Water Works

The Economic Impact of Water Infrastructure

Robyn C. Meeks

ABSTRACT

Billions of hours are spent each year on water collection in developing countries. This paper explores whether improvements in water technologies, which decrease household distance to drinking water source and the time intensity of home production, enable changes in household time allocation and, thereby, productivity gains in Kyrgyzstan. Adults reallocate time to leisure and labor on the household farm. Average yearly household cereals production increased significantly. Results imply a rate of return to labor equaling $0.11/hour, approximately half the hourly farm wage. Absent evidence of improved adult health, results suggest that productivity gains were realized primarily through increased farm labor.

I. Introduction

Processes of economic development are often accompanied by significant changes in within-household time allocation patterns.[1] Some have credited time-saving household technologies with reducing the time intensity of home production

1. See Goldin (1994) for a discussion of the U-shaped relationship between development and female labor force participation.

Robyn C. Meeks is an assistant professor of environmental economics at the University of Michigan, meeks@umich.edu. *The author thanks Rohini Pande, Rema Hanna, Michael Kremer, and Bill Clark for their comments and support, as well as Anara Choitonbaeva, Roberto Lo Cicero Vaina, Nazgul Zakiryaevas, Venera Judemisheva, Baktygul Ismailova, Larisa Praslova, Eliana Carranza, and Jeremiah Johnson for helpful conversations and comments. Merim Japarova and Wincy Poon provided excellent research assistance. This work was conducted while the author received support through the Fulbright Program, Harvard's Sustainability Science Program, the Taubman Center Dissertation Fellowship, the Center for International Development Research Grant, a Davis Center Travel Grant, and the HEEP Enel Endowment. Support from these funders is gratefully acknowledged. The views expressed in this paper are those of the author and do not necessarily reflect those of the Sustainability Science Program, the Center for International Development, or Harvard University. All errors are those of the author. Scholars can purchase the data used in this article from the Kyrgyz National Statistics Committee. The author is willing to advise on the process.*
[Submitted September 2015; accepted July 2016] doi:10.3368/jhr.52.4.0915-7408R1
ISSN 0022-166X E-ISSN 1548-8004
Supplementary materials are freely available online at: http://uwpress.wisc.edu/journals/journals/jhr-supplementary.html

activities and increasing historical labor supply.[2] Empirical research supports the hypothesis that time-saving technologies have increased labor force participation in developed countries (Coen-Pirani, Leon, and Lugauer 2010; Cavalcanti et al. 2008). Technological progress in the household sector has been found to be more of a driver of such labor-force participation increases than wage increases. Simply put, "technological progress in the household sector erodes the value of labor in the home" (Greenwood et al. 2016). However, causality has proven difficult to disentangle. This paper uses quasi-experimental variation in access to domestic water infrastructure to provide causal estimates of how technological progress in household production can lead to productivity gains.

The context I explore is important. In developing countries, households without water infrastructure spend billions of hours collecting water for domestic use every year (Cosgrove and Rijsberman 1998). This task is often designated to women. Given that water is necessary for life and used for numerous purposes beyond drinking, it is critical in household production. Lack of water infrastructure can drive up the time intensity of home production, thereby diverting time from potentially income-generating activities, such as formal work, agricultural labor, and small business activity (Harvey and Taylor 2000; Blackden and Wodon 2006). Advocates claim that the reallocation of these time savings are "one of the greatest returns to improved access to water" (Bjorkland et al. 2009; UNDP 2006) and can "lay the groundwork for economic growth" (UN Millennium Project 2005). Improvements in household technologies can help shift time allocation from basic household tasks related to water collection to increased market production, but the extent to which remains a question.

By analyzing a large-scale water infrastructure project implemented in rural Kyrgyzstan, this paper sheds light on the channels by which labor-saving water technologies may help decrease the time intensity of home production. The project's stated objective was "to increase the supply and coverage of potable water to rural communities" with "time savings due to greater proximity to water collection points" listed as the primary expected benefit prior to the project[3] (World Bank 2001). I investigate the extent to which changes in household time allocation are aided by water infrastructure and can, in turn, change labor supply and productivity outcomes.

Rural households in northern Kyrgyzstan have small family size[4] and, on average, own six acres of land. The majority of working-age people are self-employed on their household's own small farm (calculated from 1999 census data). These family farms have low levels of mechanization (World Bank 2007), a characteristic common in less developed countries. As of 2003, women in Kyrgyzstan cited home production to be the main reason (other than being in school or retired) for not participating in the labor market (World Bank 2007). As a result, household members must therefore carefully

2. For example, there is evidence that technological progress in the United States during the 1900s, in the form of household time-saving products, such as washing machines, vacuum cleaners, and frozen foods, contributed to cutting down the home labor and increasing the market work performed by women. As housework declined over time with the diffusion of new time-saving appliances, the participation of females in the labor-force increased (Greenwood, Seshadri, and Yorukoglu 2005).

3. Post construction, an average of 12 households shared each water tap and in retrospective reports adults reported working more on their farms (DFID and World Bank 2007). The second set of expected benefits were "health benefits resulting from reduced incidence of water borne disease, lower infant mortality rates, lower medical costs, less income loss from sickness, etc." (World Bank 2001).

4. After independence in 1991, Kyrgyzstan's birthrate decreased, resulting in smaller families (Dekker 2003).

allocate their time between work in the market, work at home (which includes water collection, among other forms of home production), and leisure activities.

I use household-level panel data on agricultural inputs and production, along with individual-level 24-hour time budget diaries[5] to identify how both male and female household members reallocate time saved after the construction of drinking water infrastructure. If people work more in the market, does this result in greater crop production? And if so, through which channels does the increased farm production occur?

Given the nonrandom placement of water supply systems in villages, it is possible that unobserved village-level characteristics, such as political connectedness, might be correlated with both water supply system placement and outcome measures. To isolate the effects of receiving water infrastructure, I use differences in the timing of construction across villages. This difference-in-differences approach controls for the unobserved, fixed characteristics of villages that might bias simple cross-sectional analyses.

When lacking water at their home, household members must bring water from other sources, either improved (wells, protected springs, shared standpipes, and taps) or unprotected (streams, rivers, unprotected springs, lakes, irrigation canals). Rural households can require substantial time for water collection, as each round-trip from home to water source can be lengthy, with multiple trips per day required. The average time required per round-trip to collect drinking water in rural areas is 36 minutes in Sub-Saharan Africa and 23 minutes in Asia (United Nations 2010).[6] Rural households in Kyrgyzstan similarly suffered from this time burden. Households that lack water infrastructure spent an average of 26 minutes per water collection trip (see Table 1). Of such households, approximately one-quarter spent 30–40 minutes per trip, and more than 10 percent spend more than one hour per trip (UNICEF MICS 2007).[7]

The proposition that labor-saving technologies can increase labor force participation is rooted in Becker's model of household time allocation (1965). In the model of Gronau (1977), which distinguishes between home production and leisure activities, a household will optimize where the marginal product of home production equals the market wage (Gronau 1986). A key implication is that different technologies can decrease the value of time spent working at home, which increases the probability of market work (Blau, Ferber, and Winkler 2002).

Evidence from developing countries similarly supports the proposition that shifts from home production to market work can result from certain household sector technological changes. Field (2007) found that improving property rights in urban Peru freed households from time previously spent protecting informal land claims. By not having to stay home to protect their property, households were able to increase time allocated to market work. Similarly, electrification in South Africa enabled males and females to increase hours of market work, where fuel wood collection previously required two working days per week (Dinkelman 2011).

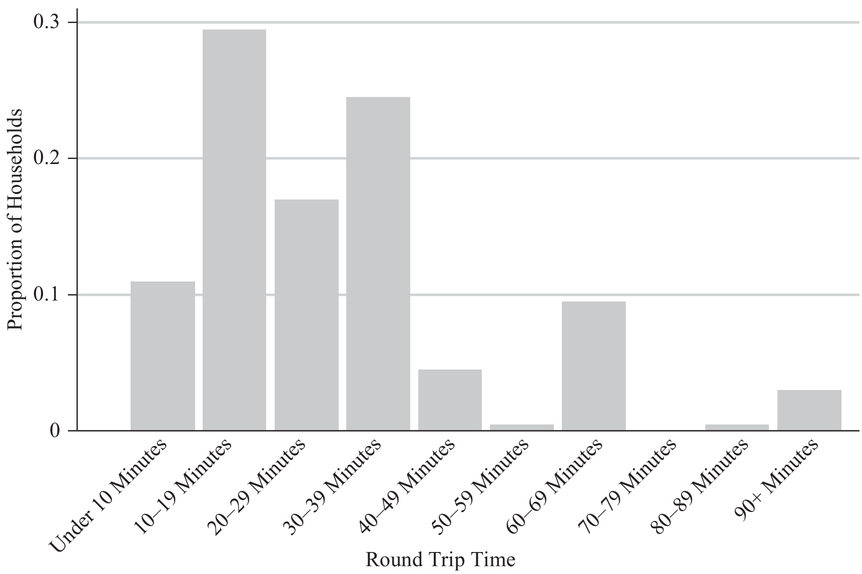
5. Historically, there has been an absence of time budget diary data. Recall methods are considered less reliable than time budget diaries, as respondents are not bound by a 24-hour constraint in recording their activities (Gronau 1986).

6. These calculations were computed by the United Nations Statistics Division using data from Macro International, Demographic and Health survey (DHS) reports; Macro International, DHS STAT compiler; and UNICEF, Multiple Indicator Cluster Survey (MICS) reports (United Nations 2010).

7. The MICS survey did not collect the number of water collection trips per day.

Table 1
Length of Time from Household to Water Source in Northern Kyrgyzstan

Region	Average Number of Minutes	Number of Households
Issyk Kul	27.42	215
Naryn	25.36	288
Talas	24.04	273
All North	25.68	776



Notes: Calculated for rural households relying on unimproved water sources (rivers, streams, etc.). Calculations made using the UNICEF Multiple Indicator Cluster Survey (2006).

Each of the existing papers on the labor impacts of water infrastructure have found that access to water infrastructure results in less time spent collecting water. However, from there, the results diverge. In urban Morocco, a randomized study found that shifting households from free neighborhood-level shared public taps to individual household connections did result in time gains, but such time was reallocated to leisure and social activities (Devoto et al. 2012). The benefits of any water intervention will depend on the location, technology, and circumstances of implementation (Whittington et al. 2008). Therefore, it is understandable that market and nonmarket tradeoffs will differ between urban and rural contexts.

