the University of North Carolina and the Chinese Academy of Preventive Medicine, Beijing. The CHNS is designed to examine "how the social and economic transformation of Chinese society and family planning programs implemented by national and local government affect the economic, health and nutritional status of its population" (CHNS, 2009).

Many prominent international researchers have joined in collecting the data. Their backgrounds include nutrition, public health, economics, sociology, Chinese studies, and demography (CHNS, 2009). The survey has been conducted for seven times (waves) for a period of 17 years (1989 – 2006). In each wave, the survey used a multistage, random cluster process to draw a sample of about 4400 households with a total of about 19,000 individuals from over 200 villages in nine provinces: Heilongjiang, Liaoning, Henan, Shangdong, Jiangsu, Hubei, Hunan, Guizhou, and Guangxi. As shown in Figure 2.2, those provinces covered stretch from the North-East to the South-West, and vary substantially in geography and economic development (Yang, 2006). In addition, detailed community data were also collected in surveys of food markets, health facilities, family planning officials, and other social services and community leaders.

Altogether, the CHNS provides about 130,000 observations for cross sectional analysis, and about 94,000 observations for the longitudinal analysis. The survey is rich in its community, household and individual level variables and therefore is beneficial to researchers from many different disciplines. CHNS website also provides information about some journal articles which used the CHNS data to conduct their empirical investigations (CHNS, 2009). The research topics belong to many different disciplines such as economics, sociology, medicine, nutrition, development and more. The studies benefited greatly from "the survey's comprehensive and thorough data collection as well as from its longitudinal design" (Liu, 2008, p375).

2.5.2 The Data Used for This Study

This study on gender gaps in education in China uses data in the first six waves (1989, 1991, 1993, 1997, 2000 and 2004) of CHNS (2009) because the latest survey data (of wave 2006) was not available when this project was initiated. The data is restricted to children aged 6-19 from rural areas, where "rural" is defined according to household registration (some data about parental characteristics (occupation, education) are obtained from the CHNS adult survey and merged into the children's file using household and household member line numbers). Tertiary education, often after age 19, is not considered since different factors such as marriage enter the schooling decision. In this sample, the mean age of menarche is 13.4 (compare 13.5 in Singh et al, 1999, and 12.9 in El Gilany et al, 2005), and thus, with the 6-19 age span, the researcher has adequate observations both before and after.

The CHNS provides a detailed per capita income estimate for rural households, which is not usually available from other sources. Gross household income in cash or kind is created for different categories and then expenses are deducted to create a net income value, deflated using the appropriate price deflators. To measure income in-kind, the CHNS relies on the respondent's (usually the household head's) estimates of the market value of the goods produced/consumed and received as gifts. For home gardening income, the total value of household food consumed at home or sold is measured. Income from farming, raising livestock/poultry; collective and household fishing; and the value of income from other household business is obtained by same calculations. The CHNS also takes into account welfare subsidies including housing subsidy, child care subsidy and gifts. These data give mean per capita rural household income as 1,225 CNY (1988 community CPI) for 1989-2004, which is generally in line with other sources (e.g., 1,067 CNY (1990 CPI) for 1987-2001 in Benjamin et al 2005).

In Table 2.1, the means and standard deviations are shown for variables used in the analysis categorised by access to tap water, and also by wave 1989-2004. The top rows give the school enrolment and years of schooling data and it is not difficult to see how girls achieve less than boys in households without tap water. In households with tap water there is little gap, with girls in fact doing better in 2004. In general, girls' education has improved faster than boys. The clearest indication of this improvement is shown from the parental education rows lower down the table. Here, we see that the mothers with poor access to water in average obtain only about 2.8 years of schooling in 1989 which is well behind the fathers with a difference of about 3 years, but has climbed to 6.9 years by 2004, narrowing the difference with fathers to 2 years. However, with good access to water, mothers lag only about 1.4 years behind fathers in school attainment.

It can be seen that households generally have more favourable circumstances when they have tap water. Thus, the 1989 measure of household per capita income is 956CNYin households with tap water, compared to 723 CNY in households without. The difference is even wider in 2004: 2,777 CNY compared to 1,846 CNY. Fathers and mothers are also more educated in households with tap water, though this difference has disappeared by 2004. This improvement in incomes and parental education will explain, at least in part, the earlier onset of menarche over time, since menarche exhibits some sensitivity to nutrition (see Field and Arbus, 2008 for a discussion). As can be seen, the incidence of menarche increases from around half of the girls in the sample in 1989 to nearly two-thirds in 2004.

However, while household income and access to water vary quite closely, there are many villages where rich households have poor access, and poor households have good access (this pattern is observed even within same villages). Figure 2.3 demonstrates this point. The researcher divides households according to whether they are above or below the median income for their county, and then show availability of tap water in the household's village. As can be seen, the distributions are bi-modal, with modes at 95~100% and 0~5% access to tap water. The distributions differ in the expected direction, with only 23% of poor households living in villages with 95~100% access to tap water, compared to 45% of rich households (Another way of making this point is to look at the between village correlation between average household income and poor access to water, which is quite high at -0.37 – Table 3.9 in Chapter 3). Nevertheless, a considerable proportion of rich households live in villages with poor access to water, and vice-versa – and there are many villages where some have good access, and others do not. Therefore, household income and poor access to water are not perfectly correlated. In any case, the regressions generally have a full set of village fixed effects.

Returning to other features of the data, Table 2.1 gives details of household and market work, and also family structure. We see that girls spend somewhat less time on household and market work in households with good access to water (0.97 to 1.6 hours/day) than in those with poor access (around 1.8 hours/day), presumably because of the convenience that tap water access brings. Girls also spend more time on household and market work than boys, which might interfere with girls' schooling. The extra time for girls is about half an hour in households with good access to water, but this time is inconsequential since girls in these households anyway do better in schooling than boys as already noted. In households with poor access to water, the difference increases to about an hour, and could have a bearing on the education gap, a fact which should be kept in mind in the testing below. Finally, there is an obvious tendency for the single child family structure to become more prevalent over time, whether or not access to water is good.

Figure 2.4 gives the proportion of households who have access to different types of water sources in rural China. Four categories of water are measured: tap water in the home (water1), tap water in the courtyard (water2), well water in the courtyard (water3), or other water outside the courtyard (water4). As can be seen, there is a massive improvement in household access to water throughout in rural this 15 year period. The proportion of tap water access (water1+water2) increased from 33% to 65%. The researcher experiments with different definitions of poor access to water. The major definition of poor water access is having no access to tap water (combining water3 and water4). The alternative definition is to take the worst category, water4, alone as poor access to check for sensitivity.

There are 2398 respondents for whom complete data are available. Some of these individuals are observed in multiple waves. For school enrolment (probit) analysis the researcher uses a cross-section data that is constructed by taking the first observation of each individual. For school duration (survival) analysis all data points are utilised. Table 2.2 shows the mean years of schooling that are calculated for girls and boys with good and poor access to water using two types of water category divisions (Division one: tap water vs. non-tap water; Division two: tap or well water vs. other water). Girls outperform the boys when the access to water is good and they accumulate about 0.20-0.25 years more schooling. However, when the access is poor boys gain about 0.15-0.46 years more schooling. The impact of access to water is more elastic for girls than for boys. For example, poor access to water makes girls accumulate 1.17-1.44 years less schooling than girls with good access, while boys with poor access only gain 0.74-0.81 years less schooling than boys with good access.

Table 2.3 provides motivation. As can be seen from the first row, girls with good access to water (tap water in the house or courtyard) have a 3 percentage point higher school enrolment rates pre-menarche. However, post-menarche the advantage is larger, 20 percentage points. Using the pre-menarche girls' experience to derive the direct beneficial effects of tap water, the researcher finds that tap water raises the enrolment rate of post-menarche girls by 17 percentage points. When looking at the figures vertically, one can see that girls with both good and poor access to water have lower school enrolment post menarche. However, while post menarche girls with good access to water have 41 (0.88-0.47) percentage points lower school enrolment than pre-menarche girls with good access, post menarche girls with poor access have 58 (0.85-0.27) percentage point lower school enrolment than pre-menarche girls with poor access. So the difference in differences is again 17 percentage points (0.58-0.41).

The Kaplan-Meier survival curves in Figure 2.5a also show that girls with poor access to water have a much lower survival curve than the other three groups, with only about a 30% chance of surviving until period 9, which is the end of junior secondary school. As can also be seen, post-menarche girls in poor access to water households have a lower survival probability from the very first school years. They seem to start school late, and progress more slowly (Note, in rural China children always start enrolling the school late (Brown & Park, 2002), so it is not surprising to see girls post-menarche in early school years). Figure 2.5b concentrates on the poor access to water households, and shows how boys' survival is similar to the pre-menarche girls. These basic descriptive statistics support the hypothesis that girls post-menarche suffer their schooling if access to water is poor. However, as mentioned earlier, multivariate analysis needs to be conducted to derive the true impact of access to water when controlling for the impact of other confounding factors.

2.6 Conclusion

In this chapter two sets of literature survey are conducted to identify the recent findings about: (1) the special impact of poor access to water and menarche on girls' schooling which may generate gender gaps in education; (2) the other causes which will generate gender gaps in education. It is found that time/health/psychic costs associated with poor access to water after the onset of menarche are widely acknowledged in many recent research works. However, no empirical test has been conducted to identify the significance and intensity of the joint impact of poor access to water and menarche on girls' schooling. With regard to other literature that analyses the causes of gender education gap, household income; parental education; parental occupational status; children's work opportunities; early marriage; different sibling structures are the usual considerations.

According to the above findings, the research hypothesis of this study is moulded as follows: Girls education suffers (early drop out and shorter duration) from the joint impact of poor access to water and menarche, presumably due to the time, health and psychic costs generated by the joint impact. By definition, this joint impact does not exist for pre-menarche girls, girls with good access to water or boys. As noted above, the impact, if tested to be true and large, should be useful to explain gender education gaps in less developed settings, where, often, access to water is poor. The impacts of other variables mentioned above will be controlled for when conducting multivariate tests in this study.

A theoretical framework is developed to model the joint impact of poor access to water and menarche on girls' schooling. The model is based on the concept that children's education is a household investment which aims to maximise the total utility of household members. The interaction of poor access to water and menarche enters the model explicitly as a cost element that only exists for girls post-menarche when they enrol at school. Higher costs of girls' education require higher returns from the educational investment to balance. Higher average costs inevitably leads girls post-menarche drop out of school early (accumulate less years of schooling) when the demand for schooling is assumed to be the same between boys and girls.

In this chapter also, the CHNS dataset is introduced and the variables from that dataset that could be used in empirical models are presented. The CHNS provides detailed information on children's schooling (enrolment status and years of schooling); household access to water and the onset of menarche, which are all crucial to test the hypothesis of this study. Besides, it contains almost all other necessary individual, household and community variables which can serve as additional controls in the empirical model. Those control variables include household income, sibling structure, children's household and market work, parental education and occupational status, children's age and other community characteristics.

The descriptive statistics support the hypothesis. Girls post-menarche have higher school drop out rates and shorter schooling duration when access to water is poor. Specifically, girls with good access to water (tap water in the house or courtyard) have a 3 percentage point higher school enrolment rates pre-menarche. However, post-menarche the advantage is larger, 20 percentage points. Using the pre-menarche girls' experience to derive the direct beneficial effects of tap water, the researcher finds that tap water raises the enrolment rate of post-menarche girls by 17 percentage points.

The Kaplan-Meier survival curves also show that girls with poor access to water have a much lower survival curve than the boys or girls with good access to water, with only about a 30% chance of surviving until grade 9, which is the end of junior secondary school. Obviously, a multivariate analysis is needed to derive the true impact of access to water on schooling of boys and girls when the impacts of other confounding factors are controlled for. The relevant multivariate tests will be conducted in the next chapter.

Figure 2.1: Access to water (AW) × menarche interaction and male-female education gap

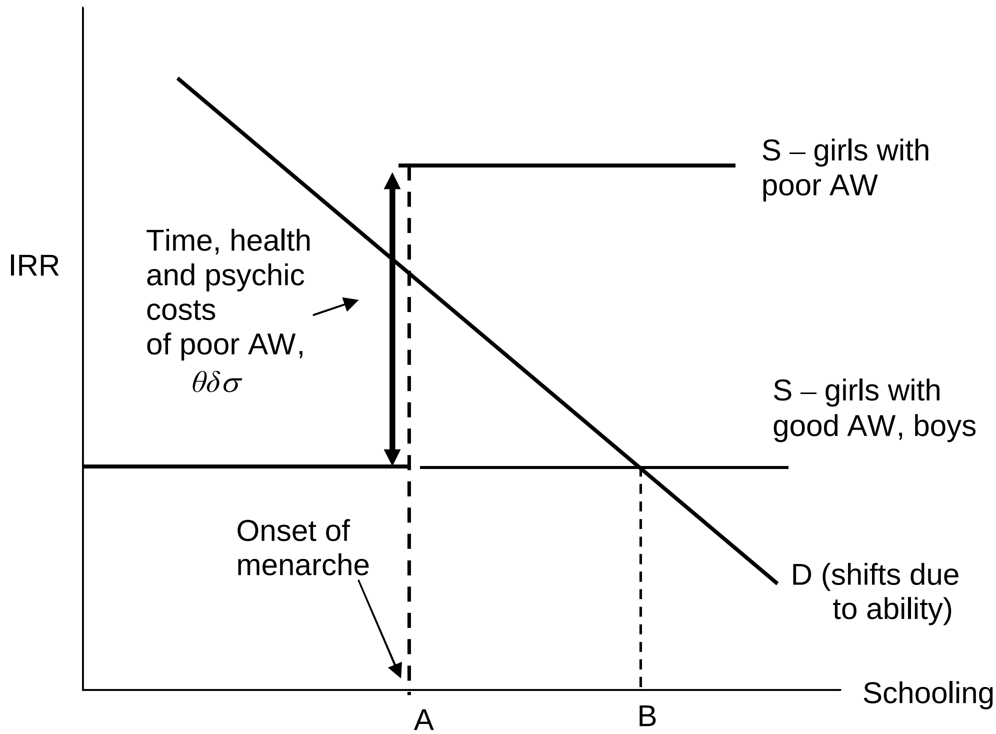
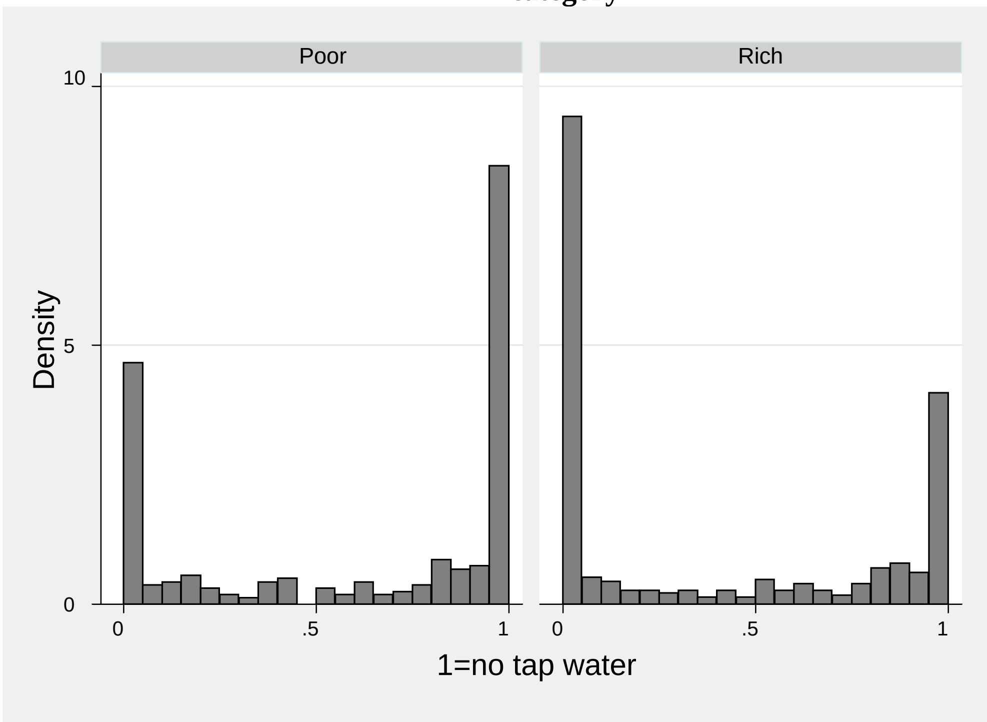


Figure 2.2: Map of provinces covered in the CHNS surveys

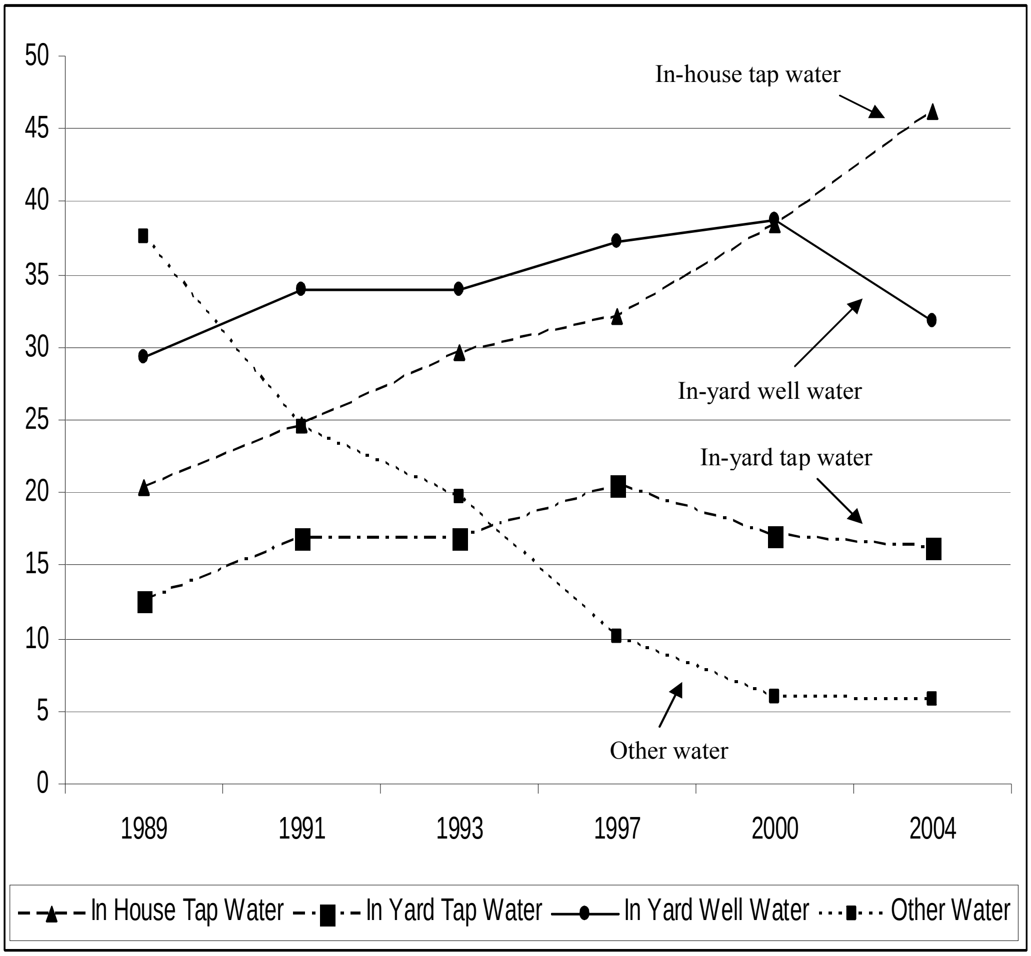
Figure 2.3: The density of poor (non-tap) water coverage by village and income category



Note: This figure shows the density of poor (non-tap) water coverage by village and income category. For each survey wave and village, the researcher computed the proportion of the tap water access and the mean per capita household income. The "poor" and "rich" households are then identified at the median of the wave and village specific per capita income ('rich' if respondent's reported per capita income is higher than the computed wave and village specific per capita income). Poor access to water in these figures includes water3 and water4 in Table 2 (non-tap water), and 0 shows 95-100% of households in a village have access to tap water while 1 shows that less than 5% has access. The two distributions are tested to be different at the 1% level.

The graphs have 20 bins. As can be seen, about 40% (8*5) of the poor households live in villages where there is almost no tap water, and about 23% (4.5*5) live in villages where there is tap water for almost all the households. The remaining 40% live in mixed access to water villages. As for the rich households, about 45% (9*5) of these live in villages where there is tap water almost for all, but still about 20% (4*5) live in villages where there is no tap water almost for all.

Figure 2.4: The proportion household by type of access to water



Note: The data is from rural households in CHNS 1989 – 2004.

Figure 2.5a: Kaplan-Meier survival distributions, schooling respondents 6-19, girls only

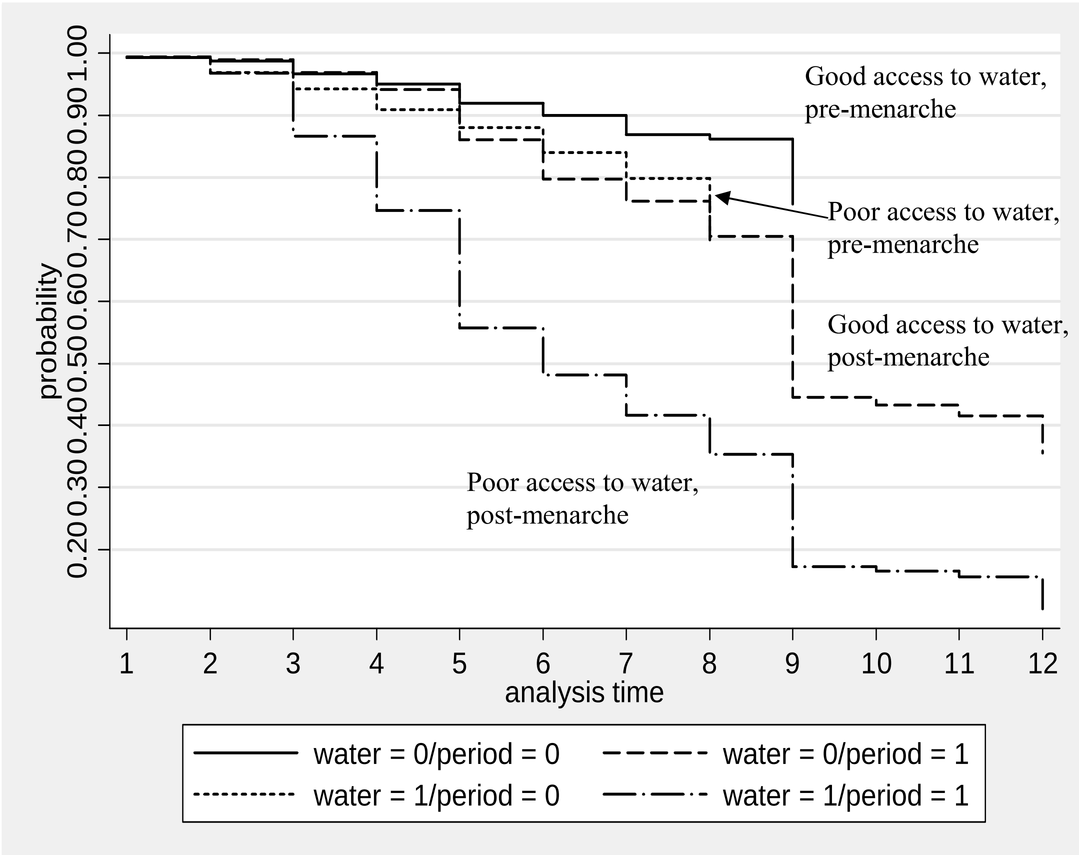
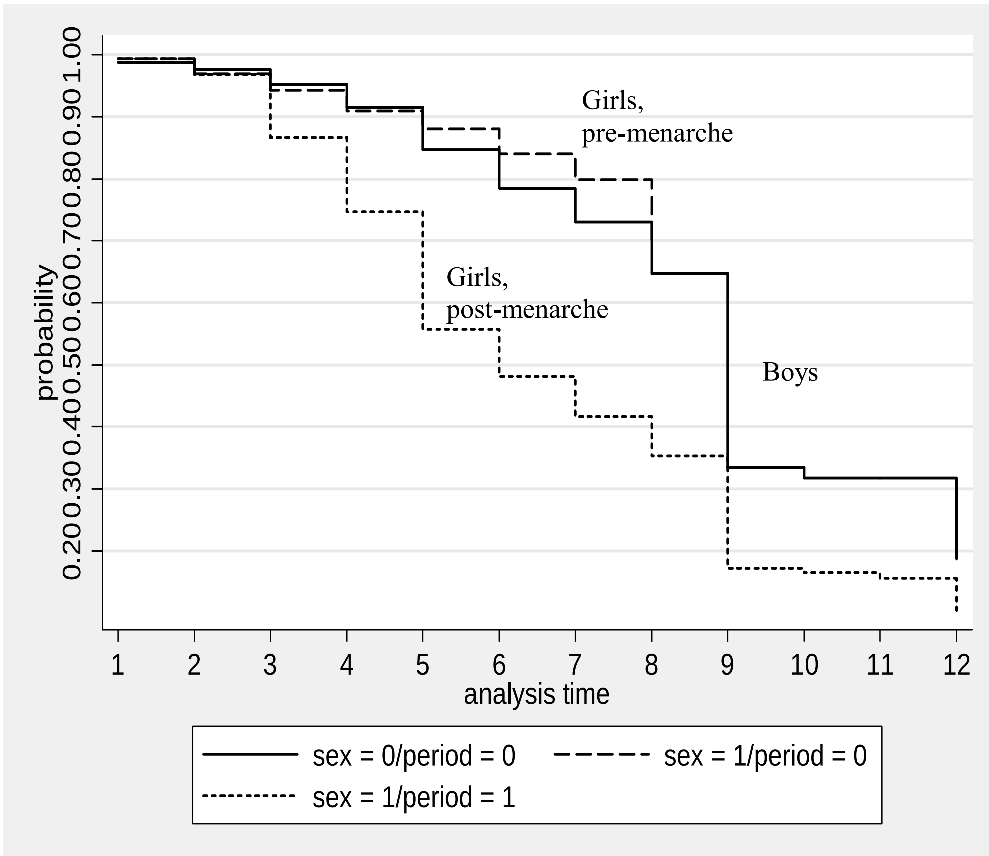


Figure 2.5b: Kaplan-Meier survival distributions, schooling respondents 6-19 - poor access to water only, boys and girls



Notes: analysis time corresponds to accumulated years of schooling: 0-6 being primary, 7-9 junior secondary (the end of compulsory education), and 10-12 senior secondary school. Poor access to water is taken as water4 (Table 2).

The reason the survival curve for girls post-menarche extends to low years of education is because some older, post-menarche, girls are in the junior school years.

Table 2.1: Descriptive Statistics, rural girls and boys 6-19 excluding those in tertiary education

Selected Variables	Household has tap water			
	1989		2004	
	No	Yes	No	Yes
school enrolment (girls)	**0.60** **(0.49)**	**0.67** **(0.47)**	**0.71** **(0.46)**	**0.85** **(0.36)**
school enrolment (boys)	**0.66** **(0.47)**	**0.69** **(0.46)**	**0.75** **(0.44)**	**0.84** **(0.36)**
years of schooling (girls)	**4.4** **(2.8)**	**5.4** **(3.0)**	**6.4** **(3.0)**	**6.8** **(2.9)**
years of schooling (boys)	**4.8** **(2.9)**	**5.3** **(3.2)**	**6.8** **(2.9)**	**6.6** **(2.9)**
menarche	**0.46** **(0.50)**	**0.47** **(0.50)**	**0.63** **(0.48)**	**0.59** **(0.49)**
household per capita income (1998 CPI)	**723** **(587)**	**956** **(554)**	**1846** **(1491)**	**2777** **(2856)**
clustered income*	**0.20** **(0.40)**	**0.39** **(0.48)**	**0.42** **(0.49)**	**0.51** **(0.50)**
fathers' education	**5.59** **(3.32)**	**6.56** **(3.6)**	**8.22** **(2.51)**	**9.62** **(3.00)**
Mothers' education	**2.78** **(3.32)**	**4.48** **(3.80)**	**6.91** **(3.07)**	**8.24** **(3.69)**
father farmer	**0.71** **(0.45)**	**0.46** **(0.50)**	**0.47** **(0.50)**	**0.32** **(0.47)**
household and market work hrs/day – girls	1.80 (1.90)	**1.60** **(1.55)**	1.85 (2.16)	**0.97** **(1.36)**
household and market work hrs/day – boys	**0.90** **(2.02)**	**1.05** **(2.06)**	**0.55** **(1.61)**	**0.67** **(1.89)**
single child	**0.11** **(0.31)**	**0.12** **(0.32)**	**0.53** **(0.50)**	**0.60** **(0.49)**
Proportion with access to tap water (water1 or water2) (%)	33		63	
Access to tap water or well water in the courtyard (water1, 2, or 3) (%)	67		88	
Total observations	1,871	923	302	520

Notes: Standard Deviations are in parentheses. Bold figures indicate significant differences between 1989 and 2004. * Clustered income gives two categories, "rich" and "poor", based on k-mean clustering using whether the household per capita income is above or below median, and mother's and father's four job status categories and four educational categories.

Table 2.2: Mean school years of girls and boys

	Girls		Boys	
Water categories	Good access to water	Poor access to water	Good access to water	Poor access to water
Division One	6.56 (2276, 3.23)	5.39 (2552, 3.03)	6.29 (2425, 3.18)	5.55 (2978, 3.06)
Division Two	6.24 (3837, 3.19)	4.78 (991, 2.87)	6.05 (4309, 3.16)	5.24 (1094, 2.93)

Note: Number of observations and standard deviations are given in parenthesis. Division one: tap water (good access) vs. non-tap water; Division two: tap or well water (good access) vs. other water. The survival analysis that follows in the next chapter will account for uncompleted spells.

Table 2.3: Differences-in-Differences estimate of poor access to water on school enrolment, pre- and post-menarche

Girls 6-19			
Menarche	Good access to Water	Poor access to water	Difference
Pre	0.88 (0.014, 614)	0.85 (0.013, 788)	0.03 (0.018)
Post	0.47 (0.029, 256)	0.27 (0.022, 405)	0.20 (0.037)
		Difference-in-Difference	-0.17 (0.036)
Memo: boys 6-19	0.79	0.72	

Notes: Good access to water refers to tap water (categories water1 and water2 in Table 2). Standard error of the estimate and sample sizes are reported in parentheses.