Three existing studies focus on rural households, all of which limit their analyses to females. Ilahi and Grimard (2000), the most similar in concept to my study, develop a household model that is based on Becker (1965) and Gronau (1977). Testing the model with cross-sectional data for female household members in rural Pakistan, they find that time working on "market-oriented activities" decreases with distance between the household and water collection point. However, the existence of unobservable household characteristics that are correlated with both distance of the water source and female labor participation may bias their results. Using a matched difference-in-difference method, Lokshin and Yemstov (2005) assess the impacts of multiple types of rural infrastructure projects, including water supply systems, in rural Georgia. With a limited sample of water projects, they find no significant impact of the water infrastructure on the share of working-aged women employed in wage labor. Koolwal and van de Walle (2013) perform a cross-sectional study utilizing data from nine developing countries to estimate the extent to which water infrastructure affects female labor force participation. The authors exclude farm self-employment from their measure of labor force participation and find no impact on women's participation in market-based activities.

This paper makes multiple contributions by adding rigorous empirical evidence on both productivity and indirect impacts of water infrastructure to the existing literature on the labor market impacts of infrastructure construction in developing countries. First, it utilizes data from detailed 24-hour time budget diaries, the data from which can be categorized into home production, market production, and leisure, permitting an analysis of time tradeoffs, following the construction of water infrastructure. This provides insight on the value of time spent collecting water and thereby enables an informed cost–benefit analysis of the welfare impacts of water infrastructure. Second, using detailed data on farm and home production, in combination with the time use data, I estimate the aggregate productivity impacts of water infrastructure. Third, using village-level data on incidence of water-related diseases, I evaluate the health impacts of shared public water taps to better understand the role of health in impacting time use patterns, both directly and indirectly.

Results indicate that households located in villages that received the water infrastructure are, on average, approximately 30 percent less likely to use an unprotected water source and 19 percent more likely to use a domestic water source that is less than 200 meters from their home. This reduces the time burden of water collection. Critically, having water closer to the house translated into time savings, with approximately 170 minutes less per day (on average) spent on home production. Less time is spent on activities that require substantial water collection, including activities related to care of one's own physiology (time spent looking after oneself, bathing, going to the doctor, etc.) and care of children (bathing and caring for them when sick, etc.).[8] Reductions in the time intensity of home production come with an average increase of 80 minutes per day in leisure activities and 90 minutes per day in farm labor.[9] Impacts are found for male and female time allocation, a logical result given males and females share water collection duties in this context. The additional farm work translates into significantly more cereals produced, specifically barley and maize, which are critical for household income generation.

I investigate the extent to which the water infrastructure might have impacted human capital and labor productivity via incidence of water-related diseases. Although the

8. A description of the time use categories is in Online Appendix Table 5.

9. As described later in the paper, to determine whether the magnitude of the water infrastructure's effects on time reallocation is reasonable, I perform some basic calculations based on the principle that 50 liters are required per person per day to provide for basic drinking, hygiene, bathing, and laundry needs (UNDP 2006). These calculations indicate that the water infrastructure could result in approximately 136 minutes per adult per day of time savings directly due to water collection, which does not include indirect sources of time savings. These calculations suggest that the magnitude of my results is plausible.

incidence of acute intestinal infections decreased by one-third among children, there is no evidence of such impact among the adult population. In addition, there is no significant impact on the average cereal production per hour worked on the farm. These results provide no indication that adults are significantly healthier in the villages that received the water infrastructure. Taken together, results suggest that the main channel through which reductions in water-related illnesses affect adult labor is through their children—the time parents spend caring for children decreases when their children are sick less often.

Having shown that the water infrastructure increases both time spent working on the farm and production of crops grown on the farmland, I test the extent to which the increase in production is due to additional hours worked. This is in the spirit of de Mel, McKenzie, and Woodruff's (2008) returns to capital estimates. Instrumental variables calculations of the agricultural returns to labor indicate that each additional hour of labor allocated to the household farm produces approximately \$0.11 in cereals harvested. This estimated return to labor is approximately one-half the reported farm wage during this time period.[10]

Finally, I undertake a cost–benefit analysis of the water infrastructure. Lacking empirical evidence, many previous cost–benefit analyses are based on assumptions of the value of time spent collecting water (Whittington, Mu, and Roche 1990). However, I can make an informed calculation by using the implied hourly farm wage of \$0.11 and by decomposing the time savings from home production (approximately 2.8 hours) according to where it is reallocated (approximately 80 minutes to leisure and 90 minutes to market labor). Just based on time reallocated to farm work alone, the benefits are substantial: The water infrastructure has a net present value of \$123 million.

The remainder of the paper is organized as follows. Section II provides background information on drinking water access and labor in the Kyrgyz agricultural sector. Section III discusses the links between water, time, and farm production. Section IV addresses the empirical framework, including the identification. Section V explains the various data sets used in this research and baseline characteristics. Section VI addresses the water infrastructure's impacts on time allocation, disease outcomes, agricultural production, and returns to labor. The cost–benefit analysis is described in Section VII. Section VIII concludes.

II. Background on Kyrgyzstan

According to the IMF's 2012 GDP (PPP) per capita rankings, Kyrgyzstan is ranked 147th (out of 187 countries) between Cambodia and Cameroon, and as such, it is listed by the World Bank as one of 35 low-income countries in the world. This section provides background on the baseline state of domestic water infrastructure and the role of agriculture for rural households in Kyrgyzstan.

A. Domestic Water Supply Systems in Rural Kyrgyzstan

While part of the former Soviet Union, some rural areas of Kyrgyzstan gained improved access to drinking water sources in the form of shared taps (also known as standpipes).

10. The average hourly wage in 2003 for "market-oriented skilled agricultural and fishery workers" was \$0.19/hour (World Bank 2007).

However, the country saw marked decreases in the level of water supply services following the country's declaration of independence in 1991, with many of the existing water supply systems falling into disrepair. This left a large proportion of the Kyrgyz population drinking from sources contaminated by fertilizers, fecal matter, and other pollutants (USAID 2006), such as irrigation canals, unprotected springs, rivers, or ponds. In the study regions, prior to the intervention, approximately 50 percent of villages had no water service at all, 30 percent of villages provided service to 20–40 percent of households, and 15 percent of villages provided service to 41–60 percent of households (DFID and World Bank 2007).

B. Labor and Agriculture in Kyrgyzstan

In Kyrgyzstan, the agricultural sector accounts for more than one-third of the country's GDP (World Bank 2004), and on-farm growth has been credited as a driver for increases in nonfarm goods and services (World Bank 2007). The country's agricultural sector relies on the production of cereals, specifically wheat, maize, and barley (FAO 2011). According to the 1999 census, 64.7 percent of the population of Kyrgyzstan, totaling approximately 3.14 million people, lives in rural areas. With 75.3 percent of the rural population over 15 years old working in agriculture (National Statistical Committee of the Kyrgyz Republic 1999), a substantial proportion of rural households rely on income from their own farms as their main source of income.

In the three provinces of interest (Naryn, Issyk Kul, and Talas), rural households have an average of 5.7 acres of land. This area is divided across an average of two plots of land, which typically include a home garden and a small farm (calculated from the 2003 Kyrgyz Integrated Household Survey [KIHS] data). There are several key differences between home gardens and small farms. A summary of the differences is presented in the Online Appendix 1A. Home gardens tend to be small plots of land (between 0.1 and 2.0 ha in size) that are adjacent to the home, whereas the household's small (or "peasant") farm tends to be a larger plot of land that is located in the area surrounding the village.[11] Land on the small farms is three times more likely to be formally irrigated than land in the home garden (KIHS 2003). Photos depicting these spatial differences are shown in the Online Appendix 1B.

The potential income generation of the plots is connected to the crops grown on each. Although 83 percent of home gardens are cultivated solely for household consumption, only 30 percent of farmlands are cultivated for solely household consumption (calculated from KIHS data, 2003). There are also several key distinctions in the allocation of crops grown on the two different types of land plots. Most fruits and nuts are grown in the home gardens. Vegetables may be grown in either the home garden or the small farm, depending on the type of vegetable. Fodder (grasses for hay) and cereals are grown almost solely on the small farms.

Small farms are constrained by low levels of mechanization and labor availability. The Kyrgyz farm sector has low access to capital equipment (World Bank 2003), and existing equipment is old and inefficient (World Bank 2007). Only 2.7 percent of rural

11. Following the independence of Kyrgyzstan, collective farms were subdivided and allocated to residents in rural areas; most of land previously held by collective farms was shifted to peasant farms during the process of land reform (Akramov and Omuraliev 2009). This process of division let to the current distance from household to farm.

households own any large agricultural equipment (including tractors), and only 9 percent own a horse (KIHS, 2003). Potentially due to the low levels of machinery, peasant farms require more labor per hectare than the collective and state farms historically did (Dekker, 2003).

These peasant farms primarily rely on family labor (Lerman, Csaki, and Feder 2004); however, since the 1990s, the birthrate has decreased, resulting in smaller families (Dekker, 2003). The median household farm in our sample is cultivating 100 percent of its farm land and not hiring any outside labor (KIHS 2003). Meeting farm labor requirements is likely particularly challenging in the spring and fall months, when sowing and harvesting occur for the major food crops grown on the farms (FAO 2011).

III. Links between Water, Time, and Farm Production

To understand the links between water, time, and agricultural production, one must understand how water infrastructure can impact the time intensity of home production. To do so, I consider a basic agricultural household model in the spirit of Becker (1965) and Gronau (1977).[12] As in Strauss and Thomas (1995), households are assumed to maximize their utility from commodities purchased in the market and produced at home and leisure, subject to a budget constraint, time constraint, and home production function. A household must tradeoff between allocating time toward leisure, home production, and work in the market. This section provides a framework through which to understand these relationships and details on the water infrastructure introduced to alleviate the time intensity of water collection.

A. Water Infrastructure and Home Production Time Intensity

In the context of this study, home production includes activities such as collecting water, performing housework (including cooking, washing dishes, doing laundry, sewing, cleaning the home, producing or buying food and nonfood items, and other types of domestic labor), caring for one's own physiological needs (including bathing, looking after oneself physically, going to public bathhouses, going to the hospital or doctor, eating, sleeping, and other needs), caring for children (including time spent bathing, feeding, and caring for sick children, as well as helping them with homework and playing with them), and helping other relatives.

Households lacking water infrastructure typically collect water for many purposes beyond drinking, such as preparing food, cleaning homes, bathing children, growing food in the family home gardens, and watering domestic animals (Schouten and Moriarty 2003). As such, home production is more time intensive for households lacking water infrastructure in two ways. First, such households must collect the water for these domestic purposes, and the collection takes time. Second, these households are limited by the water that they can transport to their homes, and the constraints on water availability can make certain household activities, such as cleaning the home and washing dishes, more cumbersome and thus time intensive.

12. Aguiar, Hurst, and Karabarbounis (2012) provides a more contemporaneous treatment of these concepts. Of the previous work on the time impacts of water provision, two other papers, Koolwal and van del Walle (2013) and Ilahi and Grimard (2000), also examine such questions explicitly in the framework of such models.

Given that households use the water for many domestic purposes, household members typically either make multiple water collection trips per day or send more than one household member to the water source.[13] The time required to make a round-trip from home to water source and back depends on a few factors. First, distance from the household to water source plays a large role. Water sources can be located a substantial distance from the house. Second, the physical characteristics of naturally occurring sources (rivers and streams, etc.) and the surrounding terrain may increase the difficulty of and time required for collection.[14] Third, many households relying on the same source can result in crowding and queuing at the source.[15] As such, time required to collect water can be much greater than one would expect just based on distance to the source.

Water collection is often primarily women's duty in many developing countries. However, based on data collected via the MICS survey, the duties of water collection tend to be shared between males and females in Kyrgyzstan. Overall, in rural communities in Kyrgyzstan, approximately 60 percent of households have females (women and girls) as their primary water collector. However, in the three provinces in which this study was conducted, an opposite pattern exists (UNICEF MICS 2006). Online Appendix 2 shows that in Issyk kul, Naryn, and Talas, approximately 60 percent of households have males as their primary water collectors. Therefore, in this context, lack of water infrastructure increases the time intensity of home production for both men and women.

Water infrastructure can address all of the constraints above by making water closer to the household, eliminating the risks of collecting from dangerous sources, and reducing the number of households queuing at a collection point. To address the lack of water infrastructure in rural Kyrgyzstan, a large-scale effort was launched in the early 2000s to construct water infrastructure, in the form of shared water taps, in rural communities. Villages were informed of the project and, if interested, they applied to receive the infrastructure. Given that there was not enough funding to provide all villages with the infrastructure, a village selection process was carried out annually between 2003 and 2006, with the following number of villages in each year: 61 villages (2003), 52 villages (2004), 46 villages (2005), and 14 villages (2006). To ensure transparency in the selection process (further described in Online Appendix 3), villages were scored based on several factors such as need for water and poverty levels.

Calculations indicate that the average length of time between village selection and the official completion date was approximately two years. The time between selection and water supply system completion for villages is shown in the Appendix 4 figure. The official date of water supply system completion does not reflect when households began to use the system. Therefore, I assume a two-year lag between selection and construction completion in all analyses.[16]

Prior to the intervention, households typically were not paying for drinking water. They were either using naturally occurring sources (springs, rivers, etc.) or the old, decaying Soviet infrastructure (if it existed in the village). Villages selected to receive

13. For example, households in some areas of rural western Kenya make, on average, almost seven water collection trips per day to their water source (Kremer et al. 2011).

14. Children can fall into rivers when collecting water, resulting in injury or sickness, particularly during the winter. Other sources dry up in the summer, making water containers difficult to fill.

15. For example, Kyrgyz villages with water infrastructure at baseline had an average of 64 houses (but at times more than 200 households) sharing one tap (DFID and World Bank 2007).

16. Results were also estimated using the government date of construction completion. Results from the two methods are very similar.

the infrastructure had to contribute a percentage of the construction costs upfront prior to construction. After construction, households were expected to pay a tariff for the water that was endogenously determined by the village. Representatives from the village were instructed to set the tariff such that it would cover the ongoing operation and maintenance costs of the infrastructure.

B. Alternative Time Uses: Leisure and Market Work

The decreased time intensity of home production frees time for leisure and market work. Leisure includes activities such as listening to the radio, playing sports, spending time with friends, and reading, among others. Market work is the potentially income-generating labor, which in this context is predominantly work on the household's own small farm, but also includes formal employment that earns a salary (teachers, government employees, and health care workers), and entrepreneurial activities, trade, and other informal employment.

Ex ante it is not obvious how households will reallocate time savings from the reductions in the time intensity of home production. This paper tests the extent to which time is reallocated to either leisure or market work.

IV. Empirical Framework

To isolate the impact of the water infrastructure, I utilize the phased-in timing of the village selection process in conjunction with panel data sets of villages, households, and household members.

A. Identification Strategy

I estimate the impact of a village being allocated a water supply system on individual time use and measures of household agricultural production. A simple cross-sectional analysis of the difference between villages that receive and villages that do not receive the infrastructure is likely to be biased due to unobserved, confounding variables. Given the phased-in selection of villages over several years, I use the differences across villages over time to estimate the impact of being allocated a water supply system on these outcome measures. This allows me to control for the unobserved, fixed confounders that are correlated with both access to water and outcome measures.

First, I test whether village selection improved household water access by decreasing household use of unprotected water sources, increasing household use of shared standpipes, and decreasing the distance between households and their domestic water sources. All regressions include village fixed effects (to account for the time-invariant village characteristics) and district–year fixed effects. Many of the outcome measures (crop production, time allocation, and even measure of health, etc.) are impacted by rainfall, which has tremendous variation spatially. District–year fixed effects will absorb much of the variance in weather, thereby allowing us to isolate the impact of the water infrastructure.

The difference-in-differences estimate of the water infrastructure's impact is calculated through the following equation:

$$(1) \quad S_{hjkl} = \beta_0 + \beta_1 w_{jkl} + \Gamma' d_{hjkl} + (\alpha_k * \delta_l) + \theta_{jk} + \epsilon_{ihjkl}$$

where S_{hjkl} represents the three indicators of water access, specifically use of an unprotected water source, use of shared standpipes, and distance of the water source of household h in village j and district k in year l; w_{jkl} indicates whether village j was allocated a water supply system two years prior; d_{hjkl} is a vector of household-level controls; $(\alpha_k * \delta_l)$ represent district–year fixed effects; and θ_{jk} are village fixed effects.

After showing that the project improved water access, I estimate the impact of the infrastructure on individual-level time allocation. The difference-in-differences estimate of the impact of the water supply system construction on individual time use is obtained through the following OLS regression:

$$(2) \quad T_{ihjkl} = \beta_0 + \beta_1 w_{jkl} + \beta_2 d_{hjkl} + \Pi' x_{ihjkl} + \Omega' z_{ihjkl} + (\alpha_k * \delta_l) + \theta_{jk} + \epsilon_{ihjkl}$$

where T_{ihjkl} is the number of minutes in a 24-hour period individual i of household h in village j and district k allocated toward a given activity in year l; w_{jkl} indicates whether village j in district k was allocated a water supply system two years prior to year l; d_{hjkl} refers to household characteristics, including the size of household h; x_{ihjkl} is a vector of individual-level controls, including age and gender; and z_{hjkl} is a vector of interview round controls, such as season and day of week on which the data were collected.

Similar to Equation 1, the following regression estimates the impact of drinking water infrastructure on household agricultural outcomes, such as crop harvests:

$$(3) \quad A_{hjkl} = \beta_0 + \beta_1 w_{jkl} + \Gamma' d_{hjkl} + (\alpha_k * \delta_l) + \theta_{jk} + \epsilon_{ihjkl}$$

where A_{hjkl} is the amount harvested by household h in year l of a particular crop (or group of crops), as measured in kilograms, and d_{hjkl} is a vector of household-level controls, which in this case also includes household farm characteristics, such as the total plot size, the proportion of land irrigated, the number of land plots owned by the household, proportion of cultivated land, and household expenditures on farm-related things.

One might be concerned that villages receiving the infrastructure earlier are different from those selected in later years in ways (for example, levels of poverty) that lead to omitted variable bias. To address any potential differences in village selection timing, we estimate these regressions both with and without controls for the scores used in village selection (a continuous measure) interacted with year dummies. Including these controls allows for differential year effects based on need for the infrastructure and poverty levels (both of which were criteria in village selection). For example, this allows for the possibility that richer and poorer locations might respond differently to year-to-year shocks. Village selection and the scoring process specifically are further described in the section below.

V. Data

This paper relies on data at the household and individual levels, as provided by the Kyrgyz Integrated Household Survey (KIHS), and village level, as provided by the Kyrgyz National Census and the Ministry of Health data. All data sources are described below.

A. Village Selection Process

Village selection occurred annually between 2003 and 2006, resulting in 173 villages chosen. Data on the village selection process were provided by the Kyrgyz Ministry of Water. Data on village selection include the villages that applied to receive water infrastructure, the scores assigned to each village in the selection process, the villages' selection status, the dates of both village selection and registered construction completion. The data on village selection are then matched with the village-level census data, village-level data on water-related diseases, household-level data on agricultural production and other household characteristics, and the individual-level data on time use.

The villages that applied for the water infrastructure were scored between zero and 100 based on four factors: (1) need for water, (2) poverty levels, (3) economic and technical feasibility, and (4) community participation.[17] Villages above a given score were to be selected for the infrastructure project. Due to an effort to ensure that all districts in the three northern provinces would be represented, albeit not equally, yearly selection was stratified by district.

Given that selection in each year was stratified by district, the "cutoff" score above which a village received the infrastructure varied for each district. For this reason, we normalize the scores across districts by creating a variable that represents the distance of an individual village's score from the score of the last village to be selected in that district. By normalizing the variable in this way, those villages with scores above the cutoff are positive, and those below the cutoff are negative.[18] A more detailed description of the selection criteria and process is in the Online Appendix 3.

B. Kyrgyz Integrated Household Survey

The Kyrgyz Integrated Household Survey (KIHS) was implemented annually by the Kyrgyz National Statistics Committee between 2003 and 2010, providing household-level data. The KIHS is a rotating panel, with one-quarter of the households changing each year. The sampling method employed for the KIHS is a two-stage stratified design. From the 1999 census, primary sampling units (PSUs) were identified, with a PSU equivalent to a village in rural areas. Stratifying by province and whether the location is rural or urban, 456 PSUs were randomly selected. The PSUs have primarily remained the same between 2003 and 2010. Within the three provinces, 66 rural PSUs were surveyed, 38 of which applied to the project, and of those 24 received the water infrastructure. Household-level data from these rural PSUs create a panel data set of approximately 420 households annually surveyed between 2003 and 2010.[19] Given the relatively small number of KIHS PSUs overlapping with the water infrastructure project, we include results from bootstrapping the standard errors through the wild cluster bootstrap procedure.

The KIHS collects data on households and their members, including information on household characteristics and consumption and individual education, health, and employment. Given the large proportion of rural households that survive on agricultural

17. To ensure the process was not manipulated for political reasons, the selection process was done by a panel representing government agencies and international organizations.

18. Even with normalized scores, being above the "cutoff" score does not perfectly predict construction of a new water supply system.