CHAPTER THREE: EMPIRICAL TEST (1) – REGRESSION ANALYSIS

3.1 Introduction

The descriptive statistics in the previous chapter suggest that the schooling of girls with poor access to water suffer more than boys and girls with good access to water after the onset of menarche. However, the relationship needs to be confirmed by including essential control variables in a multivariate analysis. Two types of empirical strategies are adopted to test the hypothesis. The first strategy uses regression analysis to test whether poor access to water has any significant impact on girls' schooling after the onset of menarche using probit (for school enrolment) and hazard (for school duration) models in a multivariate context where essential control variables are in place. This testing takes place in this chapter. The second strategy takes place in the next chapter, where the researcher uses Propensity Score Matching (PSM) methods to conduct alternative testing of the same hypothesis. The PSM results can also serve as a robustness check of the regression results obtained in this chapter.

The regression estimations control for other confounding factors which include many individual and household characteristics. Besides, the village dummies are included in the model to control for the impact of poor geographical locations. Controlling for village fixed effects is important as poor access to water is likely to be correlated with backward locations. In addition, the poor access to water variable is instrumented to account for the possible endogeneity. Two types of definitions are used for good / poor access to water to test the robustness of the results.

Regression results are found to be supportive to the hypothesis-1 of this study. Controlling for other cofounding factors, poor access to water is found to reduce the probability of school enrolment of post-menarche girls by 27 percentage points. It is also found that girls post-menarche has 2 – 2.5 times shorter conditional school duration when access to water is poor. A policy maker may be particularly interested on the average impact of water engineering on children's schooling at the village level, since water engineering is a village level project. Therefore, a village level analysis is conducted to test the average impact of access to good water on girls' schooling. It is found that a one percentage point decrease in the village average access to poor water increases post-menarche girls' school enrolment by about 0.22 percentage points holding the community rate of girls' menarche at the mean. The different kinds of regression analyses all direct to the same conclusion that girls post-menarche have higher rate of school drop-out and shorter school duration where the access to water is poor. The effect not only exists at the individual level, but is also prevalent at the village level.

This chapter is organised as follows: In section 4.2, the overall strategy of regression analysis will be outlined. Two types of regression models (probit for school enrolment and hazard models for school duration) will be introduced. Relevant control variables that are to be included in the estimation will be briefly reviewed. In section 4.3, the results from the probit models will be analysed. Moreover, the impacts of the onset of menarche will be analysed separately for older sisters, younger sisters and single daughters to check for the robustness of the assertion that girls drop out more from school after the onset of menarche due to the early marriage. In section 4.4, the results from the hazard models will be analysed.

Some sensitivity tests are conducted by restricting the sample on specific type of villages. Besides, duration distributions will be presented using the regression results. In section 4.5, the village level analysis will be conducted. The final section will conclude the chapter.

3.2 The Regression Strategies

To study the interaction of access to water and menarche, the researcher uses a difference-in-difference specification:

$$Y_{it} = \beta_1 + \beta_2 W_{it} + \beta_3 M_{it} + \beta_4 W_{it} \times M_{it} + \beta_5 X_{it} + \theta_t + \varphi_s + \varepsilon_{ist}$$

where i denotes individuals; t denotes time; Y_{it} is either years of schooling attained (survival analysis) or an indicator for currently being at school (probit); X_{it} is a vector of controls including household income, parental occupation/education, the respondent's house and market work, age (age category) and sibling structure; W_{it} is an indicator equal to one if the household has no access to tap water (other definitions are also used); M_{it} is an indicator equal to one if the individual has reached menarche; θ_t is a set of wave dummies; and φ_s is a set of village (county) dummies. ε_{ist} is assumed to follow normal (in probit) or extreme minimum value (in Weibull) distribution depending on the different types of models that are used for the testing.

β_4 is the coefficient of interest. It is expected that poor access to water have a worse impact on girls' schooling after menarche, due to the hygiene related economic and psychological problems they face as described above. These considerations point to a negative interaction between the access to water and menarche variables. The adverse impact of poor access to water on pre-menarche girls (β_2) is expected to be small or zero. In order to allow full variation of the impacts of the other control variables, the researcher also estimates hazard and probit models for these two groups of girls separately. In this case, for pre-menarche girls the model is:

$$Y_{it} = (\beta_1+\beta_3) + (\beta_2+ \beta_4)W_{it} + \beta_5 X_{it} + \theta_t + \varphi_s + \varepsilon_{ist}$$

showing that the coefficient on W is the sum of both β_2 and β_4, while for pre-menarche girls the model will simply be:

$$Y_{it} = \beta_1 + \beta_2 W_{it}+ \beta_5 X_{it} + \theta_t + \varphi_s + \varepsilon_{ist}$$

Thus, β_4 can be simply recovered by comparing the coefficient on W in the two regressions.

The probit and hazard models both have advantages and disadvantages. For example, the instrumentation of a possibly endogenous variable can be done more conveniently using well established instrumental variable probit (IV probit) models compared to hazard models. However, Dolton et al. (1994) assert that duration analysis is more powerful in addressing important variations in individual experience across time when the impact of a treatment is estimated. Due to the special characteristics of important policy variables , the researcher is not able to use the panel structure of the data to account for the impacts of unobserved individual characteristics in probit models (the reasons will be explained later). However, unobserved heterogeneity across individuals is controlled for in hazard models using ‘multiple failures per subject’ specifications. Besides, probit and hazard models have different assumptions over the distribution of error terms, therefore the results from one model can be used as sensitivity tests on the results of the other.

3.2.1 Probit Model – School Enrolment

Now the dependent variable is 1 if the respondent reported that she/he is enrolling at school at the time of survey, and 0 otherwise. A probit model (Cameron and Trivedi, 2005, 470) specifies the conditional probability *(p)* as:

$$p = \Phi(x'\beta) = \int_{-\infty}^{x'\beta} \phi(z)dz$$

where $\Phi(x)$ is the standard normal cumulative distribution function with derivative $\phi(z) = (1/\sqrt{2\pi})\exp(-z^2/2)$ which is a standard normal density function. The probit model is estimated using Maximum Likelihood Estimation (MLE) which is considered as the best estimator if the above density function is correctly specified. After estimating the probit coefficients, average marginal effects (AME) of the regressors are estimated since estimating the AME is recommended for policy analysis (Cameron and Trivedi, 2009, 340). AME is calculated as a discrete change in the dependant variable as the dummy variable changes from 0 to 1 (Cameron and Trivedi, 2009, 464). The AME may also be more comparable to the average treatment on the treated (ATT) that is to be obtained in the second phase of this research in the next chapter.

Due to the thin panel nature of the data (altogether 6 waves, and most of the subjects (40%) only appear once, see Table 2.1), the conventional panel estimation at the individual level faces many problems. For example, when running the fixed effects model, the important explanatory variables, such as menarche and access to water, mostly take 1 or 0 for a given individual across waves, so a within transformation is not possible. While most of the observations (80%) are dropped, the estimates obtained from the fixed effect model may not always be comparable to the estimates obtained from the random effects model (Since the estimates often differ a lot due to very different sample size, conventional tests such as the Hausman test always prefers fixed effects – thinking that random effects estimates are biased). Bearing this reality in mind, the researcher only retained the first observation per subject across the waves (the 75% of original observations) for the school enrolment (probit) analysis. So the nature of the data used in the probit models is the cross section data from the multiple waves with no recurring individuals.

As discussed in the last chapter, poor access to water may be correlated with backward geographical location, extreme poverty or simply unfavourable village environment or ‘culture’. These factors may generate systematic differences between the observations in treated and control groups regarding their school enrolment. So the true impact of poor access to water on the outcome (school enrolment) may become ‘contaminated’ by these confounding factors. 151 village dummies are included in the regression to capture the unmeasured village fixed effects. This solution is sufficient if the unobserved village effect is fixed, but not when the effect is time-variant. Furthermore, the unobserved within-village or household characteristics may also be correlated with access to water and make the impact biased.

Therefore, the researcher finds it necessary to check for the exogeneity of the access to water variable. Government investment in village water pipeline construction may be a good instrument which is highly correlated with the probability of every household having access to tap water, but not directly linked to children’s schooling outcome. However, there is not a direct measure in the dataset about this type of government investment. But an indirect measure about the relative intensity of government investment in water pipeline construction can be generated using a special variable in the dataset. A question is asked from the households about the source of the drinking water (Question L3 in Household Survey Data, CHNS, 2009) and option 5 for the answer is 'obtaining the water from a water plant' (water treatment plants that provide clean and safe water to industries and households).

The researcher finds that not all households that have access to tap water obtain their water via a water plant. The Table 3.1(a) gives the proportion of respondents who report that they get tap water via a water plant. There are altogether 2306 individuals (out of 2310) who responded to both of the questions (whether have tap water access, whether get the tap water via water plant) in the dataset that is used for the probit model (first observation per subject). Among the 2306 respondents, 989 reported that they had tap water at home (43%), and 1317 (57%) had no tap water at home at the time of corresponding surveys. Among the individuals with tap water access 512 (52%) respondents said they had access to tap water via a water plant, while 477 (48%) reports they got tap water from other sources.

This reality indicates that having access to tap water is not perfectly collinear with having tap water from the water plant. In other words, water plant is not the only way that households get tap water access. But having water plant(s) in a village definitely increases the probability of households within the village getting access to tap water. The researcher therefore constructed a variable that measures the proportion of people within a village who get tap water from a water plant (*water plant* hereafter). If the proportion is higher it indicates that the relative intensity of the government investment on water pipeline construction within the village is higher. So this measure can be directly linked to the government investment in water pipeline construction in a village.

The next step is to test whether this measure can be a good instrument for household access to tap water in school enrolment model. The prerequisite of being a valid instrument is that changes in the instrumental variable are associated with changes in the (possibly) endogenous variable, but do not lead to changes in the dependent variable (Cameron and Trivedi, 2005: 96). The researcher experimented by including the measure (variable *water plant*) directly in the access to water equation and children's school enrolment equation to check for the correlation between them (results not shown, but the impact is visible later in ivprobit first step regressions in Table 3.2). In the access to water equation, the measure possesses a significant (at 1% level)and strong explanatory power, while in the school enrolment model its impact turned out to be zero (results not shown). The researcher also follows Cameron and Trivedi (2009, 189) in conducting simple pairwise correlations (within and between) between school enrolment, access to water and *water plant* to further check for the validity and strength of the instrument in the village level analysis in section 3.5.

After the instrument variable is set, an IV probit model is estimated using conditional maximum likelihood estimator in the first place to check for the exogeneity of household access to tap water in school enrolment equation Wald test results suggest that access to water is exogenous (the results are presented in Table 3.2, and will be discussed later). More formal testing of the exogeneity of access to water using bootstrapped hausman test will be conducted in section 3.5, and there, the results also support the exogeneity of access to water at the village level. Therefore, in this section, an ordinary probit model is estimated to quantify the joint impact of access to water and menarche on girls' schooling.

When a regressor is tested to be exogenous, using ordinary probit has many advantages over IV probit in that in IV probit the standard asymptotic theory may generate a poor approximation to the actual sampling distribution of IV estimator in a finite sample, since estimated coefficients using IV probit is not centred on the actual $\boldsymbol{\beta}$ even though it is consistent for $\boldsymbol{\beta}$ (Cameron and Trivedi, 2009, 176). Besides, the average marginal effects (AME) can be conveniently obtained after probit, but not after IV probit. The AME is used to compare with the Average Treatment Effects on the Treated (ATT) that are to be obtained in the next chapter. Therefore during the testing of the hypothesis-1, the access to water variable will be treated as exogenous.

3.2.2 Hazard models – Conditional schooling duration

An alternative approach to test the hypothesis is using conditional schooling duration rather than school dropout as dependent variable. The relevant advantages of using the hazard models over probit models are discussed earlier. When taking schooling duration as dependent variable, one must consider the fact that some children are still attending the school while the survey is conducted, that is, the dependent variable is right censored (Singer and Willett, 1993; de Haan and Plug, 2006).

In general, hazard functions are estimated in survival analysis. A hazard function is the instantaneous probability of leaving a state conditional on survival to time t (Cameron and Trivedi, 2005, 576), which is defined as follows:

$$\lambda(t) = \lim_{\Delta t \to 0} \frac{\Pr[t \le T < t + \Delta t \mid T \ge t]}{\Delta t}$$

where T is the time to failure which is set based on actually reported years of schooling. There are two different classes of hazard models, namely, parametric versus non-parametric. The Cox proportional hazard model is regarded as non (semi-) parametric model and has an advantage over (fully) parametric models in that it does not require a specific functional form for the baseline hazard function Cleves et al (2004, 121). Furthermore, the Cox models provide a means to test whether the assumed baseline functional forms (Exponential, Weibull and Gompertz) obtained from parametric models are correctly defined. The well defined baseline function has the closest estimation results to that of Cox (Cleves et al, 2004, 204). So the Cox models will be used first to check for the proportionality of the hazards between the comparison groups. However, the researcher will still use parametric models to test the hypothesis-1 due to the many more obvious advantages that they have over Cox models. Some of the major advantages are as follows:

(1) In non-parametric and semi-parametric methods (such as Cox models) subjects are compared at the times when failures happen to occur (Cleves et al, 2004: 199), and if such a comparison is not possible, those methods simply cannot work. However, parametric models can still be able to work even there is no other subject available for the comparison within the interval.

(2) Parametric models, if correctly specified, can use more information from a given data than a Cox model when the estimation is underway (Cleves et al, 2004, 200) and hence are considered to be more efficient. For example, if a subject that failed at time *j* has a very different value at time *j-2*, the Cox model will simply ignore the change if there is no other comparable subjects exist within the span. That is because failure at time *j* only depends on surviving beyond time *j-1*. However, parametric methods will take into account those types of changes when estimating the outcome.

(3) The parametric models not only support the specification for the 'shared frailty' (within-group effect, Cleves et al., 2004, 148) but also allow control for the 'unshared frailty' (observation specific effect, Cleves et al, 2004, 279) which is not supported by the Cox model.

(4) Parametric methods allow the use of Accelerated Failure Time metric which is easy to interpret and also more relevant to my inquiry, that is, it can provide direct measure of the impact of the covariates on the school duration rather than the hazard ratio. The AFT model has a simple regression form:

$$ln(T_i) = X_i\beta_x + ln(\varepsilon_i)$$

where T is duration time (conditional schooling duration) and ε is the extreme minimum value distribution with variance or "shape parameter" ρ (for Weibull). Where $\rho>2$ (see Cleves et al, 2004, 225), as is generally found in this study, the hazard rate of dropping out of school increases with conditional schooling duration (so the duration decreases) which is reasonable. For any particular variable *k*, a "time ratio" transformation of the coefficient (Cleves et al, 2004, 209, $exp(\beta_k)$, is possible, showing the proportionate change in time to failure associated with the k_{th} variable. In this model covariates are multiplicative on the time scale, and are said to "accelerate" duration time. In practice, also recommended is the correction for heterogeneity (Hosmer and Lemeshow, 1999, 318) distributed as gamma with mean 1 and variance θ.

Consequently, there is a problem of choosing the best parametric model. The Weibull accelerated failure time (AFT) model fits best, as can be seen from the test results in Table 3.1(b) (The test results are for all girls and all boys, in other models where subsamples are used, the Weibull is still preferred over other models). Compared to the log-logistic and log-normal models, the Weibull has the largest log likelihood and the smallest Akaike Information Criterion (AIC) values. Depending on these test results, the researcher uses Weibull models to estimate the impacts of the covariates with AFT metric. The time ratios can be interpreted as duration time multipliers. For example, a time ratio of 1.5 means that, conditional on being at school up until the instant past moment, the relative time of surviving at school is 1.5 times (50%) longer if the independent variable increases by one unit. A time ratio greater than one corresponds to positive coefficient, and a ratio less than one corresponds to negative coefficients in a linear regression.

The proportionality of the hazard rates between defined categories is required for the estimation of coefficients in hazard models. The researcher uses a formal graphical method proposed by Cleves et al (2004, 183) in that the test plots an estimate of - $ln[- ln\{S(t)\}]$

versus *ln(t)* for each level of the covariate in question. The procedure is easy to follow: first, *S(t)* is the baseline survivor function obtained from Cox regression on the covariates such as menarche and household wealth (per capita household income, parental education and occupational status). The stratification is done on access to water, so that different baseline hazard for good and poor access to water is obtained. Secondly, the baseline survivor functions for each water category is used to calculate - *ln[- ln{S(t)}]* and the transformed duration curves are plotted against *ln(t)* , the log of duration time, in the same graph.

Under the proportional hazard assumption, the plotted curves should be parallel. As an example, the researcher presents the plotted curves for girls by water category adjusted for the onset of the menarche and household wealth in Figure 3.1 (similar tests are conducted for other regressions). The graph confirms that the hazard rates vary proportionally between girls with good and bad access to water conditional on the onset of menarche and household wealth. This result confirms that the proportional hazard assumption holds and a hazard function can be used to estimate the impact of the treatment.

3.2.3 The Variables

Detailed specification of the variables to be included in the probit or hazard models is as follows. The dependent variable will be an indicator of school enrolment at the time of survey (1 if enrolled, 0 otherwise) in case of a probit model; or the accumulated years of schooling which is declared to be survival time in the duration analysis, where being not at school when the survey is conducted is specified as failure event (Brown and Park, 2002). As there are multiple records per subject in hazard models, a subject ID is specified to make the estimation process take account of the reality that some observations are repeated observations of the same individual (Cleves et al, 2004, 65).

The main independent variables are access to water and menarche. With regards to the access to water variable, this effect is obviously allowed to be different for boys and girls. For both sexes, poor access to water is expected to decrease the likelihood of children's school enrolment, and shorten the duration of school attainment, both because of the general water related health problems, and because of the increased time that is required to fetch water. In this respect, poor access to water should reduce both boys' and girls' schooling. However, it is expected that poor access to water has a further worse impact on girls' schooling after menarche, due to hygiene related health and psychic problems.

The models also control for household income since high income is likely to be associated with good access to water. To supplement this measure of household income, the researcher also includes in the models the variables for fathers' and mothers' education and occupation. Clearly, the higher the education and occupational status is, the wealthier the family will be in general. These variables might also increase the parental "taste" for increased children's education (Lauer, 2003). Besides, a 'bargaining power' indicator is included in the model, which is calculated as the ratio of mother's education over the father's within a household.

A further consideration is children's work, both market work and household work, which needs to be included to control for the alternative uses of children's time. These variables are clearly endogenous. However, it is difficult to find a convincing instrument from the given dataset. Fortunately, however, these variables are not very important, since the researcher finds that even in rural China, few children report that they help much with market work or household work and time spent for these works are marginal (see Table 2.1 for details). Hence, when the researcher experimented by dropping the two work variables from the regression, similar coefficients remain for most of the other explanatory variables, with the impact of the work variables mainly changing the age dummies marginally. Therefore, the work variables do not posit a big threat to other variables due to their endogenous characteristics. Finally, 6 wave dummies and 151 village dummies (36 county dummies or 8 province dummies in some particular cases) are included in the regressions. Village dummies are important controls for unmeasured village effects including remote location and backward culture.

3.3 The Results of the Probit Models

3.3.1 The Regression Results

The IV probit results are shown in Table 3.2. These regressions control for individual and household characteristics including children's age, market work and household work, parental occupation and education, sibling structure. They also all control for village fixed effects. Moreover, the access to water variable is instrumented in order to isolate its impact from the unobserved factors. The purpose of estimating these models are twofold: one purpose is to test whether the impact of poor access to water posits different impact for different groups after being instrumented. Another purpose is to check for the exogeneity of access to water in these models using Wald test results. Since girls' median age of entering menarche is 13.4, so a cut-off age 14 is taken for boys and a separate regressions are estimated for boys before and after this age.

The regression results in Table 3.2 clearly shows that the impact of poor access to water is large and significant for girls post-menarche while the impact is small and insignificant for other groups (the marginal impacts are derived in the next stage using ordinary probit model and will be analysed later). Also clear from the Table 3.2 is the fact that the impacts of some other regressors (e.g. per capita income, having a younger brother) are different between the groups. Nevertheless, allowing the impacts of some variables to vary between the groups are necessary when group-specific impacts of those variables are sought after.

In the first stage of all these regressions, the water-plant variable has significant negative impact on the probability of having access to poor water, while household income, parental occupational status and education posit almost no impact. This finding strengthened the earlier assertion that household access to tap water is mainly an outcome of village level water engineering projects (water plant and other types of government investments) which are uncorrelated with the income level of a typical household. This lends further support to the exogeneity of the access to water. Indeed, Wald test results suggest that access to water variable is exogenous in these school enrolment models. Therefore in the following individual level analysis the access to water is treated as exogenous. When the impact of poor access to water on children's schooling is identified at the village level, different tests will be conducted to test the exogeneity of the access to water variable.

Having obtained test results about the exogeneity of access to water variable, the researcher uses ordinary probit models to estimate the impact of poor access to water separately for girls post and pre-menarche. It was clear from Table 3.2 that the impact of poor access to water is insignificant and small for boys after all control variables are included in the model, so no more probit models will be estimated for boys. The average marginal impacts (AME) of the regressors (transformed from the probit regression coefficients) are reported in Table 3.3 for girls post and pre-menarche.

As can be seen from Table 3.3, poor access to water is found to decrease the probability of school enrolment of post-menarche girls by 27 percentage points (significant at 1% level) when controlling for the impact of other factors. The results confirm the validity of the hypothesis-1 of the study – girls with poor access to water experience increased school drop out after menarche. The impact of access to poor water for other groups – girls pre-menarche and boys (before or after age 14) disappears while the impacts of other variables are controlled for. Many control variables such as parental education, job status and family income are insignificant. However, it is found that they are jointly significant at 1% level (Chi square (12) = 37.05; Prob>chi2=0.0002).

Per capita household income is found to have no explanatory power in the model. However, there is an indication that it matters more for pre-menarche girls – one unit change in log per capita income is associated with 3 percentage point increase in the school enrolment for this group, and the impact is almost significant at 10% level. This finding is in line with the findings of Conelly and Zheng (2003), who find that higher per capita income has higher impact for girls only for initial enrolment of primary school and the impact disappears in the latter stages. However, the reason is not clear.

The higher occupational status is in general found to be positively correlated with girls' schooling while the impact is particularly pronounced for pre-menarche girls, a finding that corresponds to the income impact discussed in the previous paragraph. However, the mothers' occupational status behaves strangely. Higher occupational status of mothers is indeed associated with higher school enrolment of girls post-menarche. But for girls pre-menarche, the medium occupational status (mainly skilled workers) of mothers is correlated with lower school enrolment compared to other occupational status.

Parental education is found to be insignificant in both of these models. Fathers' education generally helps the girls with their school enrolment and the impact is mostly the same between the different groups. Daughters of fathers with high school or above qualification are found to have about 10 percentage point higher probability of school enrolment compared to daughters of uneducated fathers, though the impact is insignificant. However, the mother's education again shows a strange pattern. Girls post-menarche benefit from having educated mothers, but the impact of mothers' education is again negative for pre-menarche girls. The researcher is aware that the impacts are marginal and totally insignificant which may be a product of collinearity. However, the fact that a negative impact of mother's education go together with the negative impact of their higher occupational status on pre-menarche girls' schooling indicates a systematic pattern of such negative impact does exist.

It is beyond the scope of this study to investigate the reasons of the non-symmetric impact of mothers' education and occupational status on the school enrolment of pre- and post-menarche girls. However, similar findings can also be found from other literature (Behrman and Rosenzweig, 2002; and Behrman and Rosenzweig, 2005). Behrman and Foster et al. (1999) also find that mother with primary school education (literacy level) plays more positive role in their daughters' schooling compared to the illiterate mothers *and* to the mothers with higher level schooling. They interpret the puzzle using the concept of the opportunity cost of the mothers' time. That is, mothers with higher human capital face higher opportunity costs (they have to sacrifice higher levels of income) if they choose to stay at home and help their children with their studies. However, the researcher is inclined to take this puzzle as a consequence of some other (unknown) phenomenon, since the pattern observed by Behrman and Foster et al. (1999) does not exist for the girls post-menarche. Furthermore, the mothers with primary school education do not seem to contribute more to the education of pre-menarche girls compared to uneducated (illiterate) mothers (its marginal effect is indifferent from that of uneducated mothers).

The bargaining power variable is insignificant suggesting that girls are not especially better off with regards to their school enrolment by having mothers who are more educated than their fathers assuming that the 'bargaining power' variable is not a poor variable and that there are no problems associated with collinearity. Household work seems to have no impact. However, market work posits a relatively bigger impact for post-menarche girls. The association here is definitely not causal since school drop out can also lead to greater amount of market work. Besides, as has been discussed in the previous chapter, very few children report that they do market work (any activity outside the household that can generate some sort of income to the household: e.g. gardening, farming, helping with family business). Even for girls post-menarche, only about 6% report that they do market work. Therefore, even though the impact looks big – a one hour increase in the market work per day is associated with 19 percentage point decrease in school enrolment – the impact only exists for a marginal number of girls.

The impact of having different sibling structure is also found to be neutral for girls' school enrolment. However, having an older brother is detrimental for the school enrolment of post-menarche girls. The particular mechanism is less clear here. However, this is in line with the findings of Yang (2006) who particularly investigated the impact of sibling structure on children's schooling. According to Yang (2006), this finding is a result of a particular 'culture' which favors oldest sons' education over others. However, against her assertions, no such impact is found for girls pre-menarche. If such a culture exists, pre-menarche girls' schooling should also suffer from having older brothers. Therefore, identifying the mechanism remains to be an interesting research work for the researcher. Finally, for both groups of girls, school enrolment increases with age with a decreasing rate. But the age impact is only significant for pre-menarche girls (an adjusted average marginal effects for age and age squares are computed following the suggestions in Bartus (2005), but similar impacts are observed – results not shown).

Distance to school may be an important variable in children's schooling, and a longer distance may be particularly adverse for girls for safety reasons. It may also increase the opportunity cost of children's schooling since children's time for work decreases (given that they do some kind of work). There is no distance to school measure in the dataset. However, there is a time-to-school measure from the survey year 1997 with lots of missing values. The researcher first imputed the missing values using village/wave average time-to-school, and included this measure in the regression by only using the sample of the three waves (1997, 2000, and 2004). The results show that the longer the time to school the worse off the girls with regards to their schooling attainment and enrolment (results not shown). However, the inclusion of this new variable did not alter the coefficients in the original regressions. Therefore, the researcher will stick to the current specification of the models and use the sample of all the six waves in the analysis (first observation per subject in probit models, and the full data in survival analysis). Nevertheless, the village dummies included in the regression models may partly pick up the impact of distance to school to the extent that particular villages might have few (or many) schools and hence long (short) distances to school.

3.3.2 Menarche, Sisterhood and Marriage

Field and Arbus (2008) (FA hereafter) analysed the impact of the onset of menarche on girls' schooling using Bangladesh data. They find a significant impact. However, they did not consider the important access to water variable, but rather hypothesized that early marriage was to be blamed for the girls' school drop out after the onset of menarche. They argue that oldest sisters should suffer the most as they are at the front of the queue for getting married off after menarche, and find some indications that there is indeed this tendency. However, the researcher replicates their results using CHNS data (also included single daughters) and finds some quite different results that beg for novel interpretation.

The overall strategy in this section is as follows: (1) to replicate the results of FA using CHNS data and check for the conformity of the results; (2) to restrict the sample to girls with poor access to water and check whether the impact of menarche worsens (links to the hypothesis-1 of this research).

The researcher restricted the sample to girls and dropped 28 observations that have twin sisters. Then variables of 'older sister', 'younger sisters' and 'single daughter' status are constructed. The mean number of girls is 1.51 per household and the maximum is 5. FA (p. 19) constructed Sex-Specific Birth Order (*SSBO*) by dividing number of older female siblings by the total female siblings. So *SSBO* for oldest sisters will always be 0, and for younger sisters it will be >0 and <1.

But this definition will have to drop the single daughters as they have no female siblings so the division will not work for them. Inclusion of single daughters in the analysis is vital since their position in the queue is similar to the oldest sisters. Therefore the researcher made a slight change in this definition and computed the *SSBO* as following (this change will not affect the *SSBO* value of oldest and younger sisters):

SSBO = number of older female siblings / number of girls

In this regard, the *SSBO* for an oldest sister or a single daughter will be 0. The *SSBO* gets bigger (>0 and <1) as girls have more older-sisters. According to FA's argument, oldest sisters and single daughters should have more drop outs due to their up-front order in the queue (*SSBO*=0) and younger sisters experience less drop outs since they can wait before the older sisters get married off first. In the current specification, *SSBO* takes values from 0 to 0.8. Obviously, *SSBO* transformation may not be really essential, since we only need to have 5 dummy variables for each position in the sisterhood (the position of single daughters will be similar to oldest sisters. But the researcher still uses *SSBO* classification in order to fully replicate FA's results using the very method they used.

The researcher uses probit models to perform the analysis. Following the earlier pattern the researcher retains the first observation per subject. After the restriction, in total there are 304 oldest sisters, 475 younger sisters and 1272 single daughters for the regression. Daughters may be subject to different preferences from their parents due to their sibling orders. Single daughters may be able to get more family resources allocated for their schooling. Therefore separate regressions for these three groups are estimated and all the coefficients are allowed to vary between the groups.

First the researcher runs separate probit regressions using the total sample (explanatory variables are specified as those in Table 3.6 except that province dummies are used instead of county dummies as some models have small sample size). In the second step, the researcher restricted the sample to girls with poor access to water where there are 193 older sisters, 283 younger sisters and 683 single daughters. Based on the suggestion from FA, if "culture" places the eldest sister in a queue to be married soon after menarche – older sisters schooling should especially suffer (and so should single daughters).

The researcher gets quite different results. The average marginal effects transformed using the probit coefficients are reported in Table 3.4. The impact of menarche varies between the three groups. However, the eldest sisters suffer from the onset of menarche the least (23 percentage point lower probability of school enrolment) compared to other two groups (32 and 34 percentage points lower). Furthermore, the negative impact of menarche increases when access to water is poor for all groups of girls (in accordance with the hypothesis-1 of this study). But, the pattern remains the same - eldest daughters suffer the least – only 27 percentage point reduction in the probability of school enrolment compared to 34 and 41 percentage point reduction for younger sisters and single daughters.

So the pattern that the researcher obtained from using Chinese data is very different from the results in FA. The menstruation did not posit a more adverse impact on eldest daughters schooling, instead it is smaller compared to the impacts on single daughters and younger sisters. Nevertheless, the original coefficients in probit models for different sisterhood (eldest sister, younger sisters and single daughter) are not significantly different from each other (Wald test results can not reject the null of equality of the coefficients, with probability>Chi2 = 0.89, 0.76, 0.96 respectively in three comparisons). Therefore, it is unlikely that marriage causes eldest sisters drop out of school early after menarche in China. However, poor access to water makes the impact of menarche more adverse on girls' schooling whatever the position is of girls in sisterhood, a finding that backs up the hypothesis-1 of this study.