19. Within the PSUs, households were randomly selected, with a probability proportional to village size.

production on their small farms, the survey collects quarterly agricultural data, such as crop production, land characteristics, and expenditures on farm-related activities.

Additionally, in 2005 and 2010, the KIHS included a module on time use, through which individuals kept 24-hour time use diaries. The diaries were timed such that all days of the week were represented proportionally. Individuals 12 years and older were asked to record their time use for a 24-hour (1,440 minutes) period. Online Appendix 5 shows the different categories of time use. There is, however, no category specific to water collection, so water-related time use accrues to the category in which the activity is associated. For example, if water were collected for cleaning one's home, then that time would be recorded as housework. Collecting water for bathing or for livestock kept in the family's garden would be recorded as self-care and working with in the home garden, respectively.

C. Village-Level Data

The Kyrgyz National Statistics Committee and the Kyrgyz Ministry of Health State Sanitary Epidemiological Surveillance (SSES) provided village-level data collected on village characteristics and disease incidence, respectively. Census data are collected once a decade and are available for 1999 and 2009, providing village-level characteristics for one period prior and one following the water intervention. Such data include population size, average household size, education levels, income sources, and the proportion of population self-employed.

Annual village-level data were collected on incidences of two water-related diseases over the period of 2000 to 2009: hepatitis A and acute intestinal infections.[20] These data were collected by SSES via village-level health facilities. Incidence of each disease per 100,000 people was calculated based on yearly village population estimates.

Using data reported through the government health system provides both advantages and disadvantages. These government-collected data provide a strong alternative to self-reported incidence of disease and mortality. Some experts on the topic have expressed concern regarding the strength of studies relying on self-reported child diarrhea (Schmidt and Cairncross 2009) collected through surveys, as frequent surveying may lead to respondent fatigue, social desirability bias, and health protective behaviors (Zwane et al. 2011). These factors could potentially impact individual responses and potentially bias results. In contrast, the village-level health outcomes collected through village healthcare providers are less susceptible to such biases.

The village-level health data utilized here may be subject to other biases. It is possible that the villages without health facilities are smaller or more remote than those with such facilities, and therefore poorer. If this is the case, then the poorest populations are excluded from this part of the study, as there would be no data on the incidence of water-related diseases for these locations. A few of the existing studies addressing heterogeneity of impacts indicated that poorer populations might be impacted differentially than those that are better off (Jalan and Ravallion 2003; Galdo and Briceno 2005; Galiani, Gertler, and Schargrodsky 2005). However, there is no agreement as to the direction of that effect.

20. The SES definition of acute intestinal infections includes dysentery, giardia, enterobaeces, acariasis, and acute viral hepatitis.

D. Baseline Characteristics and Tests

Baseline characteristics calculated using the 1999 village-level census data show that the average village in that group had 1,676 residents across approximately 338 households, averaging five people per household. The average village reported that 52 percent of households receive income from forms of self-employment, and 56 percent of adults had completed at least secondary school.

To alleviate concerns regarding endogenous timing of treatment, we can perform two tests with the baseline data: calculations of baseline characteristics by selection year (Table 2) and tests of pretrends to support the parallel trends assumption (Table 3).

1. Baseline characteristics by selection year

In Table 2, we present means by each selection year using both village-level characteristics (Panel A) and household-level characteristics (Panel B). Means for each group are shown in Columns 1 through 4, with standard deviations in brackets below. Columns 5 through 7 show the differences in mean baseline characteristics between those villages selected in the first year (2003) and those selected in later years. The main difference is that villages are larger (comprising more households) in later selection years. This is consistent with the selection process design, which prioritized villages with higher incidences of poverty. The smaller villages selected in earlier years are likely more remote and poorer. Similarly, villages selected in 2005 are slightly more likely to have piped water at baseline than those selected earlier, which is consistent with prioritizing villages with the greatest need for water.

2. Testing parallel trends

The difference-in-differences estimation strategy uses differences in the timing of infrastructure construction across villages over time. This empirical strategy is based on the identifying assumption that, in the absence of the water infrastructure construction, the villages selected early and those selected later would have changed similarly in the absence of the program. I test this "parallel trends" assumption using household-level data for 2003–2004, the period prior to infrastructure completion. Given the detailed baseline calculations already shown in Table 2, we present abbreviated results from tests of pretrends in Table 3. Column 3 of Table 3 shows only one statistically significant differences in trends between the two groups pre-intervention. This is true for household-level water access, as well as small farm characteristics (including farm-related expenditures, which will serve as control variables). The one statistically significant difference is that later villages are slightly more likely to have more of their land irrigated prior to 2005. If anything, we believe that this would downward bias our results, particularly those pertaining to crop yields.

Time use data were collected via the KIHS in 2005 and 2010. The program villages that were selected in 2003 are considered "treated" as of 2005, meaning that there is no pure pre-infrastructure baseline data for time use. For this reason, I cannot test the parallel trends assumption with respect to time use. Similarly, without census data prior to 1999, we cannot test pretrends with village-level data.

Table 2
Baseline Characteristics: Differences by Selection Year

	Means by Selection Year				Differences between Selection Years		
	2003 Selected (1)	2004 Selected (2)	2005 Selected (3)	2006 Selected (4)	Difference 2004–2003 (5)	Difference 2005–2003 (6)	Difference 2006–2003 (7)
Panel A: Village-Level Characteristics							
Number of households	239	330	350	385	91.8**	111.4***	146.6*
	[165]	[232]	[186]	[316]	(38.94)	(35.31)	(85.21)
Household size	5.259	5.278	5.109	5.229	0.019	–0.150	–0.03
	[0.608]	[0.408]	[0.5012]	[0.522]	(0.097)	(0.109)	(0.157)
Proportion: population unemployed	0.267	0.288	0.304	0.273	0.021	0.036	0.006
	[0.253]	[0.230]	[0.261]	[0.280]	(0.051)	(0.051)	(0.080)
Proportion of HHs with income from:							
Formal employment	0.361	0.370	0.372	0.371	0.009	0.011	0.001
	[0.080]	[0.078]	[0.064]	[0.082]	(0.015)	(0.014)	(0.024)
Government pensions	0.096	0.095	0.105	0.094	–0.000	0.009	–0.002
	[0.0301]	[0.028]	[0.027]	[0.028]	(0.006)	(0.006)	(0.008)
Government assistance	0.009	0.009	0.011	0.007	–0.000	0.002	–0.002
	[0.013]	[0.016]	[0.016]	[0.009]	(0.003)	(0.003)	(0.003)
Self-employment	0.528	0.520	0.504	0.530	–0.008	–0.024**	0.002
	[0.059]	[0.060]	[0.045]	[0.074]	(0.011)	(0.010)	(0.021)

(*continued*)

Table 2 (*continued*)

	Means by Selection Year				Differences between Selection Years		
	2003 Selected (1)	2004 Selected (2)	2005 Selected (3)	2006 Selected (4)	Difference 2004–2003 (5)	Difference 2005–2003 (6)	Difference 2006–2003 (7)
Proportion with secondary education (adults)	0.566	0.548	0.568	0.539	–0.018	0.002	–0.027
	[0.075]	[0.096]	[0.070]	[0.115]	(0.017)	(0.014)	(0.031)
Observations (number of villages)	61	51	46	14			
Panel B: Household-Level Characteristics							
Main drinking water source is:							
Shared piped water	0.211	0.364	0.604		0.153	0.394*	
	[0.410]	[0.483]	[0.492]		(0.162)	(0.203)	
Unprotected water	0.347	0.263	0.313		–0.085	–0.035	
	[0.479]	[0.442]	[0.466]		(0.196)	(0.240)	
Water <200m from HH	0.716	0.899	0.698		0.183	–0.018	
	[0.453]	[0.303]	[0.462]		(0.138)	(0.145)	
Number of land plots	1.947	1.758	1.885		–0.190	–0.0620	
	[0.305]	[0.431]	[0.432]		(0.123)	(0.131)	
Total size of plots (sq. meters)	15,493	14,188	21,001		–1,306	5,508	
	[10,434]	[11,824]	[12,815]		(4,021)	(4,587)	

Proportion of land:							
Cultivated	0.948	0.951	0.949		0.003	0.001	
	[0.206]	[0.210]	[0.216]		(0.035)	(0.055)	
Privately owned	0.972	0.974	0.965		0.012	0.008	
	[0.175]	[0.141]	[0.158]		(0.030)	(0.036)	
Land irrigated	0.991	0.961	0.949		–0.030	–0.042	
	[0.085]	[0.187]	[0.213]		(0.017)*	(0.034)	
Farm-related expenditures (KGS)	2,533	2,650	3,535		117.4	1,002	
	[2,989]	[3,691]	[3,551]		(1,031)	(1,105)	
Observations (number of households)	95	99	96				

Notes: The selection year is the year the village was chosen for treatment. Village-level characteristics are calculated using 1999 Census data from the Kyrgyz National Statistics Committee. The number of observations (villages) in each Column of Panel A match the number of villages selected in each of the years, except 2004 in which there was one village that could not be matched to the census data. Household-level characteristics are calculated using the Kyrgyz Integrated Household Survey for 2003. Columns 1–4 shows variable means by selection year, with standard deviations in brackets. Columns 5–7 show differences between selection years and the standard errors are in parentheses with statistical significance denoted by: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Household calculations have standard errors clustered at the village level. Plot size variable drops outliers (top 5% of observations).

Table 3
Testing Pretrends with Baseline Data

	2003 Difference: Late – early (1)	2004 Difference: Late – early (2)	Difference in Difference (Column 2 – 1) (3)
Main drinking water source is:			
Shared piped water	0.316	0.355*	0.040
	(0.197)	(0.204)	(0.120)
Unprotected water	0.008	–0.089	–0.097
	(0.214)	(0.212)	(0.080)
Water <200 m from HH	–0.111	0.074	0.185
	(0.113)	(0.112)	(0.141)
Number of land plots	–0.012	0.038	0.050
	(0.171)	(0.186)	(0.050)
Total size of plots (sq. meters)	6,135	4,204	−1,931
	(4,431)	(4,423)	(1,500)
Proportion of land:			
Cultivated	0.006	–0.008	–0.014
	(0.046)	(0.044)	(0.064)
Privately owned	–0.011	0.016**	0.028
	(0.034)	(0.008)	(0.033)
Land irrigated	–0.012	0.065*	0.077*
	(0.027)	(0.034)	(0.045)
Farm-related expenditures (KGS)	661.9	929.4	267.4
	(988.9)	(916.1)	(344.9)
Observations (number of households)	290	304	594

Notes: Results are from tests of pretrends. Column 1 presents results using just 2003 data. Column 2 presents results using just 2004 data. Column 3 shows results of Column 2 minus Column 1. The sample for these calculations is limited to those villages that eventually receive infrastructure through the program. “Late villages” are those selected after 2004, whereas the “early villages” are those selected in 2003 and 2004. Details on the village selection are described in the paper text. Standard errors are clustered at the village level and in parentheses. Statistical significance is denoted by: $***p<0.01$, $**p<0.05$, $*p<0.1$. Plot size variable drops outliers (top 5 percent of observations).

VI. Impacts of Drinking Water Infrastructure

A. Water Access

Results shown in Table 4 indicate that the project worked; households in villages that were allocated water infrastructure are more likely to use shared piped water and less likely to use unprotected sources for their main water supply. Importantly, these households are approximately 19 percent more likely to have their water source less than 200 meters from the household. Odd columns of the table present results from our basic specification, whereas the even columns present results from regressions including controls for the interaction of village scores and year dummies. Results from wild cluster bootstrap procedure are shown in brackets throughout the table.

B. Time Allocation

In order to understand the overarching reallocation of household time that comes with water infrastructure construction, I first estimate Equation 2 with all time used within the 24-hour period aggregated into one of three categories: leisure, home production, and market work. To do so, time use is aggregated in the spirit of Gronau (1977) and his distinction between leisure and home production. Analyzing the impacts on time use within a 24-hour period permits the measurement of the complete reallocation of time. An analysis at this level of aggregation is possible only due to the nature of the time budget diaries (and because data cover the full 24-hour period). Results of these Gronau-style regressions are shown in Table 5. As expected, the water technology decreased the time intensity of home production. Column 1 shows that home production decreases by approximately 2.8 hours per week following the introduction of the water infrastructure. Columns 2 and 3 show how this time is reallocated, with approximately half (90 minutes) going to market work and half (80 minutes) to leisure. With a significant proportion of the time savings reallocated to leisure, this result is consistent with Devoto et al. (2012). These results indicate that the water infrastructure is freeing up time that people are then able to reallocate to other productive labor. Taken together, these results are consistent with the belief that households are labor-constrained and are trading off between work in the market and home production.

A more nuanced understanding of this time reallocation is provided in Table 6,[21] which shows, for males (Panel A) and females (Panel B) separately, the impacts of water infrastructure on subcategories of market work and home production. The main areas of time savings occur in home production, including work in the home garden, caring for children, and self-care. Only a very small proportion of home gardens are formally irrigated (KIHS 2003). Given the crop production and livestock living in the garden (Currey 2009), home production activities occurring within the home gardens require substantial water. Work in the home gardens is less time intensive post-construction, as it is less challenging to collect water for garden plants and livestock kept within the gardens.

21. Due to space constraints, results from regressions controlling for village score interacted with year dummies are presented in Online Appendix 8.

Table 4
Household Water Access, Difference-in-Differences

Main Drinking Water Source is:	Shared Piped Water (1)	Shared Piped Water (2)	Unprotected Water (3)	Unprotected Water (4)	Located <200 m from HH (5)	Located <200 m from HH (6)
Water system	0.260**	0.247*	–0.297***	–0.237**	0.187**	0.144*
	(0.110)	(0.126)	(0.094)	(0.092)	(0.081)	(0.080)
	[0.064]	[0.148]	[0.020]	[0.036]	[0.040]	[0.144]
Controls for score * year	No	Yes	No	Yes	No	Yes
District-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Village fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Mean baseline water access	0.483	0.483	0.231	0.231	0.794	0.794
Number of villages	38	38	38	38	38	38
Household observations	3,235	3,235	3,235	3,235	3,235	3,235
R-squared	0.544	0.544	0.560	0.560	0.303	0.303

Notes: Results are for difference-in-differences regressions using the household survey data collected annually via the Kyrgyz Integrated Household Survey. Data include all years between 2003 and 2010. Observations are at the household level. Sample is limited to those villages (38 in total) that were eligible to receive the water infrastructure through the program. Baseline means are calculated for 2003 and 2004. All regressions include controls for household characteristics (the number of rooms in the home). Standard errors are clustered at the village level and in parentheses, with statistical significance denoted by: ***$p<0.01$, **$p<0.05$, *$p<0.1$. Wild bootstrap clustered (village) p-values in brackets.

Table 5
Aggregated Time Use of Household Members, Difference-in-Differences

	Home Production (1)	Market Work (2)	Leisure (3)
Panel A: Initial Specification			
Water system	−169.689***	89.897**	79.792**
	(47.431)	(33.644)	(37.496)
	[0.140]	[0.150]	[0.315]
Mean (minutes per day)	983.50	135.90	320.60
Observations	2,184	2,184	2,184
R-squared	0.403	0.314	0.304
Number of villages	38	38	38
Panel B: Include Score*Year Controls			
Water system	−151.169***	83.042**	68.128*
	(55.163)	(39.438)	(36.024)
	[0.182]	[0.252]	[0.240]
Observations	2014	2014	2014
R-squared	0.396	0.313	0.310
Number of villages	36	36	36

Notes: Time use data collected for household members 12 years and older via the KIHS (2005, 2010). Observations are individual level. Time use is measured in number of minutes per 24-hour period (totaling 1440 minutes). All regressions include the following controls: (1) season dummies, (2) day of week dummies, (3) respondent age and gender, (4) size of respondent's household, (5) district-year fixed effects, and (6) village fixed effects. Time use categories are described in the Online Appendix. Standard errors are clustered at the village level and in parentheses, with statistical significance denoted by: ***$p<0.01$, **$p<0.05$, *$p<0.1$. Wild bootstrap clustered (village) p-values in brackets.

Adults may spend less time caring for children if they are sick less; we see reductions for both males and females, although neither are significant. Caring for oneself (Column 3) is significantly less time-consuming, as bathing and taking oneself to the doctor require less time following infrastructure construction. These results are similar for both men and women, albeit the magnitude of the impacts on self-care is substantially larger for women.

Columns 4 through 8 of Table 6 show how time is reallocated within market work. Men and women reallocate approximately 116 and 96 minutes to farm labor, respectively. When we account for reductions in other forms of women's market work (Columns 5 and 6) their total additional market work sums to approximately 70 additional minutes. Interestingly, women also report, on average, an increase in time spent en route to and from their market work. This could reflect more frequent trips to the household farm.

Table 6
Detailed Time Use of Household Members, Difference-in-Differences

The Number of Minutes Spent On:	Types of Home Production			Types of Market Work				
	Work in Home Garden (1)	Caring for Children (2)	Self-Care (Excluding Sleep) (3)	Work on HH Farm (4)	Regular Paid Work (5)	Other Work (6)	Transport to/from Work (7)	Leisure (8)
Panel A: Males								
Water system	−23.85	−14.589	−50.813***	116.437***	−2.886	−11.575	3.834	75.343***
	(40.50)	(9.072)	(9.653)	(37.310)	(10.263)	(17.238)	(2.746)	(11.992)
	[0.744]	[0.332]	[0.048]	[0.080]	[0.716]	[0.456]	[0.224]	[0.000]
Mean (number of minutes)	97.11	8.17	153.84	218.95	21.52	32.55	13.58	315.77
Individual observations	1,090	1,090	1,090	1,090	1,090	1,090	1,090	1,090
Number of villages	38	38	38	38	38	38	38	38
R-squared	0.308	0.250	0.518	0.518	0.180	0.201	0.253	0.352
Panel B: Females								
Water system	−26.530	−29.610	−86.288***	96.413***	−20.733**	−4.031	7.806*	87.53
	(30.140)	(26.223)	(16.645)	(18.104)	(10.005)	(7.202)	(3.886)	(74.80)
	[0.564]	[0.420]	[0.028]	[0.064]	[0.084]	[0.464]	[0.252]	[0.512]
Mean (number of minutes)	72.16	51.34	165.31	59.94	32.56	38.75	6.36	262.38
Household observations	1,094	1,094	1,094	1,094	1,094	1,094	1,094	1,094
Number of villages	38	38	38	38	38	38	38	38
R-squared	0.327	0.166	0.531	0.328	0.127	0.128	0.251	0.288

Notes: Results are for difference-in-differences regressions. Time use data were collected for household members 12 years and older via the Kyrgyz Integrated Household Survey (2005 and 2010). Sample is limited to those villages (38 in total) that were eligible to receive the water infrastructure through the program. Time use is measured in number of minutes per 24-hour period (totaling 1440 minutes). All regressions include the following controls: (1) season dummies, (2) day of week dummies, (3) respondent age and gender, (3) size of respondent's household, (4) district-year fixed effects, and (5) village fixed effects. Means are calculated for 2005. For a description of the time use categories, see the Online Appendix. Standard errors are clustered at the village level and in parentheses, with statistical significance denoted by: ***$p<0.01$, **$p<0.05$, *$p<0.1$. Wild bootstrap clustered (village) p-values in brackets.

C. Agricultural Production

If labor is a constraint in agricultural production during particular seasons and farm labor increases with water infrastructure construction, one might also expect an increase in farm production. I test whether households in treated villages, on average, have greater crop production from their farms following infrastructure construction. To do so, I focus on the crop groups that are grown solely on the farmland (fodder and cereals) and regress the log production of these crops on the indicator of water infrastructure construction.

Results in Table 7 indicate that the reallocation of time to market work, and time on the household farm in particular, comes in conjunction with greater production of crops grown on farmland. There is a substantial, albeit insignificant increase in cereal production. Results in Columns 3 through 6 show the types of cereals in which the largest gains occur. Production of barley and maize increase by 40 and 114 percent, respectively. Notably, the results from regressions controlling for village score interacted with village dummies (Panel B) are larger in magnitude and statistically significant for wheat as well.

Based on worldwide quantities produced, maize and barley are the two most important coarse grains[22] (FAO 2009). Barley, which can survive droughts, low temperatures, high altitudes, and poor quality soils, suits the climate in Kyrgyzstan and is used for both livestock feed and human consumption.

The median farmer in our sample reports cultivating 100 percent of his farmland at baseline, meaning farmers cannot simply plant more of their land. One way to increase crop production would be for farmers to increase the number of plantings within a given year, which is possible for crops with winter and spring varieties. In Kyrgyzstan, both spring and winter varieties of barley (and wheat as well) are grown. Because it is a fast-growing crop, multiple plantings of barley can occur during a single calendar year (FAO 2011).