3.4 The Results of Hazard Models

3.4.1 The Regression Results

For duration analysis, all observations are used. When doing school enrolment analysis in the previous section using probit models the standard good/poor access to water definition was used (tap water vs. non tap water), and it was found that the impact of poor access to water disappeared for boys after the control variables were included in the model. In this section, the researcher also uses another water category division – for example – the water1-water3 (tap water + well water) in Table 2.1 are regarded as good access to water and water4 (other water sources outside the courtyard, e.g. river or lake water) in Table 2.1 is taken as poor access to water. The purpose of using this different good/poor access to water categorisation is to test whether extremely poor access to water (water4) has any different impacts on girls' and boys' schooling when other variables are controlled for. Obviously, tap water vs. non-tap water access categorisation of good/poor access to water will still be used to test whether the results vary with different estimation methods. The researcher will note what type of 'poor access' definition is used under each table which reports hazard model results (Table 3.5, 3.6, 3.7, 3.8(a) and 3.8(b)). In all other regressions standard definition of poor access to water is utilised (tap vs. non-tap water).

When hazard models are estimated, the girls and boys are not divided by their menarche status or ages (as was done in logit models). The reason is that the data is not purely cross sectional anymore. The 'multiple failures per subject' specification allows the same individual be appear several times in the data, and the impact of poor access to water will be identified using the full information of a subject. Therefore, division by menarche status or ages in hazard models will only reduce the efficiency of the estimation.

In the first step, separate models are estimated to compare the impact of poor access to water and other covariates between girls and boys (results are given in Table 3.5). In the second step, separate models are estimated for girls to test whether the onset of menarche will have different impacts on girls with good and poor access to water (results are given in Table 3.6). The regressions control for the 'unshared frailty' (Cleves et al, 2004, 287) and are also clustered by village in order to obtain robust standard errors. The researcher obtains largely similar results after controlling for the 'shared frailty' (random effects) and therefore abandoned the extra control for the 'shared frailty' to give way for the clustering. (The clustering and controlling for the 'shared frailty' are not allowed to appear simultaneously in regression specifications).

(1) The impact of poor access to water on girls' and boys' conditional schooling duration

The results in Table 3.5 show that baseline hazard shape parameter ρ is bigger than 2 and significant in both regressions, indicating the probability of dropping the school increases by age which is reasonable. But the frailty effect (θ) is found to be insignificant, rejecting the heterogeneity of unobserved individual characteristics. The total sample size is 4379 girls and 4879 boys, much larger than the sample size used in probit models. Weibull models are used for the regression as they were preferred over other parametric models (see Table 3.1(b) for the test results). The accelerated failure time metric is used for the analysis as the interest lies on testing the treatment effect on school duration rather than on identifying the hazard rates. The time ratios are reported so that the interpretation of the results will be easy and more relevant. Apart from the individual and household characteristics, 151 village dummies and 6 wave dummies are also included in the regressions as extra controls.

Also clear from Table 3.5 is the fact that poor access to water still posits different impacts on girls' and boys' schooling after including all those control variables. The impact of poor access to water on boys' schooling is insignificant, while the impact is strong and significant for girls (the impact is expected to get worse after menarche, and relevant models will be estimated at the second step in this section). Girls with poor access to water will have 11 (0.89 – 1) percent shorter school duration conditional on staying at school until the instant previous moment (*conditional schooling duration* hereafter) controlling for the impact of other factors. As a matter of interest, without any controls, the coefficient on the poor access to water variable increases substantially in size, as can be seen from the first and third columns of Table 3.5. These results illustrate the link between poor household circumstances and access to water which has already been noted in Table 2.1, and shows the importance of controlling for such circumstances.

The impact of the per capita income on girls' schooling looks bigger than on boys' schooling. However, test resutls show that the coefficients are not statistically different from each other (results not shown). For girls, doubling in per capita household income (100% increase – about 870 CNY, roughly 50 GBP at 2004 price) is associated with 6 percent increase in the conditional schooling duration. In probit models the impact of household income was only found to be positive for pre-menarche girls. The difference can be explained by the fact that duration analysis may be more powerful in addressing important variations in individual experience across time when the impact of a treatment is estimated using the full information of an individual in the regression. (Dolton et al., 1994). Therefore, the long term average effect of household income is still positive for girls' schooling depending on the results of Weibull models, while the impact may be different at different stages of schooling as presented by probit models.

For the same reasons (described in the previous paragraph), it is expected that the occupational status and educational qualifications of the parents, being strongly correlated with household income, should posit similar (positive) impact on children's schooling in the hazard models. High occupational status of fathers is found to increase the conditional schooling duration of girls (boys) by 17 (12) percent compared to unemployment status. The impacts of different occupational status of fathers are in general significant for both girls' and boys' schooling. Mothers' occupation status posits stronger impact on girls' schooling. It is found that even the medium occupational status of mothers increases the conditional schooling duration of girls by 14 percent compared to unemployment status. There are indications that mothers' education also affects boys' schooling in the same direction although the impacts are small and not significant. These results suggest the positive impact of the women's empowerment on girls' schooling which is in line with the findings of Qian (2008).

The increase of fathers' and mothers' educational qualifications is found to have significant positive impacts on boys and girls schooling. Higher educational qualifications of fathers' seem to help with the boys' schooling more than the girls'. For example, fathers with high school/above qualifications increase the conditional schooling duration of boys by 32 percent, but that of girls by only 11 percent (insignificant) compared to uneducated fathers.

On the contrary, higher qualifications of mothers increase conditional schooling duration of girls more than that of boys. For example, high school/above qualifications of mothers are found to increase the conditional schooling duration of girls by 29 percent, but of boys by only 11 percent (insignificant). This finding serves to strengthen the argument in the previous chapter that women's educational qualification, being another indicator of women's empowerment, is particularly good for improving the girls' schooling. The impact of the bargaining power is quantitatively bigger for boys but insignificant, indicating that relative increase in mothers' education to fathers' may be more helpful for boys' schooling, but the absolute increase is found to be good for girls' as is found earlier.

The market work variable indicates significant impacts on school attainment of both boys and girls, while the impact of household work is only significant for girls. The impact of household work is bigger in girls' regression which is reasonable considering the reality of rural China where most of the household work is done by women (Knight and Li, 1996). However, the impact is marginal given the amount of time girls spend for household work. The impact of market work is also small considering the fact that boys and girls on average spend less than an hour on market work activity (See the relevant figures in Table 2.1). Moreover, market work does not seem to have different impact on girls' and boys' schooling, a finding that comes opposite to the claim of (Song et al., 2006) that the opportunity cost of girls' schooling is 'higher' and hence contributes to the gender gaps in education in rural China.

Number of siblings and the sibling structure do not seem to have any significant impact on children's school attainment apart from the fact that having older brother is bad for boys' and girls' schooling (insignificant for girls). The results from the hazard models seem to back up the assertion of Yang (2006) that that the presence of an older brother always poses a risk to other siblings' schooling. Yang (2006) interprets the results using 'culture' argument that in rural China the eldest sons' schooling is preferred as parents are most likely to depend on the eldest son who are mainly responsible for taking care of the parents in old age. However, the interpretation of the results deserves more caution as the impact is found to be neutral for pre-menarche girls in the probit regressions in the previous section. Nevertheless, even though this future dependence argument holds, the hypothesis of this study will still remain valid, since the impact of poor access to water is identified after controlling for the impacts of sibling structure. Finally, the impacts of age group dummies show that age posits non-linear impact on conditional schooling duration as in probit models.

(2) The impact of menarche on the schooling of girls with good/poor access to water

After identifying the stronger impact of access to water on girls schooling compared to that of boys' after controlling for other variables, the researcher investigates the impact of onset of menarche given good/poor access to water. According to hypothesis-1 of this study, the impact of the onset of the menarche should be worse for girls with poor access to water.

The regressions for girls with poor access to water do not control for 'unshared frailty' when 151 village dummies are included in the models. So, the first set of regressions is estimated for girls with poor and good access to water (2 different categories are used) without the control for 'frailty effects' but by including the full village dummies (results not shown). The impact of the onset of menarche on conditional schooling duration is found to be -21 percent (t = - 3.63) for girls with poor access to water, and -8 percent (t = -1.52) for girls with good access when tap water vs. non-tap water category is used; and the impact is -24 percent (t = - 2.01) for girls with poor access to water, and -12 percent (t = -1.52) for girls with good access when poor water is defined as water4 in Table 2.1. These results show that menarche has 2 – 2.5 times worse impact on the conditional schooling duration of girls with poor access to water compared to girls with good access and provides further support to the hypothesis-1 of this study (Note that this conditions out the impact of different X's).

The control for the 'frailty effect' is allowed in a simpler specification with 36 county dummies (results are shown in Table 3.6). The effect of unobserved heterogeneity is found to be significant for girls with good access to water but not for girls with poor access. Nevertheless, the researcher did not find any significant difference of the time ratios between the models with controlling for 'frailty effect' (in Table 3.6) and the models with no controls for such an effect (results not shown – the impacts of menarche in these models are discussed in the previous paragraph). These findings also confirm that covariate impacts on girls' schooling generally remain the same between the models controlled for county fixed effects and the models controlled for village fixed effects when estimating the hazard models using Weibull.

The set of regressions with 36 county dummies (controlled for the 'frailty effect') are also estimated using two different good water / poor water definitions. When taking only water4 (the worst access, see Table 2.1) as poor access to water, the impact of the onset of menarche on conditional schooling durations is found to be -27 percent (t = - 2.16) for girls with poor access to water, and -13 percent (t = -2.89) for girls with good access (full regression results not shown); and the impact is -22 percent (t = - 3.77) for girls with poor access to water, and -10 percent (t = -1.76) for girls with good access when poor access to water is defined as non-tap water access (full results are reported in Table 3.6). Menarche is again found to have 2 times worse impact on the schooling of girls with poor access compared to girls with good access.

Admittedly, there are some differences between the equations particularly when the impacts of the household per capita income are concerned. The per capita household income posits big and significant impact on the schooling of girls with poor water access. A one unit change in log per capita income is associated with an increase of 11 percent of conditional schooling duration. For girls with good access to water, the impact of household income is small and insignificant. This higher marginal impact is reasonable given the fact that the households without access to tap water are generally poorer compared to the households that have tap water access (see Table 2.1 for figures). However, the cross product of per capita household income and menarche variable is insignificant in an alternative specification (result not shown), indicating that even the rich households may not be able to tackle the negative impact of the onset of menarche when the access to water is poor.

Parental occupational status exerts rather similar impacts among these two groups. Girls of fathers or mothers with higher occupational status attain about 15 – 20 percent longer conditional schooling duration compared to daughters of farmers (belong to low occupational status) and unemployed. This may be because that the higher occupational status is often related to higher income or a better connection in the labour market that enables the parents to invest more in their children's schooling. The impact of mothers' occupational status on girls' schooling is found to be even bigger. There is indication that conditional schooling duration, when having mothers with high occupational status, increases by 30 – 40 percent for girls from both groups compared to girls with mothers who have low employment status or unemployed.

The impact of parental education is generally in line with general expectations – higher educational qualifications of parents benefit the schooling of children. However, high school/above qualification of fathers seems to benefit the girls with good access to water greatly – these girls experience on average 20 percent longer conditional schooling duration compared to their peers who have non-educated fathers. On the contrary, high school/above qualifications of mothers are associated with 40 percent increase in conditional schooling duration of girls with poor access to water compared to their peers with uneducated mothers. These results suggest that mothers with high school/above qualifications are particularly beneficial for girls from not-so-better-off families in their school attainment.

The impacts of household work and market work variables are all found to be highly significant, but do not exert any significant differences between the two groups. However, the researcher is aware of the endogenous characteristics of these variables and therefore no causal effect can be confirmed. Nevertheless, when dropping these variables from the regression no significant changes occur on the impacts of other variables (results not shown). A one-hour-per-day increase in market work is associated with about 7 – 9 percent decrease in conditional schooling duration. However, this impact is still marginal considering the number of children who actually involve in market work (8.5% girls with good access to water, and 7.5% of girls with poor access to water repot they participate in some type of market work), and the time they spent for the work (see Table 2.1 for details).

With regard to the impacts of sibling structure, the earlier discussed pattern still remains – the only significant, and negative, impact is found for girls with good access to water from having an older brother. But the impact is not significant for girls with poor access to water. Yang (2006) explains this phenomenon using 'cultural factor' due to future dependence (discussed earlier). In general, future dependency on children will be stronger in backward geographical locations where not many wage work opportunities are available which can guarantee pensions for the parents when they retire (so less dependent on their children when getting old). Poor access to water is also prevalent in backward geographical locations. Therefore, if the negative impact of having an older brother is associated with the 'cultural factor' of preferring the eldest sons due to future dependence, the impact should be more pronounced for girls with poor access to water. In fact, the results direct towards the opposite direction that girls with good access to water suffer more from having an older brother. So a more robust interpretation of this result is necessary.

Finally, children's age still has an inverse U shaped non-linear effect on the conditional duration of girls schooling. In hazard models reported in Table 3.6, age categories are used instead of age and age squared variables that are used in probit models. The reason is that the menarche variable is highly collinear with age variable (correlation coefficient 0.83), so age group dummies is included in the regression instead of age variable itself in order to avoid the collinearity between these two variables. Age group dummies (not age and age squared) are used in Table 3.5 for comparison purposes with the results in Table

3.6. But including age and age squared in Table 3.5 does not alter the results since menarche variable is not included in those models.

3.4.2 The Restricted Sample – Villages with 15-85% Tap Water Access

The origin of the endogeneity problem in this study is the argument that access to water status is not randomly assigned to girls. If girls with good and poor access to water have systematic difference in their school enrolment, and this difference is caused by other factors rather than access to water, and if a regression analysis does not perfectly control for those confounding factors, the systematic difference that existed between the treatment and control groups regardless of access to water will make its impact shown via the treatment variable (access to water) – therefore the treatment effect will become misleading (Angrist and Pischke, 2009). One assertion is that villages with poor access to water may have different 'culture' towards educating girls (due perhaps to poverty) than villages with good access to water, and the impact of this difference is picked up by the access to water variable in the first place.

In order to mitigate the selection bias, the probit and hazard models both controlled for sets of detailed individual and household variables. The location fixed effects are controlled at the village level. The access to water variable is also instrumented in the first place to check for the robustness of the results. Therefore the assignment of the treatment (access to poor water) status can be, in a way, made random in regression analysis (see Angrist and Pischke for details, 2009, 51). In the next chapter, Propensity Score Matching techniques will be used to further reduce the selection bias under specific assumptions. In this unit, a more direct approach will be applied.

One approach to reduce the selection bias is to restrict the sample to those less 'extreme' villages where households with and without access to tap water reside together and share the same village culture. With this restriction, about 75% observations are excluded from the analysis. But the results may be useful to separate the impact of the access to water from typical village culture mentioned above if such culture does exist. Within the remaining villages there are at least 15% of the households or at most 85% of the households do have access to tap water. Now every child in the sample is from a household that belongs to a village where some households have tap water access while others not. Using this restricted sample, the researcher aims to test whether the impact of poor water access still persists on girls' schooling.

Figure 2.3 shows the density of poor (non-tap) water coverage by village and income category. For each survey wave and village, the researcher computed the proportion of the tap water access and the mean per capita household income. The "poor" and "rich" households are then identified at the median of the wave and village specific per capita income. Poor access to water in these figures includes water3 and water4 in Table 2.1 (non-tap water), and 0 represents 95-100% of households in a village have access to tap water while 1 represents less than 5% has access to tap water. The two distributions are tested to be different at the 1% level.

The graphs have 20 bins. As can be seen, about 40% (8×5) of the poor households live in villages where there is almost no tap water, and about 23% (4.5×5) live in villages where there is tap water for almost all the households. The remaining 40% live in mixed access to water villages. As for the rich households, about 45% (9×5) of these live in villages where there is tap water almost for all, but still about 20% (4×5) live in villages where there is no tap water almost for all. So when the sample is restricted to villages where 15-85% households have access to tap water, the total observations dropped from 10,398 to 2,508 with 1,166 girls in total.

The researcher uses these 1,166 observations to test whether those post-menarche girls in this restricted sample suffer less schooling since they have comparable household and village characteristics to those girls with good access to water. For example, the mean of per capita household income is similar among the two groups: 6.69 (0.79) for girls with no tap water access and 6.71 (0.90) for those that have tap water access (standard deviations in the parenthesis). A more sophisticated matching method which will be used in the next chapter also aims to balance the individual and household characteristics of the control and treated groups in order to make the subjects from two groups more 'comparable'. Results of the hazard models with restricted sample are reported in Table 3.7. Models in (1) and (2) are specified in the same way as the models in Table 3.6. But models in (3) and (4) are all re-estimated using a simpler specification (simpler control variables of parental occupational status and education qualification) due to the complications that arise from the small sample size of one of the models (the model for girls with poor access to water).

Interestingly, when no access to tap water is defined as poor access to water, the impact of menarche on the schooling of girls with poor access to water worsens with the restricted sample by about 6 percentage points (see Table 3.7). So the difference of the impact between the two groups widens to 16 percentage points in the restricted sample from 12 percentage points which is obtained from using full sample. Moreover, when using water4 (in Table 2.1) as poor access to water, the impacts become insignificant, but the difference of the impacts also widens between the groups. These results show that the hypothesis-1 of this study generally remains undisturbed, with menarche having two or three times greater impact in households with poor access to water, however defined. This finding confirms that poor access to water posits gender specific problems for girls schooling after the onset of the menarche and the impact is robust to the restriction of the sample to the villages where households with and without tap water access reside together to share the same 'culture'.

3.4.3 Survival Distributions

It is a useful practice to compute the duration distributions after the results are obtained from the hazard models. The distributions provide clearer pictures about the impact of poor access to water on children's schooling. Moreover, the distributions can be computed at different values of the covariates in interest, so they are particularly useful for interpreting the policy implications of the research. In this study, the duration distributions will be computed at the different values of access to water (poor and good access) variable by different family wealth category. Both types of good water / poor water categories will be used for the calculation.

The researcher first computes the duration distribution for different scenarios for access to water and household income by taking no access to tap water as poor access to water. Then the researcher computes the duration distribution for the same scenarios by taking water4 (in Table 2.1) as poor access to water. “Rich” and “poor” categories of family wealth are based on the clustered income which is computed based on the k-means clustering using whether the household per capita income is above or below median, and mother’s and father’s four job status categories and four educational categories (values of clustered income is provided for two waves in Table 2.1).

The results are shown in Table 3.8(a) and division two in 3.8(b). These impacts are derived after running the hazard models with all controls in Table 3.6 but two values of wealth (clustered income) on the right hand side. So the impacts can be taken as the exclusive impacts of poor access to water and household wealth (clustered income). The researcher is only able to compute the general effect of the poor access to water on the schooling of all girls since the access to water and menarche variables do not appear simultaneously in hazard models. The true impact of poor access to water after the onset of menarche is higher and the policy implications of this type of impact will be discussed in the next section using different methods.

Scenarios (1) and (2) in both Table 3.8(a) and 3.8(b) show the impact of poor access to water holding other control variables equal, and we see that with poor access, girls at the median lag on average about two years (10.3 – 8.3 in Table 3.8(a) or 9.7 – 7.8 in Table 3.8(b)), whereas the impact of poor access is only about one year for boys. In scenarios (3) and (4) of both tables, the distribution is computed using different categories of household clustered income, holding other control variables equal. The distribution shows that being in the poor family category pulls both girls and boys down about the same amount, demonstrating the fact that change in family wealth (joint impact of income, parental education and occupation) has the similar effects on boys' and girls' schooling.

In (5) and (7), the researcher sets water access as good and allows the impact of income to vary. It is found that girls in fact do better than boys in the high income category (11.7 vs. 11.0 in Table 3.8(a) and 11.2 vs. 10.7 at the median in Table 3.8(b)) while the impact is pretty much the same in low income category (10.0 vs. 9.9 in Table 3.8(a) and 9.3 vs. 9.2 in Table 3.8(b) at the median). This fact shows that as long as the access to water is good, the girls will do as well as (if not even better than) boys in school attainment no matter whether the household is rich or poor. However, when water access is poor – scenarios (6) and (8) – girls in both high income and low income categories accumulate about 0.5 – 1 year's less schooling compared to the boys in the same categories at the median and the difference persists in the lower bound of the distributions. This result again confirms how poor access to water poses special problems for girls irrespective of household income.

3.5 The Village Level Analysis

As a final step, the researcher develops some policy implications using village level regression analysis. Village level analysis is directly linked to government policy since water engineering is generally a village/county level project (see Chapter 2 for a discussion). The first step is to derive village level variables (about 144 villages per wave, unbalanced) by averaging individual level data by each village for each wave. Villages that have less than 10 observations are dropped. Mean values of these variables are given in the first column of Table 3.9. For policy analysis, the changes in the proportion of the water access across the 1989-2004 period are computed, and its contribution to the gender education gap is computed using the marginal impacts obtained from the regressions.

Table 3.9 presents within- and between-village correlations which provide instructive contrasts. The between-village correlations (i.e., simply between village averages) with girls' enrolment rate in the first row are higher, but generally in the same direction, as the within-village correlations in the second column. However, there is a difference in that the proportion of rich households (village wealth) is well correlated with girls' enrolment rate between villages (0.47), but it presents essentially a zero correlation (-0.02) within villages. For boys however, their enrolment rate and the proportion of rich households are both positively correlated within (0.09) and between (0.26) the villages. The visualisation of within and between correlations of village wealth and children's school enrolment are presented in Figure 3.2 separately for girls and boys.

The proportion of rich households is also well correlated negatively with poor access to water (-0.37) between villages, but again has no correlation (0.05) within villages. Thus, within villages, the factors which drive changes in household wealth appear to be independent of the factors which drive changes in access to water and changes in girls' enrolment. A within-village (fixed effect) analysis of girls' enrolment is therefore less likely to confound the benefits of rich households with good access to water.

The instrument variable that is used in IV probit models earlier, namely the *water plant*, shows very small within-village correlation (0.04 and 0.00) with girls' and boys' school enrolment rates, but the correlation is remarkably big for both genders between villages (0.23, 0.16). In other words, an increase in the proportion of people getting tap water from water plant does not necessarily lead to higher school enrolment rates for boys and girls within a village. Therefore, when conducting within village analysis, *water plant* may serve as a good instrument for village rate of access to poor water (negatively correlated with a coefficient of -0.29).

2SLS models are estimated for girls' and boys' school enrolment rate by instrumenting village rate of access to poor water (results not shown). Bootstrapped Hausman Test (Cameron and Trivedi, 2009, 429) results suggest that village rate of access to poor water are exogenous in children's schooling models (prob>Chi2 = 0.81 for girls; and, = 0.72 for boys). Therefore, the results of ordinary fixed effect models are presented only in Table 3.10. Random effects models are also presented for comparison purposes. One advantage of estimating fixed effects models by treating access to poor water exogenous is that the cross product of poor access to water and menstruation can also be conveniently included in the model (the cross product should also be instrumented in 2SLS models).

As can be seen from the Hausman test in the final row, the FE specification is preferred for girls' education, but makes no difference for boys. Looking down the first column giving the FE results we see that poor access to water by itself has no effect on girls' overall enrolment rate (0.07) at the village level. However, both menarche (-0.17) and particularly the interaction of menarche and poor access (-0.29) reduce enrolment. A one percentage point decline in the village average access to poor water increases post-menarche girls' school enrolment by about 0.22 (=-0.07+0.29) percentage points holding the community rate of girls' menarche at the mean. The researcher finds that village wealth (proportion of rich households) has no significant within-effect on girls' enrolment (0.02), holding other things equal, though it remains significant for boys (0.14).

From these results, the overall contribution of improved access to water on school enrolment across the years can be computed. In particular, on average, girls' school enrolment increased by 14 points (from 62% to 76%) over the 1989-2004 period. The rate remains mostly unchanged given different proportion of girls' post-menarche within the village. Over the same period the proportion of rural households with poor access to water (water 4) fell by 21 percentage points (from 33% to 12% - these proportions are different from those reported in Figure 2.4 (37% to 6%), one likely reason being that when computing village proportions, some observations are dropped if their within village sum is less than 10). Therefore, holding other things equal, about one-third (0.22×21/14=33%) of girls' schooling improvement can be attributed to improved access to water, which is considerable. As for the girls pre-menarche and boys, the researcher finds no long term impact of access to poor water at the village level. When defining good vs. poor access to water as whether or not there is tap water access, the overall results point to the same conclusion. The long term impact is smaller – about 21% (0.14×21/14) of the improvement in school enrolment is explained by the realisation of the tap water access for girls post-menarche.

3.6 Conclusion

In this chapter, the researcher uses regression analysis to test the hypothesis-1 of this study – that poor access to water posits significant negative impacts on girls schooling after menarche. The regressions are all controlled for other confounding factors which include many individual and household characteristics. Besides, a full set of village dummies are included in the model to control for the impact of poor geographical locations. Controlling for village fixed effects is important as poor access to water is likely to be correlated with backward locations. In addition, the poor access to water variable is instrumented to account for the possible endogeneity. Two types of definitions are used for good / poor access to water to test the robustness of the results.

The different kinds of regression analyses all direct to the same conclusion that girls post-menarche have higher rate of school drop-out and shorter school duration where the access to water is poor. For example, the probit model results show that having no access to tap water decreases the probability of school enrolment of post-menarche girls by 27 percentage points (significant at 1% level) when controlling for the impact of other factors. For other groups – girls pre-menarche and boys (before or after age 14) the impact of access to poor water (non tap water) disappears while the impacts of other variables are controlled for.

The results from hazard models also show that menarche has 2 – 2.5 times worse impact on the conditional schooling duration of girls with poor access to water compared to girls with good access, however the poor access to water is defined. The duration distributions are computed using represented values of the policy variables in interest. The results show that household wealth (clustered income derived using household income, parental occupation status and education qualifications – see Table 2.1) posits only a marginally bigger impact on girls' schooling compared to boys'given access to water is poor, but poor access to water always posits worse impact on girls' schooling no matter the family is 'rich' or 'poor'.

As for the impacts of other controls, the researcher finds some interesting results. The per capita household income on average posits generally the same impact on girls and boys schooling (the impacts are tested to be the same). However, household income exerts different impacts for girls at different stages of their schooling. For example, in probit models, its impact is found to be more pronounced for pre-menarche girls. In hazard models the impact mainly goes to girls with poor access to water (11 percent increase in conditional schooling duration). Another interesting finding is that having an older brother consistently posits negative impacts on children's schooling in all models, a fact which is also found in Yang (2006). However, the 'culture' based interpretation of that result in Yang (2006) may need more elaboration considering the fact that having older brothers posits different impacts on different subgroups of children.

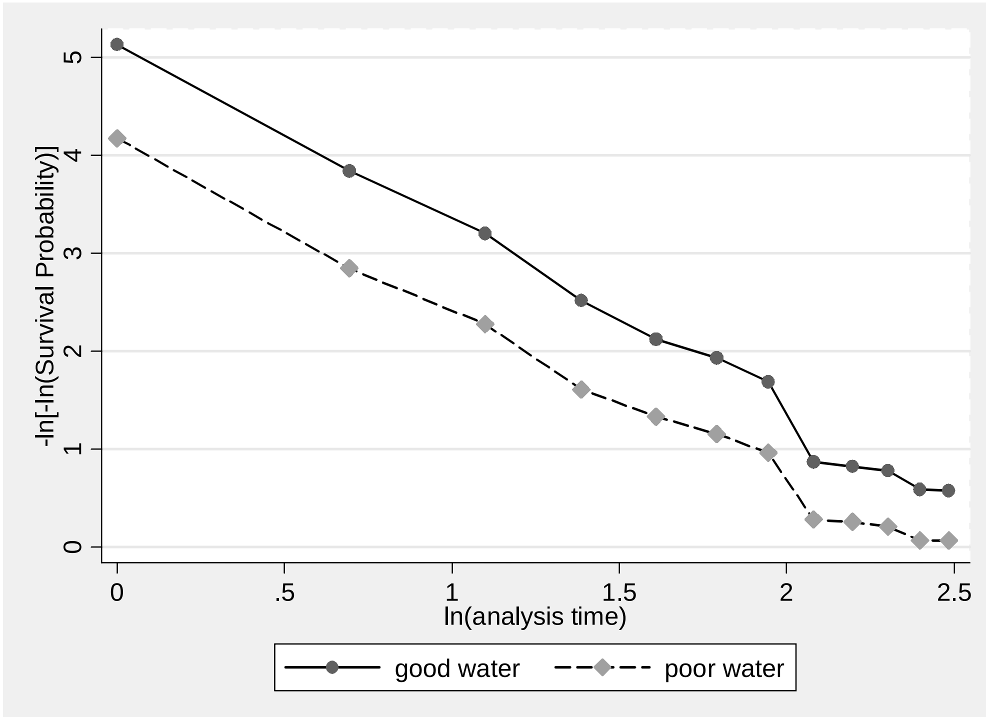
The higher parental occupation status and educational qualifications in general posits positive impacts on children's schooling. But the impacts are also found to be different in some models for different groups. For example, in probit models where the school enrolment is analysed, the higher occupational status and educational qualification of mothers are found to be positively correlated with the school enrolment of post-menarche girls, their impacts are negative (though not significant) for pre-menarche girls. Fathers' education on the contrary is found to be beneficial for all girls. However, in hazard models, high school/above qualification of fathers seems to benefit the girls with good access to water greatly – these girls experience on average 20 percent longer conditional schooling duration compared to their peers who have uneducated fathers. On the contrary, high school/above qualifications of mothers are associated with 40 percent increase in conditional schooling duration of girls with poor access to water compared to their peers with uneducated mothers. These results should be interpreted with caution as most of the impacts are insignificant. But the results do suggest that mothers with high school/above qualifications are particularly beneficial for girls from not-so-better-off families in their school attainment.

Field and Arbus (2008) assert that early marriage is to be blamed for the girls' school drop out after the onset of menarche, based on the findings that menarche has worse impacts on the schooling of the eldest sisters in Bangladesh. However, using CHNS data to replicate their results, the researcher gets quite different results. The eldest sisters suffer from the onset of menarche the least (23 percentage point lower probability of school enrolment) compared to younger sisters and single daughters (32 and 34 percentage points lower respectively). Nevertheless, the original coefficients in probit models for different sisterhood (eldest sister, younger sisters and single daughter) are not significantly different from each other. Therefore, it is unlikely that marriage causes eldest sisters drop out of school early after menarche in China. However, poor access to water makes the impact of menarche more adverse on girls' schooling whatever the position is of girls in sisterhood, a finding that backs up the hypothesis-1 of this study.

People argue that villages with poor access to water may have different 'culture' towards educating girls (due perhaps to poverty) than villages with good access to water, and the impact of this difference may be picked up by the poor access to water in the first place. However, the relatively rich controls in the regression models should be effective in filtering out the impact of the access to water variable from the impacts of other variables. An alternative approach is to restrict the sample to those less 'extreme' villages where households with and without access to tap water reside together and share the same village culture. The test results show that the worse impact of poor access to water after the onset of menarche still remains (even becomes worse) after the sample restriction and lend further support to the validity of hypothesis-1 of this study.