The demand for labor is seasonal and peaks in the fall months, which are crucial for harvesting the spring varieties and sowing the winter varieties of both wheat and barley. Maize also is harvested during this time. The timing of sowing and harvesting these crops is shown in the Online Appendix 6, making clear the peak demand for labor in farming households occurs during the late summer and early fall. In conditions in which two or more crops are grown on the same field in a year, the peak demand for harvesting labor for one crop occurs near simultaneously with the greatest labor demand for land preparation and seeding of the other crop (Pingali 2007). This suggests heterogeneities across seasons in the reallocation of time savings. We can provide some evidence on such heterogeneities in time use across seasons (shown in Online Appendix 7); however, the analysis is limited due to sample size.

D. Water-Related Diseases

Using data on village-level incidence of water-related diseases, I investigate whether the water infrastructure led to improved health. Acute intestinal infections and Hepatitis A are two such water-related diseases. If either adults or children are healthier due to the water infrastructure, one would expect incidences of these diseases to reflect as much. Table 8 shows results per 100,000 people for two age groups: children zero through 14

22. Coarse grains include cereals such as maize, barley, oats, and sorghum, but not wheat or rice (FAO 2009).

Table 7
Household Crop Harvests, Difference-in-Differences

			Categories of Cereals			
	Log Fodder (1)	Log Cereals (2)	Log Wheat (3)	Log Barley (4)	Log Maize (5)	Log Other Cereals (6)
Panel A: Initial Specification						
Water system	0.607	0.327	0.288	0.411**	1.140***	0.085
	(0.554)	(0.259)	(0.217)	(0.167)	(0.252)	(0.507)
	[0.540]	[0.510]	[0.436]	[0.082]	[0.000]	[0.738]
Mean baseline production (kg)	58.0	1746.0	1352.5	344.4	39.2	170.2
Household observations	1887	1391	1158	452	159	723
Number of villages	40	40	37	26	19	23
R-squared	0.430	0.486	0.504	0.584	0.615	0.64
Panel B: Include Score*Year Controls						
Water system	0.622	0.579***	0.598***	0.405*	1.803***	0.257
	(0.618)	(0.171)	(0.154)	(0.201)	(0.204)	(0.678)
	[0.624]	[0.004]	[0.024]	[0.204]	[0.000]	[0.780]
Mean baseline production (kg)	59.5	1796.3	1392.2	354.5	39.3	156.2
Household observations	1778	1378	1149	452	155	647
Number of villages	38	38	36	26	17	22
R-squared	0.43	0.51	0.51	0.59	0.58	0.68

Notes: Results are for difference-in-differences regressions using the household survey data collected via the Kyrgyz Integrated Household Survey (2003–2010). Sample is limited to those villages that were eligible to receive the water infrastructure through the program. "Water system" is an indicator of whether the village received the water infrastructure. Baseline means are calculated for 2003–2004. Amounts harvested are in log kilograms. All Columns include controls for (1) land characteristics (total plot size, number of land plots total, and proportion of land that is privately owned); (2) number of people and children 14 years and younger in a household; (3) district-year fixed effects; and (4) village fixed effects. Standard errors are clustered at the village level and in parentheses, with statistical significance denoted by: ***$p<0.01$, **$p<0.05$, *$p<0.1$. Wild bootstrap clustered (village) p-values in brackets.

Table 8
Village-level Health Outcomes, Difference-in-Differences

	Acute Intestinal Infection			Hepatitis A		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Village-Level Incidence in Children 14 Years Old and Younger (per 100,000 Children)						
Water system	–91.648*	–137.544**	–139.702**	–22.161	–12.694	18.445
	(49.435)	(52.953)	(65.056)	(44.333)	(42.454)	(52.256)
Mean baseline incidence		305.9			201.7	
R-squared	0.455	0.341	0.340	0.370	0.263	0.270
Panel B: Village-Level Incidence in Adults 15 Years and Older (per 100,000 Adults)						
Water system	–11.240	–10.880	–11.072	10.006	1.322	–1.912
	(18.680)	(21.724)	(27.633)	(13.348)	(13.334)	(14.707)
Mean baseline incidence		106.9			51.71	
R-squared	0.526	0.398	0.42	0.312	0.236	0.23
Score * year controls	No	No	Yes	No	No	Yes
District-year fixed effects	Yes	No	No	Yes	No	No
Year fixed effects	No	Yes	Yes	No	Yes	Yes
Observations (at village level)	2,230	2,230	1,930	2,230	2,230	1,930
Number of villages	223	223	193	223	223	193

Notes: Results are for difference-in-differences calculations using village-level health data collected by the Kyrgyz Ministry of Health for the year between 2000 and 2009. Their definition of acute intestinal infections includes dysentery, giardia, enterobaeces, acariasis, and acute viral hepatitis. Sample is limited to those villages that were eligible to receive the water infrastructure through the program. All regressions include village fixed effects. Baseline means are calculated for 2000–2004. Standard errors are clustered at the village level and in parentheses, with statistical significance denoted by: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

years old (Panel A) and adults aged 15 and older (Panel B). In Columns 1 and 2, results indicate reductions occurred in village-level incidence of acute intestinal infections, albeit, only for children. The preferred specification (in Column 1) indicates that acute intestinal infections among children fell by approximately one-third. Finding health improvements among children but not adults is consistent with findings in other health literature, such as the deworming literature, as children tend to have higher infection rates and act as disease vectors (Ahuja et al. 2015).

Additionally, I check to see whether households in villages that received the water infrastructure produced more cereals per time worked on the farm (results not shown). Although the relationship is positive, there is no statistically significant increase in this measure of labor productivity. Taken together, these results indicate that the primary channel through which water-related diseases affect adult labor is through time—children are healthier, and therefore parents allocate less time to their care.

E. Returns to Additional Farm Labor

Thus far, results indicate that the infrastructure brought water supplies closer to households, decreased the time required for water collection, increased the time spent working on household small farms, and increased farm production of cereal crops. Next, I estimate the extent to which the additional farm production is the result of additional hours of farm work to better understand the channel through which domestic water infrastructure might affect agricultural production. These calculations are analogous to the returns to capital calculated by de Mel, McKenzie, and Woodruff (2008). Specifically, I estimate the effect of the additional time spent working on household farmland on the production of cereals and fodder, the crops solely grown on farm land. This calculation uses construction of water infrastructure as an instrument for the time allocated to farm work. This provides the local average treatment effect (LATE).

To perform these calculations, I match data from the KIHS agricultural production and expenditures modules, data from the time use module (available only in 2005 and 2010), and data on agricultural land. This analysis is limited to the years in which data from all modules overlap (2005 and 2010), which results in a sample of 635 households across 37 villages.

The first-stage estimates the difference in total household time allocated toward farm labor in villages that receive the water infrastructure and is calculated through the following equation:

$$(4) \quad T_{hjkl} = \beta_0 + \beta_1 w_{jkl} + \beta_2 d_{hjkl} + \Omega' z_{hjkl} + (\alpha_k * \delta_l) + \theta_{jk} + \epsilon_{ihjkl}$$

where T_{hjkl} is the total amount of time (number of minutes out of a total of 1,440 minutes per day) the household spent working on their small farm.[23]

23. There are 3.4 workers per household (on average) in this sample. In comparison, the average household size is 5.1 people. This difference between the average household size and the average number of workers is due to children under 12 years old in the household.

The second-stage equation then estimates the increase in cereal production that results from the additional time of farm labor:

$$(5)\quad A_{hjkl} = \beta_0 + \beta_1 T_{hjkl} + \beta_2 d_{hjkl} + \Omega' z_{hjkl} + (\alpha_k * \delta_l) + \theta_{jk} + \epsilon_{ihjkl}$$

where A_{hjkl} is the amount of cereals harvested by household h in district j year l, as measured in kilograms; w_{jkl} indicates whether village j in district k was allocated a water supply system two years prior; T_{hjkl} is the total number of minutes of time allocated in one day to working on household h's farm by all individuals 12 years and older in household h; z_{hjkl} is a vector of interview controls, specifically the season and day of week on which the household members were interview occurred; d_{hjkl} is a vector of household-level controls, including household size and the number of dependents pensioners in the household and farm characteristics, such as the total plot size, the proportion of land irrigated, the number of land plots owned by the household, proportion of cultivated land, and household expenditures on farm-related things; $(\alpha_k * \delta_l)$ represent district-year fixed effects; and θ_{jk} are village fixed effects. All standard errors are clustered at the village level.

Analogous to the de Mel, McKenzie, and Woodruff (2008) calculation of the returns to capital, I estimate the returns to the additional farm labor in both levels and logs (representing the linear relationship and constant elasticity of substitution, respectively) and instrument for the additional farm labor with whether the village received the drinking water infrastructure. For the instrumental variables estimation to be valid, the exclusion restriction must hold and, receiving the water infrastructure must only change the cereal production through the hours worked on the farm, not through the other farm inputs.

The obvious concern is that households may use the drinking water to irrigate the crops grown on the farms and that could lead to greater farm production. I rule out the possibility that the domestic water is used for irrigating households' farmland and therefore impacts farm productivity through direct water supply. There are several facts that support this assertion. First, almost all land used for the small farms is irrigated in some fashion, whether by the old Soviet irrigation infrastructure or by less permanent earthen canals (KIHS 2003). Thus, the small farms do not necessarily need the domestic water. Second, as shown in Online Appendix 1B, due to the division of collective farms post-independence, most of the household farms are actually located a substantial distance from the home (Currey 2009) and are on the outskirts of each village. This makes domestic water infrastructure an extremely inconvenient and unlikely farm irrigation source. Households are therefore unlikely to use domestic water to irrigate their farm plots. As an additional check, I test whether the drinking water infrastructure has any impact on the amount households pay in irrigation fees (results not shown) and find that it does not.

In other farm contexts, farmers have been found to shift complementary inputs (such as herbicides and hired labor) when they receive fertilizer (Beaman et al. 2013). To ensure that in this setting farmers are not shifting inputs complementary to farm labor, I check whether other farm inputs changed upon receipt of the drinking water infrastructure. Results shown in Online Appendix 1C, do not show any such evidence.

As shown in Table 9, the additional farm labor that results from the water infrastructure leads to an additional 3.56 kg of cereal crops harvested. This equals an hourly wage of approximately \$0.11 per hour, which is roughly half the reported hourly farm wage.[24] In an effort to isolate the impact of farm labor on farm-grown crops, I only

24. The World Bank (2007) reported \$0.19/hour as the wage for market-oriented, skilled agricultural and fishery workers.

Table 9
Returns to Labor

	Cereals Harvested (kg) (1)	Cereals Harvested (kg) (2)	Log Cereals Value (USD) (3)	Cereals + Fodder Harvested (kg) (4)	Cereals + Fodder Harvested (kg) (5)	Log Cereals + Fodder Value (USD) (6)
Total farm work (minutes/24-hour period)	3.563***	3.420***	0.001**	3.438***	3.264***	0.003**
	(0.959)	(1.033)	(0.000)	(0.957)	(1.040)	(0.001)
First-stage						
Coefficient "water system"	337.62***	355.84***	659.33***	337.62***	355.84***	522.27***
F-statistic	19.22	19.13	16.00	19.22	19.13	18.44
Baseline mean	1946.79	2170.19	382.55	1982.56	2208.42	386.55
Score * year controls	No	Yes	Yes	No	Yes	Yes
Household observations	635	592	372	635	592	521
Number of villages	37	35	35	37	35	35
R-squared	0.579	0.58	0.64	0.581	0.58	0.56

Notes: Data are collected via the KIHS (2005 and 2010). Total farm work is the total number of minutes that all working-age household members spent working on the farm in one 24-hour period. All specifications include village fixed effects, district-year fixed effects, and day-of-week fixed effects. The log cereal values are calculated using Kyrgyzstan-specific FAO Annual Producer Prices for each crop in the analysis. Standard errors are clustered at the village level and in parentheses, with $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

include cereal and fodder production in the calculations of the returns to labor. These calculations omit the effort the additional labor might have had on other crop groups and therefore provide a lower bound for returns to labor.

Calculating the local average treatment effect here assumes the absence of externalities. In this setting, the most obvious externality would be a general equilibrium effect on wages, given the changes in labor supply. Although we do not have village-level wage data, we can shed light on this issue using province-level data on hourly wages for workers employed in agriculture over the time period of study. Documenting these wages over time (results not shown), we find wages are steadily increasing in all three provinces up through 2010. At least at the province level, there is no evidence of general equilibrium effects that impact wages.

These results contribute to the empirical literature testing models of household decisions and separation between the household's production and consumption decisions.[25] According to the standard agricultural household model, the farm's production should be determined by market wages and technology, not by the household's consumption. If labor in the market and home are perfect substitutes, then the household optimizes by allocating labor such that the marginal product of home production equals the market wage (Strauss and Thomas 1995). The \$0.11 per hour that I estimate is approximately half the wage of skilled hired farm labor. A number of studies have found evidence of nonsubstitutability between household labor and hired labor; however, the result of those studies indicate a shadow price of household labor approximately double the shadow price for hired labor (Roumasset and Lee 2007). In this case, the price of household labor is estimated to be far less than the reported price for hired labor. It might be that the wage for unskilled labor is something closer to the estimated \$0.11 per hour. If that is the wage at which households value their own labor, then the difference is explained. However, as described in Benjamin (1992), the separation property might not hold if certain markets are incomplete. In our sample, the median farmer is hiring no outside labor, suggesting that the labor markets in these contexts are indeed incomplete. Shortages of labor are expected in areas in which the population is sparse or good nonfarm labor opportunities exist (Pingali 2007). In rural Kyrgyzstan, the former is the case.

F. A Cross-Check of Time Savings

To determine whether the magnitude of the water infrastructure's effect on time reallocation is reasonable, I perform some basic calculations. According the Human Development Report 2006, 50 liters per person per day are required to meet the needs of drinking, basic hygiene, bathing, and laundry (UNDP 2006). With the average household size of 5.2 people (per the 1999 Kyrgyz census), the average household requires 260 liters per day. Assuming that a single person can carry 20 liters (which weighs 20 kg) per trip to the water source (without assistance from livestock), then 13 person-trips per day are required to collect enough water for the entire household.[26] Given that the majority of

25. Singh, Squire, and Strauss (1986) and Strauss and Thomas (1995) provide discussion of the recursive property. See Pitt and Rosenzweig (1986) and Benjamin (1992) for examples of tests of separation.

26. In practice, this could vary widely, with 13 trips by one person or multiple trips by a few people in the household.

households in my study regions report that an adult (either male or female) is their primary water collector (UNICEF MICS 2007), I assume that the time spent collecting water is divided by two adults. The average time for water collection is 26 minutes round-trip for households using unprotected water sources (based on calculations using the UNICEF MICS (2007) data), resulting in water collection requiring 338 minutes per household (or 169 minutes per each of the two adults) per day at baseline. Once a village receives the water supply system, I assume that a round-trip for water collection is reduced to five minutes per trip, equaling 65 minutes per household (or 32.5 minutes per adult person) per day. These time-savings estimates, which include only direct benefits from water collection, equal 136 minutes per adult per day. Given our estimates based on the KIHS include both direct and indirect benefits, this back-of-the-envelope calculation supports the argument that these results fall within a reasonable expected range.

VII. Cost–Benefit Analysis

From a policy perspective, it is important to understand the welfare consequences of the infrastructure. To do so, I perform a cost–benefit analysis in which I assume the water infrastructure has a lifespan of 20 years, per the World Bank (2009) analysis.

The costs of the water infrastructure include the upfront costs for the infrastructure construction, which totaled approximately $24 million, and ongoing maintenance costs. The upfront costs were comprised of a loan from the World Bank ($17.99 million),[27] an upfront contribution from the Government of Kyrgyzstan ($3.2 million) and a 15 percent labor contribution ($2.99 million) from the villages. I use data on the monthly budget for village water tariffs as the measure for ongoing maintenance costs, which equal approximately $560,000 in the first year and are assumed to increase by 2 percent each year throughout the 20-year life of the water infrastructure. Using a 12 percent discount rate results in costs of approximately $28.19 million.

In calculating the benefits, I include only the benefits from the time savings for adult beneficiaries. This is due to the lack of time use data for children. This provides a lower bound of the infrastructure's total benefits, as it omits nontime benefits for adults and all benefits for children, such as reductions in incidence of water-related diseases and improved school attendance.

To estimate the benefits, I assume the time savings begin at the time of construction completion (which is, on average, two years after village selection occurred). I assume the time savings accrue for the 20-year life of the water supply system. To count the number of people benefiting from the project, I calculate the baseline total working-age adult population for all of the villages that received water infrastructure through the project, based on the 1999 census. Although this population presumably will grow over the 20-year period, I assume that the infrastructure can serve only the population size

27. For ease, I assume that the entire loan is a cost incurred at the project outset. However, I also have performed the analysis under the specific financial conditions of the loan (which are 0.75 percent for 40-year period with a 10-year grace period). The specific choice of analysis depends on whether one is analyzing the project from the lender's perspective or that of the borrowing country. For a cost–benefit analysis, my current approach is the more conservative alternative, as costs are upfront and therefore not discounted.

at construction completion and therefore assume a constant population of project beneficiaries throughout the life of the infrastructure.

As discussed in Whittington, Mu, and Roche (1990), a dearth of data on how people value time spent in water collection has made it challenging to value the time savings that result from water infrastructure. Using a discrete choice model to analyze household decisions in a region of Kenya, they found that households value the time spent on water collection at roughly the value of the unskilled wage rate (Whittington, Mu, and Roche 1990). However, in practice, cost–benefit methods typically either assume time savings to be valued at a percentage of the market wage rate for relevant unskilled labor or they specify a proportion of time saved that is assumed to be spent in market production.[28] I do not have to make such assumptions. The Gronau-style regressions (as presented in Table 5), permit the decomposition of time savings according to time reallocation. Results indicate that time in overall home production decreases by approximately three hours per day, and of that time saved, approximately 80 minutes are reallocated to leisure and 90 minutes toward market work.

To estimate the benefits of the water infrastructure, I use an hourly wage rate of $0.11, as estimated through the returns to labor calculations and assume this grows at 2 percent per year. This is multiplied by the total working-age population benefiting from the project, as discussed above. Future benefits are assumed to accrue for the 20-year life of the infrastructure assuming a 12 percent discount rate, as was used in the preproject cost–benefit analysis (World Bank 2001). Including time reallocated to both market work and leisure results in estimated benefits equaling $232.2 million. As a lower bound, I can calculate the benefits including only those hours reallocated to market work, which results in estimated benefits of $92.3 million.

Calculating the benefits of rural water supply systems solely on time reallocation, I find that the benefits substantially outweigh the costs. Based on the above calculations, the net present value of the water infrastructure is between $64.1 million and $145.9 million.[29] This analysis suggests that even in contexts in which health benefits are ambiguous, the time use benefits alone may justify the infrastructure.

VIII. Conclusion

This paper investigates how individuals reallocate time from home production to market work following the construction of drinking water infrastructure. Given that processes of development often are associated with changes in household time allocation, it is important to understand how people reallocate time saved. Using differences in the timing across villages, I identify the impacts of shared water infrastructure on household distance to water sources, individual time use, and agricultural production. Access to drinking water infrastructure results in increases

28. For example, the preproject cost–benefit analysis for this project assumed that half the time saved could be reallocated to "commercially productive uses" (World Bank 2001).

29. I have calculated this cost–benefit with different discount rates to provide a sense of the role that it plays in calculating the net present value (NPV). Recalculating the upper-bound NPV estimate with a 10 percent discount rate, the NPV equals $176.1 million and with an 8 percent discount rate, the NPV equals $215.0 million.

in time allocated to leisure and market work, specifically work on the household farm. Time reallocation occurs for both males and females, a logical result given they both contribute to water collection.

The greater amount of time spent working on the small farms appears to translate into greater production of cereals, which are grown solely on the small farms. Significant increases in production of maize and barley indicate that the time constraint during peak sowing and harvesting months was relaxed as a result of the water infrastructure. Calculations of returns to the additional farm labor are approximately equal to half the hourly skilled farm wage.

To date, much of the empirical work estimating the impacts of drinking water provision has been related to health impacts. This study shows that even in the absence of obvious health impacts, water infrastructure may have a substantial NPV due to the reallocation of time from home production to market work and leisure. Although the reallocation of time savings from water collection to market work is a frequently mentioned benefit of water infrastructure, until now little rigorous evidence supported this actually occurring.

This study is relevant to other contexts in which households have seasonal labor constraints and therefore must make this tradeoff between home production activities and income-generating market work. This is particularly relevant for rural settings in which agriculture is a main source of income generation and labor demand is determined by the growing season. Additionally, these results are applicable to locations that may not currently be labor-constrained, but where water scarcity is a concern. The IPCC has documented increasing frequency and intensity of droughts in certain areas of Africa and much of Asia, with climate change projections indicating increased future water stress in Africa and decreased freshwater availability in many parts of Asia (United Nations 2010). In locations where water is becoming increasingly scarce, some households will face greater travel time to water sources and/or longer queues at their sources. In the face of climate change and increasing water scarcity, policy-makers ought to understand the time intensity of home production in the presence of poor quality or absent water infrastructure and how households deal with this time allocation tradeoff.