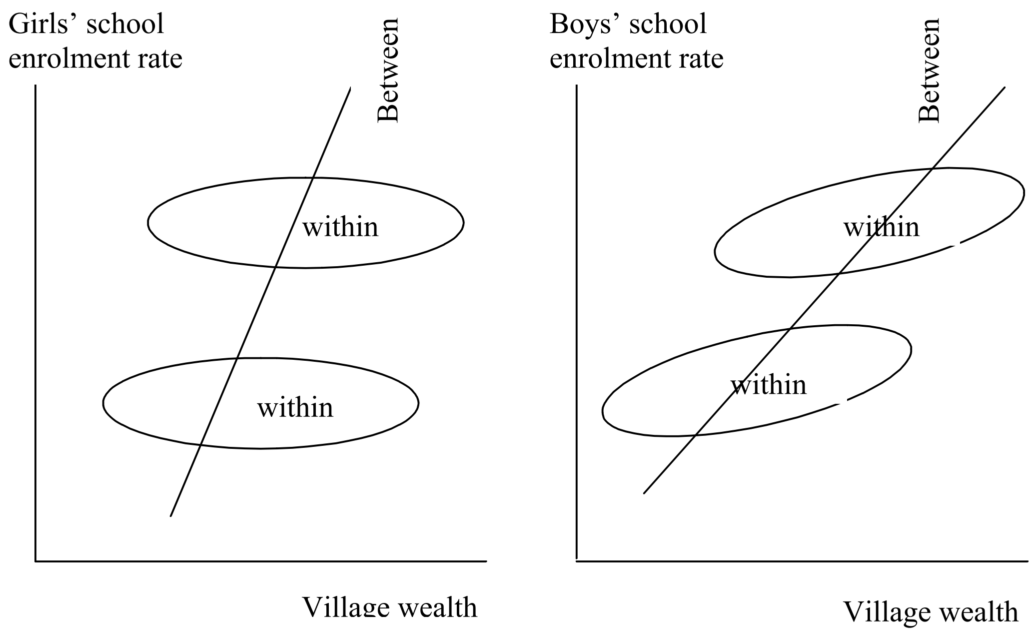
Finally, some village level analyses are conducted to test the impacts of access to water on girls' and boys' school enrolment rates at the village level. The variables used in village level analyses are means of relevant individual level variables by village/wage. The fixed effects model results further confirm the hypothesis-1 that poor access to water matters for girls schooling after the onset of menarche. A one percentage point decline in the village average access to poor water increases post-menarche girls' school enrolment by about 0.22 percentage points holding the community rate of girls' menarche at the mean. Moreover, the researcher obtains evidence that holding other things equal, poor access to water in general explains about 20 – 30% of the improvement of girls' schooling across 1989 – 2004.

Figure 3.1: Testing the proportional hazard assumption



Note: The plots are for girls with good and poor access to water adjusted for the onset of menarche and household wealth (household income, parental education and employment status). The proportionality of hazard rates is confirmed for other groups before estimations take place.

Figure 3.2: Correlations between village wealth and school enrolment rates



Note: The girls' and boys' school enrolment rates are calculated as village averages. The village wealth is the proportion of 'rich' households within the village, while 'rich' and 'poor' households are defined using the clustered income (see notes of Table 2.1).

Table 3.1(a): The sources of tap water (CHNS 1989 – 2004)

	The source of household water is not water plant	The source of household water is water plant	Total respondents
Having tap water at home	477	512	989
Having no tap water at home	1317	0	1317
Total respondents	1794	512	2306

Note: water plant is a water treatment facility that supplies clean and safe water to industries and households.

Table 3.1(b): AIC and log likelihood values

189		parametric models (AFT with heterogeneity)		
		Weibull	Log-logistic	Log-normal
Girls	Log-likelihood	-1020.1	-1042.0	-1088.2
	AIC	2422.1	2466.0	2558.4
Boys	Log-likelihood	-1006.3	-1028.7	-1072.2
	AIC	2394.6	2439.4	2526.4

Note**:** Akaike Information Criterion (AIC) =-2(log-likelihood)+2(c+p+1) where *c* is number of covariates excluding constant (189), *p* is number of ancillary parameters (all models have 1 ancillary parameter). These test results are for girls and boys in Table 3.5 (full models), and for other models, Weibull is still a preferred option (Results not shown).

Table 3.2: The impact of poor access to water by gender, menarche status and age

ivprobit models: dependent variable – school enrolment

	Girls Post-menarche		Girls Pre-Menarche		Boys 14 or older		Boys 14 or younger	
	Coef.	z	Coef.	z	Coef.	z	Coef.	z
Poor access to water	-3.24**	-2.29	0.12	0.14	0.43	0.36	-0.30	-0.26
Log percapita income	-0.03	-0.06	0.21**	2.18	-0.14*	-1.66	0.14**	2.22
Father's job status	0.11	0.79	-0.11	-1.18	-0.06	-0.48	-0.14*	-1.70
Mother's job status	-0.16	-0.60	0.15	1.43	-0.15	-0.84	-0.16	-1.32
Mother's education	0.42	1.11	-0.13	-0.87	-0.16	-0.59	-0.14	-1.16
Father's education	0.30	1.19	0.20	1.55	0.35	1.36	0.11	0.92
Bargaining power	-0.11	-0.15	0.17	0.64	0.21	0.39	0.21	0.88
Household work	-0.04**	-2.43	0.00	0.62	-0.03	-0.86		
Market work	-1.14**	-1.96	-0.18***	-2.69	-0.04*	-1.87	0.02	0.47
Having an older brother	-1.79***	-2.80	0.23	0.95	-1.26***	-2.81	-0.10	-0.48
- an older sister	-0.51	-0.63	0.27	1.14	-0.22	-0.59	0.08	0.41
- a younger brother	-0.91*	-1.79	0.66***	-2.80	-0.55	-1.29	0.10	0.42
- a younger sister	-1.22**	-2.13	-0.07	-0.26	-0.23	-0.61	-0.09	-0.35
Two or more siblings	-0.52	-1.41	0.28	1.55	-0.22	-0.99	-0.08	-0.49
First Stage: The dependent variable 'poor access to water'								
Water plant	-0.58***	-4.47	-0.59***	-5.45	-0.60***	-4.26	-0.45***	-4.50
Per capita income	0.02	0.64	-0.02	-1.06	-0.01	-0.32	-0.02	-1.42
Father's job status	0.01	0.76	0.01	0.46	0.00	-0.02	0.03**	2.21
Mother's job status	0.04*	1.84	-0.01	-0.28	-0.02	-0.95	0.01	0.45
Mother's education	-0.01	-0.21	-0.03	-1.23	0.07*	1.71	0.00	0.08
Father's education	0.03	0.67	0.00	-0.24	-0.09**	-2.16	0.01	0.36
Bargaining power	0.02	0.15	0.06	1.54	-0.19**	-2.09	-0.03	-0.74
Household work	0.01	1.07	0.01	0.78	-0.05**	-2.28	-0.06***	-3.21
Market work	0.01	0.39	-0.21**	-2.37	-0.02*	-1.69		
Having an older brother	-0.05	-0.98	-0.04	-0.87	0.01	0.12	-0.02	-0.69
- an older sister	-0.04	-0.60	-0.08**	-2.17	-0.11*	-1.72	-0.01	-0.40
- a younger brother	0.02	0.27	-0.01	-0.13	0.00	-0.07	-0.02	-0.64
- a younger sister	-0.03	-0.49	-0.04	-0.71	-0.13***	-3.06	0.01	0.32
Two or more siblings	0.01	0.28	0.01	0.24	-0.03	-0.82	0.00	-0.12
Observations	529		871		657		1372	
Log Pseudolikelihood	-122.9		-469.2		-235.8		-628.3	
Wald test of exogeneity Prob>chi2	0.32		0.88		0.79		0.83	

Note: Both first and second stage regressions are controlled for children's age, village (151) and wave (6) dummies. z values are computed using robust standard errors clustered by village. *** denotes significance at 1% level, ** 5% and * 10%.

Table 3.3: The impact of poor access to water by menarche status (girls only)
probit models (Average Marginal Effects – AME); dependent variable – school enrolment

	Post-menarche		Pre-Menarche	
	AME	z	AME	z
Poor access to water	-0.27***	-3.38	-0.02	-0.36
Log per capita income	-0.03	-1.20	0.03	1.59
Father – high occ. status (Ref)				
- medium status	-0.11	-1.10	-0.12	-1.09
- low status	-0.13	-1.44	-0.25**	-2.17
- unemployed/other	0.06	0.56	-0.22*	-1.65
Mother – high occupational status	*dropped*		0.07	1.32
- medium status (Ref)				
- low status	-0.11	-1.29	0.14***	3.47
- unemployed/other	-0.15	-1.63	0.09*	1.68
Father – no education (Ref)				
- primary education	0.03	0.25	0.05	0.98
- junior high school	0.07	0.50	0.07	1.40
- high school/above	0.11	0.61	0.08	1.25
Mother – no education (Ref)				
- primary education	0.07	0.61	0.00	0.02
- junior high school	0.19	1.02	-0.01	-0.08
- high school/above	0.18	0.88	-0.06	-0.56
Bargaining power	-0.07	-0.31	0.06	0.91
Household work	-0.01	-1.51	0.00	0.10
Market work	-0.19*	-1.66	-0.01	-1.28
Single child (Ref)				
- an older brother	-0.35***	-3.88	0.03	0.55
- an older sister	-0.09	-0.76	0.02	0.50
- a younger brother	-0.17	-1.49	0.07	1.49
- a younger sister	-0.18	-1.33	-0.13**	-2.08
- two/more siblings	-0.09	-0.96	-0.02	-0.53
Age	0.19	0.52	0.34***	22.21
Age squared	-0.01	-0.61	-0.02***	9.53
Village (151) dummies	Yes		Yes	
Wave (6) dummies	Yes		Yes	
Observations	528		877	
Log Pseudolikelihood	-158.8		-311.0	
Pseudo R squared	0.53		0.31	

Note: z values are computed using robust standard errors clustered by village. * denotes significance at 1% level, ** 5% and * 10%. *dropped* are the ones dropped due to the collinearity. (an adjusted average marginal effects for age and age squares are computed following the suggestions in Bartus (2005), but similar impacts are observed – results not shown). A significant impact of clustered income (0.15** with t value of 2.45) is observed for girls post-menarche when it is used instead of separate income related variables (per capita household income, parental education and**

job status). The clustered income has no explanatory power in model of girls pre-menarche. Table 3.4: The effect of the onset of the menarche by sisterhood

probit models (Average Marginal Effects – AME); dependent variable – school enrolment

	The eldest sister (N=304)		Younger sisters (N=475)		Single daughter (N=1272)	
Full sample	AME	z	AME	z	AME	z
	-0.23***	-3.24	-0.32***	-4.55	-0.34***	-6.59
	Log likelihood -87.7 Pseudo R2 = 0.54		Log likelihood -191.9 Pseudo R2 = 0.24		Log likelihood -482.8 Pseudo R2 = 0.37	
	The eldest sister (N=193)		Younger sisters (N=283)		Single daughter (N=683)	
Poor water households only	AME	z	AME	z	AME	z
	-0.27***	-3.26	-0.34***	-4.23	-0.41***	-6.51
	Log likelihood -45.7 Pseudo R2 = 0.66		Log likelihood -123.3 Pseudo R2 = 0.26		Log likelihood -268.7 Pseudo R2 = 0.38	

Notes: Controls in all equations are same as specified in Table 3.6 (except controlled for province dummies rather than county dummies as some models have small sample size). There are maximum five female siblings in a household and the sample is restricted to households with at least two female siblings in the first two columns. One member of twin sisters is randomly excluded (28 observations). First observation per subject is used. Data source: CHNS 1989-2004. z values are computed using robust standard errors clustered by village. *** denotes significance at 1% level, ** 5% and * 10%.

Table 3.5: The impact of poor access to water by gender
weibull models (AFT): dependent variable – school duration

	Girls				Boys			
	Time Ratio	z	Time Ratio	Z	Time Ratio	z	Time Ratio	z
Poor water (water4 - table 2.1)	0.71***	-8.03	0.89**	-2.55	0.84***	-5.22	0.94	-1.47
Log per capita income			1.06***	3.49			1.02	1.23
Father – high occ. status (Ref)								
- medium status			0.88*	-1.66			0.92	-1.06
- low status			0.85**	-2.34			0.87**	-1.97
- unemployed/other			0.83***	-2.24			0.88	-1.60
Mother – high occ. status			1.23	1.35			1.12	0.97
- medium status (Ref)								
- low status			0.88**	-2.21			0.98	-0.25
- unemployed/other			0.86**	-2.46			0.96	-0.68
Father – no education (Ref)								
- primary education			1.02	0.31			1.10*	1.82
- junior high school			1.03	0.34			1.21***	2.88
- high school/above			1.11	1.01			1.32***	2.79
Mother – no education (Ref)								
- primary education			1.10*	1.65			0.99	-0.20
- junior high school			1.09	0.93			1.04	0.56
- high school/above			1.29**	2.02			1.11	0.90
Bargaining power			0.96	-0.53			1.07	1.30
Household work			0.97***	-4.67			0.99	-0.68
Market work			0.93***	-6.95			0.93***	-6.64

(to be continued on next page)

Table 3.5: The impact of poor access to water by gender (Continued from last page)
- weibull models (AFT): dependent variable – school duration

	Girls				Boys			
	Time Ratio	z	Time Ratio	z	Time Ratio	z	Time Ratio	z
Single child (Ref)								
- an older brother			0.93	-1.09			0.89**	-2.28
- an older sister			0.99	-0.11			1.04	0.94
- a younger brother			0.98	-0.34			0.99	-0.20
- a younger sister			1.01	0.20			1.00	0.08
- two/more siblings			0.97	-0.63			1.00	0.13
Age 6-11 (Ref)								
-Age 12-16			1.19***	3.94			1.19***	3.28
-Age 17-19			1.02	0.41			1.05	0.81
Village (151) dummies	No		Yes		No		Yes	
Wave (6) dummies	No		Yes		No		Yes	
ρ (standard error in parenthesis)	2.62 (0.15)		3.15 (0.18)		3.05 (0.16)		3.37 (0.17)	
θ (standard error in parenthesis)	0.11 (0.14)		0.17 (0.11)		0.15 (0.12)		0.18 (0.12)	
Observations	4379		4371		4879		4871	
Log pseudolikelihood	-1453.7		-1020.1		-1398.4		-1006.3	

Note: ρ is the baseline hazard shape parameter (increasing when $\rho>1$, as here). θ is the fraility or unobserved heterogeneity variance (Hosmer and Lemshow, 1999). **z** scores are calculated using robust standard errors clustered by village. *** denotes significance at 1% level, ** 5% and * 10%. In this table, poor access to water is defined as water4 in Table 2.1.

Table 3.6: Schooling Duration – Girls only
Dependent variable: schooling duration (Weibull AFT Models)

	Girls with poor access to water		Girl with good access to water	
	Time Ratio	z	Time Ratio	z
menarche	0.78***	-3.77	0.90*	-1.76
Log per capita income	1.11***	4.92	1.03	1.48
Father – high occ. status (Ref)				
- medium status	0.84	-1.37	0.86	-1.46
- low status	0.80*	-1.74	0.78***	-2.69
- unemployed/other	0.79*	-1.62	0.86*	-1.37
Mother – high occ. status	1.11	0.46	1.18	0.58
- medium status (Ref)				
- low status	0.82*	-1.69	0.83***	-3.28
- unemployed/other	0.83	-1.56	0.80***	-3.27
Father – no education (Ref)				
- primary education	1.09	0.89	1.04	0.45
- junior high school	1.12	0.85	1.00	0.05
- high school/above	1.09	0.57	1.22	1.40
Mother – no education (Ref)				
- primary education	1.08	0.83	1.14*	1.76
- junior high school	0.98	-0.12	1.23*	1.70
- high school/above	1.41*	1.90	1.19	1.11
Bargaining power	0.98	-0.18	0.99	-0.14
Household work	0.98***	-2.61	0.96***	-2.49
Market work	0.93***	-5.77	0.91***	-6.76

(to be continued on next page)

Table 3.6: Schooling Duration – Girls only (Continued from last page)

Dependent variable: schooling duration (Weibull AFT Models)

	Girls with poor access to water		Girl with good access to water	
	Time Ratio	z	Time Ratio	z
Single child (Ref)				
- an older brother	0.92	-0.81	0.86*	-1.83
- an older sister	1.00	-0.03	1.11	1.02
- a younger brother	0.98	-0.23	0.96	-0.51
- a younger sister	0.99	-0.20	1.10	0.95
- two/more siblings	0.98	-0.27	0.98	-0.25
Age 6-11 (Ref)				
-Age 12-16	1.30***	3.60	1.36***	3.54
-Age 17-19	1.18**	1.97	1.27***	2.63
County (36) dummies	Yes		Yes	
Wave (6) dummies	Yes		Yes	
ρ (standard error in parenthesis)	2.65 (0.12)***		3.54 (0.25)***	
θ (standard error in parenthesis)	0.09 (0.12)		0.31 (0.13)**	
Observations	2080		1984	
Log pseudolikelihood	-561.9		-368.9	

Notes: ρ is the baseline hazard shape parameter (increasing when $\rho>1$, as here). Unobserved heterogeneity variances (θ) is significant for girls with good access to water. (Hosmer and Lemshow, 1999). **z** scores are calculated using robust standard errors, and *** denotes significance at the 1% level, ** 5% and * 10%. In this table, poor access to water is defined as water3+water4 (non-tap water) in Table 2.1.

Table 3.7: The effect of the onset of the menarche in restricted sample
(villages where only 15 – 85 % households have good access to water)
Dependent variable: schooling duration (Weibull AFT Models)

	Poor water = water3 and water4 in Table 2.1	
	poor access to water	good access to water
(1) full sample (from Table 3.6) (*z scores are in parenthesis*)	0.78*** (-3.77) N = 2080	0.90* (-1.76) N = 1984
(2) villages where 15%-85% households have good access to water (*z scores are in parenthesis*)	0.72* (-1.85) N = 542	0.88 (-1.13) N = 441
	Poor water = water4 in Table 2.1	
	poor access to water	good access to water
(3) full sample (*z scores are in parenthesis*)	0.72** (-2.54) N = 763	0.89*** (-2.11) N = 3301
(4) villages where 15%-85% households have good access to water (*z scores are in parenthesis*)	0.70 (-1.24) N = 202	0.89 (-1.22) N = 781

Notes: Controls for equations in (1), (2) are same as specified in Table 3.6. For equations in (3) and (4) a simpler specification is used due to small sample size in one model. z scores are calculated using robust standard errors clustered by village, and *** denotes significance at the 1% level, ** 5% and * 10%. The 'frailty effect' is also controlled for in all regressions.

Table 3.8(a): Percentiles of survival distributions (1) – various scenarios
The poor access to water is defined as no access to tap water (among 10232 observations 5530 (54%) do not have access to tap water)

Survival Time		**0.95**	**0.75**	**0.50**	**0.35**	**0.25**	**0.15**
Good water (1)	Girls	3.9	7.5	10.3	12.0		
	Boys	4.1	7.3	10.2	12.0		
Poor water (2)	Girls	3.1	5.8	8.3	9.9	11.3	12.0
	Boys	3.5	6.4	9.0	10.4	11.4	
High income (upper cluster) (3)	Girls	4.0	7.5	10.5	12.0		
	Boys	4.2	7.4	10.4	12.0		
Low income (lower cluster) (4)	Girls	3.3	6.5	9.1	10.8	12.0	
	Boys	3.7	6.7	9.3	10.7	11.8	
Good water & high income (5)	Girls	4.6	8.2	11.7			
	Boys	4.6	8.1	11.0			
Poor water & high income (6)	Girls	3.4	6.4	9.2	11.0		
	Boys	3.9	7.0	9.6	11.4		
Good water & low income (7)	Girls	3.7	7.3	10.0	12.0		
	Boys	4.1	7.2	9.9	11.7		
Poor water & low income (7)	Girls	3.1	5.6	8.2	9.6	10.8	
	Boys	3.8	6.3	8.7	10.1	11.3	

Notes: Weibull AFT with heterogeneity specification used to create the distributions; other variables in the model are set to their mean values. Poor access to water here includes category 3 and 4 (non-tap water). "Rich" and "poor" categories are based on k-means clustering using per capita household income, parental job status and parental educational qualifications. The cut-off point of per capita household income is set at its median value, while job status and educational qualifications variables are kept in their four original categories. We classify the data into two clusters "poor" (8095 subjects) and "rich" (2303 subjects).

Table 3.8(b): Percentiles of survival distributions (2) – various scenarios
The poor access to water is defined as water 4 (non-tap, non-well water outside the courtyard) (among 10232 observations 2058 (20%) do not have access to tap or well water)

Survival Time		**0.95**	**0.75**	**0.50**	**0.35**	**0.25**	**0.15**
Good water (1)	Girls	3.9	6.9	9.7	11.7		
	Boys	3.8	6.8	9.5	11.2	12.0	
Poor water (2)	Girls	2.8	5.4	7.8	9.3	10.4	12.0
	Boys	3.7	6.3	8.7	10.3	11.5	
High income (upper cluster) (3)	Girls	4.0	7.5	10.5	12.0		
	Boys	4.2	7.4	10.4	12.0		
Low income (lower cluster) (4)	Girls	3.3	6.5	9.1	10.8	12.0	
	Boys	3.7	6.7	9.3	10.7	11.8	
Good water & high income (5)	Girls	4.4	7.8	11.2			
	Boys	4.3	7.6	10.7			
Poor water & high income (6)	Girls	3.3	6.2	8.7	10.4	11.8	
	Boys	4.0	7.3	9.7	11.4		
Good water & low income (7)	Girls	3.5	6.7	9.3	11.2		
	Boys	3.7	6.5	9.2	10.9	12.0	
Poor water & low income (7)	Girls	2.8	5.2	7.5	8.8	10.0	11.6
	Boys	3.5	6.3	8.6	9.9	11.0	

Notes: Weibull AFT with heterogeneity specification used to create the distributions; other variables in the model are set to their mean values. Poor access to water here includes only category 4 (water outside the courtyard). “Rich” and “poor” categories are based on k-means clustering using per capita household income, parental job status and parental educational qualifications. The cut-off point of per capita household income is set at its median value, while job status and educational qualifications variables are kept in their four original categories. We classify the data into two clusters “poor” (8095 subjects) and “rich” (2303 subjects).

Table 3.9: Within and between correlations of village level variables

Between Correlations

	means	1)	2)	3)	4)	5)	6)	7)	8)	9)	10)
1) girls' enrolment rate	0.70		**0.49**	**-0.26**	**-0.28**	**0.47**	**-0.70**	**-0.32**	**-0.34**	**-0.31**	**0.23**
2) boys' enrolment rate	0.73	0.27		**-0.16**	**0.01**	**0.26**	**-0.42**	**-0.55**	**-0.36**	**-0.37**	**0.16**
3) rate of poor access to water	0.18	-0.10	-0.05		**0.05**	**-0.37**	**0.25**	**0.05**	**0.29**	**0.15**	**-0.24**
4) proportion of girls post-menarche	0.50	-0.28	-0.02	-0.18		**-0.01**	**0.27**	**0.04**	**0.25**	**0.65**	**0.13**
5) proportion of rich households	0.24	-0.02	0.09	0.05	0.22		**-0.43**	**-0.23**	**-0.32**	**-0.16**	**0.60**
6) work hours for girls per day	0.85	-0.32	-0.05	0.00	0.14	-0.09		**0.50**	**0.35**	**0.42**	**-0.14**
7) work hours for boys per day	0.51	-0.08	-0.28	-0.05	0.00	-0.15	0.31		**0.26**	**0.40**	**-0.16**
8) number of children per household	2.5	-0.20	-0.14	0.34	-0.12	-0.05	0.07	-0.09		**0.42**	**-0.15**
9) average age of children	12.8	-0.21	-0.22	-0.24	0.74	0.17	0.13	0.16	-0.19		**0.04**
10) water plant	0.25	0.04	0.00	-0.29	0.08	0.09	0.01	0.02	-0.16	0.16	

Within Correlations

Notes: within-village correlations are presented in the lower triangle, and between-village correlations are presented in bold in the upper triangle

Table 3.10: Village school enrolment rates of girls and boys

	Girls		Boys	
	Fixed Effects Models	Random Effects Models	Fixed Effects Models	Random Effects Models
village rate of poor water (1)	0.07	0.09*	0.01	0.00
	(1.12)	(1.72)	(0.26)	(0.02)
proportion of girls post-menarche (2)	-0.17***	-0.18***		
	(-3.14)	(-3.60)		
(1) × (2)	-0.29**	-0.28***		
	(-2.21)	(-2.72)		
village rate of the rich families	0.02	0.11***	0.14**	0.06**
	(0.34)	(3.85)	(2.37)	(2.30)
village average household work (girls/boys)	0.00	-0.03**	0.00	-0.05
	(0.08)	(-1.98)	(-0.13)	(-1.59)
village average market work (girls/boys)	-0.09***	-0.11***	-0.10***	-0.10***
	(-7.78)	(-10.44)	(-7.50)	(-9.01)
village av. number of children per household	0.01	-0.01	0.02	-0.02
	(0.32)	(-0.70)	(0.48)	(-1.33)
village average age of children	-0.02*	0.001	-0.04***	-0.03***
	(-1.74)	(0.10)	(-6.02)	(-5.47)
wave (6) dummies	YES	YES	YES	YES
R-sq: within	0.295		0.256	
between	0.421		0.303	
overall	0.336	0.371	0.251	0.275
No. of village-years	603	603	603	603
Hausman test – whether FE preferred	Yes, Pr>chi2 =0.087		No, Pr>chi2 =0.139	

Notes: t values are given in parentheses. *** denotes significance at the 1% level, ** at 5% and * at 10%.

CHAPTER FOUR: THE EMPIRICAL TEST (2) – PROPENSITY SCORE MATCHING

4.1 Introduction

In the previous chapter, a set of regression analysis methods is used as empirical tools to test the hypothesis-1 of this study. The estimations are all controlled for other confounding factors such as individual and household characteristics. Besides, the village dummies are included in models to control for the impact of poor geographical location. The poor access to water variable is also instrumented in probit models to examine the possible endogeneity problems. Furthermore, unobserved heterogeneity of individuals is controlled for in hazard models. Panel estimations are used in village level analysis. The results from different regression analyses all point to the same conclusion – the poor access to water produces significant negative impacts on girls' schooling after the onset of menarche.

Regression analysis provides a complete mechanism to analyse the treatment effects. In particular, any possible selection bias can be tackled by including all 'necessary' variables in ideal circumstances in the regression as controls (the so called 'long model') and appropriate instrumentation (see Angirst and Pischke, 2009). However, the Propensity Score Matching (PSM) estimator provides an alternative approach to test the robustness of the regression results and is believed to reduce the bias of regression estimates by making the observational studies more like natural experiments where allocation of treatment is more random (Becker and Ichino, 2002). Besides, PSM can use semi-parametric methods to estimate the treatment effects so there is no need to assume any functional form for the estimation (Guo and Fraser, 2009).

It is worth discussing the advantages of PSM method over OLS. In OLS, any unobservable student characteristics are the same for those who received the treatment (poor access to water) and those who did not. A problem arises since the counterfactual outcome of each type of students cannot be observed (what is the schooling outcome of students with poor access to water if they have good access? Or, vice versa?). But we can overcome the problem by assuming that errors in both type of equations have the same distribution and the values of regressors are not relevant to computing the counterfactuals. However, if there are large differences in values of regressors for treated and control, and if essential controls are missed in the regression, the OLS will yield biased estimates of the treatment effect. In other words, selection bias will occur if the unobservable characteristics of treated and control are systematically different from each other.

OLS estimates can also be biased when the assignment of the treatment is non-random between the treated and control units. Heckman two-step procedure offers a solution by providing an estimate of the conditional error known as the Inverse Mills Ratio (IMR) (also called selection term) that can be added to the regression. However, collinearity between the selection term and the explanatory variables in the second stage equation can sometimes be severe, leading to instability of estimations (Leung and Yu, 2000). Besides, when there is no common support – students with poor access to water have no similar characteristics with students with good access – the robustness of the Heckman results need to be re-estimated using samples with different values of the selection term (Black and Smith, 2004).

The problems associated with model sensitivity and 'common support' motivated the use of marching methods over Heckman approach. PSM does not have linear functional form assumptions, but makes two important assumptions: common support and conditional independence. The first assumption is about comparing the individuals with similar characteristics. In other words, based on the observable characteristics of treated and control units, the assignment of treatment can be expected to be random between them. The Conditional Independence Assumption (CIA) requires that the schooling outcome of the children is independent of student type given the values of observable characteristics.

With all those advantages over regression analyses mentioned above, PSM techniques will be used to test the hypothesis of this study in this chapter. However, PSM is also subject to certain criticism. For example, when using PSM to estimate the treatment effect, the bias in the estimates may still exist due to the fact that PSM only ensures finer randomisation based on the observed characteristics and therefore if unobserved characteristics of individuals in the treatment group are associated with treatment assignment, the treatment effects will still be biased (Shadish et al., 2002). Moreover, a number of studies found that the treatment effect obtained using PSM method differs considerably from the "true" effect obtained from experimental trial research (Lalonde, 1986; Agodini and Dynarski, 2001) although the so-called "true" effect is sometimes questionable due to the practical problems of experimental research which will be discussed below. In fact, Dehejia and Wahba (1999) find different results from Lalonde (1986) when they refine the matching techniques, and conclude that PSM should generate the same results to the experimental results when appropriate matching techniques are used.

Nevertheless, it has been found in the previous chapter that the impacts of unobserved characteristics appear to be uncorrelated to the impacts of access to water when tests are conducted using IV probit models and hazard models controlling for individual heterogeneity. Therefore, for now, the major concern is not to control for unobserved heterogeneity, but to ensure finer randomisation based on observed characteristics to reduce the bias. This task is particularly important since there is evidence from other studies that controlling for bias due to observable characteristics is more important than controlling for the bias due to unobservables (Heckman et al., 1998). Due to obvious advantages of PSM in ensuring random assignment based on observed data, recent years have seen considerable increase in the use of this technique to derive causal treatment effects (Wunder and Schwarze, 2009; Jalan and Ravallion, 2003).

A stronger and more direct method to account for the randomisation problem is to use randomised experimental trials to collect 'relevant' research data which fit well to the research questions and analytic method. The experimental approach is generally regarded as the most robust one among other evaluation approaches (Burtless, 1995). However, this method is also not free from pitfalls, among which, the 'randomisation bias' (Heckman and Smith, 1995) can be generated by a number of factors. For example, if there is systematic attrition either from control or treated group members, or the 'treated' do not take the treatment during the experiment, random assignment does not identify treatment on the treated, but instead identifies the mean effect of 'intent to treat'. In addition, if members in the control group have 'effective substitutes' for the treatment, the effect of the treatment cannot be identified (Heckman and Smith, 1995).

In addition, even though the random assignment is implemented correctly using experimental design, it may still produce unbalanced comparison groups due to insufficient data (Guo and Fraser, 2009, 323). Also due to the small experimental sample, the selection problems may arise from the outset because the sample may not represent a target group in population. Moreover, logistic difficulty, long duration and potentially high cost of experiments are typical characteristics of randomised trials (Angrist and Pischke, 2009), and therefore experimental trials may not always *match* research question with research design either.

A study of Oster and Thornton (2009) uses randomised experimental trials to investigate the impact of helping with menstruation (menstrual cup usage) on school attendance of girls, and find the impact is insignificant. However, a careful review of their research design and methodology raised a number of issues that may help explain why they find an insignificant treatment effect in their experiment. It is found that their approach of research design suffers form selection problems from the onset. Moreover, the 'substitute effects' and 'sample attrition' effects (mentioned above) which are evident from their sample violate the random assignment assumption in experimental research, and induce possible bias in their estimated treatment effects. As the experiment of Oster and Thornton (2009) is particularly relevant to this study and represents a different research methodology, a section is devoted for a detailed discussion of their research design and results.

This chapter is organised as follows: Section 4.1 outlines the mechanism of the propensity score matching technique. Section 4.2 details the procedure of estimating the propensity score. Section 4.3 estimates Average Treatment on Treated, and compares the results with regression results obtained from the last chapter. Section 4.2 reviews and evaluates the research design in Oster and Thornton (2009) in detail and explain reasons of a possible bias in their estimation of the treatment effect. The final section concludes the chapter.

4.2 The Mechanism of Propensity Score Matching

The discussions in the previous section show the difficulty of obtaining an unbiased treatment effect even from a 'well-designed' experiment due to practical problems. Propensity score matching on the other hand can avoid some of the problems of experimental research since it uses observational data. Moreover, propensity score matching is preferred over regression analysis mainly due to its explicit mechanism to ensure the randomisation of treatment assignment. Rosenbaum and Rubin (1983) assert that this method can help identify the individual impact of a treatment (in our case access to poor water) on the treated in observational studies particularly when there are other confounding factors which make the randomness of the treatment assignment questionable. Without a valid randomisation procedure, the treatment effect may not be correctly identified and estimated. In other words, the estimated treatment effect may be biased due to the possible selection problem (Guo and Fraser, 2009).

The specific procedure of PSM, under assumptions of common support and CIA, ensures that the assignment of the treatment is made random between the comparison groups: (1) it excludes the observations outside the common support region where individuals with same $\boldsymbol{X}$ values (individual, household and community characteristics) can be found both in treatment and control groups (Heckman et al, 1999), so that treatment and control units can be more comparable (Becker and Ichino, 2002). (2) The Conditional Independence Assumption (CIA) also ensures that the schooling outcome of the treated and control is independent of the treatment assignment:

$Schooling_{treated}, Schooling_{control} \perp D | X$, it is hence assumed that any systematic effect of the treatment (poor access to water) can be entirely explained in terms of some observable variables (***X***). (3) PSM separates the observations into different blocks according to their pre-treatment characteristics and ensures that they all have equal probability of having the treatment (access to poor water). In other words, even though the treatment is not random comparing all observations in treatment and control groups, but it is random within each specific block (Guo and Fraser, 2009). The effect of the treatment will then be identified (mostly) within each block first before the average treatment on treated is estimated. So the comparison may be more meaningful than regression analysis. (4) The average treatment effect on treated (ATT) is computed using non-parametric methods, so there is no need to assume any functional form for the estimation (Becker and Ichino, 2002).

However, it is always difficult to match the individuals when there are multiple characteristics and therefore a 'score' based on the pre-treatment characteristics needs to be estimated. This score is called the 'propensity score' which is the conditional probability of receiving a treatment given pre-treatment characteristics (Rosenbaum and Rubin, 1983). The propensity score is defined by as:

$$P(X) \equiv \Pr(D = 1 | X) = E(D | X)$$

D is the treatment, 1 represents an individual who receives the treatment, 0 represents the individual does not receive the treatment. X is the vector of pre-treatment characteristics. When the assignment of treatment is random among the treated and control units given the pre-treatment characteristics, the assignment can also be random given the propensity score (Rosenbaum and Rubin, 1983).

In this study, the propensity score is estimated using a logit model by making the treatment variable (poor access to water) the dependent variable (detailed specification of the model is presented in Section 4.4). After the propensity score is obtained, the average effect of the treatment on the treated (ATT) can be estimated as following (Becker and Ichino, 2002):

$$\tau \equiv E\{Y_{1i} - Y_{0i} \mid D_i = 1\}$$

where Y_{0i} is the potential outcome if the treated has not received the treatment. D is the treatment, 1 represents an individual who receives the treatment, 0 represents the individual who does not receive the treatment. However, there is the problem of so-called "fundamental problem of causal inference" (Holland, 1986, p.947). That is, it is not possible to know what the outcome would have been if the treated had not received the treatment which is $E\{Y_{0i} \mid D_i = 1\}$. However, the randomisation process will make it possible to derive the counterfactual using the average outcome of the control group where there is no treatment. More specifically, randomisation makes the assumption that $E\{Y_{0i} \mid D_i = 1\}$ is equal to $E\{Y_{0i} \mid D_i = 0\}$ in each block (defined by propensity scores) (Guo and Fraser, 2009).Therefore, given the above assumption, equation (1) can be written as follows (Becker and Ichino, 2002):

$$\tau = E\{E\{Y_{1i} - Y_{0i} \mid D_i = 1, p(X_i)\}\}$$

$$\tau = E[E\{Y_{1i} \middle| D_i = 1, p(X_i)\} - E\{Y_{0i} \middle| D_i = 0, p(X_i)\} \mid D_i = 1]$$

where *X* is the vector of pre-treatment characteristics and *p(X)* is the propensity score. Equations above suggest that ATT can be computed as the mean of mean differences by block of the outcome of the treated and the control given the same propensity score. However, there is almost zero possibility to have exactly the same propensity scores for different observations because the score is a continuous variable which is coded with double decimal precision. Therefore, various methods are developed to execute the matching.

This study uses four types of common matching techniques, namely, Nearest neighbour matching; Radius matching; Kernel matching; and Stratification matching. There is no superiority in terms of choosing which method to match. They all have advantages and disadvantages compared to one another. Brief descriptions of each method in estimating the ATT's are given in Appendix 1 (the standard errors of ATT can be computed using some analytical formulae or using bootstrapping (for details, see Becker and Ichino, 2002)).

4.3 Estimating the Propensity Score

In this section, propensity scores will be estimated using logit models. Here, the propensity score is the probability of having poor access to water. According to this probability, the observations will be separated into different blocks. Therefore within each block, the treated (poor access) and the control (good access) will have the same probability of access to water. The first task of estimating the propensity score is to identify the variables that may determine the factors that determines household access to tap water.

An obvious determinant is the government investment in tap water construction in the village where the household is located. The *water plant* variable used as an instrument (for poor access to water) in Chapter 3 is therefore included in the logit regression, since it can indirectly measure the relative intensity of government investment in water facilities in a village. The geographical location of the village is another important determinant. For example, a village which is close to big rivers may be given priority on tap water investment from the government since the cost of construction may be low. Furthermore, villages close to the big cities and provincial capitals can also be given the priority for the commercial and political (stability) reasons. In this regard, tap water access is likely to be determined by the geographical location. Therefore 151 village dummies are included in the estimation to pick up the geographical location effect. However, many village dummies are naturally dropped because of collinearity in actual regressions.

Some household and individual level characteristics which determine children's school are also included in the access to water logit, a practice which is common (Jalan and Ravallion, 2003). The reason for including these controls is that the balancing requirement should be met on all these covariates. In other words, while they may not determine household access to water, they should be balanced (having equal means) between treatment and control groups before Average Treatment on Treated are estimated.

The logit regression to obtain the propensity score is estimated for girls (post and pre-menarche) and boys (older/younger than 14) separately for each year. The reason is that even though the balancing requirement is met (means of covariates are not significantly different) between the treated and control using the total sample, the covariates may be very different when grouping the observations into different groups to estimate the ATT. Therefore, it is essential to get the balancing requirement met for each group separately, since the ATT is also estimated for each particular group separately in the second stage.

One limitation of this method is that the estimated ATT is less reliable, because for each group in each year, the estimation of the logit model and the identification of the treatment effect are restricted to only a small number of observations. However, since the estimation of ATT is repeated for each group each year, the results across the years can be compared to check for the robustness of the impact. The researcher also used 'the first observation per subject' data that were used in probit models in the previous chapter to estimate the ATT for each group. The exercise failed because balancing requirement could not be satisfied.

The results of the logit model which is used to estimate the propensity score (probaility of access to water) for girls post-menarche in 1997 are given (as an example) in Table 4.1. Altogether, 20 logit regressions were estimated for each specific group for each year (4 groups for 5 years). The *water plant* variable is indeed found to be highly correlated with tap water access for households (negatively correlated with having poor access to water) in all the regressions specified as in Table 4.1. When the proportion of people in a village who obtains tap water via water plant increases by 0.01 unit (1 percentage points), the probability of having access to tap water for each household for that community is found to increase by about 0.08 unit (8 percentage points = 8.47/100) holding other things equal. Besides, It is found that some of the village dummies are also highly significant (not shown). This fact suggests that village fixed effects play important role in determining access to water.

However, household wealth indicators (e.g per capita household income, parental job status and educational attainment) exert very mixed and mostly insignificant impacts. For example, in this model (Table 4.1) none of the household wealth indicators has an impact on the probability of having (non -) tap water access. In most of the other logit regressions, the household wealth indicators posit insignificant impacts on the household access to tap water. The results confirm the assertion that the wealth level of a typical household may not be sufficient for it to have access to tap water which is often a large scale government construction (see Chapter 2 for relevant discussion).

As noted earlier, for individual level variables, such as age, market work, household work and sibling structure and so on, the significant impact is not desired, because household access to tap water is generally irrelevant to children's characteristics. The only reason to include those variables in the regression is that the balancing requirement over those covariates must be met given the same propensity score. Only then, the estimated ATT can be more credible, because the comparison of school outcomes takes place between control and treated samples whose background characteristics are as similar as possible.

Finally, when estimating the propensity score the researcher restricted the balancing hypothesis test to be performed within common support region (in case of girls post-menarche in 1997 is [0.14, 0.96]) and this restriction will improve the quality of the matching (Guo and Fraser, 2009). In other words, the test will guarantee that within each interval, the means of each characteristic do not differ between treated and control. The balancing hypothesis is satisfied for all groups in all years. When meeting the balancing requirement, the researacher used the techniques suggested by Dehejia and Wahba (2002) and Becker and Ichino (2002) (e.g. to obtain parsimonious equations by dropping insignificant village dummies).

The Table 4.2 shows the probability of access to poor water between the control and the treated units in each block for girls post-menarche in 1997 (as an example). 5 blocks are set so that individuals from the treatment and control groups in each block will have the same probability to access to poor water (more than 5 blocks are obtained for some groups). For example, block 1 contains individuals whose probability of access to poor water (no access to tap water) ranges from 0.14 – 0.19. The mean probability (of access to poor water) ranges from 0.15/0.16 in block 1 to 0.86/0.88 in block 5. In this way, similar propensity scores are obtained for the treated and the control units in each block. The scores are tested to be insignificantly different from each other by each block (see t statistic in the final column - the biggest absolute t value is only 0.68).

4.4 Estimating the Average Treatment on Treated (ATT)

In this section, the ATT (here, the average effect of poor access to water on children's schooling) will be estimated. However, before estimating the ATT, so called 'balancing requirement' must be satisfied (Becker and Ichino, 2002). Balancing requirement demands that covariate means are not significantly different between the treated and control groups in each propensity score block. The results of the mean comparisons of some covariates between treated and control groups are shown in Table 4.3 (girls post-menarche, year 1997, given as an example). These figures are obtained after propensity scores were estimated and observations from the treated and control groups are separated into different blocks.

As can be seen from Table 4.3, the covariates means within each block are largely indifferent between the treatment and control groups. For example, in Block 1, where the probability of having no access to tap water is 0.15/0.16, there is no significant difference between the treated and control groups on their per capita household income, father's job status, mother's educational qualification, age, and amount of household work they involve. However, there are few occasions that some covariate means are different in some blocks. For example, the means of father's occupational status are different in block 3 and 4; and the means of per capita household income are different in block 5.

This difference is expected considering only a small number of observations (treated and control) available for comparison in some blocks. But the difference is neither prevalent nor systematic, and only occurs for a few covariates in a few blocks. Since ATT is an averaged effect of the mean effects in each block (using different averaging/matching techniques mentioned above), so the bias of estimation further reduces. Nevertheless, for each group each year, the balancing requirement is tested to be satisfied, that is, the covariate means are insignificantly different between the treated and control units (results not shown). After balancing the covariate means (to a large extent), ATT is estimated for four groups (girls post and pre-menarche; boys aged older/younger than 14) using four matching techniques for the first 5 years (1989, 1991, 1993, 1997 and 2000). ATT for 2004 can not be estimated due to insufficient number of matched samples. The results are given in Table 4.4.

The impact of poor access to water exerts rather different patterns among different groups. The impact is particularly adverse for girls post-menarche, a finding which supports the hypothesis-1 of this study. The probability of school enrolment of post-menarche girls with poor access to water is on average 19 percentage point smaller compared to those with good access. But the impact of poor access to water is small and mostly insignificant for girls pre-menarche (on average only 5 percentage points lower compared to their peers with good access). The impact of poor access to water is also found to be small on younger (14 -) boys' schooling (on average only 4.6 percentage points lower compared to their peers with good access). The probability of school enrolment decreases by similar percentage points for younger boys and younger (pre-menarche) girls when they have no tap water access, which is reasonable since the negative impact of poor access to water only exacerbates for girls post-menarche. The impact of poor access to water on older (14 +) boys' school enrolment is rather uncertain (positive and negative values for ATT are found). However, none of the impacts are significant.

In year 2000, the special impact of poor access to water on post-menarche girls becomes insignificant, while the impact gets bigger for other groups. This trend is presumably due to a sharp decrease in the proportion of households with water4 access (the poorest water source, see Table 2.1 and Figure 2.4) which is typically bad for post-menarche girls, and an increased pollution of water3 (well water) which generates health problems to all children in an equal manner. PSM does not allow for a test when treatment is defined as water4 (other water outside the courtyard – e.g. water from lake or river) due to very small data points. However, the results from regression estimations show that water4 indeed has bigger impact on post-menarche girls' schooling compared to water3+water4 (non tap water) (results used for comparisons are not shown).

In sum, the propensity score matching method presents that poor access reduces the probability of school enrolment of girls post-menarche by 19 percentage points on average. This figure is smaller than the estimate of probit model in the last chapter (27 percentage point in Table 3.3). One possible reason is that the impact estimated in the probit model may represent the upper bound of the 'true' impact since the data used in probit model, keeping only the first observation per subject, are largely from the earlier waves during when the impacts are larger (as can be seen from Table 4.4). Nevertheless, combining the findings from chapter 3 and this chapter, the negative impact of poor access to water on the schooling of post-menarche girls, while controlling for the impacts of other controls, can be largely confirmed.

4.5 Menstrual Cup and School Attendance – An Experiment

Oster and Thornton (2009) (OT hereafter) analyse the impact of helping with menstruation (using menstrual cup) on girls' school attendance using experimental data (see below), and find that the impact is insignificant. Their research is particularly relevant to the research in this thesis, because both studies analyse the impact of helping with menarche (menstrual cup / good access to water) on girls' schooling. A careful review of their research design and methodology raised a number of issues that may help explain why they find an insignificant treatment effect in their experiment. The issues can be summarised as follows:

Guo and Fraser (2009, 322) noted a randomised experiment will fail if the condition required for randomization of treatment does not exist. The OT experiment guarantees randomisation of the treatment on girls in their sample (age 13-14, grade 7-8, still enrolling the school), but it does not guarantee that the assignment is random on population (all girls age 13-14, including those who dropped out the school). Therefore if there is systematic difference – between girls still enrolled in school and those who dropped – on the degree of difficulty that girls face when attending school due to the onset of menarche, then the OT's approach to assign the treatment suffers from selection bias from the ontset.

Girls in OT sample are indeed found to be privileged among other girls. For example, according to UNESCO (2008), on average only 57% of girls enrol in lower secondary school and even fewer, 35%, at secondary school (see Table 4.5). The figures are national averages, and in the rural areas the enrolment rates are likely to be even lower. In addition, in OT sample, fathers' education is on averages 5.6 years (OT, 7), which is high by Nepalese standards. According to the Demographic and Health Survey Report of Nepal (2007, p24) [*Nepal Report* hereafter], the weighted average of median school attainment of men aged 30-54 is only 3.7 years in 2006, much lower than OT's 5.6 figure. Moreover, the weighted average of the proportion of married women aged 25-54 (5868 respondents) who work for wage work (cash) is 15.7% (Nepal Report, 2007, 226) which is far less than 32% in the OT sample. The same figure in the The Nepal Report for married men aged 25-54 (2149 respondents) is 44.5% which is again less than the 66% in the OT sample (Nepal Report, 2007, 225).

According to the figures shown above, the girls in OT sample belong to a privileged section of the population, and assignment of the treatment on these girls most likely downward bias the treatment effect. The main reason is that members in the control group may have effective substitutes for the treatment (menstrual cup) during their menstruation due to their households' privileged economic position. One substitute for the menstrual cup can be access to good water as discussed in this study. Accepting a request from the researcher, OT kindly provided the proportion of respondents with different types of access to water (OT collect the access to water data as indicators of household condition). The comparison of proportions of different types of household access to water of OT sample and CHNS sample (rural Nepal versus rural China, 2006) is presented in Table 4.6. One obvious problem is that the sum of proportion in OT sample exceeds one (no explanation is given from OT about the sum when the researcher made further contacts).

The proportions are context specific and should be compared by caution. However, the girls in OT sample generally have much higher chances to have access to tap water at home compared to girls in China (95% girls in OT compared to only 67% in rural China). On the contrary, 23% girls in rural China have no access to tap water compared to less then 10% in OT sample. A 95% access to tap water proportion in OT sample suggests those girls (either in treated or in control groups) already have perfect substitutes (good access to water) for menstrual cups during their period. According to Heckman and Smith (1995) when there are substitutes for the treatment for the control group members, the impact of the treatment can not be identified.

A possibility to account for the problem would be to divide their sample – both treated and non-treated – into girls from rich and poor households. This split would allow the researcher to test whether the effects of the menstrual cup are stronger among the treated girls from poor households. Admittedly, this test would lack power in the sense that OT sample is likely to have too few poor girls. Still, the results may be able to confirm the expected direction of the effects.

Finally, according to the OT table 2 (p. 20), at most less than 50% of the girls in the treatment group reported that they used the cup (OT later corrected the proportion to 60%). It is not clear from the paper why about half of the girls in the treatment group (those who were given menstrual cup) refused to use the cup. However, as noted earlier in this chapter, if there is systematic attrition either from control or treated group members during the experiment, random assignment does not identify treatment on the treated, but instead identifies the mean effect of 'intent to treat' (Heckman and Smith, 1995).

In sum, OT's approach of research design suffers form selection problems from the onset. Moreover, the 'substitute effects' and 'sample attrition' effects which are evident from their sample violate the random assignment assumption in experimental research, and are therefore likely to bias the estimated treatment effects. As a whole, their results can best be interpreted as 'the effect of menstrual cup on school attendance on the most privileged girls who have prefect substitute for the treatment', an effect which is most likely to be zero. OT's experiment also signals how a sample selection problem is generated automatically when the outcome (dependant) variable is set to be school attendance. Comparatively speaking, analysing school enrolment and schooling duration is therefore a safer option. However, compared to school attendance, the latter two measures of schooling outcome are likely to be affected by the onset of menarche in a relatively longer period of time, although poor access to water may accelerate its negative impact on girls' schooling.

4.6 Conclusion

In this chapter, the researcher investigated the impact of poor access to water on children's schooling using propensity score matching technique. The main reason of using this alternative technique is to check the robustness of the regression results found in the last chapter when finer randomisation is in place for the treatment assignment. The propensity score matching is asserted to reduce the bias in estimated treatment effects by mitigating the selection bias resulted from non-random assignment of the treatment (Becker and Ichino, 2002).

Section 4.2 briefly introduced the propensity score matching method and outlined the mechanisms of four frequently used matching techniques. In section 4.3, the procedure of estimating the propensity score was presented before the variables to be included in the model for estimating the propensity score were explained. The logit regression to obtain the propensity score was estimated for girls (post and pre-menarche) and boys (older/younger than 14) separately for each year. The reason is that even though the balancing requirement is met (covariates are balanced) between the treated and control using the total sample, the covariates may be very different when grouping the observations into different groups to estimate the ATT.

One limitation of the above approach is that the estimated ATT may be less reliable, because for each group in each year, the estimation of the logit model and the identification of the treatment effect are restricted to only a small number of observations. However, since the estimation of ATT is repeated for each group each year, the results across the years can be compared among each other to check the robustness of the impact. Some other problems are also encountered during conducting covariate mean balancing. For example, the balancing requirements for some covariates in some propensity score blocks are not satisfied. However, the pattern is neither prevalent nor systematic, so overall the balancing requirement is satisfied for all groups in each year (test results not shown).

The treatment effects (ATT) obtained from propensity score matching are found to be reasonably comparable to the treatment effects found from regression analyses in the previous chapter. The propensity score matching presents that poor access to water reduces the probability of school enrolment of girls post-menarche by 19 percentage points on average. This figure is smaller than the estimate of probit model in the last chapter (27 percentage point in Table 3.3). However, the impact estimated in the probit model may represent the upper bound of the 'true' impact since the data used in probit model, keeping only the first observation per subject, are largely from the earlier waves during when the impacts are larger (as can be seen from Table 4.4).

Combining the findings from chapter 3 and this chapter, the negative impact of poor access to water on the schooling of post-menarche girls, while controlling for the impacts of other variables, can be largely confirmed. The overall impact is 20-27 percentage point decrease in the probability of school enrolment and 2 – 2.5 times shorter conditional schooling duration compared to post-menarche girls with good access to water. The impact of poor access to water is generally found to be small and insignificant for pre-menarche girls and boys (younger or older than 14).

The results above are obtained using two different observational methods, namely, regression methods and PSM method. However, observational studies are criticised for being vulnerable in estimating the treatment effects due to non-random treatment assignment (Shadish et al., 2002). However, a randomised experiment (Oster and Thornton, 2009) which was designed to analyse the impact of menstrual cup on girls' school attendance is found to have many other practical problems. Their research design may have suffered from selection bias from the onset. Moreover, the 'substitute effects' and 'sample attrition' effects which are evident from their data violated the principles of randomisation and therefore their estimation of the treatment effect deserves careful robustness checks. The post-randomisation problems associated with experimental trials mentioned above explain the difficulty of obtaining unbiased treatment effect even from a well-designed experiment.

Table 4.1: The probability of having access to poor water (Propensity Score)

(Girls post-menarche in year 1997 – Average Marginal Effects)

	Marginal Effects	z value
log household per capita income	-0.02	-0.32
water plant	-8.47***	-2.86
father's occupational status (1 to 4 category, 1 = the highest occupational status)	0.07	1.58
father's education (1 to 4 category, 1 = the lowest (no) educational qualification)	0.02	0.73
mother's occupational status (same as father's)	0.06	0.97
mother's education (same as father's)	-0.04	-1.58
household work (hours)	-0.02	-0.39
market work (hours)	0.01	0.76
having older brother	-0.04	-0.19
having older sister	0.11	0.90
having younger brother	-0.13	-0.71
having younger sister	0.12	0.95
having 2+ siblings	-0.02	-0.10
age (years)	-0.01	-0.72
village (25) dummies	Yes	
Number of observation	125	
Pseudo R-square	0.27	
Log Likelihood	-62.96	

Table 4.2: Comparing the propensity scores of the matched samples
(Girls post-menarche in year 1997)

block numbers	Inferior of block of propensity score	control	Mean propensity score	treated	Mean propensity score	t statistic for the difference of propensity scores
1	0.14	6	0.16 (0.03)	3	0.15 (0.03)	0.47
2	0.20	15	0.31 (0.06)	6	0.30 (0.06)	0.35
3	0.40	11	0.52 (0.07)	9	0.54 (0.06)	-0.68
4	0.60	9	0.71 (0.05)	26	0.72 (0.05)	-0.52
5	0.80	3	0.86 (0.05)	23	0.88 (0.05)	-0.65
	Total Number of Observations	44		67		

Table 4.3: Comparing the selected covariate means of the matched samples
(Girls post-menarche in year 1997)

Variables		Block 1	Block 2	Block 3	Block 4	Block 5
	N	T=6 C=3	T=15 C=6	T=11 C=9	T=9 C=26	T=3 C=23
log per capita income	T	6.40(1.54)	6.95(0.59)	6.74(0.52)	6.70(0.49)	6.82(0.28)
	C	6.09(0.80)	6.91(0.57)	6.68(0.88)	6.54(1.12)	7.26(0.90)
	t	0.40	0.14	0.17	0.59	-1.92*
father's occupational status	T	2.00(1.00)	2.67(0.82)	3.44(0.89)	2.88(0.71)	2.96(0.77)
	C	2.33(1.03)	2.53(0.92)	2.73(0.47)	3.33(0.71)	2.67(0.58)
	t	-0.46	0.32	2.29**	-1.64*	0.62
mother's education qualification	T	1.00(0.00)	2.50(1.38)	2.00(1.41)	1.96(1.15)	1.96(1.46)
	C	1.33(0.52)	2.00(0.84)	2.00(1.18)	2.11(0.93)	1.33(0.58)
	t	-1.06	1.02	0.00	-0.35	0.73
age	T	17.7(0.58)	16.8(1.72)	16.4(1.51)	16.8(1.77)	16.3(1.89)
	C	17.8(1.47)	16.3(1.80)	16.5(1.92)	16.7(1.94)	18.0(1.73)
	t	-0.11	0.58	-0.12	0.14	-1.48
children's household work	T	0.01(0.10)	0.34(0.62)	0.38(0.79)	0.17(0.40)	0.13(0.30)
	C	0.14(0.34)	0.28(0.47)	0.26(0.75)	0.20(0.30)	0.20(0.17)
	t	-0.91	0.21	0.35	-0.24	-0.62

Note: Standard deviations are in parenthesis.
The significance level of the differences: *** p<0.01, ** p<0.05, * p<0.1.

Table 4.4: ATT by year and gender (Continued on next page)

Year		Girls post-menarche	Girls pre-menarche	Boys aged >14	Boys aged =<14
1989	(1)	-0.33** (-2.11) T=55 C=24	-0.04 (-0.41) T=76 C=26	0.13 (0.98) T=94 C=35	-0.01 (-0.10) T=204 C=51
	(2)	-0.17** (-2.06) T=48 C=51	-0.04 (-0.48) T=76 C=50	*Not available*	*Not available*
	(3)	-0.23** (-2.08) T=55 C=51	-0.06 (-0.86) T=76 C=52	0.09 (0.76) T=94 C=77	-0.03 (-0.59) T=204 C=70
	(4)	-0.23** (-2.04) T=55 C=51	-0.05 (-0.54) T=76 C=52	0.06 (0.36) T=94 C=77	-0.04 (-0.56) T=204 C=70
1991	(1)	-0.23** (-2.04) T=71 C=24	-0.04 (-0.76) T=114 C=32	0.08 (0.29) T=66 C=21	-0.11*** (-2.76) T=118 C=54
	(2)	*Not available*	*Not available*	-0.06 (-0.44) T=44 C=37	-0.06 (-1.52) T=103 C=121
	(3)	-0.16* (-1.56) T=71 C=71	-0.03 (-0.63) T=114 C=81	0.08 (0.38) T=66 C=39	-0.07 (-1.47) T=118 C=127
	(4)	-0.22* (-1.72) T=71 C=71	-0.02 (-0.44) T=113 C=82	0.11 (0.77) T=64 C=41	-0.08* (1.94) T=118 C=127
1993	(1)	-0.26*** (-2.74) T=106 C=36	-0.08 (-0.04) T=107 C=28	-0.10 (-0.50) T=58 C=21	-0.03 (-0.50) T=143 C=49
	(2)	-0.10 (-1.07) T=106 C=83	*Not available*	0.09 (0.67) T=58 C=40	*Not available*
	(3)	-0.17* (-1.82) T=106 C=83	-0.05 (-0.41) T=107 C=72	-0.12 (-0.63) T=58 C=46	-0.01 (-0.22) T=143 C=87
	(4)	-0.19* (1.82) T=106 C=83	0.02 (0.14) T=102 C=72	-0.10 (-0.77) T=58 C=46	0.01 (0.13) T=143 C=87

(to be continued on next page)

Table 4.4: ATT by year and gender (Continued from last page)

Year		Girls post-menarche	Girls pre-menarche	Boys aged >14	Boys aged =<14
1997	(1)	-0.28** (-1.97) T=67 C=24	-0.06** (-2.40) T=96 C=25	0.14 (0.49) T=52 C=14	-0.06*** (-3.18) T=162 C=40
	(2)	*Not available*	-0.01 (-0.37) T=80 C=35	-0.10 (-0.64) T=35 C=26	-0.06*** (-3.04) T=162 C=83
	(3)	-0.19 (-1.38) T=67 C=44	-0.04 (-1.15) T=96 C=35	0.08 (0.30) T=52 C=30	-0.06*** (-2.88) T=162 C=83
	(4)	-0.22* (-1.59) T=67 C=44	-0.05** (-2.00) T=96 C=35	0.06 (0.45) T=52 C=30	-0.06*** (-3.21) T=162 C=83
2000	(1)	-0.16 (-1.34) T=77 C=30	-0.13 (-1.45) T=23 C=14	-0.17 (-1.11) T=54 C=23	-0.05 (-0.14) T=128 C=52
	(2)	-0.10 (-1.12) T=75 C=77	*Not available*	-0.17 (-1.46) T=53 C=55	-0.02 (-0.55) T=96 C=128
	(3)	-0.08 (-0.69) T=77 C=77	-0.11 (-1.52) T=23 C=33	-0.16 (-1.20) T=54 C=56	-0.04* (-1.89) T=128 C=129
	(4)	-0.07 (-0.71) T=77 C=77	-0.12 (-1.51) T=23 C=33	-0.10 (-0.76) T=54 C=56	-0.05 (-1.49) T=128 C=129

The Matching Techniques: (1) Nearest Neighbour Matching. (2) Radius Matching. (3) Kernel Matching. (4) Stratified Matching. T = Treated; C = Control. T statistic is calculated using bootstrapped SE and given in parenthesis.