References

Aguiar, Mark, Erik Hurst, and Loukas Karabarbounis. 2012. "Recent Developments in the Economics of Time Use." *Annual Review of Economics* 2012(4):373–97.

Ahuja, Amrita, Sarah Baird, Joan H. Hicks, Michael Kremer, Edward Miguel, and Shawn Powers. 2015. "When Should Governments Subsidize Health? The Case of Mass Deworming." *The World Bank Economic Review* 29(s1):s9–s24.

Akramov, Kamiljon T., and Nurbek Omuraliev. 2009. "Institutional Change, Rural Services, and Agricultural Performance in Kyrgyzstan." IFPRI Discussion Paper 00904.

Beaman, Lori, Dean Karlan, Bram Thuysbaert, and Christopher Udry. 2013. "Profitability of Fertilizer: Experimental Evidence from Female Rice Farmers in Mali." *The American Economic Review* 103(3):381–86.

Becker, Gary S. 1965. "Theory of the Allocation of Time." *The Economic Journal* 75(299): 493–517.

Benjamin, Dwayne. 1992. "Household Composition, Labor Markets, and Labor Demand: Testing for Separation in Agricultural Household Models." *Econometrica* 60(2):287–322.

Blau, Francine D., Marianne A. Ferber, and Anne E. Winkler. 2002. *The Economics of Women, Men, and Work*. Upper Saddle River, NJ: Prentice Hall.

Cavalcanti, Tiago. V. de V., and Jose Tavares. 2008. "Assessing the 'Engines of Liberation': Home Appliances and Female Labor Force Participation." *The Review of Economics and Statistics* 90(1):81–88.

Coen-Pirani, Daniele, Alexis Leon, and Steven Lugaur. 2010. "The Effect of Household Appliances on Female Labor Force Participation: Evidence from the Micro-Data." *Labour Economics* 17(3):503–513.

Cosgrove, William J., and Frank R. Rijsberman. 1998. "Creating a Vision for Water, Life, and the Environment." *Water Policy* 1(1):115–22.

Currey, Robin. 2009. "Diversity of Hymenoptera, Cultivated Plants and Management Practices in Home Garden Agroecosystems, Kyrgyz Republic." FIU Electronic Theses and Dissertations. Paper 124.

Dekker, Henri A.L. 2003. *Property Regimes in Transition, Land Reforms, Food Security, and Economic Development: A Case Study in the Kyrgyz Republic*. Burlington, VT: Ashgate.

de Mel, Suresh, David McKenzie, and Christopher Woodruff. 2008. "Returns to Capital in Microenterprises: Evidence from a Field Experiment." *The Quarterly Journal of Economics* 123(4):1329–72.

Devoto, Florencia, Esther Duflo, Pascaline Dupas, William Pariente, and Vincent Pons. 2012. "Happiness on Tap: Piped Water Adoption in Urban Morocco." *American Economic Journal: Economic Policy* 4(4):68–99.

DFID and World Bank. 2007. "Impact Assessment Study of the Rural Water Supply and Sanitation Project Report." Unpublished Report.

Dinkelman, Taryn. 2011. "The Effects of Rural Electrification on Employment: New Evidence from South Africa." *American Economic Review* 101(7):3078–3108.

Food and Agriculture Organization (FAO). 2009. *Agribusiness Handbook for Barley*. Rome: FAO.

———. 2011. Global Information and Early Warning System (GIEWS) "Country Cereals Balance Sheets." Accessed 5/9/2011.

Field, Erica. 2007. "Entitled to Work: Urban Property Rights and Labor Supply in Peru." *Quarterly Journal of Economics* 122(4):1561–602.

Galdo, Virgilio, and Bertha Briceno. 2005. "Evaluating the Impact on Child Mortality of a Water Supply and Sewerage Expansion in Quito: Is Water Enough?" IADB Office of Evaluation and Oversight Working Paper.

Galiani, Sebastian, Paul Gertler, and Ernesto Schargrodsky. 2005. "Water for Life: The Impact of Privatization of Water Services on Child Mortality." *Journal of Political Economy* 113(1): 83–119.

Goldin, Claudia. 1994. "The U-Shaped Female Labor Force Function in Economic Development and Economic History." NBER Working Paper Number 4707.

Google Earth. 2013. Osh Oblast, Kyrgyz Republic. Accessed 11/15/2013.

Greenwood, Jeremy, Nezih Guner, Georgi Kocharkov, and Cezar Santos. 2016. "Technology and the Changing Family: A Unified Model of Marriage, Divorce, Educational Attainment, and Married Female Labor-Force Participation." *American Economic Journal: Macroeconomics* 8(1):1–41

Greenwood, Jeremy, Ananth Sheshadri, and Mehmet Yorukoglu. 2005. "Engines of Liberation." *Review of Economic Studies* 72(1):109–133.

Gronau, Reuben. 1977. "Leisure, Home Production, and Work: The Theory of the Allocation of Time Revisited." *Journal of Political Economy* 85(6):1099–1123.

———. 1986. "Home Production: A Survey." In *Handbook of Labor Economics*, ed. Orley Ashenfelter and Richard Layard, Volume 1:273304. Amsterdam, The Netherlands: Elsevier Science Publishers.

Harvey, Andrew S., and Maria Elena Taylor. 2000. "Time Use." In *Designing Household Survey Questionnaires for Developing Countries.* ed. Margaret Grosh and Paul Glewwe, 249–273. Washington, DC: The World Bank.

Ilahi, Nadim, and Franque Grimard. 2000. "Public Infrastructure and Private Costs: Water Supply and Time Allocation in Rural Pakistan." *Economic Development and Cultural Change* 49(1):45–75.

Jalan, Jyostna, and Martin Ravallion. 2003. "Does Piped Water Reduce Diarrhea for Children in Rural India?" *Journal of Econometrics* 112(1):153–73

Koolwal, Gayatrim, and Dominique van de Walle. 2013. "Access to Water, Women's Work, and Child Outcomes." *Economic Development and Cultural Change* 61(2):369–405.

Kremer, Michael, Jessica Leino, Edward Miguel, and Alix Z. Peterson. 2011. "Spring Cleaning: Rural Water Impacts, Valuation, and Property Rights Institutions." *Quarterly Journal of Economics* 126(1):145–205.

Lerman, Zvi, Csaba Csaki, and Gershon Feder. 2004. Agriculture in Transition: Land Policies and Evolving Farm Structures in Post-Soviet Countries. New York: Lexington Books.

Lokshin, Michael, and Ruslan Yemstov. 2005. "Has Rural Infrastructure Rehabilitation in Georgia Helped the Poor?" *World Bank Economic Review* 19(2):311–33.

National Statistics Committee of the Kyrgyz Republic. 1999. "Main Results of the First National Population Census of the Kyrgyz Republic of 1999." First National Population Census.

———. 2009. "Book I: Main Social and Demographic Characteristics of Population and Number of Housing Units." Population and Housing Census of the Kyrgyz Republic.

Pingali, Prabhu. 2007. "Agricultural Mechanization: Adoption Patterns and Economic Impact." In *Handbook of Agricultural Economics*, ed. Robert Evenson and Prabhu Pingali, 27792805. Amsterdam, The Netherlands: Elsevier Science Publishers.

Pitt, Mark, and Mark Rosenzweig. 1986. "Agricultural Prices, Food Consumption, and the Health and Productivity of Indonesian Farmers." In *Agricultural Household Models: Extensions, Applications, and Policy*, ed. Singh, Inderjit, Lyn Squire, John Strauss, 153–82. Baltimore: Johns Hopkins Press for the World Bank.

Roumasset, James, and Sang-Hyop Lee. 2007. "Labor: Decisions, Contracts and Organization." In *Handbook of Agricultural Economics*, ed. Robert Evenson and Prabhu Pingali, 2705–40. Amsterdam, The Netherlands: Elsevier Science Publishers.

Schmidt, Wolf-Peter, and Sandy Cairncross. 2009. "Household Water Treatment in Poor Populations: Is There Enough Evidence for Scaling Up Now?" *Environmental Science & Technology* 43(4):986–92.

Schouten, Ton, and Patrick Barre Moriarty. 2003. *Community Water, Community Management: From System to Service in Rural Areas.* London: ITDG Publishing and IRC.

Singh, Inderjit, Lyn Squire, and John Strauss. 1986. "A Survey of Agricultural Household Models: Recent Findings and Policy Implications." *World Bank Economic Review* 1(1):149–79.

Strauss, John, and Duncan Thomas. 1995. "Human Resources: Empirical Modeling of Household and Family Decisions." In *The Handbook of Development Economics*, ed. Jere Behrman and T.N. Srinivasan, 1883–2023. Amsterdam, The Netherlands: Elsevier Science Publishers.

United Nations Children's Fund (UNICEF). 2007. "Multiple Indicator Cluster Survey 2006, Kyrgyz Republic. Final Report." Bishkek, Kyrgyzstan: National Statistical Committee of the Kyrgyz Republic.

United Nations, Department of Economic and Social Affairs. 2010. "The World's Women 2010: Trends and Statistics." ST/ESA/STAT/SER.K/19.

United Nations Development Programme (UNDP). 2006. "Beyond Scarcity: Power, Poverty, and the Global Water Crisis." 2006 Human Development Report.

UN Millennium Project. 2005. "Health, Dignity, and Development: What Will It Take?" Task Force on Water and Sanitation.

Whittington, Dale, W. Michael Hanemann, Claudia Sadoff, and Marc Jeuland. 2008. "Water and Sanitation Challenge Paper." Copenhagen Consensus 2008 Challenge Paper.
Whittington, Dale, Xinming Mu, and Robert Roche. 1990. "Calculating the Value of Time Spent Collecting Water: Some Estimates for Ukunda, Kenya." *World Development* 18(2):269–80.
World Bank. 2001. "Project Appraisal Document." Report No. 23139-KG.
———. 2004. "Kyrgyz Republic Agricultural Policy Update on Sustaining Pro-Poor Rural Growth: Emerging Challenges for Government and Donors."
———. 2007. "Kyrgyz Republic Poverty Assessment."
———. 2009. "Implementation Completion and Results Report on a Credit in the Amount of SDR 12 Million to the Kyrgyz Republic for a Rural Water Supply and Sanitation Project." Report Number ICR00001084.
Zwane, Alix, Jonathan Zinman, Eric Van Dusen, William Pariente, Clair Null, Edward Miguel, Michael Kremer, Dean S. Karlan, Richard Hornbeck, Xavier Gin, Esther Duflo, Florencia Devoto, Bruno Crepon, and Abhijit Banerjee. 2011. "Being Surveyed Can Change Later Behavior and Related Parameter Estimates." *Proceedings of the National Academy of Sciences* 108(5):1821–6.