Table 4.5: Grade, age and enrolment rates in Nepal, 2008

Level	Primary	Lower Secondary	Secondary	Higher secondary + Tertiary
Grade	1 - 5	6 - 8	9 - 10	11+
Age	5 - 9	10 - 12	13 - 14	15 +
Average girls enrolment rate	92 %	57	35	--- (very low)

Sources: UNESCO 2008, p1, http://unesdoc.unesco.org/images/0017/001779/177948e.pdf, Education Report 2065, Ministry of Education, Nepal, 2008-2009, p25, p33.

Table 4.6: The proportion of different types of water access

OT sample 2006 (Rural Nepal)		CHNS sample 2006 (Rural China)	
Tube water	0.72	Tap water at home	0.49
Metered water	0.23	Tap water in yard	0.18
Open well	0.09	Open well	0.21
Stream	0.035	Stream	0.02
Total	***107.5%***	Total	100%

Note: Proportions in OT sample is kindly provided by Emily Thornton.

CHAPTER FIVE: ACCESS TO WATER, MENSTRUATION AND WOMEN'S WORK

"*Women and girls in poor countries cannot afford sanitary pads and tampons … Instead the vast majority of women and girls in Bangladesh use rags These are usually torn from old saris and known as 'nekra'… there is no private place to change and clean the rags and often no safe water and soap to wash them properly … This practice is responsible for a significant proportion of illness and infection…* " (Ahmed and Yesmin, 2008, 284)

5.1 Introduction

In previous chapters, the special impact of poor access to water on girls' education after the onset of menarche is investigated. Many different estimation methods consistently reach the same conclusion that the girls post-menarche suffer in their schooling much more than boys or girls pre-menarche if access to water is poor. The basic mechanism of the impact seems to be that poor access to water raises special costs (menstruation related - health costs; - time costs; and - psychic costs) of education for girls post-menarche and therefore inevitably leads them to have early drop-out or shorter schooling duration.

In this chapter, the researcher aims to investigate whether women's wage work participation is also subject to the above mentioned special costs. More women participated in wage work and the women's share in wage work in rural China also increased quickly since 1990s (Zhang et al, 2004). Bejamin et al (2000) also find that proportion of women with wage work within a household is already 19% in mid 1990s in rural China (43% for men). This trend is considered to be an important signal to improve women's socio-economic position in China (Zhang et al, 2002; Jacka, 1997). To increase the proportion of women in wage employment has also been considered as one of the important indicators to empower women, and therefore is listed as one of the millennium goals by the United Nations (UN Data, 2009).

It is found that the menstrual cycle indeed affects women's work attendance – again perhaps due to the menstruation related health/time/psychic problems when access to water is poor. For example, Ichino and Moretti (2009) find that about 30% of the gender difference in days of absenteeism is duo to menstrual symptoms. However, if the impact of menstrual cycle on women's work attendance is mainly through menstruation related illnesses, this impact should be worse for women with poor access to water, since menstrual problems are reported to be more pronounced for women with poor hygiene facilities (Ahmad and Yesmin, 2008; Dagwood 1995; Severino and Moline, 1995).

This study hypothesizes that, on the one hand, poor access to water increases special costs of wage work involvement for women pre-menopause due, presumably, to increased time/health/psychic costs, for which a higher wage (compensation) is required to do same amount of wage work. On the other hand, frequent absence or lower productivity resulting from working with poor health and pain may affect labour demand, for example, by pushing women pre-menopause into less responsible job categories. Demand and supply side factors may then jointly determine that pre-menopause women with poor access to water reduce the amount of the wage work they are involved in or simply are more likely to be dismissed or not hired in the first place.

Women with good access to water are expected to experience less of an impact of menstruation, and therefore their wage work involvement may be less stressful (less costly) and their productivity level is also less likely to be affected – and consequently their wage work participation rates may become higher. By definition, the menstruation-related impact of poor access to water does not exist for women post-menopause, therefore the difference in wage work participation after menopause may not be as big as that before menopause. It is, however, difficult to prove that adverse consequences of poor access to water on pre-menopause women's wage work participation arise due to lower productivity or health/time/psychic costs even though they seem to be plausible causes. So the intention of this chapter is to test, using different statistical methods, whether such an adverse impact of poor access to water exists for women pre-menopause and not for women post-menopause.

The data used in this study again come from the Chinese Health and Nutrition Survey (CHNS), jointly conducted by the University of North Carolina and the Chinese Academy of Preventive Medicine, Beijing. This chapter uses information for men and women aged 16-60 from rural areas ("rural" is defined according to household registration) unlike the previous chapters that considered only 6 – 19 year olds. The CHSN has specific information on household access to tap water as well as information on women's menopause status (though only in wave 1993). Moreover, it has virtually all the control variables that would normally be considered for testing the determinants of wage work participation.

Two empirical strategies are used for the tests and the results support the hypothesis of access to water and menstruation interacting in determining participation. First, a set of regression models are used to identify the joint impact of these variables. Secondly, the hypothesis is tested using the Propensity Score Matching (PSM) technique. A marked impact of poor access to water is indeed found for women pre-menopause. The tests show that 40% of the unconditional mean difference in wage work participation between pre-menopause women with good and poor access to water may have been caused by menstruation related problems.

The discussion below is organised as follows: in section 5.2 the research context is introduced. In section 5.3 the theoretical justification of the hypothesis is outlined. In section 5.4 the two different empirical specifications are designed for the test. In section 5.5 the regression results are analysed. The final section concludes the chapter.

5.2 Access to Water and Wage Work Participation in Rural China in 1993

The research context for this study is chosen to be rural China. This specific setting provides suitable conditions to test the hypothesis. First, a considerable number of households still did not have access to tap water in rural China in year 1993 – data from which year is used to test the hypothesis, because the menopause data only exist for this year (wave). Figure 2.4 gives the proportion of households which have access to different types of water in rural China for my sample. As can be seen, in 1993, about 54% of the households do not have access to tap water (in-house and in-yard). In this study, access to tap water is regarded as having access to good water and it is generally used as proxy for household hygiene (Jalan and Ravallion, 2003). Second, millions of women have participated in rural wage work thanks to the economic reforms carried out since early 1980s while still a great number of them do farm work and self employment outside the wage work. Such a division on water access and wage work participation makes the context (rural China, 1993) a suitable place to test the hypothesis of this research.

The development of labour markets for males and females in rural China, like in urban China, is equally unprecedented. On the demand side, more job opportunities have been created by the liberal market policies and continuous economic growth of China. Rural wage work accounts for about 1/3 of total rural labour force in the 1990s and among those workers nearly half of them were employed by private and individual enterprises (Sicular and Zhao, 2004: p 241). On the supply side, the number of individuals who newly entered the labour market may be declining because of the strict population control that started in 1970s, but education and access to water have been improving. Both demand and supply side factors make it increasingly popular to seek wage work in rural China. Women also benefited greatly from this trend. As noted earlier, women's share in wage work in rural China is found to increase quickly since 1990s (Zhang et al, 2004).

Some important laws were also passed in China after 1980s to ensure that there is not discrimination against women with regard to the labour access and pay. Among them, the most important one is "The Law of People's Republic of China on the Protection of Rights and Interests of Women, 1992 (*The Law*)" which specifies that women have equal rights in all aspects of life. The Articles 21 and 22 of *The Law* made specific notes on the protection of women's rights in the workplace. For example, women should not be subjected to discrimination and hiring and firing decisions must not be based on sex, women must be paid equal pay for equal work, and must benefit from all work-related benefits equally as men. There are specific regulations in other Articles of *The Law* about women's promotion, training, skill assessment, health and safety.

The relevant regulations and laws that are designed to protect women's rights at the workplace certainly played positive roles in increasing women's work participation and decreasing the gender pay gap. Admittedly, in some areas the carrying out of *The Law* is not strict and women's rights are not fully protected (see for example, Burda 2007, for detailed discussion). This reality suggests that there may be variations in the implementation of the same law in different villages (e.g. the implementation of the law may be less effective in villages that are geographically remote and where labour markets are not well developed). Furthermore, rural villages in different parts of the country may have their own disciplines and specific rules regarding the protection of women's rights in labour markets in those localities. Therefore, the village dummies included in the estimation are important controls to account for this variation between the villages.

Education, marriage and fertility are all important determinants of work participation and therefore their impacts should be controlled for in empirical analysis. The increase in women's educational attainment and work experience contributed in some ways to reduce the gender gap in wage work participation as well (Zhang et al., 2002). However, the marriage and the different tasks of rearing the children assigned to women are found to help widen gender gaps in wage work participation (Hare, 1999; Entwisle and Chen, 2002). The reasons may be that married women in general spent relatively more time than men in family related activities (child rearing, cooking, cleaning) and hence are less mobile, have often less experience or shorter tenure in market work.

The closest to this research is the research done by Hare (1999) and Zhang et al (2002). They both investigated the determinants of the wage work status using probit models. Following the method of Hare (1999), the ‘wage work participant’ status is a dummy variable. It takes 1 when respondents reply that they have been involved in wage work activity as employees during the last 12 months, and 0 if no wage work has ever been conducted. The proportions of wage work participants among the total labour force by gender and water access type in 1993 are given in Table 5.1: As can be seen, men in general participate more in wage work – about 33% of rural male labour force, and only 20% rural female labour force in 1993 reported that they were involved in some kind of wage work – these figures are generally in line with the findings of Benjamin et al (2000) even though the computational methods are different.

Table 5.1 provides the means of major variables used in this study. It shows some interesting patterns. Where there is good access to water, both men and women participate in wage work by 20 percentage points more than their peers with poor access to water. Women with good access to water also participate in wage work 7 percentage points more than men with poor access to water. In this regard, poor access to water is likely to be correlated with backward geographical location where wage work opportunity is scarce. This fact requires detailed control for location and other confounding factors in order to filter out the impact of poor access to water on wage work participation.

The data used in this study reveal that women mainly start to have menopause from the age 43, and after the age 50 few will be left without it. So for women younger than 43 a pre-menopause status is imposed where missing values are observed. For women older than 50 a post-menopause status is imposed where missing values are observed. For women aged 43-50, no imputation is made. Altogether, about 82% of women in the data have pre-menopause status. The total sample size is about 2700 women and 2700 men almost equally separated by access to water status as shown in Table 5.1.

Table 5.2 provides motivation. As can be seen from the first row, women with poor access to water (non tap water) have a 6 percentage point lower wage work participation rates post-menopause. However, pre-menopause the disadvantage is more pronounced, 23 percentage points. Therefore the relative disadvantage in wage work participation of pre-menopause women with poor access to water is 17 percentage points. Men are also divided into two groups based on the age distribution of menopause (post-menopause women are generally older than 45, and pre-menopause women are generally younger than 50). Men with poor access to water in whichever age category have about 20 percentage point lower wage work participation, so the relative disadvantage in wage work participation does not exist for men aged 45 or younger. Overall, the difference of the relative disadvantage of pre-menopause women with poor access to water in wage work participation reached 18 percentage points compared to that of men aged 45 or younger. In the following sections, the pattern in Table 5.2 will be tested after controlling for other confounding factors.

5.3 The Mechanism of the Joint Impact on Wage work participation

This study hypothesises that joint impact of menstruation and poor access to water may make women less likely to participate in wage works because it could decrease the labour demand in wage work sector due to lower productivity, or because it could decrease the labour supply in wage work sector due to higher costs of participation. When women find costs of participating in one sector too high, they could simply choose alternative sectors which are not subject to such high participation costs, or simply choose leisure. Following, the demand and supply side factors which decreases wage work participation of women due to the joint impact of menstrual cycle and poor access to water will be discussed in detail:

5.3.1 Demand Side Factors

Menstruation related health problems tend to create more absence (Ichino and Moretti, 2008). Pre-menopause women with poor access to water may experience even more absence because poor hygiene (one proxy is poor access to water – Jalan and Ravallion (2003)) is found to increase menstruation related health problems (see Dagwood 1995; Severino and Moline, 1995). Frequent absenteeism is considered to be a contributing factor for lower productivity at the work place, and therefore is negatively correlated with the employee's true current worth for the firm (Flabbi and Ichino, 2001). Hence, pre-menopause women with poor access to water may have higher probability of being dismissed by firm managers due to such 'lower worth' compared to pre-menopause women with good access to water and therefore may face more dismissals. Besides, firing decisions are often summary and non-reversible in less developed locations like in rural China (see for example, Burda 2007, for detailed discussion).

However, when menopause is onset, frequency of absenteeism is found to decrease (Ichino and Moretti, 2008) presumably due to the decrease in menstruation related problems. Since, post-menopause women with poor access to water do not have extra menstruation-related hygiene/health problems compared to post-menopause women with good access to water they do not require extra absence. Consequently women of these two groups may have 'equal worth' for the firm controlling for other factors, and may therefore experience similar participation rates.

The pre-menopause women with poor access to water may also likely be rejected for wage work employment by firm managers at the first place due to statistical discrimination (Phelps, 1972). Such discrimination arises because managers may often find that men and women from households where there is good access to water provide more consistent service compared to younger (pre-menopause) women from households with poor access to water (The managers do not know the access to water status of the women's households, but they may generally guess it from the average water access rates of the community that those women came from). As for older (post-menopause) women with poor access to water, managers may find, in a longer period, that they supply their labour as consistently as those older women with good access to water (due, perhaps, to a disappearance of menstruation related hygiene/health problems) controlling for other factors. So, older women, no matter they have good or poor access to water (no matter coming from what geographical location), may be treated equally when hiring decisions are made in a firm. This type of statistical discrimination will reject the pre-menopause women with poor access to water in the first place even though those women may have very different commitments and attitudes toward wage work participation among themselves.

In sum, even though the mechanism of the joint impact of poor access to water and menstruation on wage work participation is less clear to the managers, but they can identify what typical group is less likely to provide consistent service in the long run. Hence, due to this statistical discrimination, younger women from backward locations (more likely to have poor access to water) may be rejected for the work relatively more in the first place. Therefore there may be an inward shift of the demand curve for younger (pre-menopause) women from backward locations where poor access to water is prevalent.

5.3.2 Supply Side Factors

On the supply side, poor access to water may generate extra costs (menstruation related – time/health/psychic costs – discussed below) on wage work participation for women pre-menopause. Therefore, pre-menopause women require higher compensation to balance the higher cost of participation, consequently, their labour supply decreases holding wage rates constant.

Apart from carrying water to their homes and farms for daily chores, pre-menopause women with poor access to water may have to travel to the water sources more during their period for hygienic purposes (Ahmed and Yesmin, 2008). So, poor access to water may increase the marginal costs of time for pre-menopause women during their period to participate in wage work. Higher costs require higher compensation (wage) to get balanced. In a context where there is relatively sufficient labour supply such as in rural China, the higher wages are less likely to be offered to offset the adverse impact of higher time costs in wage work participation. When the increase in time costs are not compensated by increased wages, pre-menopause women with poor access to water may choose other occupations, such as farming or self employment where they do not necessarily see increased time costs during their period, because more relaxed time arrangements for labour supply are available in these occupations.

Pre-menopause women may suffer more from menstruation related health problems when access to water is poor as suggested by Dagwood (1995) and Severino and Moline (1995), and the menstruation related illness and infection caused by poor access to water may extend beyond the menstrual cycle (Ahmad and Yesmin, 2008). When they have to participate in some sort of labour during this period, the increased health concerns may increase the marginal costs of labour supply. Holding wage rates equal, higher costs of labour supply will again reduce total labour supply, therefore a decrease in wage work participation may occur. Pre-menopause women with poor access to water may again choose other occupations (farming, self employment) where timing of labour supply can be more flexibly adjusted to allow for the recovery from the illness.

In chapter two, some discussions were held about how poor access to water generates specific psychic problems for girls post-menarche when they attend schools. Burrows et al (2004, 14) describe how poor access to water make girls have a sense of being unclean when there is little water to wash themselves and how this can lead them stay away from their schools during their period. Kirk and Sommer (2006) also describe the psychic problems of post-menarche girls during school attendance when they are not able to remove the odour and spot resulted from menstruation. The same psychic problems may arise for women pre-menopause at the workplace if they can not properly wash during menstruation. Again, higher psychic costs, if they do arise for women pre-menopause due to poor access to water, will require higher wages to compensate. If wage rates remain unadjusted, high psychic costs of participating in wage work may lead women chose other occupations (farming/self employment) where timing of labour supply can be adjusted to when the psychic costs of labour supply are lower (e.g. outside the menstrual period).

5.3.3 The Mechanism

The mechanism is explained in Figure 5.1. Men have a labour supply curve S1. Pre-menopause women with good access to water are less likely to have menstruation related health problems and so are assumed to have a similar labour supply curve (S1) as men. For these types of people, the demand curve is set at (D1). Therefore, for each group, the amount of labour cleared in the market is L1. Pre-menopause women with poor access to water may suffer in wage work sector from menstruation related time/health/psychic problems during their period (discussed above) and require higher wages for same amount of work to compensate the costs, therefore supply curve moves inward (S2). The demand curve also shifts inward (D2) because of lower productivity and statistical discrimination (discussed above), and therefore, the amount of labour cleared for pre-menopause women in the labour market is L2. While there is no flexible contract or sufficient protection, women requiring fewer hours of work or higher wage compensation for equal amount of work tend to get dismissed by the management in the first place, so for them, less involvement in wage work may occur.

The overall amount of labour cleared in the market is different for pre-menopause women (as can be seen from Table 5.1) so their demand and supply curves can be drawn in a separate frame (not shown). After the onset of menopause women have no menstruation related problems due to poor access to water, therefore, holding other things constant, poor access to water does not make any difference between the supply curves of post-menopause women with good and poor access to water. The demand curve may remain the same due to 'equal worth' (discussed above) controlling for other factors. So, labour cleared in the wage work market for these two groups of women will not differ due to poor access to water.

5.4 The Empirical Strategy

5.4.1 Regression Analysis

To study the interaction of access to water and menstrual cycle, a difference-in-difference specification is used (the model is presented only for the convenience of interpreting the strategy, in most of the cases separate regressions will be estimated for different groups to allow full variation of the impacts of other control variables in the estimation models):

$$Y_i = \beta_1 + \beta_2 W_i + \beta_3 M_i + \beta_4 W_i \times M_i + \beta_5 X_i + \varepsilon_i$$

where i denotes individuals; Y_i is an indicator for having participated in any wage work during the last 12 months; X_i is a vector of controls for individual and household characteristics; W_i is an indicator equal to one if the household has no access to tap water; M_i is an indicator equal to one if the individual still experiences menstruation; and φ_s is a full set of 138 village dummies (in some cases 36 county dummies). ε_i is assumed to follow normal distribution with 0 mean and constant variance.

β_4 is the coefficient of interest (for detailed procedures, see section 3.2). It is expected that poor access to water will have a more adverse impact on pre-menopause women's wage work participation, due to the hygiene/time/psychic related menstrual problems they face as described earlier. These considerations point to a negative interaction between the access to water and menstrual cycle. The adverse impact of poor access to water on pre-menopause women (β_2) is expected to be small or zero. However, one limitation of this approach is that the only variable that is allowed to have different impact between women pre- and post-menopause is access to poor water, while there may be systematic difference in their labour market outcome given very different characteristics. For example, the latter (post-menopause) group may generally be older and therefore it may not be allowed to pool these two groups of women in a single regression.

To resolve the problem a probit model is estimated for these two groups separately. The impact of access to water on the wage work participation is then compared between the models. A separate probit model is also estimated for men, since women may have different aspirations or attachments to a specific job, and they may also differ in their commitments and attitudes to work. The separate regressions will yield similar results to a single model where effects of all control variables are allowed to vary between different groups. A probit model (Cameron and Trivedi, 2005, 470) specifies the conditional probability

$$p = \Phi(x'\beta) = \int_{-\infty}^{x'\beta} \phi(z)dz \qquad (7.2)$$

where Φ*(x)* is the standard normal cumulative distribution function with derivative $\phi(z) = (1/\sqrt{2\pi})\exp(-z^2/2)$ which is a standard normal density function. After estimating the probit coefficients, average marginal effects (AME) of the regressors are estimated since estimating the AME is recommended for policy analysis (Cameron and Trivedi, 2009, 340). The AME may also be more comparable to the average treatment on the treated (ATT) that is to be obtained in the second phase of this research since both of them measure average effects of a treatment on those who received the treatment, *not* the effects of treatment on average person as Marginal Effects at the Mean measure.

The control variables included in the regression are similar to those used in (Hare, 1999 and Zhang et al., 2002). The respondent's educational qualifications and age are included as measures of human capital which act as proxy for the expected wage offer. The quadratic in age is included to capture the non-linear effects of human capital. As for access to water, Table 5.1 shows respondents with good access to water always have higher levels of educational qualifications. For example, 68% women with poor access to water have only primary school education or no qualification at all, compared to 53% women with good access to water – the difference reach at 15 percentage points. An 8 percentage point difference in high school or above level qualifications also exists between these two groups of women. For men, marked differences in educational qualification can also be traced. This reality shows the importance of controlling for education level in the participation equation. As for ages, the means are all centred on around 35.

Table 5.1 also shows that the marital status is similar among different access to water groups with a mean of 0.82~0.85. The number of household workers is a variable included in the model to capture the scale effects in the household (see, Hare, 1999). Respondents with poor access to water generally have families with more adults who are working (all types of labour). There is not much difference between the groups with regards to the number of elderly people over 60 who are present at home. This variable together with the variable – number of children under 16 and number of children under 6 – are included in the model to capture the impact of family duties on wage work participation, and this impact is expected to be different between the men and women. Also included in the regression is land owned per family adult member. Respondents with poor access to water own about 1 times more land per adult than those with good access indicating poorer and more agricultural households. More land ownership could also indicate more home-farm work opportunities which serve to reduce the hours that an individual could supply for market (wage) work (see, Polachek and Siebert, 1999, 109).

Judging by the statistics shown in Table 5.1, poor access to water may be correlated with backward geographical location, extreme poverty or simply unfavourable village environment. These factors may generate systematic differences between the observations in treated (poor access to water) and control (good access to water) groups regarding their wage work participation. So the true impact of poor access to water on the outcome (wage work participation) may become 'contaminated' by these confounding factors if the impacts of those factors are not controlled for (Becker and Ichino, 2008).

One example is that a mountainous village, where there is no tap water access, maybe economically and culturally backward, so labour markets may not be as developed there as in some other villages where there is access to tap water to everyone. In this regard, poor water may simply pick up the effect of backward geographical location which reduces the possibility of wage work participation. To tackle the problem, a unique variable – proportion of off-farm employment in the village is generated to capture the effect of village labour market development. It is clear from the Table 5.1 that respondents with good access to water are indeed more likely to come from villages where the rate of off-farm work participation is higher. Moreover, 138 village dummies are also included in the probit regression (and in propensity score models) to capture the unmeasured village fixed effects.

In fact, wage work participation may increase the chances of household access to tap water through increased household income and may thus make tap water access endogenous (though no impact of household income on tap water access is found in Chapter 3 and Chapter 4 , see for example, Table 3.2 and Table 4.1). Besides, unobserved individual characteristics (an active attitude for hygiene and work) may be positively correlated with wage work participation and access to good water, and may also cast doubt on the exogeneity of access to tap water. Therefore, the instrumentation of access to water may become necessary.

It is found that government investment in village tap water construction (variable *plant* in chapter three) is a good instrument which is highly correlated with the probability of a household having access to tap water, but is not directly linked to an individual's wage work participation decision (the estimated impact of the *plant* variable is insignificantly different from zero in wage work participation models). For this reason, an instrumental variable probit model will be estimated in the first place (separately for men and women) to check for the exogeneity of household access to tap water in the wage work participation equation.

5.4.2 Propensity Score Matching

Regression analysis provides a complete mechanism to analyse the treatment effects. In particular, any possible selection bias can be tackled by including all 'necessary' variables in ideal circumstances in the regression as controls (the so called 'long model') and appropriate instrumentation (see Angirst and Pischke, 2009). However, the Propensity Score Matching (PSM) technique provides an alternative approach to test the robustness of the regression results and is believed to reduce the bias of regression estimates by making the observational studies more like a natural experiment where assignment of treatment is random (Becker and Ichino, 2002).

Rosenbaum and Rubin (1983) assert that this method can help identify the individual impact of a treatment (in our case access to poor water) on the treated in observational studies particularly when there are other confounding factors which make the randomness of the treatment assignment questionable. Without a valid randomisation procedure, the treatment effect may not be correctly identified and estimated. In other words, the estimated treatment effect may be biased due to the possible selection problem (Guo and Fraser, 2009).

PSM does not have linear functional form assumptions, but makes two important assumptions: common support and conditional independence (for detailed discussions, see Chapter Four). The first assumption is about comparing the individuals with similar characteristics. In other words, based on the observable characteristics of treated and control units, the assignment of treatment can be expected to be random between them. The Conditional Independence Assumption (CIA) requires that the wage work participation decision of respondents is independent of worker type given the values of observable characteristics.

The specific procedure of PSM ensures that the assignment of the treatment is more random between the comparison groups: (1) it excludes the observations outside the common support region, so that treatment and control units can be more comparable (Becker and Ichino, 2002). (2) it separates the observations into different blocks according to their pre-treatment characteristics which helps guarantee that they all have an equal probability of having the treatment (access to poor water) within each block. In other words, even though the treatment is not random comparing all observations in treatment and control groups, it is random within each specific block (Guo and Fraser, 2009). The effect of the treatment will then be identified within each block first and then the average taken across blocks. (3) The average treatment effects on the treated (ATT) is computed using non-parametric methods, so there is no need to assume any functional form for the estimation (Becker and Ichino, 2002).

The mechanisms of estimating propensity scores and the ATTs are described in detail in chapter 4, so they will not be repeated here. All four types of common matching techniques given in Appendix 1 are again used in this chapter to estimate the ATTs.

5.5 The Results and Discussion

5.5.1 Regression results

First, an instrumental variable probit model is estimated for women and men separately to test the exogeneity of poor access to water in wage work participation models. In all models, poor water access is tested to be exogenous. This is not surprising given the fact that no impact of household income on household access to tap water was found in Chapter 3 (see Table 3.2). In Chapter 2, the researcher also found that household access to water is a village level construction which requires considerable investment, an amount that can not be afforded by a typical individual or household. The IV probit model results in Table 5.3 also show that the impact of poor access to water is only significant and quantitatively much bigger for women. When separating the women's model by post- and pre- menopause status, the significant adverse impact of poor access to water only existed for women pre-menopause (results not shown – the group specific impacts will be discussed below).

Given the exogeneity of access to poor water in wage work participation equations, an ordinary probit model will instead be used to quantify the impact of poor access to water on wage work participation of a specific group (women pre-menopause and women post-menopause). As mentioned in section 3.2, when a regressor is tested to be exogenous, using ordinary probit has many advantages over IV probit.

Table 5.4 presents the average marginal effects (AME) estimated from the coefficients of ordinary probit models. Two models ((1) and (3)) allow the inclusion of village (151 in total) dummies, while in model (2) and (4) county (36 in total) are included due to small sample size. Some village and county dummies are dropped in the actual regression due to collinearity. The probit model is estimated for women pre- and post-menopause separately to allow for the impacts of different family structures to vary by menopause status. Two probit models are also estimated for men aged 45 or younger and over 45 for comparison purposes (the age spans chosen are generally accord to the age spans of pre- and post-menopause women in the sample).

As can be seen from Table 5.4, the average marginal effect of poor access to water is still only significant for women pre-menopause, while the impact is virtually zero for post-menopause women and men after controlling for other factors. On average, poor access to water is found to reduce the probability of wage work participation for women pre-menopause by 6 percentage points holding other things equal. The underlying probit coefficient is -0.37 which is a little smaller compared to IV probit estimation of -0.49 (after transforming to the coefficients to marginal effects, the difference will be smaller), suggesting that a slight negative selection bias may exist in the estimation which makes the impact of poor access to water downward biased. This reality shows the importance of improved randomisation of treatment assignment. The average treatment on treated using the propensity score matching will be compared to the estimated impacts of poor access to water

(6 percentage points) in probit models to test the validity of the claimed negative selection bias.

The impacts of other control variables are also found to be significant. Higher educational qualifications play very important role in wage work participation and the impacts are pretty much the same among women pre-menopause and men in all age categories. Having high school or above qualifications is found to increase the probability of wage work participation by about 20 percentage points compared to having primary or no qualification. However, the impact is small for women post-menopause perhaps due to the fact that post-menopause women, being older, have far less higher educational qualifications compared to other groups. Age (generally a proxy for experience effects on the wage (Hare, 1999)) is found to be positively correlated with wage work participation in most of the models, but the impact declines over time (an adjusted average marginal effects for age and age squares are computed following the suggestions in Bartus (2005), but similar impacts are observed – results not shown).

The marital status variable on the other hand has different impacts between the genders. It has a strong negative impact on pre-menopause women's participation (-0.07, presumably because wage work requires commitment and it affects women's household duties) while its impact is positive for men's (0.08~0.13, presumably because women specialises in household work and farm work so that men can involve in more wage work). This finding is in line with the findings of other literature in general (e.g. Hare, 1999). The number of workers in a household is also found to be positively related to wage work participation of pre-menopause and men aged 50 or younger, and the impact is bigger for women pre-menopause. One explanation is that more adult labourers at home will be able to share the household tasks and make it easier for women to involve themselves in wage work activities outside the home.

Elderly people at home in general have very little or no impact on participation, while the presence of children younger than 16 is a strong indicator of less participation for pre-menopause women and men aged 50 or younger. The impact is surprisingly positive for women post-menopause and non-existent for older men. However, having children under 6 has a dramatic negative impact (-0.21) on post-menopause women's wage work participation while it has virtually no impact for other groups. This finding may be related to the fact that in rural China, often older women (aged 55 or older) look after young children to support younger women and men (their daughters and sons) to do the work (Entwissle and Chen, 2002)

Land ownership is negatively correlated with the participation indicating that farming is an alternative to wage work. An increase of per capita land ownership of one *mu* reduces the probability of participation by about 2-3 percentage points for women pre-menopause and younger men, but 7 percentage points for post-menopause women. The off-farm work proportion in the village has positive impacts on wage work participation of everyone and the impact is generally found to be bigger for women, validating the claim that women benefits more from labour market developments in rural China (Zhang et al, 2004). Finally, it must be emphasised that 138 village dummies are included in the model to pick up unobserved village fixed effects – e.g. culture and remote geography. While some villages are automatically dropped at the actual regression, and many of the remaining villages possess significant fixed effects, a fact that shows the importance of controlling at the village level.

5.5.2 PSM results

The regression results show that the impact of poor access to water is found to exist only in the model of pre-menopause women, and for other groups the impact is zero after controlling for other confounding factors. However, a slight negative selection bias is suggested in regression analysis when original coefficients of IV probit and ordinary probit models are compared. If the bias indeed exists, it will downward bias the adverse impact of poor access to water on wage work participation of women pre-menopause. The propensity score matching estimator is asserted to reduce selection bias by improved randomisation of treatment assignment (Becker and Ichino, 2002), and therefore its results can be used to test the direction and intensity of the bias obtained using ordinary probit model. In this section, the tests will only be conducted for pre-menopause women. Relevant test results will also be given for men aged 50 or younger for comparison purposes.

The covariates included in the logit models to derive the propensity scores are generally the same with those in IV probit models in Table 5.3 (first stage), apart from the fact that now 138 village dummies are included in the propensity score estimation instead of 36 county dummies included in IV probit models in Table 5.3. The impacts of covariates however remain generally the same and therefore the results are not given in separate tables. The logit model is estimated for men and women (pre-menopause) separately for the reason of covariate balancing before matching. In the logit models, the most important determinants of having poor access to water is the intensity of government water pipeline construction (*water plant*) and the village fixed effects (results not shown), a finding that is in line with the findings in previous chapters.

In the logit models (results not shown), the individual and household level characteristics generally show no significant impacts (the only significant one is high school or above qualification having negative impact on poor access to water in men's model). In a separate specification, per capita household income is also included, but its impact is again found to be insignificant (results not shown). This finding lends further support to the exogeneity of access to tap water, that is, the access is not relevant to individual or household characteristics and so wage work participation does not necessarily bring tap water to home or courtyard. It is rather an outcome of geographical location and relevant investment from the government that makes household access to tap water possible.

When estimating the propensity score, the researcher restricted the balancing hypothesis test (Mean comparison of covariates between control and treated groups) to be performed within the common support region and this restriction will improve the quality of the matching (Guo and Fraser, 2009). In other words, the test will guarantee that within each interval, the means of each characteristic do not differ between treated and control. The balancing hypothesis is satisfied for all groups in all blocks.

The results of the covariate mean comparisons between treated and control groups of women are shown in the Table 5.5 (The comparison of the covariate means for men in each block is also conducted, but the results are not shown as they show the same pattern as those of women in Table 5.5). These figures are obtained after propensity scores were estimated and observations from the treated and control groups are separated into different blocks. The total number of blocks that is eventually set depends on whether the propensity score is balanced in each block. Finally 6 blocks for women and men are obtained. In Table 5.5, the first row gives the inferior (lower) bound of the probability of having poor access to water for each block. For example, in block 2, the probability of having access to water varies from 0.2 to 0.39. But the mean of propensity score between the control and the treated units should be the same in each block. The second row presents the numbers in control and treatment groups in each block after observations outside the common support region are dropped.

The t-test results show that the mean values of selected covariates within each block are not different between the treatment and control groups – in fact, there is not a single significant difference (For other covariates not shown in the table, the means are also found to be not different). As have been noted earlier, even though the covariates have systematic mean differences between control and treated, PSM will make the difference disappear within each block where matching is conducted, so that the assignment of treatment can effectively be made random. For example, the per capita land ownership varies a lot between the control and the treated in the original full sample (Table 5.1) – that is, the respondents with good access on average possess half the amount of the land of those with poor access to water. However, now in each block, the amount owned by different groups does not differ at the mean. When respondents in the control group are found to have bigger amount owned (e.g. block 1 and block 3) observations with bigger amount is also assigned in the treatment group. Smaller amount of ownership (e.g. block 2 and block 4) also correspond between control and treated groups and that the background characteristics are made as similar as possible for the two comparison groups.

Table 5.6 gives the estimation results of Average Treatment on Treated estimates. ATT is estimated for women and men separately using the four matching techniques. The results show similar pattern of the treatment effect (poor access to water) for women which are quite different from that of men. A significant impact is only found for women (pre-menopause) while no impact is found for men. The size of the impact however varies somewhat between the different techniques. The Nearest Neighbour Matching method gives ATT of -0.13, indicating on average poor access to water reduces the probability of women's wage work participation by 15 percentage points holding other things equal. This effect is much greater than the -0.6 average marginal effect in probit model. However, the other three matching techniques (Radius, Kernel and Stratified) suggest that the impact is around 9 – 10 percentage points.

The Nearest Neighbour Matching method is based on the matching of the nearest control with the treated either through random draw or equal weighting. The main limitation of the method is that sometimes the distance of the control unit and the treatment unit which are pairs of comparison is too big, so a bias in estimation can occur. Nevertheless, based on the results of the last three types of the matching, a 10 percentage point decrease in the probability of wage work participation can be confirmed for women pre-menopause if the access to water is poor. The results also show that there is indeed a negative selection bias exists in ordinary probit model which causes downward bias on treatment effect and IV probit model helped corrected for this bias. This is a large impact, considering the unconditional mean difference of wage work participation between women with good and poor access to water is about 23 percentage points (Table 5.1). In other words, about 40% (=0.10/0.23) of unconditional mean difference between pre-menopause women with good and poor access to water may disappear only if all pre-menopause women have good access to water.

The empirical strategy of this study is based on the 'labour market entry' model (i.e. involving in wage work is regarded as the entry into the labour market) to identify the factors which determine the wage work participation in China (Hare, 1999; Zhang et al., 2002). However, an alternative approach is to set up the model as 'occupational choice' model (Dolton and Makepeace, 1990). In this approach, the earnings differences between the different occupations explicitly enter the estimation equation. Applying the method of Dolton and Makepeace (1990) in this study, one can assume that there are only two types of occupation – wage work and non-wage work. First, earnings equations are estimated by correcting for selection bias so that fitted values of earnings in two occupations can be obtained for each individual (one is for the occupation he/she is involving, one for the alternative occupation). The difference of these two types of earnings then enters the occupational choice model explicitly and acts as a control variable.

In fact, using the 'occupational choice' model with the CHNS data gives the same general pattern – poor access to water only affects women pre-menopause, and for men the impact is none existent. However, the size of impact dropped to -0.03 from -0.06 (model (1) in Table 5.4). However, the standard errors exert rather strange patterns, and are prone to the change of model specifications. While the researcher acknowledges the importance of controlling for different earnings premium explicitly in different occupations, the current data structure of this study does not allow for a fine control for it. Basically, the earnings of non-wage workers are not realised by the market and therefore mostly imputed. The possible measurement error caused by this imputation may cause bias in the actual estimation. For this reason, the researcher is still inclined to stick to the 'labour market entry' model which does not require the earning difference to enter the model explicitly. However, with improved data the 'occupational choice' model may provide even more convincing results.

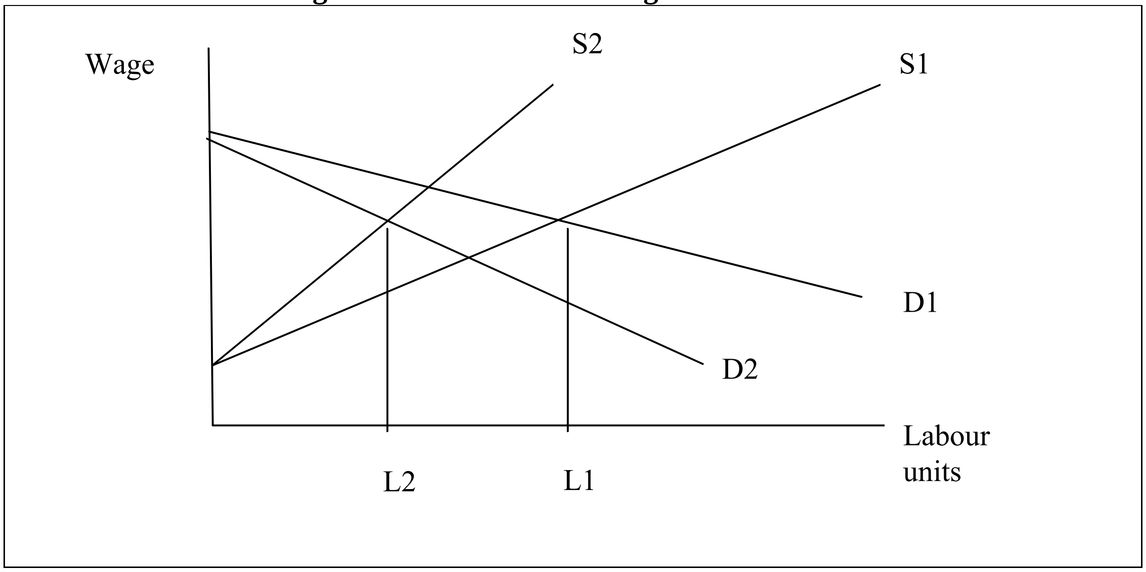
5.6 Conclusion

In this chapter, the researcher investigates the impact of poor access to water on wage work participation in rural China. This study hypothesizes that women pre-menopause face higher costs of participation and achieve lower productivity when access to water is poor (holding other things equal), and therefore have lower rate of wage work participation due to the demand and supply factors in the labour market.

The research context is chosen to be rural China, because it is an adequate setting to test the hypothesis. The researcher uses CHNS93 data to test the hypothesis. In this dataset, about half of the respondents do not have access to improved water, and also a large number of respondents are not involved in any type of wage work. Most importantly, there is specific information about women's menopause status. In addition, the data also provide good economic and demographic controls.

Two types of empirical strategies are used to test the hypothesis that poor access to water in a women's household raises health and psychic costs of menstruation enough to interfere with wage work participation. First, a regression analysis approach is used to identify the average marginal effects of poor access to water. Secondly, Propensity Score Matching method is used to identify average treatment on treated. All these methods yield supportive results for the hypothesis. The impact is found to be different for men and women. Women pre-menopause are found to be especially affected by poor access to water, that is, their probability of participating in wage work is about 10 percentage points lower than their peers with good access to water controlling for other confounding factors. Therefore, a major benefit of policies to improve water supplies may not be the obvious household or industrial benefit, but rather an unseen benefit, the improvement in the position of women. While much of these benefits have already been gained in China which has made good progress in raising access to water, the results should be relevant to other areas of the developing world.

Figure 5.1 The labour in wage work market



Note: S1 and D1 are the labour supply and demand curves of men, or pre-menopause women with good access to water. : S2 and D2 are the labour supply and demand curves of pre-menopause women with poor access to water. The demand/supply curves for women post-menopause are not shown due to the different realisation of labour in wage work market.

Table 5.1: Means and standard deviations of the major variables in wage work participation model, 1993

	Women with good access to water		Women with poor access to water		Men with good access to water		Men with poor access to water	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Wage work participation (total)	0.30	0.46	0.11	0.31	0.43	0.49	0.23	0.42
Wage work participation (pre-menopause)	0.36	0.48	0.13	0.33				
Wage work participation (post-menopause)	0.09	0.28	0.03	0.17				
Pre-menopause	0.81	0.39	0.83	0.37				
Primary education or below	0.53	0.50	0.68	0.47	0.38	0.49	0.49	0.50
Junior middle school education	0.33	0.47	0.26	0.44	0.42	0.49	0.39	0.49
High school education or above	0.14	0.35	0.06	0.24	0.20	0.40	0.12	0.33
Age	35.64	12.18	35.02	12.15	35.32	12.34	35.69	12.12
Marital status	0.84	0.37	0.84	0.36	0.82	0.39	0.85	0.36
Number of workers at home	2.64	1.36	2.90	1.37	2.65	1.36	2.85	1.39
Number of elderly over 60 at home	0.24	0.52	0.23	0.51	0.28	0.56	0.24	0.53
Number of children under 16 at home	0.34	0.61	0.43	0.69	0.31	0.59	0.43	0.70
Land per adult at home (*mu*)	0.78	1.28	1.45	1.42	0.80	1.29	1.50	1.49
Village off-farm employ. rate	0.50	0.32	0.22	0.19	0.50	0.32	0.22	0.19
N	1322		1397		1353		1406	

Note: The data is from CHNS 1993. The good access to water is defined as having tap water at home and courtyard. Village off-farm employment rate is proportion of people involving in off-farm wage work plus people involving in self employment.

Table 5.2: Differences-in-Differences estimate of poor access to water on wage work participation, pre- and post-menopause

	Good access to Water	Poor access to water	Difference
Women 16 – 60			
Post-menopause	0.09	0.03	0.06**
	(0.019, 235)	(0.012, 217)	(0.023)
Pre-menopause	0.36	0.13	0.23***
	(0.015, 982)	(0.010, 1059)	(0.018)
		Difference-in-Difference	-0.17*** (0.042)
Men 16 – 60			
45 or older	0.39	0.19	0.20***
	(0.026, 356)	(0.021, 357)	(0.033)
50 or younger	0.44	0.25	0.19***
	(0.015, 1165)	(0.013, 1180)	(0.019)
		Difference-in-Difference	0.01 (0.08)
		Difference-in-Difference-in-Difference	-0.18* (0.096)

Notes: Good access to water refers to tap water (categories water1 and water2 in Table 2.1, see also Figure 2.4). Standard errors of the estimates and sample sizes are reported in parentheses.

Table 5.3: The effect of access to water on wage work participation by gender - IV Probit

	Women		Men	
	Coef	z	Coef	z
Poor water access	-0.46***	-2.86	-0.13	-1.00
Middle school	0.42***	4.19	0.35***	4.18
High school +	0.75***	5.58	0.84***	7.99
Age	0.13***	4.10	0.10***	4.02
Age-squared	-0.00***	-4.98	-0.00***	-4.41
Marital status	-0.17	-1.03	0.19	1.34
# labourers at home	0.17***	4.81	0.07**	2.25
#elderly over 60	-0.02	-0.25	-0.14	-1.55
#children under16	-0.18*	-1.61	-0.15*	-1.75
#children under 6	0.03	0.23	0.02	0.16
Land per adult	-0.17***	-3.49	-0.11***	-3.42
Village off-farm work rate	0.75***	8.49	0.59***	10.24
County (36) dummies	Yes		Yes	
First Stage – Dependent Variable: Poor access to water				
Water Plant	-0.88***	-3.48	-0.91***	-3.29
Middle school	0.01	0.35	0.02	0.84
High school +	0.02	0.77	-0.01	-0.40
Age	-0.01	-1.29	0.00	-0.69
Age-squared	0.00	1.58	0.00	0.98
Marital status	0.01	0.54	0.03	1.10
# labourers at home	0.00	0.73	0.00	0.12
#elderly over 60	0.05	3.02	0.04*	1.92
#childr. under16	-0.01	-0.39	-0.01	-0.33
#childr. under 6	0.01	0.36	0.01	0.32
Land per adult	0.00	0.35	0.00	-0.06
Village off-farm work rate	-0.03**	-2.34	-0.02	-1.60
County (36) dummies	Yes		Yes	
Wald Test of Exo prob>Chi2	0.19		0.69	
Observations	2033		1864	
Log likelihood	-1274.8		-1441.8	

Note: The data is from CHNS 1993. The inclusion of village dummies is not possible for IV probit due to non-concavity, but they are included in some probit models in Table 5.4. When separating the women's model by post- and pre- menopause status, the significant adverse impact of poor access to water only existed for women pre-menopause (results not shown, since the same exercise is performed for models in Table 5.4).

Table 5.4: The effect of access to water on wage work participation by gender, menopause status and age

- Average Marginal Effects (AME) after Probit

	Women Pre-menopause (1)		Women Post-Menopause (2)		Men 50 or younger (3)		Men 45 or older (4)	
	AME	z	AME	z	AME	z	AME	z
Poor water access	-0.06*	-1.95	0.06	0.96	0.03	0.96	0.02	0.65
Middle school	0.10***	3.83	-0.01	-0.17	0.09***	4.45	0.08**	2.10
High school +	0.20***	5.23	0.07	0.46	0.23***	8.31	0.18***	2.98
Age	0.03***	3.32	0.04**	2.38	0.02**	2.05	-0.04	-1.47
Age-squared	-0.00***	-3.34	-0.00***	-2.89	-0.00**	-2.03	0.00	0.62
Marital status	-0.07**	-2.64	0.04	0.51	0.13***	3.25	0.08*	1.64
# labourers at home	0.05***	6.53	0.01	0.60	0.02**	2.14	0.01	0.57
#elderly over 60	0.01	0.66	-0.04	-0.85	-0.03	-1.52	-0.04	-1.18
#children under16	-0.04**	-2.06	0.15*	1.92	-0.04**	-2.22	0.01	0.28
#children under 6	0.02	1.01	-0.21**	-2.42	0.00	0.09	-0.05	-0.91
Land per adult	-0.03	-1.54	-0.07*	-1.62	-0.02**	-2.23	-0.01	-0.48
Village off-farm work rate	0.16***	15.51	0.22***	5.52	0.14***	16.61	0.17	4.18
Village-152 (county*-36) dummies	Yes		Yes*		Yes		Yes*	
Observations	1086		184		1339		423	
Pseudo R2	0.33		0.27		0.28		0.34	
Log Likelihood	-445.8		-55.9		-617.8		-109.6	

Note: * County dummies are used in Model (2) and (4) due to small sample size, but the impact of poor access to water remain insignificant when village dummies are used. Some village and county dummies are dropped in the actual regression due to collinearity.

Table 5.5: Balancing requirement: Comparing the selected covariate means of the matched samples (women – pre-menopause)

		Block 1	Block 2	Block 3	Block 4	Block 5	Block 6
Propensity Scores – lower bound		0.02	0.2	0.4	0.6	0.8	0.9
Number of Observations		C=116 T=12	C=42 T=16	C=26 T=38	C=51 T=110	C=21 T=111	C=7 T=123
Middle school	C	0.35(0.48)	0.36(0.48)	0.35(0.49)	0.24(0.42)	0.43(0.50)	0.57(0.52)
	T	0.33(0.49)	0.44(0.51)	0.29(0.46)	0.34(0.47)	0.32(0.47)	0.36(0.48)
	t	0.14	-0.56	0.49	-1.29	0.97	1.12
Age	C	32.4(9.5)	33.1(8.5)	33.1(8.7)	32.7(8.4)	33.2(8.8)	30.7(4.4)
	T	31.3(9.0)	30.2(9.1)	34.3(8.7)	33.5(7.9)	31.8(8.0)	32.2(8.9)
	t	0.35	1.27	-0.61	-0.58	0.71	-0.31
Marital status	C	0.82(0.38)	0.83(0.38)	0.86(0.36)	0.86(0.35)	0.80(0.41)	1.00(0.00)
	T	0.70(0.48)	0.77(0.43)	0.85(0.36)	0.89(0.31)	0.89(0.32)	0.87(0.34)
	t	0.93	0.56	0.11	-0.55	-1.24	1.08
Children under 16	C	0.48(0.71)	0.38(0.56)	0.29(0.46)	0.47(0.73)	0.50(0.69)	0.63(0.74)
	T	0.70(0.82)	0.28(0.46)	0.45(0.75)	0.39(0.68)	0.57(0.71)	0.53(0.74)
	t	-0.93	0.68	-1.00	0.68	-0.41	0.37
Land per adult	C	1.31(1.83)	0.88(1.50)	0.87(0.51)	0.67(0.72)	2.27(3.86)	1.07(0.72)
	T	1.52(2.77)	0.72(0.71)	1.17(1.99)	0.84(0.79)	1.61(1.94)	1.59(1.83)
	t	-0.33	0.43	-0.78	-1.30	1.19	-0.80
Village off-farm work rate	C	0.35(0.27)	0.36(0.33)	0.20(0.12)	0.44(0.17)	0.20(0.11)	0.23(0.25)
	T	0.37(0.30)	0.37(0.35)	0.25(0.19)	0.42(0.17)	0.24(0.14)	0.21(0.22)
	t	-0.22	-0.11	-1.23	0.69	-1.22	0.25
# labour-ers at home	C	2.49(1.25)	2.67(1.34)	2.5(1.1)	2.33(1.21)	2.4(1.14)	2.25(0.46)
	T	2.30(1.49)	2.39(0.77)	2.3(0.93)	2.39(1.32)	2.43(1.05)	2.78(1.65)
	t	0.45	0.84	0.81	-0.28	-0.12	-0.90

Note: Standard deviations are in parenthesis. T = Treated; C = Control. T statistic (t) is used to compare the means. The significance level of the differences: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The first row gives the inferior (lower) bound of the probability of having poor access to water for each block.

Table 5.6: Average Treatment on Treated (ATT) by gender

	Women (Pre-Menopause)	Men (aged 50 or younger)
Nearest Neighbour Matching	-0.13* (-1.65) T=410 C=107	0.02 (0.29) T=422 C=105
Radius Matching (radius=0.01)	-0.09 (-1.54) T=398 C=231	0.03 (0.51) T=413 C=218
Kernel Matching	-0.09* (-1.66) T=410 C=263	0.04 (0.61) T=422 C=235
Stratified Matching	-0.10* (-1.76) T=410 C=263	0.04 (0.67) T=422 C=235

Note: T = Treated (Having access to poor water); C = Control. T statistic is in parenthesis and is calculated using bootstrapped Standard Errors with 500 replications. The number of observations of treated and control units are given under the estimated ATT separately.

CHAPTER SIX: CONCLUSIONS

This study was separated into two parts that test the following two parallel hypotheses:

Hypothesis-1: Girls have less probability of school enrolment and shorter schooling duration due to the joint impact of poor access to water and menarche presumably because that poor access to water may raise time/health/psychic costs of school enrolment for girls post-menarche.

Hypothesis-2: Women have less probability of participating in work for wages due to the joint impact of poor access to water and menstrual cycle presumably because that poor access to water may generate lower productivity and raise time/health/psychic costs of wage work participation for women pre-menopause.

The tasks fulfilled in each part will be briefly reviewed and the research results will be summarised in section 6.1 and 6.2. The discussions over the validity of the 'culture' argument (A typical 'culture' that prefers men over women in school enrolment and wage work participation in rural China) will be summarised in Section 6.3. The relevance of the findings of this study to other developing countries in the world will be presented in the final section.

6.1 Conclusions on: Access to Water, Menarche and Girls' Education

The summary of tasks and findings in this part is as follows:

1. Literature Review: Two sets of literature survey were conducted to identify the recent findings about: (1) the special impact of poor access to water and menarche on girls' schooling which may generate gender gaps in education; (2) the other causes which will generate gender gaps in education. The researcher found that time/health/psychic costs associated with poor access to water after menarche were widely acknowledged in many recent research works. With regard to other literature that analyses the causes of gender education gap, household income; respondent's age, gender, parental education; parental occupational status; children's work opportunities; early marriage; different sibling structures were generally considered. However, the researcher found no empirical test which had been conducted to identify the significance and intensity of the joint impact of poor access to water and menarche on girls' education though the time taken to carry water had occasionally been considered as a determinant of education.

A theoretical framework was also developed based on the literature to model the joint impact of poor access to water and menarche on girls' schooling. The model was based on the concept that children's education is a household investment which aims to maximise the total utility of household members. The interaction of poor access to water and menarche entered the model explicitly as a cost element that only existed for girls post-menarche when they enrolled at school. Higher costs of girls' education would require higher returns from the educational investment in equilibrium. Higher average costs would inevitably lead post-menarche girls with poor access to water to drop out of school early (accumulate less years of schooling) when the demand for schooling was assumed to be the same for girls with good and bad access to water.

2. Data and Descriptive Statistics: The data from the CHNS dataset were used to test the hypothesis of the study. The testing was conveniently conducted because the CHNS provided detailed information on children's schooling (enrolment status and years of schooling); household access to water and the onset of menarche, which were all crucial to test the hypothesis of this study. Besides, the dataset provided almost all other necessary individual, household and community variables which could serve as additional controls in the empirical model. Those control variables in the empirical model included household income, sibling structure, age, gender, children's household and market work, parental education and occupational status, and other community characteristics.

The descriptive statistics using the CHNS data supported the hypothesis. Post-menarche girls were found to have higher school drop out rates and shorter schooling duration when access to water was poor. Specifically, girls with good access to water (tap water in the house or courtyard) were found to have a 3 percentage point higher school enrolment rates pre-menarche. However, post-menarche the advantage was found to be larger, 20 percentage points. Using the pre-menarche girls' experience to derive the direct beneficial effects of tap water, the researcher found that tap water raised the enrolment rate of post-menarche girls by 17 percentage points. The Kaplan-Meier survival curves also showed that girls with poor access to water had a much lower survival curve than the boys or girls with good access to water, with only about a 30% chance of surviving until grade 9, which was the end of junior secondary school.

3. Empirical Tests and Results: Following the descriptive tests, multivariate analyses were conducted to derive the true impact of access to water on schooling of boys and girls when the impacts of other confounding factors were controlled for. When conducting multivariate analysis, the researcher first used regression analysis techniques (probit models for school enrolment and hazard models for schooling duration). Poor access to water was found to posit significant adverse impact on girls schooling after the onset of menarche. For example, the probit model results showed that no access to tap water decreased the probability of school enrolment of post-menarche girls by 27 percentage points (significant at 1% level) when controlling for the impact of other factors. For other groups – girls pre-menarche and boys (before or after age 14) – the impact of access to poor water (non tap water) disappeared while the impacts of other variables were controlled for.

The results from hazard models also showed that menarche posited 2 – 2.5 times more adverse impact on the conditional schooling duration of girls with poor access to water compared to girls with good access, in whatever way the poor access to water was defined. The survival distributions were computed using represented values of the policy variables in interest. The results showed that household wealth - the clustered income derived using household income, parental occupation status and education qualifications (see Table 2.1) – gave only a marginally bigger impact on girls' schooling compared to boys' given access to water was poor, but poor access to water always gave a worse impact on girls' schooling whether or not the family was 'rich' or 'poor'.

As for the impacts of other controls, the researcher found some interesting results. The per capita household income on average had generally the same impact on girls' and boys' schooling (for example, see survival distributions in Table 3.8(a) and 3.8(b)). Even though the impacts were found to be higher for girls in some occasions (Table 3.5) the difference of the impacts was marginal. That is, higher/lower per capita household income increased/reduced both girls' and boys' schooling attainment with almost equal margins. This finding suggested, in an indirect way, that the impact of poor access to water was independent of the impact of poor household income, since the impact of poor access to water was always significantly adverse for girls' schooling (particularly post-menarche) and always neutral for boys' after control variables are included in the regressions. This finding also reflected the reality in rural China that higher household income was not a sufficient prerequisite to have tap water access at home, and tap water access was often a product of mass water pipeline construction conducted at a village or above-village level. Therefore, the belief that the impact of poor access to water reflected the impact of poor household environment was not supported by the findings in this study.

Another finding that suggested independent impact of poor access to water from that of poor household income was that the directions of the impacts of poor access to water and poor household income on pre- and post-menarche girls' schooling were opposite to each other (e.g. see the first two rows in Table 3.2). It seemed that the impact of poor household income was much pronounced for pre-menarche girls while the impact of poor access to water was found to be much adverse for post-menarche girls. Again, if the impacts of poor access to water and poor household income were positively correlated, the directions of the impacts should also be the same for pre- and post-menarche girls' schooling. Moreover, not only the directions of the impacts were opposite, the magnitudes of the impacts were also very different, a fact suggesting that the two impacts were indeed independent from each other. In fact, the first-stage regression in Table 3.2 and the logit regression in Table 4.1 provided clear evidence that household income was not a determinant of household access to tap water in rural China.

The parental education and occupation were found to have different impacts for different subgroups. The differences might arise because parents might have different attitudes and commitments to educate children in different schooling stages. It might also be possible that different statistical methods might sometimes yield different results (Holmlund et al., 2008). However, in hazard models, where unobserved individual characteristics were controlled for (Table 3.5), higher parental education and occupational status generally had positive impacts on children's schooling. The results in Table 3.5 also suggested that mothers' education was particularly beneficial to girls' schooling, hence educating women should generate a virtuous cycle for female education.

Some sensitivity tests were also conducted to check the robustness of the regression results. First, the joint impact of poor access to water and menarche was estimated separately for eldest sisters, younger sisters and single daughters to test the validity of the assertion that girls drop out of school after menarche due to early marriage and so eldest sisters should tend to drop out more as they are first in the 'queue' for marriage (Field and Arbus, 2008).

However, the researcher found the impact of menstruation was in fact more pronounced for the schooling of younger sisters and single daughters, while single daughters faced even greater disadvantage when the access to water was poor. Secondly, the sensitivity of the joint impact mentioned above was tested by restricting the sample to those less ‘extreme’ villages where households with and without access to tap water reside together and share the same village culture. The test results showed that the joint impact still remained (even became worse) after the sample restriction and provided further support to the validity of hypothesis-1 of this study.

Finally, some village level analyses were conducted to test the impacts of access to water on girls’ and boys’ school enrolment rates at the village level. The variables used in village level analyses were the means of relevant individual level variables by village/wave. The fixed effects model results further confirmed hypothesis-1 that poor access to water had bigger impacts on girls schooling after the onset of menarche. A one percentage point decline in the rate of village average access to poor water was found to increase post-menarche girls’ school enrolment by about 0.22 percentage points holding the community rate of girls’ menarche at the mean. Moreover, the researcher obtained evidence that holding other things equal, poor access to water in general explained about 20 – 30% of the improvement of girls’ schooling across 1989 – 2004.

Following the regression analysis, the researcher investigated the impact of poor access to water on children’s schooling using propensity score matching techniques. The main reason of using this alternative technique was to check the robustness of the regression when finer randomisation is in place for the treatment assignment. Propensity score matching is aimed at reducing the bias in estimated treatment effects by mitigating the selection bias resulted from non-random assignment of the treatment (Becker and Ichino, 2002).

The average treatment on treated (ATT) obtained from propensity score matching were found to be reasonably comparable to the treatment effects found from regression analyses in the previous chapter. The propensity score matching estimator showed that poor access to water reduced the probability of school enrolment of girls post-menarche by 19 percentage points on average. This figure is smaller than the estimate of probit model (27 percentage points). However, the impact estimated in the probit model might have represented the upper bound of the 'true' impact since the data used in probit model, keeping only the first observation per subject, were largely from the earlier waves during when the impacts were larger.

Combining the findings from regression analyses and propensity score matching, the adverse impact of poor access to water on the schooling of post-menarche girls, while controlling for the impacts of other variables, appears to be confirmed. The overall intensity of the joint impact was found to be 20-25 percentage point decrease in the probability of school enrolment and 2 – 2.5 times shorter conditional schooling duration compared to post-menarche girls with good access to water. The impact of poor access to water was generally found to be small and insignificant for pre-menarche girls and boys (younger or older than 14).

The results above were obtained using two different observational methods, namely, regression methods and PSM methods. However, a randomised experiment (Oster and

Thornton, 2009) which was designed to analyse the impact of menarche on girls' school attendance found contrary results to hypothesis-1 of this study. However, the experiment has many practical problems. That is, the sample in their experiment was found to over represent richer students who may have already succeeded in coping with the adverse impacts of menarche due to their advantageous household background (e.g. their households have access to good water). Moreover, their estimation of the treatment effect might have been biased due to considerable sample attrition during the experiment. The practical problems associated with randomised trials when estimating the treatment effect showed the difficulty of obtaining unbiased estimates even the experiment was well-designed in the first place.

6.2 Conclusions on: Access to Water, Menstrual Cycle and Women's Work

In this part, the researcher investigated the impact of poor access to water on women's wage work participation in rural China. This study hypothesized that 'pre-menopause women face higher costs of participation and achieve lower productivity when access to water is poor (holding other things equal), and therefore have lower rate of wage work participation due to the demand and supply factors in the labour market'. The specific tasks and the results are as follows:

1. Literature Review: Two sets of literature surveys were conducted to identify the recent findings about: (1) the special impact of poor access to water and menstruation on women's wage work participation; (2) the other causes which will generate gender gaps in wage work participation. With regard to other literature that analyses the causes of gender gap in wage work participation, respondent's education, age, gender, marital status, children,

and local labour market characteristics were found to be taken as the usual considerations. However, the researcher found no empirical test which had been conducted to identify the significance and intensity of the joint impact of poor access to water and menstrual cycle on women's wage work participation, although the individual impact of menstrual cycle on women's work (e.g. absenteeism and productivity) has been studied.

A theoretical framework was also developed based on the based on the mechanism of labour supply and demand. The model was based on the concept that 'poor access to water increases the (health/time/psychic) costs of wage work participation of pre-menopause women. Higher costs of participation require higher wage rates in equilibrium, so given the same wage rates, women pre-menopause with poor access to water may tend to choose other sectors where relative costs of participation (mentioned above) are not high due to the possibility of flexible time arrangements for labour supply (e.g. farming, self employment). Moreover, lower productivity and absenteeism resulted from the joint impact of menstruation and poor access to water may also lead to decreased demand. Therefore, ultimate amount of the labour cleared in wage work market for pre-menopause women will decrease due to poor access to water. A labour-leisure model was also used to explain the mechanism based on the hypothesis that poor access to water raises health/time/psychic costs for pre-menopause women and would eventually lead them choose more leisure (or other sectors) and forgo wage works.

2. Data and Descriptive Statistics: The data from the CHNS dataset (wave 1993 – the only wave in which menopause data were collected) were used to test the hypothesis of the

study. The testing was conveniently conducted because the CHNS provided detailed information on women's work types (wage work, self employment or farming); type of access to water and women's menopause status, which were all crucial to test the hypothesis of this study. Besides, the dataset provided comprehensive individual, household and community variables which could serve as additional controls in the empirical model. Those control variables in the empirical model included respondent's educational qualifications, age, marital status, number of elderly people and children at home, household per capita land ownership. 138 village dummies (county and province dummies occasionally) were included in the model to account for the impacts of remote location and backward 'culture'.

The descriptive statistics using the CHNS data supported the hypothesis. Women with poor access to water (non tap water) have a 6 percentage point lower wage work participation rates post-menopause. However, pre-menopause the disadvantage is more pronounced, 23 percentage points. Therefore the relative disadvantage in wage work participation of pre-menopause women with poor access to water is 17 percentage points. Men were divided into two groups using the age distribution of pre- and post-menopause women (aged 45 or older or 50 or younger), and in both groups, men with poor access to water were found to have about 20 percentage point lower wage work participation, so the relative disadvantage in wage work participation does not exist for men aged 45 or younger. Overall, the difference of the relative disadvantage of pre-menopause women with poor access to water in wage work participation reached 18 percentage points compared to that of men aged 45 or younger. Poor access to water thus appeared to have a 'special' impact on the wage work participation of pre-menopause women. The impact was also tested using the multivariate approach and the results are summarised below.

3. Empirical Tests and Results: Following the descriptive tests, multivariate analyses were conducted to derive the joint impact of poor access to water and menstrual cycle on women's wage work participation when the impacts of other confounding factors were controlled for. As in part 1, two types of empirical strategies were used for the test. First, a regression analysis approach was used to identify the average marginal effects of poor access to water on wage work participation of pre- and post-menopause women (and also of men, for comparison purposes). Secondly, propensity score matching method was used to identify average treatment on treated.

The impact of poor access to water was found to be different for in mens' and women's models. Women pre-menopause were found to be especially affected by poor access to water, that is, their probability of participating in wage work was about 6 percentage points lower than their peers with good access to water controlling for other confounding factors. The impact did not exist for men, nor did it exist for women post-menopause. The results from propensity score matching yielded somewhat stronger impact of poor access to water on pre-menopause women's wage work participation, that is, the ATT for women pre-menopause gave about 10 percentage points lower participation rate for poor access to water treatment. This impact was larger compared to the impact estimated from the probit model (6 percentage points), because that probit model results might have been downward biased due to a possible negative selection bias.

6.3 The Summary of Arguments on the 'Culture Effects'

A widely held belief is that a special 'culture' which prefers sons over daughters in school enrolment; and prefers men over women in wage work participation exists in rural China (Song et al, 2006 and Jacka, 1997). Poor access to water, being mainly a problem of rural areas in China, may reflect the impact of such a 'culture' on women's education and work in empirical tests. Moreover, less developed settings are also likely to be associated with 'early marriage' of girls after the onset of menarche (Field and Arbus, 2008), and early marriage may cause them to have lower school enrolment, and, later, less wage work participation. Therefore, menstrual cycle effects may simply reflect the impact of a special 'culture' of early marriage on women's education in rural settings in empirical tests.

This study conducts a number of empirical tests to 'filter out' the impact of such 'cultures' on the interaction of poor access to water and menstrual cycle. While this study acknowledges the existence of the above mentioned cultural elements in rural China, it questions the intensity and the real power of such 'cultural effects' on women's education and work. Moreover, the joint impact of poor access to water and menstrual cycle seems to exist independent of village 'culture'. The relevant findings are summarised as follows:

1. The joint impact of poor access to water and menstrual cycle on women's education and work is significant and strong even after controlling for village fixed effects (almost all regression models control for 151 village fixed effects). In other words, if the typical effect of a village 'culture' is fixed (constant) for a given period of time, the effect should be swept away by those village dummies included in the regressions. The fact that the

joint impact is still large and significant after the village controls are in place suggests that poor access to water has special and independent impact on women's education and work. In fact, post-menarche girls with good access to water are found to have higher school enrolment than boys in rural villages (Table 3.8a and 3.8b). All these findings oppose the cultural hypothesis that poor access to water reflects the impact of a special village 'culture' which prefers male's education and work over female's. In other words, girls should have lower school enrolment rates than boys no matter they have good/poor access to water in rural villages, if the poor access to water picks up the impact of such backward 'cultures'.

2. The impact of poor access to water on women's education and work is still significant and large even after the poor access to water is instrumented using *water plant* variable. The instrumentation is done because the effects of the culture may be time variant, and maybe some within-village differences between the households are not measured well enough to be controlled for in regression analyses. However, the results remain robust (Table 3.2, Table 5.2) suggesting poor access to water is not picking up the impact of such unobservables. Therefore, even if the village 'culture' which prefers male education and work over female's varies over time, poor access to water still exerts an individual adverse impact on the schooling and work of women.

3. The impact of poor access to water is worse for younger sisters and single daughters, whereas it is less adverse for eldest sisters (Table 3.4) suggesting that menarche does not necessarily leads eldest sisters to drop out more compared to younger sisters (or single daughters) and therefore the school drop-out of girls post-menarche is not necessarily linked to early marriage, at least, in rural China. Because if that is true, eldest sisters should

experience more adverse impact of menarche than younger sisters do. So the argument that menarche leads to early marriage in rural China, which in turn lower girls' education, is not supported by the results.

4. When the sample is restricted to villages where 15-85% households have tap water access (Table 3.7) the impact of the menstruation is still worse for girls with poor access to water. In fact, after this restriction, there are residents with good and poor access to water within a same village and therefore they will share the same 'culture', if any, of son preference. However, if the poor access to water is reflecting the impact of culture, the impact should now disappear since everyone within a village is sharing the same culture. The fact that the impact of poor access to water remains strong (even increases in some instances) suggests that the impact of poor access to water is independent of village 'culture'. Within village analysis results (Table 3.10) also shows that within a village, where everyone is assumed to share the same village 'culture', the improvement is access to water is found to be particularly helpful to post-menarche girls' education.

5. Propensity score matching estimator results show that even after all the observed covariates are balanced (means of covariates are not different) between the treated and the control), poor access to water still has a significant adverse impact on the schooling of post-menarche girls (Table 4.4) and wage work participation of pre-menopause women (Table 5.5). Now the treated and control group units share similar individual, household and community characteristics, the only difference is that the treated units have poor access to water while the control units have good access to water (tap water). Even with this 'advanced' randomisation of the treatment assignment, the adverse impact of poor access to

water on women's education and work still exists. Arguably, with such experiment-like randomisation, the treated and control units have high possibility of sharing the same 'culture' in rural China, but still their school enrolment and wage work participation differ from each other just because of the difference of water access, a fact again suggests the independence of the impact of poor access to water from 'culture'.

In sum, while this study acknowledges the existence of a widespread belief that preferences of male's education and work over female's in rural China account for the gender education and work gaps, the results cast doubt on the intensity of such special 'cultural effects'.

6.4 The Relevance of the Research and the Future Work Considerations

China has achieved great progress in access to good water in last two decades – tap water access in urban China covered more than 90% of its population (CHNS, 2009) by 2004. However, in some rural areas of China, access to improved water is still a concern. For example, there are still 38% rural population in China who did not have access to tap water in 2004 (Figure 2.4). Moreover, the China's Ministry of Health's 2006 survey of drinking water and hygiene in the rural areas show at least 300 million rural residents in China have no access to safe and clean drinking water, and only 31 percent of rural toilets reach hygienic standards (China View[3], 13 Aug 2006). So the findings of this study are still largely relevant to many rural settings in China.

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[3] For more information, see http://news.xinhuanet.com/english/2006-08/13/content_4955367.htm

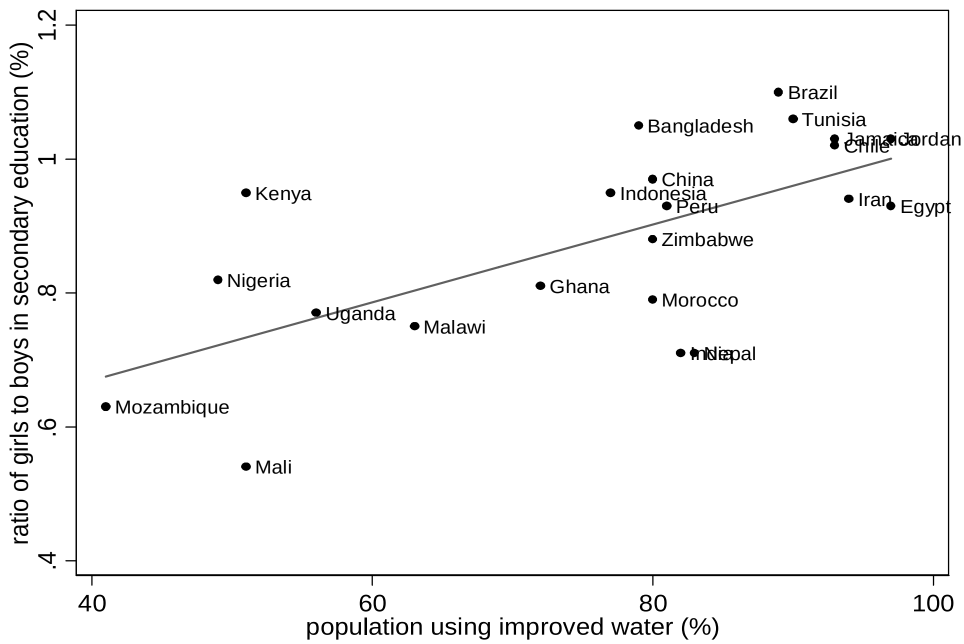
More broadly, access to improved water is a major problem in many less developed countries. Figure 6.1 gives the UN estimates of the proportion of population using improved water in some developing countries in year 2000 (source: UN Data, 2009). As can be seen, access to improved water is particularly limited in some African countries. For example, only about 40-50% of the population in countries such as Mozambique, Kenya, Nigeria and Mali have access to improved water. Comparatively doing better in access to improved water are the developing countries in Asia, North Africa, Middle East and Latin America – they normally have above 80% population using improved water. China is reported to have had 80% of its population (including urban and rural) using improved water by 2000. However, these figures are national averages and in rural settings of all these countries the access to improved water is on average 20-30 percentage point lower than in urban areas (UN Data, 2009, not shown). Hence, the findings of this study are likely to be particularly relevant to women's education and work in rural settings of less developed countries.

Figure 6.1 shows a strong positive correlation between the proportion of population using improved water and the gender education gap measured as the ratio of girls to boys in secondary education. Figure 6.2 also shows a strong positive correlation between the proportion of population using improved sanitation facilities (for which improved water is a prerequisite) and the gender education gap. On one hand, with a lower proportion of population using improved water and improved sanitation facilities, Sub-Saharan countries have higher gender education gaps compared to countries in other parts of the world. On the other hand, Latin American countries such as Jamaica, Brazil and Chile are found to have more girls than boys attending secondary schools presumably because girls' education is benefited from high access rates to improved water and improved sanitation facilities. The patterns shown in Figure 6.1 and 6.2 generally support the positive relationship between girls' education and good access to water or sanitation. This reality shows the research results of this study can generally be applied to many less developed countries to improve women's education.

UN Millennium Development Goals Indicators (UN Data, 2009) also aim at increasing the proportion of women in wage work employment in non-agricultural sectors, which is the second research subject of this study. Figure 6.3 shows the correlation between the population using improved water and the proportion of women in wage work. As can be seen, the correlation is positive but weak. One possible reason of the weak correlation here is that only women pre-menopause, in this study, are found to have lower participation rates in wage work due to poor access to water, but women post-menopause do not seem to be affected. So including the post-menopause women in the Figure 6.3 may reduce the strength of correlation (no data on wage work participation by menopause status or age range were given by UN Data, 2009, which can be used to identify age-group-based correlations). Nevertheless, a stronger correlation is found between the proportion of women in wage work employment and the proportion of population using improved sanitation facility (see, Figure 6.4). This reality shows the research results of this study can generally be applied to many less developed countries to help increase women's wage work participation.

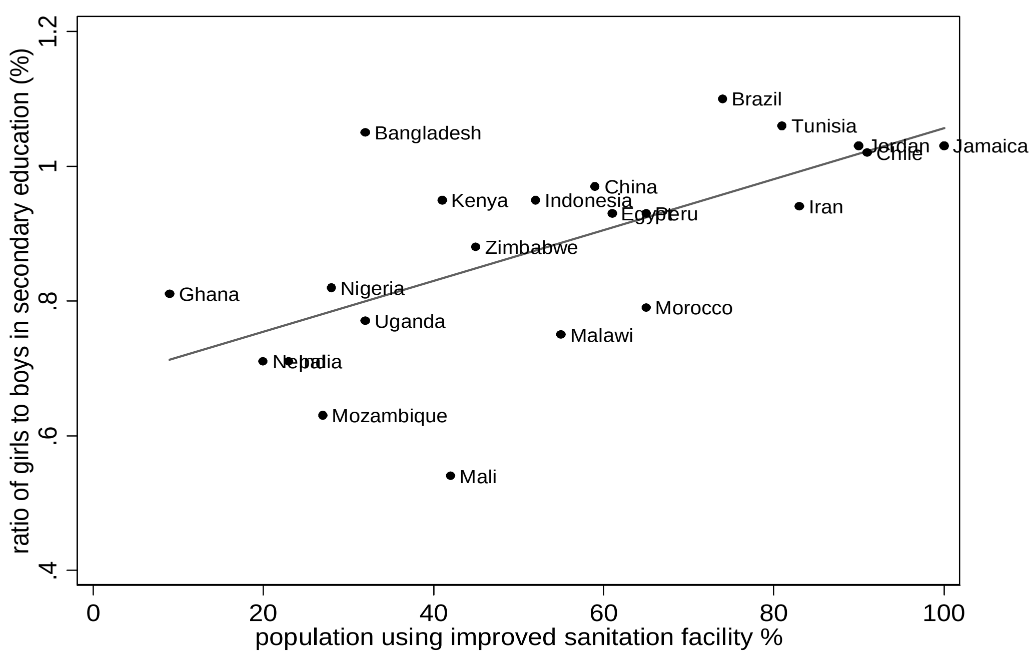
To sum up, it remains to be an important future work to investigate the joint impact of poor access to water and menstrual cycle on women's education and work in other developing settings in other parts of the world. Moreover, the research about the impact of poor access to water on women's health, child and maternal mortality is also on the list of future work considerations. This study concludes that a major benefit of policies to improve water supplies may not be the obvious household or industrial benefit, but rather an unseen benefit, the improvement in the position of women. While much of these benefits had already been gained in China which made good progress in raising access to water, the results should be relevant to other areas of the developing world.

Figure 6.1: Gender gap in secondary education and access to good water, Developing countries in 2000



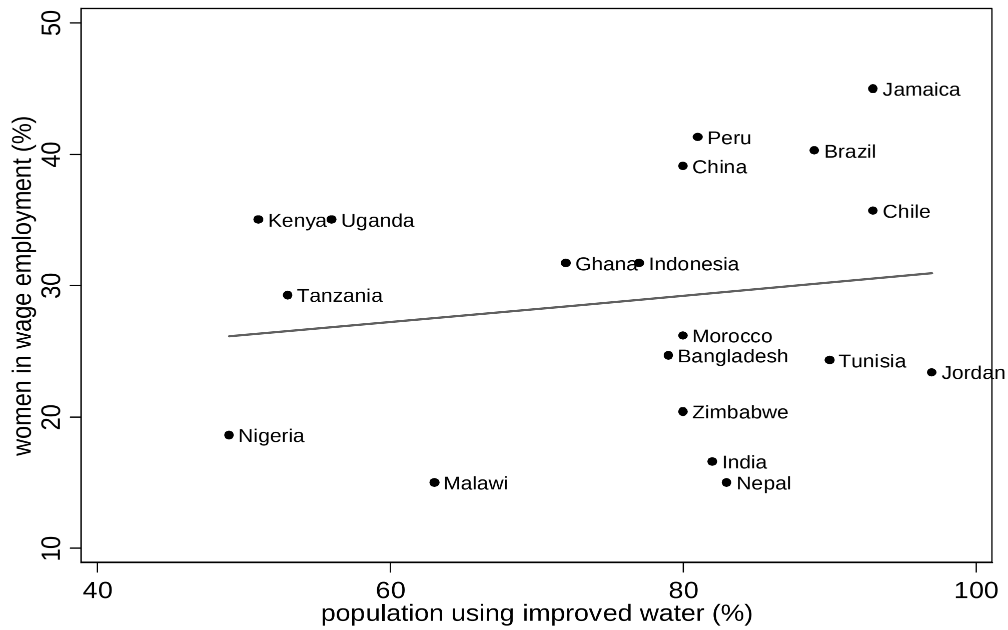
Source: UN Millennium Development Goals Indicators (UN Data, 2009)

Figure 6.2: Gender gap in secondary education and access to sanitation facility, Developing countries in 2000



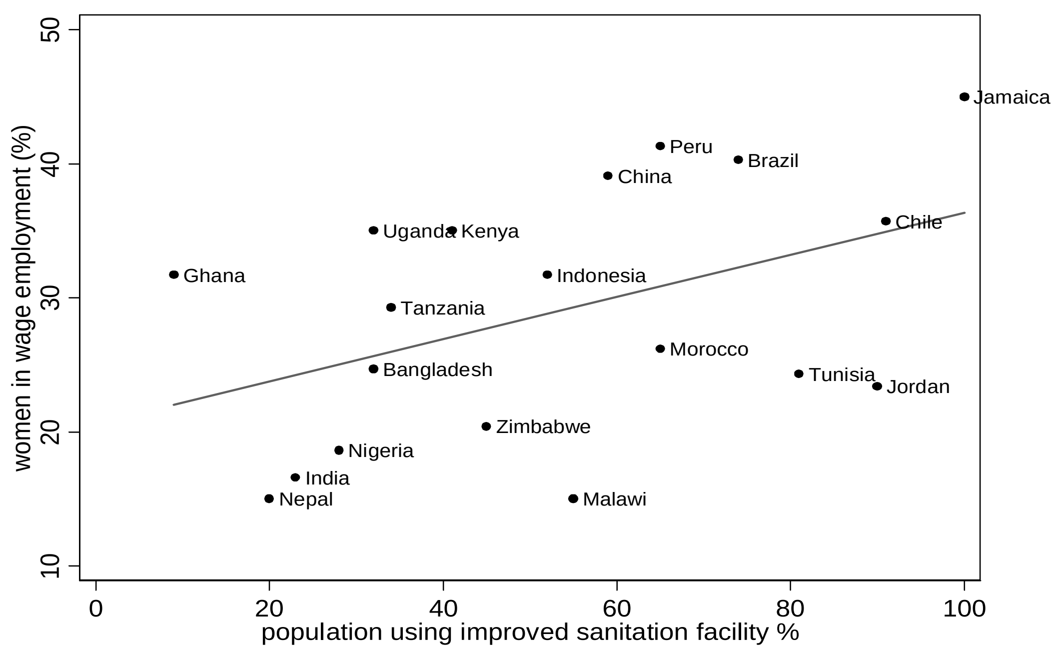
Source: UN Millennium Development Goals Indicators (UN Data, 2009)

Figure 6.3: Women's share in wage work and access to good water, Developing countries in 2000



Source: UN Millennium Development Goals Indicators (UN Data, 2009)

Figure 6.4: Women's share in wage work and access to sanitation facility, Developing countries in 2000



Source: UN Millennium Development Goals Indicators (UN Data, 2009)

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APPENDICES

Appendix 1. The Propensity Score Matching Techniques Used in this Study

Four types of common matching techniques, namely, Nearest neighbour matching; Radius matching; Kernel matching; and Stratification matching are used in this study. They all have advantages and disadvantages compared to one another. Therefore this study provides the results of all those matching techniques to assess the robustness of the estimates. Brief descriptions of each method in estimating the ATT are given below:

(1) Nearest neighbour matching – the control for the treated is chosen by picking the nearest match given the propensity score. Either random draw or equal weight options can be specified when there are multiple matches found. The advantage of this matching technique is that all the treated will have controls, but the pitfall is that nearest control may sometimes have very different propensity score when the distance is long. The formula for nearest neighbour matching can be written as follows:

$$\tau^{M} = \frac{1}{N^{T}} \sum_{i \in T} \left[Y_i^T - \sum_{i \in C(i)} w_{ij} Y_i^C \right]$$

where N^T is the number of treated units, Y_i^T and Y_i^c are observed outcomes of the treated and control units respectively. $C(i)$ are the set of control units that match the treated units. In case of nearest neighbour matching, the matched control units are selected by the following rule:

$$C(i) = \min_{i} \| p_i - p_j \|$$

where *p* denotes propensity scores. Basically, a control unit is chosen when its propensity score is the closest to the treated unit. When there are multiple control units are found with equal distance to the treated unit, they will all be used as controls and will be given equal weights as appeared in equation (4): $w_{ij} = \frac{1}{N_i^c}$ if $j \in C(i)$ and $w_{ij} = 0$ otherwise.

(2) Radius matching – this matching is conducted on units whose propensity scores fall into a predefined circle of a given radius. The advantage of this method is that the matching is conducted in a given circle (the radius is often set very small) and propensity scores of control and matched units will be very close to each other, therefore the matching results will be more representative. However, the pitfall of this method is that sometimes there may not be controls in a circle. The matching formula is the same as that for nearest neighbour matching except that the control units are now chosen when the difference of propensity scores between the treated unit *i* and other controls units is smaller than the radius.

$$C(i) = \{p_j \mid \| p_i - p_j \| < r\}$$

(3) Kernel matching – all the treated will be differenced with all the controls given the weight which is inversely proportional to the distance of the propensity scores. When estimating the ATT, the kernel matching will use the following formula:

$$\tau^{K} = \frac{1}{N^{T}} \sum_{i \in T} \left\{ Y_i^T - \frac{\sum_{j \in C} Y_j^C G(\frac{p_j - p_i}{h_n})}{\sum_{k \in C} G(\frac{p_k - p_i}{h_n})} \right\}$$

where *G(x)* is a kernel function and h_n is a bandwidth parameter. The second half of the summation yields consistent estimates for the counterfactual outcome Y_{0i}.

(4) Stratification matching – this technique first produces blocks according to the propensity scores, and calculates the difference of the average outcome of treated and control by each block, then take the average of all the difference to calculate the ATT. First, the treatment effect will be identified in each block. For example, for block *q*, the average outcome of the treated units and the average outcome of the control units are differenced as follows to get the estimate of the treatment on the treated (TT) for the block *q*:

$$\tau_q^s = \frac{\sum_{i \in I(q)} Y_i^T}{N_q^T} - \frac{\sum_{j \in I(q)} Y_j^C}{N_q^C}$$

where *I(q)* is set of units in block *q*. *N* represents the number of units in treated (T) and control (C) groups respectively. After the TT is obtained for each block, the ATT will then be computed using block weights (fraction of treated units in that block among all treated units) as follows:

$$\tau^{S} = \sum_{q=1}^{Q} \tau_q^s \frac{\sum_{i \in I(q)} D_i}{\sum_{\forall i} D_i}$$

Appendix 2. List of Variables and Their Derivations

Variables used in educational outcome models:		
Variable name	Definition	The Derivations[4]
School Enrolment	Whether the child is enrolled at school or not at the time of the survey	Child Survey data: A13: Are you currently in school 0 no 1 yes
Years of Schooling	Years of schooling the child completed at the time of the survey	Child Survey data: A11: How many years of formal education have you completed in a regular school? 00 no school completed 11 1year primary school ... 28 2 year technical school ... 36 6 year college/university or more
Menarche	The menstruation status	Child Survey data: U20: Have you ever menstruated? 0 no 1 yes 9 unknown
Household per capita income	Real per capita net household income. This variable is computed and provided as the sum of incomes from different sources divided by number of household members. The measure is deflated using 1998 CPI. The sources of income include income from farming, gardening, family business, paid work, cattle raising, fishing and others.	Income data: PCINC_AD is computed and provided in separate income data file.
Clustered income	A comprehensive income measure computed using k-means clustering	This variables is computed using variables such as per capita household income, parental income and parental occupation

[4] The original questions in the questionnaires.

		by the researcher.
Father's education	The education qualification of the father	Adult Survey data: A11: How many years of formal education have you completed in a regular school? 00 no school completed 11 1year primary school ... 28 2 year technical school ... 36 6 year college/university or more (The researcher derived the qualifications using years of schooling completed)
Mother's education	The education qualification of the mother	Adult Survey data: A11: How many years of formal education have you completed in a regular school? 00 no school completed 11 1year primary school ... 28 2 year technical school ... 36 6 year college/university or more (The researcher derived the qualifications using years of schooling completed)
Father's job status	The occupation status of the father	Adult Survey data: B4: What is your primary occupation? 01 senior professional/technical worker 02 junior professional/technical worker ... 12 athlete 13 ohter -9 unknown (The researcher derived 4 categories of occupational status by re-grouping the above division into 4 groups).
Mother's job status	The occupation status of the mother	Adult Survey data: B4: What is your primary

		occupation? 01 senior professional/technical worker 02 junior professional/technical worker ... 12 athlete 13 ohter -9 unknown (The researcher derived 4 categories of occupational status by re-grouping the above division into 4 groups).
Market work	The hours that a child spends on market work activities per day. The variable is computed as the sum of hours per day spent on many different market activities outside the home. The market work activities include work for paid work, work on farm, and gardening, cattle raising, fishing, and helping with family business	Child Survey data: C3: Last year how many months did you work at this occupation? C5: For how many days in a week, on average, did you work? C6: For how many hours in a day, on the average, did you work? (The daily market work hours are computed using the above information for each category. The researcher then sums up the hours spent on each activity to derive total hours spent on market work per day for each child).
Household work	The hours that a child spends on household work activities per day. The variable is computed as the sum of hours per day spent on many different household work activities. The household work activities include cleaning, shopping, cooking and washing.	Child Survey data: K2: During the past week, did you do this chore? K3: How much time did you spend per day on average? (minutes) (K4 – K7c repeat the above questions for each category) (The daily household work hours are computed using the above information for each category. The researcher then sums up the

		hours spent on each activity to derive total hours spent on household work per day for each child).
Single Child; Having one sibling; Having two or more siblings	Single Child; Having one sibling; Having two or more siblings	A1 Line number Computed using the line numbers of each child within a household
Age	Age of respondents	Child Survey: A3a: Age (years)
villages	Village dummies	T4 village of the respondent
counties	County dummies	T3 county of the respondent

Variables used in wage work participation models (Chapter 5):

Variable name	Definition	The Derivations
Wage (paid) work participation	Participating in any type of occupation that is paid by the employer	1993Household Survey; B4: What is your primary occupation? 01 senior professional/technical worker 02 junior professional/technical worker ... 12 athlete 13 ohter -9 unknown The researcher derived the variable using the occupational categories listed in the answers.
Pre-menopause	Women pre-menopause	1993 Physical Examination Survey: U59: Has your menstruation stopped? 0 No 1 Yes 9 Unknown
Education level (Primary, Junior Middle, High school or above)	Different education qualification	Adult Survey data: A11: How many years of formal education have you completed in a regular school? 00 no school completed 11 1year primary school ... 28 2 year technical school ...

		36 6 year college/university or more (The researcher derived the qualifications using years of schooling completed)
Age	Age of respondents	1993 Household Survey: A3a: Age (years)
Marital Status	The marital status of the respondent	1993 Household Survey: A8: What is your marital status? 1 never married 2 married 3 divorced 4 widowed 5 separated 9 unknown
Number of workers at home	Number of people who involve in any type of market work in the respondent's household	1993Household Survey; B4: What is your primary occupation? 01 senior professional/technical worker 02 junior professional/technical worker ... 12 athlete 13 ohter -9 unknown The researcher identified the job status of each household members using the information above and calculated the total number of workers in each household.
Number of elderly over 60 at home	Number of elderly people whose ages are over 60 at home	The researcher computed using the age information of the household members
Number of children under 16 at home	Number of children whose ages are under 16 at home	The researcher computed using the age information of the household members
Land per adult at home (*mu*)	Farming land owned by each adult at home	1993 Household Survey: E11d: In 1992 how many *mu* of land did your household cultivate? The researcher divided the reported figure by number of

		household members
Village off-farm employ. rate	The off-farm work employment rate in village	The researcher computed by dividing number of (off-farm) self employed and paid work workers over total labour force in the village.
villages	Village dummies	1993 Household Survey: T4 village of the respondent
counties	County dummies	1993 Household Survey: T3 county of the respondent